

APPENDIX D

Problem Bank

- 1. a.** Given: 5.2 cm
Unknown: length in millimeters
$$5.2 \text{ cm} \times \frac{10 \text{ mm}}{1 \text{ cm}} = 52 \text{ mm}$$
- b.** Given: 0.049 kg
Unknown: mass in grams
$$0.049 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 49 \text{ g}$$
- c.** Given: 1.60 mL
Unknown: volume in microliters
$$1.60 \text{ mL} \times \frac{1000 \text{ }\mu\text{L}}{1 \text{ mL}} = 1600 \text{ }\mu\text{L}$$
- d.** Given: 0.0025 g
Unknown: mass in micrograms
$$0.0025 \text{ g} \times \frac{1000000 \text{ }\mu\text{g}}{1 \text{ g}} = 2500 \text{ }\mu\text{g}$$
- e.** Given: 0.020 kg
Unknown: mass in milligrams
$$0.020 \text{ kg} \times \frac{1000000 \text{ mg}}{1 \text{ kg}} = 20000 \text{ mg}$$
- f.** Given: 3 kL
Unknown: volume in liters
$$3 \text{ kL} \times \frac{1000 \text{ L}}{1 \text{ kL}} = 3000 \text{ L}$$
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- 2. a.** Given: 150 mg
Unknown: mass in grams
$$150 \text{ mg} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.15 \text{ g}$$
- b.** Given: 2500 mL
Unknown: volume in liters
$$2500 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.5 \text{ L}$$
- c.** Given: 0.5 g
Unknown: mass in kilograms
$$0.5 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.0005 \text{ kg}$$
- d.** Given: 55 L
Unknown: volume in kiloliters
$$55 \text{ L} \times \frac{1 \text{ kL}}{1000 \text{ L}} = 0.055 \text{ kL}$$

e. Given: 35 mm
Unknown: length in cm

$$35 \text{ mm} \times \frac{1 \text{ cm}}{10 \text{ mm}} = 3.5 \text{ cm}$$

f. Given: 8740 m
Unknown: length in kilometers

$$8740 \text{ m} \times \frac{1 \text{ km}}{1000 \text{ m}} = 8.74 \text{ km}$$

g. Given: 209 nm
Unknown: length in millimeters

$$209 \text{ nm} \times \frac{1 \text{ mm}}{1000000 \text{ nm}} = 0.000209 \text{ mm}$$

h. Given: 500 000 μg
Unknown: mass in kilograms

$$500000 \mu\text{g} \times \frac{1 \text{ kg}}{1000000000 \mu\text{g}} = 0.0005 \text{ kg}$$

3. Given: 152 million km
Unknown: length in megameters

$$152000000 \text{ km} \times \frac{1 \text{ Mm}}{1000 \text{ km}} = 152000 \text{ Mm}$$

4. Given: 1.87 L in a 2.00 L bottle
Unknown: volume in milliliters needed to fill the bottle

$$2.00 \text{ L} - 1.87 \text{ L} = 0.13 \text{ L}$$
$$0.13 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 130 \text{ mL}$$

5. Given: a wire 150 cm long
Unknown: length in millimeters; number of 50 mm segments in the wire

$$150 \text{ cm} \times \frac{10 \text{ mm}}{1 \text{ cm}} = 1500 \text{ mm}$$
$$1500 \text{ mm} \times \frac{1 \text{ piece}}{50 \text{ mm}} = 30 \text{ pieces}$$

6. Given: 8500 kg to fill a ladle
646 metric tons to make rails
1 metric ton = 1000 kg
Unknown: number of ladlefuls to make rails

$$646 \text{ metric tons} \times \frac{1000 \text{ kg}}{1 \text{ metric ton}} = 646000 \text{ kg}$$
$$646000 \text{ kg} \times \frac{1 \text{ ladleful}}{8500 \text{ kg}} = 76 \text{ ladlefuls}$$

7. a. Given: 310 000 cm^3
Unknown: volume in cubic meters

$$310000 \text{ cm}^3 \times \frac{1 \text{ m}^3}{1000000 \text{ cm}^3} = 0.31 \text{ m}^3$$

b. Given: 6.5 m^2
Unknown: area in square centimeters

$$6.5 \text{ m}^2 \times \frac{10\,000 \text{ cm}^2}{\text{m}^2} = 65\,000 \text{ cm}^2$$

c. Given: 0.035 m^3
Unknown: volume in cubic centimeters

$$0.035 \text{ m}^3 \times \frac{1\,000\,000 \text{ cm}^3}{\text{m}^3} = 35\,000 \text{ cm}^3$$

d. Given: 0.49 cm^2
Unknown: area in square millimeters

$$0.49 \text{ cm}^2 \times \frac{100 \text{ mm}^2}{\text{cm}^2} = 49 \text{ mm}^2$$

e. Given: 1200 dm^3
Unknown: volume in cubic meters

$$1200 \text{ dm}^3 \times \frac{1 \text{ m}^3}{1000 \text{ dm}^3} = 1.2 \text{ m}^3$$

f. Given: 87.5 mm^3
Unknown: volume in cubic centimeters

$$87.5 \text{ mm}^3 \times \frac{1 \text{ cm}^3}{1000 \text{ mm}^3} = 0.0875 \text{ cm}^3$$

g. Given: $250\,000 \text{ cm}^2$
Unknown: area in square meters

$$250\,000 \text{ cm}^2 \times \frac{1 \text{ m}^2}{10\,000 \text{ cm}^2} = 25 \text{ m}^2$$

8. Given: volume of a cell = 0.0147 mm^3
Unknown: number of cells that fit into a volume of 1.0 cm^3

$$1.0 \text{ cm}^3 \times \frac{1000 \text{ mm}^3}{\text{cm}^3} = 1000.0 \text{ mm}^3$$

$$1000.00 \text{ mm}^3 \times \frac{1 \text{ cell}}{0.0147 \text{ mm}^3} = 68\,027 \text{ cells}$$

9. a. Given: 12.75 Mm
Unknown: length in kilometers

$$12.75 \text{ Mm} \times \frac{1000 \text{ km}}{\text{Mm}} = 12\,750 \text{ km}$$

b. Given: 277 cm
Unknown: length in meters

$$277 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} = 2.77 \text{ m}$$

c. Given: $30\,560 \text{ m}^2$
 $1 \text{ ha} = 10\,000 \text{ m}^2$
Unknown: area in hectares

$$30\,560 \text{ m}^2 \times \frac{1 \text{ ha}}{10\,000 \text{ m}^2} = 3.056 \text{ ha}$$

d. Given: 81.9 cm^2
 Unknown: area in square meters

$$81.9 \text{ cm}^2 \times \frac{1 \text{ m}^2}{10\,000 \text{ cm}^2} = 0.00819 \text{ m}^2$$

e. Given: $300\,000 \text{ km}$
 Unknown: length in megameters

$$300\,000 \text{ km} \times \frac{1 \text{ Mm}}{1000 \text{ km}} = 300 \text{ Mm}$$

10. a. Given: 0.62 km
 Unknown: length in meters

$$0.62 \text{ km} \times \frac{1000 \text{ m}}{\text{km}} = 620 \text{ m}$$

b. Given: 3857 g
 Unknown: mass in milligrams

$$3857 \text{ g} \times \frac{1000 \text{ mg}}{\text{g}} = 3857\,000 \text{ mg}$$

c. Given: 0.0036 mL
 Unknown: volume in microliters

$$0.0036 \text{ mL} \times \frac{1000 \mu\text{L}}{\text{mL}} = 3.6 \mu\text{L}$$

d. Given: $0.342 \text{ metric tons}$
 $1 \text{ metric ton} = 1000 \text{ kg}$
 Unknown: mass in kilograms

$$0.342 \text{ metric tons} \times \frac{1000 \text{ kg}}{\text{metric ton}} = 342 \text{ kg}$$

e. Given: 68.71 kL
 Unknown: volume in liters

$$68.71 \text{ kL} \times \frac{1000 \text{ L}}{\text{kL}} = 68\,710 \text{ L}$$

11. a. Given: 856 mg
 Unknown: mass in kilograms

$$856 \text{ mg} \times \frac{1 \text{ kg}}{1000\,000 \text{ mg}} = 0.000\,856 \text{ kg}$$

b. Given: $1210\,000 \mu\text{g}$
 Unknown: mass in kilograms

$$1210\,000 \mu\text{g} \times \frac{1 \text{ kg}}{1000\,000\,000 \mu\text{g}} = 0.00121 \text{ kg}$$

c. Given: $6598 \mu\text{L}$
 $1 \text{ mL} = 1 \text{ cm}^3$
 Unknown: volume in cm^3

$$6598 \mu\text{L} \times \frac{1 \text{ mL}}{1000 \mu\text{L}} \times \frac{1 \text{ cm}^3}{\text{mL}} = 6.598 \text{ cm}^3$$

d. Given: $80\,600 \text{ nm}$
 Unknown: length in millimeters

$$80\,600 \text{ nm} \times \frac{1 \text{ mm}}{1000\,000 \text{ nm}} = 0.0806 \text{ mm}$$

- e.** Given: 10.74 cm^3
Unknown: volume in
liters

$$10.74 \text{ cm}^3 \times \frac{1 \text{ mL}}{\text{cm}^3} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.01074 \text{ L}$$

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- 12. a.** Given: 7.93 L
Unknown: volume in
cubic centimeters

$$7.93 \text{ L} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{1 \text{ cm}^3}{\text{mL}} = 7930 \text{ cm}^3$$

- b.** Given: 0.0059 km
Unknown: length in
centimeters

$$0.0059 \text{ km} \times \frac{100\,000 \text{ cm}}{\text{km}} = 590 \text{ cm}$$

- c.** Given: 4.19 L
Unknown: volume in
cubic decimeters

$$4.19 \text{ L} \times \frac{1 \text{ dm}^3}{\text{L}} = 4.19 \text{ dm}^3$$

- d.** Given: 7.48 m^2
Unknown: area in
square centimeters

$$7.48 \text{ m}^2 \times \frac{10\,000 \text{ cm}^2}{\text{m}^2} = 74\,800 \text{ cm}^2$$

- e.** Given: 0.197 m^3
Unknown: volume in
liters

$$0.197 \text{ m}^3 \times \frac{1000 \text{ dm}^3}{\text{m}^3} \times \frac{1 \text{ L}}{\text{dm}^3} = 197 \text{ L}$$

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- 13.** Given: 0.05 mL oil used
per kilometer
Unknown: volume in
liters of oil
used for
 $20\,000 \text{ km}$

$$20\,000 \text{ km} \times \frac{0.05 \text{ mL}}{\text{km}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1 \text{ L}$$

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- 14.** Given: 370 mm^3
Unknown: volume in
microliters

$$370 \text{ mm}^3 \times \frac{1 \text{ cm}^3}{1000 \text{ mm}^3} \times \frac{1 \text{ mL}}{\text{cm}^3} \times \frac{1000 \text{ }\mu\text{L}}{\text{mL}} = 370 \text{ }\mu\text{L}$$

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- 15.** Given: 1.5 tsp vanilla
per cake
 $1 \text{ tsp} = 5 \text{ mL}$
Unknown: volume of
vanilla in
liters for
 800 cakes

$$800 \text{ cakes} \times \frac{1.5 \text{ tsp}}{\text{cake}} \times \frac{5 \text{ mL}}{\text{tsp}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 6 \text{ L}$$

- 16.** Given: eight 300 mL glasses of water/day
 1 yr = 365 days
 $D_{\text{water}} = 1.00 \text{ kg/L}$
 Unknown: volume in liters of water consumed in a year
 mass in kilograms of this volume
- $$\frac{8 \text{ glasses}}{\text{day}} \times \frac{365 \text{ days}}{\text{yr}} \times \frac{300 \text{ mL}}{\text{glass}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 876 \text{ L per year}$$
- $$876 \text{ L} \times \frac{1 \text{ kg}}{\text{L}} = 876 \text{ kg}$$

- 17. a.** Given: 465 m/s
 Unknown: velocity in kilometers per hour
- $$\frac{465 \text{ m}}{\text{s}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{3600 \text{ s}}{\text{h}} = 1674 \text{ km/h}$$

- b.** Given: 465 m/s
 Unknown: velocity in kilometers per day
- $$\frac{1674 \text{ km}}{\text{h}} \times \frac{24 \text{ h}}{\text{day}} = 40\,176 \text{ km/day}$$

- 18.** Given: 130 g/student
 60 students
 Unknown: total mass in kilograms
- $$\frac{130 \text{ g}}{\text{student}} \times 60 \text{ students} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 7.8 \text{ kg}$$

- 19.** Given: 750 mm/student
 60 students
 Unknown: total length in meters
- $$\frac{750 \text{ mm}}{\text{student}} \times 60 \text{ students} \times \frac{1 \text{ m}}{1000 \text{ mm}} = 45 \text{ m}$$

- 20. a.** Given: 550 $\mu\text{L/h}$
 Unknown: rate in milliliters per day
- $$\frac{550 \mu\text{L}}{\text{h}} \times \frac{1 \text{ mL}}{1000 \mu\text{L}} \times \frac{24 \text{ h}}{\text{day}} = 13.2 \text{ mL/day}$$

- b.** Given: 9.00 metric tons/h
 Unknown: rate in kilograms per minute
- $$\frac{9.00 \text{ metric tons}}{\text{h}} \times \frac{1000 \text{ kg}}{\text{metric ton}} \times \frac{1 \text{ h}}{60 \text{ min}} = 150 \text{ kg/min}$$

- c.** Given: 3.72 L/h
 Unknown: rate in cubic centimeters per minute
- $$\frac{3.72 \text{ L}}{\text{h}} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{1 \text{ cm}^3}{\text{mL}} \times \frac{1 \text{ h}}{60 \text{ min}} = 62 \text{ cm}^3/\text{min}$$

d. Given: 6.12 km/h
Unknown: rate in meters per second

$$\frac{6.12 \text{ km}}{\text{h}} \times \frac{1000 \text{ m}}{\text{km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 1.7 \text{ m/s}$$

21. a. Given: 2.97 kg/L
Unknown: rate in g/cm³

$$\frac{2.97 \text{ kg}}{\text{L}} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mL}}{\text{cm}^3} = 2.97 \text{ g/cm}^3$$

b. Given: 4128 g/dm²
Unknown: mass per area in kilograms per square centimeters

$$\frac{4128 \text{ g}}{\text{dm}^2} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{1 \text{ dm}^2}{100 \text{ cm}^2} = 0.04128 \text{ kg/cm}^2$$

c. Given: 5.27 g/cm³
Unknown: density as kilograms per cubic decimeter

$$\frac{5.27 \text{ g}}{\text{cm}^3} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{1000 \text{ cm}^3}{\text{dm}^3} = 5.27 \text{ kg/dm}^3$$

d. Given: 6.91 kg/m³
Unknown: density as milligrams per cubic millimeter

$$\frac{6.91 \text{ kg}}{\text{m}^3} \times \frac{1000 \text{ 000 mg}}{\text{kg}} \times \frac{1 \text{ m}^3}{1000 \text{ 000 000 mm}^3} = 0.00691 \text{ mg/mm}^3$$

22. a. Given: density of 5.56 g/L
Unknown: volume in milliliters occupied by 4.17 g

$$4.17 \text{ g} \times \frac{1 \text{ L}}{5.56 \text{ g}} \times \frac{1000 \text{ mL}}{\text{L}} = 750 \text{ mL}$$

b. Given: density of 5.56 g/L
Unknown: mass in kilograms of 1 m³

$$1 \text{ m}^3 \times \frac{1000 \text{ dm}^3}{\text{m}^3} \times \frac{1 \text{ L}}{\text{dm}^3} \times \frac{5.56 \text{ g}}{\text{L}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 5.56 \text{ kg}$$

23. Given: mass per area of 0.10 g/cm²
Unknown: mass in kilograms per 0.125 ha

$$0.125 \text{ ha} \times \frac{10 \text{ 000 m}^2}{\text{ha}} \times \frac{10 \text{ 000 cm}^2}{\text{m}^2} \times \frac{0.10 \text{ g}}{\text{cm}^2} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 1250 \text{ kg}$$

- 24. a.** Given: length of book
= 250. mm
width of book
= 224 mm
thickness of
book =
50.0 mm

Unknown: volume in
cubic
meters

$$250. \text{ mm} \times 224 \text{ mm} \times 50.0 \text{ mm} = 2800\,000 \text{ mm}^3 \times \frac{1 \text{ m}^3}{1000\,000\,000 \text{ mm}^3} \\ = 0.0028 \text{ m}^3$$

- b.** Given: length of book
= 250. mm
width of book
= 224 mm
thickness of
book =
50.0 mm
mass of book
= 2.94 kg

Unknown: density in
grams per
cubic cen-
timeter

$$\frac{2.94 \text{ kg}}{0.0028 \text{ m}^3} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{1 \text{ m}^3}{1000\,000 \text{ cm}^3} = 1.05 \text{ g/cm}^3$$

- c.** Given: length of book
= 250. mm
width of book
= 224 mm
thickness of
book =
50.0 mm

Unknown: area of
front
cover in
square
meters

$$250 \text{ mm} \times 224 \text{ mm} \times \frac{1 \text{ m}^2}{1000\,000 \text{ mm}^2} = 0.056 \text{ m}^2$$

- 25. a.** Given: 25 drops =
1.00 mL

Unknown: volume of
one drop
in milli-
liters

$$\frac{1.00 \text{ mL}}{25 \text{ drops}} = 0.04 \text{ mL}$$

- b.** Given: 25 drops =
1.00 mL

Unknown: volume in
milliliters
of 37
drops

$$37 \text{ drops} \times \frac{0.04 \text{ mL}}{\text{drop}} = 1.48 \text{ mL}$$

- c.** Given: 25 drops =
1.00 mL

Unknown: number of
drops in
0.68 L

$$0.68 \text{ L} \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{1 \text{ drop}}{0.04 \text{ mL}} = 17\,000 \text{ drops}$$

- 26. a.** Given: 504 700 mg
Unknown: mass in kilograms and grams

$$504\,700\text{ mg} \times \frac{1\text{ kg}}{1\,000\,000\text{ mg}} = 0.5047\text{ kg}$$

$$504\,700\text{ mg} \times \frac{1\text{ g}}{1\,000\text{ mg}} = 504.7\text{ g}$$
- b.** Given: 9200 000 µg
Unknown: mass in kilograms and grams

$$9200\,000\text{ µg} \times \frac{1\text{ kg}}{1\,000\,000\,000\text{ µg}} = 0.0092\text{ kg}$$

$$9200\,000\text{ µg} \times \frac{1\text{ g}}{1\,000\,000\text{ µg}} = 9.2\text{ g}$$
- c.** Given: 122 mg
Unknown: mass in kilograms and grams

$$122\text{ mg} \times \frac{1\text{ kg}}{1\,000\,000\text{ mg}} = 0.000\,122\text{ kg}$$

$$122\text{ mg} \times \frac{1\text{ g}}{1\,000\text{ mg}} = 0.122\text{ g}$$
- d.** Given: 7195 cg
Unknown: mass in kilograms and grams

$$7195\text{ cg} \times \frac{1\text{ kg}}{100\,000\text{ cg}} = 0.07195\text{ kg}$$

$$7195\text{ cg} \times \frac{1\text{ g}}{100\text{ cg}} = 71.95\text{ g}$$

- 27. a.** Given: 582 cm³
Unknown: volume in liters and milliliters

$$582\text{ cm}^3 \times \frac{1\text{ mL}}{\text{cm}^3} \times \frac{1\text{ L}}{1000\text{ mL}} = 0.582\text{ L}$$

$$582\text{ cm}^3 \times \frac{1\text{ mL}}{\text{cm}^3} = 582\text{ mL}$$
- b.** Given: 0.0025 m³
Unknown: volume in liters and milliliters

$$0.0025\text{ m}^3 \times \frac{1000\text{ dm}^3}{\text{m}^3} \times \frac{1\text{ L}}{\text{dm}^3} = 2.5\text{ L}$$

$$0.0025\text{ m}^3 \times \frac{1\,000\,000\text{ cm}^3}{\text{m}^3} \times \frac{1\text{ mL}}{\text{cm}^3} = 2500\text{ mL}$$
- c.** Given: 1.18 dm³
Unknown: volume in liters and milliliters

$$1.18\text{ dm}^3 \times \frac{1\text{ L}}{\text{dm}^3} = 1.18\text{ L}$$

$$1.18\text{ dm}^3 \times \frac{1\text{ L}}{\text{dm}^3} \times \frac{1000\text{ mL}}{\text{L}} = 1180\text{ mL}$$
- d.** Given: 32 900 µL
Unknown: volume in liters and milliliters

$$32\,900\text{ µL} \times \frac{1\text{ L}}{1\,000\,000\text{ µL}} = 0.0329\text{ L}$$

$$32\,900\text{ µL} \times \frac{1\text{ mL}}{1000\text{ µL}} = 32.9\text{ mL}$$

- 28. a.** Given: 1.37 g/cm³
Unknown: density in grams per liter and kilograms per cubic meter

$$\frac{1.37\text{ g}}{\text{cm}^3} \times \frac{1\text{ cm}^3}{\text{mL}} \times \frac{1000\text{ mL}}{\text{L}} = 1370\text{ g/L}$$

$$\frac{1.37\text{ g}}{\text{cm}^3} \times \frac{1\text{ kg}}{1000\text{ g}} \times \frac{1\,000\,000\text{ cm}^3}{\text{m}^3} = 1370\text{ kg/m}^3$$

b. Given: 0.692 kg/dm^3
 Unknown: density in grams per liter and kilograms per cubic meter

$$\frac{0.692 \text{ kg}}{\text{dm}^3} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{1 \text{ dm}^3}{\text{L}} = 692 \text{ g/L}$$

$$\frac{0.692 \text{ kg}}{\text{dm}^3} \times \frac{1000 \text{ dm}^3}{\text{m}^3} = 692 \text{ kg/m}^3$$

c. Given: 5.2 kg/L
 Unknown: density in grams per liter and kilograms per cubic meter

$$\frac{5.2 \text{ kg}}{\text{L}} \times \frac{1000 \text{ g}}{\text{kg}} = 5200 \text{ g/L}$$

$$\frac{5.2 \text{ kg}}{\text{L}} \times \frac{1 \text{ L}}{\text{dm}^3} \times \frac{1000 \text{ dm}^3}{\text{m}^3} = 5200 \text{ kg/m}^3$$

d. Given: $38\,000 \text{ g/m}^3$
 Unknown: density in grams per liter and kilograms per cubic meter

$$\frac{38\,000 \text{ g}}{\text{m}^3} \times \frac{1 \text{ m}^3}{1000 \text{ dm}^3} \times \frac{1 \text{ dm}^3}{\text{L}} = 38 \text{ g/L}$$

$$\frac{38\,000 \text{ g}}{\text{m}^3} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 38 \text{ kg/m}^3$$

e. Given: 5.79 mg/mm^3
 Unknown: density in grams per liter and kilograms per cubic meter

$$\frac{5.79 \text{ mg}}{\text{mm}^3} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1000\,000 \text{ mm}^3}{\text{dm}^3} \times \frac{1 \text{ dm}^3}{\text{L}} = 5790 \text{ g/L}$$

$$\frac{5.79 \text{ mg}}{\text{mm}^3} \times \frac{1 \text{ kg}}{1000\,000 \text{ mg}} \times \frac{1000\,000\,000 \text{ mm}^3}{\text{m}^3} = 5790 \text{ kg/m}^3$$

f. Given: $1.1 \text{ } \mu\text{g/mL}$
 Unknown: density in grams per liter and kilograms per cubic meter

$$\frac{1.1 \text{ } \mu\text{g}}{\text{mL}} \times \frac{1 \text{ g}}{1000\,000 \text{ } \mu\text{g}} \times \frac{1000 \text{ mL}}{\text{L}} = 0.0011 \text{ g/L}$$

$$\frac{1.1 \text{ } \mu\text{g}}{\text{mL}} \times \frac{1 \text{ kg}}{1000\,000\,000 \text{ } \mu\text{g}} \times \frac{1 \text{ mL}}{\text{cm}^3} \times \frac{1000\,000 \text{ cm}^3}{\text{m}^3} = 0.0011 \text{ kg/m}^3$$

29. a. Given: 648 kg/30.0 h
 Unknown: rate in grams per minute

$$\frac{648 \text{ kg}}{30.0 \text{ h}} \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{1 \text{ h}}{60 \text{ min}} = 360 \text{ g/min}$$

b. Given: 648 kg/30.0 h
 Unknown: rate in kilograms per day

$$\frac{648.0 \text{ kg}}{30.0 \text{ h}} \times \frac{24 \text{ h}}{\text{day}} = 518.4 \text{ kg/day}$$

c. Given: 648 kg/30.0 h
 Unknown: rate in milligrams per millisecond

$$\frac{648.0 \text{ kg}}{30.0 \text{ h}} \times \frac{1000\,000 \text{ mg}}{\text{kg}} \times \frac{1 \text{ h}}{3600 \text{ s}} \times \frac{1 \text{ s}}{1000 \text{ ms}} = 6 \text{ mg/ms}$$

30. Given: 100 km/h
Unknown: rate in meters per second

$$\frac{100. \text{ km}}{\text{h}} \times \frac{1000 \text{ m}}{\text{km}} \times \frac{1 \text{ h}}{3600 \text{ s}} = 27.8 \text{ m/s}$$

31. Given: 330 kJ/min
1 cal = 4.184 J
Unknown: rate in kilocalories per hour

$$\frac{330 \text{ kJ}}{\text{min}} \times \frac{60 \text{ min}}{\text{h}} \times \frac{1 \text{ kcal}}{4.184 \text{ kJ}} = 4732 \text{ kcal/h}$$

32. Given: 62 g/m²
1 ha = 10 000 m²
Unknown: mass in kilograms required for 1.0 ha

$$\frac{62 \text{ g}}{\text{m}^2} \times \frac{10\,000 \text{ m}^2}{\text{ha}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{1.0 \text{ ha}}{1000 \text{ g}} = 620 \text{ kg}$$

33. Given: 3.9 mL/h
1 year = 365 days
Unknown: volume in liters per year

$$\frac{3.9 \text{ mL}}{\text{h}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{24 \text{ h}}{\text{day}} \times \frac{365 \text{ days}}{\text{yr}} = 34 \text{ L/yr}$$

34. Given: 50 µL/dose
2.0 mL/bottle
Unknown: number of doses in a bottle

$$2.0 \text{ mL} \times \frac{1 \text{ dose}}{50 \text{ µL}} \times \frac{1000 \text{ µL}}{\text{mL}} = 40 \text{ doses}$$

35. a. Given: 640 cm³
Unknown: number of significant figures

2; the zero is not significant

b. Given: 200.0 mL
Unknown: number of significant figures

4; all digits are significant

c. Given: 0.5200 g
Unknown: number of significant figures

4; all digits to the right of the decimal point are significant

d. Given: 1.005 kg
Unknown: number of significant figures

4; all digits are significant

- e.** Given: 10 000 L 1; the zeros are placeholders
Unknown: number of
 signifi-
 cant
 figures
- f.** Given: 20.900 cm 5; all digits are significant
Unknown: number of
 signifi-
 cant
 figures
- g.** Given: 0.000 000 56 2; all the zeros are placeholders
 g/L
Unknown: number of
 signifi-
 cant
 figures
- h.** Given: 0.040 02 4; the two initial zeros are placeholders
 kg/m³
Unknown: number of
 signifi-
 cant
 figures
- i.** Given: 790 001 cm² 6; all digits are significant
Unknown: number of
 signifi-
 cant
 figures
- j.** Given: 665.000 6; all digits are significant
 kg • m/s²
Unknown: number of
 signifi-
 cant
 figures

- 38. a.** Given: 0.0120 m 3; the two initial zeros are placeholders
Unknown: number of
 signifi-
 cant
 figures
- b.** Given: 100.5 mL 4; all digits are significant
Unknown: number of
 signifi-
 cant
 figures

- c.** Given: 101 g 3; all digits are significant
Unknown: number of
 signifi-
 cant
 figures
- d.** Given: 350 cm² 2; zero is a placeholder
Unknown: number of
 signifi-
 cant
 figures
- e.** Given: 0.97 km 2; zero is a placeholder
Unknown: number of
 signifi-
 cant
 figures
- f.** Given: 1000 kg 1; zeros are placeholders
Unknown: number of
 signifi-
 cant
 figures
- g.** Given: 180. mm 3; all digits are significant
Unknown: number of
 signifi-
 cant
 figures
- h.** Given: 0.4936 L 4; zero is a placeholder
Unknown: number of
 signifi-
 cant
 figures
- i.** Given: 0.020 700 s 5; initial zeros are placeholders
Unknown: number of
 significant
 figures

- 39. a.** Given: 5 487 129 m 5 490 000 m; the digit following the last digit to be retained is greater than 5
Unknown: value ex-
 pressed to
 3 signifi-
 cant
 figures
- b.** Given: 0.013 479 265 mL 0.013 479 3; initial zeros are placeholders; the digit following the last digit to be retained is greater than 5
Unknown: value ex-
 pressed to
 6 signifi-
 cant
 figures

- c.** Given: 31 947.972 cm² 31 950 cm²; the digit following the last digit to be retained is greater than 5
Unknown: value expressed to 4 significant figures
- d.** Given: 192.6739 m² 192.67 m²; the digit following the last digit to be retained is less than 5
Unknown: value expressed to 5 significant figures
- e.** Given: 786.9164 cm 790 cm; the digit following the last digit to be retained is greater than 5
Unknown: value expressed to 2 significant figures
- f.** Given: 389 277 600 J 389 278 000 J; the digit following the last digit to be retained is greater than 5; the zeros are placeholders
Unknown: value expressed to 6 significant figures
- g.** Given: 225 834.762 cm³ 225 834.8 cm³; the digit following the last to be retained is greater than 5
Unknown: value expressed to 7 significant figures

- 42. a.** Given: dimensions of 87.59 cm × 35.1 mm $87.59 \text{ cm} \times 35.1 \text{ mm} \times \frac{1 \text{ cm}}{10 \text{ mm}} = 307 \text{ cm}^2$
Unknown: area in cm²
- b.** Given: dimensions of 87.59 cm × 35.1 mm $87.59 \text{ cm} \times \frac{10 \text{ mm}}{1 \text{ cm}} \times 35.1 \text{ mm} = 30\,700. \text{ mm}^2$
Unknown: area in mm²
- c.** Given: dimensions of 87.59 cm × 35.1 mm $87.59 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} \times 35.1 \text{ mm} \times \frac{1 \text{ m}}{1000 \text{ mm}} = 0.0307 \text{ m}^2$
Unknown: area in m²

- 43. a.** Given: dimensions of
 900. mm ×
 31.5 mm ×
 6.3 cm
 Unknown: volume in
 cm³
- $$900. \text{ mm} \times \frac{10 \text{ cm}}{10 \text{ mm}} \times 31.5 \text{ mm} \times \frac{1 \text{ cm}}{10 \text{ mm}} \times 6.3 \text{ cm} = 1800 \text{ cm}^3$$
- b.** Given: dimensions of
 900. mm ×
 31.5 mm ×
 6.3 cm
 Unknown: volume in
 m³
- $$900. \text{ mm} \times \frac{1 \text{ m}}{1000 \text{ mm}} \times 31.5 \text{ mm} \times \frac{1 \text{ m}}{1000 \text{ mm}} \times 6.3 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} = 0.0018 \text{ m}^3$$
- c.** Given: dimensions of
 900. mm ×
 31.5 mm ×
 6.3 cm
 Unknown: volume in
 mm³
- $$900. \text{ mm} \times 31.5 \text{ mm} \times 6.3 \text{ cm} \times \frac{10 \text{ mm}}{1 \text{ cm}} = 1\,800\,000 \text{ mm}^3$$
-
- 44. a.** Given: 0.16 kg/125 mL
 Unknown: density in
 kg/m³
- $$\frac{0.16 \text{ kg}}{125 \text{ mL}} \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1\,000\,000 \text{ cm}^3}{1 \text{ m}^3} = 1300 \text{ kg/m}^3$$
- b.** Given: 0.16 kg/125 mL
 Unknown: density in
 g/mL
- $$\frac{0.16 \text{ kg}}{125 \text{ mL}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 1.3 \text{ g/mL}$$
- c.** Given: 0.16 kg/125 mL
 Unknown: density in
 kg/dm³
- $$\frac{0.16 \text{ kg}}{125 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ L}}{1 \text{ dm}^3} = 1.3 \text{ kg/dm}^3$$
-
- 45. a.** Given: numbers with
 4, 3, and 2
 significant
 figures,
 respectively
 Unknown: product to
 2 signifi-
 cant
 figures
- $$13.75 \text{ mm} \times 10.1 \text{ mm} \times 0.91 \text{ mm} = 130 \text{ mm}^3$$
- b.** Given: numbers with
 3 and 2 signif-
 icant figures,
 respectively
 Unknown: product to
 2 signifi-
 cant
 figures
- $$89.4 \text{ cm}^2 \times 4.8 \text{ cm} = 430 \text{ cm}^3$$

- c. Given: numbers with 3 and 2 significant figures, respectively

$$14.9 \text{ m}^3 \div 3.0 \text{ m}^2 = 5.0 \text{ m}$$

Unknown: quotient to 2 significant figures

- d. Given: numbers with 4, 1, and 3 significant figures, respectively

$$6.975 \text{ m} \times 30 \text{ m} \times 21.5 \text{ m} = 4000 \text{ m}^3$$

Unknown: product to 1 significant figure

48. Given: dimensions of 30.5 mm $\times$ 202 mm $\times$ 153 mm; mass empty = 0.30 kg; mass full = 1.33 kg

$$V = 30.5 \text{ mm} \times 202 \text{ mm} \times 153 \text{ mm} = 943\,000 \text{ mm}^3$$

$$m = 1.33 \text{ kg} - 0.30 \text{ kg} = 1.03 \text{ kg}$$

$$D = \frac{1.03 \text{ kg}}{943\,000 \text{ mm}^3} \times \frac{1.000\,000 \text{ mm}^3}{1 \text{ dm}^3} \times \frac{1 \text{ dm}^3}{1 \text{ L}} = 1.09 \text{ kg/L}$$

Unknown: density of the liquid in kg/L

49. Given: 3.3 kg/7.76 km
Unknown: mass in g/m; length with a mass of 1.0 g

$$\frac{3.3 \text{ kg}}{7.76 \text{ km}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ km}}{1000 \text{ m}} = 0.43 \text{ g/m}$$

$$1.0 \text{ g} \times \frac{1 \text{ m}}{0.43 \text{ g}} = 2.3 \text{ m}$$

50. Given: rate of 52 kg/ha; container holds 10 kg; 1 ha = 10 000 m²

$$\frac{10 \text{ kg}}{1 \text{ container}} \times \frac{1 \text{ ha}}{52 \text{ kg}} \times \frac{10\,000 \text{ m}^2}{1 \text{ ha}} = 2000 \text{ m}^2$$

Unknown: area in m² covered by full container

51. Given: 974 550 kJ/37.0 min

$$\frac{974\,550 \text{ kJ}}{37.0 \text{ min}} = 26\,300 \text{ kJ/min}$$

Unknown: rate in kJ/min and kJ/s

$$\frac{974\,550 \text{ kJ}}{37.0 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} = 439 \text{ kJ/s}$$

52. a. Given: dimensions of 189 cm $\times$ 307 cm $\times$ 272 cm

$$189 \text{ cm} \times 307 \text{ cm} \times 272 \text{ cm} \times \frac{1 \text{ m}^3}{1000\,000 \text{ cm}^3} = 15.8 \text{ m}^3$$

Unknown: volume in cubic meters

- b.** Given: dimensions of
 189 cm ×
 307 cm ×
 272 cm;
 fill time of
 97 s

$$\frac{189 \text{ cm} \times 307 \text{ cm} \times 272 \text{ cm}}{97 \text{ s}} \times \frac{1 \text{ dm}^3}{1000 \text{ cm}^3} \times \frac{60 \text{ s}}{1 \text{ min}} \times \frac{1 \text{ L}}{1 \text{ dm}^3} = 9800 \text{ L/min}$$

Unknown: rate in
 liters per
 minute

- c.** Given: dimensions of
 189 cm × 307
 cm × 272 cm;
 fill time of
 97 s

$$\frac{189 \text{ cm} \times 307 \text{ cm} \times 272 \text{ cm}}{97 \text{ s}} \times \frac{1 \text{ m}^3}{1000 \text{ 000 cm}^3} \times \frac{3600 \text{ s}}{1 \text{ h}} = 590 \text{ m}^3/\text{h}$$

Unknown: rate in
 cubic
 meters
 per hour

- 55. a.** Given: lengths ex-
 pressed in
 scientific
 notation

$$\begin{aligned} &4.74 \times 10^4 \text{ km} + 7.71 \times 10^3 \text{ km} + 1.05 \times 10^3 \text{ km} \\ &= 4.74 \times 10^4 \text{ km} + 0.771 \times 10^4 \text{ km} + 0.105 \times 10^4 \text{ km} \\ &= 5.62 \times 10^4 \text{ km} \end{aligned}$$

Unknown: sum ex-
 pressed in
 scientific
 notation
 to hun-
 dredths
 place

- b.** Given: lengths ex-
 pressed in
 scientific
 notation

$$\begin{aligned} &2.75 \times 10^{-4} \text{ m} + 8.03 \times 10^{-5} \text{ m} + 2.122 \times 10^{-3} \text{ m} \\ &= 0.275 \times 10^{-3} \text{ m} + 0.0803 \times 10^{-3} \text{ m} + 2.122 \times 10^{-3} \text{ m} \\ &= 2.477 \times 10^{-3} \text{ m} \end{aligned}$$

Unknown: sum ex-
 pressed in
 scientific
 notation
 to thou-
 sandths
 place

- c.** Given: volume ex-
 pressed in
 scientific
 notation

$$\begin{aligned} &4.0 \times 10^{-5} \text{ m}^3 + 6.85 \times 10^{-6} \text{ m}^3 - 1.05 \times 10^{-5} \text{ m}^3 \\ &= 4.0 \times 10^{-5} \text{ m}^3 + 0.685 \times 10^{-5} \text{ m}^3 - 1.05 \times 10^{-5} \text{ m}^3 \\ &= 3.6 \times 10^{-5} \text{ m}^3 \end{aligned}$$

Unknown: answer
 expressed
 in scien-
 tific nota-
 tion to
 tenths
 place

- d.** Given: masses expressed in scientific notation
 Unknown: sum expressed in scientific notation to hundredths place
- $$\begin{aligned}
 &3.15 \times 10^2 \text{ mg} + 3.15 \times 10^3 \text{ mg} + 3.15 \times 10^4 \text{ mg} \\
 &= 0.0315 \times 10^4 \text{ mg} + 0.315 \times 10^4 \text{ mg} + 3.15 \times 10^4 \text{ mg} \\
 &= 3.50 \times 10^4 \text{ mg}
 \end{aligned}$$
- e.** Given: number of atoms expressed in scientific notation
 Unknown: sum expressed in scientific notation to hundredths place
- $$\begin{aligned}
 &3.01 \times 10^{22} \text{ atoms} + 1.19 \times 10^{23} \text{ atoms} + 9.80 \times 10^{21} \text{ atoms} \\
 &= 0.301 \times 10^{23} \text{ atoms} + 1.19 \times 10^{23} \text{ atoms} + 0.0980 \times 10^{23} \text{ atoms} \\
 &= 1.59 \times 10^{23} \text{ atoms}
 \end{aligned}$$
- f.** Given: lengths expressed in scientific notation
 Unknown: answer expressed in scientific notation to thousandths place
- $$\begin{aligned}
 &6.85 \times 10^7 \text{ nm} + 4.0229 \times 10^8 \text{ nm} - 8.38 \times 10^6 \text{ nm} \\
 &= 0.685 \times 10^8 \text{ nm} + 4.0229 \times 10^8 \text{ nm} - 0.0838 \times 10^8 \text{ nm} \\
 &= 4.624 \times 10^8 \text{ nm}
 \end{aligned}$$

- 65. a.** Given: 7.11×10^{24} molecules per 100.0 cm^3
 Unknown: number of molecules per 1.09 cm^3
- $$\frac{7.11 \times 10^{24} \text{ molecules}}{100.0 \text{ cm}^3} \times 1.09 \text{ cm}^3 = 7.75 \times 10^{22} \text{ molecules}$$
- b.** Given: 7.11×10^{24} molecules per 100.0 cm^3
 Unknown: number of molecules in $2.24 \times 10^4 \text{ cm}^3$
- $$\frac{7.11 \times 10^{24} \text{ molecules}}{100.0 \text{ cm}^3} \times 2.24 \times 10^4 \text{ cm}^3 = 1.59 \times 10^{27} \text{ molecules}$$

c. Given: 7.11×10^{24} molecules per 100.0 cm^3

$$\frac{7.11 \times 10^{24} \text{ molecules}}{100.0 \text{ cm}^3} \times 9.01 \times 10^{-6} \text{ cm}^3$$

Unknown: number of molecules in $9.01 \times 10^{-6} \text{ cm}^3$

$$= 0.641 \times 10^{18} \text{ molecules} = 6.41 \times 10^{17} \text{ molecules}$$

66. a. Given: 3 518 000 transistors per $9.5 \text{ mm} \times 8.2 \text{ mm}$

$$\frac{9.5 \text{ mm} \times 8.2 \text{ mm}}{3\,518\,000 \text{ transistors}} = 0.000\,022 \text{ mm}^2/\text{transistor}$$

$$= 2.2 \times 10^{-5} \text{ mm}^2/\text{transistor}$$

Unknown: area per transistor

b. Given: $2.2 \times 10^{-5} \text{ mm}^2/\text{transistor}$

$$353 \text{ mm} \times 265 \text{ mm} \times \frac{1 \text{ transistor}}{2.2 \times 10^{-5} \text{ mm}^2} = 43\,000 \times 10^5 \text{ transistors}$$

$$= 4.3 \times 10^9 \text{ transistors}$$

Unknown: number of transistors on $353 \text{ mm} \times 265 \text{ mm}$

67. Given: 0.0501 g per 1.00 L

$$\frac{0.0501 \text{ g}}{1.00 \text{ L}} \times \frac{1 \text{ L}}{1 \times 10^6 \mu\text{L}} = 0.0501 \times 10^{-6} \text{ g}/\mu\text{L} = 5.01 \times 10^{-8} \text{ g}/\mu\text{L}$$

Unknown: concentration in grams per microliter

68. Given: $5.30 \times 10^{-10} \text{ m}/\text{Cs atom}$

$$\frac{1 \text{ Cs atom}}{5.30 \times 10^{-10} \text{ m}} \times \frac{1 \text{ m}}{10^2 \text{ cm}} \times 2.54 \text{ cm} = 4.79 \times 10^7 \text{ Cs atoms}$$

Unknown: number of Cs atoms in 2.54 cm

69. Given: $V_{\text{neutron}} = 1.4 \times 10^{-44} \text{ m}^3$
 $M_{\text{neutron}} = 1.675 \times 10^{-24} \text{ g}$

$$D_{\text{neutron}} = \frac{1.675 \times 10^{-24} \text{ g}}{1.4 \times 10^{-44} \text{ m}^3} = 1.2 \times 10^{20} \text{ g}/\text{m}^3$$

Unknown: D_{neutron} in g/m^3

$$\frac{1.675 \times 10^{-24} \text{ g}}{1.4 \times 10^{-44} \text{ m}^3} \times \frac{1 \text{ kg}}{10^3 \text{ g}} \times \frac{1 \text{ m}^3}{10^6 \text{ cm}^3} \times 1.0 \text{ m}^3 = 1.2 \times 10^{11} \text{ kg}$$

mass of 1.0 cm^3 of neutrons in kg

70. Given: $1.6 \times 10^{-8} \text{ m}$ per pit

$$0.305 \text{ m} \times \frac{1 \text{ pit}}{1.6 \times 10^{-8} \text{ m}} = 1.9 \times 10^7 \text{ pits}$$

Unknown: number of pits in 0.305 m

71. a. Given: 6.022×10^{23} O₂ molecules per 22 400 mL at 0°C and standard atmospheric pressure

$$\frac{6.022 \times 10^{23} \text{ O}_2 \text{ molecules}}{22\,400 \text{ mL}} \times 0.100 \text{ mL} = 0.000\,026\,9 \times 10^{23} \text{ O}_2 \text{ molecules}$$

$$= 2.69 \times 10^{18} \text{ O}_2 \text{ molecules}$$

Unknown: number of O₂ molecules in 0.100 mL

b. Given: 6.022×10^{23} O₂ molecules per 22 400 mL at 0°C and standard atmospheric pressure

$$\frac{6.022 \times 10^{23} \text{ O}_2 \text{ molecules}}{22\,400 \text{ mL}} \times \frac{10^3 \text{ mL}}{1 \text{ L}} \times 1.00 \text{ L}$$

$$= 0.000\,269 \times 10^{26} \text{ O}_2 \text{ molecules} = 2.69 \times 10^{22} \text{ O}_2 \text{ molecules}$$

Unknown: number of O₂ molecules in 1.00 L

c. Given: 6.022×10^{23} O₂ molecules per 22 400 mL at 0°C and standard atmospheric pressure

$$\frac{22\,400 \text{ mL}}{6.022 \times 10^{23} \text{ O}_2 \text{ molecules}} = 3720 \times 10^{-23} \text{ mL/O}_2 \text{ molecule}$$

$$= 3.72 \times 10^{-20} \text{ mL/O}_2 \text{ molecule}$$

Unknown: average space in milliliters occupied by one oxygen molecule

72. a. Given: $m = 5.136 \times 10^{18}$ kg; 6 500 000 000 people

$$\frac{5.136 \times 10^{18} \text{ kg}}{6.5 \times 10^9 \text{ people}} = 7.9 \times 10^8 \text{ kg/person}$$

Unknown: mass in kg per person

b. Given: $m = 5.136 \times 10^{18}$ kg; 6 500 000 000 people

$$\frac{5.136 \times 10^{18} \text{ kg}}{6.5 \times 10^9 \text{ people}} \times \frac{1 \text{ metric ton}}{10^3 \text{ kg}} = 0.79 \times 10^6 \text{ metric ton/person}$$

$$= 7.9 \times 10^5 \text{ metric ton/person}$$

Unknown: mass in metric tons per person

- c. Given: $m = 5.136 \times 10^{18} \text{ kg}$;
 $9\,500\,000\,000$ people
 Unknown: mass in kg per person
- $$\frac{5.136 \times 10^{18} \text{ kg}}{9.5 \times 10^9 \text{ people}} = 0.54 \times 10^9 \text{ kg/person} = 5.4 \times 10^8 \text{ kg/person}$$

73. Given: $m_{\text{sun}} = 1.989 \times 10^{30} \text{ kg}$
 $m_{\text{earth}} = 5.974 \times 10^{24} \text{ kg}$
 Unknown: number of Earths to equal mass of sun
- $$\frac{1.989 \times 10^{30} \text{ kg}}{5.974 \times 10^{24} \text{ kg}} = 0.3329 \times 10^6 = 3.329 \times 10^5 \text{ Earths}$$

74. c. Given: landfill dimensions of $2.3 \text{ km} \times 1.4 \text{ km} \times 0.15 \text{ km}$;
 $250\,000\,000$ objects, each 0.060 m^3 , per year
 Unknown: how many years to fill landfill
- $$\frac{2.3 \text{ km} \times 1.4 \text{ km} \times 0.15 \text{ km}}{2.5 \times 10^8 \text{ objects/yr} \times 6.0 \times 10^{-2} \text{ m}^3/\text{objects}} \times \frac{10^9 \text{ m}^3}{1 \text{ km}^3} = 0.032 \times 10^3 \text{ yr} = 32 \text{ yr}$$

75. Given: $1 \text{ C} = 1000 \text{ cal}$ intake of 2400 C per day
 $1 \text{ cal} = 4.184 \text{ J}$
 Unknown: intake in joules per day
- $$\frac{2400 \text{ C}}{1 \text{ day}} \times \frac{1000 \text{ cal}}{1 \text{ C}} \times \frac{4.184 \text{ J}}{1 \text{ cal}} = 10\,000\,000 \text{ J/day} = 1.0 \times 10^7 \text{ J/day}$$

76. Given: $D = 0.73 \text{ g/cm}^3$
 $m_{\text{automobile}} = 1271 \text{ kg}$
 Unknown: volume in L of gasoline to raise mass of car to 1305 kg
- $$\frac{1305 \text{ kg} - 1271 \text{ kg}}{0.73 \text{ g/cm}^3} \times \frac{1 \text{ L}}{10^3 \text{ mL}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{1 \text{ cm}^3} = 47 \text{ L}$$

77. Given: pool dimensions of $9.0 \text{ m} \times 3.5 \text{ m} \times 1.75 \text{ m}$
 $D_{\text{water}} = 0.997 \text{ g/cm}^3$
 1 metric ton = 1000 kg

$$9.0 \text{ m} \times 3.5 \text{ m} \times 1.75 \text{ m} \times \frac{0.997 \text{ g}}{1 \text{ cm}^3} \times \frac{10^6 \text{ cm}^3}{1 \text{ m}^3} \times \frac{1 \text{ kg}}{10^3 \text{ g}} \times \frac{1 \text{ metric ton}}{10^3 \text{ kg}} = 55 \text{ metric tons}$$

Unknown: mass of water in pool in metric tons

78. Given: $m = 250 \text{ g}$;
 dimensions of $7.0 \text{ cm} \times 17.0 \text{ cm} \times 19.0 \text{ cm}$

$$\frac{250 \text{ g}}{7.0 \text{ cm} \times 17.0 \text{ cm} \times 19.0 \text{ cm}} \times \frac{1 \text{ kg}}{10^3 \text{ g}} \times \frac{10 \text{ cm}^3}{1 \text{ mL}} \times \frac{10^3 \text{ mL}}{1 \text{ L}} = 0.11 \text{ kg/L}$$

Unknown: density in kilograms per liter

79. Given: area of 18.5 m^2 ;
 mass of 1275 g ;
 density of 2.7 g/cm^3

$$\frac{1275 \text{ g}}{18.5 \text{ m}^2} \times \frac{1 \text{ cm}^3}{2.7 \text{ g}} \times \frac{1 \text{ m}^3}{10^6 \text{ cm}^3} \times \frac{10^3 \text{ mm}}{1 \text{ m}} = 2.6 \times 10^{-2} \text{ mm}$$

Unknown: thickness in millimeters

80. Given: density of 1.17 g/cm^3 ;
 mass of 3.75 kg

$$3.75 \text{ kg} \times \frac{1 \text{ cm}^3}{1.17 \text{ g}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1 \text{ L}}{10^3 \text{ mL}} = 3.21 \text{ L}$$

Unknown: volume in liters

81. Given: dimensions of $28 \text{ cm} \times 21 \text{ cm} \times 44.5 \text{ mm}$;
 mass of 2090 g

$$\frac{2090 \text{ g}}{28 \text{ cm} \times 21 \text{ cm} \times 44.5 \text{ mm}} \times \frac{10 \text{ mm}}{1 \text{ cm}} = 0.80 \text{ g/cm}^3$$

Unknown: density in g/cm^3

82. Given: mass of 6.58 g ;
 triangle with base of 36.4 mm , height of 30.1 mm , and thickness of 0.560 mm

$$\frac{6.58 \text{ g}}{0.5(36.4 \text{ mm} \times 30.1 \text{ mm}) \times 0.560 \text{ mm}} \times \frac{10^3 \text{ mm}^3}{1 \text{ cm}^3} = 21.4 \text{ g/cm}^3$$

Unknown: density in g/cm^3

83. Given: crate dimensions of $0.40 \text{ m} \times 0.40 \text{ m} \times 0.25 \text{ m}$;
 box dimensions of $22.0 \text{ cm} \times 12.0 \text{ cm} \times 5.0 \text{ cm}$

$$\frac{0.40 \text{ m} \times 0.40 \text{ m} \times 0.25 \text{ m}}{1 \text{ crate}} \times \frac{1 \text{ box}}{22.0 \text{ cm} \times 12.0 \text{ cm} \times 5.0 \text{ cm}} \times \frac{10^6 \text{ cm}^3}{1 \text{ m}^3} = 30 \text{ boxes/crate}$$

Unknown: number of boxes to fill the crate

84. a. Given: $V_{\text{cube}} = l \times l \times l$
 $D = 2.27 \text{ g/cm}^3$
 $m = 3.93 \text{ kg}$

$$3.93 \text{ kg} \times \frac{1 \text{ cm}^3}{2.27 \text{ g}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mL}}{1 \text{ cm}^3} \times \frac{1 \text{ L}}{10^3 \text{ mL}} = 1.73 \text{ L}$$

Unknown: volume
in liters;
dimensions
of the cube

$$1.73 \text{ L} \times \frac{1 \text{ dm}^3}{1 \text{ L}} \times \frac{1 \text{ m}^3}{10^3 \text{ dm}^3} = 1.73 \times 10^{-3} \text{ m}^3 = 0.00173 \text{ m}^3$$

$$\sqrt[3]{0.00173 \text{ m}^3} = 0.120 \text{ m}; \text{ dimensions} = 0.120 \text{ m} \times 0.120 \text{ m} \times 0.120 \text{ m}$$

b. Given: $V_{\text{rectangle}} = l \times w \times h$
 $D =$
 1.85 g/cm^3
dimensions of
 $33 \text{ mm} \times$
 $21 \text{ mm} \times 7.2 \text{ mm}$

$$V = 33 \text{ mm} \times 21 \text{ mm} \times 7.2 \text{ mm} \times \frac{1 \text{ cm}^3}{10^3 \text{ mm}^3} = 5.0 \text{ cm}^3$$

$$m = DV = \frac{1.85 \text{ g}}{1 \text{ cm}^3} \times 5.0 \text{ cm}^3 = 9.2 \text{ g}$$

Unknown: mass in
grams
volume
in cm^3

c. Given: $V_{\text{sphere}} = \frac{4}{3}\pi r^3$;
 $D = 3.21 \text{ g/L}$;
diameter =
 3.30 m

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.14 \times \left(\frac{3.30 \text{ m}}{2}\right)^3 \times \frac{10^2 \text{ dm}^3}{1 \text{ m}^3} = 18.8 \times 10^3 \text{ dm}^3$$

$$= 1.88 \times 10^4 \text{ dm}^3$$

Unknown: mass in
kilograms,
volume
in dm^3

$$m = DV = \frac{3.21 \text{ g}}{1 \text{ L}} \times 1.88 \times 10^4 \text{ dm}^3 \times \frac{1 \text{ L}}{1 \text{ dm}^3} \times \frac{1 \text{ kg}}{10^3 \text{ g}} = 60.3 \text{ kg}$$

d. Given: $V_{\text{cylinder}} = \pi r^2 \times h$;
mass = 497 g ;
dimensions of
cylinder:
 7.5 cm diame-
ter $\times 12 \text{ cm}$

$$V = \pi r^2 \times h = 3.14 \left(\frac{7.5 \text{ cm}}{2}\right)^2 \times 12 \text{ cm} \times \frac{1 \text{ m}^3}{10^6 \text{ cm}^3} = 5.3 \times 10^{-4} \text{ m}^3$$

$$D = \frac{m}{V} = \frac{497 \text{ g}}{5.3 \times 10^{-4} \text{ m}^3} \times \frac{1 \text{ m}^3}{10^6 \text{ cm}^3} = 0.94 \text{ g/cm}^3$$

Unknown: density in
 g/cm^3 ,
volume
in m^3

e. Given: $V_{\text{rectangle}} = l \times w \times h$;
 $D =$
 0.92 g/cm^3 ;
dimensions of
 $3.5 \text{ m} \times 1.2 \text{ m}$
 $\times 0.65 \text{ m}$

$$V = l \times w \times h = 3.5 \text{ m} \times 1.2 \text{ m} \times 0.65 \text{ m} \times \frac{10^6 \text{ cm}^3}{1 \text{ m}^3} = 2.7 \times 10^6 \text{ cm}^3$$

$$m = DV = \frac{0.92 \text{ g}}{1 \text{ cm}^3} \times (2.7 \times 10^6 \text{ cm}^3) \times \frac{1 \text{ kg}}{10^3 \text{ g}} = 2.5 \times 10^3 \text{ kg}$$

Unknown: mass in
kilograms,
volume
in cm^3

- 85.** Given: mass of 9.65 g;
initial $V_{\text{water}} = 16.0 \text{ mL}$;
final $V_{\text{water}} = 19.5 \text{ mL}$

Unknown: Density in g/cm^3

$$V = 19.5 \text{ mL} - 16.0 \text{ mL} = 3.5 \text{ mL}$$

$$D = \frac{m}{V} = \frac{9.65 \text{ g}}{3.5 \text{ mL}} \times \frac{1 \text{ mL}}{1 \text{ cm}^3} = 2.8 \text{ g/cm}^3$$

- 86. a.** Given: $m = 50. \text{ kg}$;
area = 3620 m^2 ;
 $D = 19.3 \text{ g/cm}^3$

Unknown: thickness
of the gold
in micro-
meters

$$D = \frac{m}{\text{area} \times \text{thickness}}; \text{thickness} = \frac{m}{\text{area} \times D}$$

$$= \frac{50. \text{ kg}}{3620 \text{ m}^2} \times \frac{1 \text{ cm}^3}{19.3 \text{ g}} \times \frac{1 \text{ m}^2}{10^4 \text{ cm}^2} \times \frac{10^4 \mu\text{m}}{\text{cm}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} = 0.00072 \times 10^3 \mu\text{m}$$

$$= 0.72 \mu\text{m}$$

- b.** Given: thickness = $0.72 \mu\text{m}$;
atom radius = $1.44 \times 10^{-10} \text{ m}$

Unknown: number of
atoms

$$\text{diameter} = 2 \times \text{radius} = 2(1.44 \times 10^{-10} \text{ m}) = 2.88 \times 10^{-10} \text{ m}$$

$$0.72 \mu\text{m} \times \frac{1 \text{ atom}}{2.88 \times 10^{-10} \text{ m}} \times \frac{1 \text{ m}}{10^6 \mu\text{m}} = 2.5 \times 10^3 \text{ atoms}$$

- 87.** Given: fill time = 238 s;
cylinder diameter = 1.2 m;
cylinder height = 4.6 m

Unknown: flow rate in
L/min

$$V_{\text{cylinder}} = \pi r^2 \times h = 3.14 \left(\frac{1.2 \text{ m}}{2} \right)^2 \times 4.6 \text{ m} = 5.2 \text{ m}^3$$

$$\frac{5.2 \text{ m}^3}{238 \text{ s}} \times \frac{10^3 \text{ dm}^3}{1 \text{ m}^3} \times \frac{1 \text{ L}}{1 \text{ dm}^3} \times \frac{60 \text{ s}}{1 \text{ min}} = 1300 \text{ L/min}$$

- 88.** Given: 2.8 g produces
1.0 J/s;
1 cal = 4.184 J;
dimensions = $4.5 \text{ cm} \times 3.05 \text{ cm} \times 15 \text{ cm}$;
 $D = 19.86 \text{ g/cm}^3$

Unknown: calories
generated
per hour

$$V = 4.5 \text{ cm} \times 3.05 \text{ cm} \times 15 \text{ cm} = 210 \text{ cm}^3$$

$$m = DV = \frac{19.86 \text{ g}}{1 \text{ cm}^3} \times 210 \text{ cm}^3 = 4200 \text{ g}$$

$$4200 \text{ g} \times \frac{1.0 \text{ J}}{2.8 \text{ g} \cdot \text{s}} \times \frac{1 \text{ cal}}{4.184 \text{ J}} \times \frac{3600 \text{ s}}{1 \text{ h}} = 1.3 \times 10^6 \text{ cal/h}$$

- 89.** Given: $m = 5.974 \times 10^{24} \text{ kg}$;
sphere diameter = $1.28 \times 10^4 \text{ km}$

Unknown: density in
 g/cm^3

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.14 \left(\frac{1.28 \times 10^4 \text{ km}}{2} \right)^3 \times \frac{10^{15} \text{ cm}^3}{1 \text{ km}^3} = 1.10 \times 10^{27} \text{ cm}^3$$

$$D = \frac{m}{V} = \frac{5.974 \times 10^{24} \text{ kg}}{1.10 \times 10^{27} \text{ cm}^3} \times \frac{10^3 \text{ g}}{1 \text{ kg}} = 5.43 \text{ g/cm}^3$$

- 90.** Given: $D_{\text{Mg}} = 1.74 \text{ g/cm}^3$
 $D_{\text{Pt}} = 21.45 \text{ g/cm}^3$
 Unknown: volume of Mg in cm^3 with the same mass as 1.82 dm^3 of Pt
- $$m_{\text{Pt}} = 1.82 \text{ dm}^3 \times \frac{21.45 \text{ g}}{1 \text{ cm}^3} \times \frac{10^3 \text{ cm}^3}{1 \text{ dm}^3} = 3.90 \times 10^4 \text{ g} = m_{\text{Mg}}$$
- $$V_{\text{Mg}} = \frac{m_{\text{Mg}}}{D_{\text{Mg}}} = 3.90 \times 10^4 \text{ g} \times \frac{1 \text{ cm}^3}{1.74 \text{ g}} = 2.24 \times 10^4 \text{ cm}^3$$

- 91.** Given: 66 m/roll;
 5.0 cm/use
 Unknown: number of uses in 24 rolls
- $$\frac{66 \text{ m}}{1 \text{ roll}} \times 24 \text{ rolls} \times \frac{1 \text{ use}}{5.0 \text{ cm}} \times \frac{100 \text{ cm}}{1 \text{ m}} = 32\,000 \text{ uses}$$

- 92.** Given: 38 km/4.0 L gasoline;
 driven 75% of year;
 86 km/day;
 1 yr = 365 days
 Unknown: volume of gasoline in liters per year
- $$365 \text{ days} \times 0.75 = 274 \text{ days driven}$$
- $$274 \text{ days driven} \times \frac{86 \text{ km}}{1 \text{ day}} = 24\,000 \text{ km driven}$$
- $$24\,000 \text{ km} \times \frac{4.0 \text{ L}}{38 \text{ km}} = 2500 \text{ L}$$

- 93.** Given: fill time of 97 h;
 pool dimensions = $9.0 \text{ m} \times 3.5 \text{ m} \times 1.75 \text{ m}$
 Unknown: rate of fill in L/min
- $$\frac{9.0 \text{ m} \times 3.5 \text{ m} \times 1.75 \text{ m}}{97 \text{ h}} \times \frac{10^3 \text{ dm}^3}{1 \text{ m}^3} \times \frac{1 \text{ L}}{1 \text{ dm}^3} \times \frac{1 \text{ h}}{60 \text{ min}} = 9.5 \text{ L/min}$$

- 94.** Given: $D_{\text{H}_2\text{SO}_4} = 1.285 \text{ g/cm}^3$;
 38% sulfuric acid in battery
 Unknown: mass of sulfuric acid in 500. mL battery acid
- $$500. \text{ mL} \times 0.38 \times \frac{1.285 \text{ g}}{1 \text{ cm}^3} \times \frac{1 \text{ cm}^3}{1 \text{ mL}} = 244 \text{ g H}_2\text{SO}_4$$

- 95. a.** Given: 64.1 g of Al
 Unknown: number of moles Al
- $$64.1 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} = 2.38 \text{ mol Al}$$
- b.** Given: 28.1 g of Si
 Unknown: number of moles Si
- $$28.1 \text{ g Si} \times \frac{1 \text{ mol Si}}{28.09 \text{ g Si}} = 1.00 \text{ mol Si}$$
- c.** Given: 0.255 g of S
 Unknown: number of moles S
- $$0.255 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 7.95 \times 10^{-3} \text{ mol S}$$

d. Given: 850.5 g of Zn
Unknown: number of moles Zn

$$850.5 \text{ g Zn} \times \frac{1 \text{ mol Zn}}{65.39 \text{ g Zn}} = 13.01 \text{ mol Zn}$$

96. a. Given: 1.22 mol Na
Unknown: mass Na

$$1.22 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} = 28.0 \text{ g Na}$$

b. Given: 14.5 mol Cu
Unknown: mass Cu

$$14.5 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} = 921 \text{ g Cu}$$

c. Given: 0.275 mol Hg
Unknown: mass Hg

$$0.275 \text{ mol Hg} \times \frac{200.59 \text{ g Hg}}{1 \text{ mol Hg}} = 55.2 \text{ g Hg}$$

d. Given: 9.37×10^{-3} mol Mg
Unknown: mass Mg

$$9.37 \times 10^{-3} \text{ mol Mg} \times \frac{24.31 \text{ g Mg}}{1 \text{ mol Mg}} = 0.228 \text{ g Mg}$$

97. a. Given: 3.01×10^{23} atoms Rb
Unknown: amount in moles

$$3.01 \times 10^{23} \text{ atoms Rb} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 0.500 \text{ mol Rb}$$

b. Given: 8.08×10^{22} atoms Kr
Unknown: amount in moles

$$8.08 \times 10^{22} \text{ atoms Kr} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 0.134 \text{ mol Kr}$$

c. Given: 5 700 000 000 atoms of Pb
Unknown: amount in moles

$$5.7 \times 10^9 \text{ atoms Pb} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 9.5 \times 10^{-15} \text{ mol Pb}$$

d. Given: 2.997×10^{25} atoms of V
Unknown: amount in moles

$$2.997 \times 10^{25} \text{ atoms V} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 49.77 \text{ mol V}$$

98. a. Given: 1.004 mol Bi
Unknown: number of atoms

$$1.004 \text{ mol Bi} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 6.046 \times 10^{23} \text{ atoms Bi}$$

b. Given: 2.5 mol Mn
Unknown: number of atoms

$$2.5 \text{ mol Mn} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.5 \times 10^{24} \text{ atoms Mn}$$

c. Given: 0.000 000 2 mol He
Unknown: number of atoms

$$2 \times 10^{-7} \text{ mol He} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1 \times 10^{17} \text{ atoms He}$$

d. Given: 32.6 mol Sr
Unknown: number of atoms

$$32.6 \text{ mol Sr} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.96 \times 10^{25} \text{ atoms Sr}$$

99. a. Given: 54.0 g Al
Unknown: number of atoms Al

$$54.0 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.21 \times 10^{24} \text{ atoms Al}$$

b. Given: 69.45 g La
Unknown: number of atoms La

$$69.45 \text{ g La} \times \frac{1 \text{ mol La}}{138.91 \text{ g La}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 3.011 \times 10^{23} \text{ atoms La}$$

c. Given: 0.697 g Ga
Unknown: number of atoms Ga

$$0.697 \text{ g Ga} \times \frac{1 \text{ mol Ga}}{69.72 \text{ g Ga}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 6.02 \times 10^{21} \text{ atoms Ga}$$

d. Given: 0.000 000 020 g Be
Unknown: number of atoms Be

$$2.0 \times 10^{-8} \text{ g Be} \times \frac{1 \text{ mol Be}}{9.01 \text{ g Be}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.3 \times 10^{15} \text{ atoms Be}$$

100. a. Given: 6.022×10^{24} atoms Ta
Unknown: mass Ta

$$6.022 \times 10^{24} \text{ atoms Ta} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{180.95 \text{ g Ta}}{1 \text{ mol Ta}} = 1810 \text{ g Ta}$$

b. Given: 3.01×10^{21} atoms Co
Unknown: mass Co

$$3.01 \times 10^{21} \text{ atoms Co} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{58.93 \text{ g Co}}{1 \text{ mol Co}} = 0.295 \text{ g Co}$$

c. Given: 1.506×10^{24} atoms Ar
Unknown: mass Ar

$$1.506 \times 10^{24} \text{ atoms Ar} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{39.95 \text{ g Ar}}{1 \text{ mol Ar}} = 99.91 \text{ g Ar}$$

d. Given: 1.20×10^{25} atoms He
Unknown: mass He

$$1.20 \times 10^{25} \text{ atoms He} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{4.00 \text{ g He}}{1 \text{ mol He}} = 79.7 \text{ g He}$$

101. a. Given: 3.00 g BBr₃
Unknown: number of moles BBr₃

$$\begin{aligned} \text{formula mass} &= 1 \text{ atom B} \times \frac{10.81 \text{ amu}}{1 \text{ atom B}} + 3 \text{ atoms Br} \times \frac{79.90 \text{ amu}}{1 \text{ atom Br}} \\ &= 10.81 \text{ amu} + 239.70 \text{ amu} = 250.51 \text{ amu} \end{aligned}$$

$$3.00 \text{ g BBr}_3 \times \frac{1 \text{ mol BBr}_3}{250.51 \text{ g BBr}_3} = 0.0120 \text{ mol BBr}_3$$

b. Given: 0.472 g NaF
Unknown: number of moles NaF

$$\begin{aligned} \text{formula mass NaF} &= 1 \text{ atom Na} \times \frac{22.99 \text{ amu}}{1 \text{ atom Na}} + 1 \text{ atom F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}} \\ &= 41.99 \text{ amu} \end{aligned}$$

$$0.472 \text{ g NaF} \times \frac{1 \text{ mol NaF}}{41.99 \text{ g NaF}} = 0.0112 \text{ mol NaF}$$

c. Given: 7.50×10^2 g CH_3OH
 Unknown: number of moles CH_3OH

$$\text{formula mass } \text{CH}_3\text{OH} = 1 \text{ atom C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 4 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 32.05 \text{ amu}$$

$$7.50 \times 10^2 \text{ g } \text{CH}_3\text{OH} \times \frac{1 \text{ mol } \text{CH}_3\text{OH}}{32.05 \text{ g } \text{CH}_3\text{OH}} = 23.4 \text{ mol } \text{CH}_3\text{OH}$$

d. Given: 50.0 g $\text{Ca}(\text{ClO}_3)_2$
 Unknown: number of moles $\text{Ca}(\text{ClO}_3)_2$

$$\text{formula mass } \text{Ca}(\text{ClO}_3)_2 = 1 \text{ atom Ca} \times \frac{40.08 \text{ amu}}{1 \text{ atom Ca}} + 2 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 206.98 \text{ amu}$$

$$50.0 \text{ g } \text{Ca}(\text{ClO}_3)_2 \times \frac{1 \text{ mol } \text{Ca}(\text{ClO}_3)_2}{206.98 \text{ g } \text{Ca}(\text{ClO}_3)_2} = 0.242 \text{ mol } \text{Ca}(\text{ClO}_3)_2$$

102. a. Given: 1.366 mol NH_3
 Unknown: mass NH_3

$$\text{formula mass } \text{NH}_3 = 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 3 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} = 17.04 \text{ amu}$$

$$1.366 \text{ mol } \text{NH}_3 \times \frac{17.04 \text{ g } \text{NH}_3}{1 \text{ mol } \text{NH}_3} = 23.28 \text{ g } \text{NH}_3$$

b. Given: 0.120 mol $\text{C}_6\text{H}_{12}\text{O}_6$
 Unknown: mass $\text{C}_6\text{H}_{12}\text{O}_6$

$$\text{formula mass } \text{C}_6\text{H}_{12}\text{O}_6 = 6 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 12 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 180.18 \text{ amu}$$

$$0.120 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6 \times \frac{180.18 \text{ g } \text{C}_6\text{H}_{12}\text{O}_6}{1 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6} = 21.6 \text{ g } \text{C}_6\text{H}_{12}\text{O}_6$$

c. Given: 6.94 mol BaCl_2
 Unknown: mass BaCl_2

$$\text{formula mass } \text{BaCl}_2 = 1 \text{ atom Ba} \times \frac{137.33 \text{ amu}}{1 \text{ atom Ba}} + 2 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} = 208.23 \text{ amu}$$

$$6.94 \text{ mol } \text{BaCl}_2 \times \frac{208.23 \text{ g } \text{BaCl}_2}{1 \text{ mol } \text{BaCl}_2} = 1450 \text{ g } \text{BaCl}_2$$

d. Given: 0.005 mol C_3H_8
 Unknown: mass C_3H_8

$$\text{formula mass } \text{C}_3\text{H}_8 = 3 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 8 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} = 44.11 \text{ amu}$$

$$0.005 \text{ mol } \text{C}_3\text{H}_8 \times \frac{44.11 \text{ g } \text{C}_3\text{H}_8}{1 \text{ mol } \text{C}_3\text{H}_8} = 0.2 \text{ g } \text{C}_3\text{H}_8$$

103. a. Given: 4.99 mol CH_4
 Unknown: number of molecules

$$4.99 \text{ mol } \text{CH}_4 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 3.00 \times 10^{24} \text{ molecules } \text{CH}_4$$

- b.** Given: 0.005 20 mol N_2
Unknown: number of molecules
$$5.20 \times 10^{-3} \text{ mol N}_2 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 3.13 \times 10^{21} \text{ molecules N}_2$$
- c.** Given: 1.05 mol PCl_3
Unknown: number of molecules
$$1.05 \text{ mol PCl}_3 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 6.32 \times 10^{23} \text{ molecules PCl}_3$$
- d.** Given: 3.5×10^{-5} mol $\text{C}_6\text{H}_8\text{O}_6$
Unknown: number of molecules
$$3.5 \times 10^{-5} \text{ mol C}_6\text{H}_8\text{O}_6 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 2.1 \times 10^{19} \text{ molecules C}_6\text{H}_8\text{O}_6$$

- 104. a.** Given: 1.25 mol KBr
Unknown: number of formula units
$$1.25 \text{ mol KBr} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 7.53 \times 10^{23} \text{ formula units KBr}$$
- b.** Given: 5.00 mol MgCl_2
Unknown: number of formula units
$$5.00 \text{ mol MgCl}_2 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 3.01 \times 10^{24} \text{ formula units MgCl}_2$$
- c.** Given: 0.025 mol Na_2CO_3
Unknown: number of formula units
$$0.025 \text{ mol Na}_2\text{CO}_3 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 1.5 \times 10^{22} \text{ formula units Na}_2\text{CO}_3$$
- d.** Given: 6.82×10^{-6} mol $\text{Pb}(\text{NO}_3)_2$
Unknown: number of formula units
$$6.82 \times 10^{-6} \text{ mol Pb}(\text{NO}_3)_2 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 4.11 \times 10^{18} \text{ formula units Pb}(\text{NO}_3)_2$$

- 105. a.** Given: 3.34×10^{34} formula units $\text{Cu}(\text{OH})_2$
Unknown: amount in moles
$$3.34 \times 10^{34} \text{ formula units Cu}(\text{OH})_2 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}} = 5.55 \times 10^{10} \text{ mol Cu}(\text{OH})_2$$
- b.** Given: 1.17×10^{16} molecules H_2S
Unknown: amount in moles
$$1.17 \times 10^{16} \text{ molecules H}_2\text{S} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} = 1.94 \times 10^{-8} \text{ mol H}_2\text{S}$$
- c.** Given: 5.47×10^{21} formula units of NiSO_4
Unknown: amount in moles
$$5.47 \times 10^{21} \text{ formula units NiSO}_4 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}} = 9.08 \times 10^{-3} \text{ mol NiSO}_4$$

d. Given: 7.66×10^{19} molecules of H_2O_2
 Unknown: amount in moles

$$7.66 \times 10^{19} \text{ molecules } \text{H}_2\text{O}_2 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} = 1.27 \times 10^{-4} \text{ mol } \text{H}_2\text{O}_2$$

106. a. Given: 2.41×10^{24} molecules H_2
 Unknown: mass H_2

$$\text{formula mass } \text{H}_2 = 2 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} = 2.02 \text{ amu}$$

$$2.41 \times 10^{24} \text{ molecules } \text{H}_2 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{2.02 \text{ g } \text{H}_2}{1 \text{ mol } \text{H}_2} = 8.08 \text{ g } \text{H}_2$$

b. Given: 5.00×10^{21} formula units $\text{Al}(\text{OH})_3$
 Unknown: mass $\text{Al}(\text{OH})_3$

$$\text{formula mass } \text{Al}(\text{OH})_3 = 1 \text{ atom Al} \times \frac{26.98 \text{ amu}}{1 \text{ atom Al}} + 3 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} + 3 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} = 78.01 \text{ amu}$$

$$5.00 \times 10^{21} \text{ formula units } \text{Al}(\text{OH})_3 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}} \times \frac{78.01 \text{ g } \text{Al}(\text{OH})_3}{1 \text{ mol } \text{Al}(\text{OH})_3} = 0.648 \text{ g } \text{Al}(\text{OH})_3$$

c. Given: 8.25×10^{22} molecules BrF_5
 Unknown: mass BrF_5

$$\text{formula mass } \text{BrF}_5 = 1 \text{ atom Br} \times \frac{79.90 \text{ amu}}{1 \text{ atom Br}} + 5 \text{ atoms F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}} = 174.90 \text{ amu}$$

$$8.25 \times 10^{22} \text{ molecules } \text{BrF}_5 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{174.90 \text{ g } \text{BrF}_5}{1 \text{ mol } \text{BrF}_5} = 24.0 \text{ g } \text{BrF}_5$$

d. Given: 1.20×10^{23} formula units $\text{Na}_2\text{C}_2\text{O}_4$
 Unknown: mass $\text{Na}_2\text{C}_2\text{O}_4$

$$\text{formula mass } \text{Na}_2\text{C}_2\text{O}_4 = 2 \text{ atoms Na} \times \frac{22.99 \text{ amu}}{1 \text{ atom Na}} + 2 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 134 \text{ amu}$$

$$1.20 \times 10^{23} \text{ formula units } \text{Na}_2\text{C}_2\text{O}_4 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}} \times \frac{134 \text{ g } \text{Na}_2\text{C}_2\text{O}_4}{1 \text{ mol } \text{Na}_2\text{C}_2\text{O}_4} = 26.7 \text{ g } \text{Na}_2\text{C}_2\text{O}_4$$

107. a. Given: 22.9 g Na_2S
 Unknown: number of formula units Na_2S

$$\text{formula mass } \text{Na}_2\text{S} = 2 \text{ atoms Na} \times \frac{22.99 \text{ amu}}{1 \text{ atom Na}} + 1 \text{ atom S} \times \frac{32.01 \text{ amu}}{1 \text{ atom S}} = 77.99 \text{ amu}$$

$$22.9 \text{ g } \text{Na}_2\text{S} \times \frac{1 \text{ mol } \text{Na}_2\text{S}}{77.99 \text{ g } \text{Na}_2\text{S}} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 1.77 \times 10^{23} \text{ formula units } \text{Na}_2\text{S}$$

b. Given: 0.272 g $\text{Ni}(\text{NO}_3)_2$
 Unknown: number of formula units $\text{Ni}(\text{NO}_3)_2$

$$\begin{aligned} \text{formula mass } \text{Ni}(\text{NO}_3)_2 &= 1 \text{ atom Ni} \times \frac{58.69 \text{ amu}}{1 \text{ atom Ni}} + 2 \text{ atoms N} \\ &\times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 182.71 \text{ amu} \\ 0.272 \text{ g } \text{Ni}(\text{NO}_3)_2 &\times \frac{1 \text{ mol } \text{Ni}(\text{NO}_3)_2}{182.71 \text{ g } \text{Ni}(\text{NO}_3)_2} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} \\ &= 8.96 \times 10^{20} \text{ formula units } \text{Ni}(\text{NO}_3)_2 \end{aligned}$$

c. Given: 260 mg CH_2CHCN
 Unknown: number of molecules CH_2CHCN

$$\begin{aligned} \text{formula mass } \text{CH}_2\text{CHCN} &= 3 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 3 \text{ atoms H} \\ &\times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} = 53.07 \text{ amu} \\ 260 \text{ mg } \text{CH}_2\text{CHCN} &\times \frac{1 \text{ mol } \text{CH}_2\text{CHCN}}{53.07 \text{ g } \text{CH}_2\text{CHCN}} \times \frac{1 \text{ g}}{1000 \text{ mg}} \\ &\times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 3.0 \times 10^{21} \text{ molecules } \text{CH}_2\text{CHCN} \end{aligned}$$

108. a. Given: 0.039 g Pd
 Unknown: number of moles Pd

$$0.039 \text{ g Pd} \times \frac{1 \text{ mol Pd}}{106.42 \text{ g Pd}} = 3.7 \times 10^{-4} \text{ mol Pd}$$

b. Given: 8200 g Fe
 Unknown: number of moles Fe

$$8200 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} = 150 \text{ mol Fe}$$

c. Given: 0.0073 kg Ta
 Unknown: number of moles Ta

$$0.0073 \text{ kg Ta} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol Ta}}{180.95 \text{ g Ta}} = 0.040 \text{ mol Ta}$$

d. Given: 0.006 55 g Sb
 Unknown: number of moles Sb

$$0.006 \text{ 55 g Sb} \times \frac{1 \text{ mol Sb}}{121.76 \text{ g Sb}} = 5.38 \times 10^{-5} \text{ mol Sb}$$

e. Given: 5.64 kg Ba
 Unknown: number of moles Ba

$$5.64 \text{ kg Ba} \times \frac{1 \text{ mol Ba}}{137.33 \text{ g Ba}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 41.1 \text{ mol Ba}$$

f. Given: 3.37×10^{-6} g Mo
 Unknown: number of moles Mo

$$3.37 \times 10^{-6} \text{ g Mo} \times \frac{1 \text{ mol Mo}}{95.94 \text{ g Mo}} = 3.51 \times 10^{-8} \text{ mol Mo}$$

109. a. Given: 1.002 mol Cr
 Unknown: mass Cr

$$1.002 \text{ mol Cr} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}} = 52.10 \text{ g Cr}$$

b. Given: 550 mol Al
 Unknown: mass Al

$$550 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 1.5 \times 10^4 \text{ g Al}$$

c. Given: 4.08×10^{-8} mol Ne
Unknown: mass Ne

$$4.08 \times 10^{-8} \text{ mol Ne} \times \frac{20.18 \text{ g Ne}}{1 \text{ mol Ne}} = 8.23 \times 10^{-7} \text{ g Ne}$$

d. Given: 7 mol Ti
Unknown: mass Ti

$$7 \text{ mol Ti} \times \frac{47.88 \text{ g Ti}}{1 \text{ mol Ti}} = 3 \times 10^2 \text{ g Ti}$$

e. Given: 0.0086 mol Xe
Unknown: mass Xe

$$0.0086 \text{ mol Xe} \times \frac{131.29 \text{ g Xe}}{1 \text{ mol Xe}} = 1.1 \text{ g Xe}$$

f. Given: 3.29×10^4 mol Li
Unknown: mass Li

$$3.29 \times 10^4 \text{ mol Li} \times \frac{6.94 \text{ g Li}}{1 \text{ mol Li}} = 2.28 \times 10^5 \text{ g Li}$$

110. a. Given: 17.0 mol Ge
Unknown: number of atoms

$$17.0 \text{ mol Ge} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.02 \times 10^{25} \text{ atoms Ge}$$

b. Given: 0.6144 mol Cu
Unknown: number of atoms

$$0.6144 \text{ mol Cu} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 3.700 \times 10^{23} \text{ atoms Cu}$$

c. Given: 3.02 mol Sn
Unknown: number of atoms

$$3.02 \text{ mol Sn} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.82 \times 10^{24} \text{ atoms Sn}$$

d. Given: 2.0×10^6 mol C
Unknown: number of atoms

$$2.0 \times 10^6 \text{ mol C} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.2 \times 10^{30} \text{ atoms C}$$

e. Given: 0.0019 mol Zr
Unknown: number of atoms

$$0.0019 \text{ mol Zr} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.1 \times 10^{21} \text{ atoms Zr}$$

f. Given: 3.227×10^{-10} mol K
Unknown: number of atoms

$$3.227 \times 10^{-10} \text{ mol K} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 1.943 \times 10^{14} \text{ atoms K}$$

111. a. Given: 6.022×10^{24} atoms Co
Unknown: number of moles Co

$$6.022 \times 10^{24} \text{ atoms Co} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 10.00 \text{ mol Co}$$

b. Given: 1.06×10^{23} atoms W
Unknown: number of moles W

$$1.06 \times 10^{23} \text{ atoms W} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 0.176 \text{ mol W}$$

c. Given: 3.008×10^{19} atoms Ag
Unknown: number of moles Ag

$$3.008 \times 10^{19} \text{ atoms Ag} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 4.995 \times 10^{-5} \text{ mol Ag}$$

d. Given: 950 000 000 atoms Pu
Unknown: number of moles Pu

$$9.5 \times 10^8 \text{ atoms Pu} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 1.6 \times 10^{-15} \text{ mol Pu}$$

e. Given: 4.61×10^{17} atoms Rn
Unknown: number of moles Rn

$$4.61 \times 10^{17} \text{ atoms Rn} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 7.66 \times 10^{-7} \text{ mol Rn}$$

f. Given: 8 trillion atoms Ce
Unknown: number of moles Ce

$$8 \times 10^{12} \text{ atoms Ce} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 1 \times 10^{-11} \text{ mol Ce}$$

112. a. Given: 0.0082 g Au
Unknown: number of atoms Au

$$0.0082 \text{ g Au} \times \frac{1 \text{ mol Au}}{196.97 \text{ g Au}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 2.5 \times 10^{19} \text{ atoms Au}$$

b. Given: 812 g Mo
Unknown: number of atoms Mo

$$812 \text{ g Mo} \times \frac{1 \text{ mol Mo}}{95.94 \text{ g Mo}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 5.10 \times 10^{24} \text{ atoms Mo}$$

c. Given: 2.00×10^2 mg Am
Unknown: number of atoms Am

$$2.00 \times 10^2 \text{ mg Am} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol Am}}{243.06 \text{ g Am}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 4.96 \times 10^{20} \text{ atoms Am}$$

d. Given: 10.09 kg Ne
Unknown: number of atoms Ne

$$10.09 \text{ kg Ne} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol Ne}}{20.18 \text{ g Ne}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 3.011 \times 10^{26} \text{ atoms Ne}$$

e. Given: 0.705 mg Bi
Unknown: number of atoms Bi

$$0.705 \text{ mg Bi} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol Bi}}{208.98 \text{ g Bi}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 2.03 \times 10^{18} \text{ atoms Bi}$$

f. Given: 37 μg U
Unknown: number of atoms U

$$37 \mu\text{g U} \times \frac{1 \text{ g}}{10^6 \mu\text{g}} \times \frac{1 \text{ mol U}}{238.03 \text{ g U}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}} = 9.4 \times 10^{16} \text{ atoms U}$$

113. a. Given: 8.22×10^{23} atoms Rb
Unknown: mass Rb

$$8.22 \times 10^{23} \text{ atoms Rb} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{85.47 \text{ g Rb}}{1 \text{ mol Rb}} = 117 \text{ g Rb}$$

- b.** Given: 4.05 Avogadro's constants of Mn atoms
Unknown: mass Mn
- $$4.05 \times 6.022 \times 10^{23} \text{ atoms Mn} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{54.94 \text{ g Mn}}{1 \text{ mol Mn}} = 223 \text{ g Mn}$$
- c.** Given: 9.96×10^{26} atoms Te
Unknown: mass Te
- $$9.96 \times 10^{26} \text{ atoms Te} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{127.60 \text{ g Te}}{1 \text{ mol Te}} = 2.11 \times 10^5 \text{ g Te}$$
- d.** Given: 0.000 025 Avogadro's constants of Rh atoms
Unknown: mass Rh
- $$2.5 \times 10^{-5} \times 6.022 \times 10^{23} \text{ atoms Rh} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{102.91 \text{ g Rh}}{1 \text{ mol Rh}} = 2.6 \times 10^{-3} \text{ g Rh}$$
- e.** Given: 88 300 000 000 000 atoms Ra
Unknown: mass Ra
- $$8.83 \times 10^{13} \text{ atoms Ra} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{226.03 \text{ g Ra}}{1 \text{ mol Ra}} = 3.31 \times 10^{-8} \text{ g Ra}$$
- f.** Given: 2.94×10^{17} atoms Hf
Unknown: mass Hf
- $$2.94 \times 10^{17} \text{ atoms Hf} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} \times \frac{178.49 \text{ g Hf}}{1 \text{ mol Hf}} = 8.71 \times 10^{-5} \text{ g Hf}$$

- 114. a.** Given: 45.0 g CH₃COOH
Unknown: moles CH₃COOH
- formula mass CH₃COOH = 2 atoms C $\times \frac{12.01 \text{ amu}}{1 \text{ atom C}}$
 + 4 atoms H $\times \frac{1.01 \text{ amu}}{1 \text{ atom H}}$ + 2 atoms O $\times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$ = 60.06 amu
- $$45.0 \text{ g CH}_3\text{COOH} \times \frac{1 \text{ mol CH}_3\text{COOH}}{60.06 \text{ g CH}_3\text{COOH}} = 0.749 \text{ mol CH}_3\text{COOH}$$
- b.** Given: 7.04 g Pb(NO₃)₂
Unknown: moles Pb(NO₃)₂
- formula mass Pb(NO₃)₂ = 1 atom Pb $\times \frac{207.2 \text{ amu}}{1 \text{ atom Pb}}$ + 2 atoms N $\times \frac{14.01 \text{ amu}}{1 \text{ atom N}}$ + 6 atoms O $\times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$ = 331.22 amu
- $$7.04 \text{ g Pb(NO}_3)_2 \times \frac{1 \text{ mol Pb(NO}_3)_2}{331.22 \text{ g Pb(NO}_3)_2} = 0.0213 \text{ mol Pb(NO}_3)_2$$
- c.** Given: 5000 kg Fe₂O₃
Unknown: moles Fe₂O₃
- formula mass Fe₂O₃ = 2 atoms Fe $\times \frac{55.85 \text{ amu}}{1 \text{ atom Fe}}$ + 3 atoms O $\times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$ = 159.70 amu
- $$5000 \text{ kg Fe}_2\text{O}_3 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol Fe}_2\text{O}_3}{159.70 \text{ g Fe}_2\text{O}_3} = 3 \times 10^4 \text{ mol Fe}_2\text{O}_3$$

d. Given: 12.0 mg $\text{C}_2\text{H}_5\text{NH}_2$
 Unknown: moles $\text{C}_2\text{H}_5\text{NH}_2$

$$\begin{aligned} \text{formula mass } \text{C}_2\text{H}_5\text{NH}_2 &= 2 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 7 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} \\ &+ 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} = 45.10 \text{ amu} \\ 12.0 \text{ mg } \text{C}_2\text{H}_5\text{NH}_2 &\times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol } \text{C}_2\text{H}_5\text{NH}_2}{45.10 \text{ g } \text{C}_2\text{H}_5\text{NH}_2} \\ &= 2.66 \times 10^{-4} \text{ mol } \text{C}_2\text{H}_5\text{NH}_2 \end{aligned}$$

e. Given: 0.003 22 g $\text{C}_{17}\text{H}_{35}\text{COOH}$
 Unknown: moles $\text{C}_{17}\text{H}_{35}\text{COOH}$

$$\begin{aligned} \text{formula mass } \text{C}_{17}\text{H}_{35}\text{COOH} &= 18 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} \\ &+ 36 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 2 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 284.54 \text{ amu} \\ 3.22 \times 10^{-3} \text{ g } \text{C}_{17}\text{H}_{35}\text{COOH} &\times \frac{1 \text{ mol } \text{C}_{17}\text{H}_{35}\text{COOH}}{284.54 \text{ g } \text{C}_{17}\text{H}_{35}\text{COOH}} \\ &= 1.13 \times 10^{-5} \text{ mol } \text{C}_{17}\text{H}_{35}\text{COOH} \end{aligned}$$

f. Given: 50.0 kg $(\text{NH}_4)_2\text{SO}_4$
 Unknown: moles $(\text{NH}_4)_2\text{SO}_4$

$$\begin{aligned} \text{formula mass } (\text{NH}_4)_2\text{SO}_4 &= 2 \text{ atoms N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 8 \text{ atoms H} \\ &\times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom S} \times \frac{32.07 \text{ amu}}{1 \text{ atom S}} + 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} \\ &= 132.17 \text{ amu} \\ 50.0 \text{ kg } (\text{NH}_4)_2\text{SO}_4 &\times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } (\text{NH}_4)_2\text{SO}_4}{132.17 \text{ g } (\text{NH}_4)_2\text{SO}_4} \\ &= 378 \text{ mol } (\text{NH}_4)_2\text{SO}_4 \end{aligned}$$

115. a. Given: 3.00 mol SeOBr_2
 Unknown: mass SeOBr_2

$$\begin{aligned} \text{formula mass } \text{SeOBr}_2 &= 1 \text{ atom Se} \times \frac{78.96 \text{ amu}}{1 \text{ atom Se}} \\ &+ 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} + 2 \text{ atoms Br} \times \frac{79.90 \text{ amu}}{1 \text{ atom Br}} \\ &= 254.76 \text{ amu} \\ 3.00 \text{ mol } \text{SeOBr}_2 &\times \frac{254.76 \text{ g } \text{SeOBr}_2}{1 \text{ mol } \text{SeOBr}_2} = 764 \text{ g } \text{SeOBr}_2 \end{aligned}$$

b. Given: 488 mol CaCO_3
 Unknown: mass CaCO_3

$$\begin{aligned} \text{formula mass } \text{CaCO}_3 &= 1 \text{ atom Ca} \times \frac{40.08 \text{ amu}}{1 \text{ atom Ca}} + 1 \text{ atom C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} \\ &+ 3 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 100.09 \text{ amu} \\ 488 \text{ mol } \text{CaCO}_3 &\times \frac{100.09 \text{ g } \text{CaCO}_3}{1 \text{ mol } \text{CaCO}_3} = 4.88 \times 10^4 \text{ g } \text{CaCO}_3 \end{aligned}$$

- c.** Given: 0.0091 mol $\text{C}_{20}\text{H}_{28}\text{O}_2$
Unknown: mass $\text{C}_{20}\text{H}_{28}\text{O}_2$
- $$\text{formula mass } \text{C}_{20}\text{H}_{28}\text{O}_2 = 20 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 28 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 2 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 300.48 \text{ amu}$$
- $$0.0091 \text{ mol } \text{C}_{20}\text{H}_{28}\text{O}_2 \times \frac{300.48 \text{ g } \text{C}_{20}\text{H}_{28}\text{O}_2}{1 \text{ mol } \text{C}_{20}\text{H}_{28}\text{O}_2} = 2.7 \text{ g } \text{C}_{20}\text{H}_{28}\text{O}_2$$
- d.** Given: 6.00×10^{-8} mol $\text{C}_{10}\text{H}_{14}\text{N}_2$
Unknown: mass $\text{C}_{10}\text{H}_{14}\text{N}_2$
- $$\text{formula mass } \text{C}_{10}\text{H}_{14}\text{N}_2 = 10 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 14 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 2 \text{ atoms N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} = 162.26 \text{ amu}$$
- $$6.00 \times 10^{-8} \text{ mol } \text{C}_{10}\text{H}_{14}\text{N}_2 \times \frac{162.26 \text{ g } \text{C}_{10}\text{H}_{14}\text{N}_2}{1 \text{ mol } \text{C}_{10}\text{H}_{14}\text{N}_2} = 9.74 \times 10^{-6} \text{ g } \text{C}_{10}\text{H}_{14}\text{N}_2$$
- e.** Given: 2.50 mol $\text{Sr}(\text{NO}_3)_2$
Unknown: mass $\text{Sr}(\text{NO}_3)_2$
- $$\text{formula mass } \text{Sr}(\text{NO}_3)_2 = 1 \text{ atom Sr} \times \frac{87.62 \text{ amu}}{1 \text{ atom Sr}} + 2 \text{ atoms N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 211.64 \text{ amu}$$
- $$2.50 \text{ mol } \text{Sr}(\text{NO}_3)_2 \times \frac{211.64 \text{ g } \text{Sr}(\text{NO}_3)_2}{1 \text{ mol } \text{Sr}(\text{NO}_3)_2} = 529 \text{ g } \text{Sr}(\text{NO}_3)_2$$
- f.** Given: 3.50×10^{-6} mol UF_6
Unknown: mass UF_6
- $$\text{formula mass } \text{UF}_6 = 1 \text{ atom U} \times \frac{238.03 \text{ amu}}{1 \text{ atom U}} + 6 \text{ atoms F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}} = 352.03 \text{ amu}$$
- $$3.50 \times 10^{-6} \text{ mol } \text{UF}_6 \times \frac{352.03 \text{ g } \text{UF}_6}{1 \text{ mol } \text{UF}_6} = 1.23 \times 10^{-3} \text{ g } \text{UF}_6$$

- 116. a.** Given: 4.27 mol WO_3
Unknown: number of formula units
- $$4.27 \text{ mol } \text{WO}_3 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 2.57 \times 10^{24} \text{ formula units } \text{WO}_3$$
- b.** Given: 0.003 00 mol $\text{Sr}(\text{NO}_3)_2$
Unknown: number of formula units
- $$3.00 \times 10^{-3} \text{ mol } \text{Sr}(\text{NO}_3)_2 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 1.81 \times 10^{21} \text{ formula units } \text{Sr}(\text{NO}_3)_2$$
- c.** Given 72.5 mol $\text{C}_6\text{H}_5\text{CH}_3$
Unknown: number of molecules
- $$72.5 \text{ mol } \text{C}_6\text{H}_5\text{CH}_3 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 4.37 \times 10^{25} \text{ molecules } \text{C}_6\text{H}_5\text{CH}_3$$

- d.** Given: 5.11×10^{-7} mol $\text{C}_{29}\text{H}_{50}\text{O}_2$
Unknown: number of molecules
- $$5.11 \times 10^{-7} \text{ mol } \text{C}_{29}\text{H}_{50}\text{O}_2 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 3.08 \times 10^{17} \text{ molecules } \text{C}_{29}\text{H}_{50}\text{O}_2$$
- e.** Given: 1500 mol N_2H_4
Unknown: number of molecules
- $$1500 \text{ mol } \text{N}_2\text{H}_4 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 9.0 \times 10^{26} \text{ molecules } \text{N}_2\text{H}_4$$
- f.** Given: 0.989 mol $\text{C}_6\text{H}_5\text{NO}_2$
Unknown: number of molecules
- $$0.989 \text{ mol } \text{C}_6\text{H}_5\text{NO}_2 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 5.96 \times 10^{23} \text{ molecules } \text{C}_6\text{H}_5\text{NO}_2$$

- 117. a.** Given: 285 g FePO_4
Unknown: number of formula units FePO_4
- $$\begin{aligned} \text{formula mass } \text{FePO}_4 &= 1 \text{ atom Fe} \times \frac{55.85 \text{ amu}}{1 \text{ atom Fe}} + 1 \text{ atom P} \times \frac{30.97 \text{ amu}}{1 \text{ atom P}} \\ &+ 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 150.82 \text{ amu} \\ 285 \text{ g } \text{FePO}_4 &\times \frac{1 \text{ mol } \text{FePO}_4}{150.82 \text{ g } \text{FePO}_4} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} \\ &= 1.14 \times 10^{24} \text{ formula units } \text{FePO}_4 \end{aligned}$$
- b.** Given: 0.0084 g $\text{C}_5\text{H}_5\text{N}$
Unknown: number of molecules $\text{C}_5\text{H}_5\text{N}$
- $$\begin{aligned} \text{formula mass } \text{C}_5\text{H}_5\text{N} &= 5 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 5 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} \\ &+ 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} = 79.11 \text{ amu} \\ 0.0084 \text{ g } \text{C}_5\text{H}_5\text{N} &\times \frac{1 \text{ mol } \text{C}_5\text{H}_5\text{N}}{79.11 \text{ g } \text{C}_5\text{H}_5\text{N}} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} \\ &= 6.4 \times 10^{19} \text{ molecules } \text{C}_5\text{H}_5\text{N} \end{aligned}$$
- c.** Given: 85 mg $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$
Unknown: number of molecules $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$
- $$\begin{aligned} \text{formula mass } (\text{CH}_3)_2\text{CHCH}_2\text{OH} &= 4 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} \\ &+ 10 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 74.14 \text{ amu} \\ 85 \text{ mg } (\text{CH}_3)_2\text{CHCH}_2\text{OH} &\times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol } (\text{CH}_3)_2\text{CHCH}_2\text{OH}}{74.14 \text{ g } (\text{CH}_3)_2\text{CHCH}_2\text{OH}} \\ &\times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 6.9 \times 10^{20} \text{ molecules } (\text{CH}_3)_2\text{CHCH}_2\text{OH} \end{aligned}$$

d. Given: 4.6×10^{-4} g $\text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2$
 Unknown: number of formula units $\text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2$

$$\begin{aligned} \text{formula mass } \text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2 &= 1 \text{ atom Hg} \times \frac{200.59 \text{ amu}}{1 \text{ atom Hg}} + 4 \text{ atoms C} \\ &\times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 6 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} \\ &= 318.69 \text{ amu} \end{aligned}$$

$$\begin{aligned} 4.6 \times 10^{-4} \text{ g } \text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2 &\times \frac{1 \text{ mol } \text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2}{318.69 \text{ g } \text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2} \\ &\times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 8.7 \times 10^{17} \text{ formula units } \text{Hg}(\text{C}_2\text{H}_3\text{O}_2)_2 \end{aligned}$$

e. Given: 0.0067 g Li_2CO_3
 Unknown: number of formula units Li_2CO_3

$$\begin{aligned} \text{formula mass } \text{Li}_2\text{CO}_3 &= 2 \text{ atoms Li} \times \frac{6.94 \text{ amu}}{1 \text{ atom Li}} + 1 \text{ atom C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} \\ &+ 3 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 73.89 \text{ amu} \\ 6.7 \times 10^{-3} \text{ g } \text{Li}_2\text{CO}_3 &\times \frac{1 \text{ mol } \text{Li}_2\text{CO}_3}{73.89 \text{ g } \text{Li}_2\text{CO}_3} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} \\ &= 5.5 \times 10^{19} \text{ formula units } \text{Li}_2\text{CO}_3 \end{aligned}$$

118. a. Given: 8.39×10^{23} molecules F_2
 Unknown: mass F_2

$$\begin{aligned} \text{formula mass } \text{F}_2 &= 2 \text{ atoms F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}} = 38.00 \text{ amu} \\ 8.39 \times 10^{23} \text{ molecules } \text{F}_2 &\times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{38.00 \text{ g } \text{F}_2}{1 \text{ mol } \text{F}_2} = 52.9 \text{ g } \text{F}_2 \end{aligned}$$

b. Given: 6.82×10^{24} formula units BeSO_4
 Unknown: mass BeSO_4

$$\begin{aligned} \text{formula mass } \text{BeSO}_4 &= 1 \text{ atom Be} \times \frac{9.01 \text{ amu}}{1 \text{ atom Be}} + 1 \text{ atom S} \times \frac{32.07 \text{ amu}}{1 \text{ atom S}} \\ &+ 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 105.08 \text{ amu} \\ 6.82 \times 10^{24} \text{ formula units } \text{BeSO}_4 &\times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}} \\ &\times \frac{105.08 \text{ g } \text{BeSO}_4}{1 \text{ mol } \text{BeSO}_4} = 1190 \text{ g } \text{BeSO}_4 \end{aligned}$$

c. Given: 7.004×10^{26} molecules CHCl_3
 Unknown: mass CHCl_3

$$\begin{aligned} \text{formula mass } \text{CHCl}_3 &= 1 \text{ atom C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 1 \text{ atom H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} \\ &+ 3 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} = 119.37 \text{ amu} \\ 7.004 \times 10^{26} \text{ molecules } \text{CHCl}_3 &\times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \\ &\times \frac{119.37 \text{ g } \text{CHCl}_3}{1 \text{ mol } \text{CHCl}_3} = 1.388 \times 10^5 \text{ g } \text{CHCl}_3 \end{aligned}$$

- d.** Given: 31 billion formula units Cr(CHO₂)₃
Unknown: mass Cr(CHO₂)₃

$$\begin{aligned}\text{formula mass Cr(CHO}_2\text{)}_3 &= 1 \text{ atom Cr} \times \frac{52.00 \text{ amu}}{1 \text{ atom Cr}} \\ &+ 3 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 3 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} \\ &= 187.06 \text{ amu}\end{aligned}$$

$$\begin{aligned}3.1 \times 10^{10} \text{ formula units Cr(CHO}_2\text{)}_3 &\times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}} \\ &\times \frac{187.06 \text{ g Cr(CHO}_2\text{)}_3}{1 \text{ mol Cr(CHO}_2\text{)}_3} = 9.6 \times 10^{-12} \text{ g Cr(CHO}_2\text{)}_3\end{aligned}$$

- e.** Given: 6.3×10^{18} molecules HNO₃
Unknown: mass HNO₃

$$\begin{aligned}\text{formula mass HNO}_3 &= 1 \text{ atom H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} \\ &+ 3 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 63.02 \text{ amu}\end{aligned}$$

$$\begin{aligned}6.3 \times 10^{18} \text{ molecules HNO}_3 &\times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{63.02 \text{ g HNO}_3}{1 \text{ mol HNO}_3} \\ &= 6.6 \times 10^{-4} \text{ g HNO}_3\end{aligned}$$

- f.** Given: 8.37×10^{25} molecules C₂Cl₂F₄
Unknown: mass C₂Cl₂F₄

$$\begin{aligned}\text{formula mass C}_2\text{Cl}_2\text{F}_4 &= 2 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} \\ &+ 2 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} + 4 \text{ atoms F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}} = 170.92 \text{ amu}\end{aligned}$$

$$\begin{aligned}8.37 \times 10^{25} \text{ molecules C}_2\text{Cl}_2\text{F}_4 &\times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \\ &\times \frac{170.92 \text{ g C}_2\text{Cl}_2\text{F}_4}{1 \text{ mol C}_2\text{Cl}_2\text{F}_4} = 2.38 \times 10^4 \text{ g C}_2\text{Cl}_2\text{F}_4\end{aligned}$$

- 119.** Given: 1 troy ounce = 31.1 g

Unknown: moles in a troy ounce of Au, Pt, Ag

$$31.1 \text{ g Au} \times \frac{1 \text{ mol Au}}{196.97 \text{ g Au}} = 0.158 \text{ mol Au}$$

$$31.1 \text{ g Pt} \times \frac{1 \text{ mol Pt}}{195.08 \text{ g Pt}} = 0.159 \text{ mol Pt}$$

$$31.1 \text{ g Ag} \times \frac{1 \text{ mol Ag}}{107.87 \text{ g Ag}} = 0.288 \text{ mol Ag}$$

- 120.** Given: 22.0 g C₆H₅OH
Unknown: moles C₆H₅OH

$$\begin{aligned}\text{formula mass C}_6\text{H}_5\text{OH} &= 6 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} \\ &+ 6 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 94.12 \text{ amu}\end{aligned}$$

$$22.0 \text{ g C}_6\text{H}_5\text{OH} \times \frac{1 \text{ mol C}_6\text{H}_5\text{OH}}{94.12 \text{ g C}_6\text{H}_5\text{OH}} = 0.234 \text{ mol C}_6\text{H}_5\text{OH}$$

- 121.** Given: 0.015 mol I₂
Unknown: mass I₂
- $$\text{formula mass I}_2 = 2 \text{ atoms I} \times \frac{126.90 \text{ amu}}{1 \text{ atom I}} = 253.80 \text{ amu}$$
- $$0.015 \text{ mol I}_2 \times \frac{253.80 \text{ g I}_2}{1 \text{ mol I}_2} = 3.8 \text{ g I}_2$$
-
- 122.** Given: 1 carat = 200 mg
Unknown: number of C atoms in 1.00 carat
- $$1 \text{ carat} \times \frac{200. \text{ mg}}{1 \text{ carat}} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} \times \frac{6.022 \times 10^{23} \text{ atoms}}{1 \text{ mol}}$$
- $$= 1.00 \times 10^{22} \text{ atoms C}$$
-
- 123. a.** Given: 8.00 g CaCl₂;
1.000 kg water
Unknown: moles of CaCl₂ and water
- $$\text{formula mass CaCl}_2 = 1 \text{ atom Ca} \times \frac{40.08 \text{ amu}}{1 \text{ atom Ca}}$$
- $$+ 2 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} = 110.98 \text{ amu}$$
- $$8.00 \text{ g CaCl}_2 \times \frac{1 \text{ mol CaCl}_2}{110.98 \text{ g CaCl}_2} = 0.0721 \text{ mol CaCl}_2$$
- $$\text{formula mass H}_2\text{O} = 2 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$$
- $$= 18.02 \text{ amu}$$
- $$1.000 \text{ kg H}_2\text{O} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} = 55.49 \text{ mol H}_2\text{O}$$
- b.** Given: 0.0721 mol CaCl₂ from part a
Unknown: moles of Ca²⁺ and Cl⁻ ions
- $$0.0721 \text{ mol CaCl}_2 \times \frac{1 \text{ mol Ca}^{2+}}{1 \text{ mol CaCl}_2} = 0.0721 \text{ mol Ca}^{2+}$$
- $$0.0721 \text{ mol CaCl}_2 \times \frac{2 \text{ mol Cl}^-}{1 \text{ mol CaCl}_2} = 0.144 \text{ mol Cl}^-$$
-
- 124. a.** Given: 453.6 g C₁₂H₂₂O₁₁
Unknown: moles C₁₂H₂₂O₁₁
- $$\text{formula mass C}_{12}\text{H}_{22}\text{O}_{11} = 12 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}}$$
- $$+ 22 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 11 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 342.34 \text{ amu}$$
- $$453.6 \text{ g C}_{12}\text{H}_{22}\text{O}_{11} \times \frac{1 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}}{342.34 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}} = 1.325 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}$$
- b.** Given: 453.6 g NaCl
Unknown: moles NaCl
- $$\text{formula mass NaCl} = 1 \text{ atom Na} \times \frac{22.99 \text{ amu}}{1 \text{ atom Na}} + 1 \text{ atom Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}}$$
- $$= 58.44 \text{ amu}$$
- $$453.6 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} = 7.762 \text{ mol NaCl}$$

- 125.** Given: 10.7 g NH_4Cl
Unknown: moles of ions
- $$\text{formula mass } \text{NH}_4\text{Cl} = 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 4 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} = 53.50 \text{ amu}$$
- $$10.7 \text{ g } \text{NH}_4\text{Cl} \times \frac{1 \text{ mol } \text{NH}_4\text{Cl}}{53.50 \text{ g } \text{NH}_4\text{Cl}} \times \frac{2 \text{ mol ions}}{1 \text{ mol } \text{NH}_4\text{Cl}} = 0.400 \text{ mol ions}$$
-
- 126.** Given: 2.41×10^{24} atoms Cr;
 1.51×10^{23} atoms Ni;
 3.01×10^{23} atoms Cr
Unknown: total moles
- $$2.41 \times 10^{24} \text{ atoms} + 0.15 \times 10^{24} \text{ atoms} + 0.301 \times 10^{24} \text{ atoms} = 2.86 \times 10^{24} \text{ atoms}$$
- $$2.86 \times 10^{24} \text{ atoms} \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}} = 4.75 \text{ mol}$$
-
- 127. a.** Given: 250.0 mL H_2O ; $D_{\text{H}_2\text{O}} = 0.997 \text{ g/mL}$
Unknown: mass H_2O
- $$250.0 \text{ mL } \text{H}_2\text{O} \times \frac{0.997 \text{ g } \text{H}_2\text{O}}{1 \text{ mL } \text{H}_2\text{O}} = 249 \text{ g } \text{H}_2\text{O}$$
- b.** Given: 249 g H_2O (from part a)
Unknown: moles H_2O
- $$\text{formula mass } \text{H}_2\text{O} = 2 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 18.02 \text{ amu}$$
- $$249 \text{ g } \text{H}_2\text{O} \times \frac{1 \text{ mol } \text{H}_2\text{O}}{18.02 \text{ g } \text{H}_2\text{O}} = 13.8 \text{ mol } \text{H}_2\text{O}$$
- c.** Given: $D_{\text{H}_2\text{O}} = 0.997 \text{ g/mL}$;
2000 mol H_2O
Unknown: volume
- $$2.000 \text{ mol } \text{H}_2\text{O} \times \frac{18.02 \text{ g } \text{H}_2\text{O}}{1 \text{ mol } \text{H}_2\text{O}} \times \frac{1 \text{ mL } \text{H}_2\text{O}}{0.997 \text{ g } \text{H}_2\text{O}} = 36.1 \text{ mL } \text{H}_2\text{O}$$
- d.** Given: 2.000 mol H_2O
Unknown: mass
- $$2.000 \text{ mol } \text{H}_2\text{O} \times \frac{18.02 \text{ g } \text{H}_2\text{O}}{1 \text{ mol } \text{H}_2\text{O}} = 36.04 \text{ g } \text{H}_2\text{O}$$
-
- 129.** Given: 6.35 g Cd
Unknown: mass of same number of Al atoms
- $$6.35 \text{ g Cd} \times \frac{1 \text{ mol}}{112.41 \text{ g Cd}} \times \frac{26.98 \text{ g Al}}{1 \text{ mol}} = 1.52 \text{ g Al}$$
-
- 130.** Given: Oxygen in cylinder: initial = 1027.8 g; final = 1023.2 g
Unknown: moles of O_2 used
- $$\text{formula mass } \text{O}_2 = 2 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 32.00 \text{ amu}$$
- $$\text{mass of } \text{O}_2 \text{ used} = 1027.8 \text{ g} - 1023.2 \text{ g} = 4.6 \text{ g}$$
- $$4.6 \text{ g } \text{O}_2 \times \frac{1 \text{ mol } \text{O}_2}{32.00 \text{ g } \text{O}_2} = 0.14 \text{ mol } \text{O}_2$$
-
- 131. a.** Given: 0.250 mol Ag_2S
Unknown: moles of Ag and S
- $$0.250 \text{ mol } \text{Ag}_2\text{S} \times \frac{2 \text{ mol Ag}}{1 \text{ mol } \text{Ag}_2\text{S}} = 0.500 \text{ mol Ag}$$
- $$0.250 \text{ mol } \text{Ag}_2\text{S} \times \frac{1 \text{ mol S}}{1 \text{ mol } \text{Ag}_2\text{S}} = 0.250 \text{ mol S}$$

b. Given: 38.8 g Ag₂S

Unknown: moles
Ag₂S, Ag,
and S

$$\begin{aligned}\text{formula mass Ag}_2\text{S} &= 2 \text{ atoms Ag} \times \frac{107.87 \text{ Amu}}{1 \text{ atom Ag}} + 1 \text{ atom S} \times \frac{32.07 \text{ amu}}{1 \text{ atom S}} \\ &= 247.81 \text{ amu}\end{aligned}$$

$$38.8 \text{ g Ag}_2\text{S} \times \frac{1 \text{ mol Ag}_2\text{S}}{247.81 \text{ g Ag}_2\text{S}} = 0.157 \text{ mol Ag}_2\text{S}$$

$$0.157 \text{ mol Ag}_2\text{S} \times \frac{2 \text{ mol Ag}}{1 \text{ mol Ag}_2\text{S}} = 0.314 \text{ mol Ag}$$

$$0.157 \text{ mol Ag}_2\text{S} \times \frac{1 \text{ mol S}}{1 \text{ mol Ag}_2\text{S}} = 0.157 \text{ mol S}$$

c. Given: 0.314 mol Ag;
0.157 mol S

Unknown: masses of
Ag and S

$$0.314 \text{ mol Ag} \times \frac{107.87 \text{ g Ag}}{1 \text{ mol Ag}} = 133.9 \text{ g Ag}$$

$$0.157 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 5.03 \text{ g S}$$

132. a. Given: Na₂C₂O₄

Unknown: percent-
age com-
position

$$\begin{aligned}\text{molar mass Na}_2\text{C}_2\text{O}_4 &= 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} + 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} \\ &+ 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 134.00 \text{ g}\end{aligned}$$

$$\frac{2 \times 22.99 \text{ g Na}}{134.00 \text{ g Na}_2\text{C}_2\text{O}_4} \times 100 = 34.31\% \text{ Na}$$

$$\frac{2 \times 12.01 \text{ g C}}{134.00 \text{ g Na}_2\text{C}_2\text{O}_4} \times 100 = 17.93\% \text{ C}$$

$$\frac{4 \times 16.00 \text{ g O}}{134.00 \text{ g Na}_2\text{C}_2\text{O}_4} \times 100 = 47.76\% \text{ O}$$

b. Given: C₂H₅OH

Unknown: percent-
age com-
position

$$\begin{aligned}\text{molar mass C}_2\text{H}_5\text{OH} &= 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 46.08 \text{ g}\end{aligned}$$

$$\frac{2 \times 12.01 \text{ g C}}{46.08 \text{ g C}_2\text{H}_5\text{OH}} \times 100 = 52.13\% \text{ C}$$

$$\frac{6 \times 1.01 \text{ g H}}{46.08 \text{ g C}_2\text{H}_5\text{OH}} \times 100 = 13.15\% \text{ H}$$

$$\frac{1 \times 16.00 \text{ g O}}{46.08 \text{ g C}_2\text{H}_5\text{OH}} \times 100 = 34.72\% \text{ O}$$

c. Given: Al₂O₃

Unknown: percent-
age com-
position

$$\text{molar mass Al}_2\text{O}_3 = 2 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} + 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 101.96 \text{ g}$$

$$\frac{2 \times 26.98 \text{ g Al}}{101.96 \text{ g Al}_2\text{O}_3} \times 100 = 52.92\% \text{ Al}$$

$$\frac{3 \times 16.00 \text{ g O}}{101.96 \text{ g Al}_2\text{O}_3} \times 100 = 47.08\% \text{ O}$$

- d.** Given: K_2SO_4
Unknown: percent-
age com-
position

$$\begin{aligned}\text{molar mass K}_2\text{SO}_4 &= 2 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} \\ &+ 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 174.27 \text{ g} \\ \frac{2 \times 39.10 \text{ g K}}{174.27 \text{ g K}_2\text{SO}_4} \times 100 &= 44.87\% \text{ K} \\ \frac{1 \times 32.07 \text{ g S}}{174.27 \text{ g K}_2\text{SO}_4} \times 100 &= 18.40\% \text{ S} \\ \frac{4 \times 16.00 \text{ O}}{174.27 \text{ g K}_2\text{SO}_4} \times 100 &= 36.72\% \text{ O}\end{aligned}$$

- 133.** Given: percentage com-
position
Unknown: identity of
the com-
pound

$$\begin{aligned}100.0 \text{ g compound contains } &42.59 \text{ g Na, } 12.02 \text{ g C, and } 44.99 \text{ g O.} \\ \frac{42.59 \text{ g Na}}{22.99 \text{ g/mol}} &= 1.853 \text{ mol Na} \approx 2 \text{ mol Na} \\ \frac{12.02 \text{ g C}}{12.01 \text{ g/mol}} &= 1.001 \text{ mol C} \approx 1 \text{ mol C} \\ \frac{44.99 \text{ g O}}{16.00 \text{ g/mol}} &= 2.812 \text{ mol O} \approx 3 \text{ mol O} \\ &\text{Na}_2\text{CO}_3, \text{ or sodium carbonate}\end{aligned}$$

- 134. a.** Given: 50.0 g KBr
Unknown: mass Br

$$\begin{aligned}\text{molar mass KBr} &= 1 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} + 1 \text{ mol Br} \times \frac{79.90 \text{ g Br}}{1 \text{ mol Br}} = 119.00 \text{ g} \\ 50.0 \text{ g KBr} \times \frac{79.90 \text{ g Br}}{119.00 \text{ g KBr}} &= 33.6 \text{ g Br}\end{aligned}$$

- b.** Given: 1.00 kg
 $\text{Na}_2\text{Cr}_2\text{O}_7$
Unknown: mass Cr

$$\begin{aligned}\text{molar mass Na}_2\text{Cr}_2\text{O}_7 &= 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} + 2 \text{ mol Cr} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}} \\ &+ 7 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 261.98 \text{ g} \\ 1.00 \text{ kg Na}_2\text{Cr}_2\text{O}_7 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{2 \times 52.00 \text{ g Cr}}{261.98 \text{ g Na}_2\text{Cr}_2\text{O}_7} &= 397 \text{ g Cr}\end{aligned}$$

- c.** Given: 85.0 mg
 $\text{C}_6\text{H}_{14}\text{N}_2\text{O}_2$
Unknown: mass N

$$\begin{aligned}\text{molar mass C}_6\text{H}_{14}\text{N}_2\text{O}_2 &= 6 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &+ 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} \\ &= 146.22 \text{ g} \\ 0.085 \text{ g C}_6\text{H}_{14}\text{N}_2\text{O}_2 \times \frac{28.02 \text{ g N}}{146.22 \text{ g C}_6\text{H}_{14}\text{N}_2\text{O}_2} &= 0.0163 \text{ g} = 16.3 \text{ mg N}\end{aligned}$$

d. Given: 2.84 g
 $\text{Co}(\text{C}_2\text{H}_3\text{O}_2)_2$

Unknown: mass of
 Co

$$\begin{aligned}\text{molar mass } \text{Co}(\text{C}_2\text{H}_3\text{O}_2)_2 &= 1 \text{ mol Co} \times \frac{58.93 \text{ g Co}}{1 \text{ mol Co}} + 4 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} \\ &+ 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 177.03 \text{ g} \\ 2.84 \text{ g Co}(\text{C}_2\text{H}_3\text{O}_2)_2 &\times \frac{58.93 \text{ g Co}}{177.03 \text{ g Co}(\text{C}_2\text{H}_3\text{O}_2)_2} = 0.945 \text{ g Co}\end{aligned}$$

135. a. Given: $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

Unknown: percent-
 age of
 water

$$\begin{aligned}\text{molar mass } \text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} &= 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} \\ &+ 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 13 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 20 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 286.19 \text{ g} \\ \text{molar mass } \text{H}_2\text{O} &= 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 18.02 \text{ g} \\ \frac{10(18.02) \text{ g H}_2\text{O}}{286.19 \text{ g Na}_2\text{CO}_3 \cdot 10 \text{H}_2\text{O}} &\times 100 = 62.97\% \text{ H}_2\text{O}\end{aligned}$$

b. Given: $\text{NiI}_2 \cdot 6\text{H}_2\text{O}$

Unknown: percent-
 age of
 water

$$\begin{aligned}\text{molar mass } \text{NiI}_2 \cdot 6\text{H}_2\text{O} &= 1 \text{ mol Ni} \times \frac{58.69 \text{ g Ni}}{1 \text{ mol Ni}} + 2 \text{ mol I} \times \frac{126.90 \text{ g I}}{1 \text{ mol I}} \\ &+ 12 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 420.61 \text{ g} \\ \frac{6(18.02) \text{ g H}_2\text{O}}{420.61 \text{ g NiI}_2 \cdot 6\text{H}_2\text{O}} &\times 100 = 25.71\% \text{ H}_2\text{O}\end{aligned}$$

c. Given: $(\text{NH}_4)_2\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}$

Unknown: percent-
 age of
 water

$$\begin{aligned}\text{molar mass } (\text{NH}_4)_2\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O} &= 8 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} \\ &+ 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} + 6 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} \\ &+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 302.13 \text{ g} \\ \frac{3(18.02) \text{ g H}_2\text{O}}{302.13 \text{ g } (\text{NH}_4)_2\text{Fe}(\text{CN})_6 \cdot 3\text{H}_2\text{O}} &\times 100 = 17.89\% \text{ H}_2\text{O}\end{aligned}$$

d. Given: $\text{AlBr}_3 \cdot 6\text{H}_2\text{O}$

Unknown: percent-
age of
water

$$\begin{aligned}\text{molar mass AlBr}_3 \cdot 6\text{H}_2\text{O} &= 1 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} \\ &+ 3 \text{ mol Br} \times \frac{79.90 \text{ g Br}}{1 \text{ mol Br}} + 12 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &+ 6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 374.80 \text{ g} \\ \frac{6(18.02) \text{ g H}_2\text{O}}{374.80 \text{ g AlBr}_3 \cdot 6 \text{ H}_2\text{O}} \times 100 &= 28.85\% \text{ H}_2\text{O}\end{aligned}$$

136. a. Given: nitric acid

Unknown: formula;
percent-
age com-
position

formula is HNO_3

$$\begin{aligned}\text{molar mass HNO}_3 &= 1 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} \\ &+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 63.02 \text{ g} \\ \frac{1.01 \text{ g H}}{63.02 \text{ g HNO}_3} \times 100 &= 1.60\% \text{ H} \\ \frac{14.01 \text{ g N}}{63.02 \text{ g HNO}_3} \times 100 &= 22.23\% \text{ N} \\ \frac{3 \times 16.00 \text{ g O}}{63.02 \text{ g HNO}_3} \times 100 &= 76.17\% \text{ O}\end{aligned}$$

b. Given: ammonia

Unknown: formula;
percent-
age com-
position

formula is NH_3

$$\begin{aligned}\text{molar mass NH}_3 &= 1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 3 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 17.04 \text{ g} \\ \frac{14.01 \text{ g N}}{17.04 \text{ g NH}_3} \times 100 &= 82.22\% \text{ N} \\ \frac{3 \times 1.01 \text{ g H}}{17.04 \text{ g NH}_3} \times 100 &= 17.78\% \text{ H}\end{aligned}$$

c. Given: mercury (II)
sulfate

Unknown: formula;
percent-
age com-
position

formula is HgSO_4

$$\begin{aligned}\text{molar mass HgSO}_4 &= 1 \text{ mol Hg} \times \frac{200.59 \text{ g Hg}}{1 \text{ mol Hg}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} \\ &+ 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 296.66 \text{ g} \\ \frac{200.59 \text{ g Hg}}{296.66 \text{ g HgSO}_4} \times 100 &= 67.616\% \text{ Hg} \\ \frac{32.07 \text{ g S}}{296.66 \text{ g HgSO}_4} \times 100 &= 10.81\% \text{ S} \\ \frac{4 \times 16.00 \text{ g O}}{296.66 \text{ g HgSO}_4} \times 100 &= 21.57\% \text{ O}\end{aligned}$$

d. Given: antimony (V)
fluoride

formula is SbF_5

Unknown: formula;
percent-
age com-
position

$$\text{molar mass SbF}_5 = 1 \text{ mol Sb} \times \frac{121.76 \text{ g Sb}}{1 \text{ mol Sb}} + 5 \text{ mol F} \times \frac{19.00 \text{ g F}}{1 \text{ mol F}} = 216.76 \text{ g}$$

$$\frac{121.76 \text{ g Sb}}{216.76 \text{ g SbF}_5} \times 100 = 56.173\% \text{ Sb}$$

$$\frac{5 \times 19.00 \text{ g F}}{216.76 \text{ g SbF}_5} \times 100 = 43.83\% \text{ F}$$

137. a. Given: LiBr

Unknown: percent-
age com-
position

$$\text{molar mass LiBr} = 1 \text{ mol Li} \times \frac{6.94 \text{ g Li}}{1 \text{ mol Li}} + 1 \text{ mol Br} \times \frac{79.90 \text{ g Br}}{1 \text{ mol Br}} = 86.84 \text{ g}$$

$$\frac{6.94 \text{ g Li}}{86.84 \text{ g LiBr}} \times 100 = 7.99\% \text{ Li}$$

$$\frac{79.90 \text{ g Br}}{86.84 \text{ g LiBr}} \times 100 = 92.01\% \text{ Br}$$

b. Given: $\text{C}_{14}\text{H}_{10}$

Unknown: percent-
age com-
position

$$\begin{aligned} \text{molar mass C}_{14}\text{H}_{10} &= 14 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 10 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &= 178.24 \text{ g} \end{aligned}$$

$$\frac{14 \times 12.01 \text{ g C}}{178.24 \text{ g C}_{14}\text{H}_{10}} \times 100 = 94.33\% \text{ C}$$

$$\frac{10 \times 1.01 \text{ g H}}{178.24 \text{ g C}_{14}\text{H}_{10}} \times 100 = 5.67\% \text{ H}$$

c. Given: NH_4NO_3

Unknown: percent-
age com-
position

$$\begin{aligned} \text{molar mass NH}_4\text{NO}_3 &= 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 80.06 \text{ g} \end{aligned}$$

$$\frac{2 \times 14.01 \text{ g N}}{80.06 \text{ g NH}_4\text{NO}_3} \times 100 = 35.00\% \text{ N}$$

$$\frac{4 \times 1.01 \text{ g H}}{80.06 \text{ g NH}_4\text{NO}_3} \times 100 = 5.05\% \text{ H}$$

$$\frac{3 \times 16.00 \text{ g O}}{80.06 \text{ g NH}_4\text{NO}_3} \times 100 = 59.96\% \text{ O}$$

d. Given: HNO_2

Unknown: percent-
age com-
position

$$\text{molar mass HNO}_2 = 1 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}}$$

$$+ 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 47.02 \text{ g}$$

$$\frac{1.01 \text{ g H}}{47.02 \text{ g HNO}_2} \times 100 = 2.15\% \text{ H}$$

$$\frac{14.01 \text{ g N}}{47.02 \text{ g HNO}_2} \times 100 = 29.80\% \text{ N}$$

$$\frac{2 \times 16.00 \text{ g O}}{47.02 \text{ g HNO}_2} \times 100 = 68.06\% \text{ O}$$

- e. Given: Ag_2S
Unknown: percent-
age com-
position

$$\text{molar mass Ag}_2\text{S} = 2 \text{ mol Ag} \times \frac{107.87 \text{ g Ag}}{1 \text{ mol Ag}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 247.81 \text{ g}$$

$$\frac{2 \times 107.87 \text{ g Ag}}{247.81 \text{ g Ag}_2\text{S}} \times 100 = 87.059\% \text{ Ag}$$

$$\frac{32.07 \text{ g S}}{247.81 \text{ g Ag}_2\text{S}} \times 100 = 12.94\% \text{ S}$$

- f. Given: $\text{Fe}(\text{SCN})_2$
Unknown: percent-
age com-
position

$$\text{molar mass Fe}(\text{SCN})_2 = 1 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} + 2 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}}$$

$$+ 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} = 172.03 \text{ g}$$

$$\frac{55.85 \text{ g Fe}}{172.03 \text{ g Fe}(\text{SCN})_2} \times 100 = 32.47\% \text{ Fe}$$

$$\frac{2 \times 32.07 \text{ g S}}{172.03 \text{ g Fe}(\text{SCN})_2} \times 100 = 37.28\% \text{ S}$$

$$\frac{2 \times 12.01 \text{ g C}}{172.03 \text{ g Fe}(\text{SCN})_2} \times 100 = 13.96\% \text{ C}$$

$$\frac{2 \times 14.01 \text{ g N}}{172.03 \text{ g Fe}(\text{SCN})_2} \times 100 = 16.29\% \text{ N}$$

- g. Given: lithium
acetate
Unknown: percent-
age com-
position

$$\text{molar mass LiC}_2\text{H}_3\text{O}_2 = 1 \text{ mol Li} \times \frac{6.94 \text{ g Li}}{1 \text{ mol Li}} + 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}}$$

$$+ 3 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 65.99 \text{ g}$$

$$\frac{6.94 \text{ g Li}}{65.99 \text{ g LiC}_2\text{H}_3\text{O}_2} \times 100 = 10.52\% \text{ Li}$$

$$\frac{2 \times 12.01 \text{ g C}}{65.99 \text{ g LiC}_2\text{H}_3\text{O}_2} \times 100 = 36.40\% \text{ C}$$

$$\frac{3 \times 1.01 \text{ g H}}{65.99 \text{ g LiC}_2\text{H}_3\text{O}_2} \times 100 = 4.59\% \text{ H}$$

$$\frac{2 \times 16.00 \text{ g O}}{65.99 \text{ g LiC}_2\text{H}_3\text{O}_2} \times 100 = 48.49\% \text{ O}$$

h. Given: nickel (II) formate

Unknown: percent-age composition

$$\begin{aligned}\text{molar mass Ni(CHO}_2\text{)}_2 &= 1 \text{ mol Ni} \times \frac{58.69 \text{ g Ni}}{1 \text{ mol Ni}} + 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} \\ &+ 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 148.73 \text{ g} \\ \frac{58.69 \text{ g Ni}}{148.73 \text{ g Ni(CHO}_2\text{)}_2} \times 100 &= 39.46\% \text{ Ni} \\ \frac{2 \times 12.01 \text{ g C}}{148.73 \text{ g Ni(CHO}_2\text{)}_2} \times 100 &= 16.15\% \text{ C} \\ \frac{2 \times 1.01 \text{ g H}}{148.73 \text{ Ni(CHO}_2\text{)}_2} \times 100 &= 1.36\% \text{ H} \\ \frac{3 \times 16.00 \text{ g O}}{148.73 \text{ g Ni(CHO}_2\text{)}_2} \times 100 &= 43.03\% \text{ O}\end{aligned}$$

138. a. Given: NH_2CONH_2

Unknown: percent-age of nitrogen

$$\begin{aligned}\text{molar mass NH}_2\text{CONH}_2 &= 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} \\ &+ 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 60.07 \text{ g} \\ \frac{2 \times 14.01 \text{ g N}}{60.07 \text{ g NH}_2\text{CONH}_2} \times 100 &= 46.65\% \text{ N}\end{aligned}$$

b. Given: SO_2Cl_2

Unknown: percent-age of sulfur

$$\begin{aligned}\text{molar mass SO}_2\text{Cl}_2 &= 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} \\ &+ 2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = 134.97 \text{ g} \\ \frac{32.07 \text{ g S}}{134.97 \text{ g SO}_2\text{Cl}_2} \times 100 &= 23.76\% \text{ S}\end{aligned}$$

c. Given: Tl_2O_3

Unknown: percent-age of thallium

$$\begin{aligned}\text{molar mass Tl}_2\text{O}_3 &= 2 \text{ mol Tl} \times \frac{204.38 \text{ g Tl}}{1 \text{ mol Tl}} + 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 456.76 \text{ g} \\ \frac{2 \times 204.38 \text{ g Tl}}{456.76 \text{ g Tl}_2\text{O}_3} \times 100 &= 89.491\% \text{ Tl}\end{aligned}$$

d. Given: KClO_3

Unknown: percent-age of oxygen

$$\begin{aligned}\text{molar mass KClO}_3 &= 1 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} + 1 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} \\ &+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 122.55 \text{ g} \\ \frac{3 \times 16.00 \text{ g O}}{122.55 \text{ g KClO}_3} \times 100 &= 39.17\% \text{ O}\end{aligned}$$

e. Given: CaBr_2
Unknown: percent-
age of
bromine

$$\text{molar mass CaBr}_2 = 1 \text{ mol Ca} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}} + 2 \text{ mol Br} \times \frac{79.90 \text{ g Br}}{1 \text{ mol Br}} = 199.88 \text{ g}$$

$$\frac{2 \times 79.9 \text{ g Br}}{199.88 \text{ g CaBr}_2} \times 100 = 79.95\% \text{ Br}$$

f. Given: SnO_2
Unknown: percent-
age of tin

$$\text{molar mass SnO}_2 = 1 \text{ mol Sn} \times \frac{118.71 \text{ g Sn}}{1 \text{ mol Sn}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$

$$= 150.71 \text{ g}$$

$$\frac{118.71 \text{ g Sn}}{150.71 \text{ g SnO}_2} \times 100 = 78.767\% \text{ Sn}$$

139. a. Given: 4.00 g MnO_2
Unknown: mass of
oxygen

$$\text{molar mass MnO}_2 = 1 \text{ mol Mn} \times \frac{54.94 \text{ g Mn}}{1 \text{ mol Mn}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 86.94 \text{ g}$$

$$\frac{4.00 \text{ g MnO}_2 \times 2 \times 16.00 \text{ g O}}{86.94 \text{ g MnO}_2} = 1.47 \text{ g O}$$

b. Given: 50.0 metric
tons Al_2O_3
Unknown: mass of
aluminum

$$\text{molar mass Al}_2\text{O}_3 = 2 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} + 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 101.96 \text{ g}$$

$$50.0 \text{ metric tons Al}_2\text{O}_3 \times \frac{2 \times 26.98 \text{ g Al}}{101.96 \text{ g Al}_2\text{O}_3} = 26.5 \text{ metric tons Al}$$

c. Given: 325 g AgCN
Unknown: mass of
silver

$$\text{molar mass AgCN} = 1 \text{ mol Ag} \times \frac{107.87 \text{ g Ag}}{1 \text{ mol Ag}} + 1 \text{ mol C} \times \frac{12.01 \text{ g}}{1 \text{ mol C}}$$

$$+ 1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} = 133.89 \text{ g}$$

$$325 \text{ g AgCN} \times \frac{107.87 \text{ g Ag}}{133.89 \text{ g AgCN}} = 262 \text{ g Ag}$$

d. Given: 0.780 g
 Au_2Se_3
Unknown: mass of
gold

$$\text{molar mass Au}_2\text{Se}_3 = 2 \text{ mol Au} \times \frac{196.97 \text{ g Au}}{1 \text{ mol Au}} + 3 \text{ mol Se} \times \frac{78.96 \text{ g Se}}{1 \text{ mol Se}}$$

$$= 630.82 \text{ g}$$

$$0.780 \text{ g Au}_2\text{Se}_3 \times \frac{2 \times 196.97 \text{ g Au}}{630.82 \text{ g Au}_2\text{Se}_3} = 0.487 \text{ g Au}$$

e. Given: 683 g
 Na_2SeO_3
Unknown: mass of
selenium

$$\text{molar mass Na}_2\text{SeO}_3 = 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} + 1 \text{ mol Se} \times \frac{78.96 \text{ g Se}}{1 \text{ mol Se}}$$

$$+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 172.94 \text{ g}$$

$$683 \text{ g Na}_2\text{SeO}_3 \times \frac{78.96 \text{ g Se}}{172.94 \text{ g Na}_2\text{SeO}_3} = 312 \text{ g Se}$$

f. Given: $5.0 \times 10^4 \text{ g CHCl}_2\text{CH}_2\text{CH}_3$
 Unknown: mass of chlorine

$$\begin{aligned} \text{molar mass CHCl}_2\text{CH}_2\text{CH}_3 &= 3 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &+ 2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = 112.99 \text{ g} \\ 5.0 \times 10^4 \text{ g CHCl}_2\text{CH}_2\text{CH}_3 &\times \frac{2 \times 35.45 \text{ g Cl}}{112.99 \text{ g CHCl}_2\text{CH}_2\text{CH}_3} = 3.1 \times 10^4 \text{ g Cl} \end{aligned}$$

140. a. Given: $\text{SrCl}_2 \cdot 6\text{H}_2\text{O}$
 Unknown: percent-age of water

$$\begin{aligned} \text{molar mass SrCl}_2 \cdot 6\text{H}_2\text{O} &= 1 \text{ mol Sr} \times \frac{87.62 \text{ g Sr}}{1 \text{ mol Sr}} + 2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} \\ &+ 12 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 266.64 \text{ g} \\ \frac{6(18.02) \text{ g H}_2\text{O}}{266.64 \text{ g SrCl}_2 \cdot 6\text{H}_2\text{O}} \times 100 &= 40.55\% \text{ H}_2\text{O} \end{aligned}$$

b. Given: $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$
 Unknown: percent-age of water

$$\begin{aligned} \text{molar mass ZnSO}_4 \cdot 7\text{H}_2\text{O} &= 1 \text{ mol Zn} \times \frac{65.39 \text{ g Zn}}{1 \text{ mol Zn}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} \\ &+ 11 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 287.60 \text{ g} \\ \frac{7(18.02) \text{ g H}_2\text{O}}{287.60 \text{ g ZnSO}_4 \cdot 7\text{H}_2\text{O}} \times 100 &= 43.86\% \text{ H}_2\text{O} \end{aligned}$$

c. Given: $\text{CaFPO}_3 \cdot 2\text{H}_2\text{O}$
 Unknown: percent-age of water

$$\begin{aligned} \text{molar mass CaFPO}_3 \cdot 2\text{H}_2\text{O} &= 1 \text{ mol Ca} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}} \\ &+ 1 \text{ mol F} \times \frac{19.00 \text{ g F}}{1 \text{ mol F}} + 1 \text{ mol P} \times \frac{30.97 \text{ g P}}{1 \text{ mol P}} + 5 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} \\ &+ 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 174.09 \text{ g} \\ \frac{2(18.02) \text{ g H}_2\text{O}}{174.09 \text{ g CaFPO}_3 \cdot 2\text{H}_2\text{O}} \times 100 &= 20.70\% \text{ H}_2\text{O} \end{aligned}$$

d. Given: $\text{Be(NO}_3)_2 \cdot 3\text{H}_2\text{O}$
 Unknown: percent-age of water

$$\begin{aligned} \text{molar mass Be(NO}_3)_2 \cdot 3\text{H}_2\text{O} &= 1 \text{ mol Be} \times \frac{9.01 \text{ g Be}}{1 \text{ mol Be}} \\ &+ 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 9 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} \\ &+ 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 187.09 \text{ g} \\ \frac{3(18.02) \text{ g H}_2\text{O}}{187.09 \text{ g Be(NO}_3)_2 \cdot 3\text{H}_2\text{O}} \times 100 &= 28.90\% \text{ H}_2\text{O} \end{aligned}$$

141. a. Given: nickel (II)
acetate
tetrahydrate

Unknown: formula;
percent-
age of
nickel

formula is $\text{Ni}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 4\text{H}_2\text{O}$

$$\begin{aligned}\text{molar mass } \text{Ni}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 4\text{H}_2\text{O} &= 1 \text{ mol Ni} \times \frac{58.69 \text{ g Ni}}{1 \text{ mol Ni}} \\ &+ 4 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 8 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} \\ &= 248.87 \text{ g}\end{aligned}$$

$$\frac{58.69 \text{ g Ni}}{248.87 \text{ g Ni}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 4\text{H}_2\text{O}} \times 100 = 23.58\% \text{ Ni}$$

b. Given: sodium
chromate
tetrahydrate

Unknown: formula;
percent-
age of
chromium

formula is $\text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$

$$\begin{aligned}\text{molar mass } \text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O} &= 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} \\ &+ 1 \text{ mol Cr} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}} + 8 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 8 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &= 234.06 \text{ g}\end{aligned}$$

$$\frac{52.00 \text{ g Cr}}{234.06 \text{ g Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}} \times 100 = 22.22\% \text{ Cr}$$

c. Given: cerium (IV)
sulfate
tetrahydrate

Unknown: percent-
age of
cerium

formula is $\text{Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}$

$$\begin{aligned}\text{molar mass } \text{Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O} &= 1 \text{ mol Ce} \times \frac{140.12 \text{ g Ce}}{1 \text{ mol Ce}} \\ &+ 2 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} + 12 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 8 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &= 404.34 \text{ g}\end{aligned}$$

$$\frac{140.12 \text{ g Ce}}{404.34 \text{ g Ce}(\text{SO}_4)_2 \cdot 4\text{H}_2\text{O}} \times 100 = 34.65\% \text{ Ce}$$

142. Given: 50.0 kg HgS
Unknown: mass of
mercury

$$\text{molar mass HgS} = 1 \text{ mol Hg} \times \frac{200.59 \text{ g Hg}}{1 \text{ mol Hg}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 232.68 \text{ g}$$

$$50.0 \text{ kg HgS} \times \frac{200.59 \text{ g Hg}}{232.68 \text{ g HgS}} = 43.1 \text{ kg Hg}$$

143. Given: 1.00×10^3 kg of each of $\text{Ca}_2(\text{OH})_2\text{CO}_3$ and CuFeS_2
Unknown: mass of copper for each; which has more Cu

$$\begin{aligned} \text{molar mass Cu}_2(\text{OH})_2\text{CO}_3 &= 2 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} + 5 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} \\ &+ 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 221.13 \text{ g} \\ 1.00 \times 10^3 \text{ kg Cu}_2(\text{OH})_2\text{CO}_3 &\times \frac{2 \times 63.55 \text{ g Cu}}{221.13 \text{ g Cu}_2(\text{OH})_2\text{CO}_3} = 575 \text{ kg Cu} \\ \text{molar mass CuFeS}_2 &= 1 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} + 1 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} \\ &+ 2 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 183.54 \text{ g} \\ 1.00 \times 10^3 \text{ kg CuFeS}_2 &\times \frac{63.55 \text{ g Cu}}{183.54 \text{ g CuFeS}_2} = 346 \text{ kg Cu} \end{aligned}$$

Malachite, $\text{Cu}_2(\text{OH})_2\text{CO}_3$, has more copper.

144. a. Given: $\text{VOSO}_4 \cdot 2\text{H}_2\text{O}$
Unknown: percent-age of vanadium

$$\begin{aligned} \text{molar mass VOSO}_4 \cdot 2\text{H}_2\text{O} &= 1 \text{ mol V} \times \frac{50.94 \text{ g V}}{1 \text{ mol V}} + 7 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} \\ &+ 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 199.05 \text{ g} \\ \frac{50.94 \text{ g V}}{199.05 \text{ g VOSO}_4 \cdot 2\text{H}_2\text{O}} \times 100 &= 25.59\% \text{ V} \end{aligned}$$

b. Given: $\text{K}_2\text{SnO}_3 \cdot 3\text{H}_2\text{O}$
Unknown: percent-age of tin

$$\begin{aligned} \text{molar mass K}_2\text{SnO}_3 \cdot 3\text{H}_2\text{O} &= 2 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} \\ &+ 1 \text{ mol Sn} \times \frac{118.71 \text{ g Sn}}{1 \text{ mol Sn}} + 6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 298.97 \text{ g} \\ \frac{118.71 \text{ g Sn}}{298.97 \text{ g K}_2\text{SnO}_3 \cdot 3\text{H}_2\text{O}} \times 100 &= 39.71\% \text{ Sn} \end{aligned}$$

c. Given: $\text{CaClO}_3 \cdot 2\text{H}_2\text{O}$
Unknown: percent-age of chlorine

$$\begin{aligned} \text{molar mass CaClO}_3 \cdot 2\text{H}_2\text{O} &= 1 \text{ mol Ca} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}} \\ &+ 1 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} + 5 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &= 159.57 \text{ g} \\ \frac{35.45 \text{ g Cl}}{159.57 \text{ g CaClO}_3 \cdot 2\text{H}_2\text{O}} \times 100 &= 22.22\% \text{ Cl} \end{aligned}$$

- 145.** Given: 500.0 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
Unknown: mass of anhydrous CuSO_4
- $$\text{molar mass CuSO}_4 = 1 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} + 1 \text{ mol S} \times \frac{32.07 \text{ g}}{1 \text{ mol S}} + 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 159.62 \text{ g}$$
- $$\text{molar mass CuSO}_4 \cdot 5\text{H}_2\text{O} = 159.62 \text{ g} + 5 \text{ mol H}_2\text{O} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 249.72 \text{ g}$$
- $$500.0 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O} \times \frac{159.62 \text{ g CuSO}_4}{249.72 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O}} = 319.6 \text{ g CuSO}_4$$
-
- 146.** Given: 1.00 g Ag
Unknown: mass of AgNO_3
- $$\text{molar mass AgNO}_3 = 1 \text{ mol Ag} \times \frac{107.87 \text{ g Ag}}{1 \text{ mol Ag}} + 1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 169.88 \text{ g}$$
- $$1.00 \text{ g Ag} \times \frac{169.88 \text{ g AgNO}_3}{107.87 \text{ g Ag}} = 1.57 \text{ g AgNO}_3$$
-
- 147.** Given: 62.4 g Ag_2S
Unknown: mass of Ag and S
- $$\text{molar mass Ag}_2\text{S} = 2 \text{ mol Ag} \times \frac{107.87 \text{ g Ag}}{1 \text{ mol Ag}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 247.81 \text{ g}$$
- $$62.4 \text{ g Ag}_2\text{S} \times \frac{2(107.87) \text{ g Ag}}{247.81 \text{ g Ag}_2\text{S}} = 54.3 \text{ g Ag}$$
- $$62.4 \text{ g Ag}_2\text{S} \times \frac{32.07 \text{ g S}}{247.81 \text{ g Ag}_2\text{S}} = 8.08 \text{ g S}$$
-
- 148.** Given: $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$; 11.8 g H_2O
Unknown: mass of $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$
- $$\text{molar mass MgSO}_4 \cdot 7\text{H}_2\text{O} = 1 \text{ mol Mg} \times \frac{24.31 \text{ g Mg}}{1 \text{ mol Mg}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} + 11 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 246.52 \text{ g}$$
- $$11.8 \text{ g H}_2\text{O} \times \frac{246.52 \text{ g MgSO}_4 \cdot 7\text{H}_2\text{O}}{7(18.02) \text{ g H}_2\text{O}} = 23.1 \text{ g MgSO}_4 \cdot 7\text{H}_2\text{O}$$
-
- 149.** Given: 1.00 kg H_2SO_4
Unknown: mass of sulfur
- $$\text{molar mass H}_2\text{SO}_4 = 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} + 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 98.09 \text{ g}$$
- $$1.00 \text{ kg H}_2\text{SO}_4 \times \frac{32.07 \text{ g S}}{98.09 \text{ g H}_2\text{SO}_4} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 3.27 \times 10^2 \text{ g S}$$
-
- 150. a.** Given: 28.4% Cu; 71.6% Br
Unknown: empirical formula of compound
- 100.0 g of compound contains 28.4 g Cu and 71.6 g Br.
- $$28.4 \text{ g Cu} \times \frac{1 \text{ mol Cu}}{63.55 \text{ g Cu}} = 0.447 \text{ mol Cu}$$
- $$71.6 \text{ g Br} \times \frac{1 \text{ mol Br}}{79.90 \text{ g Br}} = 0.896 \text{ mol Br}$$
- $$\frac{0.447 \text{ mol Cu}}{0.447} : \frac{0.896 \text{ mol Br}}{0.447} = 1.00 \text{ mol Cu} : 2.00 \text{ mol Br} \rightarrow \text{CuBr}_2$$

- b.** Given: 39.0% K;
12.0% C;
1.01% H;
47.9% O
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 39.0 g K, 12.0 g C, 1.01 g H, and 47.9 g O.
- $$39.0 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} = 0.997 \text{ mol K}$$
- $$12.0 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.999 \text{ mol C}$$
- $$1.01 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 1.00 \text{ mol H}$$
- $$47.9 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.99 \text{ mol O}$$
- $$\frac{0.997 \text{ mol K}}{0.997} : \frac{0.999 \text{ mol C}}{0.997} : \frac{1.00 \text{ mol H}}{0.997} : \frac{2.99 \text{ mol O}}{0.997} = 1.00 \text{ mol K} : 1.00 \text{ mol C} : 1.00 \text{ mol H} : 3.00 \text{ mol O} \rightarrow \text{KHCO}_3$$
- c.** Given: 77.3% Ag;
7.4% P;
15.3% O
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 77.3 g Ag, 7.4 g P, and 15.3 g O.
- $$77.3 \text{ g Ag} \times \frac{1 \text{ mol Ag}}{107.87 \text{ g Ag}} = 0.717 \text{ mol Ag}$$
- $$7.4 \text{ g P} \times \frac{1 \text{ mol P}}{30.97 \text{ g P}} = 0.24 \text{ mol P}$$
- $$15.3 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.956 \text{ mol O}$$
- $$\frac{0.717 \text{ mol Ag}}{0.24} : \frac{0.24 \text{ mol P}}{0.24} : \frac{0.956 \text{ mol O}}{0.24} = 3.0 \text{ mol Ag} : 1.0 \text{ mol P} : 4.0 \text{ mol O} \rightarrow \text{Ag}_3\text{PO}_4$$
- d.** Given: 0.57% H;
72.1% I;
27.3% O
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 0.57 g H, 72.1 g I, and 27.3 g O.
- $$0.57 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 0.56 \text{ mol H}$$
- $$72.1 \text{ g I} \times \frac{1 \text{ mol I}}{126.90 \text{ g I}} = 0.57 \text{ mol I}$$
- $$27.3 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.7 \text{ mol O}$$
- $$\frac{0.56 \text{ mol H}}{0.56} : \frac{0.57 \text{ mol I}}{0.56} : \frac{1.7 \text{ mol O}}{0.56} = 1.0 \text{ mol H} : 1.0 \text{ mol I} : 3.0 \text{ mol O} \rightarrow \text{HIO}_3$$

- 151. a.** Given: 36.2% Al;
63.8% S
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 36.2 g Al and 63.8 g S.
- $$36.2 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} = 1.34 \text{ mol Al}$$
- $$63.8 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 1.99 \text{ mol S}$$
- $$\frac{1.34 \text{ mol Al}}{1.34} : \frac{1.99 \text{ mol S}}{1.34} = 1.0 \text{ mol Al} : 1.5 \text{ mol S}$$
- $$2(1.0 \text{ mol Al} : 1.5 \text{ mol S}) = 2.0 \text{ mol Al} : 3.0 \text{ mol S} \rightarrow \text{Al}_2\text{S}_3$$

- b.** Given: 93.5% Nb;
6.50% O
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 93.5 g Nb and 6.50 g O.
- $$93.5 \text{ g Nb} \times \frac{1 \text{ mol Nb}}{92.91 \text{ g Nb}} = 1.01 \text{ mol Nb}$$
- $$6.50 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.406 \text{ mol O}$$
- $$\frac{1.01 \text{ mol Nb}}{0.406} : \frac{0.406 \text{ mol O}}{0.406} = 2.49 \text{ mol Nb} : 1.00 \text{ mol O}$$
- $$2(2.49 \text{ mol Nb} : 1.00 \text{ mol O}) = 4.98 \text{ mol Nb} : 2 \text{ mol O} \rightarrow \text{Nb}_5\text{O}_2$$
- c.** Given: 57.6% Sr;
13.8% P;
28.6% O
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 57.6 g Sr, 13.8 g P, and 28.6 g O
- $$57.6 \text{ g Sr} \times \frac{1 \text{ mol Sr}}{87.62 \text{ g Sr}} = 0.657 \text{ mol Sr}$$
- $$13.8 \text{ g P} \times \frac{1 \text{ mol P}}{30.97 \text{ g P}} = 0.446 \text{ mol P}$$
- $$28.6 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.79 \text{ mol O}$$
- $$\frac{0.657 \text{ mol Sr}}{0.446} : \frac{0.446 \text{ mol P}}{0.446} : \frac{1.79 \text{ mol O}}{0.446} = 1.47 \text{ mol Sr} : 1.00 \text{ mol P} : 4.01 \text{ mol O}$$
- $$2(1.47 \text{ mol Sr} : 1.00 \text{ mol P} : 4.01 \text{ mol O}) = 2.94 \text{ mol Sr} : 2.00 \text{ mol P} : 8.02 \text{ mol O} \rightarrow \text{Sr}_3\text{P}_2\text{O}_8$$
- d.** Given: 28.5% Fe;
48.6% O;
22.9% S
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 28.5 g Fe, 48.6 g O, and 22.9 g S
- $$28.5 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} = 0.510 \text{ mol Fe}$$
- $$48.6 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 3.04 \text{ mol O}$$
- $$22.9 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.714 \text{ mol S}$$
- $$\frac{0.510 \text{ mol Fe}}{0.510} : \frac{3.04 \text{ mol O}}{0.510} : \frac{0.714 \text{ mol S}}{0.510} = 1.00 \text{ mol Fe} : 5.96 \text{ mol O} : 1.40 \text{ mol S}$$
- $$2(1.00 \text{ mol Fe} : 5.96 \text{ mol O} : 1.40 \text{ mol S}) = 2.00 \text{ mol Fe} : 11.92 \text{ mol O} : 2.80 \text{ mol S} \rightarrow \text{Fe}_2\text{S}_3\text{O}_{12}$$

- 152. a.** Given: empirical
formula: CH_2 ;
molar mass
= 28 g/mol
Unknown: molecular
formula
- molar mass $\text{CH}_2 = 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 14.03 \text{ g}$
- $$x = \frac{28 \text{ g}}{14.03 \text{ g}} = 2.0 \quad \text{C}_x\text{H}_{2x} = \text{C}_2\text{H}_4$$
- b.** Given: empirical for-
mula: B_2H_5 ;
molar mass
= 54 g/mol
Unknown: molecular
formula
- molar mass $\text{B}_2\text{H}_5 = 2 \text{ mol B} \times \frac{10.81 \text{ g B}}{1 \text{ mol B}} + 5 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 26.67 \text{ g}$
- $$x = \frac{54 \text{ g}}{26.67 \text{ g}} = 2.0 \quad \text{B}_{2x}\text{H}_{5x} = \text{B}_4\text{H}_{10}$$

c. Given: empirical formula: C_2HCl ;
molar mass
= 179 g/mol
Unknown: molecular formula

$$\begin{aligned}\text{molar mass } \text{C}_2\text{HCl} &= 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 1 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol C}} \\ &+ 1 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = 60.48 \text{ g} \\ x &= \frac{179 \text{ g}}{60.48 \text{ g}} = 2.96 \approx 3 \quad \text{C}_{2x}\text{H}_x\text{Cl}_x = \text{C}_6\text{H}_3\text{Cl}_3\end{aligned}$$

d. Given: empirical formula: $\text{C}_6\text{H}_8\text{O}$;
molar mass
= 290 g/mol
Unknown: molecular formula

$$\begin{aligned}\text{molar mass } \text{C}_6\text{H}_8\text{O} &= 6 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 8 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 96.14 \text{ g} \\ x &= \frac{290 \text{ g}}{96.14 \text{ g}} = 3.0 \quad \text{C}_{6x}\text{H}_{8x}\text{O}_x = \text{C}_{18}\text{H}_{24}\text{O}_3\end{aligned}$$

e. Given: empirical formula: $\text{C}_3\text{H}_2\text{O}$;
molar mass
= 216 g/mol
Unknown: molecular formula

$$\begin{aligned}\text{molar mass } \text{C}_3\text{H}_2\text{O} &= 3 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ &+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 54.05 \text{ g} \\ x &= \frac{216 \text{ g}}{54.05} = 4.0 \quad \text{C}_{3x}\text{H}_{2x}\text{O}_x = \text{C}_{12}\text{H}_8\text{O}_4\end{aligned}$$

153. a. Given: 66.0% Ba;
34.0% Cl
Unknown: empirical formula of compound

$$\begin{aligned}100.0 \text{ g of compound} &\text{ contains 66.0 g Ba and 34.0 g Cl} \\ 66.0 \text{ g Ba} &\times \frac{1 \text{ mol Ba}}{137.33 \text{ g Ba}} = 0.481 \text{ mol Ba} \\ 34.0 \text{ g Cl} &\times \frac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 0.959 \text{ mol Cl} \\ \frac{0.481 \text{ mol Ba}}{0.481} : \frac{0.959 \text{ mol Cl}}{0.481} &= 1.00 \text{ mol Ba} : 1.99 \text{ mol Cl} \rightarrow \text{BaCl}_2\end{aligned}$$

b. Given: 80.38% Bi;
18.46% O;
1.16% H
Unknown: empirical formula of compound

$$\begin{aligned}100.00 \text{ g of compound} &\text{ contains 80.38 g Bi, 18.46 g O, and 1.16 g H} \\ 80.38 \text{ g Bi} &\times \frac{1 \text{ mol Bi}}{28.98 \text{ g Bi}} = 0.3846 \text{ mol Bi} \\ 18.46 \text{ g O} &\times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.154 \text{ mol O} \\ 1.16 \text{ g H} &\times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 1.149 \text{ mol H} \\ \frac{0.3846 \text{ mol Bi}}{0.3846} : \frac{1.154 \text{ mol O}}{0.3846} : \frac{1.149 \text{ mol H}}{0.3846} &= 1.000 \text{ mol Bi} : 3.001 \text{ mol O} : \\ 2.964 \text{ mol H} &\rightarrow \text{BiO}_3\text{H}_3\end{aligned}$$

- c.** Given: 12.67% Al; 19.73% N; 67.60% O
Unknown: empirical formula of compound
- 100.00 g of compound contains 12.67 g Al, 19.73 g N, and 67.60 g O.
- $$12.67 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} = 0.4696 \text{ mol Al}$$
- $$19.73 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 1.408 \text{ mol N}$$
- $$67.60 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 4.225 \text{ mol O}$$
- $$\frac{0.4696 \text{ mol Al}}{0.4696} : \frac{1.408 \text{ mol N}}{0.4696} : \frac{4.225 \text{ mol O}}{0.4696} = 1.000 \text{ mol Al} : 2.998 \text{ mol N} : 8.997 \text{ mol O} \rightarrow \text{AlN}_3\text{O}_9$$
-
- d.** Given: 35.64% Zn; 26.18% C; 34.88% O; 3.30% H
Unknown: empirical formula of compound
- 100.00 g of compound contains 35.64 g Zn, 26.18 g C, 34.88 g O, and 3.30 g H.
- $$35.64 \text{ g Zn} \times \frac{1 \text{ mol Zn}}{65.39 \text{ g Zn}} = 0.5450 \text{ mol Zn}$$
- $$26.18 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 2.180 \text{ mol C}$$
- $$34.88 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.180 \text{ mol O}$$
- $$3.30 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 3.267 \text{ mol H}$$
- $$\frac{0.5450 \text{ mol Zn}}{0.5450} : \frac{2.180 \text{ mol C}}{0.5450} : \frac{2.180 \text{ mol O}}{0.5450} : \frac{3.267 \text{ mol H}}{0.5450} = 1.000 \text{ mol Zn} : 4.000 \text{ mol C} : 4.000 \text{ mol O} : 5.994 \text{ mol H} \rightarrow \text{ZnC}_4\text{H}_6\text{O}_4$$
-
- e.** Given: 2.8% H; 9.8% N; 20.5% Ni; 44.5% O; 22.4% S
Unknown: empirical formula of compound
- 100.0 g of compound contains 2.8 g H, 9.8 g N, 20.5 g Ni, 44.5 g O, and 22.4 g S.
- $$2.8 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 2.8 \text{ mol H}$$
- $$9.8 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 0.70 \text{ mol N}$$
- $$20.5 \text{ g Ni} \times \frac{1 \text{ mol Ni}}{58.69 \text{ g Ni}} = 0.35 \text{ mol Ni}$$
- $$44.5 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.8 \text{ mol O}$$
- $$22.4 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.70 \text{ mol S}$$
- $$\frac{2.8 \text{ mol H}}{0.35} : \frac{0.70 \text{ mol N}}{0.35} : \frac{0.35 \text{ mol Ni}}{0.35} : \frac{2.8 \text{ mol O}}{0.35} : \frac{0.70 \text{ mol S}}{0.35} = 8.0 \text{ mol H} : 2.0 \text{ mol N} : 1.0 \text{ mol Ni} : 8.0 \text{ mol O} : 2.0 \text{ mol S} \rightarrow \text{NiN}_2\text{S}_2\text{H}_8\text{O}_8$$

f. Given: 8.09% C;
0.34% H;
10.78% O;
80.78% Br

Unknown: empirical
formula of
compound

100.00 g of compound contains 8.09 g C, 0.34 g H, 10.78 g O, and 80.78 g Br.

$$8.09 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.674 \text{ mol C}$$

$$0.34 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 0.34 \text{ mol H}$$

$$10.78 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.674 \text{ mol O}$$

$$80.78 \text{ g Br} \times \frac{1 \text{ mol Br}}{79.90 \text{ g Br}} = 1.011 \text{ mol Br}$$

$$\frac{0.674 \text{ mol C}}{0.34} : \frac{0.34 \text{ mol H}}{0.34} : \frac{0.674 \text{ mol O}}{0.34} : \frac{1.011 \text{ mol Br}}{0.34} = 2.0 \text{ mol C} :$$

$$1.00 \text{ mol H} : 2.0 \text{ mol O} : 3.0 \text{ mol Br} \rightarrow \text{C}_2\text{HBrO}_2$$

154. a. Given: 0.537 g Cu;
0.321 g F

Unknown: empirical
formula of
compound

$$0.537 \text{ g Cu} \times \frac{1 \text{ mol Cu}}{63.55 \text{ g Cu}} = 0.00845 \text{ mol Cu}$$

$$0.321 \text{ g F} \times \frac{1 \text{ mol F}}{19.00 \text{ g F}} = 0.0169 \text{ mol F}$$

$$\frac{0.00845 \text{ mol Cu}}{0.00845} : \frac{0.0169 \text{ mol F}}{0.00845} = 1.00 \text{ mol Cu} : 2.00 \text{ mol F} \rightarrow \text{CuF}_2$$

b. Given: 9.48 g Ba;
1.66 g C;
1.93 g N

Unknown: empirical
formula of
compound

$$9.48 \text{ g Ba} \times \frac{1 \text{ mol Ba}}{137.33 \text{ g Ba}} = 0.0690 \text{ mol Ba}$$

$$1.66 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.138 \text{ mol C}$$

$$1.93 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 0.138 \text{ mol N}$$

$$\frac{0.0690 \text{ mol Ba}}{0.0690} : \frac{0.138 \text{ mol C}}{0.0690} : \frac{0.138 \text{ mol N}}{0.0690} = 1.00 \text{ mol Ba} : 2.00 \text{ mol C} :$$

$$2.00 \text{ mol N} \rightarrow \text{BaC}_2\text{N}_2 = \text{Ba(CN)}_2$$

c. Given: 0.0091 g Mn;
0.0106 g O;
0.0053 g S

Unknown: empirical
formula of
compound

$$0.0091 \text{ g Mn} \times \frac{1 \text{ mol Mn}}{54.94 \text{ g Mn}} = 1.7 \times 10^{-4} \text{ mol Mn}$$

$$0.0106 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 6.63 \times 10^{-4} \text{ mol O}$$

$$0.0053 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 1.7 \times 10^{-4} \text{ mol S}$$

$$\frac{1.7 \times 10^{-4} \text{ mol Mn}}{1.7 \times 10^{-4}} : \frac{6.63 \times 10^{-4} \text{ mol O}}{1.7 \times 10^{-4}} : \frac{1.7 \times 10^{-4} \text{ mol S}}{1.7 \times 10^{-4}}$$

$$= 1.0 \text{ mol Mn} : 3.9 \text{ mol O} : 1.0 \text{ mol S} \rightarrow \text{MnO}_4\text{S} = \text{MnSO}_4$$

155. a. Given: 0.0015 g Ni;
0.0067 g I

Unknown: empirical
formula of
compound

$$0.0015 \text{ g Ni} \times \frac{1 \text{ mol Ni}}{58.69 \text{ g Ni}} = 2.6 \times 10^{-5} \text{ mol Ni}$$

$$0.0067 \text{ g I} \times \frac{1 \text{ mol I}}{126.90 \text{ g I}} = 5.3 \times 10^{-5} \text{ mol I}$$

$$\frac{2.6 \times 10^{-5} \text{ mol Ni}}{2.6 \times 10^{-5}} : \frac{5.3 \times 10^{-5} \text{ mol I}}{2.6 \times 10^{-5}} = 1.0 \text{ mol Ni} : 2.0 \text{ mol I} \rightarrow \text{NiI}_2$$

b. Given: 0.144 g Mn;
0.074 g N;
0.252 g O

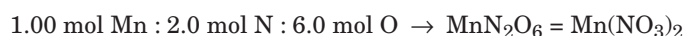
Unknown: empirical
formula of
compound

$$0.144 \text{ g Mn} \times \frac{1 \text{ mol Mn}}{54.94 \text{ g Mn}} = 2.62 \times 10^{-3} \text{ mol Mn}$$

$$0.074 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 5.3 \times 10^{-3} \text{ mol N}$$

$$0.252 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.58 \times 10^{-2} \text{ mol O}$$

$$\frac{2.62 \times 10^{-3} \text{ mol Mn}}{2.62 \times 10^{-3}} : \frac{5.3 \times 10^{-3} \text{ mol N}}{2.62 \times 10^{-3}} : \frac{1.58 \times 10^{-2} \text{ mol O}}{2.62 \times 10^{-3}} =$$



c. Given: 0.691 g Mg;
1.824 g S;
1.365 g O

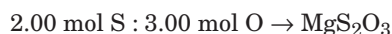
Unknown: empirical
formula of
compound

$$0.691 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}} = 0.0284 \text{ mol Mg}$$

$$1.824 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.05688 \text{ mol S}$$

$$1.365 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.08531 \text{ mol O}$$

$$\frac{0.0284 \text{ mol Mg}}{0.0284} : \frac{0.05688 \text{ mol S}}{0.0284} : \frac{0.08531 \text{ mol O}}{0.0284} = 1.00 \text{ mol Mg} :$$



d. Given: 14.77 g K;
9.06 g O;
2.42 g Sn

Unknown: empirical
formula of
compound

$$14.77 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} = 0.3777 \text{ mol K}$$

$$9.06 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.566 \text{ mol O}$$

$$22.42 \text{ g Sn} \times \frac{1 \text{ mol Sn}}{118.71 \text{ g Sn}} = 0.1889 \text{ mol Sn}$$

$$\frac{0.3777 \text{ mol K}}{0.3777} : \frac{0.566 \text{ mol O}}{0.3777} : \frac{0.1889 \text{ mol Sn}}{0.3777} = 1.000 \text{ mol K} : 1.50 \text{ mol O} :$$

$$0.5001 \text{ mol Sn}$$



- 156. a.** Given: 60.9% As;
39.1% S
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 60.9 g As and 39.1 g S.
- $$60.9 \text{ g As} \times \frac{1 \text{ mol As}}{74.92 \text{ g As}} = 0.813 \text{ mol As}$$
- $$39.1 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 1.22 \text{ mol S}$$
- $$\frac{0.813 \text{ mol As}}{0.813} : \frac{1.22 \text{ mol S}}{0.813} = 1.00 \text{ mol As} : 1.50 \text{ mol S}$$
- $$2(1.00 \text{ mol As} : 1.50 \text{ mol S}) = 2 \text{ mol As} : 3 \text{ mol S} \rightarrow \text{As}_2\text{S}_3$$
-
- b.** Given: 76.89% Re;
23.12% O
Unknown: empirical
formula of
compound
- 100.00 g of compound contains 76.89 g Re and 23.12 g O.
- $$76.89 \text{ g Re} \times \frac{1 \text{ mol Re}}{186.21 \text{ g Re}} = 0.4129 \text{ mol Re}$$
- $$23.12 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.445 \text{ mol O}$$
- $$\frac{0.4129 \text{ mol Re}}{0.4129} : \frac{1.445 \text{ mol O}}{0.4129} = 1.000 \text{ mol Re} : 3.500 \text{ mol O}$$
- $$2(1.0 \text{ mol Re} : 3.5 \text{ mol O}) = 2 \text{ mol Re} : 7 \text{ mol O} \rightarrow \text{Re}_2\text{O}_7$$
-
- c.** Given: 5.04% H;
35.00% N;
59.96% O
Unknown: empirical
formula of
compound
- 100.00 g of compound contains 5.04 g H, 35.00 g N, and 59.96 g O
- $$5.04 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 4.99 \text{ mol H}$$
- $$35.00 \text{ g N} \times 1 \frac{\text{mol N}}{14.01 \text{ g N}} = 2.498 \text{ mol N}$$
- $$59.96 \text{ g O} = \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 3.748 \text{ mol O}$$
- $$\frac{4.99 \text{ mol H}}{2.498} : \frac{2.498 \text{ mol N}}{2.498} : \frac{3.748 \text{ mol O}}{2.498} = 2.00 \text{ mol H} : 1.000 \text{ mol N} : 1.500 \text{ mol O}$$
- $$2(2.0 \text{ mol H} : 1.0 \text{ mol N} : 1.5 \text{ mol O}) = 4 \text{ mol H} : 2 \text{ mol N} : 3 \text{ mol O}$$
- $$\rightarrow \text{H}_4\text{N}_2\text{O}_3 = \text{NH}_4\text{NO}_3$$
-
- d.** Given: 24.3% Fe;
33.9% Cr;
41.8% O
Unknown: empirical
formula of
compound
- 100.0 g of compound contains 24.3 g Fe, 33.9 g Cr and 41.8 g O
- $$24.3 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} = 0.435 \text{ mol Fe}$$
- $$33.9 \text{ g Cr} \times \frac{1 \text{ mol Cr}}{52.00 \text{ g Cr}} = 0.652 \text{ mol Cr}$$
- $$41.8 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.61 \text{ mol O}$$
- $$\frac{0.435 \text{ mol Fe}}{0.435} : \frac{0.652 \text{ mol Cr}}{0.435} : \frac{2.61 \text{ mol O}}{0.435} = 1.00 \text{ mol Fe} : 1.50 \text{ mol Cr} : 6.00 \text{ mol O}$$
- $$2(1.0 \text{ mol Fe} : 1.5 \text{ mol Cr} : 6.0 \text{ mol O}) = 2 \text{ mol Fe} : 3 \text{ mol Cr} : 12 \text{ mol O}$$
- $$\rightarrow \text{Fe}_2\text{Cr}_3\text{O}_{12} = \text{Fe}_2(\text{CrO}_4)_3$$

- e.** Given: 54.03% C;
37.81% N;
8.16% H
Unknown: empirical
formula of
compound
- 100.00 g of compound contains 54.03 g C, 37.81 g N, and 8.16 g H.
- $$54.03 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.499 \text{ mol C}$$
- $$37.81 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 2.699 \text{ mol N}$$
- $$8.16 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 8.08 \text{ mol H}$$
- $$\frac{4.499 \text{ mol C}}{2.699} : \frac{2.699 \text{ mol N}}{2.699} : \frac{8.08 \text{ mol H}}{2.699} = 1.67 \text{ mol C} : 1.00 \text{ mol N} : 2.99 \text{ mol H}$$
- $$3(1.67 \text{ mol C} : 1.00 \text{ mol N} : 2.99 \text{ mol H}) = 5 \text{ mol C} : 3 \text{ mol N} : 9 \text{ mol H}$$
- $$\rightarrow \text{C}_5\text{N}_3\text{H}_9 = \text{C}_5\text{H}_9\text{N}_3$$
- f.** Given: 55.81% C;
3.90% H;
29.43% F;
10.85% N
Unknown: empirical
formula of
compound
- 100.00 g of compound contains 55.81 g C, 3.90 g H, 29.43 g F, and 10.85 g N.
- $$55.81 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.647 \text{ mol C}$$
- $$3.90 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 3.86 \text{ mol H}$$
- $$29.43 \text{ g F} \times \frac{1 \text{ mol F}}{19.00 \text{ g F}} = 1.549 \text{ mol F}$$
- $$10.85 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 0.7744 \text{ mol N}$$
- $$\frac{4.647 \text{ mol C}}{0.7744} : \frac{3.86 \text{ mol H}}{0.7744} : \frac{1.549 \text{ mol F}}{0.7744} : \frac{0.7744 \text{ mol N}}{0.7744} = 6.000 \text{ mol C} : 4.98 \text{ mol H} : 2.000 \text{ mol F} : 1.000 \text{ mol N} \rightarrow \text{C}_6\text{H}_5\text{F}_2\text{N} = \text{C}_6\text{H}_5\text{F}_2\text{NH}_2$$

- 157. a.** Given: empirical formula: $\text{C}_2\text{H}_4\text{S}$;
molar mass
= 179
Unknown: molecular
formula of
compound
- molar mass $\text{C}_2\text{H}_4\text{S} = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 60.13 \text{ g}$
- $$x = \frac{179 \text{ g}}{60.13 \text{ g}} = 2.98 \approx 3; \text{C}_{2x}\text{H}_{4x}\text{S}_x = \text{C}_6\text{H}_{12}\text{S}_3$$
- b.** Given: empirical formula: $\text{C}_2\text{H}_4\text{O}$;
molar mass
= 176
Unknown: molecular
formula of
compound
- molar mass $\text{C}_2\text{H}_4\text{O} = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 44.06 \text{ g}$
- $$x = \frac{176 \text{ g}}{44.06 \text{ g}} = 3.99 \approx 4; \text{C}_{2x}\text{H}_{4x}\text{O}_x = \text{C}_8\text{H}_{16}\text{O}_4$$
- c.** Given: empirical formula: $\text{C}_2\text{H}_3\text{O}_2$;
molar mass
= 119
Unknown: molecular
formula of
compound
- molar mass $\text{C}_2\text{H}_3\text{O}_2 = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 3 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 59.058 \text{ g}$
- $$x = \frac{119 \text{ g}}{59.05 \text{ g}} = 2.02 \approx 2; \text{C}_{2x}\text{H}_{3x}\text{O}_{2x} = \text{C}_4\text{H}_6\text{O}_4$$

d. Given: empirical formula: C_2H_2O ;
molar mass = 254
Unknown: molecular formula of compound

$$\text{molar mass } C_2H_2O = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 42.04 \text{ g}$$

$$x = \frac{254 \text{ g}}{42.04 \text{ g}} = 6.04 \approx 6; C_{2x}H_{2x}O_x = C_{12}H_{12}O_6$$

158. a. Given: percent composition;
molar mass = 116.07
Unknown: molecular formula of compound

100.00 g of compound contains 41.39 g C, 3.47 g H, and 55.14 g O.

$$41.39 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 3.446 \text{ mol C}$$

$$3.47 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 3.44 \text{ mol H}$$

$$55.14 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 3.446 \text{ mol O}$$

$$\frac{3.446 \text{ mol C}}{3.44} : \frac{3.44 \text{ mol H}}{3.44} : \frac{3.446 \text{ mol O}}{3.44} = 1.00 \text{ mol C} : 1.00 \text{ mol H} : 1.00 \text{ mol O}$$

empirical formula = CHO

$$\text{molar mass CHO} = 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 1 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 29.02 \text{ g}$$

$$x = \frac{116.07 \text{ g}}{29.02 \text{ g}} = 4.000; C_xH_xO_x = C_4H_4O_4$$

b. Given: percent composition;
molar mass = 88
Unknown: molecular formula of compound

100.00 g of compound contains 54.53 g C, 9.15 g H, and 36.32 g O.

$$54.53 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.540 \text{ mol C}$$

$$9.15 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 9.06 \text{ mol H}$$

$$36.32 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.270 \text{ mol O}$$

$$\frac{4.540 \text{ mol C}}{2.270} : \frac{9.06 \text{ mol H}}{2.270} : \frac{2.270 \text{ mol O}}{2.270} = 2.000 \text{ mol C} : 3.99 \text{ mol H} : 1.000 \text{ mol O}$$

empirical formula = C_2H_4O

$$\text{molar mass } C_2H_4O = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 44.06 \text{ g}$$

$$x = \frac{88 \text{ g}}{44.06 \text{ g}} = 2.0; C_{2x}H_{4x}O_x = C_4H_8O_2$$

c. Given: percent composition;
molar mass = 168.19

100.00 g of compound contains 64.27 g C; 7.19 g H, and 28.54 g O.

$$64.27 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 5.351 \text{ mol C}$$

Unknown: molecular formula of compound

$$7.19 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 7.12 \text{ mol H}$$

$$28.54 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.784 \text{ mol O}$$

$$\frac{5.351 \text{ mol C}}{1.784} : \frac{7.12 \text{ mol H}}{1.784} : \frac{1.784 \text{ mol O}}{1.784} = 2.999 \text{ mol C} : 3.99 \text{ mol H} :$$

1.000 mol O

empirical formula = $\text{C}_3\text{H}_4\text{O}$

$$\text{molar mass } \text{C}_3\text{H}_4\text{O} = 3 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 56.07 \text{ g}$$

$$x = \frac{168.19 \text{ g}}{56.07 \text{ g}} = 3.000; \text{C}_{3x}\text{H}_{4x}\text{O}_x = \text{C}_9\text{H}_{12}\text{O}_3$$

159. Given: 0.141 g K;
0.115 g S;
0.144 g O

Unknown: empirical formula of compound

$$0.141 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} = 3.61 \times 10^{-3} \text{ mol K}$$

$$0.115 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 3.59 \times 10^{-3} \text{ mol S}$$

$$0.144 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 9.00 \times 10^{-3} \text{ mol O}$$

$$\frac{3.61 \times 10^{-3} \text{ mol K}}{3.59 \times 10^{-3}} : \frac{3.59 \times 10^{-3} \text{ mol S}}{3.59 \times 10^{-3}} : \frac{9.00 \times 10^{-3} \text{ mol O}}{3.59 \times 10^{-3}}$$

= 1.01 mol K : 1.00 mol S : 2.51 mol O

2(1.01 mol K : 1.00 mol S : 2.51 mol O) = 2 mol K : 2 mol S : 5 mol O
→ $\text{K}_2\text{S}_2\text{O}_5$

160. a. Given: 9.65 g Pb;
0.99 g O

Unknown: empirical formula of compound

$$9.65 \text{ g Pb} \times \frac{1 \text{ mol Pb}}{207.2 \text{ g Pb}} = 0.0466 \text{ mol Pb}$$

$$0.99 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.062 \text{ mol O}$$

$$\frac{0.466 \text{ mol Pb}}{0.0466} : \frac{0.062 \text{ mol O}}{0.0466} = 1.0 \text{ mol Pb} : 1.3 \text{ mol O}$$

3 (1.0 mol Pb : 1.3 mol O) = 3 mol Pb : 4 mol O → Pb_3O_4

- 161.** Given: 0.70 g Cr; 0.65 g S; 1.30 g O;
molar mass
= 392.2
Unknown: molecular
formula of
compound
- $$0.70 \text{ g Cr} \times \frac{1 \text{ mol Cr}}{52.00 \text{ g Cr}} = 0.013 \text{ mol Cr}$$
- $$0.65 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.0203 \text{ mol S}$$
- $$1.30 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.0812 \text{ mol O}$$
- $$\frac{0.0135 \text{ mol Cr}}{0.0135} : \frac{0.0203 \text{ mol S}}{0.0135} : \frac{0.0812 \text{ mol O}}{0.0135} = 1.0 \text{ mol Cr} : 1.5 \text{ mol S} : 6.0 \text{ mol O}$$
- $$2(1.0 \text{ mol Cr} : 1.5 \text{ mol S} : 6.0 \text{ mol O}) = 2 \text{ mol Cr} : 3 \text{ mol S} : 12 \text{ mol O}$$
- $$\rightarrow \text{Cr}_2\text{S}_3\text{O}_{12} = \text{Cr}_2(\text{SO}_4)_3$$
-
- 162.** Given: 60.68% C; 3.40% H; 35.92% O
Unknown: empirical
formula of
compound
- $$100.00 \text{ compound contain } 60.68 \text{ g C, } 3.40 \text{ g H, and } 35.92 \text{ g O}$$
- $$60.68 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 5.052 \text{ mol C}$$
- $$3.40 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 3.37 \text{ mol H}$$
- $$35.92 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.245 \text{ mol O}$$
- $$\frac{5.052 \text{ mol C}}{2.245} : \frac{3.37 \text{ mol H}}{2.245} : \frac{2.245 \text{ mol O}}{2.245} = 2.25 \text{ mol C} : 1.50 \text{ mol H} : 1.00 \text{ mol O}$$
- $$4(2.25 \text{ mol C} : 1.50 \text{ mol H} : 1.00 \text{ mol O}) = 9 \text{ mol C} : 6 \text{ mol H} : 4 \text{ mol O}$$
- $$\rightarrow \text{C}_9\text{H}_6\text{O}_4$$
-
- 163.** Given: 208 mg C; 31 mg H; 146 mg N;
molar mass
= 111
Unknown: molecular
formula of
compound
- $$208 \text{ mg C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.0173 \text{ mol C}$$
- $$31 \text{ mg H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.031 \text{ mol H}$$
- $$146 \text{ mg N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 0.0104 \text{ mol N}$$
- $$\frac{0.0173 \text{ mol C}}{0.0104} : \frac{0.031 \text{ mol H}}{0.0104} : \frac{0.0104 \text{ mol N}}{0.0104} = 1.66 \text{ mol C} : 3.00 \text{ mol H} : 1.00 \text{ mol N}$$
- $$3(1.66 \text{ mol C} : 3.00 \text{ mol H} : 1.00 \text{ mol N}) = 5 \text{ mol C} : 9 \text{ mol H} : 3 \text{ mol N}$$
- empirical formula = $\text{C}_5\text{H}_9\text{N}_3$
- $$\text{molar mass } \text{C}_5\text{H}_9\text{N}_3 = 5 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 9 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$
- $$+ 3 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} = 111.17 \text{ g}$$
- $$\frac{111 \text{ g}}{111.17 \text{ g}} = 0.998 \approx 1$$
- molecular formula = $\text{C}_5\text{H}_9\text{N}_3$

165. Given: balanced equation;
4.0 mol H₂
Unknown: moles Na

$$4.0 \text{ mol H}_2 \times \frac{2 \text{ mol Na}}{1 \text{ mol H}_2} = 8.0 \text{ mol Na}$$

166. Given: balanced equation;
0.046 mol LiBr
Unknown: moles LiCl

$$0.046 \text{ mol LiBr} \times \frac{2 \text{ mol LiCl}}{2 \text{ mol LiBr}} = 0.046 \text{ mol LiCl}$$

167. a. Given: balanced equation;
18 mol Al
Unknown: moles H₂SO₄

$$18 \text{ mol Al} \times \frac{3 \text{ mol H}_2\text{SO}_4}{2 \text{ mol Al}} = 27 \text{ mol H}_2\text{SO}_4$$

b. Given: balanced equation;
18 mol Al
Unknown: moles of each product

$$18 \text{ mol Al} \times \frac{1 \text{ mol Al}_2(\text{SO}_4)_3}{2 \text{ mol Al}} = 9 \text{ mol Al}_2(\text{SO}_4)_3$$

$$18 \text{ mol Al} \times \frac{3 \text{ mol H}_2}{2 \text{ mol Al}} = 27 \text{ mol H}_2$$

168. a. Given: balanced equation;
3.85 mol C₃H₈
Unknown: moles of CO₂ and H₂O

$$3.85 \text{ mol C}_3\text{H}_8 \times \frac{3 \text{ mol CO}_2}{1 \text{ mol C}_3\text{H}_8} = 11.6 \text{ mol CO}_2$$

$$3.85 \text{ mol C}_3\text{H}_8 \times \frac{4 \text{ mol H}_2\text{O}}{1 \text{ mol C}_3\text{H}_8} = 15.4 \text{ mol H}_2\text{O}$$

b. Given: balanced equation;
0.647 mol O₂
Unknown: moles of CO₂, H₂O, and C₃H₈

$$0.647 \text{ mol O}_2 \times \frac{3 \text{ mol CO}_2}{5 \text{ mol O}_2} = 0.388 \text{ mol CO}_2$$

$$0.647 \text{ mol O}_2 \times \frac{4 \text{ mol H}_2\text{O}}{5 \text{ mol O}_2} = 0.518 \text{ mol H}_2\text{O}$$

$$0.647 \text{ mol O}_2 \times \frac{1 \text{ mol C}_3\text{H}_8}{5 \text{ mol O}_2} = 0.129 \text{ mol C}_3\text{H}_8$$

169. a. Given: balanced equation;
3.25 mol P₄O₁₀
Unknown: mass of P

$$3.25 \text{ mol P}_4\text{O}_{10} \times \frac{4 \text{ mol P}}{1 \text{ mol P}_4\text{O}_{10}} \times \frac{30.97 \text{ g P}}{1 \text{ mol P}} = 403 \text{ g P}$$

b. Given: balanced equation;
0.489 mol P
Unknown: mass of O₂ and P₄O₁₀

$$0.489 \text{ mol P} \times \frac{5 \text{ mol O}_2}{4 \text{ mol P}} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 19.6 \text{ g O}_2$$

$$0.489 \text{ mol P} \times \frac{1 \text{ mol P}_4\text{O}_{10}}{4 \text{ mol P}} \times \frac{283.88 \text{ g P}_4\text{O}_{10}}{1 \text{ mol P}_4\text{O}_{10}} = 34.7 \text{ g P}_4\text{O}_{10}$$

170. a. Given: balanced equation;
1.840 mol H_2O_2
Unknown: mass of O_2

$$1.840 \text{ mol H}_2\text{O}_2 \times \frac{1 \text{ mol O}_2}{2 \text{ mol H}_2\text{O}_2} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 29.44 \text{ g O}_2$$

b. Given: balanced equation;
5.0 mol O_2
Unknown: mass of water

$$5.0 \text{ mol O}_2 \times \frac{2 \text{ mol H}_2\text{O}}{1 \text{ mol O}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 180 \text{ g H}_2\text{O}$$

171. a. Given: balanced equation;
100.0 g NaNO_3
Unknown: moles of Na_2CO_3

$$100.0 \text{ g NaNO}_3 \times \frac{1 \text{ mol NaNO}_3}{85.01 \text{ g NaNO}_3} \times \frac{1 \text{ mol Na}_2\text{CO}_3}{2 \text{ mol NaNO}_3} = 0.5882 \text{ mol Na}_2\text{CO}_3$$

b. Given: balanced equation;
7.50 g Na_2CO_3
Unknown: moles of CO_2

$$7.50 \text{ g Na}_2\text{CO}_3 \times \frac{1 \text{ mol Na}_2\text{CO}_3}{105.99 \text{ g Na}_2\text{CO}_3} \times \frac{1 \text{ mol CO}_2}{1 \text{ mol Na}_2\text{CO}_3} = 0.0708 \text{ mol CO}_2$$

172. a. Given: balanced equation;
625 g Fe_3O_4
Unknown: moles of H_2

$$625 \text{ g Fe}_3\text{O}_4 \times \frac{1 \text{ mol Fe}_3\text{O}_4}{231.55 \text{ g Fe}_3\text{O}_4} \times \frac{4 \text{ mol H}_2}{1 \text{ mol Fe}_3\text{O}_4} = 10.8 \text{ mol H}_2$$

b. Given: balanced equation;
27 g H_2
Unknown: moles of Fe

$$27 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.02 \text{ g H}_2} \times \frac{3 \text{ mol Fe}}{4 \text{ mol H}_2} = 10. \text{ mol Fe}$$

173. a. Given: balanced equation;
22.5 g AgNO_3
Unknown: mass of AgBr

$$22.5 \text{ g AgNO}_3 \times \frac{1 \text{ mol AgNO}_3}{169.88 \text{ g AgNO}_3} \times \frac{2 \text{ mol AgBr}}{2 \text{ mol AgNO}_3} \times \frac{187.77 \text{ g AgBr}}{1 \text{ mol AgBr}} = 24.9 \text{ g AgBr}$$

174. a. Given: balanced equation;
90. g CaC_2
Unknown: mass C_2H_2

$$90. \text{ g CaC}_2 \times \frac{1 \text{ mol CaC}_2}{64.10 \text{ g CaC}_2} \times \frac{1 \text{ mol C}_2\text{H}_2}{1 \text{ mol CaC}_2} \times \frac{26.04 \text{ g C}_2\text{H}_2}{1 \text{ mol C}_2\text{H}_2} = 37 \text{ g C}_2\text{H}_2$$

175. a. Given: balanced equation;
25.0 g Cl_2
Unknown: mass MnO_2

$$25.0 \text{ g Cl}_2 \times \frac{1 \text{ mol Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{1 \text{ mol MnO}_2}{1 \text{ mol Cl}_2} \times \frac{86.94 \text{ g MnO}_2}{1 \text{ mol MnO}_2} = 30.7 \text{ g MnO}_2$$

b. Given: balanced equation; 0.091 g Cl ₂ Unknown: mass MnCl ₂	$0.091 \text{ g Cl}_2 \times \frac{1 \text{ mol Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{1 \text{ mol MnCl}_2}{1 \text{ mol Cl}_2} \times \frac{125.84 \text{ g MnCl}_2}{1 \text{ mol MnCl}_2} = 0.16 \text{ g MnCl}_2$
176. Given: balanced equation; 30.0 mol NH ₃ Unknown: moles (NH ₄) ₂ SO ₄	$30.0 \text{ mol NH}_3 \times \frac{1 \text{ mol (NH}_4)_2\text{SO}_4}{2 \text{ mol NH}_3} = 15.0 \text{ mol (NH}_4)_2\text{SO}_4$
177. a. Given: balanced equation; 150 g Fe ₂ O ₃ Unknown: mass Al	$150 \text{ g Fe}_2\text{O}_3 \times \frac{1 \text{ mol Fe}_2\text{O}_3}{159.70 \text{ g Fe}_2\text{O}_3} \times \frac{2 \text{ mol Al}}{1 \text{ mol Fe}_2\text{O}_3} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 51 \text{ g Al}$
b. Given: balanced equation; 0.905 mol Al ₂ O ₃ Unknown: mass Fe	$0.905 \text{ mol Al}_2\text{O}_3 \times \frac{2 \text{ mol Fe}}{1 \text{ mol Al}_2\text{O}_3} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 101 \text{ g Fe}$
c. Given: balanced equation; 99.0 g Al Unknown: moles Fe ₂ O ₃	$99.0 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{1 \text{ mol Fe}_2\text{O}_3}{2 \text{ mol Al}} = 1.83 \text{ mol Fe}_2\text{O}_3$
178. Given: 1.40 g N ₂ ; balanced equation Unknown: mass H ₂	$1.40 \text{ g N}_2 \times \frac{1 \text{ mol N}_2}{28.02 \text{ g N}_2} \times \frac{3 \text{ mol H}_2}{1 \text{ mol N}_2} \times \frac{2.02 \text{ g H}_2}{1 \text{ mol H}_2} = 0.303 \text{ g H}_2$
179. Given: 1.27 g KOH Unknown: mass of H ₂ SO ₄	$2\text{KOH} + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O}$ $1.27 \text{ g KOH} \times \frac{1 \text{ mol KOH}}{56.11 \text{ g KOH}} \times \frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol KOH}} \times \frac{98.09 \text{ g H}_2\text{SO}_4}{1 \text{ mol H}_2\text{SO}_4} = 1.11 \text{ g H}_2\text{SO}_4$
180. a. Given: reactants and products Unknown: balanced equation	$\text{H}_3\text{PO}_4 + 2\text{NH}_3 \rightarrow (\text{NH}_4)_2\text{HPO}_4$
b. Given: 10.00 g NH ₃ Unknown: moles (NH ₄) ₂ HPO ₄	$10.00 \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.04 \text{ g NH}_3} \times \frac{1 \text{ mol (NH}_4)_2\text{HPO}_4}{2 \text{ mol NH}_3} = 0.293 \text{ mol (NH}_4)_2\text{HPO}_4$
c. Given: 2800 kg H ₃ PO ₄ Unknown: mass NH ₃	$2800 \text{ kg H}_3\text{PO}_4 \times \frac{1 \text{ mol H}_3\text{PO}_4}{98.00 \text{ g H}_3\text{PO}_4} \times \frac{2 \text{ mol NH}_3}{1 \text{ mol H}_3\text{PO}_4} \times \frac{17.04 \text{ g NH}_3}{1 \text{ mol NH}_3} = 970 \text{ kg NH}_3$

- 181. a.** Given: balanced equation;
30.0 mol $\text{Zn}_3(\text{C}_6\text{H}_5\text{O}_7)_2$
 $(\text{C}_6\text{H}_5\text{O}_7)_2$
Unknown: moles ZnCO_3
and $\text{C}_6\text{H}_8\text{O}_7$
- $$30.0 \text{ mol } \text{Zn}_3(\text{C}_6\text{H}_5\text{O}_7)_2 \times \frac{3 \text{ mol } \text{ZnCO}_3}{1 \text{ mol } \text{Zn}_3(\text{C}_6\text{H}_5\text{O}_7)_2} = 90.0 \text{ mol } \text{ZnCO}_3$$
- $$30.0 \text{ mol } \text{Zn}_3(\text{C}_6\text{H}_5\text{O}_7)_2 \times \frac{2 \text{ mol } \text{C}_6\text{H}_8\text{O}_7}{1 \text{ mol } \text{Zn}_3(\text{C}_6\text{H}_5\text{O}_7)_2} = 60.0 \text{ mol } \text{C}_6\text{H}_8\text{O}_7$$
- b.** Given: balanced equation;
500. mol $\text{C}_6\text{H}_8\text{O}_7$
Unknown: mass in kg of H_2O
and CO_2
- $$500. \text{ mol } \text{C}_6\text{H}_8\text{O}_7 \times \frac{3 \text{ mol } \text{H}_2\text{O}}{2 \text{ mol } \text{C}_6\text{H}_8\text{O}_7} \times \frac{18.02 \text{ g } \text{H}_2\text{O}}{1 \text{ mol } \text{H}_2\text{O}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 13.5 \text{ kg } \text{H}_2\text{O}$$
- $$500. \text{ mol } \text{C}_6\text{H}_8\text{O}_7 \times \frac{3 \text{ mol } \text{CO}_2}{2 \text{ mol } \text{C}_6\text{H}_8\text{O}_7} \times \frac{44.01 \text{ g } \text{CO}_2}{1 \text{ mol } \text{CO}_2} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 33.0 \text{ kg } \text{CO}_2$$
-
- 182. a.** Given: balanced equation;
52.5 g $\text{C}_3\text{H}_7\text{COOH}$
Unknown: mass $\text{C}_3\text{H}_7\text{COOCH}_3$
- $$52.5 \text{ g } \text{C}_3\text{H}_7\text{COOH} \times \frac{1 \text{ mol } \text{C}_3\text{H}_7\text{COOH}}{88.12 \text{ g } \text{C}_3\text{H}_7\text{COOH}} \times \frac{1 \text{ mol } \text{C}_3\text{H}_7\text{COOCH}_3}{1 \text{ mol } \text{C}_3\text{H}_7\text{COOH}} \times \frac{102.15 \text{ g } \text{C}_3\text{H}_7\text{COOCH}_3}{1 \text{ mol } \text{C}_3\text{H}_7\text{COOCH}_3} = 60.9 \text{ g } \text{C}_3\text{H}_7\text{COOCH}_3$$
- b.** Given: balanced equation;
5800. g CH_3OH
Unknown: mass H_2O
- $$5800. \text{ g } \text{CH}_3\text{OH} \times \frac{1 \text{ mol } \text{CH}_3\text{OH}}{32.05 \text{ g } \text{CH}_3\text{OH}} \times \frac{1 \text{ mol } \text{H}_2\text{O}}{1 \text{ mol } \text{CH}_3\text{OH}} \times \frac{18.02 \text{ g } \text{H}_2\text{O}}{1 \text{ mol } \text{H}_2\text{O}} = 3261 \text{ g } \text{H}_2\text{O}$$
-
- 183. a.** Given: balanced equation;
36.0 g NH_4NO_3
Unknown: moles N_2
- $$36.0 \text{ g } \text{NH}_4\text{NO}_3 \times \frac{1 \text{ mol } \text{NH}_4\text{NO}_3}{80.06 \text{ g } \text{NH}_4\text{NO}_3} \times \frac{2 \text{ mol } \text{N}_2}{2 \text{ mol } \text{NH}_4\text{NO}_3} = 0.450 \text{ mol } \text{N}_2$$
- b.** Given: balanced equation;
7.35 mol H_2O
Unknown: mass NH_4NO_3
- $$7.35 \text{ mol } \text{H}_2\text{O} \times \frac{2 \text{ mol } \text{NH}_4\text{NO}_3}{4 \text{ mol } \text{H}_2\text{O}} \times \frac{80.06 \text{ g } \text{NH}_4\text{NO}_3}{1 \text{ mol } \text{NH}_4\text{NO}_3} = 294 \text{ g } \text{NH}_4\text{NO}_3$$
-
- 184.** Given: 1.23 mg $\text{Pb}(\text{NO}_3)_2$
Unknown: mass KNO_3
- $$\text{Pb}(\text{NO}_3)_2 + 2\text{KI} \rightarrow \text{PbI}_2 + 2\text{KNO}_3$$
- $$1.23 \text{ mg } \text{Pb}(\text{NO}_3)_2 \times \frac{1 \text{ mol } \text{Pb}(\text{NO}_3)_2}{331.22 \text{ g } \text{Pb}(\text{NO}_3)_2} \times \frac{2 \text{ mol } \text{KNO}_3}{1 \text{ mol } \text{Pb}(\text{NO}_3)_2} \times \frac{101.11 \text{ g } \text{KNO}_3}{1 \text{ mol } \text{KNO}_3} = 0.751 \text{ mg } \text{KNO}_3$$
-
- 185.** Given: balanced equation; 0.34 kg Pb
Unknown: moles PbSO_4
- $$0.34 \text{ kg } \text{Pb} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } \text{Pb}}{207.2 \text{ g } \text{Pb}} \times \frac{2 \text{ mol } \text{PbSO}_4}{1 \text{ mol } \text{Pb}} = 3.3 \text{ mol } \text{PbSO}_4$$

186. Given: 20.0 mol CO ₂ Unknown: mass H ₂ O	$\text{CO}_2 + 2\text{LiOH} \rightarrow \text{H}_2\text{O} + \text{Li}_2\text{CO}_3$ $20.0 \text{ mol CO}_2 \times \frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol CO}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 360. \text{ g H}_2\text{O}$
187. a. Given: balanced equation; 1.00 × 10 ² g P ₄ O ₁₀ Unknown: mass H ₂ O	$1.00 \times 10^2 \text{ g P}_4\text{O}_{10} \times \frac{1 \text{ mol P}_4\text{O}_{10}}{283.88 \text{ g P}_4\text{O}_{10}} \times \frac{6 \text{ mol H}_2\text{O}}{1 \text{ mol P}_4\text{O}_{10}} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 38.1 \text{ g H}_2\text{O}$
b. Given: balanced equation; 0.614 mol H ₂ O Unknown: mass H ₃ PO ₄	$0.614 \text{ mol H}_2\text{O} \times \frac{4 \text{ mol H}_3\text{PO}_4}{6 \text{ mol H}_2\text{O}} \times \frac{98.00 \text{ g H}_3\text{PO}_4}{1 \text{ mol H}_3\text{PO}_4} = 40.1 \text{ g H}_3\text{PO}_4$
c. Given: mass of H ₂ O Unknown: moles H ₂ O	$(63.70 \text{ g} - 56.64 \text{ g}) \text{ H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} = 0.392 \text{ mol H}_2\text{O}$
188. Given: 95.0 g H ₂ O Unknown: mass C ₂ H ₅ OH	$\text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$ $95.0 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \times \frac{1 \text{ mol C}_2\text{H}_5\text{OH}}{3 \text{ mol H}_2\text{O}} \times \frac{46.08 \text{ g C}_2\text{H}_5\text{OH}}{1 \text{ mol C}_2\text{H}_5\text{OH}} = 81.0 \text{ g C}_2\text{H}_5\text{OH}$
189. Given: balanced equation; 50.0 g SO ₂ Unknown: mass H ₂ SO ₄ and O ₂	$50.0 \text{ g SO}_2 \times \frac{1 \text{ mol SO}_2}{64.07 \text{ g SO}_2} \times \frac{2 \text{ mol H}_2\text{SO}_4}{2 \text{ mol SO}_2} \times \frac{98.09 \text{ g H}_2\text{SO}_4}{1 \text{ mol H}_2\text{SO}_4} = 76.5 \text{ g H}_2\text{SO}_4$ $50.0 \text{ g SO}_2 \times \frac{1 \text{ mol SO}_2}{64.07 \text{ g SO}_2} \times \frac{1 \text{ mol O}_2}{2 \text{ mol SO}_2} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 12.5 \text{ g O}_2$
190. Given: 5.00 g NaHCO ₃ Unknown: mass CO ₂	$2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$ $5.00 \text{ g NaHCO}_3 \times \frac{1 \text{ mol NaHCO}_3}{84.01 \text{ g NaHCO}_3} \times \frac{1 \text{ mol CO}_2}{2 \text{ mol NaHCO}_3} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 1.31 \text{ g CO}_2$
191. c. Given: 20 000 mol N ₂ H ₄ Unknown: mol N ₂	$20\,000 \text{ mol N}_2\text{H}_4 \times \frac{3 \text{ mol N}_2}{2 \text{ mol N}_2\text{H}_4} = 30\,000 \text{ mol N}_2$
d. Given: 450. kg N ₂ O ₄ Unknown: mass H ₂ O	$450. \text{ kg N}_2\text{O}_4 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol N}_2\text{O}_4}{92.02 \text{ g N}_2\text{O}_4} \times \frac{4 \text{ mol H}_2\text{O}}{1 \text{ mol N}_2\text{O}_4} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 3.52 \times 10^5 \text{ g H}_2\text{O}$

- 192.** Given: 517.84 g HgO
Unknown: mol O₂
- $$2\text{HgO} \rightarrow 2\text{Hg} + \text{O}_2$$
- $$517.84 \text{ g HgO} \times \frac{1 \text{ mol HgO}}{216.59 \text{ g HgO}} \times \frac{1 \text{ mol O}_2}{2 \text{ mol HgO}} = 1.1954 \text{ mol O}_2$$
-
- 193.** Given: 58.0 g Cl₂
Unknown: mass Fe
- $$2\text{Fe} + 3\text{Cl}_2 \rightarrow 2\text{FeCl}_3$$
- $$58.0 \text{ g Cl}_2 \times \frac{1 \text{ mol Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{2 \text{ mol Fe}}{3 \text{ mol Cl}_2} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 30.5 \text{ g Fe}$$
-
- 194.** Given: balanced equation; 5.00 mg Na₂S
Unknown: mass CdS in mg
- $$5.00 \text{ mg Na}_2\text{S} \times \frac{1 \text{ mol Na}_2\text{S}}{78.05 \text{ g Na}_2\text{S}} \times \frac{1 \text{ mol CdS}}{1 \text{ mol Na}_2\text{S}} \times \frac{144.48 \text{ g CdS}}{1 \text{ mol CdS}} = 9.26 \text{ mg CdS}$$
-
- 195. a.** Given: balanced equation; 4.44 mol KMnO₄
Unknown: mol CO₂
- $$4.44 \text{ mol KMnO}_4 \times \frac{5 \text{ mol CO}_2}{14 \text{ mol KMnO}_4} = 1.59 \text{ mol CO}_2$$
- b.** Given: 5.21 g H₂O
Unknown: mol C₃H₅(OH)₃
- $$5.21 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \times \frac{4 \text{ mol C}_3\text{H}_5(\text{OH})_3}{16 \text{ mol H}_2\text{O}} = 0.0723 \text{ mol C}_3\text{H}_5(\text{OH})_3$$
- c.** Given: 3.39 mol K₂CO₃
Unknown: mass Mn₂O₃ in grams
- $$3.39 \text{ mol K}_2\text{CO}_3 \times \frac{7 \text{ mol Mn}_2\text{O}_3}{7 \text{ mol K}_2\text{CO}_3} \times \frac{157.88 \text{ g Mn}_2\text{O}_3}{1 \text{ mol Mn}_2\text{O}_3} = 535 \text{ g Mn}_2\text{O}_3$$
- d.** Given: 50.0 g KMnO₄
Unknown: mass C₃H₅(OH)₃ and CO₂ in grams
- $$50.0 \text{ g KMnO}_4 \times \frac{1 \text{ mol KMnO}_4}{158.04 \text{ g KMnO}_4} \times \frac{4 \text{ mol C}_3\text{H}_5(\text{OH})_3}{14 \text{ mol KMnO}_4} \times \frac{92.11 \text{ g C}_3\text{H}_5(\text{OH})_3}{1 \text{ mol C}_3\text{H}_5(\text{OH})_3} = 8.33 \text{ g C}_3\text{H}_5(\text{OH})_3$$
- $$50.0 \text{ g KMnO}_4 \times \frac{1 \text{ mol KMnO}_4}{158.04 \text{ g KMnO}_4} \times \frac{5 \text{ mol CO}_2}{14 \text{ mol KMnO}_4} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 4.97 \text{ g CO}_2$$
-
- 196. a.** Given: balanced equation; 5.00 × 10³ kg CaCl₂
Unknown: mass HCl
- $$5.00 \times 10^3 \text{ kg CaCl}_2 \times \frac{1 \text{ mol CaCl}_2}{110.98 \text{ g CaCl}_2} \times \frac{2 \text{ mol HCl}}{1 \text{ mol CaCl}_2} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 3.29 \times 10^3 \text{ kg HCl}$$

b. Given: balanced equation; 750 g CaCO ₃ Unknown: mass CO ₂	$750 \text{ g CaCO}_3 \times \frac{1 \text{ mol CaCO}_3}{100.09 \text{ g CaCO}_3} \times \frac{1 \text{ mol CO}_2}{1 \text{ mol CaCO}_3} \times \frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2} = 330 \text{ g CO}_2$
197. a. Given: balanced equation; 1.50 × 10 ⁵ g Al Unknown: mass NH ₄ ClO ₄	$1.50 \times 10^5 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3 \text{ mol NH}_4\text{ClO}_4}{3 \text{ mol Al}} \times \frac{117.50 \text{ g NH}_4\text{ClO}_4}{1 \text{ mol NH}_4\text{ClO}_4}$ $= 6.53 \times 10^5 \text{ g NH}_4\text{ClO}_4$
b. Given: balanced equation; 620 kg NH ₄ ClO ₄ Unknown: mass NO	$620 \text{ kg NH}_4\text{ClO}_4 \times \frac{1 \text{ mol NH}_4\text{ClO}_4}{117.50 \text{ g NH}_4\text{ClO}_4} \times \frac{3 \text{ mol NO}}{3 \text{ mol NH}_4\text{ClO}_4} \times \frac{30.01 \text{ g NO}}{1 \text{ mol NO}}$ $= 160 \text{ kg NO}$
198. a. Given: balanced equation; 2.50 × 10 ⁵ kg H ₂ SO ₄ Unknown: moles H ₃ PO ₄	$2.50 \times 10^5 \text{ kg H}_2\text{SO}_4 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol H}_2\text{SO}_4}{98.09 \text{ g H}_2\text{SO}_4} \times \frac{2 \text{ mol H}_3\text{PO}_4}{3 \text{ mol H}_2\text{SO}_4}$ $= 1.70 \times 10^6 \text{ mol H}_3\text{PO}_4$
b. Given: balanced equation; 400. kg Ca ₃ (PO ₄) ₂ Unknown: mass CaSO ₄ • 2H ₂ O	$400 \text{ kg Ca}(\text{PO}_4)_2 \times \frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{310.18 \text{ g Ca}_3(\text{PO}_4)_2} \times \frac{3 \text{ mol CaSO}_4 \cdot 2\text{H}_2\text{O}}{1 \text{ mol Ca}_3(\text{PO}_4)_2}$ $\times \frac{172.19 \text{ g CaSO}_4 \cdot 2\text{H}_2\text{O}}{1 \text{ mol CaSO}_4 \cdot 2\text{H}_2\text{O}} = 666 \text{ kg CaSO}_4 \cdot 2\text{H}_2\text{O}$
c. Given: balanced equation; 68 metric tons rock; 78.8% Ca ₃ (PO ₄) ₂ Unknown: mass H ₃ PO ₄ in metric tons	$68 \text{ metric tons rock} \times \frac{0.788 \text{ g Ca}_3(\text{PO}_4)_2}{1 \text{ g rock}} \times \frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{310.18 \text{ g Ca}_3(\text{PO}_4)_2}$ $\times \frac{2 \text{ mol H}_3\text{PO}_4}{1 \text{ mol Ca}_3(\text{PO}_4)_2} \times \frac{98.00 \text{ g H}_3\text{PO}_4}{1 \text{ mol H}_3\text{PO}_4} = 34 \text{ metric tons H}_3\text{PO}_4$
199. Given: balanced equation; mass Fe = 3.19% × 1650 kg Unknown: mass of steel scrap after 1 yr	$0.0319 \times 1650 \text{ kg Fe} = 52.6 \text{ kg Fe}$ $52.6 \text{ kg Fe} \times \frac{\text{mol Fe}}{55.85 \text{ g Fe}} \times \frac{2 \text{ mol Fe}_2\text{O}_3}{4 \text{ mol Fe}} \times \frac{159.70 \text{ g Fe}_2\text{O}_3}{1 \text{ mol Fe}_2\text{O}_3} = 75.2 \text{ kg Fe}_2\text{O}_3$ $1650 \text{ kg} - 52.6 \text{ kg} + 75.2 \text{ kg} = 1670 \text{ kg}$
200. Given: balanced equation; 0.048 mol Al; 0.030 mol O ₂	$0.048 \text{ mol Al} \times \frac{3 \text{ mol O}_2}{4 \text{ mol Al}} = 0.036 \text{ mol O}_2$ 0.036 mol O₂ needed; 0.030 mol O₂ available limiting reactant: O₂

201. Given: balanced equation; 862 g ZrSiO ₄ ; 950. g Cl ₂ Unknown: limiting reactant; mass ZrCl ₄	$862 \text{ g ZrSiO}_4 \times \frac{1 \text{ mol ZrSiO}_4}{183.31 \text{ g ZrSiO}_4} \times \frac{2 \text{ mol Cl}_2}{1 \text{ mol ZrSiO}_4} \times \frac{70.90 \text{ g Cl}_2}{1 \text{ mol Cl}_2} = 667 \text{ g Cl}_2$ 667 g Cl₂ needed; 950. g Cl₂ available; limiting reactant is ZrSiO₄ $862 \text{ g ZrSiO}_4 \times \frac{1 \text{ mol ZrSiO}_4}{183.31 \text{ g ZrSiO}_4} \times \frac{1 \text{ mol ZrCl}_4}{1 \text{ mol ZrSiO}_4} \times \frac{233.02 \text{ g ZrCl}_4}{1 \text{ mol ZrCl}_4}$ $= 1.10 \times 10^3 \text{ g ZrCl}_4$
202. Given: 1.72 mol ZnS; 3.04 mol O ₂ Unknown: balanced equation; limiting reactant	$2\text{ZnS} + 3\text{O}_2 \rightarrow 2\text{ZnO} + 2\text{SO}_2$ $1.72 \text{ mol ZnS} \times \frac{3 \text{ mol O}_2}{2 \text{ mol ZnS}} = 2.58 \text{ mol O}_2$ 2.58 mol O₂ needed; 3.04 mol O₂ available; limiting reactant is ZnS.
203. a. Given: balanced equation; 0.32 mol Al; 0.26 mol O ₂ Unknown: limiting reactant	$0.32 \text{ mol Al} \times \frac{3 \text{ mol O}_2}{4 \text{ mol Al}} = 0.24 \text{ mol O}_2$ 0.24 mol O₂ needed; 0.26 mol O₂ available; limiting reactant is Al
b. Given: balanced equation; 6.38×10^{-3} mol O ₂ ; 9.15×10^{-3} mol Al Unknown: moles Al ₂ O ₃	$6.38 \times 10^{-3} \text{ mol O}_2 \times \frac{4 \text{ mol Al}}{3 \text{ mol O}_2} = 8.51 \times 10^{-3} \text{ mol Al}$ 8.51×10^{-3} mol Al needed; 9.15×10^{-3} mol Al available; limiting reactant: O₂ $6.38 \times 10^{-3} \text{ mol O}_2 \times \frac{2 \text{ mol Al}_2\text{O}_3}{3 \text{ mol O}_2} = 4.25 \times 10^{-3} \text{ mol Al}_2\text{O}_3$
c. Given: balanced equation; 3.17 g Al; 2.55 g O ₂ Unknown: limiting reactant	$3.17 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3 \text{ mol O}_2}{4 \text{ mol Al}} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 2.82 \text{ g O}_2$ 2.82 g O₂ needed; 2.55 g O₂ available; limiting reactant: O₂
204. a. Given: balanced equation; 100. g CuS; 56 g O ₂ Unknown: limiting reactant	$100. \text{ g CuS} \times \frac{1 \text{ mol CuS}}{95.62 \text{ g CuS}} \times \frac{3 \text{ mol O}_2}{2 \text{ mol CuS}} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 50.2 \text{ g O}_2$ 50.2 g O₂ needed; 56 g O₂ available; limiting reactant: CuS
b. Given: balanced equation; 18.7 g CuS; 12.0 g O ₂ Unknown: mass CuO	$18.7 \text{ g CuS} \times \frac{1 \text{ mol CuS}}{95.62 \text{ g CuS}} \times \frac{3 \text{ mol O}_2}{2 \text{ mol CuS}} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 9.39 \text{ g O}_2$ 9.39 g O₂ needed; 12.0 g O₂ available; limiting reactant: CuS $18.7 \text{ g CuS} \times \frac{1 \text{ mol CuS}}{95.62 \text{ g CuS}} \times \frac{2 \text{ mol CuO}}{2 \text{ mol CuS}} \times \frac{79.55 \text{ g CuO}}{1 \text{ mol CuO}} = 15.6 \text{ g CuO}$

205. Given: balanced equation; 0.092 mol Fe; 0.158 mol CuSO ₄ Unknown: limiting reactant; moles Cu	$0.092 \text{ mol Fe} \times \frac{3 \text{ mol CuSO}_4}{2 \text{ mol Fe}} = 0.14 \text{ mol CuSO}_4$ 0.14 mol CuSO₄ needed; 0.158 mol CuSO₄ available; limiting reactant: Fe $0.092 \text{ mol Fe} \times \frac{3 \text{ mol Cu}}{2 \text{ mol Fe}} = 0.14 \text{ mol Cu}$
206. Given: balanced equation; 55 g BaCO ₃ ; 26 g HNO ₃ Unknown: mass Ba(NO ₃) ₂	$55 \text{ g BaCO}_3 \times \frac{1 \text{ mol BaCO}_3}{197.34 \text{ g BaCO}_3} \times \frac{2 \text{ mol HNO}_3}{1 \text{ mol BaCO}_3} \times \frac{63.02 \text{ g HNO}_3}{1 \text{ mol HNO}_3}$ = 35 g HNO₃ 35 g HNO₃ needed; 26 g HNO₃ available; limiting reactant: HNO₃ $26 \text{ g HNO}_3 \times \frac{1 \text{ mol HNO}_3}{63.02 \text{ g HNO}_3} \times \frac{1 \text{ mol Ba(NO}_3)_2}{2 \text{ mol HNO}_3} \times \frac{261.35 \text{ g Ba(NO}_3)_2}{1 \text{ mol Ba(NO}_3)_2}$ = 54 g Ba(NO₃)₂
207. a. Given: balanced equation; 560 g MgI ₂ ; 360 g Br ₂ Unknown: excess reactant; remaining mass	$560 \text{ g MgI}_2 \times \frac{1 \text{ mol MgI}_2}{278.11 \text{ g MgI}_2} \times \frac{1 \text{ mol Br}_2}{1 \text{ mol MgI}_2} \times \frac{159.80 \text{ g Br}_2}{1 \text{ mol Br}_2} = 322 \text{ g Br}_2$ Br₂ is in excess; 360 g Br₂ – 322 g Br₂ = 38 g Br₂ excess
b. Given: balanced equation; 560 g MgI ₂ Unknown: mass I ₂	$560 \text{ g MgI}_2 \times \frac{1 \text{ mol MgI}_2}{278.11 \text{ g MgI}_2} \times \frac{1 \text{ mol I}_2}{1 \text{ mol MgI}_2} \times \frac{253.80 \text{ g I}_2}{1 \text{ mol I}_2} = 510 \text{ g I}_2$
208. a. Given: balanced equation; 22.9 g Ni; 112 g AgNO ₃ Unknown: excess reactant	$22.9 \text{ g Ni} \times \frac{1 \text{ mol Ni}}{58.69 \text{ g Ni}} \times \frac{2 \text{ mol AgNO}_3}{1 \text{ mol Ni}} \times \frac{169.88 \text{ g AgNO}_3}{1 \text{ mol AgNO}_3} = 133 \text{ g AgNO}_3$ Ni is in excess
b. Given: balanced equation; 112 g AgNO ₃ Unknown: mass Ni(NO ₃) ₂	$112 \text{ g AgNO}_3 \times \frac{1 \text{ mol AgNO}_3}{169.88 \text{ g AgNO}_3} \times \frac{1 \text{ mol Ni(NO}_3)_2}{2 \text{ mol AgNO}_3} \times \frac{182.71 \text{ g Ni(NO}_3)_2}{1 \text{ mol Ni(NO}_3)_2}$ = 60.2 g Ni(NO₃)₂
209. Given: 1.60 mol CS ₂ ; 5.60 mol O ₂ Unknown: balanced equation; moles of excess, reactant	$\text{CS}_2(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{SO}_2(\text{g}) + \text{CO}_2(\text{g})$ $1.60 \text{ mol CS}_2 \times \frac{3 \text{ mol O}_2}{1 \text{ mol CS}_2} = 4.80 \text{ mol O}_2$ 5.60 mol O₂ – 4.80 mol O₂ = 0.80 mol O₂ excess

- 210. a.** Given: balanced equation;
0.91 g HgCl₂
Unknown: mass Hg(NH₂)Cl
- $$0.91 \text{ g HgCl}_2 \times \frac{1 \text{ mol HgCl}_2}{271.49 \text{ g HgCl}_2} \times \frac{1 \text{ mol Hg(NH}_2\text{)Cl}}{1 \text{ mol HgCl}_2} \times \frac{252.07 \text{ g Hg(NH}_2\text{)Cl}}{1 \text{ mol Hg(NH}_2\text{)Cl}} = 0.84 \text{ g Hg(NH}_2\text{)Cl}$$
- b.** Given: balanced equation;
0.91 g HgCl₂;
0.15 g NH₃
Unknown: mass Hg(NH₂)Cl
- $$0.91 \text{ g HgCl}_2 \times \frac{1 \text{ mol HgCl}_2}{271.49 \text{ g HgCl}_2} \times \frac{2 \text{ mol NH}_3}{1 \text{ mol HgCl}_2} \times \frac{17.04 \text{ g NH}_3}{1 \text{ mol NH}_3} = 0.11 \text{ g NH}_3$$
- 0.11 g NH₃ needed; 0.15 g NH₃ available; limiting reactant: HgCl₂
- $$0.91 \text{ g HgCl}_2 \times \frac{1 \text{ mol HgCl}_2}{271.49 \text{ g HgCl}_2} \times \frac{1 \text{ mol Hg(NH}_2\text{)Cl}}{1 \text{ mol HgCl}_2} \times \frac{252.07 \text{ g Hg(NH}_2\text{)Cl}}{1 \text{ mol Hg(NH}_2\text{)Cl}} = 0.84 \text{ g Hg(NH}_2\text{)Cl}$$
-
- 211. b.** Given: balanced equation from **a**; 0.57 mol Al;
0.37 mol NaOH; excess water
Unknown: moles H₂
- $$0.57 \text{ mol Al} \times \frac{2 \text{ mol NaOH}}{2 \text{ mol Al}} = 0.57 \text{ mol NaOH}$$
- 0.57 mol NaOH needed; 0.37 mol NaOH available; limiting reactant: NaOH
- $$0.37 \text{ mol NaOH} \times \frac{3 \text{ mol H}_2}{2 \text{ mol NaOH}} = 0.56 \text{ mol H}_2$$
-
- 212. a.** Given: balanced equation;
0.0845 mol NO₂
Unknown: moles of HNO₃ and Cu
- $$0.0845 \text{ mol NO}_2 \times \frac{4 \text{ mol HNO}_3}{2 \text{ mol NO}_2} = 0.169 \text{ mol HNO}_3$$
- $$0.0845 \text{ mol NO}_2 \times \frac{1 \text{ mol Cu}}{2 \text{ mol NO}_2} = 0.0422 \text{ mol Cu}$$
- b.** Given: balanced equation;
5.94 g Cu;
23.23 g HNO₃
Unknown: excess reactant
- $$5.94 \text{ g Cu} \times \frac{1 \text{ mol Cu}}{63.55 \text{ g Cu}} \times \frac{4 \text{ mol HNO}_3}{1 \text{ mol Cu}} \times \frac{63.02 \text{ g HNO}_3}{1 \text{ mol HNO}_3} = 23.6 \text{ g HNO}_3$$
- 23.6 g HNO₃ needed; 23.23 g HNO₃ available: Cu is in excess.
-
- 213. a.** Given: balanced equation;
2.90 mol NH₃;
3.75 mol O₂
Unknown: moles of NO and H₂O
- $$2.90 \text{ mol NH}_3 \times \frac{5 \text{ mol O}_2}{4 \text{ mol NH}_3} = 3.62 \text{ mol O}_2; \text{NH}_3 \text{ is limiting.}$$
- $$2.90 \text{ mol NH}_3 \times \frac{4 \text{ mol NO}}{4 \text{ mol NH}_3} = 2.90 \text{ mol NO}$$
- $$2.90 \text{ mol NH}_3 \times \frac{6 \text{ mol H}_2\text{O}}{4 \text{ mol NH}_3} = 4.35 \text{ mol H}_2\text{O}$$

b. Given: balanced equation;
 4.20×10^4 g NH_3 ; 1.31×10^5 g O_2
 Unknown: limiting reactant

$$4.20 \times 10^4 \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.04 \text{ g NH}_3} \times \frac{5 \text{ mol O}_2}{4 \text{ mol NH}_3} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2}$$

$$= 9.86 \times 10^4 \text{ g O}_2$$

9.86×10^4 g O_2 needed; 1.31×10^5 g O_2 available; limiting reactant: NH_3

c. Given: balanced equation;
 869 kg NH_3 ;
 2480 kg O_2
 Unknown: mass NO

$$869 \text{ kg NH}_3 \times \frac{1 \text{ mol NH}_3}{17.04 \text{ g NH}_3} \times \frac{5 \text{ mol O}_2}{4 \text{ mol NH}_3} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2} = 2040 \text{ kg O}_2$$

2040 kg O_2 needed; 2480 kg O_2 available; limiting reactant: NH_3

$$869 \text{ kg NH}_3 \times \frac{1 \text{ mol NH}_3}{17.04 \text{ g NH}_3} \times \frac{4 \text{ mol NO}}{4 \text{ mol NH}_3} \times \frac{30.01 \text{ g NO}}{1 \text{ mol NO}}$$

$$= 1.53 \times 10^3 \text{ kg NO}$$

214. Given: balanced equation;
 620 g $\text{C}_2\text{H}_5\text{OH}$;
 1020 g CuO
 Unknown: mass CH_3CHO ;
 mass excess reactant left

$$620 \text{ g C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol C}_2\text{H}_5\text{OH}}{46.08 \text{ g C}_2\text{H}_5\text{OH}} \times \frac{1 \text{ mol CuO}}{1 \text{ mol C}_2\text{H}_5\text{OH}} \times \frac{79.55 \text{ g CuO}}{1 \text{ mol CuO}}$$

$$= 1070 \text{ g CuO}$$

1070 g CuO needed; 1020 g CuO available; limiting reactant: CuO

$$1020 \text{ g CuO} \times \frac{1 \text{ mol CuO}}{79.55 \text{ g CuO}} \times \frac{1 \text{ mol CH}_3\text{CHO}}{1 \text{ mol CuO}} \times \frac{44.06 \text{ g CH}_3\text{CHO}}{1 \text{ mol CH}_3\text{CHO}}$$

$$= 565 \text{ g CH}_3\text{CHO}$$

$$1020 \text{ g CuO} \times \frac{1 \text{ mol CuO}}{79.55 \text{ g CuO}} \times \frac{1 \text{ mol C}_2\text{H}_5\text{OH}}{1 \text{ mol CuO}} \times \frac{46.08 \text{ g C}_2\text{H}_5\text{OH}}{1 \text{ mol C}_2\text{H}_5\text{OH}}$$

$$= 591 \text{ g C}_2\text{H}_5\text{OH}$$

$$620 \text{ g C}_2\text{H}_5\text{OH} - 591 \text{ g C}_2\text{H}_5\text{OH} = 29 \text{ g C}_2\text{H}_5\text{OH excess}$$

215. Given: balanced equation; 250 g SO_2 ; 650 g Br_2 ;
 excess H_2O
 Unknown: mass HBr

$$250 \text{ g SO}_2 \times \frac{1 \text{ mol SO}_2}{64.07 \text{ g SO}_2} \times \frac{1 \text{ mol Br}_2}{1 \text{ mol SO}_2} \times \frac{159.80 \text{ g Br}_2}{1 \text{ mol Br}_2} = 624 \text{ g Br}_2$$

624 g Br_2 needed; 650 g Br_2 available; limiting reactant: SO_2

$$250 \text{ g SO}_2 \times \frac{1 \text{ mol SO}_2}{64.07 \text{ g SO}_2} \times \frac{2 \text{ mol HBr}}{1 \text{ mol SO}_2} \times \frac{80.91 \text{ g HBr}}{1 \text{ mol HBr}} = 630 \text{ g HBr}$$

216. Given: balanced equation;
 25.0 g Na_2SO_3 ;
 22.0 g HCl
 Unknown: mass SO_2

$$25.0 \text{ g Na}_2\text{SO}_3 \times \frac{1 \text{ mol Na}_2\text{SO}_3}{126.05 \text{ g Na}_2\text{SO}_3} \times \frac{2 \text{ mol HCl}}{1 \text{ mol Na}_2\text{SO}_3} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 14.5 \text{ g HCl}$$

14.5 g HCl needed; 22.0 g HCl available; limiting reactant: Na_2SO_3

$$25.0 \text{ g Na}_2\text{SO}_3 \times \frac{1 \text{ mol Na}_2\text{SO}_3}{126.05 \text{ g Na}_2\text{SO}_3} \times \frac{1 \text{ mol SO}_2}{1 \text{ mol Na}_2\text{SO}_3} \times \frac{64.07 \text{ g SO}_2}{1 \text{ mol SO}_2}$$

$$= 12.7 \text{ g SO}_2$$

- 217. a.** Given: balanced equation;
27.5 g TbF₃;
6.96 g Ca
Unknown: mass Tb
- $$27.5 \text{ g TbF}_3 \times \frac{1 \text{ mol TbF}_3}{215.93 \text{ g TbF}_3} \times \frac{3 \text{ mol Ca}}{2 \text{ mol TbF}_3} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}} = 7.66 \text{ g Ca}$$
- 7.66 g Ca needed; 6.96 g Ca available; limiting reactant: Ca
- $$6.96 \text{ g Ca} \times \frac{1 \text{ mol Ca}}{40.08 \text{ g Ca}} \times \frac{2 \text{ mol Tb}}{3 \text{ mol Ca}} \times \frac{158.93 \text{ g Tb}}{1 \text{ mol Tb}} = 18.4 \text{ g Tb}$$
- b.** Given: balanced equation;
6.96 g Ca;
27.5 g TbF₃;
Ca is limiting
Unknown: mass TbF₃ remaining
- $$6.96 \text{ g Ca} \times \frac{1 \text{ mol Ca}}{40.08 \text{ g Ca}} \times \frac{2 \text{ mol TbF}_3}{3 \text{ mol Ca}} \times \frac{215.93 \text{ g TbF}_3}{1 \text{ mol TbF}_3} = 25.0 \text{ g TbF}_3$$
- $$27.5 \text{ g TbF}_3 - 25.0 \text{ g TbF}_3 = 2.5 \text{ g TbF}_3 \text{ remaining}$$

- 218. a.** Given: theoretical yield = 50.0 g; actual yield = 41.9 g
Unknown: percent yield
- $$\frac{41.9 \text{ g}}{50.0 \text{ g}} \times 100 = 83.8\% \text{ yield}$$
- b.** Given: theoretical yield = 290 kg; actual yield = 270 kg
Unknown: percent yield
- $$\frac{270 \text{ kg}}{290 \text{ kg}} \times 100 = 93\% \text{ yield}$$
- c.** Given: theoretical yield = 6.05×10^4 kg; actual yield = 4.18×10^4 kg
Unknown: percent yield
- $$\frac{4.18 \times 10^4 \text{ kg}}{6.05 \times 10^4 \text{ kg}} \times 100 = 69.1\% \text{ yield}$$
- d.** Given: theoretical yield = 0.00192 g; actual yield = 0.00089 g
Unknown: percent yield
- $$\frac{0.00089 \text{ g}}{0.00192 \text{ g}} \times 100 = 46\% \text{ yield}$$

- 219. a.** Given: balanced equation;
8.87 g As₂O₃;
actual yield As = 5.33 g
Unknown: percent yield
- $$\text{theoretical yield} = 8.87 \text{ g As}_2\text{O}_3 \times \frac{1 \text{ mol As}_2\text{O}_3}{197.84 \text{ g As}_2\text{O}_3} \times \frac{4 \text{ mol As}}{2 \text{ mol As}_2\text{O}_3} \times \frac{74.92 \text{ g As}}{1 \text{ mol As}} = 6.72 \text{ g As}$$
- $$\frac{5.33 \text{ g As}}{6.72 \text{ g As}} \times 100 = 79.3\% \text{ yield}$$
- b.** Given: balanced equation;
67 g C,
actual yield As = 425 g
Unknown: percent yield
- $$\text{theoretical yield} = 67 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} \times \frac{4 \text{ mol As}}{3 \text{ mol C}} \times \frac{74.92 \text{ g As}}{1 \text{ mol As}} = 560 \text{ g As}$$
- $$\frac{425 \text{ g As}}{560 \text{ g As}} \times 100 = 76\% \text{ yield}$$

- 220. a.** Given: theoretical yield = 68.3 g;
actual yield = 43.9 g
Unknown: percent yield
- $$\frac{43.9 \text{ g}}{68.3 \text{ g}} \times 100 = 64.3\% \text{ yield}$$
- b.** Given: theoretical yield = 0.0722 mol;
actual yield = 0.0419 mol
Unknown: percent yield
- $$\frac{0.0419 \text{ mol}}{0.0722 \text{ mol}} \times 100 = 58.0\% \text{ yield}$$
- c.** Given: 4.29 mol $\text{C}_2\text{H}_5\text{OH}$;
actual yield $\text{CH}_3\text{COOC}_2\text{H}_5$ = 2.98 mol;
balanced equation
Unknown: percent yield
- theoretical yield $\text{CH}_3\text{COOC}_2\text{H}_5$ =
- $$4.29 \text{ mol } \text{C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol } \text{CH}_3\text{COOC}_2\text{H}_5}{1 \text{ mol } \text{C}_2\text{H}_5\text{OH}} = 4.29 \text{ mol } \text{CH}_3\text{COOC}_2\text{H}_5$$
- $$\frac{2.98 \text{ mol } \text{CH}_3\text{COOC}_2\text{H}_5}{4.29 \text{ mol } \text{CH}_3\text{COOC}_2\text{H}_5} \times 100 = 69.5\% \text{ yield}$$
- d.** Given: balanced equation; 0.58 mol $\text{C}_2\text{H}_5\text{OH}$;
0.82 mol CH_3COOH ;
actual yield $\text{CH}_3\text{COOC}_2\text{H}_5$ = 0.46 mol
Unknown: percent yield
- 0.58 mol $\text{C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol } \text{CH}_3\text{COOH}}{1 \text{ mol } \text{C}_2\text{H}_5\text{OH}} = 0.58 \text{ mol } \text{CH}_3\text{COOH}$
 $\text{C}_2\text{H}_5\text{OH}$ is limiting.
- $$0.58 \text{ mol } \text{C}_2\text{H}_5\text{OH} \times \frac{1 \text{ mol } \text{CH}_3\text{COOC}_2\text{H}_5}{1 \text{ mol } \text{C}_2\text{H}_5\text{OH}} = 0.58 \text{ mol } \text{CH}_3\text{COOC}_2\text{H}_5$$
- $$\frac{0.46 \text{ mol}}{0.58 \text{ mol}} \times 100 = 79\% \text{ yield}$$
-
- 221. a.** Given: balanced equation;
0.0251 mol A;
actual yield C = 0.0349 mol
Unknown: percent yield
- theoretical yield C = 0.0251 mol A $\times \frac{4 \text{ mol C}}{2 \text{ mol A}} = 0.0502 \text{ mol C}$
- $$\frac{0.0349 \text{ mol}}{0.0502 \text{ mol}} \times 100 = 69.5\% \text{ yield}$$
- b.** Given: balanced equation;
1.19 mol A;
actual yield D = 1.41 mol
Unknown: percent yield
- theoretical yield D = 1.19 mol A $\times \frac{3 \text{ mol D}}{2 \text{ mol A}} = 1.785 \text{ mol D}$
- $$\frac{1.41 \text{ mol}}{1.785 \text{ mol}} \times 100 = 79.0\% \text{ yield}$$
- c.** Given: balanced equation;
189 mol B;
actual yield D = 39 mol
Unknown: percent yield
- theoretical yield D = 189 mol B $\times \frac{3 \text{ mol D}}{7 \text{ mol B}} = 81.0 \text{ mol D}$
- $$\frac{39 \text{ mol}}{81.0 \text{ mol}} \times 100 = 48\% \text{ yield}$$

- d.** Given: balanced equation;
3500 mol B;
actual yield C = 1700 mol

Unknown: percent yield

$$\text{theoretical yield C} = 3500 \text{ mol B} \times \frac{4 \text{ mol C}}{7 \text{ mol B}} = 2.0 \times 10^3 \text{ mol C}$$

$$\frac{1.7 \times 10^3 \text{ mol}}{2.0 \times 10^3 \text{ mol}} \times 100 = 85\% \text{ C}$$

- 222. a.** Given: balanced equation;
57 mol $\text{Ca}_3(\text{PO}_4)_2$;
actual yield CaSiO_3 = 101 mol

Unknown: percent yield

$$\begin{aligned} \text{theoretical yield CaSiO}_3 &= 57 \text{ mol Ca}_3(\text{PO}_4)_2 \times \frac{3 \text{ mol CaSiO}_3}{1 \text{ mol Ca}_3(\text{PO}_4)_2} \\ &= 170 \text{ mol CaSiO}_3 \end{aligned}$$

$$\frac{101 \text{ mol}}{170 \text{ mol}} \times 100 = 59\% \text{ yield}$$

- b.** Given: balanced equation;
1280 mol C;
actual yield CaSiO_3 = 622 mol

Unknown: percent yield

$$\text{theoretical yield CaSiO}_3 = 1280 \text{ mol C} \times \frac{3 \text{ mol CaSiO}_3}{5 \text{ mol C}} = 768 \text{ mol CaSiO}_3$$

$$\frac{622 \text{ mol}}{768 \text{ mol}} \times 100 = 81.0\% \text{ yield}$$

- c.** Given: balanced equation;
81.5% yield;
 1.4×10^5 mol $\text{Ca}_3(\text{PO}_4)_2$

Unknown: actual mol P

$$1.4 \times 10^5 \text{ mol Ca}_3(\text{PO}_4)_2 \times \frac{2 \text{ mol P}}{1 \text{ mol Ca}_3(\text{PO}_4)_2} \times 0.815 = 2.3 \times 10^5 \text{ mol}$$

- 223. a.** Given: balanced equation;
56.9 g WO_3 ;
actual yield W = 41.4 g

Unknown: percent yield

$$56.9 \text{ g WO}_3 \times \frac{1 \text{ mol WO}_3}{231.84 \text{ g WO}_3} \times \frac{1 \text{ mol W}}{1 \text{ mol WO}_3} \times \frac{183.84 \text{ g W}}{1 \text{ mol W}} = 45.1 \text{ g W}$$

$$\frac{41.4 \text{ g}}{45.1 \text{ g}} \times 100 = 91.8\% \text{ yield}$$

- b.** Given: balanced equation;
3.72 g WO_3 ;
92.0% yield

Unknown: moles W

$$3.72 \text{ g WO}_3 \times \frac{1 \text{ mol WO}_3}{231.84 \text{ g WO}_3} \times \frac{1 \text{ mol W}}{1 \text{ mol WO}_3} \times \frac{92.0\%}{100\%} = 0.0148 \text{ mol W}$$

- c.** Given: balanced equation;
actual yield W = 11.4 g;
89.4% yield

Unknown: mass WO_3

$$\frac{11.4 \text{ g W}}{x} = \frac{89.4 \text{ g}}{100.0 \text{ g}}; x = 12.8 \text{ g W}$$

$$12.8 \text{ g W} \times \frac{1 \text{ mol W}}{183.84 \text{ g W}} \times \frac{1 \text{ mol WO}_3}{1 \text{ mol W}} \times \frac{231.84 \text{ g WO}_3}{1 \text{ mol WO}_3} = 16.1 \text{ g WO}_3$$

- 224. a.** Given: balanced equation;
410. kg CS₂;
actual yield
CCl₄ = 719 kg
Unknown: percent yield
- $$\text{theoretical yield} = 410. \text{ kg CS}_2 \times \frac{1 \text{ mol CS}_2}{76.15 \text{ g CS}_2} \times \frac{1 \text{ mol CCl}_4}{1 \text{ mol CS}_2}$$
- $$\times \frac{153.81 \text{ g CCl}_4}{1 \text{ mol CCl}_4} = 828 \text{ kg CCl}_4$$
- $$\frac{719 \text{ kg}}{828 \text{ kg}} \times 100 = 86.8\% \text{ yield}$$
- b.** Given: balanced equation;
67.5 g Cl₂;
actual yield
S₂Cl₂ = 39.5 g
Unknown: percent yield
- $$\text{theoretical yield} = 67.5 \text{ g Cl}_2 \times \frac{1 \text{ mol Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{1 \text{ mol S}_2\text{Cl}_2}{3 \text{ mol Cl}_2}$$
- $$\times \frac{135.04 \text{ g S}_2\text{Cl}_2}{1 \text{ mol S}_2\text{Cl}_2} = 42.8 \text{ g S}_2\text{Cl}_2$$
- $$\frac{39.5 \text{ g}}{42.8 \text{ g}} \times 100 = 92.2\% \text{ yield}$$
- c.** Given: balanced equation;
83.3% yield;
actual yield
CCl₄ =
5.00 × 10⁴ kg
Unknown: kg CS₂
and S₂Cl₂
- $$5.00 \times 10^4 \text{ kg CCl}_4 \times \frac{100\%}{83.3\%} \times \frac{1 \text{ mol CCl}_4}{153.81 \text{ g CCl}_4} \times \frac{1 \text{ mol CS}_2}{1 \text{ mol CCl}_4} \times \frac{76.15 \text{ g CS}_2}{1 \text{ mol CS}_2} =$$
- $$2.97 \times 10^4 \text{ kg CS}_2$$
- $$5.00 \times 10^4 \text{ kg CCl}_4 \times \frac{83.3\%}{100\%} \times \frac{1 \text{ mol CCl}_4}{153.81 \text{ g CCl}_4} \times \frac{1 \text{ mol S}_2\text{Cl}_2}{1 \text{ mol CCl}_4}$$
- $$\times \frac{135.04 \text{ g S}_2\text{Cl}_2}{1 \text{ mol S}_2\text{Cl}_2} = 3.66 \times 10^4 \text{ kg S}_2\text{Cl}_2$$
-
- 225. a.** Given: balanced equation;
0.38 g NO₂;
actual yield
N₂O₅ = 0.36 g
Unknown: percent yield
- $$0.38 \text{ g NO}_2 \times \frac{1 \text{ mol NO}_2}{46.01 \text{ g NO}_2} \times \frac{1 \text{ mol N}_2\text{O}_5}{2 \text{ mol NO}_2} \times \frac{108.02 \text{ g N}_2\text{O}_5}{1 \text{ mol N}_2\text{O}_5} = 0.45 \text{ g N}_2\text{O}_5$$
- $$\frac{0.36 \text{ g}}{0.45 \text{ g}} \times 100 = 80.\% \text{ g yield}$$
- b.** Given: balanced equation;
6.0 mol NO₂;
61.1% yield
Unknown: mass
N₂O₅
- $$6.0 \text{ mol NO}_2 \times \frac{1 \text{ mol N}_2\text{O}_5}{2 \text{ mol NO}_2} \times \frac{108.02 \text{ g N}_2\text{O}_5}{1 \text{ mol N}_2\text{O}_5} = 320 \text{ g N}_2\text{O}_5$$
- $$320 \text{ g N}_2\text{O}_5 \times \frac{61.1\%}{100\%} = 2.0 \times 10^2 \text{ g N}_2\text{O}_5$$
-
- 226.** Given: balanced equation; 30.0 g NaCl; 0.250 mol H₂SO₄; actual yield HCl = 14.6 g
Unknown: percent yield
- $$30.0 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} \times \frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol NaCl}} = 0.257 \text{ mol H}_2\text{SO}_4$$
- 0.250 mol H₂SO₄ available, 0.257 mol H₂SO₄ needed; H₂SO₄ is limiting.
- $$0.250 \text{ mol H}_2\text{SO}_4 \times \frac{2 \text{ mol HCl}}{1 \text{ mol H}_2\text{SO}_4} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 18.2 \text{ g HCl}$$
- $$\frac{14.6 \text{ g}}{18.2 \text{ g}} \times 100 = 80.2\% \text{ yield}$$

- 227. a.** Given: balanced equation;
410 g Au;
actual yield NaAu(CN)₂ = 540 g
Unknown: percent yield
- $$\text{theoretical yield} = 410 \text{ g Au} \times \frac{1 \text{ mol Au}}{196.97 \text{ g Au}} \times \frac{4 \text{ mol NaAu(CN)}_2}{4 \text{ mol Au}}$$
- $$\times \frac{272.00 \text{ g NaAu(CN)}_2}{1 \text{ mol NaAu(CN)}_2} = 570 \text{ g NaAu(CN)}_2$$
- $$\frac{540 \text{ g}}{570 \text{ g}} \times 100 = 95\% \text{ yield}$$
- b.** Given: balanced equation;
79.6% yield;
1.00 kg NaAu(CN)₂
Unknown: mass Au
- $$1.00 \text{ kg NaAu(CN)}_2 \times \frac{100\%}{79.6\%} \times \frac{1 \text{ mol NaAu(CN)}_2}{272.00 \text{ g NaAu(CN)}_2}$$
- $$\times \frac{4 \text{ mol Au}}{4 \text{ mol NaAu(CN)}_2} \times \frac{196.97 \text{ g Au}}{1 \text{ mol Au}} = 0.910 \text{ kg Au} = 9.10 \times 10^2 \text{ g Au}$$
- c.** Given: 0.910 kg Au;
ore is 0.001% Au
Unknown: mass of ore
- $$\frac{x}{0.910 \text{ kg Au}} = \frac{100\%}{0.001\%}; x = 9 \times 10^4 \text{ kg ore}$$
-
- 228. a.** Given: balanced equation;
2.00 g CO;
actual yield I₂ = 3.17 g
Unknown: percent yield
- $$\text{theoretical yield} = 2.00 \text{ g CO} \times \frac{1 \text{ mol CO}}{28.01 \text{ g CO}} \times \frac{1 \text{ mol I}_2}{5 \text{ mol CO}} \times \frac{253.80 \text{ g I}_2}{1 \text{ mol I}_2}$$
- $$= 3.63 \text{ g I}_2$$
- $$\frac{3.17 \text{ g}}{3.63 \text{ g}} \times 100 = 87.3\% \text{ yield}$$
- b.** Given: 87.6% yield;
2.00 g CO
Unknown: mass of unreacted CO
- $$100.0\% - 87.6\% = 12.4\% \text{ unreacted}$$
- $$0.124 \times 2.00 \text{ g CO} = 0.248 \text{ g CO}$$
-
- 229. a.** Given: balanced equation; 1.2 kg Cl₂; actual yield NaClO = 0.90 kg
Unknown: percent yield
- $$\text{theoretical yield} = 1.2 \text{ kg Cl}_2 \times \frac{1 \text{ mol Cl}_2}{70.90 \text{ g Cl}_2} \times \frac{1 \text{ mol NaClO}}{1 \text{ mol Cl}_2}$$
- $$\times \frac{74.44 \text{ g NaClO}}{1 \text{ mol NaClO}} = 1.3 \text{ kg NaClO}$$
- $$\frac{0.90 \text{ kg}}{1.3 \text{ kg}} \times 100 = 69\%$$
- b.** Given: balanced equation;
91.8% yield;
25 metric tons actual yield NaClO
Unknown: metric tons Cl₂
- $$25 \text{ metric tons NaClO} \times \frac{100\%}{91.8\%} \times \frac{1 \text{ mol NaClO}}{65.46 \text{ g NaClO}} \times \frac{1 \text{ mol Cl}_2}{1 \text{ mol NaClO}}$$
- $$\times \frac{70.90 \text{ g Cl}_2}{1 \text{ mol Cl}_2} = 29 \text{ metric tons Cl}_2$$

c. Given: balanced equation;
81.8% yield;
1 mol Cl₂
Unknown: mass NaCl

$$1.00 \text{ mol Cl}_2 \times \frac{1 \text{ mol NaCl}}{1 \text{ mol Cl}_2} \times \frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} \times \frac{81.8\%}{100\%} = 47.8 \text{ g NaCl}$$

d. Given: balanced equation;
79.5% yield;
actual rate NaClO
370 kg/h
Unknown: rate NaOH in kg/h

$$\frac{370 \text{ kg NaClO}}{1 \text{ h}} \times \frac{100\%}{79.5\%} \times \frac{1 \text{ mol NaClO}}{65.46 \text{ g NaClO}} \times \frac{2 \text{ mol NaOH}}{1 \text{ mol NaClO}} \times \frac{40.00 \text{ g NaOH}}{1 \text{ mol NaOH}} = 568 \text{ kg NaOH/h}$$

230. b. Given: theoretical yield = 2.04 g;
actual yield = 1.79 g
Unknown: percent yield

$$\frac{1.79 \text{ g}}{2.04 \text{ g}} \times 100 = 87.7\% \text{ yield}$$

d. Given: balanced equation
from c; 0.097 mol Mg; 0.027 mol Mg₃N₂
Unknown: percent yield

$$\text{theoretical yield} = 0.097 \text{ mol Mg} \times \frac{1 \text{ mol Mg}_3\text{N}_2}{3 \text{ mol Mg}} = 0.032 \text{ mol Mg}_3\text{N}_2$$

$$\frac{0.027 \text{ mol}}{0.032 \text{ mol}} \times 100 = 84\% \text{ yield}$$

231. a. Given: balanced equation; 0.89 g C₃H₇OH;
actual yield C₂H₅COOH = 0.88 g
Unknown: percent yield

$$\text{theoretical yield} = 0.89 \text{ g C}_3\text{H}_7\text{OH} \times \frac{1 \text{ mol C}_3\text{H}_7\text{OH}}{60.11 \text{ g C}_3\text{H}_7\text{OH}} \times \frac{3 \text{ mol C}_2\text{H}_5\text{COOH}}{3 \text{ mol C}_3\text{H}_7\text{OH}} \times \frac{74.09 \text{ g C}_2\text{H}_5\text{COOH}}{1 \text{ mol C}_2\text{H}_5\text{COOH}} = 1.1 \text{ g C}_2\text{H}_5\text{COOH}$$

$$\frac{0.88 \text{ g}}{1.1 \text{ g}} \times 100 = 80.\% \text{ yield}$$

b. Given: balanced equation;
actual yield C₂H₅COOH = 1.50 mol;
136 g C₃H₇OH
Unknown: percent yield

$$\text{theoretical yield} = 136 \text{ g C}_3\text{H}_7\text{OH} \times \frac{1 \text{ mol C}_3\text{H}_7\text{OH}}{60.11 \text{ g C}_3\text{H}_7\text{OH}} \times \frac{3 \text{ mol C}_2\text{H}_5\text{COOH}}{3 \text{ mol C}_3\text{H}_7\text{OH}} = 2.26 \text{ mol C}_2\text{H}_5\text{COOH}$$

$$\frac{1.50 \text{ mol}}{2.26 \text{ mol}} \times 100 = 66.4\% \text{ yield}$$

c. Given: balanced equation; 116 g Na₂Cr₂O₇;
actual yield C₂H₅COOH = 28.1 g
Unknown: percent yield

$$\text{theoretical yield} = 116 \text{ g Na}_2\text{Cr}_2\text{O}_7 \times \frac{1 \text{ mol Na}_2\text{Cr}_2\text{O}_7}{261.98 \text{ g Na}_2\text{Cr}_2\text{O}_7} \times \frac{3 \text{ mol C}_2\text{H}_5\text{COOH}}{2 \text{ mol Na}_2\text{Cr}_2\text{O}_7} \times \frac{74.09 \text{ g C}_2\text{H}_5\text{COOH}}{1 \text{ mol C}_2\text{H}_5\text{COOH}} = 49.2 \text{ g C}_2\text{H}_5\text{COOH}$$

$$\frac{28.1 \text{ g}}{49.2 \text{ g}} \times 100 = 57.1\% \text{ yield}$$

232. Given: unbalanced equation; 850. g C₃H₆; 300. g NH₃; excess O₂; actual yield C₃H₃N = 850. g
Unknown: balanced equation; limiting reactant; percent yield

$$2\text{C}_3\text{H}_6(g) + 2\text{NH}_3(g) + 3\text{O}_2(g) \rightarrow 2\text{C}_3\text{H}_3\text{N}(g) + 6\text{H}_2\text{O}(g)$$

$$850. \text{ g C}_3\text{H}_6 \times \frac{1 \text{ mol C}_3\text{H}_6}{42.09 \text{ g C}_3\text{H}_6} \times \frac{2 \text{ mol NH}_3}{2 \text{ mol C}_3\text{H}_6} \times \frac{17.04 \text{ g NH}_3}{1 \text{ mol NH}_3} = 344 \text{ g NH}_3$$

300 g NH₃ available, 344 g NH₃ needed; NH₃ is limiting.

$$300. \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.04 \text{ g NH}_3} \times \frac{2 \text{ mol C}_3\text{H}_3\text{N}}{2 \text{ mol NH}_3} \times \frac{53.07 \text{ g C}_3\text{H}_3\text{N}}{1 \text{ mol C}_3\text{H}_3\text{N}}$$

$$= 934 \text{ g C}_3\text{H}_3\text{N}$$

$$\frac{850. \text{ g}}{934 \text{ g}} \times 100 = 91.0\% \text{ yield}$$

233. a. Given: 430 kg H₂; reactants and product
Unknown: balanced equation; mass CH₃OH

$$\text{CO} + 2\text{H}_2 \rightarrow \text{CH}_3\text{OH}$$

$$430. \text{ kg H}_2 \times \frac{1 \text{ mol H}_2}{2.02 \text{ g H}_2} \times \frac{1 \text{ mol CH}_3\text{OH}}{2 \text{ mol H}_2} \times \frac{32.05 \text{ g CH}_3\text{OH}}{1 \text{ mol CH}_3\text{OH}}$$

$$= 3.41 \times 10^3 \text{ kg CH}_3\text{OH}$$

b. Given: balanced equation and theoretical yield from **a**; actual yield CH₃OH = 3.12 × 10³ kg
Unknown: percent yield

$$\frac{3.12 \times 10^3 \text{ kg}}{3.41 \times 10^3 \text{ kg}} \times 100 = 91.5\% \text{ yield}$$

234. Given: balanced equation; 750. g C₆H₁₀O₄; actual yield C₆H₁₆N₂ = 578 g
Unknown: percent yield

$$750. \text{ g C}_6\text{H}_{10}\text{O}_4 \times \frac{1 \text{ mol C}_6\text{H}_{10}\text{O}_4}{146.16 \text{ g C}_6\text{H}_{10}\text{O}_4} \times \frac{1 \text{ mol C}_6\text{H}_{16}\text{N}_2}{1 \text{ mol C}_6\text{H}_{10}\text{O}_4}$$

$$\times \frac{116.24 \text{ g C}_6\text{H}_{16}\text{N}_2}{1 \text{ mol C}_6\text{H}_{16}\text{N}_2} = 596 \text{ g C}_6\text{H}_{16}\text{N}_2$$

$$\frac{578 \text{ g}}{596 \text{ g}} \times 100 = 97.0\% \text{ yield}$$

235. Given: unbalanced equation; 1.37 × 10⁴ g CO₂; 63.4% yield
Unknown: balanced equation; mass O₂

$$6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$

$$1.37 \times 10^4 \text{ g CO}_2 \times \frac{1 \text{ mol CO}_2}{44.01 \text{ g CO}_2} \times \frac{6 \text{ mol O}_2}{6 \text{ mol CO}_2} \times \frac{32.00 \text{ g O}_2}{1 \text{ mol O}_2}$$

$$= 9.96 \times 10^3 \text{ g O}_2$$

$$9.96 \times 10^3 \text{ g O}_2 \times \frac{63.4\%}{100\%} = 6.32 \times 10^3 \text{ g O}_2$$

236. Given: balanced equation; 2.67 × 10² mol Ca(OH)₂; 54.3% yield
Unknown: mass CaO in kg

$$2.67 \times 10^2 \text{ mol Ca(OH)}_2 \times \frac{100\%}{54.3\%} \times \frac{1 \text{ mol CaO}}{1 \text{ mol Ca(OH)}_2} \times \frac{56.08 \text{ g CaO}}{1 \text{ mol CaO}}$$

$$\times \frac{1 \text{ kg}}{1000 \text{ g}} = 27.6 \text{ kg}$$

- 237. a.** Given: $P_1 = 3.0 \text{ atm}$;
 $V_1 = 25 \text{ mL}$;
 $P_2 = 6.0 \text{ atm}$

$$V_2 = \frac{P_1 V_1}{P_2} = 3.0 \text{ atm} \times \frac{25 \text{ mL}}{6.0 \text{ atm}} = 13 \text{ mL}$$

Unknown: V_2

- b.** Given: $P_1 = 99.97 \text{ kPa}$;
 $V_1 = 550. \text{ mL}$;
 $V_2 = 275 \text{ mL}$

$$P_2 = \frac{P_1 V_1}{V_2} = \frac{99.97 \text{ kPa} \times 550. \text{ mL}}{275 \text{ mL}} = 200. \text{ kPa}$$

Unknown: P_2

- c.** Given: $P_1 = 0.89 \text{ atm}$;
 $P_2 = 3.56 \text{ atm}$;
 $V_2 = 20.0 \text{ L}$

$$V_1 = \frac{P_2 V_2}{P_1} = \frac{3.56 \text{ atm} \times 20.0 \text{ L}}{0.89 \text{ atm}} = 80. \text{ L}$$

Unknown: V_1

- d.** Given: $V_1 = 800. \text{ mL}$;
 $P_2 = 500. \text{ kPa}$;
 $V_2 = 160. \text{ mL}$

$$P_1 = \frac{P_2 V_2}{V_1} = \frac{500. \text{ kPa} \times 160. \text{ mL}}{800. \text{ mL}} = 100. \text{ kPa}$$

Unknown: P_1

- e.** Given: $P_1 = 0.040 \text{ atm}$;
 $P_2 = 250 \text{ atm}$;
 $V_2 = 1.0 \times 10^{-2} \text{ L}$

$$V_1 = \frac{P_2 V_2}{P_1} = \frac{250 \text{ atm} \times 1.0 \times 10^{-2} \text{ L}}{0.040 \text{ atm}} = 63 \text{ L}$$

Unknown: V_1

- 238.** Given: $P_1 = 1.8 \text{ atm}$;
 $V_1 = 2.8 \text{ L}$;
 $P_2 = 1.2 \text{ atm}$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{1.8 \text{ atm} \times 2.8 \text{ L}}{1.2 \text{ atm}} = 4.2 \text{ L}$$

Unknown: V_2

- 239.** Given: $P_1 = 99.3 \text{ kPa}$;
 $V_1 = 48.0 \text{ L}$;
 $V_2 = 16.0 \text{ L}$

$$P_2 = \frac{P_1 V_1}{V_2} = \frac{99.3 \text{ kPa} \times 48.0 \text{ L}}{16.0 \text{ L}} = 298 \text{ kPa}$$

Unknown: P_2

- 240.** Given: $P_1 = 0.989 \text{ atm}$;
 $V_1 = 59.0 \text{ mL}$;
 $P_2 = 0.967 \text{ atm}$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{0.989 \text{ atm} \times 59.0 \text{ mL}}{0.967 \text{ atm}} = 60.3 \text{ mL}$$

Unknown: V_2

- 241.** Given: $P_1 = 6.5 \text{ atm}$;
 $V_1 = 2.2 \text{ L}$;
 $P_2 = 1.15 \text{ atm}$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{6.5 \text{ atm} \times 2.2 \text{ L}}{1.15 \text{ atm}} = 12 \text{ L}$$

Unknown: V_2

242. a. Given: $V_1 = 40.0 \text{ mL}$;
 $T_1 = 280. \text{ K}$;
 $T_2 = 350. \text{ K}$

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{40.0 \text{ mL} \times 350 \text{ K}}{280. \text{ K}} = 50.0 \text{ mL}$$

Unknown: V_2

b. Given: $V_1 = 0.606 \text{ L}$;
 $T_1 = 300. \text{ K}$;
 $V_2 = 0.404 \text{ L}$

$$T_2 = \frac{V_2 T_1}{V_1} = \frac{0.404 \text{ L} \times 300. \text{ K}}{0.606 \text{ L}} = 200. \text{ K}$$

Unknown: T_2

c. Given: $T_1 = 292 \text{ K}$;
 $V_2 = 250. \text{ mL}$;
 $T_2 = 365 \text{ K}$

$$V_1 = \frac{V_2 T_1}{T_2} = \frac{250. \text{ mL} \times 292 \text{ K}}{365 \text{ K}} = 200. \text{ mL}$$

Unknown: V_1

d. Given: $V_1 = 100. \text{ mL}$;
 $V_2 = 125 \text{ mL}$;
 $T_2 = 305 \text{ K}$

$$T_1 = \frac{T_2 V_1}{V_2} = \frac{305 \text{ K} \times 100. \text{ mL}}{125 \text{ mL}} = 244 \text{ K}$$

Unknown: T_1

e. Given: $V_1 = 0.0024 \text{ L}$;
 $T_1 = 22^\circ\text{C}$;
 $T_2 = -14^\circ\text{C}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{0.0024 \text{ L} \times (273 - 14) \text{ K}}{(273 + 22) \text{ K}} = \frac{0.0024 \text{ L} \times 259 \text{ K}}{259 \text{ K}} = 0.0021 \text{ L}$$

Unknown: V_2

243. Given: $V_1 = 2.75 \text{ L}$; $T_1 = 18^\circ\text{C}$; $T_2 = 45^\circ\text{C}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{2.75 \text{ L} \times (273 + 45) \text{ K}}{(273 + 18) \text{ K}} = \frac{2.75 \text{ L} \times 318 \text{ K}}{291 \text{ K}} = 3.01 \text{ L}$$

Unknown: V_2

244. Given: $V_1 = 0.43 \text{ mL}$;
 $T_1 = 24^\circ\text{C}$; $V_2 = 0.57 \text{ mL}$; $\text{K} = 273 + ^\circ\text{C}$

$$T_2 = \frac{T_1 V_2}{V_1} = \frac{(273 + 24) \text{ K} \times 0.57 \text{ mL}}{0.43 \text{ mL}} = 394 \text{ K}$$

$$394 \text{ K} - 273 = 121^\circ\text{C}$$

Unknown: T_2

245. a. Given: $P_1 = 1.50 \text{ atm}$;
 $T_1 = 273 \text{ K}$;
 $T_2 = 410 \text{ K}$

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{1.50 \text{ atm} \times 410 \text{ K}}{273 \text{ K}} = 2.25 \text{ atm}$$

Unknown: P_2

b. Given: $P_1 = 0.208 \text{ atm}$;
 $T_1 = 300. \text{ K}$;
 $P_2 = 0.156 \text{ atm}$

$$T_2 = \frac{T_1 P_2}{P_1} = \frac{300. \text{ K} \times 0.156 \text{ atm}}{0.208 \text{ atm}} = 225 \text{ K}$$

Unknown: T_2

c. Given: $T_1 = 52^\circ\text{C}$;
 $P_2 = 99.7 \text{ kPa}$;
 $T_2 = 77^\circ\text{C}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$P_1 = \frac{P_2 T_1}{T_2} = \frac{99.7 \text{ kPa} \times (52 + 273) \text{ K}}{(77 + 273) \text{ K}} = \frac{99.7 \text{ kPa} \times 325 \text{ K}}{350. \text{ K}} = 92.6 \text{ kPa}$$

Unknown: P_1

d. Given: $P_1 = 5.20 \text{ atm}$;
 $P_2 = 4.16 \text{ atm}$;
 $T_2 = -13^\circ\text{C}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$T_1 = \frac{P_1 T_2}{P_2} = \frac{5.20 \text{ atm} \times (273 - 13) \text{ K}}{4.16 \text{ atm}} = \frac{5.20 \text{ atm} \times 260. \text{ K}}{4.16 \text{ atm}} = 325 \text{ K}$$

$$325 \text{ K} - 273 = 52^\circ\text{C}$$

Unknown: T_1

e. Given: $P_1 = 8.33 \times 10^{-4} \text{ atm}$;
 $T_1 = -84^\circ\text{C}$;
 $P_2 = 3.92 \times 10^{-3} \text{ atm}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$T_2 = \frac{T_1 P_2}{P_1} = \frac{(273 - 84) \text{ K} \times 3.92 \times 10^{-3} \text{ atm}}{8.33 \times 10^{-4} \text{ atm}} = \frac{189 \text{ K} \times 3.92 \times 10^{-3}}{8.33 \times 10^{-4}} = 889 \text{ K}$$

$$889 \text{ K} - 273 = 616^\circ\text{C}$$

Unknown: T_2

246. Given: $P_1 = 4.882 \text{ atm}$;
 $P_2 = 4.690 \text{ atm}$;
 $T_2 = 8^\circ\text{C}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$T_1 = \frac{P_1 T_2}{P_2} = \frac{4.882 \text{ atm} \times (273 + 8) \text{ K}}{4.690 \text{ atm}} = \frac{4.882 \text{ atm} \times 281 \text{ K}}{4.690 \text{ atm}} = 293 \text{ K}$$

$$293 \text{ K} - 273 = 20.^\circ\text{C}$$

Unknown: T_1

247. Given: $P_1 = 107 \text{ kPa}$;
 $T_1 = 22^\circ\text{C}$;
 $T_2 = 45^\circ\text{C}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{107 \text{ kPa} \times (273 + 45) \text{ K}}{(273 + 22) \text{ K}} = \frac{107 \text{ kPa} \times 318 \text{ K}}{295 \text{ K}} = 115 \text{ kPa}$$

Unknown: P_2

248. a. Given: $P_1 = 99.3 \text{ kPa}$;
 $V_1 = 225 \text{ mL}$;
 $T_1 = 15^\circ\text{C}$;
 $P_2 = 102.8 \text{ kPa}$;
 $T_2 = 24^\circ\text{C}$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{99.3 \text{ kPa} \times 225 \text{ mL} \times (273 + 24) \text{ K}}{(273 + 15) \text{ K} \times 102.8 \text{ kPa}} = 224 \text{ mL}$$

Unknown: V_2

b. Given: $P_1 = 0.959 \text{ atm}$;
 $V_1 = 3.50 \text{ L}$;
 $T_1 = 45^\circ\text{C}$;
 $V_2 = 3.70 \text{ L}$;
 $T_2 = 37^\circ\text{C}$

$$P_2 = \frac{P_1 V_1 T_2}{T_1 V_2} = \frac{0.959 \text{ atm} \times 3.50 \text{ L} \times (273 + 37) \text{ K}}{(273 + 45) \text{ K} \times 3.70 \text{ L}} = 0.884 \text{ atm}$$

Unknown: P_2

c. Given: $P_1 = 0.0036 \text{ atm}$;
 $V_1 = 62 \text{ mL}$;
 $T_1 = 373 \text{ K}$;
 $P_2 = 0.0029 \text{ atm}$;
 $V_2 = 64 \text{ mL}$

$$T_2 = \frac{T_1 P_2 V_2}{P_1 V_1} = \frac{373 \text{ K} \times 0.0029 \text{ atm} \times 64 \text{ mL}}{0.0036 \text{ atm} \times 62 \text{ mL}} = 310 \text{ K}$$

Unknown: T_2

d. Given: $P_1 = 100.$ kPa;
 $V_1 = 43.2$ mL;
 $T_1 = 19^\circ\text{C}$;
 $P_2 = 101.3$
 kPa; $T_2 = 0^\circ\text{C}$
 Unknown: V_2

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{100. \text{ kPa} \times 43.2 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 19) \text{ K} \times 101.3 \text{ kPa}} = 39.9 \text{ mL}$$

249. Given: $V_1 = 450.$ mL;
 $P_1 = 100.$ kPa;
 $T_1 = 17^\circ\text{C}$;
 $T_2 = 0^\circ\text{C}$;
 $P_2 = 101.3$ kPa
 Unknown: V_2

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{100. \text{ kPa} \times 450. \text{ mL} \times (273 + 0) \text{ K}}{(273 + 17) \text{ K} \times 101.3 \text{ kPa}} = 418 \text{ mL}$$

250. Given: $T = 27^\circ\text{C}$; H_2S
 gas; $P_T = 207.33$
 kPa; $V = 15$ mL
 Unknown: $P_{\text{H}_2\text{O}}$; $P_{\text{H}_2\text{S}}$

Per Table A-8: $P_{\text{H}_2\text{O}} = 3.57$ kPa
 $P_{\text{H}_2\text{S}} = P_T - P_{\text{H}_2\text{O}} = 207.33 \text{ kPa} - 3.57 \text{ kPa} = 203.76 \text{ kPa}$

251. Given: $T = 10^\circ\text{C}$;
 $P_T = 105.5$ kPa;
 $V = 1.93$ L;
 $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$
 Unknown: V_{H_2} at STP

Per Table A-8: $P_{\text{H}_2\text{O}} = 1.23$ kPa
 $P_{\text{H}_2} = P_T - P_{\text{H}_2\text{O}} = 105.5 \text{ kPa} - 1.23 \text{ kPa} = 104.3 \text{ kPa}$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{104.3 \text{ kPa} \times 1.93 \text{ L} \times (273 + 0) \text{ K}}{(273 + 10) \text{ K} \times 101.3 \text{ kPa}} = 1.92 \text{ L}$$

252. Given: $V_1 = 338$ mL
 CH_4 at $T_1 =$
 19°C , $P_1 =$
 0.9566 atm;
 $T_2 = 26^\circ\text{C}$,
 $P_2 = 0.989$
 Unknown: V_2 of CH_4

$P_{I(\text{H}_2\text{O})} = 2.19$ kPa; $P_{2(\text{H}_2\text{O})} = 3.36$ kPa

$$P_{I(\text{CH}_4)} = 0.9566 \text{ atm} - \left(2.19 \text{ kPa} \times \frac{1 \text{ atm}}{101.3 \text{ kPa}} \right) = 0.935 \text{ atm}$$

$$P_{2(\text{CH}_4)} = 0.989 \text{ atm} - \left(3.36 \text{ kPa} \times \frac{1 \text{ atm}}{101.3 \text{ kPa}} \right) = 0.956 \text{ atm}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{0.935 \text{ atm} \times 338 \text{ mL} \times (273 + 26) \text{ K}}{(273 + 19) \text{ K} \times 0.956 \text{ atm}} = 339 \text{ mL}$$

 $V_2 > V_1$; Student 2 collected more.

253. T is constant; $P_1 V_1 =$
 $P_2 V_2$
 a. Given: $P_1 = 127.3$ kPa;
 $V_1 = 796 \text{ cm}^3$;
 $V_2 = 965 \text{ cm}^3$
 Unknown: P_2

$$P_2 = \frac{P_1 V_1}{V_2} = \frac{127.3 \text{ kPa} \times 796 \text{ cm}^3}{965 \text{ cm}^3} = 105 \text{ kPa}$$

b. Given: $P_1 = 7.1 \times 10^2 \text{ atm}$; $V_1 = \frac{P_2 V_2}{P_1} = \frac{9.6 \times 10^{-1} \text{ atm} \times 3.7 \times 10^3 \text{ mL}}{7.1 \times 10^2 \text{ atm}} = 5.0 \text{ mL}$
 $P_2 = 9.6 \times 10^{-1} \text{ atm}$;
 $V_2 = 3.7 \times 10^3 \text{ mL}$

Unknown: V_1

c. Given: $V_1 = 1.77 \text{ L}$; $P_1 = \frac{P_2 V_2}{V_1} = \frac{30.79 \text{ kPa} \times 2.44 \text{ L}}{1.77 \text{ L}} = 42.4 \text{ kPa}$
 $P_2 = 30.79 \text{ kPa}$;
 $V_2 = 2.44 \text{ L}$

Unknown: P_1

d. Given: $P_1 = 114 \text{ kPa}$; $V_2 = \frac{P_1 V_1}{P_2} = \frac{114 \text{ kPa} \times 2.93 \text{ dm}^3}{4.93 \times 10^4 \text{ kPa}} = 6.78 \times 10^{-3} \text{ dm}^3$
 $V_1 = 2.93 \text{ dm}^3$;
 $P_2 = 4.93 \times 10^4 \text{ kPa}$

Unknown: V_2

e. Given: $P_1 = 1.00 \text{ atm}$; $P_2 = \frac{P_1 V_1}{V_2} = \frac{1.00 \text{ atm} \times 120. \text{ mL}}{97.0 \text{ mL}} = 1.24 \text{ atm}$
 $V_1 = 120. \text{ mL}$;
 $V_2 = 97.0 \text{ mL}$

Unknown: P_2

f. Given: $P_1 = 0.77 \text{ atm}$; $V_2 = \frac{P_1 V_1}{P_2} = \frac{0.77 \text{ atm} \times 3.6 \text{ m}^3}{1.90 \text{ atm}} = 1.5 \text{ m}^3$
 $V_1 = 3.6 \text{ m}^3$;
 $P_2 = 1.90 \text{ atm}$

Unknown: V_2

254. Given: $V_1 = 0.722 \text{ m}^3$; $V_2 = \frac{P_1 V_1}{P_2} = \frac{10.6 \text{ atm} \times 0.722 \text{ m}^3}{0.96 \text{ atm}} = 8.0 \text{ m}^3$
 $P_1 = 10.6 \text{ atm}$;
 $P_2 = 0.96 \text{ atm}$;
 $P_1 V_1 = P_2 V_2$

Unknown: V_2

255. Given: $V_1 = 7.50 \times 10^3 \text{ L}$; $P_1 = \frac{P_2 V_2}{V_1} = \frac{0.993 \text{ atm} \times 195 \text{ L}}{7.50 \times 10^3 \text{ L}} = 0.0258 \text{ atm}$
 $V_2 = 195 \text{ L}$;
 $P_2 = 0.993 \text{ atm}$;
 $P_1 V_1 = P_2 V_2$

Unknown: P_1

256. Given: $V_1 = 5.70 \times 10^{-1} \text{ dm}^3$; $V_2 = \frac{P_1 V_1}{P_2} = \frac{1.05 \text{ atm} \times 5.70 \times 10^{-1} \text{ dm}^3}{7.47 \text{ atm}} = 8.01 \times 10^{-2} \text{ dm}^3$
 $P_1 = 1.05 \text{ atm}$;
 $P_2 = 7.47 \text{ atm}$;
 $P_1 V_1 = P_2 V_2$

Unknown: V_2

257. P is constant; $\frac{V_1}{T_1} = \frac{V_2}{T_2}$;

$$K = 273 + ^\circ\text{C}$$

a. Given: $V_1 = 26.5 \text{ mL}$;
 $V_2 = 32.9 \text{ mL}$;
 $T_2 = 290. \text{ K}$

$$T_1 = \frac{T_2 V_1}{V_2} = \frac{290. \text{ K} \times 26.5 \text{ mL}}{32.9 \text{ mL}} = 234 \text{ K}$$

Unknown: T_1

b. Given: $T_1 = 100^\circ\text{C}$;
 $V_2 = 0.83 \text{ dm}^3$;
 $T_2 = 29^\circ\text{C}$

$$V_1 = \frac{T_1 V_2}{T_2} = \frac{(273 + 100) \text{ K} \times 0.83 \text{ dm}^3}{(273 + 29) \text{ K}} = 1.0 \text{ dm}^3$$

Unknown: V_1

c. Given: $V_1 = 7.44 \times 10^4 \text{ mm}^3$;
 $T_1 = 870^\circ\text{C}$;
 $V_2 = 2.59 \times 10^2 \text{ mm}^3$

$$T_2 = \frac{T_1 V_2}{V_1} = \frac{(870. + 273) \text{ K} \times 2.59 \times 10^2 \text{ mm}^3}{7.44 \times 10^4 \text{ mm}^3} = 3.98 \text{ K}$$
$$3.98 \text{ K} - 273.15 = -269.17^\circ\text{C}$$

Unknown: T_2 in $^\circ\text{C}$

d. Given: $V_1 = 5.63 \times 10^{-2} \text{ L}$;
 $T_1 = 132 \text{ K}$;
 $T_2 = 190. \text{ K}$

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{5.63 \times 10^{-2} \text{ L} \times 190. \text{ K}}{132 \text{ K}} = 8.10 \times 10^{-2} \text{ L}$$

Unknown: V_2

e. Given: $T_1 = 243 \text{ K}$;
 $V_2 = 819 \text{ cm}^3$;
 $T_2 = 409 \text{ K}$

$$V_1 = \frac{V_2 T_1}{T_2} = \frac{819 \text{ cm}^3 \times 243 \text{ K}}{409 \text{ K}} = 487 \text{ cm}^3$$

Unknown: V_1

f. Given: $V_1 = 679 \text{ m}^3$;
 $T_1 = -3^\circ\text{C}$;
 $T_2 = -246^\circ\text{C}$

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{679 \text{ m}^3 \times (273 - 246) \text{ K}}{(273 - 3) \text{ K}} = 67.9 \text{ m}^3$$

Unknown: V_2

258. Given: $V_1 = 1.15 \text{ cm}^3$;
 $T_1 = 22^\circ\text{C}$;
 $T_2 = 99^\circ\text{C}$;
 $\frac{V_1}{T_1} = \frac{V_2}{T_2}$;
 $K = 273 + ^\circ\text{C}$

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{1.15 \text{ cm}^3 \times (273 + 99) \text{ K}}{(273 + 22) \text{ K}} = 1.45 \text{ cm}^3$$

Unknown: V_2

259. Given: $V_1 = 6.75 \text{ dm}^3$;
 $T_1 = 40.^\circ\text{C}$;
 $V_2 = 5.03 \text{ dm}^3$;
 $\frac{V_1}{T_1} = \frac{V_2}{T_2}$;
 $K = 273 + ^\circ\text{C}$

$$T_2 = \frac{V_2 T_1}{V_1} = \frac{5.03 \text{ dm}^3 \times (273 + 40.) \text{ K}}{6.75 \text{ dm}^3} = 233 \text{ K}$$
$$233 \text{ K} - 273 = -40.^\circ\text{C}$$

Unknown: T_2

- 260.** V is constant;
 $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
 $K = 273 + ^\circ\text{C}$
a. Given: $P_1 = 0.777$
 atm;
 $P_2 = 5.6$ atm;
 $T_2 = 192^\circ\text{C}$
 Unknown: T_1 in $^\circ\text{C}$

$$T_1 = \frac{T_2 P_1}{P_2} = \frac{(273 + 192) \text{ K} \times 0.777 \text{ atm}}{5.6 \text{ atm}} = 64.5 \text{ K}$$

$$64.5 \text{ K} - 273 = -208^\circ\text{C}$$
- b.** Given: $P_1 = 152$ kPa;
 $T_1 = 302$ K;
 $T_2 = 11$ K
 Unknown: P_2

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{152 \text{ kPa} \times 11 \text{ K}}{302 \text{ K}} = 5.5 \text{ kPa}$$
- c.** Given: $T_1 = -76^\circ\text{C}$;
 $P_2 = 3.97$ atm;
 $T_2 = 27^\circ\text{C}$
 Unknown: P_1

$$P_1 = \frac{P_2 T_1}{T_2} = \frac{3.97 \text{ atm} \times (273 - 76) \text{ K}}{(273 + 27) \text{ K}} = 2.61 \text{ atm}$$
- d.** Given: $P_1 = 395$ atm;
 $T_1 = 46^\circ\text{C}$;
 $P_2 = 706$ atm
 Unknown: T_2 in $^\circ\text{C}$

$$T_2 = \frac{T_1 P_2}{P_1} = \frac{(273 + 46) \text{ K} \times 706 \text{ atm}}{395 \text{ atm}} = 570. \text{ K}$$

$$570. \text{ K} - 273 = 297^\circ\text{C}$$
- e.** Given: $T_1 = -37^\circ\text{C}$;
 $P_2 = 350.$ atm;
 $T_2 = 2050^\circ\text{C}$
 Unknown: P_1

$$P_1 = \frac{P_2 T_1}{T_2} = \frac{350. \text{ atm} \times (273 - 37) \text{ K}}{(273 + 2050) \text{ K}} = 35.6 \text{ atm}$$
- f.** Given: $P_1 = 0.39$ atm;
 $T_1 = 263$ K;
 $P_2 = 0.058$
 atm
 Unknown: T_2

$$T_2 = \frac{T_1 P_2}{P_1} = \frac{263 \text{ K} \times 0.058 \text{ atm}}{0.39 \text{ atm}} = 39 \text{ K}$$

- 261.** Given: $T_1 = 22^\circ\text{C}$;
 $P_1 = 0.982$ atm;
 $T_2 = -3^\circ\text{C}$;
 $\frac{P_1}{T_1} = \frac{P_2}{T_2}$;
 $K = 273 + ^\circ\text{C}$
 Unknown: P_2

$$P_2 = \frac{T_2 P_1}{T_1} = \frac{(273 - 3) \text{ K} \times 0.982 \text{ atm}}{(273 + 22) \text{ K}} = 0.899 \text{ atm}$$

- 262.** Given: $P_1 = 2.50$ atm;
 $T_1 = 33^\circ\text{C}$;
 $T_2 = 0^\circ\text{C}$;
 $\frac{P_1}{T_1} = \frac{P_2}{T_2}$;
 $K = 273 + ^\circ\text{C}$
 Unknown: P_2

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{2.50 \text{ atm} \times (273 + 0) \text{ K}}{(273 + 33) \text{ K}} = 2.23 \text{ atm}$$

- 263.** Given: $P_1 = 127.5$ kPa;
 $T_1 = 290.$ K;
 $P_2 = 3.51$ kPa;
 $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
 Unknown: T_2

$$T_2 = \frac{T_1 P_2}{P_1} = \frac{290. \text{ K} \times 3.51 \text{ kPa}}{127.5 \text{ kPa}} = 7.98 \text{ K}$$

$$264. \frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2}; \quad K = 273 + ^\circ C; \quad V_2 = \frac{V_1 P_1 T_2}{T_1 P_2} = \frac{1.65 \text{ L} \times 1.03 \text{ atm} \times (273 + 46) \text{ K}}{(273 + 19) \text{ K} \times 0.920 \text{ atm}} = 2.02 \text{ L}$$

- a. Given: $P_1 = 1.03 \text{ atm}$;
 $V_1 = 1.65 \text{ L}$;
 $T_1 = 19^\circ \text{C}$;
 $P_2 = 0.920 \text{ atm}$;
 $T_2 = 46^\circ \text{C}$

Unknown: V_2

- b. Given: $P_1 = 107.0 \text{ kPa}$;
 $V_1 = 3.79 \text{ dm}^3$;
 $T_1 = 73^\circ \text{C}$;
 $V_2 = 7.58 \text{ dm}^3$;
 $T_2 = 217^\circ \text{C}$

Unknown: P_2

- c. Given: $P_1 = 0.029 \text{ atm}$;
 $V_1 = 249 \text{ mL}$;
 $P_2 = 0.098 \text{ atm}$;
 $V_2 = 197 \text{ mL}$;
 $T_2 = 293 \text{ K}$

Unknown: T_1

- d. Given: $P_1 = 113 \text{ kPa}$;
 $T_1 = 12^\circ \text{C}$;
 $P_2 = 149 \text{ kPa}$;
 $V_2 = 3.18 \times 10^3 \text{ mm}^3$;
 $T_2 = -18^\circ \text{C}$

Unknown: V_1

- e. Given: $P_1 = 1.15 \text{ atm}$;
 $V_1 = 0.93 \text{ m}^3$;
 $T_1 = -22^\circ \text{C}$;
 $P_2 = 1.01 \text{ atm}$;
 $V_2 = 0.85 \text{ m}^3$

Unknown: T_2

- f. Given: $V_1 = 156 \text{ cm}^3$;
 $T_1 = 195 \text{ K}$;
 $P_2 = 2.25 \text{ atm}$;
 $V_2 = 468 \text{ cm}^3$;
 $T_2 = 585 \text{ K}$

Unknown: P_1

$$265. \text{ Given: } \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}; \quad K = 273 + ^\circ C; \quad V_2 = \frac{V_1 P_1 T_2}{T_1 P_2} = \frac{392 \text{ cm}^3 \times 0.987 \text{ atm} \times (273 + 13) \text{ K}}{(273 + 21) \text{ K} \times 0.992 \text{ atm}} = 379 \text{ cm}^3$$

$K = 273 + ^\circ C$;
 $V_1 = 392 \text{ cm}^3$;
 $P_1 = 0.987 \text{ atm}$;
 $T_1 = 21^\circ \text{C}$;
 $T_2 = 13^\circ \text{C}$;
 $P_2 = 0.992 \text{ atm}$

Unknown: V_2

- 266.** Given: $P_T = 0.989 \text{ atm}$;
 $T = 17^\circ\text{C}$
 Unknown: P_{H_2}
- from Table A-8: $P_{\text{H}_2\text{O}} = 1.94 \text{ kPa} \times \frac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.0192 \text{ atm}$
- $P_{\text{H}_2} = P_T - P_{\text{H}_2\text{O}} = 0.989 \text{ atm} - 0.0192 \text{ atm} = 0.970 \text{ atm}$ or 98.3 kPa

- 267.** Given: $P_1 = 1.77 \text{ atm}$;
 $V_1 = 1.00 \text{ L}$;
 $V_2 = 1.50 \text{ L}$;
 $P_2 = 0.487 \text{ atm}$;
 $P_1V_1 = P_2V_2$
 Unknown: equalized
 P in V_T
- $V_T = V_1 + V_2 = 1.00 \text{ L} + 1.50 \text{ L} = 2.50 \text{ L}$
- $\frac{P_1V_1}{V_T} = \frac{1.77 \text{ atm} \times 1.00 \text{ L}}{2.50 \text{ L}} = 0.708 \text{ atm}$
- $\frac{P_2V_2}{V_T} = \frac{0.487 \text{ atm} \times 1.50 \text{ L}}{2.50 \text{ L}} = 0.292 \text{ atm}$
- $P_T = 0.708 \text{ atm} + 0.292 \text{ atm} = 1.00 \text{ atm}$

- 268.** Given: $T_1 = 10.^\circ\text{C}$;
 $P_T = 1.02 \text{ atm}$;
 $V_1 = 293 \text{ mL}$;
 $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$;
 $P_2 = 1.00 \text{ atm}$;
 $T_2 = 0^\circ\text{C}$;
 $\text{K} = 273$
 Unknown: V_{O_2} at STP
 (V_2)
- From Table A-8: $P_{\text{H}_2\text{O}} = 1.23 \text{ kPa} \times \frac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.0121 \text{ atm}$
- $P_{\text{O}_2} = P_T - P_{\text{H}_2\text{O}} = 1.02 \text{ atm} - 0.0121 \text{ atm} = 1.01 \text{ atm} = P_1$
- $V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.01 \text{ atm} \times 293 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 10) \text{ K} \times 1.00 \text{ atm}} = 285 \text{ mL}$

- 269.** Given: $P_1 = 101.3 \text{ kPa}$;
 $T_1 = 20^\circ\text{C}$;
 $V_1 = 325 \text{ cm}^3$;
 $P_2 = 76.24 \text{ kPa}$;
 $T_2 = 10^\circ\text{C}$;
 gases are air
 over water;
 $\text{K} = 273 + ^\circ\text{C}$;
 $P_T = P_{\text{air}} + P_{\text{H}_2\text{O}}$;
 $P_{\text{H}_2\text{O}(20^\circ\text{C})} = 2.34 \text{ kPa}$;
 $P_{\text{H}_2\text{O}(10^\circ\text{C})} = 1.23 \text{ kPa}$
 Unknown: V_2 ; V of
 water lost
- $P_{A_1} = P_1 - P_{\text{H}_2\text{O}(20^\circ\text{C})} = 101.3 \text{ kPa} - 2.34 \text{ kPa} = 99.0 \text{ kPa}$
- In sealed bottle on mountain: $P_{A_2} = P_{A_1} + P_{\text{H}_2\text{O}(10^\circ\text{C})}$
- $= 99.0 \text{ kPa} + 1.23 \text{ kPa} = 100.2 \text{ kPa}$
- $V_2 = \frac{P_{A_2}V_1T_2}{T_1P_2} = \frac{100.2 \text{ kPa} \times 325 \text{ cm}^3 \times (273 + 10) \text{ K}}{(273 + 20) \text{ K} \times 76.24 \text{ kPa}} = 413 \text{ cm}^3$
- $V_{\text{H}_2\text{O}} = 413 \text{ cm}^3 - 325 \text{ cm}^3 = 88 \text{ cm}^3 \text{ H}_2\text{O}$

- 270.** Given: 1°C change in
 T produces a
 change of
 0.20 cm^3 in V ;
 $\frac{V_1}{T_1} = \frac{V_2}{T_2}$;
 $\text{K} = 273 + ^\circ\text{C}$
 Unknown: V at $20.^\circ\text{C}$
- $\frac{V}{(273 + 20) \text{ K}} = \frac{V + 0.20 \text{ cm}^3}{(273 + 21) \text{ K}}$
- $294 V = 293 V + 293 \times 0.20 \text{ cm}^3$
- $V = 59 \text{ cm}^3$

- 271.** Given: $V_1 = 62.25 \text{ mL}$;
 $T = 22^\circ\text{C}$;
 $P_T = 97.7 \text{ kPa}$;
 $V_2 = 50.00 \text{ mL}$;
 $P_{\text{H}_2\text{O}} = 2.64 \text{ kPa}$
 Unknown: P_2
- $P_{\text{N}_2} = P_T - P_{\text{H}_2\text{O}} = 97.7 \text{ kPa} - 2.64 \text{ kPa} = 95.1 \text{ kPa}$
- $P_2 = \frac{P_{\text{N}_2}V_1}{V_2} = \frac{95.1 \text{ kPa} \times 62.25 \text{ mL}}{50.00 \text{ mL}} = 118 \text{ kPa}$

272. Given: $V_1 = 844 \text{ mL}$;
 $T_1 = 0.00^\circ\text{C}$;
 $P_1 = 1.000 \text{ atm}$;
 $P_T = 1.017 \text{ atm}$;
 $P_{\text{H}_2\text{O}} = 3.17 \text{ kPa}$;
 $T_2 = 25^\circ\text{C}$;
 $P_T = 1.017 \text{ atm}$;
 $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$P_2 = P_{\text{NF}_3} = P_T - P_{\text{H}_2\text{O}} = 1.017 \text{ atm} - 3.17 \text{ kPa} \left(\frac{1 \text{ atm}}{101.3 \text{ kPa}} \right) = 0.9857 \text{ atm}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.000 \text{ atm} \times 844 \text{ mL} \times (273 + 25) \text{ K}}{(273 + 0) \text{ K} \times 0.9857 \text{ atm}} = 935 \text{ mL}$$

Unknown: V_2 ; V_T at
 25°C and
 1.017 atm

273. Given: $V_1 = 2.94 \text{ kL}$;
 $P_1 = 1.06 \text{ atm}$;
 $T_1 = 32^\circ\text{C}$;
 $P_2 = 0.092 \text{ atm}$;
 $T_2 = -35^\circ\text{C}$;
 $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.06 \text{ atm} \times 2.94 \text{ kL} \times (273 - 35) \text{ K}}{(273 + 32) \text{ K} \times 0.092 \text{ atm}} = 26.4 \text{ kL}$$

Unknown: V_2

274. Given: $P_1 = 2.96 \text{ atm}$;
 $T_1 = 17^\circ\text{C}$;
 $T_2 = 95^\circ\text{C}$;
 $\frac{P_1}{T_1} = \frac{P_2}{T_2}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{2.96 \text{ atm} \times (273 + 95) \text{ K}}{(273 + 17) \text{ K}} = 3.76 \text{ atm}$$

Unknown: P_2

275. Given: $T_1 = 39^\circ\text{C}$;
 $V_2 = 108 \text{ mL}$;
 $T_2 = 21^\circ\text{C}$;
 $\frac{V_1}{T_1} = \frac{V_2}{T_2}$;
 $\text{K} = 273 + ^\circ\text{C}$

$$V_1 = \frac{V_2 T_1}{T_2} = \frac{108 \text{ mL} \times (273 + 39) \text{ K}}{(273 + 21) \text{ K}} = 115 \text{ mL}$$

Unknown: V_1

276. Given: $V_1 = 624 \text{ L}$;
 $P_1 = 1.40 \text{ atm}$;
 $V_2 = 80.0 \text{ L}$;
 $P_1 V_1 = P_2 V_2$

$$P_2 = \frac{P_1 V_1}{V_2} = \frac{1.40 \text{ atm} \times 624 \text{ L}}{80.0 \text{ L}} = 10.9 \text{ atm}$$

Unknown: P_2

277. a. Given: $P = 1.09 \text{ atm}$;
 $n = 0.0881 \text{ mol}$;
 $T = 302 \text{ K}$

$$V = \frac{nRT}{P} = \frac{0.0881 \text{ mol} \cdot 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times 302 \text{ K}}{1.09 \text{ atm}} = 2.00 \text{ L}$$

Unknown: V in L

b. Given: $P = 94.9 \text{ kPa}$;
 $V = 0.0350 \text{ L}$;
 $T = 55^\circ\text{C}$

$$n = \frac{PV}{RT} = \frac{94.9 \text{ kPa} \times 0.0350 \text{ L}}{8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 55) \text{ K}} = 1.22 \times 10^{-3} \text{ mol}$$

Unknown: n

c. Given: $V = 15.7 \text{ L}$;
 $n = 0.815 \text{ mol}$;
 $T = -20.^{\circ}\text{C}$
 Unknown: P in kPa

$$P = \frac{nRT}{V} = \frac{0.815 \text{ mol} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 - 20) \text{ K}}{15.7 \text{ L}} = 109 \text{ kPa}$$

d. Given: $P = 0.500 \text{ atm}$;
 $V = 629 \text{ mL}$;
 $n = 0.0337 \text{ mol}$
 Unknown: T in K

$$T = \frac{PV}{nR} = \frac{0.500 \text{ atm} \times 629 \text{ mL} \times 1 \text{ L}}{0.0337 \text{ mol} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times 1000 \text{ mL}} = 114 \text{ K}$$

e. Given: $P = 0.950 \text{ atm}$;
 $n = 0.0818 \text{ mol}$;
 $T = 19^{\circ}\text{C}$
 Unknown: V in L

$$V = \frac{nRT}{P} = \frac{0.0818 \text{ mol} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 19) \text{ K}}{0.950 \text{ atm}} = 2.06 \text{ L}$$

f. Given: $P = 107 \text{ kPa}$;
 $V = 39.0 \text{ mL}$;
 $T = 27^{\circ}\text{C}$
 Unknown: n

$$n = \frac{PV}{RT} = \frac{107 \text{ kPa} \times 39.0 \text{ mL} \times 1 \text{ L}}{8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 27) \text{ K} \times 1000 \text{ mL}} = 1.67 \times 10^{-3} \text{ mol}$$

278. Given: $V = 425 \text{ mL}$;
 $T = 24^{\circ}\text{C}$;
 $P = 0.899 \text{ atm}$
 Unknown: n

$$n = \frac{PV}{RT} = \frac{0.899 \text{ atm} \times 425 \text{ mL} \times 1 \text{ L}}{0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 24) \text{ K} \times 1000 \text{ mL}} = 1.57 \times 10^{-2} \text{ mol}$$

279. Given: $m = 0.116 \text{ g}$;
 $V = 25.0 \text{ mL}$;
 $T = 127^{\circ}\text{C}$;
 $P = 155.3 \text{ kPa}$;
 $PV = \frac{mRT}{M}$
 Unknown: M

$$M = \frac{mRT}{PV} = \frac{0.116 \text{ g} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 127) \text{ K} \times 1000 \text{ mL}}{155.3 \text{ kPa} \times 25.0 \text{ mL} \times 1 \text{ L}} = 99.4 \text{ g/mol}$$

280. Given: CO_2 gas;
 $V = 7.10 \text{ L}$;
 $P = 1.11 \text{ atm}$;
 $T = 31^{\circ}\text{C}$;
 $PV = \frac{mRT}{M}$
 Unknown: m

$$M = 1 \text{ atom C} \times 12.01 \text{ amu/atom} + 2 \text{ atoms O} \times 16.00 \text{ amu/atom} = 44.01 \text{ amu}; M = 44.01 \text{ g/mol}$$

$$m = \frac{MPV}{RT} = \frac{44.01 \text{ g/mol} \times 1.11 \text{ atm} \times 7.10 \text{ L}}{0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 31) \text{ K}} = 13.9 \text{ g}$$

281. Given: $T = 72^{\circ}\text{C}$;
 $P = 144.5 \text{ kPa}$;
 SiF_4 gas;
 $D = \frac{MP}{RT}$
 Unknown: D

$$D = \frac{MP}{RT} = \frac{104.09 \text{ g/mol} \times 144.5 \text{ kPa}}{8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 72) \text{ K}} = 5.24 \text{ g/L}$$

282. Given: $D = 1.13 \text{ g/L}$;
 $P = 1.09 \text{ atm}$;
 N_2 gas;
 $D = \frac{MP}{RT}$
 Unknown: T

$$T = \frac{MP}{DR} = \frac{28.02 \text{ g/mol} \times 1.09 \text{ atm}}{1.13 \text{ g/L} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}} = 329 \text{ K}$$

283. a. Given: $P = 0.0477 \text{ atm}$;
 $V = 15\,200 \text{ L}$;
 $T = -15^\circ\text{C}$

$$n = \frac{PV}{RT} = \frac{0.0477 \text{ atm} \times 15\,200 \text{ L}}{0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 - 15) \text{ K}} = 34.2 \text{ mol}$$

Unknown: n

b. Given: $V = 0.119 \text{ mL}$;
 $n = 0.000\,350 \text{ mol}$;
 $T = 0^\circ\text{C}$

$$P = \frac{nRT}{V} = \frac{0.000\,350 \text{ mol} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 0) \text{ K} \times 1000 \text{ mL}}{0.119 \text{ mL} \times 1 \text{ L}} = 6.68 \times 10^3 \text{ kPa}$$

Unknown: P in kPa

c. Given: $P = 500.0 \text{ kPa}$;
 $V = 250. \text{ mL}$;
 $n = 0.120 \text{ mol}$

$$T = \frac{PV}{nR} = \frac{500.0 \text{ kPa} \times 250. \text{ mL} \times 1 \text{ L}}{0.120 \text{ mol} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times 1000 \text{ mL}} = 125 \text{ K}$$

Unknown: T in $^\circ\text{C}$

$$125 \text{ K} - 273 = -148^\circ\text{C}$$

d. Given: $P = 19.5 \text{ atm}$;
 $n = 4.7 \times 10^4 \text{ mol}$;
 $T = 300.^\circ\text{C}$

$$V = \frac{nRT}{P} = \frac{4.7 \times 10^4 \text{ mol} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 300) \text{ K}}{19.5 \text{ atm}} = 1.1 \times 10^5 \text{ L}$$

Unknown: V

284. Given: $PV = \frac{mRT}{M}$

$$M = \frac{mRT}{PV} = \frac{8.23 \text{ g} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 25) \text{ K}}{0.955 \text{ atm} \times 3.77 \text{ L}} = 55.9 \text{ g/mol}$$

a. Given: $P = 0.955 \text{ atm}$;
 $V = 3.77 \text{ L}$;
 $m = 8.23 \text{ g}$;
 $T = 25^\circ\text{C}$

Unknown: M

b. Given: $P = 105.0 \text{ kPa}$;
 $V = 50.0 \text{ mL}$;
 $M = 48.02 \text{ g/mol}$;
 $T = 0^\circ\text{C}$

$$m = \frac{PVM}{RT} = \frac{105.0 \text{ kPa} \times 50.0 \text{ mL} \times 48.02 \text{ g/mol} \times 1 \text{ L}}{8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 0) \text{ K} \times 1000 \text{ mL}} = 0.111 \text{ g}$$

Unknown: m

c. Given: $P = 0.782 \text{ atm}$;
 $m = 3.20 \times 10^{-3} \text{ g}$;
 $M = 2.02 \text{ g/mol}$;
 $T = -5^\circ\text{C}$

$$V = \frac{mRT}{PM} = \frac{3.20 \times 10^{-3} \text{ g} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 - 5) \text{ K}}{0.782 \text{ atm} \times 2.02 \text{ g/mol}} = 4.46 \times 10^{-2} \text{ L}$$

Unknown: V in L

d. Given: $V = 2.00 \text{ L}$;
 $m = 7.19 \text{ g}$;
 $M = 159.8 \text{ g/mol}$;
 $T = 185^\circ\text{C}$

$$P = \frac{mRT}{MV} = \frac{7.19 \text{ g} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 185) \text{ K}}{159.8 \text{ g/mol} \times 2.00 \text{ L}} = 0.846 \text{ atm}$$

Unknown: P in atm

e. Given: $P = 107.2 \text{ kPa}$;
 $V = 26.1 \text{ mL}$;
 $m = 0.414 \text{ g}$;
 $T = 45^\circ\text{C}$

$$M = \frac{mRT}{PV} = \frac{0.414 \text{ g} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 45) \text{ K} \times 1000 \text{ mL}}{107.2 \text{ kPa} \times 26.1 \text{ mL} \times 1 \text{ L}} = 391 \text{ g/mol}$$

Unknown: M

285. Given: $n = 1.00 \text{ mol}$;
 $T = 25^\circ\text{C}$;
 $P = 0.915 \text{ kPa}$

$$V = \frac{nRT}{P} = \frac{1.00 \text{ mol} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 25) \text{ K}}{0.915 \text{ kPa}} = 2.71 \times 10^3 \text{ L}$$

Unknown: V

286. $D = \frac{MP}{RT}$

a. Given: $P = 1.12 \text{ atm}$;
 $D = 2.40 \text{ g/L}$;
 $T = 2^\circ\text{C}$

$$M = \frac{DRT}{P} = \frac{2.40 \text{ g/L} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 2) \text{ K}}{1.12 \text{ atm}} = 48.4 \text{ g/mol}$$

Unknown: M

b. Given: $P = 7.50 \text{ atm}$;
 $M = 30.07 \text{ g/mol}$;
 $T = 20.^\circ\text{C}$

$$D = \frac{30.07 \text{ g/mol} \times 7.50 \text{ atm}}{0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 20.) \text{ K}} = 9.38 \text{ g/L}$$

Unknown: D in g/L

c. Given: $P = 97.4 \text{ kPa}$;
 $M = 104.09 \text{ g/mol}$;
 $D = 4.37 \text{ g/L}$

$$T = \frac{MP}{DR} = \frac{104.09 \text{ g/mol} \times 97.4 \text{ kPa}}{4.37 \text{ g/L} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}}} = 279 \text{ K}$$

Unknown: T in $^\circ\text{C}$ $279 \text{ K} - 273 = 6^\circ\text{C}$

d. Given: $M = 77.95 \text{ g/mol}$;
 $D = 6.27 \text{ g/L}$;
 $T = 66^\circ\text{C}$

$$P = \frac{DRT}{M} = \frac{6.27 \text{ g/L} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 66) \text{ K}}{77.95 \text{ g/mol}} = 2.24 \text{ atm}$$

Unknown: P in atm

287. Given: $m = 1.36 \text{ kg}$;
 N_2O gas;
 $V = 25.0 \text{ L}$;
 $T = 59^\circ\text{C}$

$$P = \frac{mRT}{MV} = \frac{1.36 \text{ kg} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 59) \text{ K} \times 1000 \text{ g}}{44.02 \text{ g/mol} \times 25.0 \text{ L} \times 1 \text{ kg}} = 33.7 \text{ atm}$$

Unknown: P in atm

288. Given: AlCl_3 vapor;
 $T = 225^\circ\text{C}$;
 $P = 0.939 \text{ atm}$

$$D = \frac{MP}{RT} = \frac{133.33 \text{ g/mol} \times 0.939 \text{ atm}}{0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 225) \text{ K}} = 3.06 \text{ g/L}$$

Unknown: D

289. Given: $D = 0.0262 \text{ g/mL}$;
 $P = 0.918 \text{ atm}$;
 $T = 10.^\circ\text{C}$

$$M = \frac{DRT}{P} = \frac{0.0262 \text{ g/mL} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 10) \text{ K} \times 1000 \text{ mL}}{0.918 \text{ atm} \times 1 \text{ L}} = 663 \text{ g/mol}$$

Unknown: M

290. Given: $m = 11.7\text{ g}$;
 He gas;
 $P = 0.262\text{ atm}$;
 $T = -50.^{\circ}\text{C}$

$$V = \frac{mRT}{MP} = \frac{11.9\text{ g} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 - 50)\text{ K}}{4.00\text{ g/mol} \times 0.262\text{ atm}} = 208\text{ L}$$

Unknown: V

291. Given: $T = 15.^{\circ}\text{C}$; $P_{\text{H}_2\text{O}} = 1.5988\text{ kPa}$; $P_T = 100.0\text{ kPa}$; C_2H_6 gas; $V = 245\text{ mL}$

$$P_{\text{C}_2\text{H}_6} = P_T - P_{\text{H}_2\text{O}} = 100.0\text{ kPa} - 1.5988\text{ kPa} = 98.4\text{ kPa}$$

$$n = \frac{PV}{RT} = \frac{98.4\text{ kPa} \times 245\text{ mL} \times 1\text{ L}}{8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 15)\text{ K} \times 1000\text{ mL}} = 0.0101\text{ mol}$$

Unknown: n

292. Given: $V = 3.75\text{ L}$; NO gas; $T = 19.^{\circ}\text{C}$;
 $P = 1.10\text{ atm}$

$$m = \frac{MPV}{RT} = \frac{30.01\text{ g/mol} \times 1.10\text{ atm} \times 3.75\text{ L}}{0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 19)\text{ K}} = 5.16\text{ g}$$

Unknown: m

293. Given: theoretical yield $\text{NH}_3 = 8.83\text{ g}$;
 actual yield $\text{NH}_3 = 10.24\text{ L}$;
 $T_1 = 52.^{\circ}\text{C}$;
 $P_1 = 105.3\text{ kPa}$;
 1 mole gas at STP = 22.4 L ;
 STP = $0.^{\circ}\text{C}$, 101.3 kPa

$$V_{\text{STP}} = \frac{P_1 V_1 T_{\text{STP}}}{T_1 P_{\text{STP}}} = \frac{105.3\text{ kPa} \times 10.24\text{ L} \times (273 + 0)\text{ K}}{(273 + 52)\text{ K} \times 101.3\text{ kPa}} = 8.94\text{ L}$$

$$8.94\text{ L} \times \frac{1\text{ mol}}{22.4\text{ L}} \times \frac{17.04\text{ g}}{1\text{ mol}} = 6.80\text{ g actual yield}$$

$$\frac{6.80\text{ g}}{8.83\text{ g}} \times 100 = 77.0\% \text{ yield}$$

Unknown: percent yield

294. Given: $D = 0.405\text{ g/L}$;
 $P = 0.889\text{ atm}$;
 $T = 7.^{\circ}\text{C}$

$$M = \frac{DRT}{P} = \frac{0.405\text{ g/L} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 7)\text{ K}}{0.889\text{ atm}} = 10.5\text{ g/mol}$$

Unknown: molar mass

295. Given: $V = 90.0\text{ L}$;
 $P = 1780\text{ kPa}$;
 $T = 18.^{\circ}\text{C}$;
 mass empty tank = 39.2 kg ;
 mass tank + gas = 50.5 kg

$$m = 50.5\text{ kg} - 39.2\text{ kg} = 11.3\text{ kg}$$

$$M = \frac{mRT}{PV} = \frac{11.3\text{ kg} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 18)\text{ K} \times 1000\text{ g}}{1780\text{ kPa} \times 90.0\text{ L} \times 1\text{ kg}} = 171\text{ g/mol}$$

Unknown: molar mass (M) of gas

296. Given: $V = 1.20 \times 10^3\text{ L}$;
 $m = 12.0\text{ kg}$; HCl gas; $T = 18.^{\circ}\text{C}$

$$P = \frac{mRT}{MV} = \frac{12.0\text{ kg} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 18)\text{ K} \times 1000\text{ g}}{36.46\text{ g/mol} \times 1.20 \times 10^3\text{ L} \times 1\text{ kg}} = 6.55\text{ atm}$$

Unknown: P

297. Given: $T = 20.^{\circ}\text{C}$; Ne gas; $D = 2.70\text{ g/L}$

$$P = \frac{DRT}{M} = \frac{2.70\text{ g/L} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 20)\text{ K}}{20.18\text{ g/mol}} = 326\text{ kPa}$$

Unknown: P in kPa

298. Given: $V = 658 \text{ mL}$;
 $m = 1.50 \text{ g}$; Ne
 gas; $P = 4.50 \times 10^2 \text{ kPa}$

$$T = \frac{MPV}{mR} = \frac{20.18 \text{ g/mol} \times 4.50 \times 10^2 \text{ kPa} \times 658 \text{ mL} \times 1 \text{ L}}{1.50 \text{ g} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times 1000 \text{ mL}} = 479 \text{ K}$$

Unknown: T

299. Given: $m = 1.00 \text{ g}$; H_2
 gas; $P = 6.75$
 millibars; $1 \text{ bar} =$
 $100 \text{ kPa} =$
 0.9869 atm ;
 $T_1 = -75^\circ\text{C}$;
 $T_2 = -8^\circ\text{C}$

$$V = \frac{TmR}{MP} = \frac{(273 - 75) \text{ K} \times 1.00 \text{ g} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}}}{2.02 \text{ g/mol} \times 0.675 \text{ kPa}} = 1210 \text{ L at } -75^\circ\text{C}$$

$$V = \frac{TmR}{MP} = \frac{(273 - 8) \text{ K} \times 1.00 \text{ g} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}}}{2.02 \text{ g/mol} \times 0.675 \text{ kPa}} = 1620 \text{ L at } -8^\circ\text{C}$$

Unknown: V at T_1 and
 T_2

300. Given: $n = 3.95 \text{ mol}$;
 $V = 850. \text{ mL}$;
 $T = 15^\circ\text{C}$

$$P = \frac{nRT}{V} = \frac{3.95 \text{ mol} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 15) \text{ K} \times 1000 \text{ mL}}{850. \text{ mL} \times 1 \text{ L}} = 1.11 \times 10^4 \text{ kPa}$$

Unknown: P in kPa

301. Given: $n = 0.00660 \text{ mol}$;
 $P = 0.907 \text{ atm}$;
 $T = 9^\circ\text{C}$

$$V = \frac{nRT}{P} = \frac{0.00660 \text{ mol} \times 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \times (273 + 9) \text{ K} \times 1000 \text{ mL}}{0.907 \text{ atm} \times 1 \text{ L}} = 168 \text{ mL}$$

Unknown: V in mL

302. Given: $m = 8.47 \text{ kg}$;
 SO_2 gas;
 $P = 89.4 \text{ kPa}$;
 $T = 40.^\circ\text{C}$

$$V = \frac{mRT}{MP} = \frac{8.47 \text{ kg} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 40) \text{ K} \times 1000 \text{ g}}{64.07 \text{ g/mol} \times 89.4 \text{ kPa} \times 1 \text{ kg}} = 3.85 \times 10^3 \text{ L}$$

Unknown: V

303. Given: $m = 908 \text{ g}$;
 He gas;
 $P = 128.3 \text{ kPa}$;
 $T = 2^\circ\text{C}$

$$V = \frac{mRT}{MP} = \frac{908 \text{ g} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 2) \text{ K}}{4.00 \text{ g/mol} \times 128.3 \text{ kPa}} = 4.05 \times 10^3 \text{ L}$$

Unknown: V

304. Given: $D = 1.162 \text{ g/L}$;
 $T = 27^\circ\text{C}$;
 $P = 100.0 \text{ kPa}$

$$M = \frac{DRT}{P} = \frac{1.162 \text{ g/L} \times 8.314 \frac{\text{L} \cdot \text{kPa}}{\text{mol} \cdot \text{K}} \times (273 + 27) \text{ K}}{100.0 \text{ kPa}} = 29.0 \text{ g/mol}$$

Unknown: M

305. Given: balanced equation; 2800 L NH_3

$$2800 \text{ L NH}_3 \times \frac{5 \text{ L O}_2}{4 \text{ L NH}_3} = 3500 \text{ L O}_2$$

Unknown: V of NO ;
 V of O_2

$$2800 \text{ L NH}_3 \times \frac{4 \text{ L NO}}{4 \text{ L NH}_3} = 2800 \text{ L NO}$$

306. Given: balanced equation; $3.60 \times 10^4 \text{ mL F}_2$

$$3.60 \times 10^4 \text{ mL F}_2 \times \frac{1 \text{ mL O}_3}{3 \text{ mL F}_2} = 1.20 \times 10^4 \text{ mL O}_3$$

Unknown: V of O_3 ;
 V of HF

$$3.60 \times 10^4 \text{ mL F}_2 \times \frac{6 \text{ mL HF}}{3 \text{ mL F}_2} = 7.20 \times 10^4 \text{ mL HF}$$

- 307.** Given: balanced equation; $P_1 = 2.26 \text{ atm}$; $T_1 = 40^\circ\text{C}$; $V_1 = 55.8 \text{ mL}$
 Unknown: V_{CO_2} produced at STP
- $$V_2 (\text{at STP}) = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{2.26 \text{ atm} \times 55.8 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 40) \text{ K} \times 1.00 \text{ atm}} = 110. \text{ mL}$$
- $$110. \text{ mL O}_2 \times \frac{2 \text{ mol CO}_2}{3 \text{ mol O}_2} = 73.3 \text{ mL CO}_2$$

- 308.** Given: reactants and products: V_1 (of N_2O_5 at STP) = 5.00 L ; $T_2 = 64.5^\circ\text{C}$; $P_2 = 1.76 \text{ atm}$
 Unknown: balanced equation; V_2 for N_2O_5 ; V of NO_2
- $$2\text{N}_2\text{O}_5 \rightarrow 4\text{NO}_2 + \text{O}_2$$
- $$V_2 = \frac{V_1 P_1 T_2}{T_1 P_2} = \frac{5.00 \text{ L} \times 1.00 \text{ atm} \times (273 + 64.5) \text{ K}}{(273 + 0) \text{ K} \times 1.76 \text{ atm}} = 3.51 \text{ L N}_2\text{O}_5$$
- $$3.51 \text{ L N}_2\text{O}_5 \times \frac{4 \text{ L NO}_2}{2 \text{ L N}_2\text{O}_5} = 7.02 \text{ NO}_2$$

- 309.** Given: balanced equation
- a.** Given: excess Al; STP; mass $\text{AlCl}_3 = 7.15 \text{ g}$
 Unknown: V of Cl_2
- $$7.15 \text{ g AlCl}_3 \times \frac{1 \text{ mol AlCl}_3}{133.33 \text{ g AlCl}_3} \times \frac{3 \text{ mol Cl}_2}{2 \text{ mol AlCl}_3} \times \frac{22.4 \text{ L Cl}_2}{1 \text{ mol Cl}_2} = 1.80 \text{ L Cl}_2$$
- b.** Given: 19.4 g Al , STP
 Unknown: V of Cl_2
- $$19.4 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3 \text{ mol Cl}_2}{2 \text{ mol Al}} \times \frac{22.4 \text{ L Cl}_2}{1 \text{ mol Cl}_2} = 24.2 \text{ L Cl}_2$$
- c.** Given: 1.559 kg Al ; $T = 20.^\circ\text{C}$; $P = 0.945 \text{ atm}$
 Unknown: V of Cl_2
- $$1.559 \text{ kg Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{3 \text{ mol Cl}_2}{2 \text{ mol Al}} \times \frac{22.4 \text{ L Cl}_2}{1 \text{ mol Cl}_2} = 1940 \text{ L Cl}_2$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 1940 \text{ L} \times (273 + 20) \text{ K}}{(273 + 0) \text{ K} \times 0.945 \text{ atm}} = 2.21 \times 10^3 \text{ L Cl}_2$$
- d.** Given: excess Al; $920. \text{ L Cl}_2$; STP
 Unknown: mass AlCl_3 in g
- $$920 \text{ L Cl}_2 \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{2 \text{ mol AlCl}_3}{3 \text{ mol Cl}_2} \times \frac{133.33 \text{ g AlCl}_3}{1 \text{ mol AlCl}_3} = 3.65 \times 10^3 \text{ g AlCl}_3$$
- e.** Given: $V_1 = 1.049 \text{ mL Cl}_2$; $T_1 = 37^\circ\text{C}$; $P_1 = 5.00 \text{ atm}$
 Unknown: mass Al in g
- Find V at STP:
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{5.00 \text{ atm} \times 1.049 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 37) \text{ K} \times 1.00 \text{ atm}} = 4.62 \text{ mL}$$
- $$4.62 \text{ mL Cl}_2 \times \frac{1 \text{ mol Cl}_2}{22\,400 \text{ mL Cl}_2} \times \frac{2 \text{ mol Al}}{3 \text{ mol Cl}_2} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 3.71 \times 10^{-3} \text{ g Al}$$
- f.** Given: 500.00 kg Al ; $T_2 = 15^\circ\text{C}$; $P_2 = 83.0 \text{ kPa}$
 Unknown: V of Cl_2 in m^3
- $$500.00 \text{ kg Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3 \text{ mol Cl}_2}{2 \text{ mol Al}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} \times \frac{1 \text{ m}^3}{1000 \text{ L}}$$
- $$= 623 \text{ m}^3 \text{ Cl}_2 \text{ at STP}$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{101.3 \text{ kPa} \times 623 \text{ m}^3 \times (273 + 15) \text{ K}}{(273 + 0) \text{ K} \times 83.0 \text{ kPa}} = 802 \text{ m}^3$$

- 310. a.** Given: balanced equation; STP; 57.0 mL H₂
Unknown: V of N₂
- $$57.0 \text{ mL H}_2 \times \frac{1 \text{ mL N}_2}{3 \text{ mL H}_2} = 19.0 \text{ mL N}_2$$
- b.** Given: balanced equation; STP; 6.39×10^4 L H₂
Unknown: V of NH₃
- $$6.39 \times 10^4 \text{ L H}_2 \times \frac{2 \text{ L NH}_3}{3 \text{ L H}_2} = 4.26 \times 10^4 \text{ L NH}_3$$
- c.** Given: balanced equation; 20.0 mol N₂; STP
Unknown: V of NH₃
- $$20.0 \text{ mol N}_2 \times \frac{2 \text{ mol NH}_3}{1 \text{ mol N}_2} \times \frac{22.4 \text{ L NH}_3}{1 \text{ mol NH}_3} = 896 \text{ L NH}_3$$
- d.** Given: balanced equation; V₁ = 800. L NH₃; T₁ = 55°C; P₁ = 0.900 atm
Unknown: V of H₂ at STP
- V of NH₃ at STP =
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{0.900 \text{ atm} \times 800. \text{ L NH}_3 \times (273 + 0) \text{ K}}{(273 + 55) \text{ K} \times 1.00 \text{ atm}} = 599 \text{ L NH}_3$$
- $$599 \text{ L NH}_3 \times \frac{3 \text{ L H}_2}{2 \text{ L NH}_3} = 899 \text{ L H}_2$$
-
- 311. a.** Given: balanced equation; V_{C₃H₈} = 3 L at STP; T₂ = 250.°C; P₂ = 1.00 atm
Unknown: V of H₂O
- $$3.0 \text{ L C}_3\text{H}_8 \times \frac{4 \text{ L H}_2\text{O}}{1 \text{ L C}_3\text{H}_8} = 12 \text{ L H}_2\text{O at STP}$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 12 \text{ L} \times (273 + 250) \text{ K}}{(273 + 0) \text{ K} \times 1.00 \text{ atm}} = 23 \text{ L}$$
- b.** Given: balanced equation; 640. L CO₂
Unknown: V of O₂
- $$640. \text{ L CO}_2 \times \frac{5 \text{ L O}_2}{3 \text{ L CO}_2} = 1070 \text{ L O}_2$$
- c.** Given: 465 mL O₂ at STP; balanced equation; T₂ = 37°C; P₂ = 0.973 atm
Unknown: V₂ of CO₂
- $$465 \text{ mL O}_2 \times \frac{3 \text{ mL CO}_2}{5 \text{ mL O}_2} = 279 \text{ mL CO}_2 \text{ at STP}$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 279 \text{ mL} \times (273 + 37) \text{ K}}{(273 + 0) \text{ K} \times 0.973 \text{ atm}} = 326 \text{ mL}$$
- d.** Given: 2.50 L of C₃H₈ at STP; balanced equation; T₂ = 175°C; P₂ = 1.14 atm
Unknown: V of products at T₂ and P₂ (V₂)
- $$2.50 \text{ L C}_3\text{H}_8 \times \frac{3 \text{ L CO}_2}{1 \text{ L C}_3\text{H}_8} = 7.50 \text{ L CO}_2 \text{ at STP}$$
- $$2.50 \text{ L C}_3\text{H}_8 \times \frac{4 \text{ L H}_2\text{O}}{1 \text{ L C}_3\text{H}_8} = 10.0 \text{ L H}_2\text{O}$$
- $$V_1 \text{ at STP} = 7.50 \text{ L} + 10.0 \text{ L} = 17.5 \text{ L}$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 17.5 \text{ L} \times (273 + 175) \text{ K}}{(273 + 0) \text{ K} \times 1.14 \text{ atm}} = 25.2 \text{ L}$$

- 312.** Given: balanced equation; $V_1 = 3500$. L CO; $T_1 = 20.^{\circ}\text{C}$; $P_1 = 0.953$ atm

Unknown: V of O_2 at STP

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{0.953 \text{ atm} \times 3500. \text{ L} \times (273 + 0) \text{ K}}{(273 + 20) \text{ K} \times 1.00 \text{ atm}} = 3110 \text{ L CO at STP}$$

$$V \text{ of } \text{O}_2 = 3110 \text{ L CO} \times \frac{1 \text{ L O}_2}{2 \text{ L CO}} = 1550 \text{ L O}_2$$

- 313.** Given: balanced equation; $V_1 = 1.00$ L HF; $P_1 = 3.48$ atm; $T_1 = 25.^{\circ}\text{C}$; $T_2 = 15.^{\circ}\text{C}$; $P_2 = 0.940$ atm

Unknown: V of SiF_4 at V_2 and P_2

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{3.48 \text{ atm} \times 1.00 \text{ L} \times (273 + 15) \text{ K}}{(273 + 25) \text{ K} \times 0.940 \text{ atm}} = 3.58 \text{ L HF}$$

$$3.58 \text{ L HF} \times \frac{1 \text{ L SiF}_4}{4 \text{ L HF}} = 0.894 \text{ L SiF}_4$$

- 314.** Given: balanced equation

- a.** Given: 6.28 g Fe

Unknown: V of H_2 at STP

$$6.28 \text{ g Fe} \times \frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} \times \frac{4 \text{ mol H}_2}{3 \text{ mol Fe}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 3.36 \text{ L H}_2$$

- b.** Given: $V_1 = 500.$ L H_2O ; $T_1 = 250.^{\circ}\text{C}$; $P_1 = 1.00$ atm

Unknown: mass Fe

Convert to STP:

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 500. \text{ L} \times (273 + 0) \text{ K}}{(273 + 250) \text{ K} \times 1.00 \text{ atm}} = 261 \text{ L}$$

$$261 \text{ L H}_2\text{O} \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{3 \text{ mol Fe}}{4 \text{ mol H}_2\text{O}} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 488 \text{ g Fe}$$

- c.** Given: 285 g Fe_3O_4
Unknown: V of H_2 at $20.^{\circ}\text{C}$ and 1.06 atm

$$285 \text{ g Fe}_3\text{O}_4 \times \frac{1 \text{ mol Fe}_3\text{O}_4}{231.55 \text{ g Fe}_3\text{O}_4} \times \frac{4 \text{ mol H}_2}{1 \text{ mol Fe}_3\text{O}_4} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 110. \text{ L H}_2 \text{ at STP}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 110. \text{ L} \times (273 + 20) \text{ K}}{(273 + 0) \text{ K} \times 1.06 \text{ atm}} = 111 \text{ L}$$

- 315.** Given: balanced equation; 0.027 g Na; excess H_2O

Unknown: V of H_2 at STP

$$0.027 \text{ g Na} \times \frac{1 \text{ mol Na}}{22.99 \text{ g Na}} \times \frac{1 \text{ mol H}_2}{2 \text{ mol Na}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 0.013 \text{ L H}_2$$

- 316.** Given: balanced equation; $V_1 = 7.15$ L CO_2 ; $T_1 = 125.^{\circ}\text{C}$; $P_1 = 1.02$ atm

Unknown: V of O_2 at STP; mass $\text{C}_4\text{H}_{10}\text{O}$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.02 \text{ atm} \times 7.15 \text{ L} \times (273 + 0) \text{ K}}{(273 + 125) \text{ K} \times 1.00 \text{ atm}} = 5.00 \text{ L CO}_2 \text{ at STP}$$

$$5.00 \text{ L CO}_2 \times \frac{6 \text{ L O}_2}{4 \text{ L CO}_2} = 7.50 \text{ L O}_2$$

$$5.00 \text{ L CO}_2 \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{1 \text{ mol C}_4\text{H}_{10}\text{O}}{4 \text{ mol CO}_2} \times \frac{74.14 \text{ g C}_4\text{H}_{10}\text{O}}{1 \text{ mol C}_4\text{H}_{10}\text{O}} = 4.14 \text{ g C}_4\text{H}_{10}\text{O}$$

- 317.** Given: balanced equation
 a. Given: 0.100 mol $\text{C}_3\text{H}_5\text{N}_3\text{O}_9$
 Unknown: V of products at STP
- $$0.100 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9 \times \frac{6 \text{ mol } \text{N}_2}{4 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 3.36 \text{ L } \text{N}_2$$
- $$0.100 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9 \times \frac{12 \text{ mol } \text{CO}_2}{4 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 6.72 \text{ L } \text{CO}_2$$
- $$0.100 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9 \times \frac{10 \text{ mol } \text{H}_2\text{O}}{4 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 5.60 \text{ L } \text{H}_2\text{O}$$
- $$0.100 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9 \times \frac{1 \text{ mol } \text{O}_2}{4 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 0.560 \text{ L } \text{O}_2$$
- b. Given: 10.0 g $\text{C}_3\text{H}_5\text{N}_3\text{O}_9$
 Unknown: total V gases produced at 300.°C and 1.00 atm
- $$V_T \text{ from a} = 3.36 \text{ L} + 6.72 \text{ L} + 5.60 \text{ L} + 0.560 \text{ L} = 16.24 \text{ L}$$
- $$10.0 \text{ g } \text{C}_3\text{H}_5\text{N}_3\text{O}_9 \times \frac{1 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9}{227.11 \text{ g } \text{C}_3\text{H}_5\text{N}_3\text{O}_9} \times \frac{16.24 \text{ L gases}}{0.100 \text{ mol } \text{C}_3\text{H}_5\text{N}_3\text{O}_9} = 7.15 \text{ L gases at STP}$$
- $$V_2 = \frac{V_1 P_1 T_2}{T_1 P_2} = \frac{7.15 \text{ L} \times 1.00 \text{ atm} \times (273 + 300) \text{ K}}{(273 + 0) \text{ K} \times 1.00 \text{ atm}} = 15.0 \text{ L gases}$$
-
- 318.** Given: balanced equation; 250. mL N_2O at STP
 Unknown: mass NH_4NO_3
- $$250. \text{ mL } \text{N}_2\text{O} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{1 \text{ mol } \text{NH}_4\text{NO}_3}{1 \text{ mol } \text{N}_2\text{O}} \times \frac{80.06 \text{ g } \text{NH}_4\text{NO}_3}{1 \text{ mol } \text{NH}_4\text{NO}_3} = 0.894 \text{ g } \text{NH}_4\text{NO}_3$$
-
- 319.** Given: balanced equation; 8.46 g Ca_3P_2
 Unknown: V of PH_3 at 18°C and 102.4 kPa
- $$8.46 \text{ g } \text{Ca}_3\text{P}_2 \times \frac{1 \text{ mol } \text{Ca}_3\text{P}_2}{182.18 \text{ g } \text{Ca}_3\text{P}_2} \times \frac{2 \text{ mol } \text{PH}_3}{1 \text{ mol } \text{Ca}_3\text{P}_2} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 2.08 \text{ L } \text{PH}_3 \text{ at STP}$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{101.3 \text{ kPa} \times 2.08 \text{ L} \times (273 + 18) \text{ K}}{(273 + 0) \text{ K} \times 102.4 \text{ kPa}} = 2.19 \text{ L } \text{PH}_3$$
-
- 320.** Given: balanced equation; $6.0 \times 10^3 \text{ kg } \text{AlCl}_3$
 Unknown: mass Al; V of HCl at 4.71 atm + 43°C
- $$6.0 \times 10^3 \text{ kg } \text{AlCl}_3 \times \frac{1 \text{ mol } \text{AlCl}_3}{133.33 \text{ g } \text{AlCl}_3} \times \frac{2 \text{ mol } \text{Al}}{2 \text{ mol } \text{AlCl}_3} \times \frac{26.98 \text{ g } \text{Al}}{1 \text{ mol } \text{Al}} = 1.2 \times 10^3 \text{ kg Al}$$
- $$6.0 \times 10^3 \text{ kg } \text{AlCl}_3 \times \frac{1 \text{ mol } \text{AlCl}_3}{133.33 \text{ g } \text{AlCl}_3} \times \frac{6 \text{ mol } \text{HCl}}{2 \text{ mol } \text{AlCl}_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 3.0 \times 10^6 \text{ L HCl at STP}$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 3.0 \times 10^6 \text{ L} \times (273 + 43) \text{ K}}{(273 + 0) \text{ K} \times 4.71 \text{ atm}} = 7.4 \times 10^5 \text{ L HCl}$$
-
- 321.** Given: balanced equation; actual yield = $8.50 \times 10^4 \text{ kg } (\text{NH}_2)_2\text{CO}$; 89.5% yield
 Unknown: V of NH_3
- $$\text{theoretical yield } (\text{NH}_2)_2\text{CO} = 8.50 \times 10^4 \text{ kg } (\text{NH}_2)_2\text{CO} \times \frac{100\%}{89.5\%} = 9.50 \times 10^4 \text{ kg } (\text{NH}_2)_2\text{CO}$$
- $$9.50 \times 10^4 \text{ kg } (\text{NH}_2)_2\text{CO} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } (\text{NH}_2)_2\text{CO}}{60.07 \text{ g } (\text{NH}_2)_2\text{CO}} \times \frac{2 \text{ mol } \text{NH}_3}{1 \text{ mol } (\text{NH}_2)_2\text{CO}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 7.08 \times 10^7 \text{ L } \text{NH}_3$$

- 322.** Given: $V_1 = 265 \text{ mL O}_2$;
 $T_1 = 10.^{\circ}\text{C}$; $P_1 = 0.975 \text{ atm}$; bal-
 anced equation
 Unknown: mass of
 BaO_2
- $$P_{\text{O}_2} = P_T - P_{\text{H}_2\text{O}} = 0.975 \text{ atm} - 1.23 \text{ kPa} \times \frac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.963 \text{ atm}$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{0.963 \text{ atm} \times 265 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 10) \text{ K} \times 1.00 \text{ atm}} = 246 \text{ mL O}_2 \text{ at STP}$$
- $$246 \text{ mL O}_2 \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{2 \text{ mol BaO}_2}{1 \text{ mol O}_2} \times \frac{169.33 \text{ g BaO}_2}{1 \text{ mol BaO}_2}$$
- $$= 3.72 \text{ g BaO}_2$$
-
- 323.** Given: balanced equa-
 tion; 15.0 g KMnO_4
 Unknown: V of Cl_2 at
 15°C and
 0.959 atm
- $$15.0 \text{ g KMnO}_4 \times \frac{1 \text{ mol KMnO}_4}{158.04 \text{ g KMnO}_4} \times \frac{5 \text{ mol Cl}_2}{2 \text{ mol KMnO}_4} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$$
- $$= 5.32 \text{ L Cl}_2 \text{ at STP}$$
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 5.32 \text{ L} \times (273 + 15) \text{ K}}{(273 + 0) \text{ K} \times 0.959 \text{ atm}} = 5.85 \text{ L Cl}_2$$
-
- 324.** Given: balanced equa-
 tions; 35.0 kL O_2
 at STP
 Unknown: V of NH_3 at
 STP; V of
 NO_2 at STP
- $$35.0 \text{ kL O}_2 \times \frac{4 \text{ L NH}_3}{5 \text{ L O}_2} = 28.0 \text{ kL NH}_3$$
- $$28.0 \text{ kL NH}_3 \times \frac{4 \text{ L NO}}{4 \text{ L NH}_3} \times \frac{2 \text{ L NO}_2}{2 \text{ L NO}} = 28.0 \text{ kL NO}_2$$
-
- 325.** Given: balanced equa-
 tion; 5.00 L O_2
 at STP
 Unknown: mass of
 KClO_3
- $$5.00 \text{ L O}_2 \times \frac{1 \text{ mol O}_2}{22.4 \text{ L O}_2} \times \frac{2 \text{ mol KClO}_3}{3 \text{ mol O}_2} \times \frac{122.55 \text{ g KClO}_3}{1 \text{ mol KClO}_3} = 18.2 \text{ g KClO}_3$$
-
- 326.** Given: balanced
 equation
- a.** Given: $38\,000 \text{ L CO}_2$
 Unknown: V of NH_3
 under the
 same con-
 ditions
- $$38\,000 \text{ L CO}_2 \times \frac{1 \text{ L NH}_3}{1 \text{ L CO}_2} = 38\,000 \text{ L NH}_3$$
- b.** Given: $38\,000 \text{ L CO}_2$
 at 25°C and
 1.00 atm
 Unknown: mass of
 NaHCO_3
- $$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 38\,000 \text{ L} \times (273 + 0) \text{ K}}{(273 + 25) \text{ K} \times 1.00 \text{ atm}}$$
- $$= 34\,800 \text{ L CO}_2 \text{ at STP}$$
- $$34\,800 \text{ L CO}_2 \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{1 \text{ mol NaHCO}_3}{1 \text{ mol CO}_2} \times \frac{84.01 \text{ g NaHCO}_3}{1 \text{ mol NaHCO}_3}$$
- $$= 1.30 \times 10^5 \text{ g NaHCO}_3$$
- c.** Given: 46.0 kg NaHCO_3
 Unknown: V of NH_3
 at STP
- $$46.0 \text{ kg NaHCO}_3 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol NaHCO}_3}{84.01 \text{ g NaHCO}_3} \times \frac{1 \text{ mol NH}_3}{1 \text{ mol NaHCO}_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$$
- $$= 1.23 \times 10^4 \text{ L NH}_3$$

- d. Given: 100.00 kg NaHCO_3
Unknown: V of CO_2 at 5.50 atm and 42°C

$$100.00 \text{ kg NaHCO}_3 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol NaHCO}_3}{84.01 \text{ g NaHCO}_3} \times \frac{1 \text{ mol CO}_2}{1 \text{ mol NaHCO}_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$$

$$= 2.67 \times 10^4 \text{ L CO}_2 \text{ at STP}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 2.67 \times 10^4 \text{ L} \times (273 + 42) \text{ K}}{(273 + 0) \text{ K} \times 5.50 \text{ atm}} = 5.60 \times 10^3 \text{ L CO}_2$$

327. Given: balanced equation

- a. Given: 4.74 g C_4H_{10} ; excess O_2
Unknown: V of CO_2 at 150°C and 1.14 atm

$$4.74 \text{ g C}_4\text{H}_{10} \times \frac{1 \text{ mol C}_4\text{H}_{10}}{58.14 \text{ g C}_4\text{H}_{10}} \times \frac{8 \text{ mol CO}_2}{2 \text{ mol C}_4\text{H}_{10}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 7.30 \text{ L CO}_2 \text{ at STP}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 7.30 \text{ L} \times (273 + 150) \text{ K}}{(273 + 0) \text{ K} \times 1.14 \text{ atm}} = 9.92 \text{ L CO}_2$$

- b. Given: 0.500 g C_4H_{10}
Unknown: V of O_2 at 0.980 atm and 75°C

$$0.500 \text{ g C}_4\text{H}_{10} \times \frac{1 \text{ mol C}_4\text{H}_{10}}{58.14 \text{ g C}_4\text{H}_{10}} \times \frac{13 \text{ mol O}_2}{2 \text{ mol C}_4\text{H}_{10}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 1.25 \text{ L O}_2 \text{ at STP}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{1.00 \text{ atm} \times 1.25 \text{ L} \times (273 + 75) \text{ K}}{(273 + 0) \text{ K} \times 0.980 \text{ atm}} = 1.63 \text{ L O}_2$$

- c. Given: mass₁ (torch + fuel) = 876.2 g;
mass₂ (torch + fuel) = 859.3 g
Unknown: V of CO_2 at STP

$$\text{mass butane reacted} = 876.2 \text{ g} - 859.3 \text{ g} = 16.9 \text{ g}$$

$$16.9 \text{ g C}_4\text{H}_{10} \times \frac{1 \text{ mol C}_4\text{H}_{10}}{58.14 \text{ g C}_4\text{H}_{10}} \times \frac{8 \text{ mol CO}_2}{2 \text{ mol C}_4\text{H}_{10}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 26.0 \text{ L CO}_2$$

- d. Given: 3270 L of CO_2 at 35°C and 0.993 atm
Unknown: mass H_2O

$$V_2 = \frac{V_1 P_1 T_2}{T_1 P_2} = \frac{3270 \text{ L} \times 0.993 \text{ atm} \times (273 + 0) \text{ K}}{(273 + 35) \text{ K} \times 1.00 \text{ atm}} = 3270 \text{ L CO}_2 \text{ at STP}$$

$$3270 \text{ L CO}_2 \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{10 \text{ mol H}_2\text{O}}{8 \text{ mol CO}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 3290 \text{ g H}_2\text{O}$$

328. Given: 75.0 g ethanol; 500.0 g H_2O
Unknown: percentage concentration

$$\frac{75.0 \text{ g ethanol}}{(500.0 + 75.0) \text{ g}} \times 100 = 13.0\% \text{ ethanol}$$

329. Given: 3.50 g KIO_3 ; 6.23 g KOH ; 805.05 g H_2O
Unknown: percentage concentration of KIO_3 and KOH

$$\frac{3.50 \text{ g KIO}_3}{(3.50 + 6.23 + 805.05) \text{ g}} \times 100 = 0.430\% \text{ KIO}_3$$

$$\frac{6.23 \text{ g KOH}}{(3.50 + 6.23 + 805.05) \text{ g}} \times 100 = 0.765\% \text{ KOH}$$

330. Given: 0.377 g RbCl to make a 5.00% solution Unknown: mass of H ₂ O	$0.377 \text{ g RbCl} \times \frac{100 \text{ g solution}}{5 \text{ g RbCl}} = 7.54 \text{ g solution}$ $7.54 \text{ g solution} - 0.377 \text{ g RbCl} = 7.16 \text{ g H}_2\text{O}$
331. Given: 30.0 g H ₂ O; 18.0% LiNO ₃ solution Unknown: mass of LiNO ₃	$\frac{x}{30.0 \text{ g} + x} = 0.18 ; x = 6.59 \text{ g LiNO}_3$
332. Given: 141.6 g C ₃ H ₅ O(COOH) ₃ ; V of solution = 3500.0 mL Unknown: molarity	$141.6 \text{ g C}_3\text{H}_5\text{O(COOH)}_3 \times \frac{1 \text{ mol C}_3\text{H}_5\text{O(COOH)}_3}{192.14 \text{ g C}_3\text{H}_5\text{O(COOH)}_3} = 0.7370 \text{ mol}$ $\frac{0.7370 \text{ mol}}{3500.0 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.2106 \text{ M}$
333. Given: 280.0 mg NaCl; 2.00 mL H ₂ O Unknown: molarity	$280.0 \text{ mg NaCl} \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} = 0.00479 \text{ mol NaCl}$ $\frac{0.00479 \text{ mol NaCl}}{2.00 \text{ mL solution}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 2.40 \text{ M}$
334. Given: 390.0 g CH ₃ COOH; 1000.0 mL solution Unknown: molarity	$390.0 \text{ g CH}_3\text{COOH} \times \frac{1 \text{ mol CH}_3\text{COOH}}{60.06 \text{ g CH}_3\text{COOH}} = 6.494 \text{ mol CH}_3\text{COOH}$ $\frac{6.494 \text{ mol CH}_3\text{COOH}}{1000.0 \text{ mL solution}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 6.494 \text{ M}$
335. Given: 5.000 × 10 ³ L; 0.215 M Unknown: mass of C ₆ H ₁₂ O ₆	$0.215 \text{ mol/L} \times (5.00 \times 10^3 \text{ L}) \times \frac{180.18 \text{ g C}_6\text{H}_{12}\text{O}_6}{1 \text{ mol C}_6\text{H}_{12}\text{O}_6} = 1.94 \times 10^5 \text{ g C}_6\text{H}_{12}\text{O}_6$
336. Given: 720. mL solution; 0.0939 M Unknown: mass of MgBr ₂	$\frac{0.0939 \text{ mol}}{\text{L}} \times 720. \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{184.10 \text{ g MgBr}_2}{1 \text{ mol MgBr}_2} = 12.4 \text{ g MgBr}_2$
337. Given: 300. mL solution; 0.875 M Unknown: mass of NH ₄ Cl	$\frac{0.875 \text{ mol}}{\text{L}} \times 300. \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{53.50 \text{ g NH}_4\text{Cl}}{1 \text{ mol NH}_4\text{Cl}} = 14.0 \text{ g NH}_4\text{Cl}$
338. Given: 560 g CH ₃ COCH ₃ solute; 620 g H ₂ O solvent Unknown: molality	$560 \text{ g CH}_3\text{COCH}_3 \times \frac{1 \text{ mol CH}_3\text{COCH}_3}{58.09 \text{ g CH}_3\text{COCH}_3} = 9.64 \text{ mol CH}_3\text{COCH}_3$ $\frac{9.64 \text{ mol CH}_3\text{COCH}_3}{0.620 \text{ kg solvent}} = 16 \text{ m}$

- 339.** Given: 12.9 g C₆H₁₂O₆ solute; 31.0 g H₂O solvent
Unknown: molality
- $$12.9 \text{ g C}_6\text{H}_{12}\text{O}_6 \times \frac{1 \text{ mol C}_6\text{H}_{12}\text{O}_6}{180.18 \text{ g C}_6\text{H}_{12}\text{O}_6} = 0.0716 \text{ mol C}_6\text{H}_{12}\text{O}_6$$
- $$\frac{0.0716 \text{ mol C}_6\text{H}_{12}\text{O}_6}{31.0 \text{ g solvent}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 2.31 \text{ m}$$
-
- 340.** Given: 125 g solvent; 12.0 m solution
Unknown: moles of solute (CH₃CHOHCH₂CH₃); mass of solute
- $$125 \text{ g solvent} \times \frac{12.0 \text{ mol solute}}{1 \text{ kg solvent}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 1.50 \text{ mol solute}$$
- $$1.50 \text{ mol CH}_3\text{CHOHCH}_2\text{CH}_3 \times \frac{74.14 \text{ g CH}_3\text{CHOHCH}_2\text{CH}_3}{1 \text{ mol CH}_3\text{CHOHCH}_2\text{CH}_3} = 111 \text{ g CH}_3\text{CHOHCH}_2\text{CH}_3$$
-
- 341. a.** Given: 12.0% KMnO₄; 500.0 g solution
Unknown: mass solute; mass solvent (H₂O)
- $$500.0 \text{ g} \times 0.120 = 60.0 \text{ g KMnO}_4$$
- $$500.0 \text{ g} - 60.0 \text{ g} = 440.0 \text{ g H}_2\text{O}$$
- b.** Given: 0.60 M BaCl₂; 1.750 L solution
Unknown: mass solute
- $$\frac{0.60 \text{ mol BaCl}_2}{1.00 \text{ L solution}} \times 1.750 \text{ L solution} = 1.1 \text{ mol BaCl}_2$$
- $$1.1 \text{ mol BaCl}_2 \times \frac{208.23 \text{ g BaCl}_2}{1 \text{ mol BaCl}_2} = 230 \text{ g BaCl}_2$$
- c.** Given: 6.20 m glycerol (HOCH₂CHOHCH₂OH); 800.0 g H₂O solvent
Unknown: mass glycerol in g
- $$\frac{6.20 \text{ mol glycerol}}{1 \text{ kg solvent}} \times 800.0 \text{ g solvent} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 4.96 \text{ mol glycerol}$$
- $$4.96 \text{ mol glycerol} \times \frac{92.11 \text{ g glycerol}}{1 \text{ mol glycerol}} = 457 \text{ g glycerol}$$
- d.** Given: 12.27 g solute (K₂Cr₂O₇); 650. mL solution
Unknown: molarity
- $$\frac{12.27 \text{ g K}_2\text{Cr}_2\text{O}_7}{650. \text{ mL solution}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ mol K}_2\text{Cr}_2\text{O}_7}{294.20 \text{ g K}_2\text{Cr}_2\text{O}_7} = 0.0642 \text{ M K}_2\text{Cr}_2\text{O}_7$$
- e.** Given: 288 g CaCl₂ solute; 2.04 kg H₂O solvent
Unknown: molality
- $$\frac{288 \text{ g CaCl}_2}{2.04 \text{ kg H}_2\text{O}} \times \frac{1 \text{ mol CaCl}_2}{110.98 \text{ g CaCl}_2} = 1.27 \text{ m}$$

f. Given: 0.160 M NaCl solution; 25.0 mL solution

$$\frac{0.160 \text{ mol NaCl}}{1.00 \text{ L solution}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 25.0 \text{ mL solution} = 0.00400 \text{ mol NaCl}$$

Unknown: mass solute in g

$$0.00400 \text{ mol NaCl} \times \frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} = 0.234 \text{ g NaCl}$$

g. Given: 2.00 *m* C₆H₁₂O₆; 1.50 kg H₂O solvent

$$\frac{2.00 \text{ mol C}_6\text{H}_{12}\text{O}_6}{1.00 \text{ kg H}_2\text{O}} \times 1.50 \text{ kg H}_2\text{O} = 3.00 \text{ mol C}_6\text{H}_{12}\text{O}_6$$

Unknown: mass of solute and total mass of solution

$$3.00 \text{ mol C}_6\text{H}_{12}\text{O}_6 \times \frac{180.18 \text{ g C}_6\text{H}_{12}\text{O}_6}{1 \text{ mol C}_6\text{H}_{12}\text{O}_6} = 541 \text{ g C}_6\text{H}_{12}\text{O}_6$$

$$1.50 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} + 541 \text{ g} = 2040 \text{ g total}$$

342. Given: 2.50 L of 4.25 M solution of H₂SO₄

$$2.50 \text{ L solution} \times \frac{4.25 \text{ mol H}_2\text{SO}_4}{1.00 \text{ L solution}} = 10.6 \text{ mol H}_2\text{SO}_4$$

Unknown: moles of H₂SO₄

343. Given: 71.5 g C₁₈H₃₂O₂ solute; 525 g solvent

$$71.5 \text{ g C}_{18}\text{H}_{32}\text{O}_2 \times \frac{1 \text{ mol C}_{18}\text{H}_{32}\text{O}_2}{280.50 \text{ g C}_{18}\text{H}_{32}\text{O}_2} = 0.255 \text{ mol C}_{18}\text{H}_{32}\text{O}_2$$

Unknown: molality

$$\frac{0.255 \text{ mol C}_{18}\text{H}_{32}\text{O}_2}{525 \text{ g solvent}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 0.486 \text{ } m$$

344. Given: 16.2% Na₂S₂O₃ solution by mass

a. Unknown: mass Na₂S₂O₃ in 80.0 g solution

$$80.0 \text{ g} \times \frac{16.2\%}{100\%} = 13.0 \text{ g Na}_2\text{S}_2\text{O}_3$$

b. Unknown: moles Na₂S₂O₃ in 80.0 g solution

$$80.0 \text{ g} \times \frac{16.2\%}{100\%} \text{ Na}_2\text{S}_2\text{O}_3 \times \frac{1 \text{ mol Na}_2\text{S}_2\text{O}_3}{158.12 \text{ g Na}_2\text{S}_2\text{O}_3} = 0.0820 \text{ mol Na}_2\text{S}_2\text{O}_3$$

c. Given: 80.0 g of 16.2% Na₂S₂O₃ solution (see **b**) diluted to 250.0 mL with H₂O

$$\frac{0.0820 \text{ mol Na}_2\text{S}_2\text{O}_3}{250.0 \text{ mL solution}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.328 \text{ M}$$

Unknown: molarity of final solution

345. Given: CoCl_2 solute; 650.00 mL of 4.00 M solution Unknown: mass of CoCl_2	$\frac{4.00 \text{ mol CoCl}_2}{1.00 \text{ L solution}} \times 650.00 \text{ mL solution} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.60 \text{ mol CoCl}_2$ $2.60 \text{ mol CoCl}_2 \times \frac{129.83 \text{ g CoCl}_2}{1.00 \text{ mol CoCl}_2} = 338 \text{ g CoCl}_2$
346. Given: 11.27 g AgNO_3 ; 0.150 M solution Unknown: volume of solution	$11.27 \text{ g AgNO}_3 \times \frac{1 \text{ mol AgNO}_3}{169.88 \text{ g AgNO}_3} = 0.0663 \text{ mol AgNO}_3$ $0.0663 \text{ mol AgNO}_3 \times \frac{1 \text{ L solution}}{0.150 \text{ mol AgNO}_3} = 0.442 \text{ L solution}$
347. Given: 2250 g H_2O solvent; 1.50 m solution Unknown: mass of NH_2CONH_2	$\frac{1.50 \text{ mol NH}_2\text{CONH}_2}{1.00 \text{ kg solvent}} \times 2250 \text{ g solvent} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 3.38 \text{ mol NH}_2\text{CONH}_2$ $3.38 \text{ mol NH}_2\text{CONH}_2 \times \frac{60.07 \text{ g NH}_2\text{CONH}_2}{1 \text{ mol NH}_2\text{CONH}_2} = 203 \text{ g NH}_2\text{CONH}_2$
348. Given: 21.29 mL of a 3.38 M $\text{Ba}(\text{NO}_3)_2$ solution Unknown: mass of $\text{Ba}(\text{NO}_3)_2$	$21.29 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{3.38 \text{ mol Ba}(\text{NO}_3)_2}{1 \text{ L}} = 0.0720 \text{ mol Ba}(\text{NO}_3)_2$ $0.0720 \text{ mol Ba}(\text{NO}_3)_2 \times \frac{261.35 \text{ g Ba}(\text{NO}_3)_2}{1 \text{ mol Ba}(\text{NO}_3)_2} = 18.8 \text{ g Ba}(\text{NO}_3)_2$
349. Given: 100.0 g of a 3.5% $(\text{NH}_4)_2\text{SO}_4$ solution Unknown: description of prepara- tion	$100.0 \text{ g} \times \frac{3.5\%}{100\%} (\text{NH}_4)_2\text{SO}_4 = 3.5 \text{ g } (\text{NH}_4)_2\text{SO}_4$ $100.0 \text{ g solution} - 3.5 \text{ g solute} = 96.5 \text{ g solvent}$ Add 3.5 g $(\text{NH}_4)_2\text{SO}_4$ to 96.5 g H_2O
350. Given: 590.0 g water solvent; 0.82 m solution Unknown: mass CaCl_2 solute	$\frac{0.82 \text{ mol CaCl}_2}{1.00 \text{ kg H}_2\text{O}} \times 590.0 \text{ g H}_2\text{O} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.48 \text{ mol CaCl}_2$ $0.48 \text{ mol CaCl}_2 \times \frac{110.98 \text{ g CaCl}_2}{1 \text{ mol CaCl}_2} = 53 \text{ g CaCl}_2$
351. Given: 0.250 L of 5.00 M NH_3 diluted to 1.000 L Unknown: moles NH_3 ; final molarity	$0.250 \text{ L} \times \frac{5.00 \text{ mol NH}_3}{1 \text{ L}} = 1.25 \text{ mol NH}_3$ $\frac{1.25 \text{ mol NH}_3}{1.000 \text{ L}} = 1.25 \text{ M}$
352. Given: 62.0 g solute; 125 g H_2O ; 5.3 m solution Unknown: molar mass of solute	$\frac{5.3 \text{ mol solute}}{1.00 \text{ kg H}_2\text{O}} \times 125 \text{ g H}_2\text{O} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.662 \text{ mol solute}$ $M = \frac{62.0 \text{ g solute}}{0.662 \text{ mol solute}} = 93.7 \text{ g/mol}$
353. Given: 0.9% NaCl Unknown: masses of NaCl and H_2O to pre- pare 50. L	$50. \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.000 \text{ g}}{1 \text{ mL}} = 50\,000 \text{ g} = 50 \text{ kg}$ $\frac{0.9\%}{100\%} \times 50 \text{ kg} = 0.45 \text{ kg NaCl}; 50 \text{ kg} - 0.45 = 49.6 \text{ kg H}_2\text{O}$

354. Given: mass beaker = 68.60 g; mass beaker + H₂O = 115.12 g; 4.08 g glucose solute
Unknown: percentage concentration glucose

mass H₂O = 115.12 g – 68.60 g = 46.52 g
total mass of solution = 46.52 g + 4.08 g = 50.60 g
 $\frac{4.08 \text{ g glucose}}{50.60 \text{ g solution}} \times 100 = 8.06\% \text{ glucose}$

355. Given: D = 0.902 g/mL at 20°C for ethyl acetate solvent; cellulose nitrate solute
Unknown: V of solvent to prepare a 2.0% solution using 25 g of solute

$\frac{25 \text{ g}}{x + 25 \text{ g}} = 0.020$
 $x = \frac{25 \text{ g}}{0.020} - 25 \text{ g} = 1200 \text{ g solvent}$
 $1200 \text{ g solvent} \times \frac{1 \text{ mL}}{0.902 \text{ g}} = 1400 \text{ mL or } 1.4 \text{ L solvent}$

356. Given: reactants and products
Unknown: balanced equation

$\text{CdCl}_2 + \text{Na}_2\text{S} \rightarrow \text{CdS} + 2\text{NaCl}$

a. Given: 50.00 mL of a 3.91 M solution
Unknown: moles CdCl₂

$\frac{3.91 \text{ mol CdCl}_2}{1 \text{ L}} \times 50.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.196 \text{ mol CdCl}_2$

b. Given: 0.196 mol CdCl₂ from **a**; balanced equation; excess Na₂S
Unknown: moles CdS

$0.196 \text{ mol CdCl}_2 \times \frac{1 \text{ mol CdS}}{1 \text{ mol CdCl}_2} = 0.196 \text{ mol CdS}$

c. Given: 0.196 mol CdS from **b**
Unknown: mass CdS

$0.196 \text{ mol CdS} \times \frac{144.48 \text{ g CdS}}{1 \text{ mol CdS}} = 28.3 \text{ g CdS}$

357. Given: 60.00 mL of 5.85 M H₂SO₄ solution
Unknown: mass H₂SO₄

$\frac{5.85 \text{ mol H}_2\text{SO}_4}{1.00 \text{ L}} \times 60.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.351 \text{ mol H}_2\text{SO}_4$
 $0.351 \text{ mol H}_2\text{SO}_4 \times \frac{98.09 \text{ g H}_2\text{SO}_4}{1 \text{ mol H}_2\text{SO}_4} = 34.4 \text{ g H}_2\text{SO}_4$

358. Given: 22.5 kL of 6.83 M HCl
Unknown: moles HCl

$\frac{6.83 \text{ mol HCl}}{1.00 \text{ L}} \times 22.5 \text{ kL} \times \frac{1000 \text{ L}}{1 \text{ kL}} = 1.54 \times 10^5 \text{ mol HCl}$

359. Given: balanced equation; excess H_2SO_4 ; 0.600 M BaCl_2 solution
Unknown: V BaCl_2 solution to produce 12.00 g BaSO_4

$$12.00 \text{ g BaSO}_4 \times \frac{1 \text{ mol BaSO}_4}{233.40 \text{ g BaSO}_4} = 0.05141 \text{ mol BaSO}_4$$

$$0.05141 \text{ mol BaSO}_4 \times \frac{1 \text{ mol BaCl}_2}{1 \text{ mol BaSO}_4} = 0.05141 \text{ mol BaCl}_2$$

$$0.05141 \text{ mol BaCl}_2 \times \frac{1.00 \text{ L}}{0.600 \text{ mol BaCl}_2} = 0.0857 \text{ L BaCl}_2 = 85.7 \text{ mL BaCl}_2$$

360. Given: $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ solute

a. Given: 100. g of a 6.00% CuSO_4 solution

Unknown: preparation of solution

$$100. \text{ g} \times \frac{6.00\%}{100\%} \text{ CuSO}_4 = 6.00 \text{ g CuSO}_4$$

$$6.00 \text{ g CuSO}_4 \times \frac{1 \text{ mol CuSO}_4}{159.62 \text{ g CuSO}_4} \times \frac{1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}}{1 \text{ mol CuSO}_4}$$

$$\times \frac{249.72 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O}}{1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}} = 9.39 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O in } 100. \text{ g} - 9.39 \text{ g}$$

$$= 90.61 \text{ g H}_2\text{O}$$

b. Given: 1.00 L of a 0.800 M CuSO_4 solution

Unknown: preparation of solution

$$1.00 \text{ L} \times \frac{0.800 \text{ mol CuSO}_4}{1.00 \text{ L}} \times \frac{1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}}{1 \text{ mol CuSO}_4}$$

$$\times \frac{249.72 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O}}{1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}} = 200. \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O in water to make } 1.00 \text{ L}$$

of solution

c. Given: 3.5 m solution of CuSO_4 in 1.0 kg H_2O

Unknown: preparation of solution

$$\frac{3.5 \text{ mol CuSO}_4}{1.0 \text{ kg H}_2\text{O}} \times 1.0 \text{ kg H}_2\text{O} \times \frac{1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}}{1 \text{ mol CuSO}_4} \times \frac{249.72 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O}}{1 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}}$$

$$= 870 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O}$$

$$3.5 \text{ mol CuSO}_4 \times \frac{159.62 \text{ g CuSO}_4}{1 \text{ mol CuSO}_4} = 560 \text{ g CuSO}_4$$

$$870 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O} - 560 \text{ g CuSO}_4 = 310 \text{ g H}_2\text{O}$$

$$1.0 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} - 310 \text{ g} = 690 \text{ g added water}$$

361. Given: 700.0 mL of 2.50 M CaCl_2 solution

Unknown: mass $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$

$$700.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{2.50 \text{ mol CaCl}_2}{1 \text{ L}} \times \frac{1 \text{ mol CaCl}_2 \cdot 6\text{H}_2\text{O}}{1 \text{ mol CaCl}_2}$$

$$\times \frac{219.10 \text{ g CaCl}_2 \cdot 6\text{H}_2\text{O}}{1 \text{ mol CaCl}_2 \cdot 6\text{H}_2\text{O}} = 383 \text{ g CaCl}_2 \cdot 6\text{H}_2\text{O}$$

362. Given: 1.250 L of 0.00205 M $\text{C}_6\text{H}_{14}\text{N}_4\text{O}_2$

Unknown: mass of $\text{C}_6\text{H}_{14}\text{N}_4\text{O}_2$

$$1.250 \text{ L} \times \frac{0.00205 \text{ mol C}_6\text{H}_{14}\text{N}_4\text{O}_2}{1 \text{ L}} = 0.00256 \text{ mol C}_6\text{H}_{14}\text{N}_4\text{O}_2$$

$$0.00256 \text{ mol C}_6\text{H}_{14}\text{N}_4\text{O}_2 \times \frac{174.24 \text{ g C}_6\text{H}_{14}\text{N}_4\text{O}_2}{1 \text{ mol C}_6\text{H}_{14}\text{N}_4\text{O}_2} = 0.446 \text{ g C}_6\text{H}_{14}\text{N}_4\text{O}_2$$

363. Given: 2.402 kg
 $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$;
 25% solution
 Unknown: mass of
 water

$$2.402 \text{ kg NiSO}_4 \cdot 6\text{H}_2\text{O} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol NiSO}_4 \cdot 6\text{H}_2\text{O}}{262.88 \text{ g NiSO}_4 \cdot 6\text{H}_2\text{O}}$$

$$\times \frac{1 \text{ mol NiSO}_4}{1 \text{ mol NiSO}_4 \cdot 6\text{H}_2\text{O}} \times \frac{154.76 \text{ g NiSO}_4}{1 \text{ mol NiSO}_4} = 1414 \text{ g NiSO}_4$$

$$\frac{1414 \text{ g}}{x + 1414 \text{ g}} = 0.25; x = \frac{1414 \text{ g}}{0.25} - 1414 \text{ g} = 4242 \text{ g H}_2\text{O in solution}$$

$$4242 \text{ g H}_2\text{O} - (2402 \text{ g} - 1414 \text{ g}) = 3254 \text{ g H}_2\text{O added}$$

364. Given: $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ solute;
 35.0 g of a 15%
 $\text{KAl}(\text{SO}_4)_2$
 solution
 Unknown: mass of
 solute;
 mass of H_2O
 added

$$35.0 \text{ g} \times 0.15 \text{ KAl}(\text{SO}_4)_2 = 5.25 \text{ g KAl}(\text{SO}_4)_2$$

$$5.25 \text{ g KAl}(\text{SO}_4)_2 \times \frac{1 \text{ mol KAl}(\text{SO}_4)_2}{258.22 \text{ g KAl}(\text{SO}_4)_2} \times \frac{1 \text{ mol KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}}{1 \text{ mol KAl}(\text{SO}_4)_2}$$

$$\times \frac{474.46 \text{ g KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}}{1 \text{ mol KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}} = 9.646 \text{ g KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$$

$$35.0 \text{ g solution} - 9.646 \text{ g solute} = 25.35 \text{ g water added}$$

365. a. Given: $M_S =$
 0.500 M KBr;
 $V_S = 20.00 \text{ mL}$;
 $V_D =$
 100.00 mL;
 $M_S V_S = M_D V_D$
 Unknown: M_D

$$M_D = \frac{M_S V_S}{V_D} = \frac{0.500 \text{ M KBr} \times 20.00 \text{ mL}}{100.00 \text{ mL}} = 0.100 \text{ M KBr}$$

b. Given: $M_S = 1.00 \text{ M}$
 LiOH;
 $M_D = 0.075 \text{ M}$
 LiOH;
 $V_D =$
 500.00 mL;
 $M_S V_S = M_D V_D$
 Unknown: V_S

$$V_S = \frac{M_D V_D}{M_S} = \frac{0.075 \text{ M LiOH} \times 500.00 \text{ mL}}{1.00 \text{ M LiOH}} = 38 \text{ mL}$$

c. Given: $V_S = 5.00 \text{ mL}$;
 $M_D = 0.0493 \text{ M}$
 HI; $V_D =$
 100.00 mL;
 $M_S V_S = M_D V_D$
 Unknown: M_S

$$M_S = \frac{M_D V_D}{V_S} = \frac{0.0493 \text{ M HI} \times 100.00 \text{ mL}}{5.00 \text{ mL}} = 0.986 \text{ M HI}$$

d. Given: $M_S = 12.0 \text{ M}$
 HCl; $V_S =$
 0.250 L; $M_D =$
 1.8 M HCl;
 $M_S V_S = M_D V_D$
 Unknown: V_D

$$V_D = \frac{M_S V_S}{M_D} = \frac{12.0 \text{ M HCl} \times 0.250 \text{ L}}{1.8 \text{ M HCl}} = 1.7 \text{ L}$$

e. Given: $M_S = 7.44 \text{ M}$
 NH_3 ; $M_D =$
 0.093 M NH_3 ;
 $V_D = 4.00 \text{ L}$;
 $M_S V_S = M_D V_D$

$$V_S = \frac{M_D V_D}{M_S} = \frac{0.093 \text{ M NH}_3 \times 4.00 \text{ L}}{7.44 \text{ M NH}_3} = 0.050 \text{ L} = 50. \text{ mL}$$

Unknown: V_S

366. Given: $M_S = 0.0813 \text{ M}$;
 $V_S = 16.5 \text{ mL}$;
 $M_D = 0.0200 \text{ M}$;
 $M_S V_S = M_D V_D$

$$V_D = \frac{M_S V_S}{M_D} = \frac{0.0813 \text{ M} \times 16.5 \text{ mL}}{0.0200 \text{ M}} = 67.1 \text{ mL}$$

$67.1 \text{ mL} - 16.5 \text{ mL} = 50.6 \text{ mL H}_2\text{O added}$

Unknown: V_D ; V of
 water added

367. Given: $M_S = 3.79 \text{ M}$
 NH_4Cl ; $V_S =$
 50.00 mL ; $V_D =$
 2.00 L ; $M_S V_S =$
 $M_D V_D$

$$M_D = \frac{M_S V_S}{V_D} = \frac{3.79 \text{ M NH}_4\text{Cl} \times 50.00 \text{ mL}}{2000 \text{ mL}} = 0.0948 \text{ M NH}_4\text{Cl}$$

Unknown: M_D

368. Given: $100.00 \text{ mL H}_2\text{O}$
 added; $M_D =$
 0.046 M KOH ;
 $M_S = 2.09 \text{ M}$
 KOH ; $M_S V_S =$
 $M_D V_D$

$$V_D = V_S + 100.00 \text{ mL}$$

$$M_S V_S = M_D V_D$$

$$2.09 \text{ M KOH} \times V_S = 0.046 \text{ M KOH} (V_S + 100.00 \text{ mL})$$

$$V_S = 2.3 \text{ mL}$$

Unknown: V_S

369. a. Given: $V_S =$
 20.00 mL ;
 $M_D = 0.50 \text{ M}$;
 100.00 mL
 $\text{H}_2\text{O added}$;
 $M_S V_S =$
 $M_D V_D$

$$M_S = \frac{M_D V_D}{V_S} = \frac{0.50 \text{ M} \times (100.00 \text{ mL} + 20.00 \text{ mL})}{20.00 \text{ mL}} = 3.0 \text{ M}$$

Unknown: M_S

b. Given: $V_D = 5.00 \text{ L}$;
 $M_D = 3.0 \text{ M}$;
 $M_S = 18.0 \text{ M}$;
 $M_S V_S =$
 $M_D V_D$

$$V_S = \frac{M_D V_D}{M_S} = \frac{3.0 \text{ M} \times 5.00 \text{ L}}{18.0 \text{ M}} = 0.83 \text{ L}$$

Unknown: V_S

c. Given: $V = 0.83 \text{ L}$,
 from b; $D =$
 1.84 g/mL

$$m = VD = 0.83 \text{ L} \times 1.84 \frac{\text{g}}{\text{mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1.5 \times 10^3 \text{ g}$$

Unknown: mass
 H_2SO_4

370. Given: $V_S = 1.19 \text{ mL}$;
 $M_S = 8.00 \text{ M}$; M_D
 $= 1.50 \text{ M}$; $M_S V_S =$
 $M_D V_D$

$$V_D = \frac{M_S V_S}{M_D} = \frac{8.00 \text{ M} \times 1.19 \text{ mL}}{1.50 \text{ M}} = 6.35 \text{ mL}$$

Unknown: V_D

371. Given: $M_S = 5.75 \text{ M}$; $V_D = 2.00 \text{ L}$; $M_D = 1.00 \text{ M}$; $M_S V_S = M_D V_D$
 Unknown: V_S

$$V_S = \frac{M_D V_D}{M_S} = \frac{1.00 \text{ M} \times 2.00 \text{ L}}{5.75 \text{ M}} = 0.348 \text{ L or } 348 \text{ mL}$$

372. a. Given: $V_S = 25.00 \text{ mL}$; $M_D = 0.186 \text{ M}$; $50.00 \text{ mL H}_2\text{O}$ added; $M_S V_S = M_D V_D$
 Unknown: M_S

$$M_S = \frac{M_D V_D}{V_S} = \frac{0.186 \text{ M} \times (25.00 \text{ mL} + 50.00 \text{ mL})}{25.00 \text{ mL}} = 0.558 \text{ M}$$

373. a. Given: 36% HCl solution; $D = 1.18 \text{ g/mL}$
 Unknown: V_1 of 1.0 kg of HCl solution;
 V_2 that contains 1.0 g HCl;
 V_3 that contains 1.0 mol HCl

$$V_1 = \frac{m}{D} = 1.0 \text{ kg} \times \frac{1 \text{ mL}}{1.18 \text{ g}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 850 \text{ mL}$$

$$V_2 = \frac{100\% \times 1 \text{ g}}{36\%} \times \frac{1 \text{ mL}}{1.18 \text{ g}} = 2.4 \text{ mL}$$

$$V_3 = 36.46 \text{ g} \times \frac{100\%}{36\%} \times \frac{1 \text{ mL}}{1.18 \text{ g}} = 86 \text{ mL}$$

b. Given: $D = 1.42 \text{ g/mL}$; 71% HNO_3 solution; $M_S V_S = M_D V_D$
 Unknown: V of HNO_3 to prepare 10.0 L of 2.00 M HNO_3 (V_S)

$$\frac{71 \text{ g HNO}_3}{100 \text{ g}} \times \frac{1.42 \text{ g}}{1 \text{ mL}} \times \frac{1 \text{ mol HNO}_3}{63.02 \text{ g HNO}_3} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 16 \frac{\text{mol HNO}_3}{\text{L}} = 16 \text{ M HNO}_3$$

$$V_S = \frac{M_D V_D}{M_S} = \frac{2.00 \text{ M} \times 10.0 \text{ L}}{16 \text{ M}} = 1.2 \text{ L}$$

c. Given: 86 mL contains 1.0 mol (from **a**); $M_S V_S = M_D V_D$; $M_D = 3.0 \text{ M}$; $V_D = 4.50 \text{ L}$
 Unknown: V_S

$$M_S = \frac{1 \text{ mol}}{86 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 12 \text{ M}$$

$$V_S = \frac{M_D V_D}{M_S} = \frac{3.0 \text{ M} \times 4.50 \text{ L}}{12 \text{ M}} = 1.1 \text{ L}$$

374. Given: $M_S = 3.8 \text{ M}$; $V_D = 8 V_S$; $M_S V_S = M_D V_D$
 Unknown: M_D

$$M_D = \frac{M_S V_S}{V_D} = \frac{3.8 \text{ M} \times V_S}{8 V_S} = 0.48 \text{ M}$$

- 375.** Given: $M_D = 2.50 \text{ M}$;
 $V_D = 480. \text{ mL}$;
 $39 \text{ mL H}_2\text{O}$
 evaporated;
 $M_S V_S = M_D V_D$
 Unknown: M_S
- $$M_S = \frac{M_D V_D}{V_S} = \frac{2.50 \text{ M} \times 480. \text{ mL}}{(480. - 39) \text{ mL}} = 2.72 \text{ M}$$
-
- 376.** Given: $M_D = 1.22 \text{ M}$;
 $V_D = 25.00 \text{ mL}$;
 $M_S = 6.45 \text{ M}$;
 $M_S V_S = M_D V_D$
 Unknown: V_S ;
 procedure
- $$V_S = \frac{M_D V_D}{M_S} = \frac{1.22 \text{ M} \times 25.00 \text{ mL}}{6.45 \text{ M}} = 4.73 \text{ mL}$$
- Dilute the 6.45 M acid by adding 4.73 mL of it to enough distilled water to make 25.00 mL of solution.
-
- 377.** Given: 100.0 mL of a
 2.41 M solution;
 9.56 g solute
 Unknown: molar mass
 of solute
- $$100.0 \text{ mL} \times \frac{2.41 \text{ mol}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.241 \text{ mol solute}$$
- $$\text{molar mass} = \frac{9.56 \text{ g}}{0.241 \text{ mol}} = 39.7 \text{ g/mol}$$
-
- 378.** Given: 34 g I_2 ; $V_S = 25 \text{ mL}$; $V_D = 500 \text{ mL}$; $M_S V_S = M_D V_D$
 Unknown: M_D
- $$M_S = \frac{34 \text{ g I}_2}{25 \text{ mL}} \times \frac{1 \text{ mol I}_2}{253.8 \text{ g I}_2} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 5.36 \text{ M}$$
- $$M_D = \frac{M_S V_S}{V_D} = \frac{5.36 \text{ M} \times 25 \text{ mL}}{500 \text{ mL}} = 0.27 \text{ M}$$
-
- 379.** Given: 85% H_3PO_4
 solution;
 $V = 600.0 \text{ mL}$;
 2.80 M
 Unknown: mass of
 solution
- $$600.0 \text{ mL} \times \frac{2.80 \text{ mol}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.68 \text{ mol H}_3\text{PO}_4$$
- $$1.68 \text{ mol H}_3\text{PO}_4 \times \frac{98.00 \text{ g H}_3\text{PO}_4}{1 \text{ mol H}_3\text{PO}_4} = 165 \text{ g H}_3\text{PO}_4$$
- $$\text{mass of solution} = \frac{165 \text{ g H}_3\text{PO}_4 \times 100. \text{ g solution}}{85 \text{ g H}_3\text{PO}_4} = 190 \text{ g solution}$$
-
- 380.** Given: $M_S = 18.0 \text{ M}$;
 $M_D = 4.0 \text{ M}$;
 $V_D = 3.00 \text{ L}$;
 $M_S V_S = M_D V_D$
 Unknown: V_S
- $$V_S = \frac{M_D V_D}{M_S} = \frac{4.0 \text{ M} \times 3.00 \text{ L}}{18.0 \text{ M}} = 0.67 \text{ L}$$
-
- 381.** Given: $V_D = 1.00 \text{ L}$; $M_D = 0.495 \text{ M}$;
 $M_S = 3.07 \text{ M}$;
 $M_S V_S = M_D V_D$
 Unknown: V_S
- $$V_S = \frac{M_D V_D}{M_S} = \frac{0.495 \text{ M} \times 1.00 \text{ L}}{3.07 \text{ M}} = 0.161 \text{ L} = 161 \text{ mL}$$
- Dilute 161 mL stock urea solution to 1.00 L.
-
- 382. a.** Given: 76.2%
 $\text{C}_6\text{H}_{12}\text{O}_6$
 Unknown: molality
- $$\frac{76.2 \text{ g C}_6\text{H}_{12}\text{O}_6}{(100. - 76.2) \text{ g H}_2\text{O}} \times \frac{1 \text{ mol C}_6\text{H}_{12}\text{O}_6}{180.18 \text{ g C}_6\text{H}_{12}\text{O}_6} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 17.8 \text{ m}$$

b. Given: 76.2% $\text{C}_6\text{H}_{12}\text{O}_6$;
 $D = 1.42 \text{ g/mL}$;
 $V = 1.00 \text{ L}$

$$\frac{1.42 \text{ g}}{1 \text{ mL}} \times 1.00 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{76.2\%}{100\%} = 1080 \text{ g}$$

$$\frac{1080 \text{ g}}{1 \text{ L}} \times \frac{1 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6}{180.18 \text{ g } \text{C}_6\text{H}_{12}\text{O}_6} = 5.99 \text{ M}$$

Unknown: mass of $\text{C}_6\text{H}_{12}\text{O}_6$;
 molarity

383. Given: $M_D = 0.0890 \text{ M}$;
 $V_S = 10.00 \text{ mL}$;
 $V_D = 50.00 \text{ mL}$;
 $M_S V_S = M_D V_D$;
 molar mass $\text{Na}_2\text{CO}_3 = 105.99 \text{ g}$

$$M_S = \frac{M_D V_D}{V_S} = \frac{0.0890 \text{ M} \times 50.00 \text{ mL}}{10.00 \text{ mL}} = 0.445 \text{ M}$$

$$\frac{0.445 \text{ mol}}{1 \text{ L}} \times 1.000 \text{ L} \times \frac{105.99 \text{ g}}{1 \text{ mol}} = 47.17 \text{ g } \text{Na}_2\text{CO}_3$$

$$\frac{47.17 \text{ g } \text{Na}_2\text{CO}_3}{50.00 \text{ g sample}} \times 100 = 94.34\% \text{ Na}_2\text{CO}_3$$

Unknown: M_S ; percent-
 age Na_2CO_3
 in 50.00 g of
 a material
 used to make
 1.000 L stock
 solution

384. Given: V_T of CuCl_2
 stock solution
 $= 0.600 \text{ L}$;
 $V_S = 20.0 \text{ mL}$;
 $V_D = 150.0 \text{ mL}$;
 $M_D = 0.250 \text{ M}$;
 $M_S V_S = M_D V_D$

$$M_S = \frac{M_D V_D}{V_S} = \frac{0.250 \text{ M} \times 150.0 \text{ mL}}{20.0 \text{ mL}} = 1.88 \text{ M}$$

$$\frac{1.88 \text{ mol } \text{CuCl}_2}{1 \text{ L}} \times 0.600 \text{ L} \times \frac{134.45 \text{ g } \text{CuCl}_2}{1 \text{ mol } \text{CuCl}_2} = 152 \text{ g } \text{CuCl}_2$$

Unknown: mass CuCl_2
 to make
 stock
 solution

385. Given: $M_S = 2.15 \text{ M}$;
 $M_D = 0.65 \text{ M}$;
 $M_S V_S = M_D V_D$

$$2.15 \text{ M} \times V = 0.65 \times \text{kV}; \text{k} = 3.3; V_D = 3.3 V_S$$

$$V_D - V_S = 3.3 V_S - 1.0 V_S = 2.3 V_S; \text{Add } 2.3 \text{ volumes of } \text{H}_2\text{O} \text{ per volume of stock solution.}$$

Unknown: dilution
 factor

386. a. Given: 18.2%
 $\text{Sr}(\text{NO}_3)_2$
 solution;
 $D = 1.02 \text{ g/mL}$
 $V = 80.00 \text{ mL}$

$$80.00 \text{ mL} \times \frac{1.02 \text{ g}}{1 \text{ mL}} \times \frac{18.2 \text{ g } \text{Sr}(\text{NO}_3)_2}{100 \text{ g solution}} = 14.9 \text{ g } \text{Sr}(\text{NO}_3)_2$$

Unknown: mass of
 $\text{Sr}(\text{NO}_3)_2$

b. Given: 14.9 g
 $\text{Sr}(\text{NO}_3)_2$
 from **a**

$$14.9 \text{ g } \text{Sr}(\text{NO}_3)_2 \times \frac{1 \text{ mol } \text{Sr}(\text{NO}_3)_2}{211.64 \text{ g } \text{Sr}(\text{NO}_3)_2} = 7.04 \times 10^{-2} \text{ mol } \text{Sr}(\text{NO}_3)_2$$

Unknown: moles Sr
 $(\text{NO}_3)_2$

c. Given: 7.04×10^{-2}
mol $\text{Sr}(\text{NO}_3)_2$
from **b**;
420.0 mL
 H_2O added
Unknown: molarity
(M_D)

$$M_S = \frac{7.04 \times 10^{-2} \text{ mol}}{80.0 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.880 \text{ M}$$

$$M_D = \frac{M_S V_S}{V_D} = \frac{0.880 \text{ M} \times 80.0 \text{ mL}}{(80.0 + 420.0) \text{ mL}} = 0.141 \text{ M}$$

387. Given: 60.0 g $\text{C}_6\text{H}_{12}\text{O}_6$
in 80.0 g H_2O ;
 K_f for water =
 $-1.86^\circ\text{C}/m$;
 $\Delta t_f = K_f m$

Unknown: freezing
point

$$60.0 \text{ g } \text{C}_6\text{H}_{12}\text{O}_6 \times \frac{1 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6}{180.18 \text{ g } \text{C}_6\text{H}_{12}\text{O}_6} = 0.333 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6$$

$$\frac{0.333 \text{ mol } \text{C}_6\text{H}_{12}\text{O}_6}{80.0 \text{ g } \text{H}_2\text{O}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 4.16 \text{ m}$$

$$\Delta t_f = K_f m = \frac{-1.86^\circ\text{C}}{m} \times 4.16 \text{ m} = -7.74^\circ\text{C}$$

$$\text{fp (solution)} = \text{fp (solvent)} + \Delta t_f = 0.00^\circ\text{C} - 7.74^\circ\text{C} = -7.74^\circ\text{C}$$

388. Given: 645 g
 H_2NCONH_2 ;
980. g H_2O

Unknown: freezing
point

$$645 \text{ g } \text{H}_2\text{NCONH}_2 \times \frac{1 \text{ mol } \text{H}_2\text{NCONH}_2}{60.07 \text{ g } \text{H}_2\text{NCONH}_2} = 10.7 \text{ mol } \text{H}_2\text{NCONH}_2$$

$$\frac{10.7 \text{ mol } \text{H}_2\text{NCONH}_2}{980. \text{ g } \text{H}_2\text{O}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 10.9 \text{ m}$$

$$\Delta t_f = K_f m = -\frac{1.86^\circ\text{C}}{m} \times 10.9 \text{ m} = -20.3^\circ\text{C}$$

$$f_p = 0.0^\circ\text{C} - 20.3^\circ\text{C} = -20.3^\circ\text{C}$$

389. Given: 30.00 g KBr;
100.00 g H_2O

Unknown: boiling point

$$30.00 \text{ g KBr} \times \frac{1 \text{ mol KBr}}{119.00 \text{ g KBr}} = 0.252 \text{ mol KBr}$$

$$\Delta t_b = \frac{0.252 \text{ mol KBr}}{100.00 \text{ g } \text{H}_2\text{O}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{2 \text{ mol ions}}{1 \text{ mol KBr}} \times \frac{0.51^\circ\text{C}}{\text{mol}} = 2.6^\circ\text{C}$$

$$\text{bp} = 100.0^\circ\text{C} + 2.6^\circ\text{C} = 102.6^\circ\text{C}$$

390. Given: 385 g CaCl_2 ;
 $1.230 \times 10^3 \text{ g}$
 H_2O

Unknown: boiling point

$$385 \text{ g } \text{CaCl}_2 \times \frac{1 \text{ mol } \text{CaCl}_2}{110.97 \text{ g } \text{CaCl}_2} = 3.47 \text{ mol } \text{CaCl}_2$$

$$\Delta t_b = \frac{3.47 \text{ mol } \text{CaCl}_2}{1.230 \times 10^3 \text{ g } \text{H}_2\text{O}} \times \frac{10^3 \text{ g}}{1 \text{ kg}} \times \frac{3 \text{ mol ions}}{1 \text{ mol } \text{CaCl}_2} \times \frac{0.51^\circ\text{C}}{m} = 4.3^\circ\text{C}$$

$$\text{bp} = 100.0^\circ\text{C} + 4.3^\circ\text{C} = 104.3^\circ\text{C}$$

391. Given: 0.827 g nonelec-
trolyte; 2.500 g
 H_2O ; fp =
 -10.18°C

Unknown: molar mass

$$m = \frac{\Delta t_f}{K_f} = \frac{-10.18^\circ\text{C}}{-1.86^\circ\text{C}/m} = 5.47 \text{ m}$$

$$\frac{5.47 \text{ mol}}{1.00 \text{ kg } \text{H}_2\text{O}} \times 2.500 \text{ g } \text{H}_2\text{O} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.0137 \text{ mol}$$

$$\frac{0.827 \text{ g}}{0.0137 \text{ mol}} = 60.4 \text{ g/mol}$$

- 392.** Given: 0.171 g nonelectrolyte; ether solvent; mass of solution = 2.470 g; bp = 36.43°C
Unknown: molar mass
- $$\text{mass of ether solvent} = 2.470 \text{ g} - 0.171 \text{ g} = 2.299 \text{ g}$$
- $$\Delta t_b = \text{bp} - \text{normal bp} = 36.43^\circ\text{C} - 34.6^\circ\text{C} = 1.83^\circ\text{C}$$
- $$m = \frac{\Delta t_b}{K_b} = \frac{1.83^\circ\text{C}}{2.02^\circ\text{C}/m} = 0.906 m$$
- $$\frac{0.906 \text{ mol}}{1.00 \text{ kg ether}} \times 2.299 \text{ g ether} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.00208 \text{ mol}$$
- $$\frac{0.171 \text{ g}}{0.00208 \text{ mol}} = 82.2 \text{ g/mol}$$
-
- 393.** Given: 383 g glucose; 400. g H₂O
Unknown: freezing point; boiling point
- $$383 \text{ g C}_6\text{H}_{12}\text{O}_6 \times \frac{1 \text{ mol C}_6\text{H}_{12}\text{O}_6}{180.18 \text{ g C}_6\text{H}_{12}\text{O}_6} = 2.13 \text{ mol C}_6\text{H}_{12}\text{O}_6$$
- $$\frac{2.13 \text{ mol}}{400. \text{ g H}_2\text{O}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 5.32 m$$
- $$\text{fp} = \text{normal fp} + (K_f m) = 0.00^\circ\text{C} + \left(\frac{-1.86^\circ\text{C}}{m} \times 5.32 m \right) = -9.90^\circ\text{C}$$
- $$\text{bp} = \text{normal bp} + (K_b m) = 100.00^\circ\text{C} + \left(\frac{0.51^\circ\text{C}}{m} \times 5.32 m \right) = 102.7^\circ\text{C}$$
-
- 394.** Given: 72.4 g glycerol; 122.5 g H₂O
Unknown: boiling point
- $$72.4 \text{ g glycerol} \times \frac{1 \text{ mol glycerol}}{92.08 \text{ g glycerol}} = 0.786 \text{ mol glycerol}$$
- $$\frac{0.786 \text{ mol}}{122.5 \text{ g H}_2\text{O}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 6.42 m$$
- $$\text{bp} = \text{normal bp} + (K_b m) = 100.00^\circ\text{C} + \left(\frac{0.51^\circ\text{C}}{m} \times 6.42 m \right) = 103.3^\circ\text{C}$$
-
- 395.** Given: 30.20 g HOCH₂CH₂OH solute; 88.40 g phenol
Unknown: boiling point
- $$30.20 \text{ g HOCH}_2\text{CH}_2\text{OH} \times \frac{1 \text{ mol HOCH}_2\text{CH}_2\text{OH}}{62.08 \text{ g HOCH}_2\text{CH}_2\text{OH}} = 0.4865 \text{ mol HOCH}_2\text{CH}_2\text{OH}$$
- $$\frac{0.4865 \text{ mol}}{88.04 \text{ g}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 5.503 m$$
- $$\text{bp} = \text{normal bp} + (K_b m) = 181.8^\circ\text{C} + \left(\frac{3.60^\circ\text{C}}{m} \times 5.503 m \right) = 201.6^\circ\text{C}$$
-
- 396.** Given: 450. g H₂O; fp = -4.5°C
Unknown: mass of ethanol solute
- $$m = \frac{\text{fp}}{K_f} = \frac{-4.5^\circ\text{C}}{-1.86^\circ\text{C}/m} = 2.4 m$$
- $$\frac{2.4 \text{ mol}}{1 \text{ kg}} \times 450. \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 1.1 \text{ mol}$$
- $$1.1 \text{ mol ethanol} \times \frac{46.08 \text{ g ethanol}}{1 \text{ mol ethanol}} = 51 \text{ g ethanol}$$

- 397.** Given: fp = -3.9°C 25.00 g H_2O ; 4.27 g solute
Unknown: molar mass of solute
- $$m = \frac{\text{fp}}{K_f} = \frac{-3.9^{\circ}\text{C}}{-1.86^{\circ}\text{C}/m} = 2.1\ m$$
- $$\frac{2.1\ \text{mol}}{1\ \text{kg}\ \text{H}_2\text{O}} \times 25.00\ \text{g}\ \text{H}_2\text{O} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.052\ \text{mol}$$
- $$\frac{4.27\ \text{g}}{0.052\ \text{mol}} = 82\ \text{g/mol}$$
-
- 398.** Given: 1.17 g $\text{C}_{10}\text{H}_8\text{O}$; 2.00 mL benzene; $T = 20^{\circ}\text{C}$; D of benzene = $0.876\ \text{g/mL}$; K_f for benzene = $-5.12^{\circ}\text{C}/m$; normal fp of benzene = 5.53°C
Unknown: freezing point
- $$\text{mass benzene} = 2.00\ \text{mL} \times \frac{0.8769}{1\ \text{mL}} = 1.75\ \text{g}$$
- $$\text{mol}\ \text{C}_{10}\text{H}_8\text{O} = 1.17\ \text{g}\ \text{C}_{10}\text{H}_8\text{O} \times \frac{1\ \text{mol}\ \text{C}_{10}\text{H}_8\text{O}}{144.18\ \text{g}\ \text{C}_{10}\text{H}_8\text{O}} = 0.00811\ \text{mol}\ \text{C}_{10}\text{H}_8\text{O}$$
- $$\frac{0.00811\ \text{mol}\ \text{C}_{10}\text{H}_8\text{O}}{1.75\ \text{g}\ \text{benzene}} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 4.63\ m$$
- $$\text{fp} = \text{normal fp} + (K_fm) = 5.53^{\circ}\text{C} + \left(\frac{-5.12^{\circ}\text{C}}{m} \times 4.63\ m \right) = -18.2^{\circ}\text{C}$$
-
- 399.** Given: 10.44 g solute; 50.00 g CH_3COOH solvent; bp = 159.2°C
Unknown: molar mass
- $$m = \frac{\text{bp} - \text{normal bp}}{K_b} = \frac{159.2^{\circ}\text{C} - 117.9^{\circ}\text{C}}{3.07^{\circ}\text{C}/m} = 13.5\ m$$
- $$\frac{13.5\ \text{mol}}{1\ \text{kg}\ \text{solvent}} \times 50.00\ \text{g}\ \text{solvent} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.675\ \text{mol}$$
- $$\frac{10.44\ \text{g}}{0.675\ \text{mol}} = 15.5\ \text{g/mol}$$
-
- 400.** Given: 0.0355 g solute; 1.000 g camphor solvent; $T = 200.0^{\circ}\text{C}$; fp = 157.7°C
Unknown: molar mass
- $$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{157.7^{\circ}\text{C} - 178.8^{\circ}\text{C}}{-39.7^{\circ}\text{C}/m} = 0.531\ m$$
- $$\frac{0.531\ \text{mol}}{1\ \text{kg}\ \text{solvent}} \times 1.000\ \text{g}\ \text{solvent} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 5.31 \times 10^{-4}\ \text{mol}$$
- $$\frac{0.0355\ \text{g}}{5.31 \times 10^{-4}\ \text{mol}} = 66.8\ \text{g/mol}$$
-
- 401.** Given: 22.5 g $\text{C}_6\text{H}_{12}\text{O}_6$; 294 g phenol
Unknown: boiling point
- $$22.5\ \text{g}\ \text{C}_6\text{H}_{12}\text{O}_6 \times \frac{1\ \text{mol}\ \text{C}_6\text{H}_{12}\text{O}_6}{180.18\ \text{g}\ \text{C}_6\text{H}_{12}\text{O}_6} = 0.125\ \text{mol}\ \text{C}_6\text{H}_{12}\text{O}_6$$
- $$\frac{0.125\ \text{mol}}{294\ \text{g}} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 0.425\ m$$
- $$\text{bp} = 181.8^{\circ}\text{C} + (3.60^{\circ}\text{C}/m \times 0.425\ m) = 183.3^{\circ}\text{C}$$
-
- 402.** Given: 50.0% solution of ethylene glycol in H_2O
- $$\frac{50.0\ \text{g}\ \text{ethylene glycol}}{50.0\ \text{g}\ \text{H}_2\text{O}} \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol}\ \text{ethylene glycol}}{62.08\ \text{g}\ \text{ethylene glycol}} = 16.1\ m$$
- a.** Unknown: freezing point
- $$\text{fp} = \text{normal fp} + (K_fm) = 0.00^{\circ}\text{C} + (-1.86^{\circ}\text{C}/m \times 16.1\ m) = -29.9^{\circ}\text{C}$$
- b.** Unknown: boiling point
- $$\text{bp} = \text{normal bp} + (K_bm) = 100.00^{\circ}\text{C} + (0.51^{\circ}\text{C}/m \times 16.1\ m) = 108.2^{\circ}\text{C}$$

403. Given: $K_f = -20.0^\circ\text{C}/m$;
normal fp =
 6.6°C ; cyclo-
hexane solvent;
1.604 g solute;
10.000 g cyclo-
hexane; fp =
 -4.4°C

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-4.4^\circ\text{C} - 6.6^\circ\text{C}}{-20.0^\circ\text{C}/m} = 0.550\ m$$

$$\frac{0.550\ \text{mol}}{1.00\ \text{kg solvent}} \times 10.000\ \text{g solvent} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.00550\ \text{mol}$$

$$\frac{1.604\ \text{g}}{0.00550\ \text{mol}} = 292\ \text{g/mol}$$

Unknown: molar mass

404. Given: 2.62 kg HNO_3 ;
 H_2O solvent;
mass of solution
= 5.91 kg

mass $\text{H}_2\text{O} = 5.91\ \text{kg} - 2.62\ \text{kg} = 3.29\ \text{kg}$

$$2.62\ \text{kg HNO}_3 \times \frac{1\ \text{mol HNO}_3}{63.02\ \text{g HNO}_3} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 41.6\ \text{mol HNO}_3 = 83.2\ \text{mol ions}$$

Unknown: freezing
point

$$\frac{83.2\ \text{mol ions}}{3.29\ \text{kg H}_2\text{O}} = 25.3\ m$$

$$\text{fp} = \text{normal fp} + (K_f m) = 0.00^\circ\text{C} + (-1.86^\circ\text{C}/m \times 25.3\ m) = -47.1^\circ\text{C}$$

405. Given: 0.5190 g naph-
thalene solvent;
mass solution =
0.5959 g; fp =
 74.8°C

mass solute = $0.5959\ \text{g} - 0.5190\ \text{g} = 0.0769\ \text{g}$

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{74.8^\circ\text{C} - 80.2^\circ\text{C}}{-6.94^\circ\text{C}/m} = 0.778\ m$$

Unknown: molar mass

$$\frac{0.778\ \text{mol}}{1.00\ \text{kg solvent}} \times 0.5190\ \text{g solvent} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 4.04 \times 10^{-4}\ \text{mol}$$

$$\frac{0.0769\ \text{g}}{4.04 \times 10^{-4}\ \text{mol}} = 190.\ \text{g/mol}$$

406. Given: 8.69 g
 NaCH_3COO ;
15.00 g H_2O

$8.69\ \text{g NaCH}_3\text{COO} \times \frac{1\ \text{mol NaCH}_3\text{COO}}{82.04\ \text{g NaCH}_3\text{COO}} \times \frac{2\ \text{mol ions}}{1\ \text{mol NaCH}_3\text{COO}}$

= 0.212 mol ions

Unknown: boiling point

$$\frac{0.212\ \text{mol}}{15.00\ \text{g H}_2\text{O}} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 14.1\ m$$

$$\text{bp} = \text{normal bp} + (K_b m) = 100.00^\circ\text{C} + (0.51^\circ\text{C}/m \times 14.1\ m) = 107.2^\circ\text{C}$$

407. Given: 110.5 g H_2SO_4 ;
225 g H_2O

$110.5\ \text{g H}_2\text{SO}_4 \times \frac{1\ \text{mol H}_2\text{SO}_4}{98.09\ \text{g H}_2\text{SO}_4} \times \frac{3\ \text{mol ions}}{1\ \text{mol H}_2\text{SO}_4} = 3.38\ \text{mol ions}$

Unknown: freezing
point

$$\frac{3.38\ \text{mol}}{225\ \text{g H}_2\text{O}} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 15.0\ m$$

$$\text{fp} = \text{normal fp} + (K_f m) = 0.00^\circ\text{C} + (-1.86^\circ\text{C}/m \times 15.0\ m) = -27.9^\circ\text{C}$$

- 408.** Given: empirical formula is C_8H_5 ;
4.04 g pyrene;
10.00 g benzene solvent; bp = 85.1°C ; $K_b = 2.53^\circ\text{C}/m$; normal bp = 80.1°C
- Unknown: molar mass;
molecular formula
- $$m = \frac{\text{bp} - \text{normal bp}}{K_b} = \frac{85.1^\circ\text{C} - 80.1^\circ\text{C}}{2.53^\circ\text{C}/m} = 1.98\ m$$
- $$\frac{1.98\ \text{mol}}{1\ \text{Kg solvent}} \times 10.00\ \text{g solvent} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.0198\ \text{mol}$$
- $$\frac{4.04\ \text{g}}{0.0198\ \text{mol}} = 204\ \text{g/mol}$$
- $$\text{molar mass } \text{C}_8\text{H}_5 = 101.13\ \text{g/mol}$$
- $$\frac{204\ \text{g}}{1\ \text{mol}} \times \frac{1\ \text{mol}}{101.13\ \text{g}} = 2.02 \approx 2$$
- $$\text{molecular formula} = \text{C}_{8 \times 2}\text{H}_{5 \times 2} = \text{C}_{16}\text{H}_{10}$$
-
- 409.** Given: CaCl_2 solute;
100.00 g H_2O ;
fp = -5.0°C
- Unknown: mass CaCl_2 ;
mass $\text{C}_6\text{H}_{12}\text{O}_6$
for same fp
- $$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-5.0^\circ\text{C} - 0.0^\circ\text{C}}{-1.86^\circ\text{C}/m} = 2.7\ m\ (\text{ions})$$
- $$\frac{2.7\ \text{mol ions}}{1.0\ \text{kg}} \times \frac{1\ \text{mol } \text{CaCl}_2}{3\ \text{mol ions}} = 0.90\ m\ \text{CaCl}_2$$
- $$\frac{0.90\ \text{mol } \text{CaCl}_2}{1.0\ \text{kg } \text{H}_2\text{O}} \times 100.00\ \text{g } \text{H}_2\text{O} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.090\ \text{mol } \text{CaCl}_2$$
- $$0.090\ \text{mol } \text{CaCl}_2 \times \frac{110.98\ \text{g } \text{CaCl}_2}{1\ \text{mol } \text{CaCl}_2} = 10.\ \text{g } \text{CaCl}_2$$
- Because glucose is a nonelectrolyte, m of glucose = 2.7 m
- $$\frac{2.7\ \text{mol glucose}}{1.0\ \text{kg } \text{H}_2\text{O}} \times 100.00\ \text{g } \text{H}_2\text{O} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.27\ \text{mol glucose}$$
- $$0.27\ \text{mol } \text{C}_6\text{H}_{12}\text{O}_6 \times \frac{180.18\ \text{g } \text{C}_6\text{H}_{12}\text{O}_6}{1\ \text{mol } \text{C}_6\text{H}_{12}\text{O}_6} = 49\ \text{g glucose}$$
-
- 410.** Given: empirical formula is CH_2O ;
0.0866 g solute;
1.000 g ether;
bp = 36.5°C
- Unknown: molecular formula
- $$m = \frac{\text{bp} - \text{normal bp}}{K_b} = \frac{36.5^\circ\text{C} - 34.6^\circ\text{C}}{2.02^\circ\text{C}/m} = 0.941\ m$$
- $$\frac{0.941\ \text{mol}}{1.00\ \text{kg solvent}} \times 1.000\ \text{g solvent} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 9.41 \times 10^{-4}\ \text{mol}$$
- $$\frac{0.0866\ \text{g}}{9.41 \times 10^{-4}\ \text{mol}} = 92.0\ \text{g/mol for the molecule}$$
- $$\text{molar mass } \text{CH}_2\text{O} = 30.03\ \text{g/mol}$$
- $$\frac{92.0\ \text{g/mol}}{30.03\ \text{g/mol}} = 3.06$$
- $$\text{molecular formula} = \text{C}_{1 \times 3}\text{H}_{2 \times 3}\text{O}_{1 \times 3} = \text{C}_3\text{H}_6\text{O}_3$$
-
- 411.** Given: 28.6% HCl by mass
- Unknown: freezing point
- $$\frac{28.6\ \text{g HCl}}{(100.0\ \text{g} - 28.6\ \text{g})\ \text{H}_2\text{O}} \times \frac{1\ \text{mol HCl}}{36.46\ \text{g HCl}} \times \frac{2\ \text{mol ions}}{1\ \text{mol HCl}} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 22.0\ m\ \text{ions}$$
- $$\text{fp} = \text{normal fp} + (K_f m) = 0.00^\circ\text{C} + (-1.86^\circ\text{C}/m \times 22.0\ m) = -40.9^\circ\text{C}$$

- 412.** Given: 4.510 kg H₂O;
fp = -18.0°C;
HOCH₂CH₂OH
solute

Unknown: mass of
solute; boil-
ing point

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-18.0^\circ\text{C} - 0.0^\circ\text{C}}{-1.86^\circ\text{C}/m} = 9.68\ m$$

$$\frac{9.68\ \text{mol}}{1.00\ \text{kg solvent}} \times 4.510\ \text{kg solvent} = 43.7\ \text{mol}$$

$$43.7\ \text{mol HOCH}_2\text{CH}_2\text{OH} \times \frac{62.08\ \text{g HOCH}_2\text{CH}_2\text{OH}}{1\ \text{mol HOCH}_2\text{CH}_2\text{OH}}$$

$$= 2710\ \text{g HOCH}_2\text{CH}_2\text{OH} = 2.71\ \text{kg HOCH}_2\text{CH}_2\text{OH}$$

$$\text{bp} = \text{normal bp} \times (K_b m) = 100.00^\circ\text{C} \times (0.51^\circ\text{C}/m \times 9.68\ m) = 104.9^\circ\text{C}$$

- 413. a.** Given: 2.00 g solute;
10.00 g H₂O;
fp = -4.0°C

Unknown: molality

$$\frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-4.0^\circ\text{C} - 0.0^\circ\text{C}}{-1.86^\circ\text{C}/m} = 2.2\ m$$

- b.** Given: 2.00 g solute;
acetone sol-
vent; bp =
58.9°C; nor-
mal bp =
56.00°C; K_b =
1.71°C/m

Unknown: molality

$$\frac{\text{bp} - \text{normal bp}}{K_b} = \frac{58.9^\circ\text{C} - 56.00^\circ\text{C}}{1.71^\circ\text{C}/m} = 1.7\ m$$

- 414.** Given: fp = -22.0°C;
100.00 g glycerol
solute

Unknown: mass of H₂O

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-22.0^\circ\text{C} - 0.0^\circ\text{C}}{-1.86^\circ\text{C}/m} = 11.8\ m$$

$$100.00\ \text{g C}_3\text{H}_5(\text{OH})_3 \times \frac{1\ \text{mol C}_3\text{H}_5(\text{OH})_3}{92.11\ \text{g C}_3\text{H}_5(\text{OH})_3} = 1.086\ \text{mol C}_3\text{H}_5(\text{OH})_3$$

$$1.110\ \text{mol C}_3\text{H}_5(\text{OH})_3 \times \frac{1\ \text{kg H}_2\text{O}}{11.8\ \text{mol C}_3\text{H}_5(\text{OH})_3} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 92.0\ \text{g H}_2\text{O}$$

- 415.** Given: empirical for-
mula is CH₂O;
0.515 g solute;
1.717 g acetic
acid; fp = 8.8°C

Unknown: molar mass;
molecular
formula

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{8.8^\circ\text{C} - 16.6^\circ\text{C}}{-3.90^\circ\text{C}/m} = 2.0\ m$$

$$\frac{2.0\ \text{mol}}{1.00\ \text{kg acetic acid}} \times 1.717\ \text{g acetic acid} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.0034\ \text{mol}$$

$$\frac{0.515\ \text{g}}{0.0034\ \text{mol}} = 150\ \text{g/mol}$$

$$\text{molar mass CH}_2\text{O} = 30.03\ \text{g/mol}$$

$$\frac{150\ \text{g/mol}}{30.03\ \text{g/mol}} = 5.0$$

$$\text{molecular formula} = \text{C}_{1 \times 5}\text{H}_{2 \times 5}\text{O}_{1 \times 5} = \text{C}_5\text{H}_{10}\text{O}_5$$

416. Given: empirical formula is $\text{C}_2\text{H}_2\text{O}$; 3.775 g solute; 12.00 g H_2O ; fp = -4.72°C	$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-4.72^\circ\text{C} - 0.00^\circ\text{C}}{-1.86^\circ\text{C}/m} = 2.54\ m$ $\frac{2.54\ \text{mol}}{1.00\ \text{kg}\ \text{H}_2\text{O}} \times 12.00\ \text{g}\ \text{H}_2\text{O} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.0305\ \text{mol}$ Unknown: molar mass; molecular formula $\frac{3.775\ \text{g}}{0.0305\ \text{mol}} = 124\ \text{g/mol}$ molar mass $\text{C}_2\text{H}_2\text{O} = 42.04\ \text{g/mol}$ $\frac{124\ \text{g/mol}}{42.04\ \text{g/mol}} = 2.95 \approx 3$ molecular formula = $\text{C}_{2 \times 3}\text{H}_{2 \times 3}\text{O}_{1 \times 3} = \text{C}_6\text{H}_6\text{O}_3$
417. Given: $[\text{OH}^-] = 6.4 \times 10^{-5}\ \text{M}$ Unknown: $[\text{H}_3\text{O}^+]$	$[\text{H}_3\text{O}^+][\text{OH}^-] = 1.0 \times 10^{-14}\ \text{M}^2$ $\frac{1.0 \times 10^{-14}\ \text{M}^2}{6.4 \times 10^{-5}\ \text{M}} = 1.6 \times 10^{-10}\ \text{M}$
418. Given: $7.50 \times 10^{-4}\ \text{M}\ \text{HNO}_3$ Unknown: $[\text{H}_3\text{O}^+]$; $[\text{OH}^-]$	$[\text{H}_3\text{O}^+] = 7.50 \times 10^{-4}\ \text{M}\ \text{HNO}_3 \times \frac{1\ \text{M}\ \text{H}_3\text{O}^+}{1\ \text{M}\ \text{HNO}_3} = 7.50 \times 10^{-4}\ \text{M}$ $[\text{H}_3\text{O}^+][\text{OH}^-] = 1.00 \times 10^{-14}\ \text{M}^2$ $[\text{OH}^-] = \frac{1.00 \times 10^{-14}\ \text{M}^2}{7.50 \times 10^{-4}\ \text{M}} = 1.33 \times 10^{-11}\ \text{M}$
419. Given: $0.00118\ \text{M}\ \text{HBr}$ Unknown: pH	$\text{pH} = -\log[\text{H}_3\text{O}^+] = -\log(1.18 \times 10^{-3}) = 2.928$
420. a. Given: $[\text{H}_3\text{O}^+] = 1.0\ \text{M}$ Unknown: pH	$\text{pH} = -\log(1.0) = 0.0$
b. Given: $2.0\ \text{M}\ \text{HCl}$ solution Unknown: pH	$\text{pH} = -\log(2.0) = -0.30$
c. Given: $10.\ \text{M}\ \text{HCl}$ solution Unknown: pH	$\text{pH} = -\log(10.) = -1.00$
421. a. Given: $[\text{OH}^-] = 1 \times 10^{-5}\ \text{M}$ Unknown: pH	$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}\ \text{M}^2$ $[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14}\ \text{M}^2}{[\text{OH}^-]} = \frac{1 \times 10^{-14}\ \text{M}^2}{1 \times 10^{-5}\ \text{M}} = 1 \times 10^{-9}\ \text{M}$ $\text{pH} = -\log[\text{H}_3\text{O}^+] = -\log(1 \times 10^{-9}) = 9.0$

b. Given: $[\text{OH}^-] = 5 \times 10^{-8} \text{ M}$

Unknown: pH

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{OH}^-]} = \frac{1 \times 10^{-14} \text{ M}^2}{5 \times 10^{-8} \text{ M}} = 2 \times 10^{-7} \text{ M}$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (2 \times 10^{-7}) = 7 - 0.3 = 6.7$$

c. Given: $[\text{OH}^-] = 2.90 \times 10^{-11} \text{ M}$

Unknown: pH

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{OH}^-]} = \frac{1.00 \times 10^{-14} \text{ M}^2}{2.90 \times 10^{-11} \text{ M}} = 3.45 \times 10^{-4} \text{ M}$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (3.45 \times 10^{-4}) = 3.462$$

422. Given: pH = 8.92

Unknown: pOH; $[\text{OH}^-]$

$$\text{pH} + \text{pOH} = 14$$

$$\text{pOH} = 14.00 - \text{pH} = 14.00 - 8.92 = 5.08$$

$$[\text{OH}^-] = \text{antilog} (-\text{pOH}) = 1 \times 10^{-5.08} = 8.3 \times 10^{-6} \text{ M}$$

423. a. Given: $[\text{H}_3\text{O}^+] = 2.51 \times 10^{-13} \text{ M}$

Unknown: pOH

$$[\text{OH}^-] = \frac{1.00 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1.00 \times 10^{-14} \text{ M}^2}{2.51 \times 10^{-13} \text{ M}} = 3.98 \times 10^{-2} \text{ M}$$

$$\text{pOH} = -\log [\text{OH}^-] = -\log (3.98 \times 10^{-2}) = 1.400$$

b. Given: $[\text{H}_3\text{O}^+] = 4.3 \times 10^{-3} \text{ M}$

Unknown: pOH

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1.0 \times 10^{-14} \text{ M}^2}{4.3 \times 10^{-3} \text{ M}} = 2.3 \times 10^{-12} \text{ M}$$

$$\text{pOH} = -\log [\text{OH}^-] = -\log (2.3 \times 10^{-12}) = 11.64$$

c. Given: $[\text{H}_3\text{O}^+] = 9.1 \times 10^{-6} \text{ M}$

Unknown: pOH

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1.0 \times 10^{-14} \text{ M}^2}{9.1 \times 10^{-6} \text{ M}} = 1.1 \times 10^{-9} \text{ M}$$

$$\text{pOH} = -\log [\text{OH}^-] = -\log (1.1 \times 10^{-9}) = 8.96$$

d. Given: $[\text{H}_3\text{O}^+] = 0.070 \text{ M}$

Unknown: pOH

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1.0 \times 10^{-14} \text{ M}^2}{7.0 \times 10^{-2} \text{ M}} = 1.4 \times 10^{-13} \text{ M}$$

$$\text{pOH} = -\log [\text{OH}^-] = -\log (1.4 \times 10^{-13}) = 12.85$$

424. Given: 3.50 g NaOH
solute; V = 2.50 L

Unknown: $[\text{OH}^-]$;
 $[\text{H}_3\text{O}^+]$

$$3.50 \text{ g NaOH} \times \frac{1 \text{ mol NaOH}}{40.00 \text{ g NaOH}} = 0.0875 \text{ mol NaOH}$$

$$[\text{OH}^-] = \frac{0.0875 \text{ mol}}{2.50 \text{ L}} = 0.0350 \text{ M}$$

$$[\text{H}_3\text{O}^+] = \frac{1.00 \times 10^{-14} \text{ M}^2}{[\text{OH}^-]} = \frac{1.00 \times 10^{-14} \text{ M}^2}{3.50 \times 10^{-2} \text{ M}} = 2.86 \times 10^{-13} \text{ M}$$

425. Given: $V_1 = 1.00 \text{ L}$;
 $\text{pH}_1 = 12.90$;
 $V_2 = 2.00 \text{ L}$

Unknown: pH_2

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH}) = 1 \times 10^{-12.90} = 1.3 \times 10^{-13} \text{ M}$$

$$M_2 = \frac{M_1 V_1}{V_2} = \frac{1.3 \times 10^{-13} \text{ M} \times 1.00 \text{ L}}{2.00 \text{ L}} = 6.5 \times 10^{-14} \text{ M}$$

$$\text{pH}_2 = -\log [\text{H}_3\text{O}^+] = -\log (6.5 \times 10^{-14}) = 13.19$$

- 426.** Unknown: $[\text{H}_3\text{O}^+]$; $[\text{OH}^-] = 5 \times 10^{-2} \text{ M}$
 $[\text{OH}^-]$
- a.** Given: 0.05 M NaOH $[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{OH}^-]} = \frac{1 \times 10^{-14} \text{ M}^2}{5 \times 10^{-2} \text{ M}} = 2 \times 10^{-13} \text{ M}$
- b.** Given: 0.0025 M H_2SO_4 $[\text{H}_3\text{O}^+] = 0.0025 \text{ M H}_2\text{SO}_4 \times \frac{2 \text{ M H}_3\text{O}^+}{1 \text{ M H}_2\text{SO}_4} = 0.0050 \text{ M} = 5.0 \times 10^{-3} \text{ M}$
 $[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1.0 \times 10^{-14} \text{ M}^2}{5.0 \times 10^{-3} \text{ M}} = 2.0 \times 10^{-12} \text{ M}$
- c.** Given: 0.013 M LiOH $[\text{OH}^-] = 1.3 \times 10^{-2} \text{ M}$
 $[\text{H}_3\text{O}^+] = \frac{1.0 \times 10^{-14} \text{ M}^2}{1.3 \times 10^{-2} \text{ M}} = 7.7 \times 10^{-13} \text{ M}$
- d.** Given: 0.150 M HNO_3 $[\text{H}_3\text{O}^+] = 1.50 \times 10^{-1} \text{ M}$
 $[\text{OH}^-] = \frac{1.00 \times 10^{-14} \text{ M}^2}{1.50 \times 10^{-1} \text{ M}} = 6.67 \times 10^{-14} \text{ M}$
- e.** Given: 0.0200 M Ca $[\text{OH}^-] = 2[\text{Ca}(\text{OH})_2] = 4.00 \times 10^{-2} \text{ M}$
 $(\text{OH})_2$ $[\text{H}_3\text{O}^+] = \frac{1.00 \times 10^{-14} \text{ M}^2}{4.00 \times 10^{-2} \text{ M}} = 2.50 \times 10^{-13} \text{ M}$
- f.** Given: 0.390 M HClO_4 $[\text{H}_3\text{O}^+] = 3.90 \times 10^{-1} \text{ M}$
 $[\text{OH}^-] = \frac{1.00 \times 10^{-14} \text{ M}^2}{3.90 \times 10^{-1} \text{ M}} = 2.56 \times 10^{-14} \text{ M}$

- 427.** Unknown: pH
- a.** Given: $[\text{H}_3\text{O}^+] = 2 \times 10^{-13} \text{ M}$ $\text{pH} = -\log (2 \times 10^{-13}) = 12.7$
- b.** Given: $[\text{H}_3\text{O}^+] = 5.0 \times 10^{-3} \text{ M}$ $\text{pH} = -\log (5.0 \times 10^{-3}) = 2.30$
- c.** Given: $[\text{H}_3\text{O}^+] = 7.7 \times 10^{-13} \text{ M}$ $\text{pH} = -\log (7.7 \times 10^{-13}) = 12.11$
- d.** Given: $[\text{H}_3\text{O}^+] = 1.50 \times 10^{-1} \text{ M}$ $\text{pH} = -\log (1.50 \times 10^{-1}) = 0.824$
- e.** Given: $[\text{H}_3\text{O}^+] = 2.50 \times 10^{-13} \text{ M}$ $\text{pH} = -\log (2.50 \times 10^{-13}) = 12.602$
- f.** Given: $[\text{H}_3\text{O}^+] = 3.90 \times 10^{-1} \text{ M}$ $\text{pH} = -\log (3.90 \times 10^{-1}) = 0.409$

- 428.** Given: 0.160 M KOH $[\text{OH}^-] = [\text{KOH}] = 1.60 \times 10^{-1} \text{ M}$
 Unknown: $[\text{H}_3\text{O}^+]$; $[\text{OH}^-]$ $[\text{H}_3\text{O}^+] = \frac{1.00 \times 10^{-14} \text{ M}^2}{1.60 \times 10^{-1} \text{ M}} = 6.25 \times 10^{-14} \text{ M}$

429. Given: pH = 12.9; NaOH solution Unknown: molarity	$\text{pOH} = 14.0 - 12.9 = 1.1$ $[\text{NaOH}] = [\text{OH}^-] = \text{antilog}(-\text{pOH}) = 1.0 \times 10^{-1.1} = 0.08 \text{ M}$
430. Given: 0.001 25 M HBr; $V_1 = 175 \text{ mL}$; $V_2 = 3.00 \text{ L}$; $M_1V_1 = M_2V_2$ Unknown: pH before and after dilution	$M_2 = \frac{M_1V_1}{V_2} = \frac{0.001\ 25 \text{ M} \times 175 \text{ mL}}{3.00 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 7.29 \times 10^{-5} \text{ M}$ $[\text{HBr}] = [\text{H}_3\text{O}^+]$ $\text{pH}_1 = -\log [\text{H}_3\text{O}^+] = -\log (1.25 \times 10^{-3}) = 2.903$ $\text{pH}_2 = -\log [\text{H}_3\text{O}^+] = -\log (7.29 \times 10^{-5}) = 4.137$
431. Given: NaOH solutions of 0.0001 M and 0.0005 M Unknown: pH for both solutions	$[\text{NaOH}] = [\text{OH}^-] = 1 \times 10^{-4} \text{ M}; \text{pOH} = -\log (1 \times 10^{-4}) = 4.0$ $\text{pH} = 14.0 - 4.0 = 10.0$ $[\text{NaOH}] = [\text{OH}^-] = 5 \times 10^{-4} \text{ M}; \text{pOH} = -\log (5 \times 10^{-4}) = 3.3$ $\text{pH} = 14.0 - 3.3 = 10.7$
432. Given: $V_1 = 15.0 \text{ mL}$; $M_1 = 1.0 \text{ M HCl}$; $V_2 = 20.0 \text{ mL}$; $M_2 = 0.50 \text{ M}$ HNO_3 ; $V_F = 1.25 \text{ L}$ a. Unknown: $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ of final solution b. Unknown: pH of final solution	Before dilution: $15.0 \text{ mL} \times \frac{1.0 \text{ mol}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} + 20.0 \text{ mL} \times \frac{0.50 \text{ mol}}{1 \text{ L}}$ $\times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.0150 \text{ mol} + 0.0100 \text{ mol} = 0.0250 \text{ mol}$ $[\text{H}_3\text{O}^+] = \frac{0.0250 \text{ mol}}{(15.0 + 20.0) \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.714 \text{ M}$ After dilution: $[\text{H}_3\text{O}^+] = M_F = \frac{0.714 \text{ M} \times 0.035 \text{ L}}{1.25 \text{ L}} = 0.020 \text{ M}$ $[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{2.0 \times 10^{-2} \text{ M}} = 5.0 \times 10^{-13} \text{ M}$ $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (2.0 \times 10^{-2}) = 1.70$
433. a. Given: 0.001 57 M HNO_3 Unknown: pH b. Given: $V_1 = 500.0$ mL ; $M_1 =$ 0.001 57 M; $V_2 = 447.0 \text{ mL}$ Unknown: pH at V_2	$[\text{H}_3\text{O}^+] = [\text{HNO}_3] = 1.57 \times 10^{-3} \text{ M}$ $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (1.57 \times 10^{-3}) = 2.804$ $M_2 = \frac{M_1V_1}{V_2} = \frac{1.57 \times 10^{-3} \text{ M} \times 500.0 \text{ mL}}{447.0 \text{ mL}} = 1.76 \times 10^{-3} \text{ M}$ $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (1.76 \times 10^{-3}) = 2.754$
434. Given: $[\text{H}_3\text{O}^+] =$ 0.00035 M Unknown: $[\text{OH}^-]$	$[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{3.5 \times 10^{-4} \text{ M}} = 2.9 \times 10^{-11} \text{ M}$

- 435.** Given: NaOH solute;
 $\text{pH}_1 = 12.14$;
 $V_1 = 50.00 \text{ mL}$;
 $V_2 = 2.000 \text{ L}$
 Unknown: pH_2
- $$\text{pOH}_1 = 14.00 - \text{pH} = 14.00 - 12.14 = 1.86$$
- $$[\text{OH}^-]_1 = \text{antilog}(-\text{pOH}) = 1.0 \times 10^{-1.86} = 1.4 \times 10^{-2} \text{ M}$$
- $$[\text{OH}^-]_2 = \frac{[\text{OH}^-]_1 V_1}{V_2} = \frac{1.4 \times 10^{-2} \text{ M} \times 50.00 \text{ mL}}{2.000 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 3.5 \times 10^{-4} \text{ M}$$
- $$\text{pOH}_2 = -\log(3.5 \times 10^{-4}) = 3.46$$
- $$\text{pH}_2 = 14.00 - 3.46 = 10.54$$
-
- 436.** Given: $\text{pH} = 4.0$
 Unknown: $[\text{H}_3\text{O}^+]$;
 $[\text{OH}^-]$
- $$[\text{H}_3\text{O}^+] = \text{antilog}(-\text{pH}) = \text{antilog}(-4.0) = 1 \times 10^{-4} \text{ M}$$
- $$[\text{OH}^-] = \frac{1 \times 10^{-14} \text{ M}^2}{1 \times 10^{-4} \text{ M}} = 1 \times 10^{-10} \text{ M}$$
-
- 437.** Given: $0.000\,460 \text{ M}$
 $\text{Ca}(\text{OH})_2$ solution
 Unknown: pH
- $$[\text{OH}^-] = 4.60 \times 10^{-4} \text{ M Ca}(\text{OH})_2 \times \frac{2 \text{ M OH}^-}{1 \text{ M Ca}(\text{OH})_2} = 9.20 \times 10^{-4} \text{ M}$$
- $$[\text{H}_3\text{O}^+] = \frac{1.00 \times 10^{-14} \text{ M}^2}{9.20 \times 10^{-4} \text{ M}} = 1.09 \times 10^{-11} \text{ M}$$
- $$\text{pH} = -\log(1.09 \times 10^{-11}) = 10.963$$
-
- 438.** Given: $\text{Sr}(\text{OH})_2$ solute;
 $\text{pH} = 11.4$; 1.00 L
 Unknown: mass
 $\text{Sr}(\text{OH})_2$
- $$\text{pOH} = 14.0 - 11.4 = 2.6$$
- $$[\text{OH}^-] = \text{antilog}(-\text{pOH}) = \text{antilog}(-2.6) = 10^{-2.6} = 3 \times 10^{-3} \text{ M}$$
- $$[\text{Sr}(\text{OH})_2] = 3 \times 10^{-3} \text{ M OH}^- \times \frac{1 \text{ M Sr}(\text{OH})_2}{2 \text{ M OH}^-} = 2 \times 10^{-3} \text{ M}$$
- $$\frac{2 \times 10^{-3} \text{ mol}}{1 \text{ L}} \times 1.00 \text{ L} = 2 \times 10^{-3} \text{ mol}$$
- $$2 \times 10^{-3} \text{ mol Sr}(\text{OH})_2 \times \frac{121.64 \text{ g Sr}(\text{OH})_2}{1 \text{ mol Sr}(\text{OH})_2} = 0.2 \text{ g Sr}(\text{OH})_2$$
-
- 439.** Given: NH_3 solute;
 $\text{pH} = 11.00$
 Unknown: $[\text{H}_3\text{O}^+]$;
 $[\text{OH}^-]$
- $$[\text{H}_3\text{O}^+] = \text{antilog}(-11.00) = 1.0 \times 10^{-11} \text{ M}$$
- $$[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{1.0 \times 10^{-11} \text{ M}} = 1.0 \times 10^{-3} \text{ M}$$
-
- 440. a.** Given: 1.0 M
 CH_3COOH ;
 $\text{pH} = 2.40$
 Unknown: percent
 ionization
- $$[\text{H}_3\text{O}^+] = \text{antilog}(-2.40) = 1.00 \times 10^{-2.40} = 3.98 \times 10^{-3} \text{ M}$$
- $$\frac{3.98 \times 10^{-3} \text{ M}}{1.0 \text{ M}} \times 100 = 0.40\% \text{ ionized}$$
- b.** Given: 0.10 M
 CH_3COOH ;
 $\text{pH} = 2.90$
 Unknown: percent
 ionization
- $$[\text{H}_3\text{O}^+] = \text{antilog}(-2.90) = 1.00 \times 10^{-2.90} = 1.26 \times 10^{-3} \text{ M}$$
- $$\frac{1.26 \times 10^{-3} \text{ M}}{0.10 \text{ M}} \times 100 = 1.3\% \text{ ionized}$$
- c.** Given: 0.010 M
 CH_3COOH ;
 $\text{pH} = 3.40$
 Unknown: percent
 ionization
- $$[\text{H}_3\text{O}^+] = \text{antilog}(-3.40) = 1.00 \times 10^{-3.40} = 3.98 \times 10^{-4} \text{ M}$$
- $$\frac{3.98 \times 10^{-4} \text{ M}}{1.0 \times 10^{-2} \text{ M}} \times 100 = 4.0\%$$

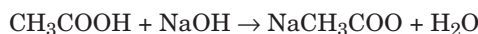
- 441.** Given: 5.00 g HNO₃; 2.00 L
Unknown: pH
- $$5.00 \text{ g HNO}_3 \times \frac{1 \text{ mol HNO}_3}{63.02 \text{ g HNO}_3} = 0.0793 \text{ mol HNO}_3$$
- $$[\text{H}_3\text{O}^+] = [\text{HNO}_3] = \frac{0.0793 \text{ mol}}{2.00 \text{ L}} = 0.0396 \text{ M}$$
- $$\text{pH} = -\log(0.0396) = 1.402$$
-
- 442.** Given: stock pH = 1.50; HCl solute
Unknown: pH of diluted solution
- $$M_S = [\text{H}_3\text{O}^+] = [\text{HCl}] = \text{antilog}(-1.50) = 1.0 \times 10^{-1.50} \text{ M} = 3.16 \times 10^{-2} \text{ M}$$
- a.** Given: $V_S = 1.00 \text{ mL}$; $V_D = 1000. \text{ mL}$
- $$M_D = \frac{M_S V_S}{V_D} = \frac{3.16 \times 10^{-2} \text{ M} \times 1.00 \text{ mL}}{1000. \text{ mL}} = 3.16 \times 10^{-5} \text{ M}$$
- $$\text{pH} = -\log(3.16 \times 10^{-5}) = 4.50$$
- b.** Given: $V_S = 25.00 \text{ mL}$; $V_D = 200. \text{ mL}$
- $$M_D = \frac{M_S V_S}{V_D} = \frac{3.16 \times 10^{-2} \text{ M} \times 25.00 \text{ mL}}{200. \text{ mL}} = 3.95 \times 10^{-3} \text{ M}$$
- $$\text{pH} = -\log(3.95 \times 10^{-3}) = 2.40$$
- c.** Given: $V_S = 18.83 \text{ mL}$; $V_D = 4.000 \text{ L}$
- $$M_D = \frac{M_S V_S}{V_D} = \frac{3.16 \times 10^{-2} \text{ M} \times 18.83 \text{ mL}}{4.000 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.49 \times 10^{-4} \text{ M}$$
- $$\text{pH} = -\log(1.49 \times 10^{-4}) = 3.83$$
- d.** Given: $V_S = 1.50 \text{ L}$; $V_D = 20.0 \text{ kL}$
- $$M_D = \frac{M_S V_S}{V_D} = \frac{3.16 \times 10^{-2} \text{ M} \times 1.50 \text{ L}}{20.0 \text{ kL}} \times \frac{1 \text{ kL}}{1000 \text{ L}} = 2.37 \times 10^{-6} \text{ M}$$
- $$\text{pH} = -\log(2.37 \times 10^{-6}) = 5.63$$
-
- 443.** Given: $[\text{H}_3\text{O}^+] = 10\,000 [\text{OH}^-]$; aqueous solution
Unknown: $[\text{H}_3\text{O}^+]$; $[\text{OH}^-]$
- $$[\text{H}_3\text{O}^+][\text{OH}^-] = 10\,000 [\text{OH}^-][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$
- $$[\text{OH}^-]^2 = \frac{1 \times 10^{-14} \text{ M}^2}{10^4} = 1 \times 10^{-18} \text{ M}^2$$
- $$[\text{OH}^-] = 1 \times 10^{-9} \text{ M}$$
- $$[\text{H}_3\text{O}^+] = 10^4 [\text{OH}^-] = 10^4 \times 1 \times 10^{-9} \text{ M} = 1 \times 10^{-5} \text{ M}$$
-
- 444.** Given: KOH solute; pH = 12.90; acid reacts with half of OH⁻
Unknown: resulting pH
- $$\text{pOH} = 14.00 - \text{pH} = 14.00 - 12.90 = 1.10$$
- $$[\text{OH}^-] = \text{antilog}(-1.10) = 1.0 \times 10^{-1.10} = 0.079 \text{ M}$$
- after reaction:
- $$[\text{OH}^-] = \frac{0.079 \text{ M}}{2} = 0.040 \text{ M}$$
- $$[\text{H}_3\text{O}^+] = \frac{1.0 \times 10^{-14} \text{ M}^2}{4.0 \times 10^{-2} \text{ M}} = 2.5 \times 10^{-13} \text{ M}$$
- $$\text{pH} = -\log(2.5 \times 10^{-13}) = 12.60$$
-
- 445.** Given: HCl solute; pH = 1.70
Unknown: $[\text{H}_3\text{O}^+]$; $[\text{HCl}]$
- $$[\text{H}_3\text{O}^+] = \text{antilog}(-1.70) = 1.0 \times 10^{-1.70} = 0.020 \text{ M}$$
- $$[\text{HCl}] = [\text{H}_3\text{O}^+] = 0.020 \text{ M}$$

- 446.** Given: Ca(OH)_2 solute: $\text{pOH} = 14.00 - \text{pH} = 14.00 - 10.80 = 3.20$
 $\text{pH} = 10.80$ $[\text{OH}^-] = \text{antilog}(-3.20) = 1.0 \times 10^{-3.20} = 6.3 \times 10^{-4} \text{ M}$
 Unknown: molarity $[\text{Ca(OH)}_2] = 6.3 \times 10^{-4} \text{ M OH}^- \times \frac{1 \text{ M Ca(OH)}_2}{2 \text{ M OH}^-} = 3.2 \times 10^{-4} \text{ M}$
-
- 447.** Given: 1.00 M stock HCl $\text{pH} = -\log(1.00 \times 10^0) = 0.000$
 Unknown: pH
- Given: $\text{pH} = 4.00$; 1.00 L stock HCl $[\text{H}_3\text{O}^+] = \text{antilog}(-4.00) = 1.0 \times 10^{-4.00} = 1.0 \times 10^{-4} \text{ M}$
 Unknown: V_D $V_D = \frac{M_S V_S}{M_D} = \frac{1.00 \text{ M} \times 1.00 \text{ L}}{1.0 \times 10^{-4} \text{ M}} = 1.0 \times 10^4 \text{ L} = 10. \text{ kL}$
- Given: 1.00 L of pH 4.00 $[\text{H}_3\text{O}^+] \text{ at pH } 4.00 = 1.0 \times 10^{-4} \text{ M}$
 Unknown: V at pH 6.00 $[\text{H}_3\text{O}^+] \text{ at pH } 6.00 = \text{antilog}(-6.00) = 1.0 \times 10^{-6.00} = 1.0 \times 10^{-6} \text{ M}$
 $V = \frac{1.0 \times 10^{-4} \text{ M} \times 1.00 \text{ L}}{1.0 \times 10^{-6} \text{ M}} = 1.0 \times 10^2 \text{ L}$
- Given: 1.00 L of pH 4.00 $[\text{H}_3\text{O}^+] \text{ at pH } 4.00 = 1.00 \times 10^{-4} \text{ M}$
 Unknown: V at pH 8.00 $[\text{H}_3\text{O}^+] \text{ at pH } 8.00 = \text{antilog}(-8.00) = 1.0 \times 10^{-8.00} = 1.0 \times 10^{-8} \text{ M}$
 $V = \frac{1.0 \times 10^{-4} \text{ M} \times 1.00 \text{ L}}{1.0 \times 10^{-8} \text{ M}} = 1.0 \times 10^4 \text{ L} = 10. \text{ kL}$
-
- 448.** Given: $\text{pH} = 1.28$; 1.00 L HClO_3 $\text{HClO}_3 + \text{NaOH} \rightarrow \text{NaClO}_3 + \text{H}_2\text{O}$
 Unknown: moles NaOH to react; mass NaOH $[\text{H}_3\text{O}^+] = \text{antilog}(-1.28) = 1.0 \times 10^{-1.28} = 5.2 \times 10^{-2} \text{ M}$
 $\frac{5.2 \times 10^{-2} \text{ mol}}{1.0 \text{ L}} \times 1.00 \text{ L HClO}_3 = 5.2 \times 10^{-2} \text{ mol HClO}_3$
 $= 5.2 \times 10^{-2} \text{ mol NaOH}$
 $0.052 \text{ mol NaOH} \times \frac{40.00 \text{ g NaOH}}{1.0 \text{ mol NaOH}} = 2.1 \text{ g NaOH}$
-
- 449.** Given: NH_3 solute; $\text{pH} = 11.90$; 1.00 L NH_3 solution $\text{pOH} = 14.00 - 11.90 = 2.10$
 Unknown: moles HCl to react $[\text{OH}^-] = \text{antilog}(-2.10) = 1.0 \times 10^{-2.10} = 7.9 \times 10^{-3} \text{ M}$
 $\frac{7.9 \times 10^{-3} \text{ mol}}{1.0 \text{ L}} \times 1.00 \text{ L} = 7.9 \times 10^{-3} \text{ mol OH}^- = 7.9 \times 10^{-3} \text{ mol HCl}$
-
- 450.** Given: $\text{pH} = 3.15$ $[\text{H}_3\text{O}^+] = \text{antilog}(-3.15) = 1.0 \times 10^{-3.15} = 7.1 \times 10^{-4} \text{ M}$
 Unknown: $[\text{H}_3\text{O}^+]$; $[\text{OH}^-]$ $[\text{OH}^-] = \frac{1.0 \times 10^{-14} \text{ M}^2}{7.1 \times 10^{-4} \text{ M}} = 1.4 \times 10^{-11} \text{ M}$

- 451.** Given: 20.00 mL HBr;
20.05 mL of
0.1819 M NaOH
Unknown: molarity
HBr
- $$\text{HBr} + \text{NaOH} \rightarrow \text{NaBr} + \text{H}_2\text{O}$$
- $$\frac{0.1819 \text{ mol NaOH}}{\text{L}} \times 20.05 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 3.647 \times 10^{-3} \text{ mol NaOH}$$
- $$3.647 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol HBr}}{1 \text{ mol NaOH}} = 3.647 \times 10^{-3} \text{ mol HBr}$$
- $$\frac{3.647 \times 10^{-3} \text{ mol HBr}}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.1824 \text{ M HBr}$$
-
- 452.** Given: 15.00 mL
CH₃COOH;
22.70 mL of
0.550 M NaOH
Unknown: molarity of
CH₃COOH
- $$\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{NaCH}_3\text{COO} + \text{H}_2\text{O}$$
- $$\frac{0.550 \text{ mol NaOH}}{\text{L}} \times 22.70 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.25 \times 10^{-2} \text{ mol NaOH}$$
- $$1.25 \times 10^{-2} \text{ mol NaOH} \times \frac{1 \text{ mol CH}_3\text{COOH}}{1 \text{ mol NaOH}} = 1.25 \times 10^{-2} \text{ mol CH}_3\text{COOH}$$
- $$\frac{1.25 \times 10^{-2} \text{ mol CH}_3\text{COOH}}{15.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.833 \text{ M CH}_3\text{COOH}$$
-
- 453.** Given: 20.00 mL
Sr(OH)₂;
43.03 mL of
0.1159 M HCl
Unknown: molarity of
Sr(OH)₂
solution
- $$\text{Sr}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{SrCl}_2 + 2\text{H}_2\text{O}$$
- $$\frac{0.1159 \text{ mol HCl}}{\text{L}} \times 43.03 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 4.987 \times 10^{-3} \text{ mol HCl}$$
- $$4.987 \times 10^{-3} \text{ mol HCl} \times \frac{1 \text{ mol Sr}(\text{OH})_2}{2 \text{ mol HCl}} = 2.494 \times 10^{-3} \text{ mol Sr}(\text{OH})_2$$
- $$\frac{2.494 \times 10^{-3} \text{ mol Sr}(\text{OH})_2}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.1247 \text{ M Sr}(\text{OH})_2$$
-
- 454.** Given: 35.00 mL NH₃
solution;
54.95 mL of
0.400 M H₂SO₄
Unknown: molarity of
NH₃ solution
- $$2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$$
- $$\frac{0.400 \text{ mol H}_2\text{SO}_4}{\text{L}} \times 54.95 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.20 \times 10^{-2} \text{ mol H}_2\text{SO}_4$$
- $$2.20 \times 10^{-2} \text{ mol H}_2\text{SO}_4 \times \frac{2 \text{ mol NH}_3}{1 \text{ mol H}_2\text{SO}_4} = 4.40 \times 10^{-2} \text{ mol NH}_3$$
- $$\frac{4.40 \times 10^{-2} \text{ mol NH}_3}{35.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1.26 \text{ M NH}_3$$

- 455.** Given: 28.25 mL of
0.218 M NaOH;
2.000 g acetic
acid diluted to
100.00 mL;
20.00 mL acetic
acid

Unknown: % acetic acid
in stock
solution



$$\frac{0.218 \text{ mol NaOH}}{\text{L}} \times 28.25 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 6.16 \times 10^{-3} \text{ mol NaOH}$$

$$6.16 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol CH}_3\text{COOH}}{1 \text{ mol NaOH}} = 6.16 \times 10^{-3} \text{ mol CH}_3\text{COOH}$$

$$\frac{6.16 \times 10^{-3} \text{ mol CH}_3\text{COOH}}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.308 \text{ M CH}_3\text{COOH}$$

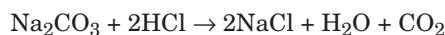
$$\frac{2.000 \text{ g CH}_3\text{COOH}}{100.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ mol CH}_3\text{COOH}}{60.06 \text{ g CH}_3\text{COOH}}$$

$$= 0.3333 \text{ M CH}_3\text{COOH}$$

$$\frac{0.308 \text{ M}}{0.3333 \text{ M}} \times 100 = 92.5\% \text{ CH}_3\text{COOH}$$

- 456.** Given: 9.709 g Na₂CO₃
diluted to
1.0000 L;
10.00 mL
Na₂CO₃ solu-
tion; 16.90 mL of
0.1022 M HCl

Unknown: percentage of
Na₂CO₃



$$\frac{0.1022 \text{ mol HCl}}{\text{L}} \times 16.90 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.727 \times 10^{-3} \text{ mol HCl}$$

$$1.727 \times 10^{-3} \text{ mol HCl} \times \frac{1 \text{ mol Na}_2\text{CO}_3}{2 \text{ mol HCl}} = 8.635 \times 10^{-4} \text{ mol Na}_2\text{CO}_3$$

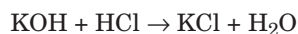
$$\frac{8.635 \times 10^{-4} \text{ mol Na}_2\text{CO}_3}{10.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 8.635 \times 10^{-2} \text{ M Na}_2\text{CO}_3$$

$$\frac{9.709 \text{ g Na}_2\text{CO}_3}{1.0000 \text{ L}} \times \frac{1 \text{ mol Na}_2\text{CO}_3}{105.99 \text{ g Na}_2\text{CO}_3} = 9.160 \times 10^{-2} \text{ M Na}_2\text{CO}_3$$

$$\frac{8.635 \times 10^{-2} \text{ M Na}_2\text{CO}_3}{9.160 \times 10^{-2} \text{ M Na}_2\text{CO}_3} \times 100 = 94.27\% \text{ Na}_2\text{CO}_3$$

- 457.** Given: 50.00 mL KOH;
27.87 mL of
0.8186 M HCl

Unknown: molarity of
KOH



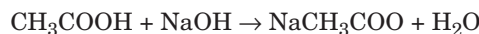
$$\frac{0.8186 \text{ mol HCl}}{\text{L}} \times 27.87 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.281 \times 10^{-2} \text{ mol HCl}$$

$$2.281 \times 10^{-2} \text{ mol HCl} \times \frac{1 \text{ mol KOH}}{1 \text{ mol HCl}} = 2.281 \times 10^{-2} \text{ mol KOH}$$

$$\frac{2.281 \times 10^{-2} \text{ mol KOH}}{50.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.4562 \text{ M KOH}$$

- 458.** Given: 15.00 mL
CH₃COOH;
34.13 mL of
0.9940 M NaOH

Unknown: molarity of
CH₃COOH



$$\frac{0.9940 \text{ mol NaOH}}{\text{L}} \times 34.13 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 3.393 \times 10^{-2} \text{ mol NaOH}$$

$$3.393 \times 10^{-2} \text{ mol NaOH} \times \frac{1 \text{ mol CH}_3\text{COOH}}{1 \text{ mol NaOH}}$$

$$= 3.393 \times 10^{-2} \text{ mol CH}_3\text{COOH}$$

$$\frac{3.393 \times 10^{-2} \text{ mol CH}_3\text{COOH}}{15.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 2.262 \text{ M CH}_3\text{COOH}$$

- 459.** Given: 12.00 mL NH_3 solution;
19.48 mL of 1.499 M HNO_3
- Unknown: molarity of NH_3 solution
- $$\text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_4\text{NO}_3$$
- $$\frac{1.499 \text{ mol HNO}_3}{\text{L}} \times 19.48 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.920 \times 10^{-2} \text{ mol HNO}_3$$
- $$2.920 \times 10^{-2} \text{ mol HNO}_3 \times \frac{1 \text{ mol NH}_3}{1 \text{ mol HNO}_3} = 2.920 \times 10^{-2} \text{ mol NH}_3$$
- $$\frac{2.920 \times 10^{-2} \text{ mol NH}_3}{12.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 2.433 \text{ M NH}_3$$
-
- 460. a.** Given: 1 mol acid : 1 mol base;
 $M_A = M_B$;
20.00 mL base
- Unknown: V of acid
- 20.00 mL base because $M \times V$ provides number of moles, which are in a 1 : 1 ratio
- b.** Given: $M_A = 2M_B$;
20.00 mL base
- Unknown: V of acid
- $$M_A \times V_A = M_B \times 20.00 \text{ mL}$$
- $$2M_B \times V_A = M_B \times 20.00 \text{ mL}$$
- $$V_A = \frac{M_B \times 20.00 \text{ mL base}}{2M_B} = 10.00 \text{ mL}$$
- c.** Given: $M_B = 4M_A$;
20.00 mL base
- Unknown: V of acid
- $$M_A \times V_A = M_B \times 20.00 \text{ mL}$$
- $$M_A \times V_A = 4M_A \times 20.00 \text{ mL}$$
- $$V_A = \frac{4M_A \times 20.00 \text{ mL}}{M_A} = 80.00 \text{ mL}$$
-
- 461.** Given: 10.00 mL stock HF diluted to 500.00 mL;
20.00 mL HF;
13.51 mL of 0.1500 M NaOH
- Unknown: molarity of stock HF
- $$\text{HF} + \text{NaOH} \rightarrow \text{NaF} + \text{H}_2\text{O}$$
- $$\frac{0.1500 \text{ mol NaOH}}{\text{L}} \times 13.51 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.026 \times 10^{-3} \text{ mol NaOH}$$
- $$2.026 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol HF}}{1 \text{ mol NaOH}} = 2.026 \times 10^{-3} \text{ mol HF}$$
- $$\frac{2.026 \times 10^{-3} \text{ mol HF}}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.1013 \text{ M HF}$$
- $$\frac{0.1013 \text{ mol HF}}{\text{L}} \times 500.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.05065 \text{ mol HF}$$
- $$\frac{0.05065 \text{ mol HF}}{10.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 5.065 \text{ M HF}$$
-
- 462.** Given: 16.22 mL of 0.5030 M KOH;
18.41 mL diprotic acid
- Unknown: molarity of acid
- $$\frac{0.5030 \text{ mol KOH}}{\text{L}} \times 16.22 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 8.159 \times 10^{-3} \text{ mol KOH}$$
- $$8.159 \times 10^{-3} \text{ mol KOH} \times \frac{1 \text{ mol acid}}{2 \text{ mol KOH}} = 4.080 \times 10^{-3} \text{ mol acid}$$
- $$\frac{4.080 \times 10^{-3} \text{ mol acid}}{18.41 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.2216 \text{ M acid}$$

463. Given: 42.27 mL of 1.209 M NaOH; 25.00 mL H ₂ SO ₄ Unknown: molarity of the H ₂ SO ₄	$\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ $\frac{1.209 \text{ mol NaOH}}{\text{L}} \times 42.27 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 5.110 \times 10^{-2} \text{ mol NaOH}$ $5.110 \times 10^{-2} \text{ mol NaOH} \times \frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol NaOH}} = 2.555 \times 10^{-2} \text{ mol H}_2\text{SO}_4$ $\frac{2.555 \times 10^{-2} \text{ mol H}_2\text{SO}_4}{25.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1.022 \text{ M H}_2\text{SO}_4$
464. Given: 1 mol acid: 1 mol base; 0.7025 g KHC ₈ H ₄ O ₄ ; 20.18 mL KOH Unknown: molarity of KOH	$0.7025 \text{ g KHC}_8\text{H}_4\text{O}_4 \times \frac{1 \text{ mol KHC}_8\text{H}_4\text{O}_4}{204.23 \text{ g KHC}_8\text{H}_4\text{O}_4}$ $= 3.440 \times 10^{-3} \text{ mol KHC}_8\text{H}_4\text{O}_4$ $3.440 \times 10^{-3} \text{ mol KHC}_8\text{H}_4\text{O}_4 \times \frac{1 \text{ mol KOH}}{1 \text{ mol KHC}_8\text{H}_4\text{O}_4} = 3.440 \times 10^{-3} \text{ mol KOH}$ $\frac{3.440 \times 10^{-3} \text{ mol KOH}}{20.18 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.1705 \text{ M KOH}$
465. Given: 20.00 mL triprotic acid; 17.03 mL of 2.025 M NaOH Unknown: molarity of acid	$\frac{2.025 \text{ mol NaOH}}{\text{L}} \times 17.03 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 3.449 \times 10^{-2} \text{ mol NaOH}$ $3.449 \times 10^{-2} \text{ mol NaOH} \times \frac{1 \text{ mol acid}}{3 \text{ mol NaOH}} = 1.150 \times 10^{-2} \text{ mol acid}$ $\frac{1.150 \times 10^{-2} \text{ mol acid}}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.5750 \text{ M acid}$
466. Given: 41.04 mL KOH; 21.65 mL of 0.6515 M HNO ₃ Unknown: molarity of KOH	$\text{KOH} + \text{HNO}_3 \rightarrow \text{KNO}_3 + \text{H}_2\text{O}$ $\frac{0.6515 \text{ mol HNO}_3}{\text{L}} \times 21.65 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.410 \times 10^{-2} \text{ mol HNO}_3$ $1.410 \times 10^{-2} \text{ mol HNO}_3 \times \frac{1 \text{ mol KOH}}{1 \text{ mol HNO}_3} = 1.410 \times 10^{-2} \text{ mol KOH}$ $\frac{1.410 \times 10^{-2} \text{ mol KOH}}{41.04 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.3436 \text{ M KOH}$
467. Given: 20.00 mL of 2.00 M H ₂ SO ₄ ; 1.85 M NaOH Unknown: V of NaOH	$\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ $\frac{2.00 \text{ mol H}_2\text{SO}_4}{\text{L}} \times 20.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 4.00 \times 10^{-2} \text{ mol H}_2\text{SO}_4$ $4.00 \times 10^{-2} \text{ mol H}_2\text{SO}_4 \times \frac{2 \text{ mol NaOH}}{1 \text{ mol H}_2\text{SO}_4} = 8.00 \times 10^{-2} \text{ mol NaOH}$ $\frac{8.00 \times 10^{-2} \text{ mol NaOH}}{1.85 \text{ mol/L}} = 0.0432 \text{ L NaOH} = 43.2 \text{ mL NaOH}$

468. Given: 0.5200 M H₂SO₄; 100.00 mL of 0.1225 M Sr(OH)₂

$$\text{H}_2\text{SO}_4 + \text{Sr}(\text{OH})_2 \rightarrow \text{SrSO}_4 + 2\text{H}_2\text{O}$$

$$\frac{0.1225 \text{ mol Sr}(\text{OH})_2}{\text{L}} \times 100.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.225 \times 10^{-2} \text{ mol Sr}(\text{OH})_2$$

Unknown: V of H₂SO₄

$$1.225 \times 10^{-2} \text{ mol Sr}(\text{OH})_2 \times \frac{1 \text{ mol H}_2\text{SO}_4}{1 \text{ mol Sr}(\text{OH})_2} = 1.225 \times 10^{-2} \text{ mol H}_2\text{SO}_4$$

$$\frac{1.225 \times 10^{-2} \text{ mol H}_2\text{SO}_4}{0.5200 \text{ mol/L}} = 0.02356 \text{ L H}_2\text{SO}_4 = 23.56 \text{ mL H}_2\text{SO}_4$$

469. Given: 4.005 g KOH in 200.00 mL solution; 25.00 mL KOH; 19.93 mL of 0.4388 M HCl

$$\text{KOH} + \text{HCl} \rightarrow \text{KCl} + \text{H}_2\text{O}$$

$$\frac{0.4388 \text{ mol HCl}}{\text{L}} \times 19.93 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 8.745 \times 10^{-3} \text{ mol HCl}$$

Unknown: moles KOH in 4.005 g; mass KOH; percent KOH

$$8.745 \times 10^{-3} \text{ mol HCl} \times \frac{1 \text{ mol KOH}}{1 \text{ mol HCl}} = 8.745 \times 10^{-3} \text{ mol KOH in 25.00 mL}$$

$$8.745 \times 10^{-3} \text{ mol KOH} \times \frac{200.00 \text{ mL}}{25.00 \text{ mL}} = 6.996 \times 10^{-2} \text{ mol KOH}$$

in 4.005 g KOH

$$6.996 \times 10^{-2} \text{ mol KOH} \times \frac{56.11 \text{ g KOH}}{1 \text{ mol KOH}} = 3.925 \text{ g KOH}$$

$$\frac{3.925 \text{ g}}{4.005 \text{ g}} \times 100 = 98.00\% \text{ KOH}$$

470. Given: 558 mL of 3.18 M HCl

$$\text{Mg}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{MgCl}_2 + 2\text{H}_2\text{O}$$

Unknown: mass of Mg(OH)₂ to react

$$\frac{3.18 \text{ mol HCl}}{\text{L}} \times 558 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.77 \text{ mol HCl}$$

$$1.77 \text{ mol HCl} \times \frac{1 \text{ mol Mg}(\text{OH})_2}{2 \text{ mol HCl}} = 0.885 \text{ mol Mg}(\text{OH})_2$$

$$0.885 \text{ mol Mg}(\text{OH})_2 \times \frac{58.32 \text{ g Mg}(\text{OH})_2}{1 \text{ mol Mg}(\text{OH})_2} = 51.6 \text{ g Mg}(\text{OH})_2$$

471. Given: 12.61 mL NH₃ solution; 5.19 mL of 1.25 M HCl

$$\frac{1.25 \text{ mol HCl}}{\text{L}} \times 5.19 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 6.49 \times 10^{-3} \text{ mol HCl}$$

$$6.49 \times 10^{-3} \text{ mol HCl} \times \frac{1 \text{ mol NH}_3}{1 \text{ mol HCl}} = 6.49 \times 10^{-3} \text{ mol NH}_3$$

Unknown: molarity of NH₃ solution

$$\frac{6.49 \times 10^{-3} \text{ mol NH}_3}{12.61 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.515 \text{ M NH}_3$$

472. Given: 5.090 g sample of 92.10% NaOH; 2.811 M diprotic acid

$$5.090 \text{ g NaOH} \times 0.9210 = 4.688 \text{ g NaOH}$$

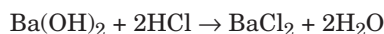
$$4.688 \text{ g NaOH} \times \frac{1 \text{ mol NaOH}}{40.00 \text{ g NaOH}} \times \frac{1 \text{ mol acid}}{2 \text{ mol NaOH}} = 0.05860 \text{ mol acid}$$

Unknown: V of acid

$$\frac{0.05860 \text{ mol acid}}{2.811 \text{ mol/L}} = 0.02085 \text{ L acid} = 20.85 \text{ mL acid}$$

473. Given: 43.09 mL of
0.1529 M
Ba(OH)₂;
26.06 mL HCl
for Ba(OH)₂;
27.05 mL HCl
for 15.00 mL
RbOH

a. Unknown: molarity
of HCl

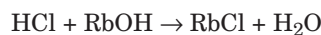


$$\frac{0.1529 \text{ mol Ba(OH)}_2}{\text{L}} \times 43.09 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 6.588 \times 10^{-3} \text{ mol Ba(OH)}_2$$

$$6.588 \times 10^{-3} \text{ mol Ba(OH)}_2 \times \frac{2 \text{ mol HCl}}{1 \text{ mol Ba(OH)}_2} = 1.318 \times 10^{-2} \text{ mol HCl}$$

$$\frac{1.318 \times 10^{-2} \text{ mol HCl}}{26.06 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.5058 \text{ M HCl}$$

b. Unknown: molarity
of RbOH



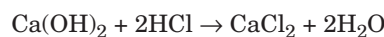
$$\frac{0.5058 \text{ mol HCl}}{\text{L}} \times 27.05 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.368 \times 10^{-2} \text{ mol HCl}$$

$$1.368 \times 10^{-2} \text{ mol HCl} \times \frac{1 \text{ mol RbOH}}{1 \text{ mol HCl}} = 1.368 \times 10^{-2} \text{ mol RbOH}$$

$$\frac{1.368 \times 10^{-2} \text{ mol RbOH}}{15.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.9120 \text{ M RbOH}$$

474. Given: 2800 kg of 6.0 M
HCl; $D_{\text{HCl}} =$
1.10 g/mL

Unknown: mass
Ca(OH)₂



$$2800 \text{ kg HCl} \times \frac{1 \text{ mL}}{1.10 \text{ g}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2500 \text{ L HCl}$$

$$\frac{6.0 \text{ mol HCl}}{\text{L}} \times 2500 \text{ L} = 1.5 \times 10^4 \text{ mol HCl}$$

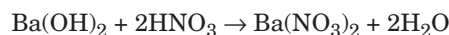
$$1.5 \times 10^4 \text{ mol HCl} \times \frac{1 \text{ mol Ca(OH)}_2}{2 \text{ mol HCl}} = 7.5 \times 10^3 \text{ mol Ca(OH)}_2$$

$$7.5 \times 10^3 \text{ mol Ca(OH)}_2 \times \frac{74.10 \text{ g Ca(OH)}_2}{1 \text{ mol Ca(OH)}_2} = 5.6 \times 10^5 \text{ g Ca(OH)}_2$$

$$= 560 \text{ kg Ca(OH)}_2$$

475. Given: 1.00 mL HNO₃
diluted to
200.00 mL;
10.00 mL of
diluted HNO₃;
23.94 mL of
0.0177 M
Ba(OH)₂

Unknown: molarity of
original
HNO₃



$$\frac{0.0177 \text{ mol Ba(OH)}_2}{\text{L}} \times 23.94 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 4.24 \times 10^{-4} \text{ mol Ba(OH)}_2$$

$$4.24 \times 10^{-4} \text{ mol Ba(OH)}_2 \times \frac{2 \text{ mol HNO}_3}{1 \text{ mol Ba(OH)}_2} = 8.48 \times 10^{-4} \text{ mol HNO}_3$$

$$\frac{8.48 \times 10^{-4} \text{ mol HNO}_3}{10.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 8.48 \times 10^{-2} \text{ M HNO}_3$$

$$\frac{8.48 \times 10^{-2} \text{ mol HNO}_3}{1 \text{ L}} \times 200.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.70 \times 10^{-2} \text{ mol HNO}_3$$

$$\frac{1.70 \times 10^{-2} \text{ mol HNO}_3}{1.00 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 17.0 \text{ M HNO}_3$$

476. Given: 4.494 M H ₂ SO ₄ ; 7.2280 g LiOH Unknown: V of H ₂ SO ₄	$\text{H}_2\text{SO}_4 + 2\text{LiOH} \rightarrow \text{Li}_2\text{SO}_4 + 2\text{H}_2\text{O}$ $7.2280 \text{ g LiOH} \times \frac{1 \text{ mol LiOH}}{23.95 \text{ g LiOH}} = 0.3018 \text{ mol LiOH}$ $0.3018 \text{ mol LiOH} \times \frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol LiOH}} = 0.1509 \text{ mol H}_2\text{SO}_4$ $\frac{0.1509 \text{ mol H}_2\text{SO}_4}{4.494 \text{ mol/L}} = 0.03358 \text{ L H}_2\text{SO}_4 = 33.58 \text{ mL H}_2\text{SO}_4$
477. Given: 5CO ₂ (g) + Si ₃ N ₄ (s) → 3SiO(s) + 2N ₂ O(g) + 5CO(g) Unknown: reaction enthalpy for the given reaction	$(1) \text{CO(g)} + \text{SiO}_2\text{(s)} \rightarrow \text{SiO(g)} + \text{CO}_2\text{(g)}$ $(2) 8\text{CO}_2\text{(g)} + \text{Si}_3\text{N}_4\text{(s)} \rightarrow 3\text{SiO}_2\text{(s)} + 2\text{N}_2\text{O(g)} + 8\text{CO(g)}$ $\Delta H_{\text{reaction 1}} = +520.9 \text{ kJ}$ $\Delta H_{\text{reaction 2}} = +461.05 \text{ kJ}$ $3[\text{CO(g)} + \text{SiO}_2\text{(s)} \rightarrow \text{SiO(g)} + \text{CO}_2\text{(g)}] \quad \Delta H = 3(+520.9) = +1562.7 \text{ kJ}$ $8\text{CO}_2\text{(g)} + \text{Si}_3\text{N}_4\text{(s)} \rightarrow 3\text{SiO}_2\text{(s)} + 2\text{N}_2\text{O(g)} + 8\text{CO(g)} \quad \Delta H = +461.05 \text{ kJ}$ $5\text{CO}_2\text{(g)} + \text{Si}_3\text{N}_4\text{(s)} \rightarrow 3\text{SiO(s)} + 2\text{N}_2\text{O(g)} + 5\text{CO(g)}$ $\Delta H = 2024 \text{ kJ}$
478. Given: CaCO ₃ (s) → CaO(s) + CO ₂ (g) Unknown: ΔH	$\text{CaCO}_3\text{(s)} \rightarrow \text{Ca(s)} + \text{C(s)} + \frac{3}{2}\text{O}_2\text{(g)} \quad \Delta H = 1207.6 \text{ kJ/mol}$ $\text{Ca(s)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CaO(s)} \quad \Delta H = -634.9 \text{ kJ/mol}$ $\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} \quad \Delta H = -393.5 \text{ kJ/mol}$ $\text{CaCO}_3\text{(s)} \rightarrow \text{CaO(s)} + \text{CO}_2\text{(g)} \quad \Delta H = 179.2 \text{ kJ/mol}$
479. Given: 2FeO(s) + O ₂ (g) → Fe ₂ O ₃ (s) Unknown: ΔH	$4\text{Fe(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Fe}_2\text{O}_3\text{(s)} \quad \Delta H = -1118.4 \text{ kJ/mol}$ $2[2\text{FeO(s)} \rightarrow 2\text{Fe(s)} + \text{O}_2\text{(g)}] \quad \Delta H = 2(+825.5) = +1651.0$ $4\text{FeO(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{Fe}_2\text{O}_3\text{(s)} \quad \Delta H = 533 \text{ kJ/mol}$
480. Given: NH ₃ (g) + HF(g) → NH ₄ F(s) Unknown: ΔH	$\text{NH}_3\text{(g)} \rightarrow \text{N(g)} + \frac{3}{2}\text{H}_2\text{(g)} \quad \Delta H = 45.9 \text{ kJ/mol}$ $\text{HF(g)} \rightarrow \frac{1}{2}\text{H}_2\text{(g)} + \text{F(s)} \quad \Delta H = 273.3 \text{ kJ/mol}$ $\text{N(g)} + 2 \text{H}_2\text{(g)} + \text{F(s)} \rightarrow \text{NH}_4\text{F(s)} \quad \Delta H = -125 \text{ kJ/mol}$ $\text{NH}_3\text{(g)} + \text{HF(g)} \rightarrow \text{NH}_4\text{F(s)} \quad \Delta H = 194 \text{ kJ/mol}$
481. Given: H ₂ S(g) + O ₂ (g) → H ₂ O(l) + SO ₂ (g) ΔH _{reaction} = -562.1 kJ/mol ΔS _{reaction} = -0.092 78 kJ/mol • K T = 25°C = 298 K Unknown: ΔG	$\Delta G = \Delta H - T\Delta S$ $= -562.1 \text{ kJ/mol} - [(298 \text{ K})(-0.092 78 \text{ kJ/mol} \cdot \text{K})]$ $= -534.5 \text{ kJ/mol}$

482. Given: $\text{NaClO}_3(s) \rightarrow \text{NaCl}(s) + \text{O}_2(g)$
 $\Delta H_{\text{reaction}} = -19.1 \text{ kJ/mol}$
 $\Delta S_{\text{reaction}} = 0.1768 \text{ kJ/mol} \cdot \text{K}$
 $T = 25^\circ\text{C} = 298 \text{ K}$

Unknown: ΔG

$$\Delta G = \Delta H - T\Delta S$$

$$= -19.1 \text{ kJ/mol} - [(298 \text{ K})(0.1768 \text{ kJ/mol} \cdot \text{K})]$$

$$= -71.8 \text{ kJ/mol}$$

483. Given: $\text{C}_2\text{H}_6(g) + \text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$
 $\Delta H_{\text{reaction}} = -1561 \text{ kJ/mol}$
 $\Delta S_{\text{reaction}} = -1.4084 \text{ kJ/mol} \cdot \text{K}$
 $T = 25^\circ\text{C} = 298 \text{ K}$

Unknown: ΔG for combustion of 1 mole of C_2H_6

$$\Delta G = \Delta H - T\Delta S$$

$$= -1561 \text{ kJ/mol} - [(298 \text{ K})(-0.4084 \text{ kJ/mol} \cdot \text{K})]$$

$$= -1683 \text{ kJ/mol}$$

484. Given: $\text{F}_2(g) + \text{H}_2\text{O}(l) \rightarrow 2\text{HF}(g) + \text{O}_2(g)$

Unknown: ΔH

$$2[\text{H}_2 + \text{F}_2 \rightarrow 2\text{HF}] \quad \Delta H = 2(-273.3) = -546.6 \text{ kJ/mol}$$

$$2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2 \quad \Delta H = +285.8$$

$$2\text{F}_2(g) + 2\text{H}_2\text{O}(l) \rightarrow 4\text{HF}(g) + \text{O}_2(g) \quad \Delta H = -260.8 \text{ kJ/mol}$$

485. Given: $\text{CaO}(s) + \text{SO}_3(g) \rightarrow \text{CaSO}_4(s)$
 $\text{H}_2\text{O}(l) + \text{SO}_3(g) \rightarrow \text{H}_2\text{SO}_4(l)$
 $\Delta H = -132.5 \text{ kJ/mol}$
 $\text{H}_2\text{SO}_4(l) + \text{Ca}(s) \rightarrow \text{CaSO}_4(s) + \text{H}_2(g)$
 $\Delta H = -602.5 \text{ kJ/mol}$
 $\text{Ca}(s) + \text{O}_2(g) \rightarrow \text{CaO}(s)$
 $\Delta H = -634.9 \text{ kJ/mol}$
 $\text{H}_2(g) + \text{O}_2(g) \rightarrow \text{H}_2\text{O}(l)$
 $\Delta H = -285.8 \text{ kJ/mol}$

Unknown: ΔH for reaction of CaO + SO_3

$$\text{CaO}(s) \rightarrow \text{Ca}(s) + \frac{1}{2}\text{O}_2(g) \quad \Delta H = +634.9 \text{ kJ/mol}$$

$$\text{H}_2\text{O}(l) + \text{SO}_3(g) \rightarrow \text{H}_2\text{SO}_4(l) \quad \Delta H = -132.5 \text{ kJ/mol}$$

$$\text{H}_2\text{SO}_4(l) + \text{Ca}(s) \rightarrow \text{CaSO}_4(s) + \text{H}_2(g) \quad \Delta H = -602.5 \text{ kJ/mol}$$

$$\text{H}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{H}_2\text{O}(l) \quad \Delta H = -285.8 \text{ kJ/mol}$$

$$\text{CaO}(s) + \text{SO}_3(g) \rightarrow \text{CaSO}_4(s) \quad \Delta H = -385.9 \text{ kJ/mol}$$

486. Given: $\text{Na}_2\text{O}(s) + \text{SO}_2(g) \rightarrow \text{Na}_2\text{SO}_3(s)$

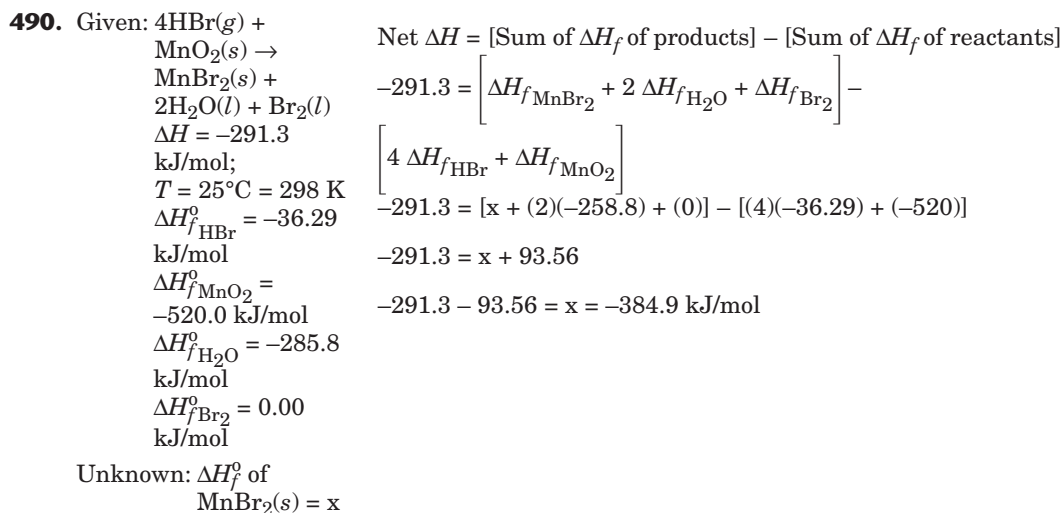
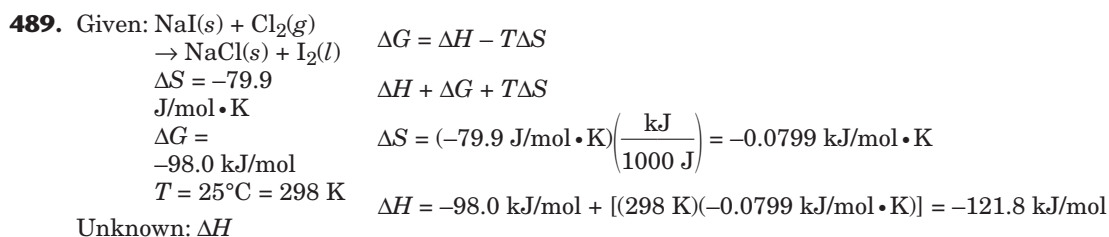
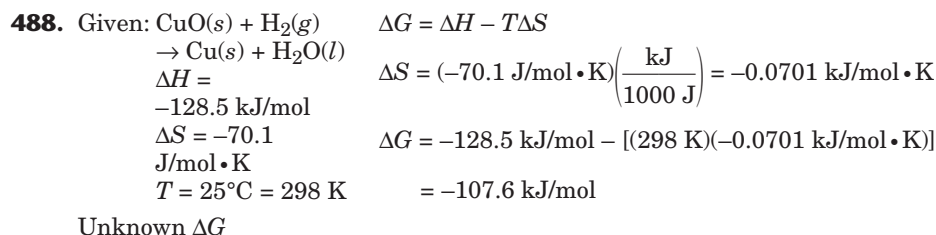
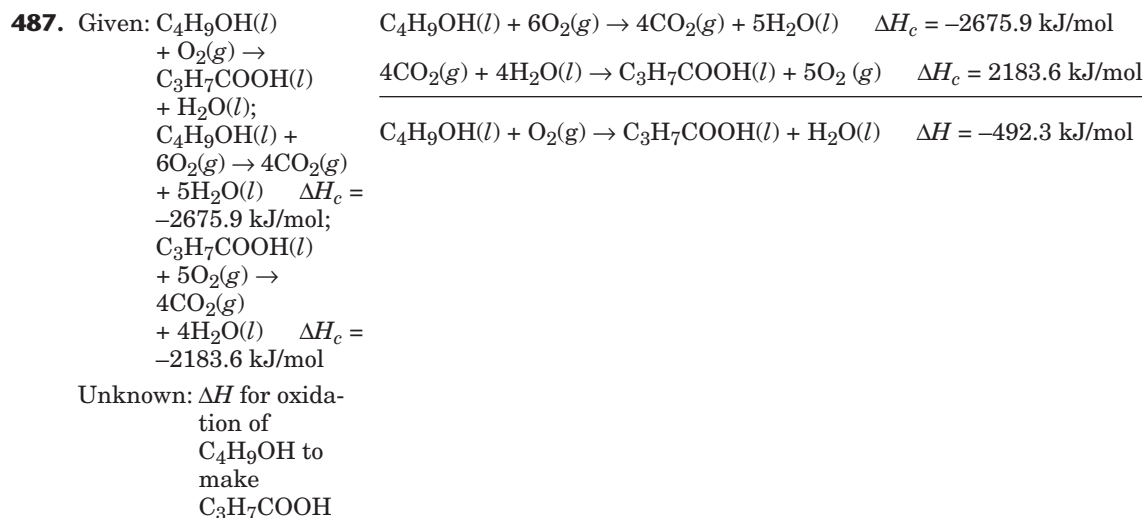
Unknown: ΔH

$$\text{Na}_2\text{O}(s) \rightarrow 2\text{Na}(s) + \frac{1}{2}\text{O}_2(g) \quad \Delta H = +414.2 \text{ kJ/mol}$$

$$\text{SO}_2(g) \rightarrow \text{S}(s) + \text{O}_2(g) \quad \Delta H = +296.8 \text{ kJ/mol}$$

$$2\text{Na}(s) + \text{S}(s) + \frac{3}{2}\text{O}_2(g) \rightarrow \text{Na}_2\text{SO}_3(s) \quad \Delta H = -1101 \text{ kJ/mol}$$

$$\text{Na}_2\text{O}(s) + \text{SO}_2(g) \rightarrow \text{Na}_2\text{SO}_3(s) \quad \Delta H = -390. \text{ kJ/mol}$$



491. Given: $\text{CaC}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_2\text{H}_2(\text{g}) + \text{Ca}(\text{OH})_2(\text{s})$
 $\Delta G = -147.7 \text{ kJ/mol}$
 $\Delta H = -125.6 \text{ kJ/mol}$
 $T = 25^\circ\text{C} = 298 \text{ K}$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta S = (\Delta H - \Delta G)/T$$

$$= [-125.6 \text{ kJ/mol} - (-147.7 \text{ kJ/mol})]/298 \text{ K}$$

$$= 0.0742 \text{ kJ/mol}$$

Unknown: ΔS

492. Given: $\text{NH}_4\text{NO}_3(\text{s}) \rightarrow \text{N}_2\text{O}(\text{g}) + 2\text{H}_2\text{O}(\text{g})$
 $\Delta S = 446.4 \text{ J/mol}\cdot\text{K}$
 $T = 25^\circ\text{C} = 298 \text{ K}$

$$2\text{N}(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{N}_2\text{O}(\text{g}) \quad \Delta H = 82.1 \text{ kJ/mol}$$

$$2[\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g})] \quad \Delta H = (2)(-241.82) = -483.64 \text{ kJ/mol}$$

$$2[\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g})] \quad \Delta H = (2)(285.8) = 571.6 \text{ kJ/mol}$$

Unknown: ΔG

$$\text{NH}_4\text{NO}_3(\text{s}) \rightarrow \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) + \frac{1}{2}\text{O}_2 \quad \Delta H = 365.56 \text{ kJ/mol}$$

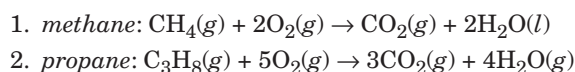
$$\text{NH}_4\text{NO}_3(\text{s}) \rightarrow \text{N}_2\text{O}(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \quad \Delta H = -35.98 \text{ kJ/mol}$$

$$\Delta S = (446.4 \text{ J/mol}\cdot\text{K})(\text{kJ}/1000 \text{ J}) = 0.4464 \text{ kJ/mol}\cdot\text{K}$$

$$\Delta G = \Delta H - T\Delta S$$

$$= -35.98 \text{ kJ/mol} - [(298 \text{ K})(0.4464 \text{ kJ/mol}\cdot\text{K})] = -169.0 \text{ kJ/mol}$$

493. a. Unknown: Chemical equations for combustion of (1) 1 mol of methane (CH_4) and (2) 1 mol of propane (C_3H_8)



b. Unknown: Enthalpy change (ΔH) for each reaction

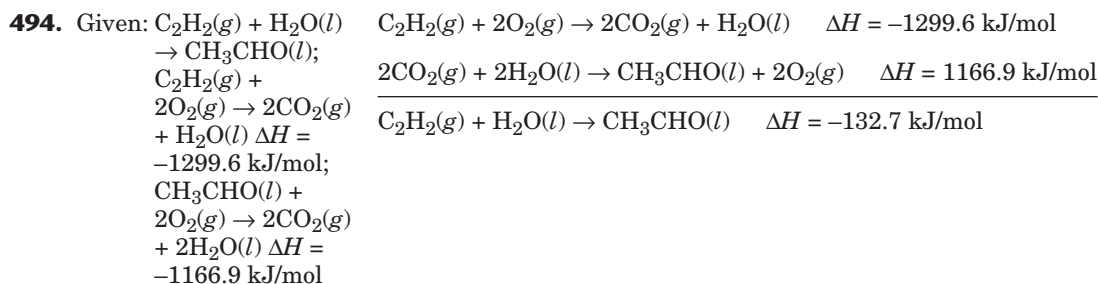
1. *methane*: $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{s}) + 2\text{H}_2(\text{g}) \quad \Delta H = 74.9 \text{ kJ/mol}$
 $\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) \quad \Delta H = -393.5 \text{ kJ/mol}$
 $2[\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g})] \quad \Delta H = (2)(-241.82) = -483.64 \text{ kJ/mol}$

 $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g}) \quad \Delta H = -802.2 \text{ kJ/mol}$
 2. *propane*: $3[\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})] \quad \Delta H = (3)(-393.5) = -1180.5 \text{ kJ/mol}$
 $4[\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{g})] \quad \Delta H = (4)(-241.82) = -967.28 \text{ kJ/mol}$
 $\text{C}_3\text{H}_8(\text{g}) \rightarrow 3\text{C}(\text{s}) + 4\text{H}_2(\text{g}) \quad \Delta H = 104.7 \text{ kJ/mol}$

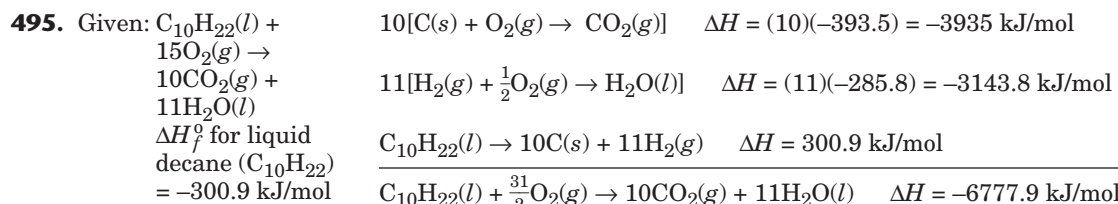
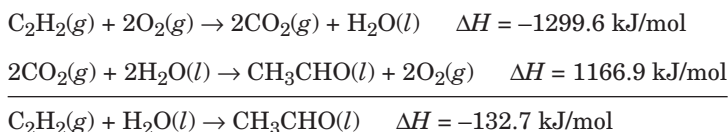
 $\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g}) \quad \Delta H = -2043 \text{ kJ/mol}$

c. Unknown: Heat output per kilogram of each fuel

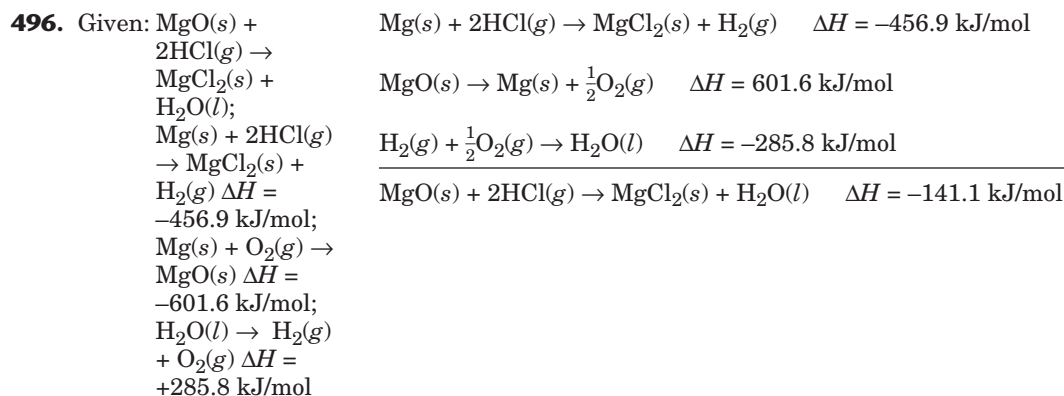
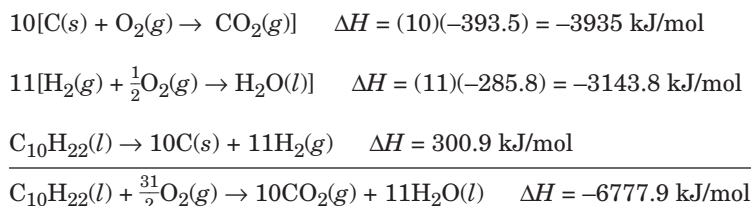
1. *methane*: $(1000 \text{ g CH}_4)\left(\frac{\text{mol CH}_4}{16.05 \text{ g CH}_4}\right) = 62.3 \text{ mol CH}_4$
 $(62.3 \text{ mol CH}_4)(-802.2 \text{ kJ/mol}) = -4.998 \times 10^4 \text{ kJ/kg}$
 2. *propane*: $(1000 \text{ g C}_3\text{H}_8)\left(\frac{\text{mol C}_3\text{H}_8}{44.11 \text{ g C}_3\text{H}_8}\right) = 22.67 \text{ mol C}_3\text{H}_8$
 $(22.67 \text{ mol C}_3\text{H}_8)(-2043 \text{ kJ/mol}) = -4.632 \times 10^4 \text{ kJ/kg}$



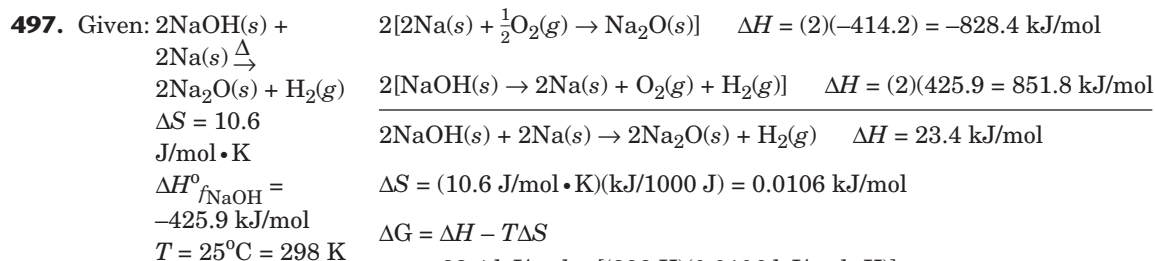
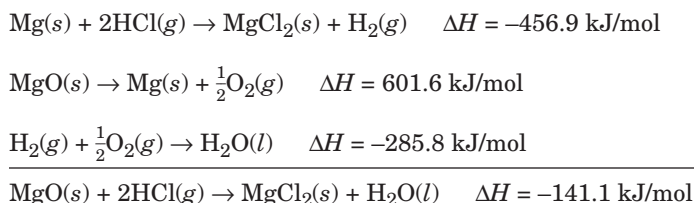
Unknown: Enthalpy (ΔH) for reaction of acetylene with water



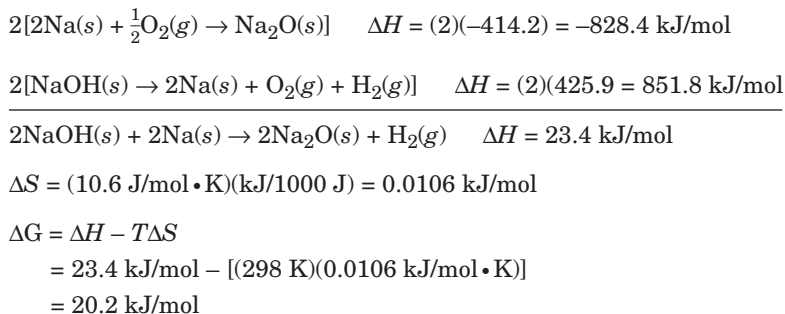
Unknown: Enthalpy (ΔH) for combustion of decane

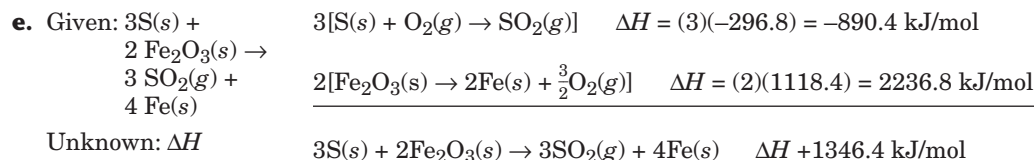
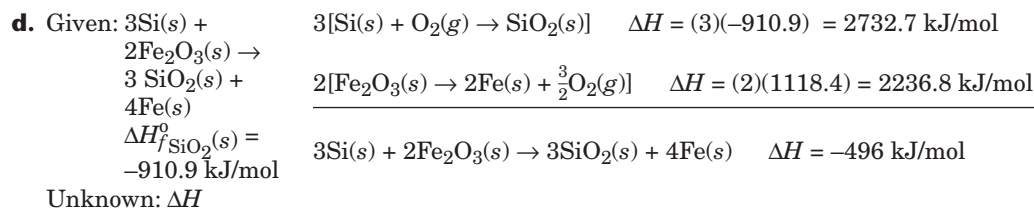
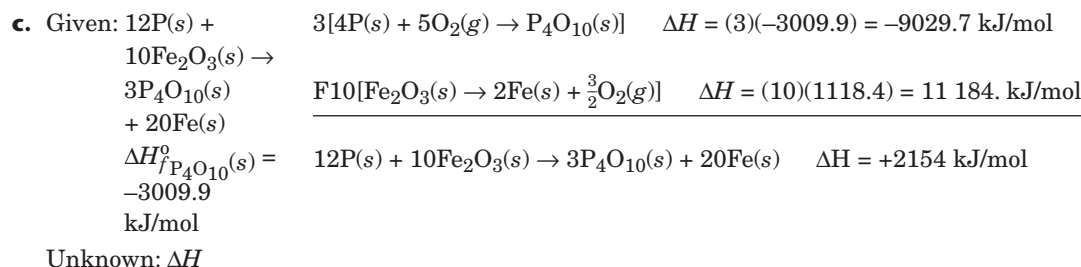
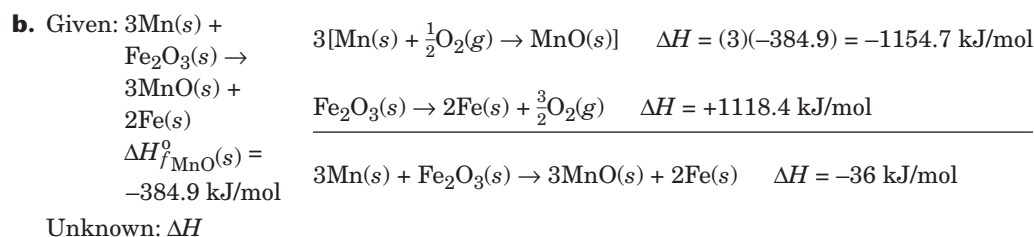
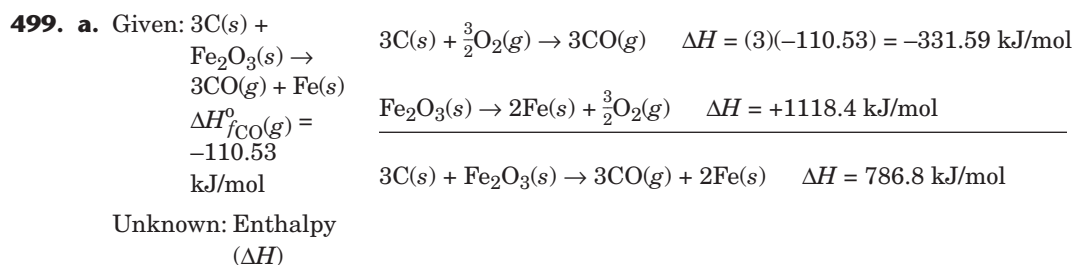
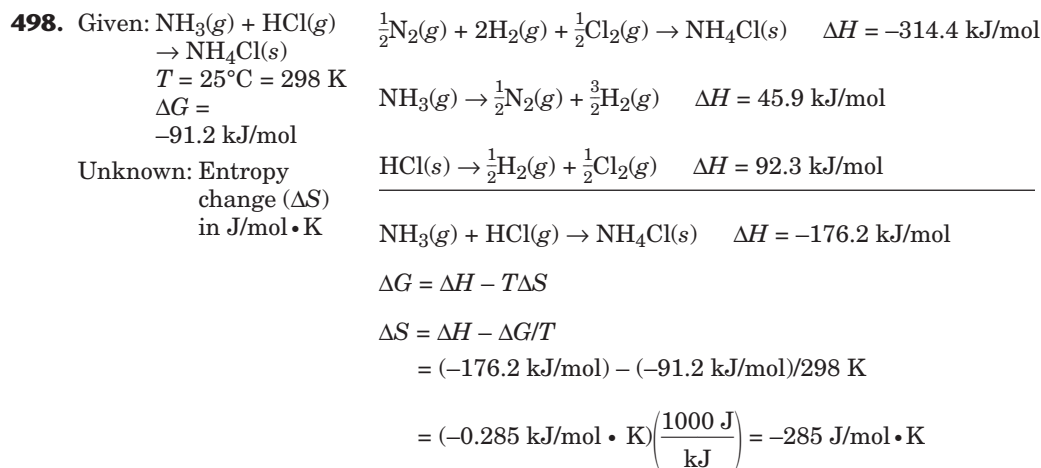


Unknown: Enthalpy (ΔH) of reaction of MgO with HCl



Unknown: ΔG





500. a. Given: $A \rightleftharpoons C + D$

$$[A] = 2.24 \times 10^{-2} \text{ M}$$

$$[C] = 6.41 \times 10^{-3} \text{ M}$$

$$[D] = 6.41 \times 10^{-3} \text{ M}$$

Unknown: K

$$K = \frac{[C][D]}{[A]} = \frac{(6.41 \times 10^{-3} \text{ M})^2}{2.24 \times 10^{-2} \text{ M}} = 1.83 \times 10^{-3}$$

b. Given: $A + B \rightleftharpoons C$

+ D

$$[A] = 3.23 \times 10^{-5} \text{ M} = [B]$$

$$[C] = 1.27 \times 10^{-2} \text{ M} = [D]$$

Unknown: K

$$K = \frac{[C][D]}{[A][B]} = \frac{(1.27 \times 10^{-2} \text{ M})^2}{(3.23 \times 10^{-5} \text{ M})^2} = 1.55 \times 10^5$$

c. Given: $A + B \rightleftharpoons 2 C$

$$[A] = 7.02 \times 10^{-3} \text{ M} = [B]$$

$$[C] = 2.16 \times 10^{-2} \text{ M}$$

Unknown: K

$$K = \frac{[C]^2}{[A][B]} = \frac{(2.16 \times 10^{-2} \text{ M})^2}{(7.02 \times 10^{-3} \text{ M})^2} = 9.47$$

d. Given: $2A \rightleftharpoons 2C$

+ D

$$[A] = 6.59 \times 10^{-4} \text{ M}$$

$$[C] = 4.06 \times 10^{-3} \text{ M}$$

$$[D] = 2.03 \times 10^{-3} \text{ M}$$

Unknown: K

$$K = \frac{[C]^2[D]}{[A]^2} = \frac{(4.06 \times 10^{-3} \text{ M})^2(2.03 \times 10^{-3} \text{ M})}{(6.59 \times 10^{-4} \text{ M})^2} = 7.71 \times 10^{-2}$$

e. Given: $A + B \rightleftharpoons C$

+ D + E

$$[A] = 3.73 \times 10^{-4} \text{ M} = [B]$$

$$[C] = 9.35 \times 10^{-4} \text{ M} = [D]$$

$$= [E]$$

Unknown: K

$$K = \frac{[C][D][E]}{[A][B]} = \frac{(9.35 \times 10^{-4} \text{ M})^3}{(3.73 \times 10^{-4} \text{ M})^2} = 5.88 \times 10^{-3}$$

f. Given: $2A + B \rightleftharpoons 2C$

$$[A] = 5.50 \times 10^{-3} \text{ M}$$

$$[B] = 2.25 \times 10^{-3} \text{ M}$$

$$[C] = 1.02 \times 10^{-2} \text{ M}$$

Unknown: K

$$K = \frac{[C]^2}{[A]^2[B]} = \frac{(1.02 \times 10^{-2} \text{ M})^2}{(5.50 \times 10^{-3} \text{ M})^2(2.25 \times 10^{-3} \text{ M})} = 1.53 \times 10^3$$

501. Given: $2A(g) \rightleftharpoons 2C(g) + D(g)$
 $[A] = 1.88 \times 10^{-1} \text{ M}$
 $[C] = 6.56 \text{ M}$
 $K = 2.403 \times 10^2$
Unknown: $[D]$

$$K = \frac{[C]^2[D]}{[A]^2}$$

$$[D] = (K) [A]^2/[C]^2$$

$$= (2.403 \times 10^2) (1.88 \times 10^{-1} \text{ M})^2/(6.56 \text{ M})^2$$

$$= 0.197 \text{ M}$$

502. Given: $T = 700 \text{ K}$
 $K = 3.164 \times 10^3$
 $C_2H_4(g) + H_2(g) \rightleftharpoons C_2H_6(g)$
Unknown: $[C_2H_4]$ if
 $[H_2] = 0.0619 \text{ M}$ and
 $[C_2H_6] = 1.055 \text{ M}$

$$K = \frac{[C_2H_6]}{[C_2H_4][H_2]}$$

$$[C_2H_4] = \frac{[C_2H_6]}{[H_2] (K)} = \frac{1.055 \text{ M}}{(0.0619 \text{ M})(3.164 \times 10^3)} = 5.39 \times 10^{-3} \text{ M}$$

503. Given: $A + 2B \rightleftharpoons C + 2D$
 $[A] = 0.0567 \text{ M}$
 $[B] = 0.1171 \text{ M}$
 $[C] = 0.000 3378 \text{ M}$
 $[D] = 0.000 6756 \text{ M}$
Unknown: K

$$K = \frac{[C][D]^2}{[A][B]^2} = \frac{(0.000 3378 \text{ M})(0.000 6756 \text{ M})^2}{(0.0567 \text{ M})(0.1171 \text{ M})^2} = 1.98 \times 10^{-7}$$

504. Given: $2A \rightleftharpoons 2C + 2D$
 $[A] = 0.1077 \text{ M}$
 $[C] = 0.000 4104 \text{ M}$
 $[D] = 0.000 4104 \text{ M}$
Unknown: K

$$K = \frac{[C]^2[D]^2}{[A]^2} = \frac{(0.000 4104 \text{ M})^2(0.000 4104 \text{ M})^2}{0.1077 \text{ M}^2} = 2.446 \times 10^{-12}$$

506. a. Given: $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$
 $T = 25^\circ\text{C}$
 $K = 4.282 \times 10^{-2}$
 $[CO] = 5.90 \times 10^{-3} \text{ M} = [Cl_2]$
Unknown: $[COCl_2]$

$$K = \frac{[CO][Cl_2]}{[COCl_2]}$$

$$[COCl_2] = \frac{[CO][Cl_2]}{K} = \frac{(5.90 \times 10^{-3} \text{ M})^2}{4.282 \times 10^{-2}} = 8.13 \times 10^{-4} \text{ M}$$

b. Given: $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$
 $K = 4.282 \times 10^{-2}$
 $[COCl_2] = 0.003 70 \text{ M}$
 $[CO] = [Cl_2]$
Unknown: $[CO]$ and $[Cl_2]$

$$K = \frac{[CO][Cl_2]}{[COCl_2]}$$

$$K = \frac{x^2}{[COCl_2]}$$

$$x^2 = (K) [COCl_2]$$

$$x = \sqrt{(K) [COCl_2]} = \sqrt{(4.282 \times 10^{-2})(0.003 70 \text{ M})} = 0.0126 \text{ M}$$

507. Given: $A(g) + B(s) \rightleftharpoons C(g) + D(s)$
 $K = 1$
 $T = 500 \text{ K}$
a. Unknown: $[A]$ and $[C]$

B and D are solids; therefore their concentrations = 1.
 $K = \frac{[C][1]}{[A][1]}$
 If $K = 1$ $[C][D] = [A][B]$
 $K = 1 = \frac{[C][1]}{[A][1]} = \frac{[C]}{[A]}$
 Therefore, $[A] = [C]$

508. Given: $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$
 $K = 4.251 \times 10^{-2}$
 $T = 800 \text{ K}$
 $[H_2O] = 0.1990 \text{ M}$
 Unknown: $[CO]$ and $[H_2]$

C is a solid; $[C] = 1$
 $K = \frac{[CO][H_2]}{[1][H_2O]}$
 $[CO][H_2] = (K) [H_2O]$
 $x^2 = (4.251 \times 10^{-2})(0.1990 \text{ M})$
 $x = \sqrt{8.459 \times 10^{-3} \text{ M}}$
 $= 0.0918 \text{ M}$

509. a. Given: $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$
 $T = 500 \text{ K}$
 $K = 1.671 \times 10^4$
 $[NO] = 6.200 \times 10^{-2} \text{ M}$
 $[O_2] = 8.305 \times 10^{-3} \text{ M}$
 Unknown: $[NO_2]$

$K = \frac{[NO_2]^2}{[NO]^2[O_2]}$
 $[NO_2]^2 = K[NO]^2[O_2]$
 $[NO_2] = \sqrt{K[NO]^2[O_2]}$
 $= \sqrt{(1.671 \times 10^4)(6.200 \times 10^{-2} \text{ M})^2(8.305 \times 10^{-3} \text{ M})}$
 $= 0.7304 \text{ M}$

b. Given: $T = 1000 \text{ K}$
 $K = 1.315 \times 10^{-2}$
 $[NO] = 6.200 \times 10^{-2} \text{ M}$
 $[O_2] = 8.305 \times 10^{-3} \text{ M}$
 Unknown: $[NO_2]$

$[NO_2] = \sqrt{K[NO]^2[O_2]}$
 $= \sqrt{(1.315 \times 10^{-2})(6.200 \times 10^{-2} \text{ M})^2(8.305 \times 10^{-3} \text{ M})}$
 $= 6.479 \times 10^{-4} \text{ M}$

511. b. Given: $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$
 $K = 5.628 \times 10^{18}$
 $[H_2]_{\text{initial}} = [Br_2]_{\text{initial}} = 0.500 \text{ M}$
 Unknown: $[H_2]$

$K = \frac{[HBr]^2}{[H_2][Br_2]}$
 $[H_2] = [Br_2] = x$
 $[H_2] = \frac{[HBr]^2}{(K)(x)}$
 $x^2 = \frac{(0.500 \text{ M})^2}{(5.628 \times 10^{18})}$
 $x = \sqrt{\frac{(0.500 \text{ M})^2}{(5.628 \times 10^{18})}} = 2.11 \times 10^{-10} \text{ M}$

512. Given: $\text{N}_2\text{F}_4(g) \rightleftharpoons 2\text{NF}_2(g)$
 $T = 25^\circ\text{C}$
 $[\text{N}_2\text{F}_4] = 0.9989\text{ M}$
 $[\text{NF}_2] = 1.131 \times 10^{-3}\text{ M}$
 Unknown: K

$$K = \frac{[\text{NF}_2]^2}{[\text{N}_2\text{F}_4]} = \frac{(1.131 \times 10^{-3}\text{ M})^2}{0.9989\text{ M}} = 1.281 \times 10^{-6}$$

513. Given: $\text{N}_2\text{O}_4(g) \rightleftharpoons 2\text{NO}_2(g)$
 $T = 25^\circ\text{C}$
 $[\text{N}_2\text{O}_4] = 5.95 \times 10^{-1}\text{ M}$
 $[\text{NO}_2] = 5.24 \times 10^{-2}\text{ M}$
 Unknown: K

$$K = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{(5.24 \times 10^{-2}\text{ M})^2}{(5.95 \times 10^{-1}\text{ M})} = 4.61 \times 10^{-3}$$

514. a. Given: $\text{NaCN}(s) + \text{HCl}(g) \rightleftharpoons \text{HCN}(g) + \text{NaCl}(s)$
 Unknown: Expression for equilibrium constant (K)

$$K = \frac{[\text{HCN}][\text{NaCl}]}{[\text{NaCN}][\text{HCl}]}$$

NaCN and NaCl are solids; therefore their concentrations equal 1.

$$K = \frac{[\text{HCN}]}{[\text{HCl}]}$$

b. Given: $K = 2.405 \times 10^6$
 $[\text{HCN}] = 0.8959\text{ M}$
 Unknown: $[\text{HCl}]$

$$K = \frac{[\text{HCN}]}{[\text{HCl}]}$$

$$[\text{HCl}] = \frac{[\text{HCN}]}{K} = \frac{0.8959\text{ M}}{2.405 \times 10^6} = 3.725 \times 10^{-7}\text{ M}$$

515. a. Given: $\text{CH}_4(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}(g) + 3\text{H}_2(g)$
 At 1100 K, $K = 3.112 \times 10^2$

$$K = \frac{[\text{CO}][\text{H}_2]^3}{[\text{CH}_4][\text{H}_2\text{O}]}$$

$$[\text{CO}] = (K) \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{H}_2]^3} = \frac{(3.112 \times 10^2)(3.70 \times 10^{-2}\text{ M})(8.27 \times 10^{-1}\text{ M})}{(1.56\text{ M})^3}$$

$$= 2.51\text{ M}$$

b. Temperature = 110 K, $K = 3.112 \times 10^2$
 $[\text{H}_2] = 1.56\text{ M}$
 $[\text{CH}_4] = 3.70 \times 10^{-2}\text{ M}$
 $[\text{H}_2\text{O}] = 8.27 \times 10^{-1}\text{ M}$
 Unknown: $[\text{CO}]$

516. Given: $\text{N}_2\text{O}_4 \rightleftharpoons \text{NO}_2$
 $T = 20^\circ\text{C} = 293 \text{ K}$
 $[\text{N}_2\text{O}_4] = 2.55 \times 10^{-3} \text{ M}$
 $[\text{NO}_2] = 10.4 \times 10^{-3} \text{ M}$
 Unknown: K

$$\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$$

$$K = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{(10.4 \times 10^{-3} \text{ M})^2}{(2.55 \times 10^{-3} \text{ M})} = 0.0424$$

517. Given: $\text{N}_2\text{O}_4 \rightleftharpoons \text{NO}_2$
 $T = 20^\circ\text{C} = 293 \text{ K}$
 $[\text{N}_2\text{O}_4] = 2.67 \times 10^{-3} \text{ M}$
 $[\text{NO}_2] = 10.2 \times 10^{-3} \text{ M}$
 Unknown: K

$$\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$$

$$K = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = \frac{(10.2 \times 10^{-3} \text{ M})^2}{2.67 \times 10^{-3} \text{ M}} = 0.0390$$

518. Given: $T = 25^\circ\text{C}$
 $[\text{HCOOH}] = 0.025 \text{ M}$
 $[\text{H}_3\text{O}^+] = 2.03 \times 10^{-3} \text{ M}$
 Unknown: K_a

$$\text{HCOOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HCOO}^-$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{HCOO}^-]}{[\text{HCOOH}]}$$

$$[\text{H}_3\text{O}^+] = [\text{HCOO}^-] = 2.03 \times 10^{-3} \text{ M}$$

$$[\text{HCOOH}] = 0.025 - 2.03 \times 10^{-3} = 0.02297 \text{ M}$$

$$K_a = \frac{(2.03 \times 10^{-3})^2}{0.02297} = 1.8 \times 10^{-4}$$

519. Given: $[\text{HIO}_3] = 0.400 \text{ M}$
 $\text{pH} = 0.726$
 $T = 25^\circ\text{C}$
 Unknown: K_a

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\log [\text{H}_3\text{O}^+] = -\text{pH}$$

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH})$$

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-\text{pH}}$$

$$= 1 \times 10^{-0.726}$$

$$= 0.1879 \text{ M}$$

$$\text{HIO}_3 + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{IO}_3^-$$

$$[\text{H}_3\text{O}^+] = [\text{IO}_3^-] = 0.1879 \text{ M}$$

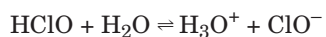
$$[\text{HIO}_3] = 0.400 - 0.1879 = 0.212 \text{ M}$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{IO}_3^-]}{[\text{HIO}_3]} = \frac{(0.1879)^2}{0.212} = 0.167$$

- 520.** Given: $[\text{HClO}] = 0.150 \text{ M}$
 $\text{pH} = 4.55$
 $T = 25^\circ\text{C}$
 Unknown: K_a

$$[\text{H}_3\text{O}^+] = \text{antilog}(-\text{pH})$$

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-\text{pH}} = 1 \times 10^{-4.55} = 2.8 \times 10^{-5}$$



$$[\text{H}_3\text{O}^+] = [\text{ClO}^-] = 2.8 \times 10^{-5} \text{ M}$$

$$[\text{HClO}] = 0.150 - 2.8 \times 10^{-5} = 0.15 \text{ M}$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{ClO}^-]}{[\text{HClO}]} = \frac{(2.8 \times 10^{-5})^2}{0.15} = 5.2 \times 10^{-9}$$

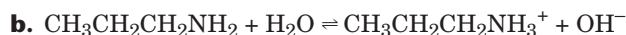
- 521.** Given: $[\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2] = 0.039 \text{ M}$
 $[\text{OH}^-] = 3.74 \times 10^{-3} \text{ M}$
 Unknown: (a) pH of solution;
 (b) K_b for propylamine

a. $\text{pH} = -\log [\text{H}_3\text{O}^+]$

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[\text{H}_3\text{O}^+] = \frac{1.0 \times 10^{-14} \text{ M}^2}{3.74 \times 10^{-3} \text{ M}} = 2.67 \times 10^{-12} \text{ M}$$

$$\text{pH} = -\log (2.67 \times 10^{-12}) = 11.573$$



$$K_b = \frac{[\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_3^+][\text{OH}^-]}{[\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2]}$$

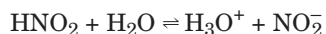
$$[\text{OH}^-] = [\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_3^+] = 3.74 \times 10^{-3} \text{ M}$$

$$[\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2] = 0.039 - 3.74 \times 10^{-3} \text{ M} = 0.03526$$

$$K_b = \frac{(3.74 \times 10^{-3})^2}{0.03526} = 4.0 \times 10^{-4}$$

- 522.** Given: K_a of $\text{HNO}_2 = 4.6 \times 10^{-4}$
 $T = 25^\circ\text{C}$
 $[\text{HNO}_2] = 0.0450 \text{ M}$

Unknown: $[\text{H}_3\text{O}^+]$



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{NO}_2^-]}{[\text{HNO}_2]}$$

$$[\text{H}_3\text{O}^+] = [\text{NO}_2^-] = x$$

$$x^2 = (K_a)[\text{HNO}_2] = (4.6 \times 10^{-4})(0.0450 \text{ M}) = 2.07 \times 10^{-5} \text{ M}$$

$$x = \sqrt{2.07 \times 10^{-5} \text{ M}} = 4.5 \times 10^{-3} \text{ M}$$

523. Given: $[\text{HN}_3] = 0.102 \text{ M}$
 $[\text{H}_3\text{O}^+] = 1.39$
 $\times 10^{-3} \text{ M}$
 $T = 25^\circ\text{C}$

Unknown: **a.** pH
b. K_a

a. $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (1.39 \times 10^{-3}) = 2.857$



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{N}_3^-]}{[\text{HN}_3]}$$

$$[\text{H}_3\text{O}^+] = [\text{N}_3^-] = 1.39 \times 10^{-3} \text{ M}$$

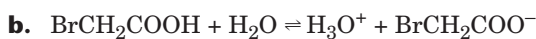
$$[\text{HN}_3] = 0.102 \text{ M} - 1.39 \times 10^{-3} \text{ M} = 0.10061 \text{ M}$$

$$K_a = \frac{(1.39 \times 10^{-3})^2}{0.10061} = 1.92 \times 10^{-5}$$

524. Given: $[\text{BrCH}_2\text{COOH}]$
 $= 0.200 \text{ M}$
 $[\text{H}_3\text{O}^+] =$
 0.0192 M
 $T = 25^\circ\text{C}$

Unknown: **a.** pH
b. K_a

a. $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (0.0192) = 1.717$



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{BrCH}_2\text{COO}^-]}{[\text{BrCH}_2\text{COOH}]}$$

$$[\text{H}_3\text{O}^+] = [\text{BrCH}_2\text{COO}^-] = 0.0192 \text{ M}$$

$$[\text{BrCH}_2\text{COOH}] = 0.200 \text{ M} - 0.0192 \text{ M} = 0.1808 \text{ M}$$

$$K_a = \frac{(0.0192)^2}{0.1808} = 2.04 \times 10^{-3}$$

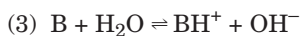
525. a. Given: $\text{B} + \text{H}_2\text{O} \rightleftharpoons$
 $\text{BH}^+ + \text{OH}^-$
 $[\text{B}]_{\text{initial}} =$
 0.400 M
 $[\text{OH}^-] = 2.70$
 $\times 10^{-4} \text{ M}$

Unknown: (1) $[\text{H}_3\text{O}^+]$
(2) pH
(3) K_b

(1) $[\text{H}_3\text{O}^+][\text{OH}^-] = 1.00 \times 10^{-14} \text{ M}^2$

$$[\text{H}_3\text{O}^+] = \frac{1.00 \times 10^{-14} \text{ M}^2}{2.70 \times 10^{-4} \text{ M}} = 3.70 \times 10^{-11} \text{ M}$$

(2) $\text{pH} = -\log (3.70 \times 10^{-11}) = 10.431$



$$K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$$

$$[\text{OH}^-] = [\text{BH}^+] = 2.70 \times 10^{-4} \text{ M}$$

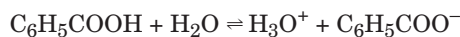
$$[\text{B}] = 0.400 \text{ M} - 2.70 \times 10^{-4} \text{ M} = 0.39973 \text{ M}$$

$$K_b = \frac{(2.70 \times 10^{-4})^2}{0.39973} = 1.82 \times 10^{-7}$$

- b.** Given: $B_{\text{initial}} = 0.00550 \text{ M}$
 $[\text{OH}^-] = 8.45 \times 10^{-4} \text{ M}$
 Unknown: (1) $[\text{B}]$ at equilibrium
 (2) K_b
 (3) pH
- (1) $[\text{B}]$ at equilibrium $= 0.00550 \text{ M} - 8.45 \times 10^{-4} \text{ M} = 4.66 \times 10^{-3} \text{ M}$
- (2) $\text{B} + \text{H}_2\text{O} \rightleftharpoons \text{BH}^+ + \text{OH}^-$
- $$K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$$
- $$[\text{OH}^-] = [\text{BH}^+] = 8.45 \times 10^{-4} \text{ M}$$
- $$K_b = \frac{(8.45 \times 10^{-4} \text{ M})^2}{4.66 \times 10^{-3} \text{ M}} = 1.53 \times 10^{-4}$$
- (3) $\text{pH} = -\log [\text{H}_3\text{O}^+]$
- $$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$
- $$[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14} \text{ M}^2}{8.45 \times 10^{-4} \text{ M}} = 1.18 \times 10^{-11} \text{ M}$$
- $$\text{pH} = -\log (1.18 \times 10^{-11}) = 10.93$$
-
- c.** Given: $[\text{B}]_{\text{initial}} = 0.0350 \text{ M}$
 $\text{pH} = 11.29$
 Unknown: (1) $[\text{H}_3\text{O}^+]$
 (2) $[\text{OH}^-]$
 (3) $[\text{B}]$ at equilibrium
 (4) K_b
- (1) $[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH}) = 1 \times 10^{-\text{pH}} = 1 \times 10^{-11.29} = 5.13 \times 10^{-12} \text{ M}$
- (2) $[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$
- $$[\text{OH}^-] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1 \times 10^{-14} \text{ M}^2}{5.13 \times 10^{-12} \text{ M}} = 1.9 \times 10^{-3} \text{ M}$$
- (3) $[\text{B}]$ at equilibrium $= 0.0350 \text{ M} - 1.9 \times 10^{-3} \text{ M} = 0.0331 \text{ M}$
- (4) $K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$
- $$[\text{OH}^-] = [\text{BH}^+] = 1.9 \times 10^{-3} \text{ M}$$
- $$K_b = \frac{(1.9 \times 10^{-3})^2}{0.0331} = 1.1 \times 10^{-4}$$
-
- d.** Given: $[\text{B}]$ at equilibrium $= 0.00628 \text{ M}$
 $[\text{OH}^-] = 0.00092 \text{ M}$
 Unknown: (1) $[\text{B}]_{\text{initial}}$
 (2) K_b
 (3) pH
- (1) $[\text{B}]_{\text{eq}} = [\text{B}]_{\text{initial}} - [\text{OH}^-]$
- $$[\text{B}]_{\text{initial}} = [\text{B}]_{\text{eq}} + [\text{OH}^-] = 0.00628 \text{ M} + 0.00092 \text{ M} = 7.2 \times 10^{-3} \text{ M}$$
- (2) $K_b = \frac{[\text{BH}^+][\text{OH}^-]}{[\text{B}]}$
- $$[\text{OH}^-] = [\text{BH}^+] = 0.00092 \text{ M}$$
- $$K_b = \frac{(0.00092 \text{ M})^2}{0.00628 \text{ M}} = 1.35 \times 10^{-4}$$
- (3) $\text{pH} = -\log [\text{H}_3\text{O}^+]$
- $$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$
- $$[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14} \text{ M}^2}{0.00092 \text{ M}} = 1.1 \times 10^{-11}$$
- $$\text{pH} = -\log (1.1 \times 10^{-11}) = 10.96$$

526. Given: Solubility of
 $\text{C}_6\text{H}_5\text{COOH}$ in
 water = 2.9 g/L
 $\text{pH} = 2.92$
 $T = 25^\circ\text{C}$

Unknown: K_a



$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\log [\text{H}_3\text{O}^+] = -\text{pH}$$

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH})$$

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-\text{pH}} = 1 \times 10^{-2.92} = 1.2 \times 10^{-3} \text{ M}$$

$$[\text{H}_3\text{O}^+] = [\text{C}_6\text{H}_5\text{COO}^-] = 1.2 \times 10^{-3} \text{ M}$$

$$\left(\frac{2.9 \text{ g C}_6\text{H}_5\text{COOH}}{\text{L}} \right) \left(\frac{1 \text{ mol C}_6\text{H}_5\text{COOH}}{122.11 \text{ g C}_6\text{H}_5\text{COOH}} \right) = 0.02375 \text{ M}$$

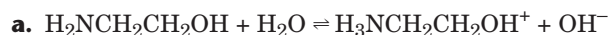
$$= [\text{C}_6\text{H}_5\text{COOH}]_{\text{initial}}$$

$$[\text{C}_6\text{H}_5\text{COOH}] = 0.02375 - 1.2 \times 10^{-3} = 0.02255$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{C}_6\text{H}_5\text{COO}^-]}{[\text{C}_6\text{H}_5\text{COOH}]} = \frac{(1.2 \times 10^{-2} \text{ M})^2}{0.02255 \text{ M}} = 6.4 \times 10^{-5}$$

527. Given: $[\text{H}_2\text{NCH}_2\text{CH}_2\text{OH}]_{\text{initial}} =$
 0.00650 M
 $\text{pH} = 10.64$
 $T = 25^\circ\text{C}$

Unknown: **a.** $[\text{H}_2\text{NCH}_2\text{CH}_2\text{OH}]$ at
 equilibrium
b. K_b



$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\log [\text{H}_3\text{O}^+] = -\text{pH}$$

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH})$$

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-\text{pH}} = 1 \times 10^{-10.64} = 2.3 \times 10^{-11} \text{ M}$$

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[\text{OH}^-] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1 \times 10^{-14} \text{ M}^2}{2.3 \times 10^{-11} \text{ M}} = 4.35 \times 10^{-4} \text{ M}$$

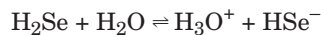
$$[\text{H}_2\text{NCH}_2\text{CH}_2\text{OH}] = 0.00650 \text{ M} - 4.35 \times 10^{-4} \text{ M} = 6.06 \times 10^{-3} \text{ M}$$

$$[\text{H}_3\text{NCH}_2\text{CH}_2\text{OH}^+] = [\text{OH}^-] = 4.35 \times 10^{-4} \text{ M}$$

$$\text{b. } K_b = \frac{[\text{H}_3\text{NCH}_2\text{CH}_2\text{OH}^+][\text{OH}^-]}{[\text{H}_2\text{NCH}_2\text{CH}_2\text{OH}]} = \frac{(4.35 \times 10^{-4} \text{ M})^2}{6.06 \times 10^{-3} \text{ M}} = 3.1 \times 10^{-5}$$

528. Given: $[\text{H}_2\text{Se}] = 0.060 \text{ M}$
 $[\text{H}_3\text{O}^+] = 2.72 \times$
 10^{-3} M
 $T = 25^\circ\text{C}$

Unknown: K_a



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{HSe}^-]}{[\text{H}_2\text{Se}]}$$

$$[\text{HSe}^-] = [\text{H}_3\text{O}^+] = 2.72 \times 10^{-3} \text{ M}$$

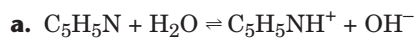
$$[\text{H}_2\text{Se}] = 0.060 \text{ M} - 2.72 \times 10^{-3} \text{ M} = 0.05728 \text{ M}$$

$$K_a = \frac{(2.72 \times 10^{-3} \text{ M})^2}{0.05728 \text{ M}} = 1.3 \times 10^{-4}$$

529. Given: K_b of C_5H_5N
 $= 1.78 \times 10^{-9}$
 $[C_5H_5N] =$
 0.140 M

Unknown: **a.** $[OH^-]$

b. pH



$$K_b = \frac{[C_5H_5NH^+][OH^-]}{C_5H_5N}$$

$$[C_5H_5NH^+] = [OH^-] = x$$

$$x^2 = K_b[C_5H_5N] = (1.78 \times 10^{-9})(0.140 \text{ M}) = 2.5 \times 10^{-10}$$

$$x = \sqrt{2.5 \times 10^{-10}} = 1.58 \times 10^{-5} \text{ M} = [OH^-]$$

b. $pH = -\log [H_3O^+]$

$$[H_3O^+][OH^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[H_3O^+] = \frac{1 \times 10^{-14} \text{ M}^2}{[OH^-]}$$

$$= \frac{1 \times 10^{-14} \text{ M}^2}{1.58 \times 10^{-5} \text{ M}} = 6.329 \times 10^{-10} \text{ M}$$

$$pH = -\log [6.329 \times 10^{-10} \text{ M}] = 9.20$$

530. Given: $[HA] = 0.0208 \text{ M}$
 $pH = 2.17$

Unknown: **a.** $[HA]_{\text{initial}}$

b. K_a



$$pH = -\log [H_3O^+]$$

$$\log [H_3O^+] = -pH$$

$$[H_3O^+] = \text{antilog}(-pH) = 1 \times 10^{-pH} = 1 \times 10^{-2.17} = 6.76 \times 10^{-3} \text{ M}$$

$$[HA] = [HA]_{\text{initial}} - [H_3O^+]$$

$$[HA]_{\text{initial}} = [HA] + [H_3O^+]$$

$$= 0.0208 \text{ M} + 6.76 \times 10^{-3} \text{ M} = 0.02756 \text{ M}$$

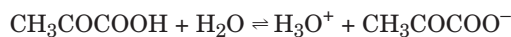
b. $K_a = \frac{[H_3O^+][A^-]}{[HA]}$

$$[H_3O^+] = [A^-] = 6.76 \times 10^{-3} \text{ M}$$

$$K_a = \frac{(6.76 \times 10^{-3} \text{ M})^2}{0.0208 \text{ M}} = 2.2 \times 10^{-3}$$

531. Given: Mass of solute
(CH₃COCOOH)
= 438 mg
volume of
solvent (H₂O)
= 10.00 mL
pH = 1.34

Unknown: K_a



$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\log [\text{H}_3\text{O}^+] = -\text{pH}$$

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH})$$

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-\text{pH}} = 1 \times 10^{-1.34} = 0.0457 \text{ M}$$

$$[\text{H}_3\text{O}^+] = [\text{CH}_3\text{COCOO}^-] = 0.0457 \text{ M}$$

$$\left(\frac{438 \text{ mg CH}_3\text{COCOOH}}{10.00 \text{ mL}} \right) \left(\frac{\text{g}}{1000 \text{ mg}} \right) \left(\frac{1000 \text{ mL}}{\text{L}} \right) \left(\frac{1 \text{ mol CH}_3\text{COCOOH}}{88.04 \text{ g CH}_3\text{COCOOH}} \right)$$

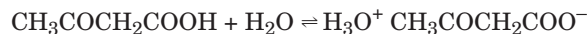
$$= 0.4975 \text{ M} = [\text{CH}_3\text{COCOOH}]_{\text{initial}}$$

$$[\text{CH}_3\text{COCOOH}] = 0.4975 - 0.0457 = 0.4518 \text{ M}$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COCOO}^-]}{[\text{CH}_3\text{COCOOH}]} = \frac{(0.0457 \text{ M})^2}{0.4518 \text{ M}} = 4.63 \times 10^{-3}$$

532. Given: $[\text{H}_3\text{O}^+]$ of
solution of
acetoacetic acid
(CH₃COCH₂CO
OH) = 4.38
 $\times 10^{-3} \text{ M}$
[CH₃COCH₂CO
OH] (nonionized)
= 0.0731 M

Unknown: K_a



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{COCH}_2\text{COO}^-]}{[\text{CH}_3\text{COCH}_2\text{COOH}]}$$

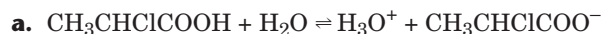
$$[\text{CH}_3\text{COCH}_2\text{COO}^-] = [\text{H}_3\text{O}^+] = 4.38 \times 10^{-3} \text{ M}$$

$$[\text{CH}_3\text{COCH}_2\text{COOH}] = 0.0731 \text{ M} - 4.38 \times 10^{-3} \text{ M} = 0.06872 \text{ M}$$

$$K_a = \frac{(4.38 \times 10^{-3} \text{ M})^2}{0.06872 \text{ M}} = 2.62 \times 10^{-4}$$

533. Given: K_a of
CH₃CHClCOOH
= 1.48×10^{-3}
[CH₃CHClCOO
H]_{initial} =
0.116 M

Unknown: **a.** $[\text{H}_3\text{O}^+]$
b. pH



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CH}_3\text{CHClCOO}^-]}{[\text{CH}_3\text{CHClCOOH}]}$$

$$[\text{H}_3\text{O}^+] = x = [\text{CH}_3\text{CHClCOO}^-]$$

$$[\text{CH}_3\text{CHClCOOH}] = 0.116 - x$$

$$K_a = \frac{(x)(x)}{0.116 - x} = \frac{x^2}{0.116 - x}$$

$$K_a = 1.48 \times 10^{-3}$$

$$1.48 \times 10^{-3} = \frac{x^2}{0.116 - x}$$

$$\text{By the quadratic equation, } x = 0.0124 \text{ M.}$$

b. $\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (0.0124) = 1.907$

534. Given: First ionization:
 $\text{H}_2\text{SO}_4 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{HSO}_4^-$
 Ionization
 $= 100\%$
 Second ionization:
 $\text{HSO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{SO}_4^{2-}$
 $K_{a2} = 1.3 \times 10^{-2}$
 $[\text{H}_2\text{SO}_4] = 0.0788 \text{ M}$

Unknown: **a.** total $[\text{H}_3\text{O}^+]$
b. pH of H_2SO_4 solution

$$\text{a. } K_{a2} = 1.3 \times 10^{-2} = \frac{[\text{H}_3\text{O}^+][\text{SO}_4^{2-}]}{[\text{HSO}_4^-]}$$

$$[\text{H}_3\text{O}^+] = 0.0788 + x$$

$$[\text{SO}_4^{2-}] = x$$

$$[\text{HSO}_4^-] = 0.0788 - x$$

$$1.3 \times 10^{-2} = \frac{(0.0788 + x)(x)}{(0.0788 - x)}$$

$$(1.3 \times 10^{-2})(0.0788 - x) = (0.0788 + x)(x)$$

$$(1.0244 \times 10^{-3}) - (1.3 \times 10^{-2})x = (7.88 \times 10^{-2})x + x^2$$

$$x^2 + (9.18 \times 10^{-2})x - (1.0244 \times 10^{-3}) = 0$$

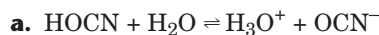
By the quadratic formula, $x = 0.010024$.

$$[\text{H}_3\text{O}^+] = 0.0788 + 0.01 = 0.0888$$

$$\text{b. } \text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (0.0888) = 1.05$$

535. Given: $[\text{HOCN}] = 0.100 \text{ M}$
 $[\text{H}_3\text{O}^+] = 5.74 \times 10^{-3} \text{ M}$

Unknown: **a.** K_a
b. pH



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{OCN}^-]}{[\text{HOCN}]}$$

$$[\text{H}_3\text{O}^+] = [\text{OCN}^-] = 5.74 \times 10^{-3} \text{ M}$$

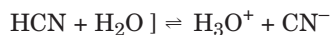
$$[\text{HOCN}] = 0.100 \text{ M} - 5.74 \times 10^{-3} \text{ M} = 0.094 \text{ M}$$

$$K_a = \frac{(5.74 \times 10^{-3})^2}{0.094} = 3.5 \times 10^{-4}$$

$$\text{b. } \text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (5.74 \times 10^{-3}) = 2.241$$

536. Given: $[\text{HCN}] = 0.025 \text{ M}$
 $[\text{CN}^-] = 3.16 \times 10^{-6} \text{ M}$

a. Unknown: $[\text{H}_3\text{O}^+]$



$$[\text{CN}^-] = [\text{H}_3\text{O}^+] = 3.16 \times 10^{-6} \text{ M}$$

b. Unknown: pH

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (3.16 \times 10^{-6}) = 5.500$$

d. Unknown: K_a

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CN}^-]}{[\text{HCN}]}$$

$$[\text{HCN}] = 0.025 \text{ M} - 3.16 \times 10^{-6} \text{ M} = 0.0249 \text{ M}$$

$$K_a = \frac{(3.16 \times 10^{-6} \text{ M})^2}{0.0249 \text{ M}} = 4.0 \times 10^{-10}$$

f. Given: $[\text{HCN}] = 0.085 \text{ M}$

Unknown: $[\text{H}_3\text{O}^+]$

$$K_a = \frac{x^2}{0.085}$$

$$x^2 = (K_a)(0.085)$$

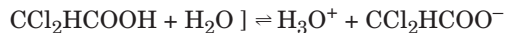
$$x = \sqrt{(K_a)(0.085)} = \sqrt{(4.0 \times 10^{-10})(0.085)} = \sqrt{3.4 \times 10^{-11}} = 5.8 \times 10^{-6}$$

537. Given: $[\text{CCl}_2\text{HCOOH}] = 1.20 \text{ M}$
 $[\text{H}_3\text{O}^+] = 0.182 \text{ M}$

a. Unknown: pH

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (0.182) = 0.740$$

b. Unknown: K_a



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CCl}_2\text{HCOO}^-]}{[\text{CCl}_2\text{HCOOH}]}$$

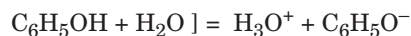
$$[\text{H}_3\text{O}^+] = [\text{CCl}_2\text{HCOO}^-] = 0.182 \text{ M}$$

$$[\text{CCl}_2\text{HCOOH}] = 1.20 \text{ M} - 0.182 \text{ M} = 1.018 \text{ M}$$

$$K_a = \frac{(0.182)^2}{1.018} = 0.0325$$

538. Given: $[\text{C}_6\text{H}_5\text{OH}] = 0.215 \text{ M}$
 $\text{pH} = 5.61$

Unknown: K_a



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{C}_6\text{H}_5\text{O}^-]}{[\text{C}_6\text{H}_5\text{OH}]}$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\log [\text{H}_3\text{O}^+] = -\text{pH}$$

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH})$$

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-\text{pH}} = 1 \times 10^{-5.61} = 2.45 \times 10^{-6} \text{ M}$$

$$[\text{H}_3\text{O}^+] = [\text{C}_6\text{H}_5\text{O}^-] = 2.45 \times 10^{-6} \text{ M}$$

$$[\text{C}_6\text{H}_5\text{OH}] = 0.215 - 2.45 \times 10^{-6} = 0.215 \text{ M}$$

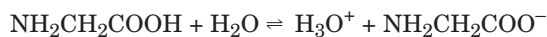
$$K_a = \frac{(2.45 \times 10^{-6})^2}{0.215} = 2.80 \times 10^{-11}$$

539. Given: Solution of $\text{NH}_2\text{CH}_2\text{COOH}$
 is 3.75 g in
 250.0 mL H_2O
 $\text{pH} = 0.890$

a. Unknown: molarity
 of $\text{NH}_2\text{CH}_2\text{COOH}$

$$\left(\frac{3.75 \text{ g NH}_2\text{CH}_2\text{COOH}}{250 \text{ mL}} \right) \left(\frac{1000 \text{ mL}}{\text{L}} \right) \left(\frac{1 \text{ mol NH}_2\text{CH}_2\text{COOH}}{75.06 \text{ g NH}_2\text{CH}_2\text{COOH}} \right) = 0.200 \text{ M NH}_2\text{CH}_2\text{COOH}$$

b. Unknown: K_a



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{NH}_2\text{CH}_2\text{COO}^-]}{[\text{NH}_2\text{CH}_2\text{COOH}]}$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\log [\text{H}_3\text{O}^+] = -\text{pH}$$

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH})$$

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-\text{pH}} = 1 \times 10^{-0.890} = 0.1288 \text{ M}$$

$$[\text{H}_3\text{O}^+] = [\text{NH}_2\text{CH}_2\text{COO}^-] = 0.1288 \text{ M}$$

$$[\text{NH}_2\text{CH}_2\text{COOH}] = 0.200 \text{ M} - 0.1288 \text{ M} = 0.0712 \text{ M}$$

$$K_a = \frac{(0.1288)^2}{0.0712} = 0.233$$

540. Given: $(\text{CH}_3)_3\text{N} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{NH}^+ + \text{OH}^-$
 $[(\text{CH}_3)_3\text{N}] = 0.0750 \text{ M}$
 $[\text{OH}^-] = 2.32 \times 10^{-3} \text{ M}$

Unknown: **a.** pH
b. K_b

a. $[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$

$$[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{OH}^-]} = \frac{1 \times 10^{-14} \text{ M}^2}{2.32 \times 10^{-3} \text{ M}} = 4.31 \times 10^{-12} \text{ M}$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (4.31 \times 10^{-12}) = 11.37$$

b. $K_b = \frac{[\text{CH}_3\text{NH}^+][\text{OH}^-]}{[(\text{CH}_3)_3\text{N}]}$

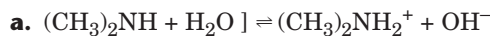
$$[\text{OH}^-] = [\text{CH}_3\text{NH}^+] = 2.32 \times 10^{-3} \text{ M}$$

$$[(\text{CH}_3)_3\text{N}] = 0.0750 \text{ M} - 2.32 \times 10^{-3} \text{ M} = 0.07268 \text{ M}$$

$$K_b = \frac{(2.32 \times 10^{-3})^2}{0.07268} = 7.41 \times 10^{-5}$$

541. Given: $[(\text{CH}_3)_2\text{NH}] = 5.00 \times 10^{-3} \text{ M}$
 $\text{pH} = 11.20$

Unknown: **a.** K_b
b. Which base is stronger: $(\text{CH}_3)_2\text{NH}$ or $(\text{CH}_3)_3\text{N}$?



$$K_b = \frac{[(\text{CH}_3)_2\text{NH}_2^+][\text{OH}^-]}{[(\text{CH}_3)_2\text{NH}]}$$

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$\log [\text{H}_3\text{O}^+] = -\text{pH}$$

$$[\text{H}_3\text{O}^+] = \text{antilog} (-\text{pH}) = 1 \times 10^{-\text{pH}} = 1 \times 10^{-11.20} = 6.31 \times 10^{-12} \text{ M}$$

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[\text{OH}^-] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1 \times 10^{-14} \text{ M}^2}{6.31 \times 10^{-12} \text{ M}} = 1.585 \times 10^{-3} \text{ M}$$

$$[\text{OH}^-] = [(\text{CH}_3)_2\text{NH}_2^+] = 1.585 \times 10^{-3} \text{ M}$$

$$[(\text{CH}_3)_2\text{NH}] = 5.00 \times 10^{-3} \text{ M} - 1.585 \times 10^{-3} \text{ M} = 3.415 \times 10^{-3} \text{ M}$$

$$K_b = \frac{(1.585 \times 10^{-3})^2}{3.415 \times 10^{-3}} = 7.36 \times 10^{-4}$$

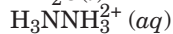
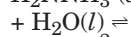
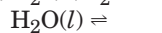
b. K_b of $(\text{CH}_3)_3\text{N} = 7.41 \times 10^{-5}$

$$K_b \text{ of } (\text{CH}_3)_2\text{NH} = 7.36 \times 10^{-4}$$

$$7.36 \times 10^{-4} > 7.41 \times 10^{-5}$$

Therefore $(\text{CH}_3)_2\text{NH}$ (dimethylamine) is the stronger base.

542. Given: $\text{H}_2\text{NNH}_2 +$



$$K_{b2} = 8.9 \times 10^{-16}$$

a. $[\text{H}_2\text{NNH}_2] = 0.120 \text{ M}$

pH = 10.50

Unknown: K_{b1}

(Assume

that

$[\text{H}_2\text{NNH}_2]$

initial does

not

change.)

$$K_{b1} = \frac{[\text{H}_2\text{NNH}_3^+][\text{OH}^-]}{[\text{H}_2\text{NNH}_2]}$$

$$[\text{H}_3\text{O}^+] = \text{antilog}(-\text{pH})$$

$$[\text{H}_3\text{O}^+] = 1 \times 10^{-\text{pH}}$$

$$= 1 \times 10^{-10.50}$$

$$= 3.16 \times 10^{-11} \text{ M}$$

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[\text{OH}^-] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{H}_3\text{O}^+]} = \frac{1 \times 10^{-14} \text{ M}^2}{3.16 \times 10^{-11} \text{ M}}$$

$$= 3.16 \times 10^{-4} \text{ M}$$

$$[\text{OH}^-] = 3.16 \times 10^{-4} \text{ M} = [\text{H}_2\text{NNH}_3^+]$$

$$K_{b1} = \frac{(3.16 \times 10^{-4})^2}{0.120 \text{ M}} = 8.3 \times 10^{-7}$$

b. Given: $[\text{H}_2\text{NNH}_2] =$
0.020 M

Unknown: $[\text{OH}^-]$

$$K_{b1} = \frac{[\text{H}_2\text{NNH}_3^+][\text{OH}^-]}{[\text{H}_2\text{NNH}_2]}$$

$$8.3 \times 10^{-7} = \frac{x^2}{0.020}$$

$$x = \sqrt{(8.3 \times 10^{-7})(0.020)} = 1.3 \times 10^{-4} \text{ M} = [\text{OH}^-]$$

c. Unknown: pH of
0.020 M
 $[\text{H}_2\text{NNH}_2]$
solution

$$[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14} \text{ M}^2}{[\text{OH}^-]} = \frac{1 \times 10^{-14} \text{ M}^2}{1.3 \times 10^{-4} \text{ M}} = 7.7 \times 10^{-11} \text{ M}$$

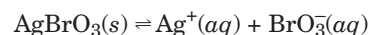
$$\text{pH} = -\log [\text{H}_3\text{O}^+] = -\log (7.7 \times 10^{-11}) = 10.11$$

543. Given: Saturated solu-
tion: 0.276 g
 AgBrO_3 in
150.0 mL H_2O

Unknown: K_{sp}

$$\text{solubility} = \left(\frac{0.276 \text{ g AgBrO}_3}{150.0 \text{ mL H}_2\text{O}} \right) \left(\frac{1000 \text{ mL}}{\text{L}} \right) \left(\frac{1 \text{ mol AgBrO}_3}{235.74 \text{ g AgBrO}_3} \right)$$

$$= 7.80 \times 10^{-3} \text{ M AgBrO}_3$$



$$K_{sp} = [\text{Ag}^+][\text{BrO}_3^-]$$

$$[\text{Ag}^+] = 7.80 \times 10^{-3} \text{ M}$$

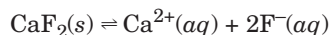
$$[\text{BrO}_3^-] = 7.80 \times 10^{-3} \text{ M}$$

$$K_{sp} = (7.80 \times 10^{-3})^2 = 6.08 \times 10^{-5}$$

544. Given: solubility of CaF_2
 $= 0.0427 \text{ g}/2.50 \text{ L}$

$$\left(\frac{0.0427 \text{ g CaF}_2}{2.50 \text{ L}} \right) \left(\frac{1 \text{ mol CaF}_2}{78.06 \text{ g CaF}_2} \right) = 2.19 \times 10^{-4} \text{ M CaF}_2$$

Unknown: K_{sp}



$$K_{sp} = [\text{Ca}^{2+}][\text{F}^-]^2$$

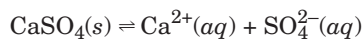
$$[\text{Ca}^{2+}] = 2.19 \times 10^{-4} \text{ M}$$

$$[\text{F}^-] = (2)(2.19 \times 10^{-4}) = 4.38 \times 10^{-4} \text{ M}$$

$$\begin{aligned} K_{sp} &= (2.19 \times 10^{-4})(4.38 \times 10^{-4})^2 \\ &= 4.20 \times 10^{-11} \end{aligned}$$

545. Given: K_{sp} of CaSO_4
 $= 9.1 \times 10^{-6}$

Unknown: $[\text{CaSO}_4]$ in a
saturated
solution



$$K_{sp} = [\text{Ca}^{2+}][\text{SO}_4^{2-}]$$

$$[\text{Ca}^{2+}] = [\text{SO}_4^{2-}] = x$$

$$K_{sp} = x^2 = 9.1 \times 10^{-6}$$

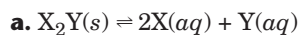
$$x = \sqrt{9.1 \times 10^{-6}}$$

$$= 3.0 \times 10^{-3} \text{ M} = [\text{CaSO}_4]$$

546. Given: A salt = X_2Y
 $K_{sp} = 4.25 \times 10^{-7}$

Unknown: **a.** molarity
of a saturated
solution of
the salt

b. molarity
of a solution
of AZ with
the same K_{sp}



$$K_{sp} = [\text{X}]^2[\text{Y}]$$

$$[\text{X}] = 2x$$

$$[\text{Y}] = x$$

$$K_{sp} = 4.25 \times 10^{-7} = (2x)^2(x) = 4x^3$$

$$x = 4.74 \times 10^{-3} \text{ M} = [\text{X}_2\text{Y}]$$



$$K_{sp} = [\text{A}][\text{Z}] = x^2$$

$$x = \sqrt{4.25 \times 10^{-7}} = 6.52 \times 10^{-4} \text{ M}$$

547. Given: $V \text{ NaOH} = 0.320 \text{ L}$ $2\text{NaOH} + \text{CaCl}_2 \rightarrow 2\text{NaCl} + \text{Ca(OH)}_2$
 $[\text{NaOH}] = 0.046 \text{ M}$ $\text{Ca(OH)}_2(s) \rightleftharpoons \text{Ca}^{2+}(aq) + 2\text{OH}^-(aq)$
 $V \text{ CaCl}_2 = 0.400 \text{ L}$ $K_{sp} = [\text{Ca}^{2+}][\text{OH}^-]^2 = 5.5 \times 10^{-6}$
 $[\text{CaCl}_2] = 0.085 \text{ M}$
 $K_{sp} \text{ Ca(OH)}_2$
 $= 5.5 \times 10^{-6}$

Unknown: whether a precipitate of Ca(OH)_2 forms

$$(0.400 \text{ L}) \left(\frac{0.085 \text{ mol Ca}^{2+}}{\text{L}} \right) = 0.034 \text{ mol Ca}^{2+}$$

$$(0.320 \text{ L}) \left(\frac{0.046 \text{ mol OH}^-}{\text{L}} \right) = 0.0147 \text{ mol OH}^-$$

$$\text{Total volume} = 0.320 \text{ L} + 0.400 \text{ L} = 0.720 \text{ L}$$

$$\frac{0.034 \text{ mol Ca}^{2+}}{0.720 \text{ L}} = 0.0472 \text{ mol/L Ca}^{2+}$$

$$\frac{0.0147 \text{ mol OH}^-}{0.720 \text{ L}} = 0.0204 \text{ mol/L OH}^-$$

$$[\text{Ca}^{2+}][\text{OH}^-]^2 = (0.0472)(0.0204)^2$$

$$= 1.9 \times 10^{-5} = \text{ion product}$$

$$1.9 \times 10^{-5} > K_{sp}; \text{precipitation occurs}$$

548. Given: $V \text{ AgNO}_3 = 0.020 \text{ L}$ $\text{AgNO}_3 + \text{NaC}_2\text{H}_3\text{O}_2 \rightarrow \text{AgC}_2\text{H}_3\text{O}_2 + \text{NaNO}_3$
 $[\text{AgNO}_3] = 0.077 \text{ M}$ $\text{AgC}_2\text{H}_3\text{O}_2(s) \rightleftharpoons \text{Ag}^+(aq) + \text{C}_2\text{H}_3\text{O}_2^-(aq)$
 $V \text{ NaC}_2\text{H}_3\text{O}_2$
 $= 0.030 \text{ L}$ $K_{sp} = [\text{Ag}^+][\text{C}_2\text{H}_3\text{O}_2^-] = 2.5 \times 10^{-3}$
 $[\text{NaC}_2\text{H}_3\text{O}_2]$
 $= 0.043 \text{ M}$
 $K_{sp} \text{ AgC}_2\text{H}_3\text{O}_2$
 $= 2.5 \times 10^{-3}$

Unknown: whether a precipitate forms

$$(0.020 \text{ L}) \left(\frac{0.077 \text{ mol Ag}^+}{\text{L}} \right) = 1.54 \times 10^{-3} \text{ mol Ag}^+$$

$$(0.030 \text{ L}) \left(\frac{0.043 \text{ mol C}_2\text{H}_3\text{O}_2^-}{\text{L}} \right) = 1.29 \times 10^{-3} \text{ mol C}_2\text{H}_3\text{O}_2^-$$

$$\text{Total volume} = 0.020 \text{ L} + 0.030 \text{ L} = 0.050 \text{ L}$$

$$\frac{1.54 \times 10^{-3} \text{ mol Ag}^+}{0.050 \text{ L}} = 0.031 \text{ mol/L Ag}^+$$

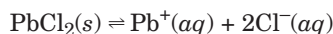
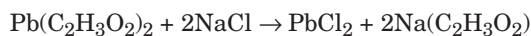
$$\frac{1.29 \times 10^{-3} \text{ mol C}_2\text{H}_3\text{O}_2^-}{0.050 \text{ L}} = 0.026 \text{ mol/L C}_2\text{H}_3\text{O}_2^-$$

$$[\text{Ag}^+][\text{C}_2\text{H}_3\text{O}_2^-] = (0.031)(0.026) = 8.1 \times 10^{-4} = \text{ion product}$$

$$8.1 \times 10^{-4} < 2.5 \times 10^{-3}; \text{no precipitation}$$

549. Given: $V \text{ Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$
 $= 0.100 \text{ L}$
 $[\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2]$
 $= 0.036 \text{ M}$
 $V \text{ NaCl} = 0.050 \text{ L}$
 $[\text{NaCl}] = 0.074 \text{ M}$
 $K_{sp} \text{ PbCl}_2$
 $= 1.9 \times 10^{-4}$

Unknown: whether a
precipitate
forms



$$K_{sp} = [\text{Pb}^+][\text{Cl}^-]^2 = 1.9 \times 10^{-4}$$

$$(0.100 \text{ L}) \left(\frac{0.036 \text{ mol Pb}^+}{\text{L}} \right) = 3.6 \times 10^{-3} \text{ mol Pb}^+$$

$$(0.050 \text{ L}) \left(\frac{0.074 \text{ mol Cl}^-}{\text{L}} \right) = 3.7 \times 10^{-3} \text{ mol Cl}^-$$

$$\text{Total volume} = 0.1 \text{ L} + 0.05 \text{ L} = 0.15 \text{ L}$$

$$\frac{3.6 \times 10^{-3} \text{ mol Pb}^+}{0.15 \text{ L}} = 0.024 \text{ mol/L Pb}^+$$

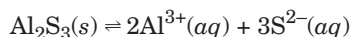
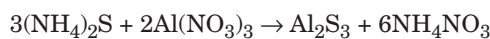
$$\frac{3.7 \times 10^{-3} \text{ mol Cl}^-}{0.15 \text{ L}} = 0.025 \text{ mol/L Cl}^-$$

$$[\text{Pb}^+][\text{Cl}^-]^2 = (0.024)(0.025)^2 = 1.5 \times 10^{-5} = \text{ion product}$$

$$1.5 \times 10^{-5} < 1.9 \times 10^{-4}; \text{ no precipitation}$$

550. Given: $V (\text{NH}_4)_2\text{S}$
 $= 0.020 \text{ L}$
 $[(\text{NH}_4)_2\text{S}]$
 $= 0.0090 \text{ M}$
 $V \text{ Al}(\text{NO}_3)_3$
 $= 0.120 \text{ L}$
 $[\text{Al}(\text{NO}_3)_3]$
 $= 0.0082 \text{ M}$
 $K_{sp} \text{ Al}_2\text{S}_3$
 $= 2.00 \times 10^{-7}$

Unknown: whether a
precipitate
forms



$$K_{sp} = [\text{Al}^{3+}]^2[\text{S}^{2-}]^3 = 2.00 \times 10^{-7}$$

$$(0.120 \text{ L}) \left(\frac{0.0082 \text{ mol Al}^{3+}}{\text{L}} \right) = 9.8 \times 10^{-4} \text{ mol Al}^{3+}$$

$$(0.020 \text{ L}) \left(\frac{0.0090 \text{ mol S}^{2-}}{\text{L}} \right) = 1.8 \times 10^{-4} \text{ mol S}^{2-}$$

$$\text{Total volume} = 0.120 \text{ L} + 0.020 \text{ L} = 0.140 \text{ L}$$

$$\frac{9.8 \times 10^{-4} \text{ mol Al}^{3+}}{0.140 \text{ L}} = 7.0 \times 10^{-3} \text{ mol/L Al}^{3+}$$

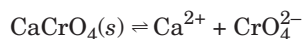
$$\frac{1.8 \times 10^{-4} \text{ mol S}^{2-}}{0.140 \text{ L}} = 1.3 \times 10^{-3} \text{ mol/L S}^{2-}$$

$$[\text{Al}^{3+}]^2[\text{S}^{2-}]^3 = (7.0 \times 10^{-3})^2(1.3 \times 10^{-3})^3 = 1.1 \times 10^{-13} = \text{ion product}$$

$$1.1 \times 10^{-13} < 2.00 \times 10^{-7}; \text{ no precipitation}$$

551. Given: $[\text{CaCrO}_4] =$
 0.010 M

Unknown: K_{sp}



$$K_{sp} = [\text{Ca}^{2+}][\text{CrO}_4^{2-}]$$

$$[\text{Ca}^{2+}] = 0.010 \text{ M}$$

$$[\text{CrO}_4^{2-}] = 0.010 \text{ M}$$

$$K_{sp} = (0.010)^2 = 1.0 \times 10^{-4}$$

552. Given: Solubility of $\text{PbSeO}_4 = 0.00136 \text{ g}/10.00 \text{ mL}$
 Unknown: K_{sp}

$$\left(\frac{0.00136 \text{ g PbSeO}_4}{10.00 \text{ mL}} \right) \left(\frac{1000 \text{ mL}}{1 \text{ L}} \right) \left(\frac{1 \text{ mol PbSeO}_4}{350.12 \text{ g PbSeO}_4} \right) = 3.88 \times 10^{-4} \text{ M PbSeO}_4$$

$$\text{PbSeO}_4(s) \rightleftharpoons \text{Pb}^{2+}(aq) + \text{SeO}_4^{2-}(aq)$$

$$K_{sp} = [\text{Pb}^{2+}][\text{SeO}_4^{2-}]$$

$$[\text{Pb}^{2+}] = [\text{SeO}_4^{2-}] = 3.88 \times 10^{-4} \text{ M}$$

$$K_{sp} = (3.88 \times 10^{-4})^2 = 1.51 \times 10^{-7}$$

553. Given: V of $\text{CuSCN} = 0.0225 \text{ L}$
 $[\text{CuSCN}] = 4.0 \times 10^{-6} \text{ M}$
 Unknown: **a.** K_{sp}
b. mass of CuSCN dissolved in $1 \times 10^{-3} \text{ L}$ of solution

a. $\text{CuSCN}(s) \rightleftharpoons \text{Cu}^{1+}(aq) + \text{SCN}^{1-}(aq)$
 $K_{sp} = [\text{Cu}^{1+}][\text{SCN}^{1-}]$
 $[\text{Cu}^{1+}] = [\text{SCN}^{1-}] = 4.0 \times 10^{-6} \text{ M}$
 $K_{sp} = (4.0 \times 10^{-6})^2 = 1.6 \times 10^{-11}$

b. solubility = $4.0 \times 10^{-6} \text{ M} = \left(\frac{x \text{ g CuSCN}}{1 \times 10^3 \text{ L}} \right) \left(\frac{1 \text{ mol CuSCN}}{121.64 \text{ g CuSCN}} \right)$
 $x = (4.0 \times 10^{-6} \text{ M})(1000 \text{ L})(121.64 \text{ g})/1 \text{ mol} = 0.49 \text{ g}$

554. Given: $[\text{Ag}_2\text{Cr}_2\text{O}_7] = 3.684 \times 10^{-3} \text{ M}$
 Unknown: K_{sp}

$$\text{Ag}_2\text{Cr}_2\text{O}_7(s) \rightleftharpoons 2\text{Ag}^+(aq) + \text{Cr}_2\text{O}_7^{2-}(aq)$$

$$K_{sp} = [\text{Ag}^+]^2[\text{Cr}_2\text{O}_7^{2-}]$$

$$[\text{Ag}^+] = (2)(3.684 \times 10^{-3} \text{ M}) = 7.368 \times 10^{-3} \text{ M}$$

$$[\text{Cr}_2\text{O}_7^{2-}] = 3.684 \times 10^{-3} \text{ M}$$

$$K_{sp} = (7.368 \times 10^{-3})^2(3.684 \times 10^{-3}) = 2.000 \times 10^{-7}$$

555. Given: $K_{sp} \text{ BaSO}_3 = 8.0 \times 10^{-7}$
 Unknown: **a.** $[\text{BaSO}_3]$
b. mass of BaSO_3 dissolved in $500. \text{ mL H}_2\text{O}$

a. $\text{BaSO}_3(s) \rightleftharpoons \text{Ba}^{2+}(aq) + \text{SO}_3^{2-}(aq)$
 $K_{sp} = [\text{Ba}^{2+}][\text{SO}_3^{2-}]$
 $[\text{Ba}^{2+}] = [\text{SO}_3^{2-}] = x$
 $K_{sp} = x^2 = 8.0 \times 10^{-7}$
 $x = \sqrt{8.0 \times 10^{-7}} = 8.9 \times 10^{-4} \text{ M} = [\text{BaSO}_3]$

b. solubility = $8.9 \times 10^{-4} \text{ M} = \left(\frac{x \text{ g BaSO}_3}{500 \text{ mL}} \right) \left(\frac{1000 \text{ mL}}{1 \text{ L}} \right) \left(\frac{1 \text{ mol BaSO}_3}{217.37 \text{ g BaSO}_3} \right)$
 $x = \frac{(8.9 \times 10^{-4} \text{ M})(500 \text{ mL})(1 \text{ L})(217.37 \text{ g})}{(1000 \text{ mL})(1 \text{ mol})}$
 $= 0.097 \text{ g}$

556. Given: $K_{sp} \text{ PbCl}_2 = 1.9 \times 10^{-4}$
 Unknown: $[\text{PbCl}_2]$

$$\text{PbCl}_2(s) \rightleftharpoons \text{Pb}^{2+}(aq) + 2\text{Cl}^-(aq)$$

$$K_{sp} = [\text{Pb}^{2+}][\text{Cl}^-]^2$$

$$[\text{Pb}^{2+}] = x$$

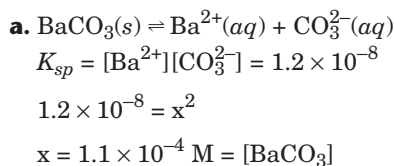
$$[\text{Cl}^-] = 2x$$

$$K_{sp} = 1.9 \times 10^{-4} = (x)(2x)^2 = 4x^3$$

$$x = \sqrt[3]{1.9 \times 10^{-4}/4} = 0.036 \text{ M} = [\text{PbCl}_2]$$

557. Given: K_{sp} $\text{BaCO}_3 = 1.2 \times 10^{-8}$

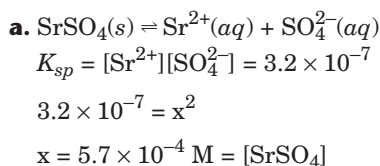
Unknown: **a.** $[\text{BaCO}_3]$
b. volume of water needed to dissolve 0.10 g BaCO_3



b. solubility =
 $1.1 \times 10^{-4} \text{ M} = \left(\frac{0.10 \text{ g BaCO}_3}{x} \right) \left(\frac{1 \text{ mol BaCO}_3}{197.31 \text{ g BaCO}_3} \right)$
 $x = (0.10 \text{ g BaCO}_3) \left(\frac{1 \text{ mol BaCO}_3}{197.31 \text{ g BaCO}_3} \right) \left(\frac{1}{1.1 \times 10^{-4} \text{ M}} \right)$
 $x = 4.6 \text{ L}$

558. Given: K_{sp} $\text{SrSO}_4 = 3.2 \times 10^{-7}$

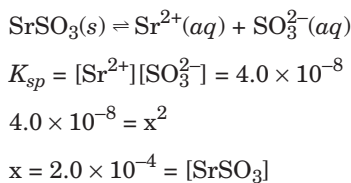
Unknown: **a.** $[\text{SrSO}_4]$
b. mass of SrSO_4 remaining after 20.0 L saturated solution is evaporated



b. solubility =
 $5.7 \times 10^{-4} \text{ M} = \left(\frac{x \text{ g SrSO}_4}{20.0 \text{ L}} \right) \left(\frac{1 \text{ mol SrSO}_4}{183.65 \text{ g SrSO}_4} \right)$
 $x = (5.7 \times 10^{-4} \text{ M})(20.0 \text{ L})(183.65 \text{ g SrSO}_4/\text{mol})$
 $= 2.1 \text{ g}$

559. Given: K_{sp} $\text{SrSO}_3 = 4.0 \times 10^{-8}$
solubility = 1.0000 g/5.0 L H_2O

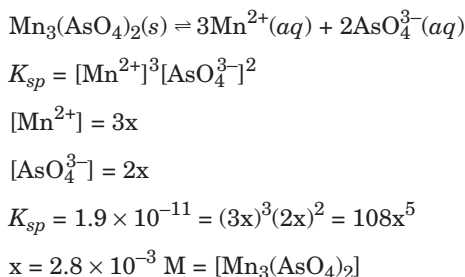
Unknown: mass of SrSO_3 remaining after saturated solution is filtered



solubility =
 $2.0 \times 10^{-4} \text{ M} = \left(\frac{x}{5 \text{ L}} \right) \left(\frac{1 \text{ mol}}{167.66 \text{ g SrSO}_3} \right)$
 $x = (2.0 \times 10^{-4} \text{ M})(5 \text{ L}) \left(\frac{167.66 \text{ g SrSO}_3}{1 \text{ mol}} \right)$
 $= 0.17 \text{ g SrSO}_3$
 $1.000 \text{ g} - 0.17 \text{ g} = 0.83 \text{ g SrSO}_3$

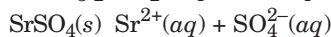
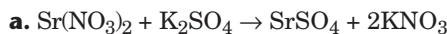
560. Given: K_{sp} $\text{Mn}_3(\text{AsO}_4)_2 = 1.9 \times 10^{-11}$

Unknown: $[\text{Mn}_3(\text{AsO}_4)_2]$ in a saturated solution



561. Given: $V \text{ Sr(NO}_3)_2 = 0.030 \text{ L}$
 $[\text{Sr(NO}_3)_2] = 0.0050 \text{ M}$
 $V \text{ K}_2\text{SO}_4 = 0.020 \text{ L}$
 $[\text{K}_2\text{SO}_4] = 0.010 \text{ M}$
 $K_{sp} \text{ SrSO}_4 = 3.2 \times 10^{-7}$

Unknown: **a.** ion product of the ions that can form a precipitate
(b) whether a precipitate forms



$$K_{sp} = [\text{Sr}^{2+}][\text{SO}_4^{2-}] = 3.2 \times 10^{-7}$$

$$(0.030 \text{ L}) \left(\frac{0.0050 \text{ mol Sr}^{2+}}{\text{L}} \right) = 1.5 \times 10^{-4} \text{ mol Sr}^{2+}$$

$$(0.020 \text{ L}) \left(\frac{0.010 \text{ mol SO}_4^{2-}}{\text{L}} \right) = 2.0 \times 10^{-4} \text{ mol SO}_4^{2-}$$

$$\text{Total volume} = 0.030 \text{ L} + 0.020 \text{ L} = 0.050 \text{ L}$$

$$\frac{1.5 \times 10^{-4} \text{ mol Sr}^{2+}}{0.050 \text{ L}} = 3.0 \times 10^{-3} \text{ mol/L Sr}^{2+}$$

$$\frac{2.0 \times 10^{-4} \text{ mol SO}_4^{2-}}{0.050 \text{ L}} = 4.0 \times 10^{-3} \text{ mol/L SO}_4^{2-}$$

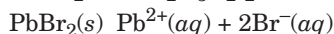
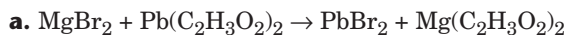
$$[\text{Sr}^{2+}][\text{SO}_4^{2-}] = (3.0 \times 10^{-3})(4.0 \times 10^{-3})$$

$$= 1.2 \times 10^{-5} = \text{ion product}$$

b. $1.2 \times 10^{-5} > 3.2 \times 10^{-7}$; precipitation occurs

562. Given: $K_{sp} \text{ PbBr}_2 = 6.3 \times 10^{-6}$
 $V \text{ MgBr}_2 = 0.120 \text{ L}$
 $[\text{MgBr}_2] = 0.0035 \text{ M}$
 $V \text{ Pb(C}_2\text{H}_3\text{O}_2)_2 = 0.180 \text{ L}$
 $[\text{Pb(C}_2\text{H}_3\text{O}_2)_2] = 0.0024 \text{ M}$

Unknown: **a.** ion product of Br^- and Pb^{2+} in the mixed solution
b. whether a precipitate forms



$$K_{sp} = [\text{Pb}^{2+}][\text{Br}^-]^2 = 6.3 \times 10^{-6}$$

$$(0.180 \text{ L}) \left(\frac{0.0024 \text{ mol Pb}^{2+}}{\text{L}} \right) = 4.3 \times 10^{-4} \text{ mol Pb}^{2+}$$

$$(0.120 \text{ L}) \left(\frac{0.0035 \text{ mol Br}^-}{\text{L}} \right) = 4.2 \times 10^{-4} \text{ mol Br}^-$$

$$\text{Total volume} = 0.180 \text{ L} + 0.120 \text{ L} = 0.3 \text{ L}$$

$$\frac{4.3 \times 10^{-4} \text{ mol Pb}^{2+}}{0.3 \text{ L}} = 1.4 \times 10^{-3} \text{ mol/L Pb}^{2+}$$

$$\frac{4.2 \times 10^{-4} \text{ mol Br}^-}{0.3 \text{ L}} = 1.4 \times 10^{-3} \text{ mol/L Br}^-$$

$$[\text{Br}^-] = (2)(1.4 \times 10^{-3}) = 2.8 \times 10^{-3}$$

$$\text{ion product} = [\text{Pb}^{2+}][\text{Br}^-]^2 = (1.4 \times 10^{-3})(2.8 \times 10^{-3})^2$$

$$= 1.1 \times 10^{-8}$$

b. $1.1 \times 10^{-8} < 6.3 \times 10^{-6}$; no precipitation occurs

563. Given: $K_{sp} \text{ Mg(OH)}_2 = 1.5 \times 10^{-11}$

Unknown: **b.** volume of H_2O required to dissolve 0.10 g Mg(OH)_2

b. $K_{sp} = [\text{Mg}^{2+}][\text{OH}^-]^2$
 $[\text{Mg}^{2+}] = x$

$[\text{OH}^-] = 2x$

$K_{sp} = 1.5 \times 10^{-11} = (x)(2x)^2 = 4x^3$

$x = 1.6 \times 10^{-4} \text{ M} = [\text{Mg(OH)}_2]$

solubility =

$1.6 \times 10^{-4} \text{ M} = \left(\frac{0.10 \text{ g Mg(OH)}_2}{x} \right) \left(\frac{1 \text{ mol Mg(OH)}_2}{58.3 \text{ g Mg(OH)}_2} \right)$

$x = (0.10 \text{ g Mg(OH)}_2) \left(\frac{1 \text{ mol Mg(OH)}_2}{58.3 \text{ g Mg(OH)}_2} \right) \left(\frac{1}{1.6 \times 10^{-4} \text{ M}} \right)$
 $= 11 \text{ L}$

564. Given: $K_{sp} \text{ Li}_2\text{CO}_3 = 2.51 \times 10^{-2}$

Unknown: **a.** $[\text{Li}_2\text{CO}_3]$
b. mass of Li_2CO_3 dissolved to make 3440 mL of saturated solution

a. $\text{Li}_2\text{CO}_3 \rightleftharpoons 2\text{Li}^+ + \text{CO}_3^{2-}$
 $K_{sp} = [\text{Li}^+]^2[\text{CO}_3^{2-}]$

$[\text{Li}^+] = 2x$

$[\text{CO}_3^{2-}] = x$

$K_{sp} = 2.51 \times 10^{-2} = (2x)^2(x) = 4x^3$

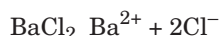
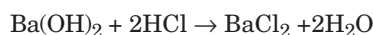
$x = 0.184 \text{ M} = [\text{Li}_2\text{CO}_3]$

b. solubility =
 $0.184 \text{ M} = \left(\frac{x}{3440 \text{ mL}} \right) \left(\frac{1000 \text{ mL}}{\text{L}} \right) \left(\frac{1 \text{ mol Li}_2\text{CO}_3}{73.86 \text{ g Li}_2\text{CO}_3} \right)$

$x = (0.184 \text{ M})(3440 \text{ mL}) \left(\frac{1 \text{ L}}{1000 \text{ mL}} \right) \left(\frac{73.86 \text{ g Li}_2\text{CO}_3}{1 \text{ mol}} \right)$
 $= 46.8 \text{ g}$

565. Given: $V \text{ Ba(OH)}_2 = 0.050 \text{ L}$
 $V \text{ HCl} = 0.03161 \text{ L}$
 $[\text{HCl}] = 0.3417 \text{ M}$

Unknown: $K_{sp} \text{ Ba(OH)}_2$



$(0.03161 \text{ L}) \left(\frac{0.3417 \text{ mol HCl}}{\text{L}} \right) = 0.01080 \text{ mol HCl}$

$\left(\frac{1 \text{ mol Ba(OH)}_2}{2 \text{ mol HCl}} \right) (0.01080 \text{ mol HCl}) = 5.400 \times 10^{-3} \text{ mol Ba(OH)}_2$

$\frac{5.400 \times 10^{-3} \text{ mol Ba(OH)}_2}{0.050 \text{ L}} = 0.1080 \text{ M Ba(OH)}_2$

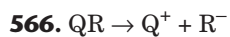
$K_{sp} = [\text{Ba}^{2+}][\text{Cl}^-]^2$

$[\text{Ba(OH)}_2] = 0.1080 \text{ M}$

$[\text{Ba}^{2+}] = 0.1080 \text{ M}$

$[\text{Cl}^-] = (2)(0.1080) = 0.2160 \text{ M}$

$K_{sp} = (0.1080)(0.2160)^2$
 $= 5.040 \times 10^{-3}$



a. Given: $[\text{QR}] = 1.0 \text{ M}$

Unknown: K_{sp}

b. Given: $[\text{QR}] = 0.50 \text{ M}$

Unknown: K_{sp}

c. Given: $[\text{QR}] = 0.1 \text{ M}$

Unknown: K_{sp}

d. Given: $[\text{QR}] = 0.001 \text{ M}$

Unknown: K_{sp}

$$\begin{aligned} K_{sp} &= [\text{Q}^+][\text{R}^-] \\ &= (1.0)(1.0) = 1.0 \end{aligned}$$

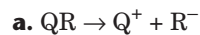
$$\begin{aligned} K_{sp} &= [\text{Q}^+][\text{R}^-] \\ &= (0.50)(0.50) = 0.25 \end{aligned}$$

$$K_{sp} = (0.1)(0.1) = 0.01$$

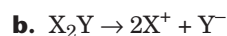
$$K_{sp} = (0.001)(0.001) = 1 \times 10^{-6}$$

567. Given: Saturated solutions of the salts QR , X_2Y , KL_2 , A_3Z , and D_2E_3 are 0.02 M

Unknown: K_{sp} for each salt



$$K_{sp} = [\text{Q}^+][\text{R}^-] = (0.02)^2 = 4 \times 10^{-4}$$

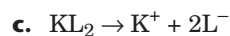


$$K_{sp} = [\text{X}^+]^2[\text{Y}^-]$$

$$[\text{X}^+] = (2)(0.02) = 0.04 \text{ M}$$

$$[\text{Y}^-] = 0.02 \text{ M}$$

$$K_{sp} = (0.04)^2(0.02) = 3 \times 10^{-5}$$

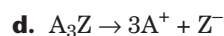


$$K_{sp} = [\text{K}^+][\text{L}^-]^2$$

$$[\text{K}^+] = 0.02 \text{ M}$$

$$[\text{L}^-] = (2)(0.02) = 0.04 \text{ M}$$

$$K_{sp} = (0.02)(0.04)^2 = 3 \times 10^{-5}$$

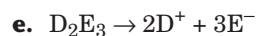


$$K_{sp} = [\text{A}^+]^3[\text{Z}^-]$$

$$[\text{A}^+] = (3)(0.02) = 0.06 \text{ M}$$

$$[\text{Z}^-] = 0.02 \text{ M}$$

$$K_{sp} = (0.06)^3(0.02) = 4 \times 10^{-6}$$



$$K_{sp} = [\text{D}^+]^2[\text{E}^-]^3$$

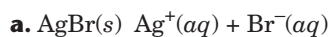
$$[\text{D}^+] = (2)(0.02) = 0.04 \text{ M}$$

$$[\text{E}^-] = (3)(0.02) = 0.06 \text{ M}$$

$$K_{sp} = (0.04)^2(0.06)^3 = 3 \times 10^{-7}$$

568. Given: K_{sp} of AgBr = 5.0×10^{-13}

Unknown: **a.** [AgBr]
b. mass of AgBr in 10.0 L of saturated solution



$$K_{sp} = [\text{Ag}^+][\text{Br}^-]$$

$$[\text{Ag}^+] = [\text{Br}^-] = x$$

$$K_{sp} = x^2 = 5.0 \times 10^{-13}$$

$$x = 7.1 \times 10^{-7} \text{ M} = [\text{AgBr}]$$

b. solubility =

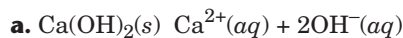
$$7.1 \times 10^{-7} \text{ M} = \left(\frac{x \text{ AgBr}}{10.0 \text{ L}} \right) \left(\frac{1 \text{ mol AgBr}}{187.87 \text{ g AgBr}} \right)$$

$$x = (7.1 \times 10^{-7} \text{ M})(10.0 \text{ L})(187.87 \text{ g})/1 \text{ mol}$$

$$= 1.3 \times 10^{-3} \text{ g}$$

569. Given: K_{sp} of $\text{Ca}(\text{OH})_2$ = 5.5×10^{-6}

Unknown: **a.** molarity of saturated $\text{Ca}(\text{OH})_2$ solution
b. $[\text{OH}^-]$
c. pH



$$K_{sp} = [\text{Ca}^{2+}][\text{OH}^-]^2$$

$$[\text{Ca}^{2+}] = x$$

$$[\text{OH}^-] = 2x$$

$$K_{sp} = 5.5 \times 10^{-6} = (x)(2x)^2 = 4x^3$$

$$x = 0.011 \text{ M} = [\text{Ca}(\text{OH})_2]$$

b. $[\text{OH}^-] = (2)(x) = (2)(0.011 \text{ M}) = 0.022 \text{ M}$

c. $[\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$

$$[\text{H}_3\text{O}^+] = \frac{1 \times 10^{-14} \text{ M}^2}{0.022 \text{ M}}$$

$$= 4.5 \times 10^{-13}$$

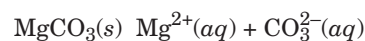
$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

$$= -\log (4.5 \times 10^{-13})$$

$$= 12.35$$

570. Given: K_{sp} of MgCO_3 = 3.5×10^{-8}

Unknown: mass of MgCO_3 dissolved in 4.00 L of water



$$K_{sp} = [\text{Mg}^{2+}][\text{CO}_3^{2-}]$$

$$[\text{Mg}^{2+}] = [\text{CO}_3^{2-}] = x$$

$$K_{sp} = x^2 = 3.5 \times 10^{-8}$$

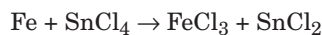
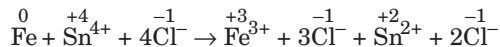
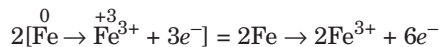
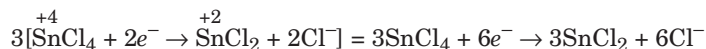
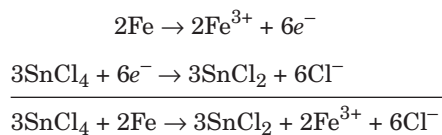
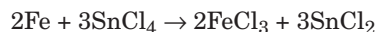
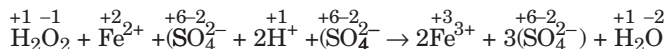
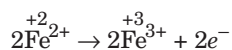
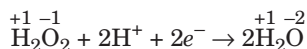
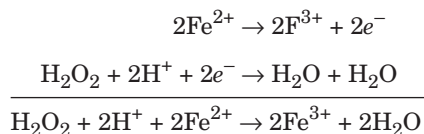
$$x = 1.9 \times 10^{-4} \text{ M} = [\text{MgCO}_3]$$

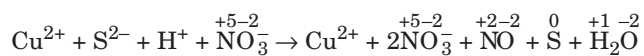
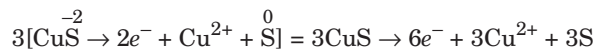
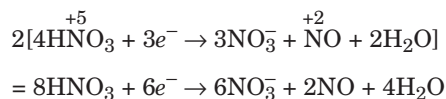
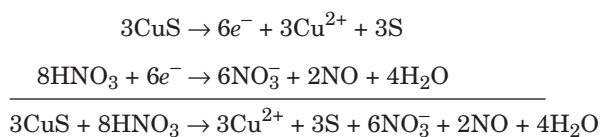
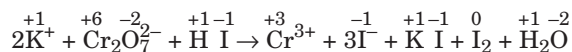
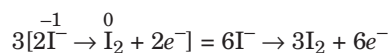
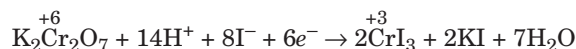
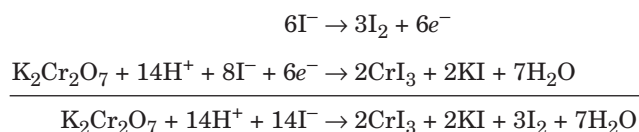
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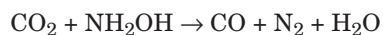
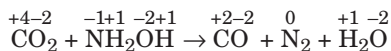
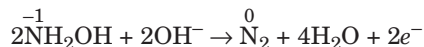
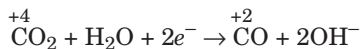
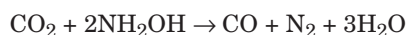
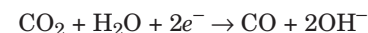
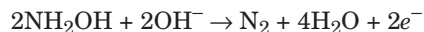
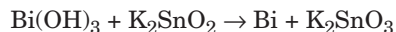
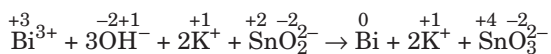
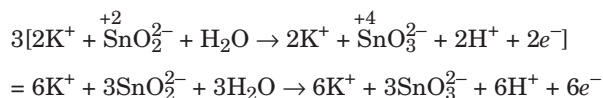
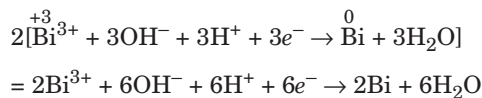
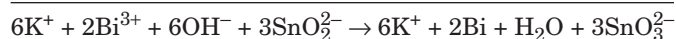
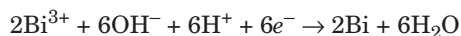
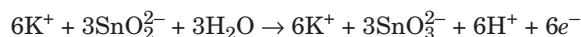
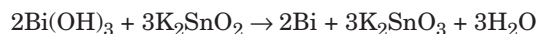
$$1.9 \times 10^{-4} \text{ M} = \left(\frac{x}{4.00 \text{ L}} \right) \left(\frac{1 \text{ mol MgCO}_3}{84.29 \text{ g MgCO}_3} \right)$$

$$x = (1.9 \times 10^{-4} \text{ M})(4.00 \text{ L})(84.29 \text{ g})/1 \text{ mol}$$

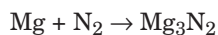
$$= 0.064 \text{ g}$$

571. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***572. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

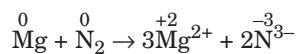
573. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***574. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

575. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***576. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

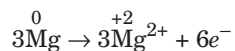
577. *Formula equation:*



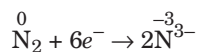
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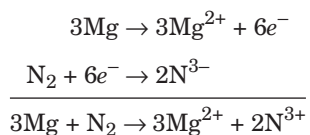
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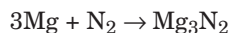
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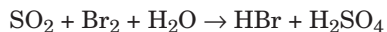
Combine half-reactions:



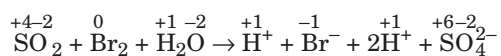
Combine ions to form balanced equation:



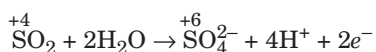
578. *Formula equation:*



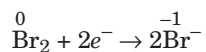
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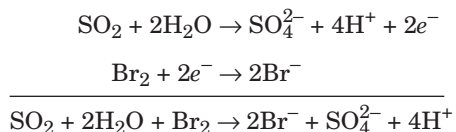
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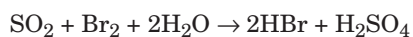
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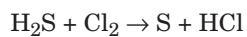
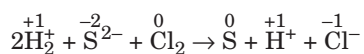
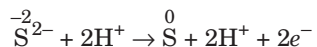
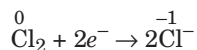
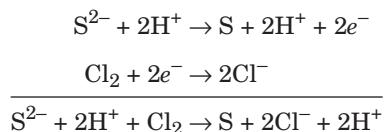
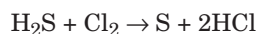
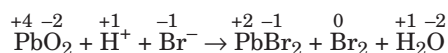
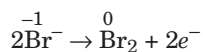
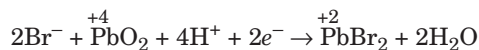
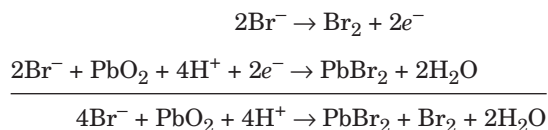


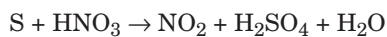
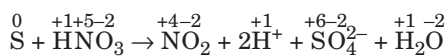
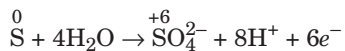
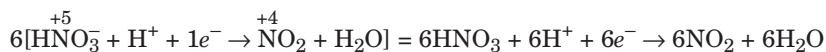
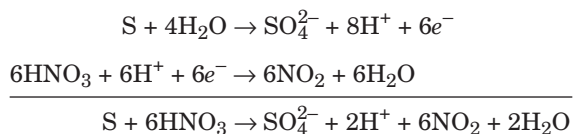
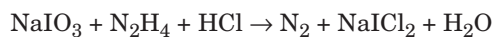
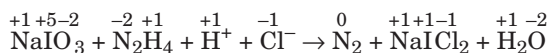
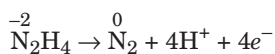
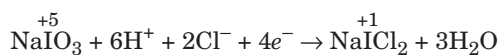
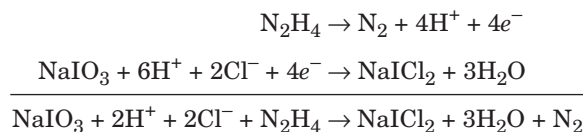
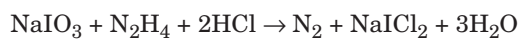
Combine half-reactions:

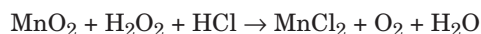
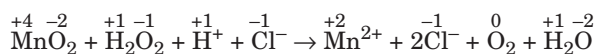
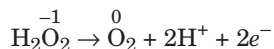
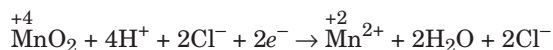
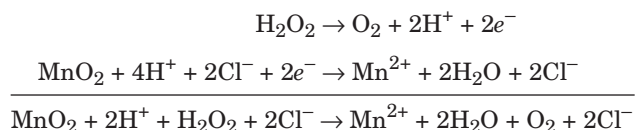
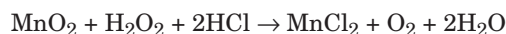
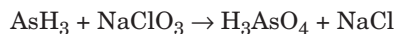
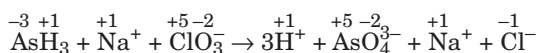
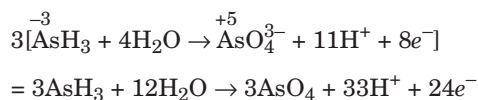
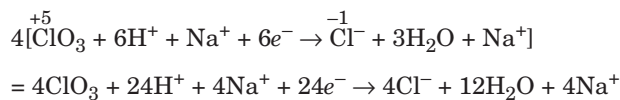
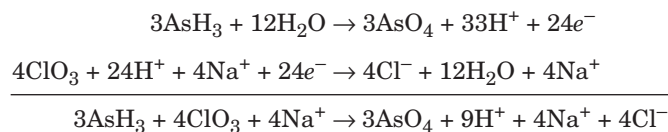
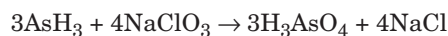


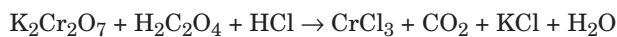
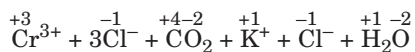
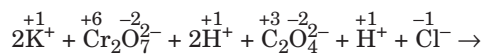
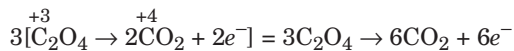
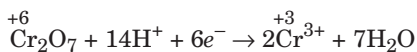
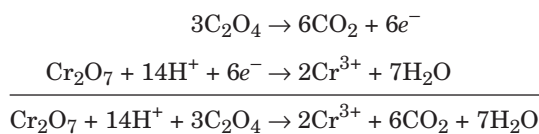
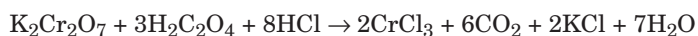
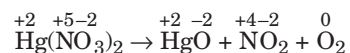
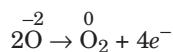
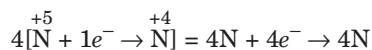
Combine ions to form balanced equation:

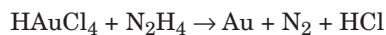
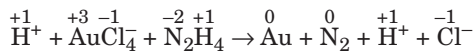
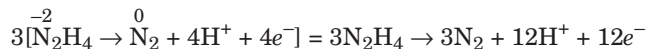
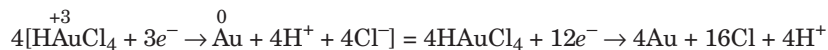
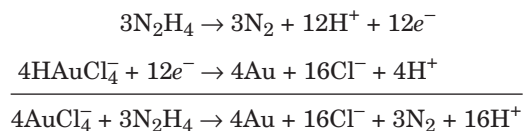
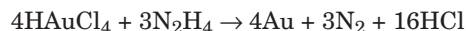
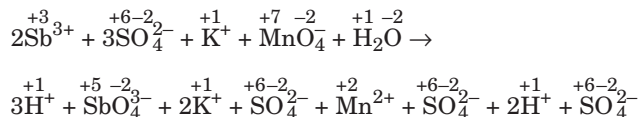
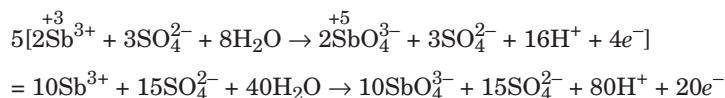
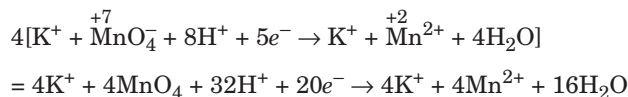
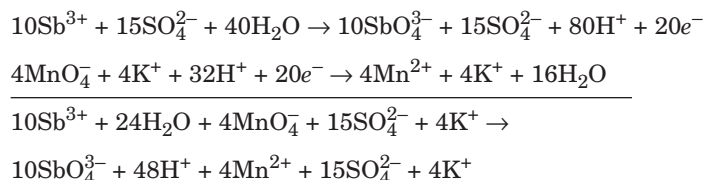


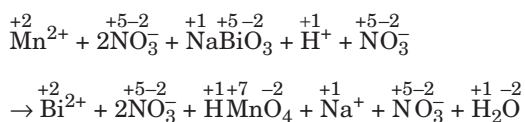
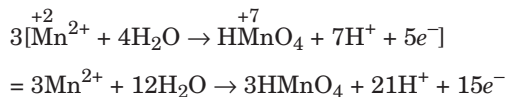
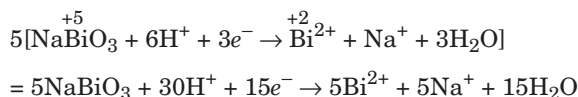
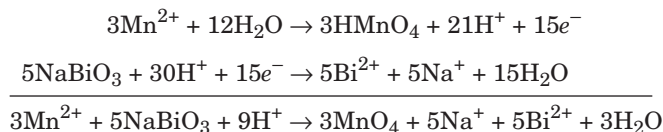
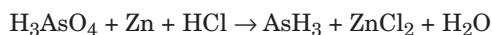
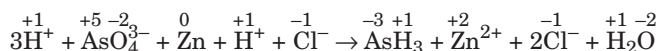
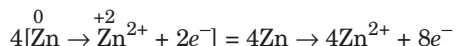
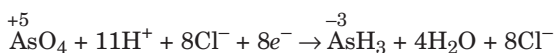
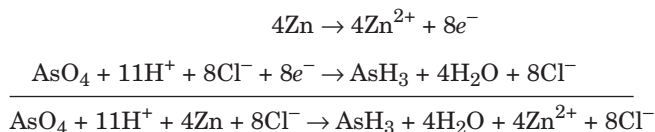
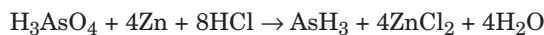
579. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***580. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

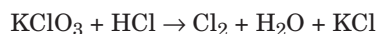
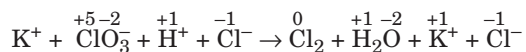
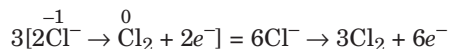
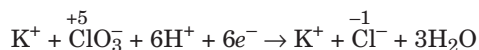
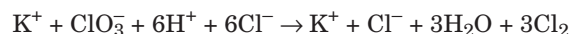
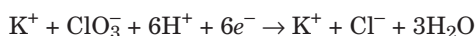
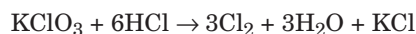
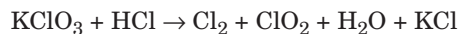
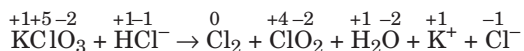
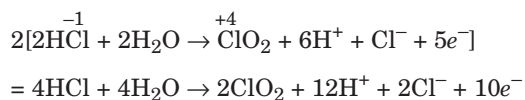
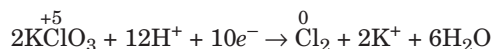
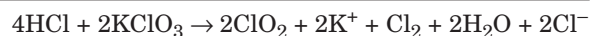
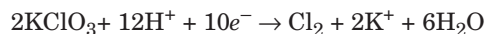
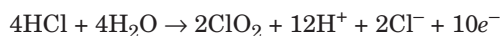
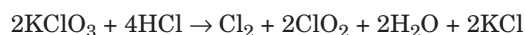
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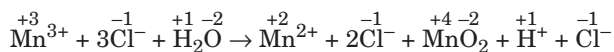
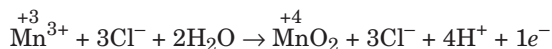
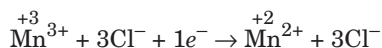
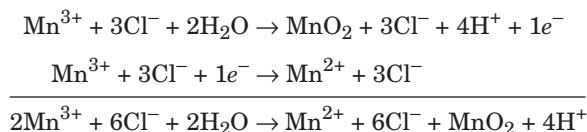
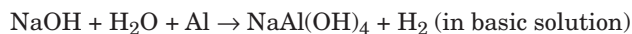
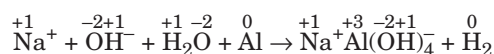
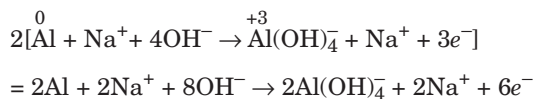
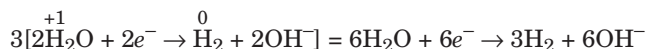
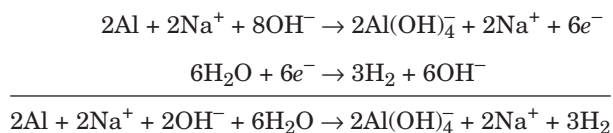
583. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***584. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

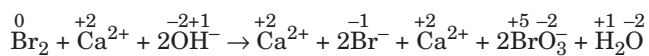
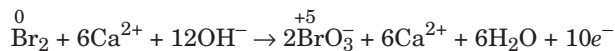
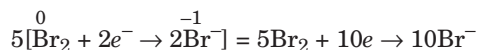
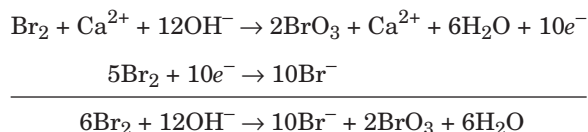
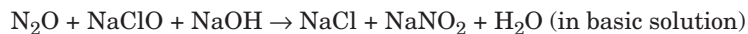
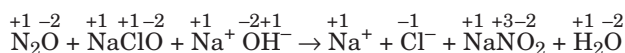
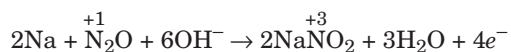
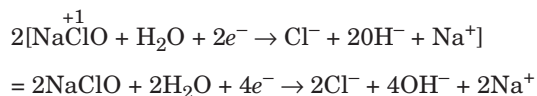
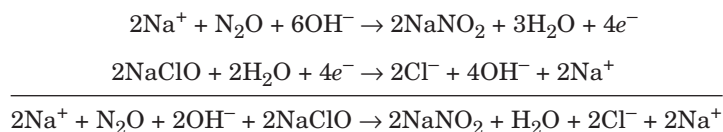
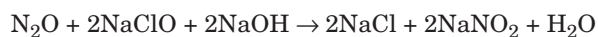
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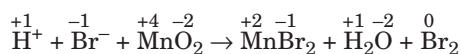
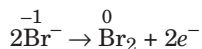
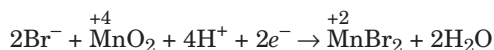
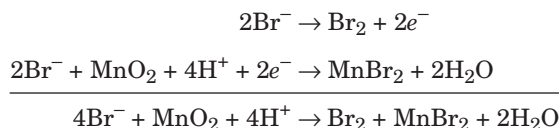
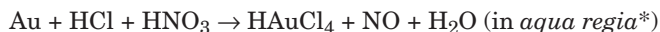
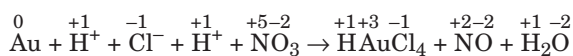
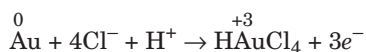
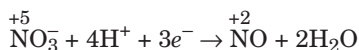
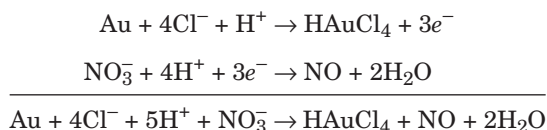
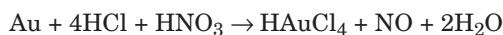
587. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***588. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

589. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***590. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

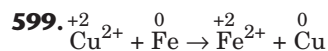
591. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***592. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

593. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***594. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

595. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***596. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

597. Formula equation:*Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:***598. Formula equation:***Ionic equation:**Oxidation half-reaction:**Reduction half-reaction:**Combine half-reactions:**Combine ions to form balanced equation:*

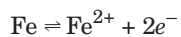
*Aqua regia = concentrated HCl + concentrated HNO₃.



Anode = Fe (oxidation)

Cathode = Cu (reduction)

Half-reactions:

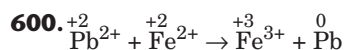


$E^0 = +0.45 \text{ V}$



$E^0 = +0.34 \text{ V}$

$E^0_{\text{cell}} = +0.79 \text{ V; spontaneous}$



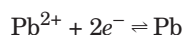
Anode = Fe (oxidation)

Cathode = Pb (reduction)

Half-reactions:

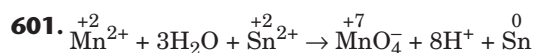


$E^0 = -0.77 \text{ V}$



$E^0 = -0.13 \text{ V}$

$E^0_{\text{cell}} = -0.90 \text{ V; not spontaneous}$



Anode = Mn (oxidation)

Cathode = Sn (reduction)

Half-reactions:

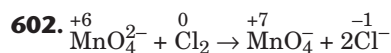


$E^0 = -1.50 \text{ V}$



$E^0 = -0.14 \text{ V}$

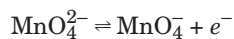
$E^0_{\text{cell}} = -1.64 \text{ V; not spontaneous}$



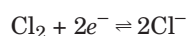
Anode = Mn (oxidation)

Cathode = Cl (reduction)

Half-reactions:

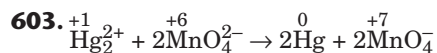


$E^0 = -0.56 \text{ V}$



$E^0 = +1.36 \text{ V}$

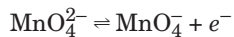
$E^0_{\text{cell}} = +0.80 \text{ V; spontaneous}$



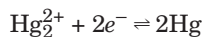
Anode = Mn (oxidation)

Cathode = Hg (reduction)

Half-reactions:

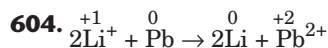


$$E^0 = -0.56 \text{ V}$$



$$E^0 = +0.80 \text{ V}$$

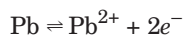
$$E_{\text{cell}}^0 = +0.24 \text{ V; spontaneous}$$



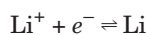
Anode = Pb (oxidation)

Cathode = Li (reduction)

Half-reactions:

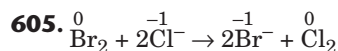


$$E^0 = +0.13 \text{ V}$$



$$E^0 = -3.04 \text{ V}$$

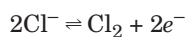
$$E_{\text{cell}}^0 = -2.91 \text{ V; not spontaneous}$$



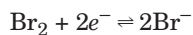
Anode = Cl (oxidation)

Cathode = Br (reduction)

Half-reactions:

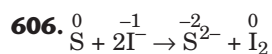


$$E^0 = -1.36 \text{ V}$$



$$E^0 = +1.07 \text{ V}$$

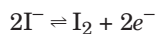
$$E_{\text{cell}}^0 = -0.29 \text{ V; not spontaneous}$$



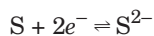
Anode = I (oxidation)

Cathode = S (reduction)

Half-reactions:



$$E^0 = -0.54 \text{ V}$$



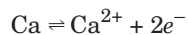
$$E^0 = -0.48 \text{ V}$$

$$E_{\text{cell}}^0 = -1.02 \text{ V; not spontaneous}$$



Anode = Ca (oxidation)
Cathode = Fe (reduction)

Anode reaction:



Cathode reaction:

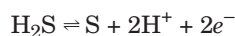


$E^0_{\text{cell}} = E^0_{\text{cathode}} - E^0_{\text{anode}} = -0.04 - (-2.87) = +2.83 \text{ V}$

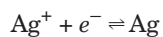


Anode = S (oxidation)
Cathode = Ag (reduction)

Anode reaction:



Cathode reaction:



$E^0_{\text{cell}} = E^0_{\text{cathode}} - E^0_{\text{anode}} = +0.80 - (+0.14) = +0.66 \text{ V}$

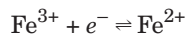


Anode = Sn (oxidation)
Cathode = Fe (reduction)

Anode reaction:



Cathode reaction:



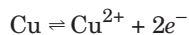
$E^0_{\text{cell}} = E^0_{\text{cathode}} - E^0_{\text{anode}} = +0.77 - (-0.14) = +0.91 \text{ V}$



Anode = Cu (oxidation)

Cathode = Au (reduction)

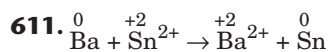
Anode reaction:



Cathode reaction:



$$E^0_{\text{cell}} = E^0_{\text{cathode}} - E^0_{\text{anode}} = +1.50 - (+0.34) = +1.16 \text{ V}$$



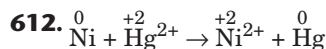
Anode = Ba (oxidation)

Cathode = Sn (reduction)

Half-reactions:



$$E^0_{\text{cell}} = +2.77 \text{ V; spontaneous}$$



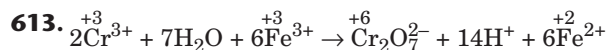
Anode = Ni (oxidation)

Cathode = Hg (reduction)

Half-reactions:



$$E^0_{\text{cell}} = +1.11 \text{ V; spontaneous}$$



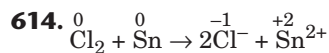
Anode = Cr (oxidation)

Cathode = Fe (reduction)

Half-reactions:



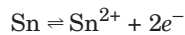
$$E^0_{\text{cell}} = -0.46 \text{ V; not spontaneous}$$



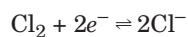
Anode = Sn (oxidation)

Cathode = Cl (reduction)

Half-reactions:

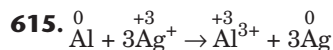


$$E^0 = +0.14 \text{ V}$$



$$E^0 = +1.36 \text{ V}$$

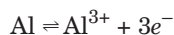
$$E^0_{\text{cell}} = +1.50 \text{ V; spontaneous}$$



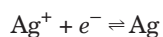
Anode = Al (oxidation)

Cathode = Ag (reduction)

Half-reactions:

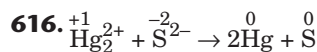


$$E^0 = +1.66 \text{ V}$$



$$E^0 = +0.80 \text{ V}$$

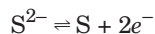
$$E^0_{\text{cell}} = +2.46 \text{ V; spontaneous}$$



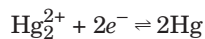
Anode = S (oxidation)

Cathode = Hg (reduction)

Half-reactions:

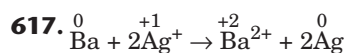


$$E^0 = +0.48 \text{ V}$$



$$E^0 = +0.80 \text{ V}$$

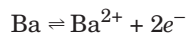
$$E^0_{\text{cell}} = +1.28 \text{ V; spontaneous}$$



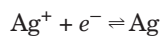
Anode = Ba (oxidation)

Cathode = Ag (reduction)

Half-reactions:

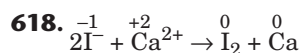


$$E^0 = +2.91 \text{ V}$$



$$E^0 = +0.80 \text{ V}$$

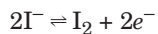
$$E^0_{\text{cell}} = +3.71 \text{ V; spontaneous}$$



Anode = I (oxidation)

Cathode = Ca (reduction)

Half-reactions:

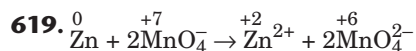


$$E^0 = -0.54 \text{ V}$$



$$E^0 = -2.87 \text{ V}$$

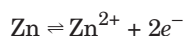
$$E_{\text{cell}}^0 = -3.41 \text{ V; not spontaneous}$$



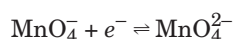
Anode = Zn (oxidation)

Cathode = Mn (reduction)

Half-reactions:

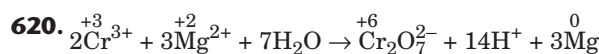


$$E^0 = +0.76 \text{ V}$$



$$E^0 = +0.56 \text{ V}$$

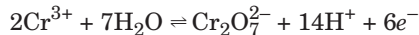
$$E_{\text{cell}}^0 = +1.32 \text{ V; spontaneous}$$



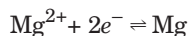
Anode = Cr (oxidation)

Cathode = Mg (reduction)

Half-reactions:

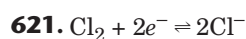


$$E^0 = -1.23 \text{ V}$$

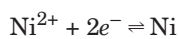


$$E^0 = -2.37 \text{ V}$$

$$E_{\text{cell}}^0 = -3.60 \text{ V; not spontaneous}$$



$$E^0 = +1.36 \text{ V}$$

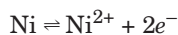


$$E^0 = -0.26 \text{ V}$$

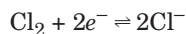
Anode = Ni (oxidation)

Cathode = Cl (reduction)

Anode reaction:

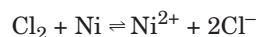
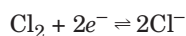
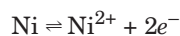


Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = +1.36 - (-0.26) = +1.62 \text{ V}$$

Combine half-reactions:

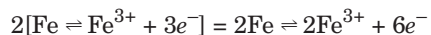




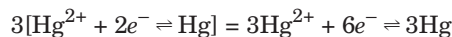
Anode = Fe (oxidation)

Cathode = Hg (reduction)

Anode reaction:

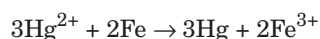


Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = +0.85 - (-0.04) = +0.89 \text{ V}$$

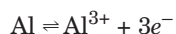
Combine half-reactions:



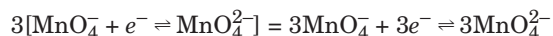
Anode = Al (oxidation)

Cathode = Mn (reduction)

Anode reaction:

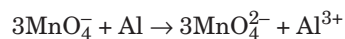
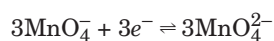
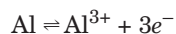


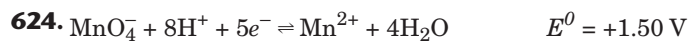
Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = +0.56 - (-1.66) = +2.22 \text{ V}$$

Combine half-reactions:

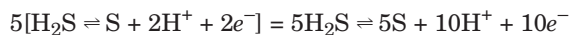




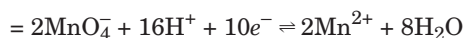
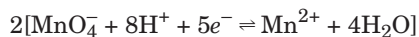
Anode = S (oxidation)

Cathode = Mn (reduction)

Anode reaction:

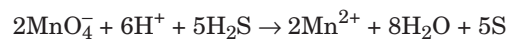
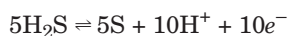


Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = +1.50 - (+0.14) = +1.36 \text{ V}$$

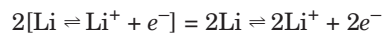
Combine half-reactions:



Anode = Li (oxidation)

Cathode = Ca (reduction)

Anode reaction:

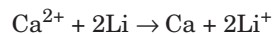
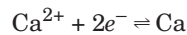


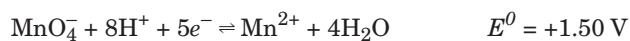
Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = -2.87 - (-3.04) = +0.17 \text{ V}$$

Combine half-reactions:

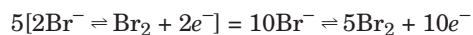




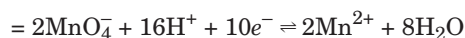
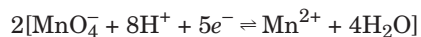
Anode = Br (oxidation)

Cathode = Mn (reduction)

Anode reaction:

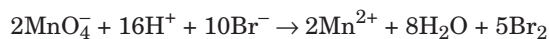


Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = +1.50 - (+1.07) = +0.43 \text{ V}$$

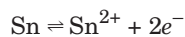
Combine half-reactions:



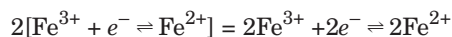
Anode = Sn (oxidation)

Cathode = Fe (reduction)

Anode reaction:

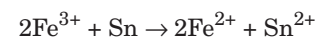
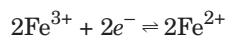


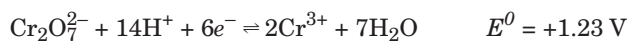
Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = +0.77 - (-0.14) = +0.91 \text{ V}$$

Combine half-reactions:

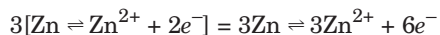




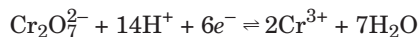
Anode = Zn (oxidation)

Cathode = Cr (reduction)

Anode reaction:

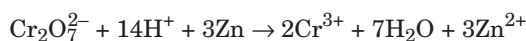
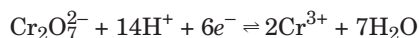


Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = +1.23 - (-0.76) = +1.99 \text{ V}$$

Combine half-reactions:



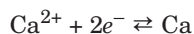
Anode = Ba (oxidation)

Cathode = Ca (reduction)

Anode reaction:

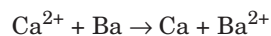
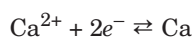


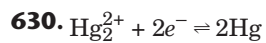
Cathode reaction:



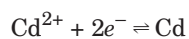
$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = -2.87 - (-2.91) = +0.04 \text{ V}$$

Combine half-reactions:





$$E^0 = +0.80 \text{ V}$$

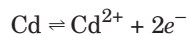


$$E^0 = -0.40 \text{ V}$$

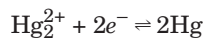
Anode = Cd (oxidation)

Cathode = Hg (reduction)

Anode reaction:



Cathode reaction:



$$E_{\text{cell}}^0 = E_{\text{cathode}}^0 - E_{\text{anode}}^0 = +0.80 - (-0.40) = +1.20 \text{ V}$$

Combine half-reactions:

