APPENDIX D

Problem Bank

1. a. Given: 5.2 cm
Unknown: length in millimeters

$$5.2 \text{ cm} \times \frac{10 \text{ mm}}{\text{cm}} = 52 \text{ mm}$$

b. Given: 0.049 kg
Unknown: mass in grams

$$0.049 \text{ kg} \times \frac{1000 \text{ g}}{\text{kg}} = 49 \text{ g}$$

c. Given: 1.60 mL
Unknown: volume in microliters

$$1.60 \text{ mL} \times \frac{1000\ \mu\text{L}}{\text{mL}} = 1600\ \mu\text{L}$$

d. Given: 0.0025 g
Unknown: mass in micrograms

$$0.0025 \text{ g} \times \frac{1000\ 000\ \mu\text{g}}{\text{g}} = 2500\ \mu\text{g}$$

e. Given: 0.020 kg
Unknown: mass in milligrams

$$0.020 \text{ kg} \times \frac{1000\ 000 \text{ mg}}{\text{kg}} = 20\ 000 \text{ mg}$$

f. Given: 3 kL
Unknown: volume in liters

$$3 \text{ kL} \times \frac{1000 \text{ L}}{\text{kL}} = 3000 \text{ L}$$

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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

$$209\text{ nm} \times \frac{1\text{ mm}}{1000\ 000\text{ nm}} = 0.000\ 209\text{ mm}$$

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

$$500\ 000\ \mu\text{g} \times \frac{1\text{ kg}}{1000\ 000\ 000\ \mu\text{g}} = 0.0005\text{ kg}$$

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

$$152\ 000\ 000\text{ km} \times \frac{1\text{ Mm}}{1000\text{ km}} = 152\ 000\text{ Mm}$$

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

$$2.00\text{ L} - 1.87\text{ L} = 0.13\text{ L}$$

$$0.13\text{ L} \times \frac{1000\text{ mL}}{\text{L}} = 130\text{ mL}$$

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

$$150\text{ cm} \times \frac{10\text{ mm}}{\text{cm}} = 1500\text{ mm}$$

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

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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

$$646\text{ metric tons} \times \frac{1000\text{ kg}}{\text{metric ton}} = 646\ 000\text{ kg}$$

$$646\ 000\text{ kg} \times \frac{1\text{ ladleful}}{8500\text{ kg}} = 76\text{ ladlefuls}$$

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

$$310\ 000\text{ cm}^3 \times \frac{1\text{ m}^3}{1\ 000\ 000\text{ cm}^3} = 0.31\text{ m}^3$$

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

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

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

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

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

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

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

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

f. Given: 87.5 mm3
Unknown: volume in cubic centimeters

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

g. Given: 250 000 cm^2
Unknown: area in square meters

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

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

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

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

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

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

b. Given: 277 cm
Unknown: length in meters

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

c. Given: 30 560 m^2
1 ha = 10 000 m^2
Unknown: area in hectares

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

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

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

e. Given: 300 000 km
Unknown: length in megameters

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

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

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

b. Given: 3857 g
Unknown: mass in milligrams

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

c. Given: 0.0036 mL
Unknown: volume in microliters

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

d. Given: 0.342 metric tons
1 metric ton = 1000 kg
Unknown: mass in kilograms

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

e. Given: 68.71 kL
Unknown: volume in liters

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

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

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

b. Given: 1210 000 μg
Unknown: mass in kilograms

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

c. Given: 6598 μL
1 mL = 1 cm^3
Unknown: volume in cm^3

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

d. Given: 80 600 nm
Unknown: length in millimeters

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

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

$$10.74\ cm^3 \times \frac{1\ mL}{cm^3} \times \frac{1\ L}{1000\ mL} = 0.010\ 74\ L$$

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

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

b. Given: 0.0059 km
Unknown: length in centimeters

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

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

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

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

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

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

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

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13. Given: 0.05 mL oil used per kilometer
Unknown: volume in liters of oil used for 20 000 km

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

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

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

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15. Given: 1.5 tsp vanilla per cake
1 tsp = 5 mL
Unknown: volume of vanilla in liters for 800 cakes

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

16. Given: eight 300 mL glasses of water/day
1 yr = 365 days
D_{water} = 1.00 kg/L
Unknown: volume in liters of water consumed in a year
mass in kilograms of this volume

$$\frac{8 \text{ glasses}}{\text{day}} \times \frac{365 \text{ days}}{\text{yr}} \times \frac{300 \text{ mL}}{\text{glass}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 876 \text{ L per year}$$

$$876 \text{ L} \times \frac{1 \text{ kg}}{\text{L}} = 876 \text{ kg}$$

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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

$$\frac{1674 \text{ km}}{\text{h}} \times \frac{24 \text{ h}}{\text{day}} = 40\ 176 \text{ km/day}$$

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18. Given: 130 g/student
60 students
Unknown: total mass in kilograms

$$\frac{130 \text{ g}}{\text{student}} \times 60 \text{ students} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 7.8 \text{ kg}$$

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19. Given: 750 mm/student
60 students
Unknown: total length in meters

$$\frac{750 \text{ mm}}{\text{student}} \times 60 \text{ students} \times \frac{1 \text{ m}}{1000 \text{ mm}} = 45 \text{ m}$$

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20. a. Given: 550 µL/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

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

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21. a. Given: 2.97 kg/L
Unknown: rate in g/cm^3

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

b. Given: 4128 g/dm^2
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/cm^3
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/m^3
Unknown: density as milligrams per cubic millimeter

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

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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 m^3

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

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23. Given: mass per area of 0.10 g/cm^2
Unknown: mass in kilometers per 0.125 ha

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

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 centimeter

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

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

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

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25. a. Given: 25 drops = 1.00 mL

Unknown: volume of one drop in milliliters

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

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

$$504\ 700\ \text{mg} \times \frac{1\ \text{kg}}{1000\ 000\ \text{mg}} = 0.5047\ \text{kg}$$

$$504\ 700\ \text{mg} \times \frac{1\text{g}}{1000\ \text{mg}} = 504.7\ \text{g}$$

b. Given: 9200 000 μg
Unknown: mass in kilograms and grams

$$9200\ 000\ \mu\text{g} \times \frac{1\ \text{kg}}{1000\ 000\ 000\ \mu\text{g}} = 0.0092\ \text{kg}$$

$$9200\ 000\ \mu\text{g} \times \frac{1\ \text{g}}{1000\ 000\ \mu\text{g}} = 9.2\ \text{kg}$$

c. Given: 122 mg
Unknown: mass in kilograms and grams

$$122\ \text{mg} \times \frac{1\ \text{kg}}{1000\ 000\ \text{mg}} = 0.000\ 122\ \text{kg}$$

$$122\ \text{mg} \times \frac{1\ \text{g}}{1000\ \text{mg}} = 0.122\ \text{g}$$

d. Given: 7195 cg
Unknown: mass in kilograms and grams

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

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

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27. a. Given: 582 cm^3
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 m^3
Unknown: volume in liters and milliliters

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

$$0.0025\ \text{m}^3 \times \frac{1000\ 000\ \text{cm}^3}{\text{m}^3} \times \frac{1\ \text{mL}}{\text{cm}^3} = 2500\ \text{mL}$$

c. Given: 1.18 dm^3
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

$$32\ 900\ \mu\text{L} \times \frac{1\ \text{L}}{1000\ 000\ \mu\text{L}} = 0.0329\ \text{L}$$

$$32\ 900\ \mu\text{L} \times \frac{1\ \text{mL}}{1000\ \mu\text{L}} = 32.9\ \text{mL}$$

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28. a. Given: 1.37 g/cm^3
Unknown: density in grams per liter and kilograms per cubic meter

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

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

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 gams 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 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 µg/ml
Unknown: density in grams per liter and kilograms per cubic meter

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

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

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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 milli-grams per milli-second

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

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

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

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

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

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32. Given: 62 g/m^2
1 ha = 10 000 m^2
Unknown: mass in kilograms required for 1.0 ha

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

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

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

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

$$2.0\text{ mL} \times \frac{1\text{ do se}}{50\ \mu\text{L}} \times \frac{1000\ \mu\text{L}}{\text{mL}} = 40\text{ doses}$$

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35. **a.** Given: 640 cm^3
Unknown: number of signicant 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 Unknown: number of significant figures	1; the zeros are placeholders
f.	Given: 20.900 cm Unknown: number of significant figures	5; all digits are significant
g.	Given: 0.000 000 56 g/L Unknown: number of significant figures	2; all the zeros are placeholders
h.	Given: 0.040 02 kg/m^3 Unknown: number of significant figures	4; the two initial zeros are placeholders
i.	Given: 790 001 cm^2 Unknown: number of significant figures	6; all digits are significant
j.	Given: 665.000 $kg \bullet m/s^2$ Unknown: number of significant figures	6; all digits are significant

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

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

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

c. Given: 31 947.972 cm^2
Unknown: value expressed to 4 significant figures

31 950 cm^2; the digit following the last digit to be retained is greater than 5

d. Given: 192.6739 m^2
Unknown: value expressed to 5 significant figures

192.67 m^2; the digit following the last digit to be retained is less than 5

e. Given: 786.9164 cm
Unknown: value expressed to 2 significant figures

790 cm; the digit following the last digit to be retained is greater than 5

f. Given: 389 277 600 J
Unknown: value expressed to 6 significant figures

389 278 000 J; the digit following the last digit to be retained is greater than 5; the zeros are placeholders

g. Given: 225 834.762 cm^3
Unknown: value expressed to 7 significant figures

225 834.8 cm^3; the digit following the last to be retained is greater than 5

---

42. a. Given: dimensions of 87.59 cm × 35.1 mm
Unknown: area in cm^2

$$87.59 \text{ cm} \times 35.1 \text{ mm} \times \frac{1 \text{ cm}}{10 \text{ mm}} = 307 \text{ cm}^2$$

b. Given: dimensions of 87.59 cm × 35.1 mm
Unknown: area in mm^2

$$87.59 \text{ cm} \times \frac{10 \text{ mm}}{1 \text{ cm}} \times 35.1 \text{ mm} = 30\ 700.\ \text{mm}^2$$

c. Given: dimensions of 87.59 cm × 35.1 mm
Unknown: area in m^2

$$87.59 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} \times 35.1 \text{ mm} \times \frac{1 \text{ m}}{1000 \text{ mm}} = 0.0307 \text{ m}^2$$

43. a. Given: dimensions of 900. mm × 31.5 mm × 6.3 cm
Unknown: volume in cm^3

$$900.\ \text{mm} \times \frac{10\ \text{cm}}{10\ \text{mm}} \times 31.5\ \text{mm} \times \frac{1\ \text{cm}}{10\ \text{mm}} \times 6.3\ \text{cm} = 1800\ \text{cm}^3$$

b. Given: dimensions of 900. mm × 31.5 mm × 6.3 cm
Unknown: volume in m^3

$$900.\ \text{mm} \times \frac{1\ \text{m}}{1000\ \text{mm}} \times 31.5\ \text{mm} \times \frac{1\ \text{m}}{1000\ \text{mm}} \times 6.3\ \text{cm} \times \frac{1\text{m}}{100\ \text{cm}}$$
$$= 0.0018\ \text{m}^3$$

c. Given: dimensions of 900. mm × 31.5 mm × 6.3 cm
Unknown: volume in mm^3

$$900.\ \text{mm} \times 31.5\ \text{mm} \times 6.3\ \text{cm} \times \frac{10\ \text{mm}}{1\ \text{cm}} = 1\ 800\ 000\ \text{mm}^3$$

---

44. a. Given: 0.16 kg/125 mL
Unknown: density in kg/m^3

$$\frac{0.16\ \text{kg}}{125\ \text{mL}} \times \frac{1\ \text{mL}}{1\ \text{cm}^3} \times \frac{1\ 000\ 000\ \text{cm}^3}{1\ \text{m}^3} = 1300\ \text{kg/m}^3$$

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/dm^3

$$\frac{0.16\ \text{kg}}{125\ \text{mL}} \times \frac{1000\ \text{mL}}{1\ \text{L}} \times \frac{1\ \text{L}}{1\ \text{dm}^3} = 1.3\ \text{kg/dm}^3$$

---

45. a. Given: numbers with 4, 3, and 2 significant figures, respectively
Unknown: product to 2 significant 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 significant figures, respectively
Unknown: product to 2 significant 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
Unknown: quotient to 2 significant figures

$14.9\ m^3 \div 3.0\ m^2 = 5.0\ m$

d. Given: numbers with 4, 1, and 3 significant figures, respectively
Unknown: product to 1 significant figure

$6.975\ m \times 30\ m \times 21.5\ m = 4000\ m^3$

---

48. Given: dimensions of 30.5 mm × 202 mm × 153 mm; mass empty = 0.30 kg; mass full = 1.33 kg
Unknown: density of the liquid in kg/L

$V = 30.5\ mm \times 202\ mm \times 153\ mm = 943\ 000\ mm^3$

$m = 1.33\ kg - 0.30\ kg = 1.03\ kg$

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

---

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

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

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

---

50. Given: rate of 52 kg/ha; container holds 10 kg; 1 ha = 10 000 m^2
Unknown: area in m^2 covered by full container

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

---

51. Given: 974 550 kJ/37.0 min
Unknown: rate in kJ/min and kJ/s

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

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

---

52. a. Given: dimensions of 189 cm × 307 cm × 272 cm
Unknown: volume in cubic meters

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

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

Unknown: rate in liters per minute

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

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

Unknown: rate in cubic meters per hour

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

---

55. a. Given: lengths expressed in scientific notation

Unknown: sum expressed in scientific notation to hundredths place

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

b. Given: lengths expressed in scientific notation

Unknown: sum expressed in scientific notation to thousandths place

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

c. Given: volume expressed in scientific notation

Unknown: answer expressed in scientific notation to tenths place

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

d. Given: masses expressed in scientific notation

Unknown: sum expressed in scientific notation to hundredths place

3.15×10^2 mg + 3.15×10^3 mg + 3.15×10^4 mg
= 0.0315×10^4 mg + 0.315×10^4 mg + 3.15×10^4 mg
= 3.50×10^4 mg

e. Given: number of atoms expressed in scientific notation

Unknown: sum expressed in scientific notation to hundredths place

3.01×10^{22} atoms + 1.19×10^{23} atoms + 9.80×10^{21} atoms
= 0.301×10^{23} atoms + 1.19×10^{23} atoms + 0.0980×10^{23} atoms
= 1.59×10^{23} atoms

f. Given: lengths expressed in scientific notation

Unknown: answer expressed in scientific notation to thousandths place

6.85×10^7 nm + 4.0229×10^8 nm – 8.38×10^6 nm
= 0.685×10^8 nm + 4.0229×10^8 nm – 0.0838×10^8 nm
= 4.624×10^8 nm

---

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 2.24×10^4 cm^3

$$\frac{7.11 \times 10^{24}\ \text{molecules}}{100.0\ \text{cm}^3} \times 2.24 \times 10^4\ \text{cm}^3 = 0.159 \times 10^{28}\ \text{molecules}$$

= 1.59×10^{27} molecules

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

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

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

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

---

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

Unknown: area per transistor

$$\frac{9.5\ \text{mm} \times 8.2\ \text{mm}}{3\ 578\ 000\ \text{transistors}} = 0.000\ 022\ \text{mm}^2/\text{transistor}$$

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

b. Given: 2.2×10^{-5} mm^2/ transistor

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

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

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

---

67. Given: 0.0501 g per 1.00 L

Unknown: concentration in grams per microliter

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

---

68. Given: 5.30×10^{-10} m/Cs atom

Unknown: number of Cs atoms in 2.54 cm

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

---

69. Given: $V_{neutron} = 1.4 \times 10^{-44}\ m^3$

$M_{neutron} = 1.675 \times 10^{-24}$ g

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

mass of 1.0 cm^3 of neutrons in kg

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

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

---

70. Given: 1.6×10^{-8} m per pit

Unknown: number of pits in 0.305 m

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

71. a. Given: 6.022×10^{23} O_2 molecules per 22 400 mL at 0°C and standard atmospheric pressure

Unknown: number of O_2 molecules in 0.100 mL

$$\frac{6.022 \times 10^{23}\ O_2 \text{ molecules}}{22\ 400 \text{ mL}} \times 0.100 \text{ mL} = 0.000\ 026\ 9 \times 10^{23}\ O_2 \text{ molecules}$$

$$= 2.69 \times 10^{18}\ O_2 \text{ molecules}$$

b. Given: 6.022×10^{23} O_2 molecules per 22 400 mL at 0°C and standard atmospheric pressure

Unknown: number of O_2 molecules in 1.00 L

$$\frac{6.022 \times 10^{23}\ O_2 \text{ molecules}}{22\ 400 \text{ mL}} \times \frac{10^3 \text{ mL}}{1 \text{ L}} \times 1.00 \text{ L}$$

$$= 0.000\ 269 \times 10^{26}\ O_2 \text{ molecules} = 2.69 \times 10^{22}\ O_2 \text{ molecules}$$

c. Given: 6.022×10^{23} O_2 molecules per 22 400 mL at 0°C and standard atmospheric pressure

Unknown: average space in milliliters occupied by one oxygen molecule

$$\frac{22\ 400 \text{ mL}}{6.022 \times 10^{23}\ O_2 \text{ molecules}} = 3720 \times 10^{-23} \text{ mL}/O_2 \text{ molecule}$$

$$= 3.72 \times 10^{-20} \text{ mL}/O_2 \text{ molecule}$$

---

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

Unknown: mass in kg per person

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

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

Unknown: mass in metric tons per person

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

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

c. Given: $m = 5.136 \times 10^{18}$ 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: $m_{sun} = 1.989 \times 10^{30}$ kg
$m_{earth} = 5.974 \times 10^{24}$ 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 dimesions of 2.3 km × 1.4 km × 0.15 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 C = 1000 cal
intake of 2400 C per day
1 cal = 4.184 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: $D = 0.73\ \text{g/cm}^3$
$m_{automobile} = 1271$ 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 m × 3.5 m × 1.75 m
D_{water} = 0.997 g/cm^3
1 metric ton = 1000 kg

Unknown: mass of water in pool in metric tons

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

= 55 metric tons

---

78. Given: m = 250 g; dimensions of 7.0 cm × 17.0 cm × 19.0 cm

Unknown: density in kilograms per liter

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

---

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

Unknown: thickness in millimeters

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

---

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

Unknown: volume in liters

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

---

81. Given: dimensions of 28 cm × 21 cm × 44.5 mm; mass of 2090 g

Unknown: density in g/cm^3

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

---

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

Unknown: density in g/cm^3

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

---

83. Given: crate dimensions of 0.40 m × 0.40 m × 0.25 m; box dimensions of 22.0 cm × 12.0 cm × 5.0 cm

Unknown: number of boxes to fill the crate

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

= 30 boxes/crate

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

Unknown: volume in liters; dimensions of the cube

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

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

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

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

Unknown: mass in grams volume in cm^3

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

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

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

Unknown: mass in kilograms, volume in dm^3

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.14 \times \left(\frac{3.30\ m}{2}\right)^3 \times \frac{10^2\ dm^3}{1\ m^3} = 18.8 \times 10^3\ dm^3$$
$$= 1.88 \times 10^4\ dm^3$$

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

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

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

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

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

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

Unknown: mass in kilograms, volume in cm^3

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

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

85. Given: mass of 9.65 g; initial V_{water} = 16.0 mL; final V_{water} = 19.5 mL
Unknown: Density in g/cm^3

$V = 19.5\ mL - 16.0\ mL = 3.5\ mL$

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

---

86. a. Given: m = 50. kg; area = 3620 m^2; D = 19.3 g/cm^3
Unknown: thickness of the gold in micrometers

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

$$= \frac{50.\ kg}{3620\ m^2} \times \frac{1\ cm^3}{19.3\ g} \times \frac{1\ m^2}{10^4\ cm^2} \times \frac{10^4\ \mu m}{cm} \times \frac{10^3\ g}{1\ kg} = 0.000\ 72 \times 10^3\ \mu m$$

$$= 0.72\ \mu m$$

b. Given: thickness = 0.72 μm; atom radius = 1.44×10^{-10} m
Unknown: number of atoms

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

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

---

87. Given: fill time = 238 s; cylinder diameter = 1.2 m; cylinder height = 4.6 m
Unknown: flow rate in L/min

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

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

---

88. Given: 2.8 g produces 1.0 J/s; 1 cal = 4.184 J; dimensions = 4.5 cm × 3.05 cm × 15 cm; D = 19.86 g/cm^3
Unknown: calories generated per hour

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

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

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

---

89. Given: $m = 5.974 \times 10^{24}$ kg; sphere diameter = 1.28×10^4 km
Unknown: density in g/cm^3

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

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

90. Given: $D_{Mg} = 1.74\ g/cm^3$
$D_{Pt} = 21.45\ g/cm^3$
Unknown: volume of Mg in cm^3 with the same mass as $1.82\ dm^3$ of Pt

$$m_{Pt} = 1.82\ dm^3 \times \frac{21.45\ g}{1\ cm^3} \times \frac{10^3\ cm^3}{1\ dm^3} = 3.90 \times 10^4\ g = m_{Mg}$$

$$V_{Mg} = \frac{m_{Mg}}{D_{Mg}} = 3.90 \times 10^4\ g \times \frac{1\ cm^3}{1.74\ g} = 2.24 \times 10^4\ cm^3$$

---

91. Given: 66 m/roll; 5.0 cm/use
Unknown: number of uses in 24 rolls

$$\frac{66\ m}{1\ roll} \times 24\ rolls \times \frac{1\ use}{5.0\ cm} \times \frac{100\ cm}{1\ m} = 32\ 000\ uses$$

---

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

$$365\ days \times 0.75 = 274\ days\ driven$$

$$274\ days\ driven \times \frac{86\ km}{1\ day} = 24\ 000\ km\ driven$$

$$24\ 000\ km \times \frac{4.0\ L}{38\ km} = 2500\ L$$

---

93. Given: fill time of 97 h; pool dimensions $= 9.0\ m \times 3.5\ m \times 1.75\ m$
Unknown: rate of fill in L/min

$$\frac{9.0\ m \times 3.5\ m \times 1.75\ m}{97\ h} \times \frac{10^3\ dm^3}{1\ m^3} \times \frac{1\ L}{1\ dm^3} \times \frac{1\ h}{60\ min} = 9.5\ L/min$$

---

94. Given: $D_{H_2SO_4} = 1.285\ g/cm^3$; 38% sulfuric acid in battery
Unknown: mass of sulfuric acid in 500. mL battery acid

$$500.\ mL \times 0.38 \times \frac{1.285\ g}{1\ cm^3} \times \frac{1\ cm^3}{1\ mL} = 244\ g\ H_2SO_4$$

---

95. **a.** Given: 64.1 g of Al
Unknown: number of moles Al

$$64.1\ g\ Al \times \frac{1\ mol\ Al}{26.98\ g\ Al} = 2.38\ mol\ Al$$

b. Given: 28.1 g of Si
Unknown: number of moles Si

$$28.1\ g\ Si \times \frac{1\ mol\ Si}{28.09\ g\ Si} = 1.00\ mol\ Si$$

c. Given: 0.255 g of S
Unknown: number of moles S

$$0.255\ g\ S \times \frac{1\ mol\ S}{32.07\ g\ S} = 7.95 \times 10^{-3}\ mol\ S$$

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

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

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 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 BBr_3
Unknown: number of moles BBr_3

$$\text{formula mass} = 1 \text{ atom B} \times \frac{10.81 \text{ amu}}{1 \text{ atom B}} + 3 \text{ atoms Br} \times \frac{79.90 \text{ amu}}{1 \text{ atom Br}}$$

$$= 10.81 \text{ amu} + 239.70 \text{ amu} = 250.51 \text{ amu}$$

$$3.00 \text{ g } BBr_3 \times \frac{1 \text{ mol } BBr_3}{250.51 \text{ g } BBr_3} = 0.0120 \text{ mol } BBr_3$$

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

$$\text{formula mass NaF} = 1 \text{ atom Na} \times \frac{22.99 \text{ amu}}{1 \text{ atom Na}} + 1 \text{ atom F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}}$$

$$= 41.99 \text{ amu}$$

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

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

$$\text{formula mass } CH_3OH = 1 \text{ atom C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 4 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 32.05 \text{ amu}$$

$$7.50 \times 10^2 \text{ g } CH_3OH \times \frac{1 \text{ mol } CH_3OH}{32.05 \text{ g } CH_3OH} = 23.4 \text{ mol } CH_3OH$$

d. Given: 50.0 g $Ca(ClO_3)_2$
Unknown: number of moles $Ca(ClO_3)_2$

$$\text{formula mass } Ca(ClO_3)_2 = 1 \text{ atom Ca} \times \frac{40.08 \text{ amu}}{1 \text{ atom Ca}} + 2 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 206.98 \text{ amu}$$

$$50.0 \text{ g } Ca(ClO_3)_2 \times \frac{1 \text{ mol } Ca(ClO_3)_2}{206.98 \text{ g } Ca(ClO_3)_2} = 0.242 \text{ mol } Ca(ClO_3)_2$$

---

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

$$\text{formula mass } NH_3 = 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 3 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} = 17.04 \text{ amu}$$

$$1.366 \text{ mol } NH_3 \times \frac{17.04 \text{ g } NH_3}{1 \text{ mol } NH_3} = 23.28 \text{ g } NH_3$$

b. Given: 0.120 mol $C_6H_{12}O_6$
Unknown: mass $C_6H_{12}O_6$

$$\text{formula mass } C_6H_{12}O_6 = 6 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 12 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 180.18 \text{ amu}$$

$$0.120 \text{ mol } C_6H_{12}O_6 \times \frac{180.18 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} = 21.6 \text{ g } C_6H_{12}O_6$$

c. Given: 6.94 mol $BaCl_2$
Unknown: mass $BaCl_2$

$$\text{formula mass } BaCl_2 = 1 \text{ atom Ba} \times \frac{137.33 \text{ amu}}{1 \text{ atom Ba}} + 2 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} = 208.23 \text{ amu}$$

$$6.94 \text{ mol } BaCl_2 \times \frac{208.23 \text{ g } BaCl_2}{1 \text{ mol } BaCl_2} = 1450 \text{ g } BaCl_2$$

d. Given: 0.005 mol C_3H_8
Unknown: mass C_3H_8

$$\text{formula mass } C_3H_8 = 3 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 8 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} = 44.11 \text{ amu}$$

$$0.005 \text{ mol } C_3H_8 \times \frac{44.11 \text{ g } C_3H_8}{1 \text{ mol } C_3H_8} = 0.2 \text{ g } C_3H_8$$

---

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

$$4.99 \text{ mol } CH_4 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 3.00 \times 10^{24} \text{ molecules } CH_4$$

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 $C_6H_8O_6$
Unknown: number of molecules

$$3.5 \times 10^{-5} \text{ mol } C_6H_8O_6 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$$

$$= 2.1 \times 10^{19} \text{ molecules } C_6H_8O_6$$

---

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

$$0.025 \text{ mol } Na_2CO_3 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$$= 1.5 \times 10^{22} \text{ formula units } Na_2CO_3$$

d. Given: 6.82×10^{-6} mol $Pb(NO_3)_2$
Unknown: number of formula units

$$6.82 \times 10^{-6} \text{ mol } Pb(NO_3)_2 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$$= 4.11 \times 10^{18} \text{ formula units } Pb(NO_3)_2$$

---

105. a. Given: 3.34×10^{34} formula units $Cu(OH)_2$
Unknown: amount in moles

$$3.34 \times 10^{34} \text{ formula units } Cu(OH)_2 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}}$$

$$= 5.55 \times 10^{10} \text{ mol } Cu(OH)_2$$

b. Given: 1.17×10^{16} molecules of H_2S
Unknown: amount in moles

$$1.17 \times 10^{16} \text{ molecules } H_2S \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} = 1.94 \times 10^{-8} \text{ mol } H_2S$$

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

$$7.66 \times 10^{19} \text{ molecules } H_2O_2 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}}$$

$$= 1.27 \times 10^{-4} \text{ mol } H_2O_2$$

---

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

$$\text{formula mass } H_2 = 2 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} = 2.02 \text{ amu}$$

$$2.41 \times 10^{24} \text{ molecules } H_2 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{2.02 \text{ g } H_2}{1 \text{ mol } H_2}$$

$$= 8.08 \text{ g } H_2$$

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

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

$$\times \frac{16.00 \text{ amu}}{1 \text{ atom O}} + 3 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} = 78.01 \text{ amu}$$

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

$$\times \frac{78.01 \text{ g } Al(OH)_3}{1 \text{ mol } Al(OH)_3} = 0.648 \text{ g } Al(OH)_3$$

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

$$\text{formula mass } BrF_5 = 1 \text{ atom Br} \times \frac{79.90 \text{ amu}}{1 \text{ atom Br}} + 5 \text{ atoms F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}}$$

$$= 174.90 \text{ amu}$$

$$8.25 \times 10^{22} \text{ molecules } BrF_5 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{174.90 \text{ g } BrF_5}{1 \text{ mol } BrF_5}$$

$$= 24.0 \text{ g } BrF_5$$

d. Given: 1.20×10^{23} formula units $Na_2C_2O_4$
Unknown: mass $Na_2C_2O_4$

$$\text{formula mass } Na_2C_2O_4 = 2 \text{ atoms Na} \times \frac{22.99 \text{ amu}}{1 \text{ atom Na}} + 2 \text{ atoms C}$$

$$\times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 134 \text{ amu}$$

$$1.20 \times 10^{23} \text{ formula units } Na_2C_2O_4 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}}$$

$$\times \frac{134 \text{ g } Na_2C_2O_4}{1 \text{ mol } Na_2C_2O_4} = 26.7 \text{ g } Na_2C_2O_4$$

---

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

$$\text{formula mass } Na_2S = 2 \text{ atoms Na} \times \frac{22.99 \text{ amu}}{1 \text{ atom Na}} + 1 \text{ atom S} \times \frac{32.01 \text{ amu}}{1 \text{ atom S}}$$

$$= 77.99 \text{ amu}$$

$$22.9 \text{ g } Na_2S \times \frac{1 \text{ mol } Na_2S}{77.99 \text{ g } Na_2S} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$$= 1.77 \times 10^{23} \text{ formula units } Na_2S$$

b. Given: 0.272 g $Ni(NO_3)_2$

Unknown: number of formula units $Ni(NO_3)_2$

$$\text{formula mass } Ni(NO_3)_2 = 1 \text{ atom Ni} \times \frac{58.69 \text{ amu}}{1 \text{ atom Ni}} + 2 \text{ atoms N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 182.71 \text{ amu}$$

$$0.272 \text{ g } Ni(NO_3)_2 \times \frac{1 \text{ mol } Ni(NO_3)_2}{182.71 \text{ g } Ni(NO_3)_2} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$$= 8.96 \times 10^{20} \text{ formula units } Ni(NO_3)_2$$

c. Given: 260 mg CH_2CHCN

Unknown: number of molecules CH_2CHCN

$$\text{formula mass } CH_2CHCN = 3 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 3 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} = 53.07 \text{ amu}$$

$$260 \text{ mg } CH_2CHCN \times \frac{1 \text{ mol } CH_2CHCN}{53.07 \text{ g } CH_2CHCN} \times \frac{1 \text{ g}}{1000 \text{ mg}}$$

$$\times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 3.0 \times 10^{21} \text{ molecules } CH_2CHCN$$

---

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

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

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 CH_3COOH
Unknown: moles CH_3COOH

$$\text{formula mass } CH_3COOH = 2 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}}$$
$$+ 4 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 2 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 60.06 \text{ amu}$$
$$45.0 \text{ g } CH_3COOH \times \frac{1 \text{ mol } CH_3COOH}{60.06 \text{ g } CH_3COOH} = 0.749 \text{ mol } CH_3COOH$$

b. Given: 7.04 g $Pb(NO_3)_2$
Unknown: moles $Pb(NO_3)_2$

$$\text{formula mass } Pb(NO_3)_2 = 1 \text{ atom Pb} \times \frac{207.2 \text{ amu}}{1 \text{ atom Pb}} + 2 \text{ atoms N}$$
$$\times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 331.22 \text{ amu}$$
$$7.04 \text{ g } Pb(NO_3)_2 \times \frac{1 \text{ mol } Pb(NO_3)_2}{331.22 \text{ g } Pb(NO_3)_2} = 0.0213 \text{ mol } Pb(NO_3)_2$$

c. Given: 5000 kg Fe_2O_3
Unknown: moles Fe_2O_3

$$\text{formula mass } Fe_2O_3 = 2 \text{ atoms Fe} \times \frac{55.85 \text{ amu}}{1 \text{ atom Fe}} + 3 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$$
$$= 159.70 \text{ amu}$$
$$5000 \text{ kg } Fe_2O_3 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } Fe_2O_3}{159.70 \text{ g } Fe_2O_3} = 3 \times 10^{4} \text{ mol } Fe_2O_3$$

d. Given: 12.0 mg $C_2H_5NH_2$
Unknown: moles $C_2H_5NH_2$

$$\text{formula mass } C_2H_5NH_2 = 2 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 7 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} = 45.10 \text{ amu}$$

$$12.0 \text{ mg } C_2H_5NH_2 \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol } C_2H_5NH_2}{45.10 \text{ g } C_2H_5NH_2}$$

$$= 2.66 \times 10^{-4} \text{ mol } C_2H_5NH_2$$

e. Given: 0.003 22 g $C_{17}H_{35}COOH$
Unknown: moles $C_{17}H_{35}COOH$

$$\text{formula mass } C_{17}H_{35}COOH = 18 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 36 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 2 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 284.54 \text{ amu}$$

$$3.22 \times 10^{-3} \text{ g } C_{17}H_{35}COOH \times \frac{1 \text{ mol } C_{17}H_{35}COOH}{284.54 \text{ g } C_{17}H_{35}COOH}$$

$$= 1.13 \times 10^{-5} \text{ mol } C_{17}H_{35}COOH$$

f. Given: 50.0 kg $(NH_4)_2SO_4$
Unknown: moles $(NH_4)_2SO_4$

$$\text{formula mass } (NH_4)_2SO_4 = 2 \text{ atoms N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 8 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom S} \times \frac{32.07 \text{ amu}}{1 \text{ atom S}} + 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$$

$$= 132.17 \text{ amu}$$

$$50.0 \text{ kg } (NH_4)_2SO_4 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } (NH_4)_2SO_4}{132.17 \text{ g } (NH_4)_2SO_4}$$

$$= 378 \text{ mol } (NH_4)_2SO_4$$

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

$$\text{formula mass } SeOBr_2 = 1 \text{ atom Se} \times \frac{78.96 \text{ amu}}{1 \text{ atom Se}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} + 2 \text{ atoms Br} \times \frac{79.90 \text{ amu}}{1 \text{ atom Br}}$$

$$= 254.76 \text{ amu}$$

$$3.00 \text{ mol } SeOBr_2 \times \frac{254.76 \text{ g } SeOBr_2}{1 \text{ mol } SeOBr_2} = 764 \text{ g } SeOBr_2$$

b. Given: 488 mol $CaCO_3$
Unknown: mass $CaCO_3$

$$\text{formula mass } CaCO_3 = 1 \text{ atom Ca} \times \frac{40.08 \text{ amu}}{1 \text{ atom Ca}} + 1 \text{ atom C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 3 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 100.09 \text{ amu}$$

$$488 \text{ mol } CaCO_3 \times \frac{100.09 \text{ g } CaCO_3}{1 \text{ mol } CaCO_3} = 4.88 \times 10^4 \text{ g } CaCO_3$$

c. Given: 0.0091 mol $C_{20}H_{28}O_2$
Unknown: mass $C_{20}H_{28}O_2$

$$\text{formula mass } C_{20}H_{28}O_2 = 20 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 28 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 2 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 300.48 \text{ amu}$$

$$0.0091 \text{ mol } C_{20}H_{28}O_2 \times \frac{300.48 \text{ g } C_{20}H_{28}O_2}{1 \text{ mol } C_{20}H_{28}O_2} = 2.7 \text{ g } C_{20}H_{28}O_2$$

d. Given: 6.00×10^{-8} mol $C_{10}H_{14}N_2$
Unknown: mass $C_{10}H_{14}N_2$

$$\text{formula mass } C_{10}H_{14}N_2 = 10 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 14 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 2 \text{ atoms N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} = 162.26 \text{ amu}$$

$$6.00 \times 10^{-8} \text{ mol } C_{10}H_{14}N_2 \times \frac{162.26 \text{ g } C_{10}H_{14}N_2}{1 \text{ mol } C_{10}H_{14}N_2} = 9.74 \times 10^{-6} \text{ g } C_{10}H_{14}N_2$$

e. Given: 2.50 mol $Sr(NO_3)_2$
Unknown: mass $Sr(NO_3)_2$

$$\text{formula mass } Sr(NO_3)_2 = 1 \text{ atom Sr} \times \frac{87.62 \text{ amu}}{1 \text{ atom Sr}} + 2 \text{ atoms N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$$

$$= 211.64 \text{ amu}$$

$$2.50 \text{ mol } Sr(NO_3)_2 \times \frac{211.64 \text{ g } Sr(NO_3)_2}{1 \text{ mol } Sr(NO_3)_2} = 529 \text{ g } Sr(NO_3)_2$$

f. Given: 3.50×10^{-6} mol UF_6
Unknown: mass UF_6

$$\text{formula mass } UF_6 = 1 \text{ atom U} \times \frac{238.03 \text{ amu}}{1 \text{ atom U}} + 6 \text{ atoms F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}}$$

$$= 352.03 \text{ amu}$$

$$3.50 \times 10^{-6} \text{ mol } UF_6 \times \frac{352.03 \text{ g } UF_6}{1 \text{ mol } UF_6} = 1.23 \times 10^{-3} \text{ g } UF_6$$

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116. a. Given: 4.72 mol WO_3
Unknown: number of formula units

$$4.27 \text{ mol } WO_3 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$$= 2.57 \times 10^{24} \text{ formula units } WO_3$$

b. Given: 0.003 00 mol $Sr(NO_3)_2$
Unknown: number of formula units

$$3.00 \times 10^{-3} \text{ mol } Sr(NO_3)_2 \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$$= 1.81 \times 10^{21} \text{ formula units } Sr(NO_3)_2$$

c. Given 72.5 mol $C_6H_5CH_3$
Unknown: number of molecules

$$72.5 \text{ mol } C_6H_5CH_3 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$$

$$= 4.37 \times 10^{25} \text{ molecules } C_6H_5CH_3$$

d. Given: 5.11×10^{-7} mol $C_{29}H_{50}O_2$
Unknown: number of molecules

$$5.11 \times 10^{-7} \text{ mol } C_{29}H_{50}O_2 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$$

$$= 3.08 \times 10^{17} \text{ molecules } C_{29}H_{50}O_2$$

e. Given: 1500 mol N_2H_4
Unknown: number of molecules

$$1500 \text{ mol } N_2H_4 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 9.0 \times 10^{26} \text{ molecules } N_2H_4$$

f. Given: 0.989 mol $C_6H_5NO_2$
Unknown: number of molecules

$$0.989 \text{ mol } C_6H_5NO_2 \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$$

$$= 5.96 \times 10^{23} \text{ molecules } C_6H_5NO_2$$

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117. a. Given: 285 g $FePO_4$
Unknown: number of formula units $FePO_4$

$$\text{formula mass } FePO_4 = 1 \text{ atom Fe} \times \frac{55.85 \text{ amu}}{1 \text{ atom Fe}} + 1 \text{ atom P} \times \frac{30.97 \text{ amu}}{1 \text{ atom P}}$$

$$+ 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 150.82 \text{ amu}$$

$$285 \text{ g } FePO_4 \times \frac{1 \text{ mol } FePO_4}{150.82 \text{ g } FePO_4} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}}$$

$$= 1.14 \times 10^{24} \text{ formula units } FePO_4$$

b. Given: 0.0084 g C_5H_5N
Unknown: number of molecules C_5H_5N

$$\text{formula mass } C_5H_5N = 5 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 5 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}}$$

$$+ 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} = 79.11 \text{ amu}$$

$$0.0084 \text{ g } C_5H_5N \times \frac{1 \text{ mol } C_5H_5N}{79.11 \text{ g } C_5H_5N} \times \frac{6.022 \times 10^{23} \text{ molecules}}{1 \text{ mol}}$$

$$= 6.4 \times 10^{19} \text{ molecules } C_5H_5N$$

c. Given: 85 mg $(CH_3)_2CHCH_2OH$
Unknown: number of molecules $(CH_3)_2CHCH_2OH$

$$\text{formula mass } (CH_3)_2CHCH_2OH = 4 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}}$$

$$+ 10 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 74.14 \text{ amu}$$

$$85 \text{ mg } (CH_3)_2CHCH_2OH \times \frac{1 \text{ g}}{1000 \text{ mg}} \times \frac{1 \text{ mol } (CH_3)_2CHCH_2OH}{74.14 \text{ g } (CH_3)_2CHCH_2OH}$$

$$\times \frac{6022 \times 10^{23} \text{ molecules}}{1 \text{ mol}} = 6.9 \times 10^{20} \text{ molecules } (CH_3)_2CHCH_2OH$$

d. Given: 4.6×10^{-4} g $Hg(C_2H_3O_2)_2$
Unknown: number of formula units $Hg(C_2H_3O_2)_2$

$$\text{formula mass } Hg(C_2H_3O_2)_2 = 1 \text{ atom Hg} \times \frac{200.59 \text{ amu}}{1 \text{ atom Hg}} + 4 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 6 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 318.69 \text{ amu}$$

$$4.6 \times 10^{-4} \text{ g } Hg(C_2H_3O_2)_2 \times \frac{1 \text{ mol } Hg(C_2H_3O_2)_2}{318.69 \text{ g } Hg(C_2H_3O_2)_2} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 8.7 \times 10^{17} \text{ formula units } Hg(C_2H_3O_2)_2$$

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

$$\text{formula mass } Li_2CO_3 = 2 \text{ atoms Li} \times \frac{6.94 \text{ amu}}{1 \text{ atom Li}} + 1 \text{ atom C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 3 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 73.89 \text{ amu}$$

$$6.7 \times 10^{-3} \text{ g } Li_2CO_3 \times \frac{1 \text{ mol } Li_2CO_3}{73.89 \text{ g } Li_2CO_3} \times \frac{6.022 \times 10^{23} \text{ formula units}}{1 \text{ mol}} = 5.5 \times 10^{19} \text{ formula units } Li_2CO_3$$

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

$$\text{formula mass } F_2 = 2 \text{ atoms F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}} = 38.00 \text{ amu}$$

$$8.39 \times 10^{23} \text{ molecules } F_2 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{38.00 \text{ g } F_2}{1 \text{ mol } F_2} = 52.9 \text{ g } F_2$$

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

$$\text{formula mass } BeSO_4 = 1 \text{ atom Be} \times \frac{9.01 \text{ amu}}{1 \text{ atom Be}} + 1 \text{ atom S} \times \frac{32.07 \text{ amu}}{1 \text{ atom S}} + 4 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 105.08 \text{ amu}$$

$$6.82 \times 10^{24} \text{ formula units } BeSO_4 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}} \times \frac{105.08 \text{ g } BeSO_4}{1 \text{ mol } BeSO_4} = 1190 \text{ g } BeSO_4$$

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

$$\text{formula mass } CHCl_3 = 1 \text{ atom C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 1 \text{ atom H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 3 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} = 119.37 \text{ amu}$$

$$7.004 \times 10^{26} \text{ molecules } CHCl_3 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{119.37 \text{ g } CHCl_3}{1 \text{ mol } CHCl_3} = 1.388 \times 10^5 \text{ g } CHCl_3$$

d. Given: 31 billion formula units $Cr(CHO_2)_3$
Unknown: mass $Cr(CHO_2)_3$

formula mass $Cr(CHO_2)_3 = 1 \text{ atom Cr} \times \frac{52.00 \text{ amu}}{1 \text{ atom Cr}}$

$+ 3 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}} + 3 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 6 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$

$= 187.06 \text{ amu}$

$3.1 \times 10^{10} \text{ formula units } Cr(CHO_2)_3 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ formula units}}$

$\times \frac{187.06 \text{ g } Cr(CHO_2)_3}{1 \text{ mol } Cr(CHO_2)_3} = 9.6 \times 10^{-12} \text{ g } Cr(CHO_2)_3$

e. Given: 6.3×10^{18} molecules HNO_3
Unknown: mass HNO_3

formula mass HNO $= 1 \text{ atom H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}}$

$+ 3 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 63.02 \text{ amu}$

$6.3 \times 10^{18} \text{ molecules } HNO_3 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \times \frac{63.02 \text{ g } HNO_3}{1 \text{ mol } HNO_3}$

$= 6.6 \times 10^{-4} \text{ g } HNO_3$

f. Given: 8.37×10^{25} molecules $C_2Cl_2F_4$
Unknown: mass $C_2Cl_2F_4$

formula mass $C_2Cl_2F_4 = 2 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}}$

$+ 2 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} + 4 \text{ atoms F} \times \frac{19.00 \text{ amu}}{1 \text{ atom F}} = 170.92 \text{ amu}$

$8.37 \times 10^{25} \text{ molecules } C_2Cl_2F_4 \times \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}}$

$\times \frac{170.92 \text{ g } C_2Cl_2F_4}{1 \text{ mol } C_2Cl_2F_4} = 2.38 \times 10^4 \text{ g } C_2Cl_2F_4$

---

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 C_6H_5OH
Unknown: moles C_6H_5OH

formula mass $C_6H_5OH = 6 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}}$

$+ 6 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 94.12 \text{ amu}$

$22.0 \text{ g } C_6H_5OH \times \frac{1 \text{ mol } C_6H_5OH}{94.12 \text{ g } C_6H_5OH} = 0.234 \text{ mol } C_6H_5OH$

121. Given: 0.015 mol I_2
Unknown: mass I_2

$$\text{formula mass } I_2 = 2 \text{ atoms I} \times \frac{126.90 \text{ amu}}{1 \text{ atom I}} = 253.80 \text{ amu}$$

$$0.015 \text{ mol } I_2 \times \frac{253.80 \text{ g } I_2}{1 \text{ mol } I_2} = 3.8 \text{ g } I_2$$

---

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 $CaCl_2$; 1.000 kg water
Unknown: moles of $CaCl_2$ and water

$$\text{formula mass } CaCl_2 = 1 \text{ atom Ca} \times \frac{40.08 \text{ amu}}{1 \text{ atom Ca}}$$

$$+ 2 \text{ atoms Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} = 110.98 \text{ amu}$$

$$8.00 \text{ g } CaCl_2 \times \frac{1 \text{ mol } CaCl_2}{110.98 \text{ g } CaCl_2} = 0.0721 \text{ mol } CaCl_2$$

$$\text{formula mass } H_2O = 2 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$$

$$= 18.02 \text{ amu}$$

$$1.000 \text{ kg } H_2O \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 55.49 \text{ mol } H_2O$$

b. Given: 0.0721 mol $CaCl_2$ from part **a**
Unknown: moles of Ca^{2+} 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 $C_{12}H_{22}O_{11}$
Unknown: moles $C_{12}H_{22}O_{11}$

$$\text{formula mass } C_{12}H_{22}O_{11} = 12 \text{ atoms C} \times \frac{12.01 \text{ amu}}{1 \text{ atom C}}$$

$$+ 22 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 11 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 342.34 \text{ amu}$$

$$453.6 \text{ g } C_{12}H_{22}O_{11} \times \frac{1 \text{ mol } C_{12}H_{22}O_{11}}{342.34 \text{ g } C_{12}H_{22}O_{11}} = 1.325 \text{ mol } C_{12}H_{22}O_{11}$$

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

$$\text{formula mass } NH_4Cl = 1 \text{ atom N} \times \frac{14.01 \text{ amu}}{1 \text{ atom N}} + 4 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}}$$

$$+ 1 \text{ atom Cl} \times \frac{35.45 \text{ amu}}{1 \text{ atom Cl}} = 53.50 \text{ amu}$$

$$10.7 \text{ g } NH_4Cl \times \frac{1 \text{ mol } NH_4Cl}{53.50 \text{ g } NH_4Cl} \times \frac{2 \text{ mol ions}}{1 \text{ mol } NH_4Cl} = 0.400 \text{ mol ions}$$

---

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_{H_2O} = 0.997 g/mL
Unknown: mass H_2O

$$250.0 \text{ mL } H_2O \times \frac{0.997 \text{ g } H_2O}{1 \text{ mL } H_2O} = 249 \text{ g } H_2O$$

b. Given: 249 g H_2O (from part **a**)
Unknown: moles H_2O

$$\text{formula mass } H_2O = 2 \text{ atoms H} \times \frac{1.01 \text{ amu}}{1 \text{ atom H}} + 1 \text{ atom O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}}$$
$$= 18.02 \text{ amu}$$

$$249 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 13.8 \text{ mol } H_2O$$

c. Given: D_{H_2O} = 0.997 g/mL; 2000 mol H_2O
Unknown: volume

$$2.000 \text{ mol } H_2O \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} \times \frac{1 \text{ mL } H_2O}{0.997 \text{ g } H_2O} = 36.1 \text{ mL } H_2O$$

d. Given: 2.000 mol H_2O
Unknown: mass

$$2.000 \text{ mol } H_2O \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = 36.04 \text{ g } H_2O$$

---

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

$$\text{formula mass } O_2 = 2 \text{ atoms O} \times \frac{16.00 \text{ amu}}{1 \text{ atom O}} = 32.00 \text{ amu}$$

mass of O_2 used = 1027.8 g – 1023.2 g = 4.6 g

$$4.6 \text{ g } O_2 \times \frac{1 \text{ mol } O_2}{32.00 \text{ g } O_2} = 0.14 \text{ mol } O_2$$

---

131. a. Given: 0.250 mol Ag_2S
Unknown: moles of Ag and S

$$0.250 \text{ mol } Ag_2S \times \frac{2 \text{ mol Ag}}{1 \text{ mol } Ag_2S} = 0.500 \text{ mol Ag}$$

$$0.250 \text{ mol } Ag_2S \times \frac{1 \text{ mol S}}{1 \text{ mol } Ag_2S} = 0.250 \text{ mol S}$$

b. Given: 38.8 g Ag_2S
Unknown: moles Ag_2S, Ag, and S

$$\text{formula mass } Ag_2S = 2 \text{ atoms Ag} \times \frac{107.87 \text{ Amu}}{1 \text{ atom Ag}} + 1 \text{ atom S} \times \frac{32.07 \text{ amu}}{1 \text{ atom S}}$$

$$= 247.81 \text{ amu}$$

$$38.8 \text{ g } Ag_2S \times \frac{1 \text{ mol } Ag_2S}{247.81 \text{ g } Ag_2S} = 0.157 \text{ mol } Ag_2S$$

$$0.157 \text{ mol } Ag_2S \times \frac{2 \text{ mol Ag}}{1 \text{ mol } Ag_2S} = 0.314 \text{ mol Ag}$$

$$0.157 \text{ mol } Ag_2S \times \frac{1 \text{ mol S}}{1 \text{ mol } Ag_2S} = 0.157 \text{ mol S}$$

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: $Na_2C_2O_4$
Unknown: percentage composition

$$\text{molar mass } Na_2C_2O_4 = 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} + 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}}$$

$$+ 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 134.00 \text{ g}$$

$$\frac{2 \times 22.99 \text{ g Na}}{134.00 \text{ g } Na_2C_2O_4} \times 100 = 34.31\% \text{ Na}$$

$$\frac{2 \times 12.01 \text{ g C}}{134.00 \text{ g } Na_2C_2O_4} \times 100 = 17.93\% \text{ C}$$

$$\frac{4 \times 16.00 \text{ g O}}{134.00 \text{ g } Na_2C_2O_4} \times 100 = 47.76\% \text{ O}$$

b. Given: C_2H_5OH
Unknown: percentage composition

$$\text{molar mass } C_2H_5OH = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 46.08 \text{ g}$$

$$\frac{2 \times 12.01 \text{ g C}}{46.08 \text{ g } C_2H_5OH} \times 100 = 52.13\% \text{ C}$$

$$\frac{6 \times 1.01 \text{ g H}}{46.08 \text{ g } C_2H_5OH} \times 100 = 13.15\% \text{ H}$$

$$\frac{1 \times 16.00 \text{ g O}}{46.08 \text{ g } C_2H_5OH} \times 100 = 34.72\% \text{ O}$$

c. Given: Al_2O_3
Unknown: percentage composition

$$\text{molar mass } Al_2O_3 = 2 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} + 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 101.96 \text{ g}$$

$$\frac{2 \times 26.98 \text{ Al}}{101.96 \text{ } Al_2O_3} \times 100 = 52.92\% \text{ Al}$$

$$\frac{3 \times 16.00 \text{ g O}}{101.96 \text{ g } Al_2O_3} \times 100 = 47.08\% \text{ O}$$

d. Given: K_2SO_4
Unknown: percentage composition

$$\text{molar mass } K_2SO_4 = 2 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}}$$

$$+ 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 174.27 \text{ g}$$

$$\frac{2 \times 39.10 \text{ g K}}{174.27 \text{ g } K_2SO_4} \times 100 = 44.87\% \text{ K}$$

$$\frac{1 \times 32.07 \text{ g S}}{174.27 \text{ g } K_2SO_4} \times 100 = 18.40\% \text{ S}$$

$$\frac{4 \times 16.00 \text{ O}}{174.27 \text{ g } K_2SO_4} \times 100 = 36.72\% \text{ O}$$

---

133. Given: percentage composition
Unknown: identity of the compound

100.0 g compound contains 42.59 g Na, 12.02 g C, and 44.99 g O.

$$\frac{42.59 \text{ g Na}}{22.99 \text{ g/mol}} = 1.853 \text{ mol Na} \cong 2 \text{ mol Na}$$

$$\frac{12.02 \text{ g C}}{12.01 \text{ g/mol}} = 1.001 \text{ mol C} \cong 1 \text{ mol C}$$

$$\frac{44.99 \text{ g O}}{16.00 \text{ g/mol}} = 2.812 \text{ mol O} \cong 3 \text{ mol O}$$

Na_2CO_3, or sodium carbonate

---

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

$$\text{molar mass KBr} = 1 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} + 1 \text{ mol Br} \times \frac{79.90 \text{ g Br}}{1 \text{ mol Br}} = 119.00 \text{ g}$$

$$50.0 \text{ g KBr} \times \frac{79.90 \text{ g Br}}{119.00 \text{ g KBr}} = 33.6 \text{ g Br}$$

b. Given: 1.00 kg $Na_2Cr_2O_7$
Unknown: mass Cr

$$\text{molar mass } Na_2Cr_2O_7 = 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} + 2 \text{ mol Cr} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}}$$

$$+ 7 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 261.98 \text{ g}$$

$$1.00 \text{ kg } Na_2Cr_2O_7 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{2 \times 52.00 \text{ g Cr}}{261.98 \text{ g } Na_2Cr_2O_7} = 397 \text{ g Cr}$$

c. Given: 85.0 mg $C_6H_{14}N_2O_2$
Unknown: mass N

$$\text{molar mass } C_6H_{14}N_2O_2 = 6 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$

$$= 146.22 \text{ g}$$

$$0.085 \text{ g } C_6H_{14}N_2O_2 \times \frac{28.02 \text{ g N}}{146.22 \text{ g } C_6H_{14}N_2O_2} = 0.0163 \text{ g} = 16.3 \text{ mg N}$$

d. Given: 2.84 g $Co(C_2H_3O_2)_2$
Unknown: mass of Co

$$\text{molar mass } Co(C_2H_3O_2)_2 = 1 \text{ mol Co} \times \frac{58.93 \text{ g Co}}{1 \text{ mol Co}} + 4 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}}$$

$$+ 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 177.03 \text{ g}$$

$$2.84 \text{ g } Co(C_2H_3O_2)_2 \times \frac{58.93 \text{ g Co}}{177.03 \text{ g } Co(C_2H_3O_2)_2} = 0.945 \text{ g Co}$$

---

135. a. Given: $Na_2CO_3 \bullet 10H_2O$
Unknown: percentage of water

$$\text{molar mass } Na_2CO_3 \bullet 10H_2O = 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}}$$

$$+ 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 13 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 20 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 286.19 \text{ g}$$

$$\text{molar mass } H_2O = 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 18.02 \text{ g}$$

$$\frac{10(18.02) \text{ g } H_2O}{286.19 \text{ g } Na_2CO_3 \bullet 10\, H_2O} \times 100 = 62.97\% \; H_2O$$

b. Given: $NiI_2 \bullet 6H_2O$
Unknown: percentage of water

$$\text{molar mass } NiI_2 \bullet 6H_2O = 1 \text{ mol Ni} \times \frac{58.69 \text{ g Ni}}{1 \text{ mol Ni}} + 2 \text{ mol I} \times \frac{126.90 \text{ g I}}{1 \text{ mol I}}$$

$$+ 12 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 420.61 \text{ g}$$

$$\frac{6(18.02) \text{ g } H_2O}{420.61 \text{ g } NiI_2 \bullet 6H_2O} \times 100 = 25.71\% \; H_2O$$

c. Given: $(NH_4)_2Fe(CN)_6 \bullet 3H_2O$
Unknown: percentage of water

$$\text{molar mass } (NH_4)_2Fe(CN)_6 \bullet 3H_2O = 8 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}}$$

$$+ 14 \text{ mol H} \times \frac{1.01 \text{ H}}{1 \text{ mol H}} + 1 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} + 6 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}}$$

$$+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 302.13 \text{ g}$$

$$\frac{3(18.02) \text{ g } H_2O}{302.13 \text{ g } (NH_4)_2Fe(CN)_6 \bullet 3H_2O} \times 100 = 17.89\% \; H_2O$$

d. Given: $AlBr_3 \cdot 6H_2O$
Unknown: percentage of water

$$\text{molar mass } AlBr_3 \cdot 6H_2O = 1 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}}$$

$$+ 3 \text{ mol Br} \times \frac{79.90 \text{ g Br}}{1 \text{ mol Br}} + 12 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 374.80 \text{ g}$$

$$\frac{6(18.02) \text{ g } H_2O}{374.80 \text{ g } AlBr_3 \cdot 6\,H_2O} \times 100 = 28.85\%\ H_2O$$

---

136. a. Given: nitric acid
Unknown: formula; percentage composition

formula is HNO_3

$$\text{molar mass } HNO_3 = 1 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}}$$

$$+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 63.02 \text{ g}$$

$$\frac{1.01 \text{ g H}}{63.02 \text{ g } HNO_3} \times 100 = 1.60\% \text{ H}$$

$$\frac{14.01 \text{ g N}}{63.02 \text{ g } HNO_3} \times 100 = 22.23\% \text{ N}$$

$$\frac{3 \times 16.00 \text{ g O}}{63.02 \text{ g } HNO_3} \times 100 = 76.17\% \text{ O}$$

b. Given: ammonia
Unknown: formula; percentage composition

formula is NH_3

$$\text{molar mass } NH_3 = 1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 3 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 17.04 \text{ g}$$

$$\frac{14.01 \text{ g N}}{17.04 \text{ g } NH_3} \times 100 = 82.22\% \text{ N}$$

$$\frac{3 \times 1.01 \text{ g H}}{17.04 \text{ g } NH_3} \times 100 = 17.78\% \text{ H}$$

c. Given: mercury (II) sulfate
Unknown: formula; percentage composition

formula is $HgSO_4$

$$\text{molar mass } HgSO_4 = 1 \text{ mol Hg} \times \frac{200.59 \text{ g Hg}}{1 \text{ mol Hg}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}}$$

$$+ 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 296.66 \text{ g}$$

$$\frac{200.59 \text{ g Hg}}{296.66 \text{ g } HgSO_4} \times 100 = 67.616\% \text{ Hg}$$

$$\frac{32.07 \text{ g S}}{296.66 \text{ g } HgSO_4} \times 100 = 10.81\% \text{ S}$$

$$\frac{4 \times 16.00 \text{ g O}}{296.66 \text{ g } HgSO_4} \times 100 = 21.57\% \text{ O}$$

d. Given: antimony (V) flouride
Unknown: formula; percentage composition

formula is SbF_5

$$\text{molar mass } SbF_5 = 1 \text{ mol Sb} \times \frac{121.76 \text{ g Sb}}{1 \text{ mol Sb}} + 5 \text{ mol F} \times \frac{19.00 \text{ g F}}{1 \text{ mol F}} = 216.76 \text{ g}$$

$$\frac{121.76 \text{ g Sb}}{216.76 \text{ g } SbF_5} \times 100 = 56.173\% \text{ Sb}$$

$$\frac{5 \times 19.00 \text{ g F}}{216.76 \text{ g } SbF_5} \times 100 = 43.83\% \text{ F}$$

---

137. a. Given: LiBr
Unknown: percentage composition

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

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

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

b. Given: $C_{14}H_{10}$
Unknown: percentage composition

$$\text{molar mass } C_{14}H_{10} = 14 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 10 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$
$$= 178.24 \text{ g}$$

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

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

c. Given: NH_4NO_3
Unknown: percentage composition

$$\text{molar mass } NH_4NO_3 = 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$
$$+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 80.06 \text{ g}$$

$$\frac{2 \times 14.01 \text{ g N}}{80.06 \text{ g } NH_4NO_3} \times 100 = 35.00\% \text{ N}$$

$$\frac{4 \times 1.01 \text{ g H}}{80.06 \text{ g } NH_4NO_3} \times 100 = 5.05\% \text{ H}$$

$$\frac{3 \times 16.00 \text{ g O}}{80.06 \text{ g } NH_4NO_3} \times 100 = 59.96\% \text{ O}$$

d. Given: HNO_2
Unknown: percentage composition

$$\text{molar mass } HNO_2 = 1 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}}$$
$$+ 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 47.02 \text{ g}$$

$$\frac{1.01 \text{ g H}}{47.02 \text{ g } HNO_2} \times 100 = 2.15\% \text{ H}$$

$$\frac{14.01 \text{ g N}}{47.02 \text{ g } HNO_2} \times 100 = 29.80\% \text{ N}$$

$$\frac{2 \times 16.00 \text{ g O}}{47.02 \text{ g } HNO_2} \times 100 = 68.06\% \text{ O}$$

e. Given: Ag_2S
Unknown: percentage composition

$$\text{molar mass } Ag_2S = 2 \text{ mol Ag} \times \frac{107.87 \text{ g Ag}}{1 \text{ mol Ag}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 247.81 \text{ g}$$

$$\frac{2 \times 107.87 \text{ g Ag}}{247.81 \text{ g } Ag_2S} \times 100 = 87.059\% \text{ Ag}$$

$$\frac{32.07 \text{ g S}}{247.81 \text{ g } Ag_2S} \times 100 = 12.94\% \text{ S}$$

f. Given: $Fe(SCN)_2$
Unknown: percentage composition

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

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

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

$$\frac{2 \times 32.00 \text{ g S}}{172.03 \text{ g } Fe(SCN)_2} \times 100 = 37.28\% \text{ S}$$

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

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

g. Given: lithium acetate
Unknown: percentage composition

$$\text{molar mass } LiC_2H_3O_2 = 1 \text{ mol Li} \times \frac{6.94 \text{ g Li}}{1 \text{ mol Li}} + 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}}$$

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

$$\frac{6.94 \text{ g Li}}{65.99 \text{ g } LiC_2H_3O_2} \times 100 = 10.52\% \text{ Li}$$

$$\frac{2 \times 12.01 \text{ g C}}{65.99 \text{ g } LiC_2H_3O_2} \times 100 = 36.40\% \text{ C}$$

$$\frac{3 \times 1.01 \text{ g H}}{65.99 \text{ g } LiC_2H_3O_2} \times 100 = 4.59\% \text{ H}$$

$$\frac{2 \times 16.00 \text{ g O}}{65.99 \text{ g } LiC_2H_3O_2} \times 100 = 48.49\% \text{ O}$$

h. Given: nickel (II) formate
Unknown: percentage composition

$$\text{molar mass Ni(CHO}_2)_2 = 1 \text{ mol Ni} \times \frac{58.69 \text{ g Ni}}{1 \text{ mol Ni}} + 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}}$$

$$+ 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 148.73 \text{ g}$$

$$\frac{58.69 \text{ g Ni}}{148.73 \text{ g Ni(CHO}_2)_2} \times 100 = 39.46\% \text{ Ni}$$

$$\frac{2 \times 12.01 \text{ g C}}{148.73 \text{ g Ni(CHO}_2)_2} \times 100 = 16.15\% \text{ C}$$

$$\frac{2 \times 1.01 \text{ g H}}{148.73 \text{ Ni(CHO}_2)_2} \times 100 = 1.36\% \text{ H}$$

$$\frac{3 \times 16.00 \text{ g O}}{148.73 \text{ g Ni(CHO}_2)_2} \times 100 = 43.03\% \text{ O}$$

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138. a. Given: NH_2CONH_2
Unknown: percentage of nitrogen

$$\text{molar mass NH}_2\text{CONH}_2 = 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} + 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}}$$

$$+ 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 60.07 \text{ g}$$

$$\frac{2 \times 14.01 \text{ g N}}{60.07 \text{ g NH}_2\text{CONH}_2} \times 100 = 46.65\% \text{ N}$$

b. Given: SO_2Cl_2
Unknown: percentage of sulfur

$$\text{molar mass SO}_2\text{Cl}_2 = 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$

$$+ 2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = 134.97 \text{ g}$$

$$\frac{32.07 \text{ g S}}{134.97 \text{ g SO}_2\text{Cl}_2} \times 100 = 23.76\% \text{ S}$$

c. Given: Tl_2O_3
Unknown: percentage of thallium

$$\text{molar mass Tl}_2\text{O}_3 = 2 \text{ mol Tl} \times \frac{204.38 \text{ g Tl}}{1 \text{ mol Tl}} + 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 456.76 \text{ g}$$

$$\frac{2 \times 204.38 \text{ g Tl}}{456.76 \text{ g Tl}_2\text{O}_3} \times 100 = 89.491\% \text{ Tl}$$

d. Given: $KClO_3$
Unknown: percentage of oxygen

$$\text{molar mass KClO}_3 = 1 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} + 1 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}}$$

$$+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1\text{mol O}} = 122.55 \text{ g}$$

$$\frac{3 \times 16.00 \text{ g O}}{122.55 \text{ g KClO}_3} \times 100 = 39.17\% \text{ O}$$

e. Given: $CaBr_2$
Unknown: percentage 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: percentage of tin

$$\text{molar mass } SnO_2 = 1 \text{ mol Sn} \times \frac{118.71 \text{ g Sn}}{1 \text{ mol Sn}} + 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$
$$= 150.71 \text{ g}$$

$$\frac{118.71 \text{ g Sn}}{150.71 \text{ g } SnO_2} \times 100 = 78.767\% \text{ Sn}$$

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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

$$\text{molar mass } Al_2O_3 = 2 \text{ mol Al} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} + 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 101.96 \text{ g}$$

$$50.0 \text{ metric tons } Al_2O_3 \times \frac{2 \times 26.98 \text{ g Al}}{101.96 \text{ g } Al_2O_3} = 26.5 \text{ metric tons Al}$$

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

$$\text{molar mass } Au_2Se_3 = 2 \text{ mol Au} \times \frac{196.97 \text{ g Au}}{1 \text{ mol Au}} + 3 \text{ mol Se} \times \frac{78.96 \text{ g Se}}{1 \text{ mol Se}}$$
$$= 630.82 \text{ g}$$

$$0.780 \text{ g } Au_2Se_3 \times \frac{2 \times 196.97 \text{ g Au}}{630.82 \text{ g } Au_2Se_3} = 0.487 \text{ g Au}$$

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

$$\text{molar mass } Na_2SeO_3 = 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}} + 1 \text{ mol Se} \times \frac{78.96 \text{ g Se}}{1 \text{ mol Se}}$$
$$+ 3 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 172.94 \text{ g}$$

$$683 \text{ g } Na_2SeO_3 \times \frac{78.96 \text{ g Se}}{172.94 \text{ g } Na_2SeO_3} = 312 \text{ g Se}$$

f. Given: 5.0×10^4 g $CHCl_2CH_2CH_3$

Unknown: mass of chlorine

$$\text{molar mass } CHCl_2CH_2CH_3 = 3 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = 112.99 \text{ g}$$

$$5.0 \times 10^4 \text{ g } CHCl_2CH_2CH_3 \times \frac{2 \times 35.45 \text{ g Cl}}{112.99 \text{ g } CHCl_2CH_2CH_3} = 3.1 \times 10^4 \text{ g Cl}$$

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140. a. Given: $SrCl_2 \bullet 6H_2O$

Unknown: percentage of water

$$\text{molar mass } SrCl_2 \bullet 6\,H_2O = 1 \text{ mol Sr} \times \frac{87.62 \text{ g Sr}}{1 \text{ mol Sr}} + 2 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}}$$

$$+ 12 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 266.64 \text{ g}$$

$$\frac{6(18.02) \text{ g } H_2O}{266.64 \text{ g } SrCl_2 \bullet 6H_2O} \times 100 = 40.55\%\ H_2O$$

b. Given: $ZnSO_4 \bullet 7H_2O$

Unknown: percentage of water

$$\text{molar mass } ZnSO_4 \bullet 7H_2O = 1 \text{ mol Zn} \times \frac{65.39 \text{ g Zn}}{1 \text{ mol Zn}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}}$$

$$+ 11 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 287.60 \text{ g}$$

$$\frac{7(18.02) \text{ g } H_2O}{287.60 \text{ g } ZnSO_4 \bullet 7H_2O} \times 100 = 43.86\%\ H_2O$$

c. Given: $CaFPO_3 \bullet 2H_2O$

Unknown: percentage of water

$$\text{molar mass } CaFPO_3 \bullet 2H_2O = 1 \text{ mol Ca} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}}$$

$$+ 1 \text{ mol F} \times \frac{19.00 \text{ g F}}{1 \text{ mol F}} + 1 \text{ mol P} \times \frac{30.97 \text{ g P}}{1 \text{ mol P}} + 5 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$

$$+ 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 174.09 \text{ g}$$

$$\frac{2(18.02) \text{ g } H_2O}{174.09 \text{ g } CaFPO_3 \bullet 2H_2O} \times 100 = 20.70\%\ H_2O$$

d. Given: $Be(NO_3)_2 \bullet 3H_2O$

Unknown: percentage of water

$$\text{molar mass } Be(NO_3)_2 \bullet 3H_2O = 1 \text{ mol Be} \times \frac{9.01 \text{ g Be}}{1 \text{ mol Be}}$$

$$+ 2 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} \times 9 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$

$$+ 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 187.09 \text{ g}$$

$$\frac{3(18.02) \text{ g } H_2O}{187.09 \text{ g } Be(NO_3)_2 \bullet 3H_2O} \times 100 = 28.90\%\ H_2O$$

141. a. Given: nickel (II) acetate tetrahydrate
Unknown: formula; percentage of nickel

formula is $Ni(C_2H_3O_2)_2 \cdot 4H_2O$

$$\text{molar mass } Ni(C_2H_3O_2)_2 \cdot 4H_2O = 1 \text{ mol Ni} \times \frac{58.69 \text{ g Ni}}{1 \text{ mol Ni}}$$

$$+ 4 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 8 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$

$$= 248.87 \text{ g}$$

$$\frac{58.69 \text{ g Ni}}{248.87 \text{ g } Ni(C_2H_3O_2)_2 \cdot 4H_2O} \times 100 = 23.58\% \text{ Ni}$$

b. Given: sodium chromate tetrahydrate
Unknown: formula; percentage of chromium

formula is $Na_2CrO_4 \cdot 4H_2O$

$$\text{molar mass } Na_2CrO_4 \cdot 4H_2O = 2 \text{ mol Na} \times \frac{22.99 \text{ g Na}}{1 \text{ mol Na}}$$

$$+ 1 \text{ mol Cr} \times \frac{52.00 \text{ g Cr}}{1 \text{ mol Cr}} + 8 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 8 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$= 234.06 \text{ g}$$

$$\frac{52.00 \text{ g Cr}}{234.06 \text{ g } Na_2CrO_4 \cdot 4H_2O} \times 100 = 22.22\% \text{ Cr}$$

c. Given: cerium (IV) sulfate tetrahydrate
Unknown: percentage of cerium

formula is $Ce(SO_4)_2 \cdot 4H_2O$

$$\text{molar mass } Ce(SO_4)_2 \cdot 4H_2O = 1 \text{ mol Ce} \times \frac{140.12 \text{ g Ce}}{1 \text{ mol Ce}}$$

$$+ 2 \text{ mol S} \times \frac{32.07 \text{ g S}}{1\text{mol S}} + 12 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 8 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$= 404.34 \text{ g}$$

$$\frac{140.12 \text{ g Ce}}{404.34 \text{ g } Ce(SO_4)_2 \cdot 4H_2O} \times 100 = 34.65\% \text{ Ce}$$

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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 $Ca_2(OH)_2CO_3$ and $CuFeS_2$

Unknown: mass of copper for each; which has more Cu

$$\text{molar mass } Cu_2(OH)_2CO_3 = 2 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} + 5 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$

$$+ 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1\text{mol C}} = 221.13 \text{ g}$$

$$1.00 \times 10^3 \text{ kg } Cu_2(OH)_2CO_3 \times \frac{2 \times 63.55 \text{ g Cu}}{221.13 \text{ g } Cu_2(OH)_2CO_3} = 575 \text{ kg Cu}$$

$$\text{molar mass } CuFeS_2 = 1 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} + 1 \text{ mol Fe} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol F}}$$

$$+ 2 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 183.54 \text{ g}$$

$$1.00 \times 10^3 \text{ kg } CuFeS_2 \times \frac{63.55 \text{ g Cu}}{183.54 \text{ g } CuFeS_2} = 346 \text{ kg Cu}$$

Malachite, $Cu_2(OH)_2CO_3$, has more copper.

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144. a. Given: $VOSO_4 \bullet 2H_2O$

Unknown: percentage of vanadium

$$\text{molar mass } VOSO_4 \bullet 2H_2O = 1 \text{ mol V} \times \frac{50.94 \text{ g V}}{1 \text{ mol V}} + 7 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}}$$

$$+ 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 199.05 \text{ g}$$

$$\frac{50.94 \text{ g V}}{199.05 \text{ g } VOSO_4 \bullet 2\,H_2O} \times 100 = 25.59\% \text{ V}$$

b. Given: $K_2SnO_3 \bullet 3H_2O$

Unknown: percentage of tin

$$\text{molar mass } K_2SnO_3 \bullet 3H_2O = 2 \text{ mol K} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}}$$

$$+ 1 \text{ mol Sn} \times \frac{118.71 \text{ g Sn}}{1 \text{ mol Sn}} + 6 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 6 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 298.97 \text{ g}$$

$$\frac{118.71 \text{ g Sn}}{298.97 \text{ g } K_2SnO_3 \bullet 3H_2O} \times 100 = 39.71\% \text{ Sn}$$

c. Given: $CaClO_3 \bullet 2H_2O$

Unknown: percentage of chlorine

$$\text{molar mass } CaClO_3 \bullet 2H_2O = 1 \text{ mol Ca} \times \frac{40.08 \text{ g Ca}}{1 \text{ mol Ca}}$$

$$+ 1 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} + 5 \text{ mol O} \times \frac{16.00 \text{ g O}}{1\text{mol O}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$= 159.57 \text{ g}$$

$$\frac{35.45 \text{ g Cl}}{159.57 \text{ g } CaClO_3 \bullet 2H_2O} \times 100 = 22.22\% \text{ Cl}$$

145. Given: 500.0 g $CuSO_4 \cdot 5H_2O$
Unknown: mass of anhydrous $CuSO_4$

$$\text{molar mass } CuSO_4 = 1 \text{ mol Cu} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} + 1 \text{ mol S} \times \frac{32.07 \text{ g}}{1 \text{ mol S}}$$

$$+ 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 159.62 \text{ g}$$

$$\text{molar mass } CuSO_4 \cdot 5H_2O = 159.62 \text{ g} + 5 \text{ mol } H_2O \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = 249.72 \text{ g}$$

$$500.0 \text{ g } CuSO_4 \cdot 5H_2O \times \frac{159.62 \text{ g } CuSO_4}{249.72 \text{ g } CuSO_4 \cdot 5H_2O} = 319.6 \text{ g } CuSO_4$$

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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

$$\text{molar mass } Ag_2S = 2 \text{ mol Ag} \times \frac{107.87 \text{ g Ag}}{1 \text{ mol Ag}} + 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 247.81 \text{ g}$$

$$62.4 \text{ g } Ag_2S \times \frac{2(107.87) \text{ g Ag}}{247.81 \text{ g } Ag_2S} = 54.3 \text{ g Ag}$$

$$62.4 \text{ g } Ag_2S \times \frac{32.07 \text{ g S}}{247.81 \text{ g } Ag_2S} = 8.08 \text{ g S}$$

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148. Given: $MgSO_4 \cdot 7H_2O$; 11.8 g H_2O
Unknown: mass of $MgSO_4 \cdot 7H_2O$

$$\text{molar mass } MgSO_4 \cdot 7H_2O = 1 \text{ mol Mg} \times \frac{24.31 \text{ g Mg}}{1 \text{ mol Mg}}$$

$$+ 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} + 11 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} + 14 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$= 246.52 \text{ g}$$

$$11.8 \text{ g } H_2O \times \frac{246.52 \text{ g } MgSO_4 \cdot 7H_2O}{7(18.02) \text{ g } H_2O} = 23.1 \text{ g } MgSO_4 \cdot 7H_2O$$

---

149. Given: 1.00 kg H_2SO_4
Unknown: mass of sulfur

$$\text{molar mass } H_2SO_4 = 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} + 1 \text{ mol S} \times \frac{32.07 \text{ S}}{1 \text{ mol S}}$$

$$+ 4 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 98.09 \text{ g}$$

$$1.00 \text{ kg } H_2SO_4 \times \frac{32.07 \text{ g S}}{98.09 \text{ g } H_2SO_4} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 3.27 \times 10^2 \text{ g S}$$

---

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.

$$28.4 \text{ g Cu} \times \frac{1 \text{ mol Cu}}{63.55 \text{ g Cu}} = 0.447 \text{ mol Cu}$$

$$71.6 \text{ g Br} \times \frac{1 \text{ mol Br}}{79.90 \text{ g Br}} = 0.896 \text{ mol Br}$$

$$\frac{0.447 \text{ mol Cu}}{0.447} : \frac{0.896 \text{ mol Br}}{0.447} = 1.00 \text{ mol Cu} : 2.00 \text{ mol Br} \rightarrow CuBr_2$$

b. Given: 39.0% K; 12.0% C; 1.01% H; 47.9% O

Unknown: empirical formual 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.

$$39.0 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} = 0.997 \text{ mol K}$$

$$12.0 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.999 \text{ mol C}$$

$$1.01 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 1.00 \text{ mol H}$$

$$47.9 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.99 \text{ mol O}$$

$$\frac{0.997 \text{ mol k}}{0.997} : \frac{0.999 \text{ mol C}}{0.997} : \frac{1.00 \text{ mol H}}{0.997} : \frac{2.99 \text{ mol O}}{0.997} = 1.00 \text{ mol K} : 1.00 \text{ mol}$$

$$\text{C} : 1.00 \text{ mol H} : 3.00 \text{ mol O} \rightarrow KHCO_3$$

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.

$$77.3 \text{ g Ag} \times \frac{1 \text{ mol Ag}}{107.87 \text{ g Ag}} = 0.717 \text{ mol Ag}$$

$$7.4 \text{ g P} \times \frac{1 \text{ mol P}}{30.97 \text{ g P}} = 0.24 \text{ mol P}$$

$$15.3 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.956 \text{ mol O}$$

$$\frac{0.717 \text{ mol Ag}}{0.24} : \frac{0.24 \text{ mol P}}{0.24} : \frac{0.956 \text{ mol O}}{0.24} = 3.0 \text{ mol Ag} : 1.0 \text{ mol P} :$$

$$4.0 \text{ mol O} \rightarrow Ag_3PO_4$$

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

$$0.57 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 0.56 \text{ mol H}$$

$$72.1 \text{ g I} \times \frac{1 \text{ mol I}}{126.90 \text{ g I}} = 0.57 \text{ mol I}$$

$$27.3 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.7 \text{ mol O}$$

$$\frac{0.56 \text{ mol H}}{0.56} : \frac{0.57 \text{ mol I}}{0.56} : \frac{1.7 \text{ mol O}}{0.56} = 1.0 \text{ mol H} : 1.0 \text{ mol I} : 3.0 \text{ mol O}$$

$$\rightarrow HIO_3$$

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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.

$$36.2 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} = 1.34 \text{ mol Al}$$

$$63.8 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 1.99 \text{ mol S}$$

$$\frac{1.34 \text{ mol Al}}{1.34} : \frac{1.99 \text{ mol S}}{1.34} = 1.0 \text{ mol Al} : 1.5 \text{ mol S}$$

$$2(1.0 \text{ mol Al} : 1.5 \text{ mol S}) = 2.0 \text{ mol Al} : 3.0 \text{ mol S} \rightarrow Al_2S_3$$

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.

$$93.5 \text{ g Nb} \times \frac{1 \text{ mol Nb}}{92.91 \text{ g Nb}} = 1.01 \text{ mol Nb}$$

$$6.50 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.406 \text{ mol O}$$

$$\frac{1.01 \text{ mol Nb}}{0.406} : \frac{0.406 \text{ mol O}}{0.406} = 2.49 \text{ mol Nb} : 1.00 \text{ mol O}$$

$$2(2.49 \text{ mol Nb} : 1.00 \text{ mol O}) = 4.98 \text{ mol Nb} : 2 \text{ mol O} \rightarrow Nb_5O_2$$

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

$$57.6 \text{ g Sr} \times \frac{1 \text{ mol Sr}}{87.62 \text{ g Sr}} = 0.657 \text{ mol Sr}$$

$$13.8 \text{ g P} \times \frac{1 \text{ mol P}}{30.97 \text{ g P}} = 0.446 \text{ mol P}$$

$$28.6 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.79 \text{ mol O}$$

$$\frac{0.657 \text{ mol Sr}}{0.446} : \frac{0.446 \text{ mol P}}{0.446} : \frac{1.79 \text{ mol O}}{0.446} = 1.47 \text{ mol Sr} : 1.00 \text{ mol P} : 4.01 \text{ mol O}$$

$$2(1.47 \text{ mol Sr} : 1.00 \text{ mol P} : 4.01 \text{ mol O}) = 2.94 \text{ mol Sr} : 2.00 \text{ mol P} : 8.02 \text{ mol O} \rightarrow Sr_3P_2O_8$$

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 mol S

$$2(1.00 \text{ mol Fe} : 5.96 \text{ mol O} : 1.40 \text{ mol S}) = 2.00 \text{ mol Fe} : 11.92 \text{ mol O} : 2.80 \text{ mol S} \rightarrow Fe_2S_3O_{12}$$

---

152. a. Given: empirical formula: CH_2; molar mass = 28 g/mol
Unknown: molecular formula

$$\text{molar mass } CH_2 = 1 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 14.03 \text{ g}$$

$$x = \frac{28 \text{ g}}{14.03 \text{ g}} = 2.0 \qquad C_xH_{2x} = C_2H_4$$

b. Given: empirical formula: B_2H_5; molar mass = 54 g/mol
Unknown: molecular formula

$$\text{molar mass } B_2H_5 = 2 \text{ mol B} \times \frac{10.81 \text{ g B}}{1 \text{ mol B}} + 5 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 26.67 \text{ g}$$

$$x = \frac{54 \text{ g}}{26.67 \text{ g}} = 2.0 \qquad B_{2x}H_{5x} = B_4H_{10}$$

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

$$\text{molar mass } C_2HCl = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 1 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol C}}$$

$$+ 1 \text{ mol Cl} \times \frac{35.45 \text{ g Cl}}{1 \text{ mol Cl}} = 60.48 \text{ g}$$

$$x = \frac{179 \text{ g}}{60.48 \text{ g}} = 2.96 \cong 3 \qquad C_{2x}H_xCl_x = C_6H_3Cl_3$$

d. Given: empirical formula: C_6H_8O; molar mass = 290 g/mol
Unknown: molecular formula

$$\text{molar mass } C_6H_8O = 6 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 8 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 96.14 \text{ g}$$

$$x = \frac{290 \text{ g}}{96.14 \text{ g}} = 3.0 \qquad C_{6x}H_{8x}O_x = C_{18}H_{24}O_3$$

e. Given: empirical formula: C_3H_2O; molar mass = 216 g/mol
Unknown: molecular formula

$$\text{molar mass } C_3H_2O = 3 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 2 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 54.05 \text{ g}$$

$$x = \frac{216 \text{ g}}{54.05} = 4.0 \qquad C_{3x}H_{2x}O_x = C_{12}H_8O_4$$

---

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

100.0 g of compound contains 66.0 g Ba and 34.0 g Cl

$$66.0 \text{ g Ba} \times \frac{1 \text{ mol Ba}}{137.33 \text{ g Ba}} = 0.481 \text{ mol Ba}$$

$$34.0 \text{ g Cl} \times \frac{1 \text{ mol Cl}}{35.45 \text{ g Cl}} = 0.959 \text{ mol Cl}$$

$$\frac{0.481 \text{ mol Ba}}{0.481} : \frac{0.959 \text{ mol Cl}}{0.481} = 1.00 \text{ mol Ba} : 1.99 \text{ mol Cl} \rightarrow BaCl_2$$

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

100.00 g of compound contains 80.38 g Bi, 18.46 g O, and 1.16 g H

$$80.38 \text{ g Bi} \times \frac{1 \text{ mol Bi}}{28.98 \text{ g Bi}} = 0.3846 \text{ mol Bi}$$

$$18.46 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.154 \text{ mol O}$$

$$1.16 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 1.149 \text{ mol H}$$

$$\frac{0.3846 \text{ mol Bi}}{0.3846} : \frac{1.154 \text{ mol O}}{0.3846} : \frac{1.149 \text{ mol H}}{0.3846} = 1.000 \text{ mol Bi} : 3.001 \text{ mol O} :$$

$$2.964 \text{ mol H} \rightarrow BiO_3H_3$$

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.

$$12.67 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} = 0.4696 \text{ mol Al}$$

$$19.73 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 1.408 \text{ mol N}$$

$$67.60 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 4.225 \text{ mol O}$$

$$\frac{0.4696 \text{ mol Al}}{0.4696} : \frac{1.408 \text{ mol N}}{0.4696} : \frac{4.225 \text{ mol O}}{0.4696} = 1.000 \text{ mol Al} : 2.998 \text{ mol N} :$$

$$8.997 \text{ mol O} \rightarrow AlN_3O_9$$

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.

$$35.64 \text{ g Zn} \times \frac{1 \text{ mol Zn}}{65.39 \text{ g Zn}} = 0.5450 \text{ mol Zn}$$

$$26.18 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 2.180 \text{ mol C}$$

$$34.88 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.180 \text{ mol O}$$

$$3.30 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 3.267 \text{ mol H}$$

$$\frac{0.5450 \text{ mol Zn}}{0.5450} : \frac{2.180 \text{ mol C}}{0.5450} : \frac{2.180 \text{ mol O}}{0.5450} : \frac{3.267 \text{ mol H}}{0.5450} = 1.000 \text{ mol Zn} :$$

$$4.000 \text{ mol C} : 4.000 \text{ mol O} : 5.994 \text{ mol H} \rightarrow ZnC_4H_6O_4$$

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.

$$2.8 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 2.8 \text{ mol H}$$

$$9.8 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 0.70 \text{ mol N}$$

$$20.5 \text{ g Ni} \times \frac{1 \text{ mol Ni}}{58.69 \text{ g Ni}} = 0.35 \text{ mol Ni}$$

$$44.5 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 2.8 \text{ mol O}$$

$$22.4 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.70 \text{ mol S}$$

$$\frac{2.8 \text{ mol H}}{0.35} : \frac{0.70 \text{ mol N}}{0.35} : \frac{0.35 \text{ mol Ni}}{0.35} : \frac{2.8 \text{ mol O}}{0.35} : \frac{0.70 \text{ mol S}}{0.35} = 8.0 \text{ mol H} :$$

$$2.0 \text{ mol N} : 1.0 \text{ mol Ni} : 8.0 \text{ mol O} : 2.0 \text{ mol S} \rightarrow NiN_2S_2H_8O_8$$

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.

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

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

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

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

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

$$1.00 \text{ mol H} : 2.0 \text{ mol O} : 3.0 \text{ mol Br} \rightarrow C_2HBrO_2$$

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

Unknown: empirical formula of compound

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

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

$$\frac{0.00845 \text{ mol Cu}}{0.00845} : \frac{0.0169 \text{ Mol F}}{0.00845} = 1.00 \text{ mol Cu} : 2.00 \text{ mol F} \rightarrow CuF_2$$

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

Unknown: empirical formula of compound

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

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

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

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

$$2.00 \text{ mol N} \rightarrow BaC_2N_2 = Ba(CN)_2$$

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

Unknown: empirical formula of compound

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

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

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

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

$$= 1.0 \text{ mol Mn} : 3.9 \text{ mol O} : 1.0 \text{ mol S} \rightarrow MnO_4S = MnSO_4$$

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

Unknown: empirical formula of compound

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

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

$$\frac{2.6 \times 10^{-5} \text{ mol Ni}}{2.6 \times 10^{-5}} : \frac{5.3 \times 10^{-5} \text{ mol I}}{2.6 \times 10^{-5}} = 1.0 \text{ mol Ni} : 2.0 \text{ mol I} \rightarrow NiI_2$$

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

Unknown: empirical formula of compound

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

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

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

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

$1.00 \text{ mol Mn} : 2.0 \text{ mol N} : 6.0 \text{ mol O} \rightarrow MnN_2O_6 = Mn(NO_3)_2$

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

Unknown: empirical formula of compound

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

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

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

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

$2.00 \text{ mol S} : 3.00 \text{ mol O} \rightarrow MgS_2O_3$

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 mol Sn

$2(1.0 \text{ mol K} : 1.5 \text{ mol O} : 0.5 \text{ mol Sn}) = 2 \text{ mol K} : 3 \text{ mol O} : 1 \text{ mol Sn}$
$\rightarrow K_2O_3Sn = K_2SnO_3$

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.

$$60.9 \text{ g As} \times \frac{1 \text{ mol As}}{74.92 \text{ g As}} = 0.813 \text{ mol As}$$

$$39.1 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 1.22 \text{ mol S}$$

$$\frac{0.813 \text{ mol As}}{0.813} : \frac{1.22 \text{ mol S}}{0.813} = 1.00 \text{ mol As: } 1.50 \text{ mol S}$$

$2(1.00 \text{ mol As} : 1.50 \text{ mol S}) = 2 \text{ mol As} : 3 \text{ mol S} \rightarrow As_2S_3$

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.

$$76.89 \text{ g Re} \times \frac{1 \text{ mol Re}}{186.21 \text{ g Re}} = 0.4129 \text{ mol Re}$$

$$23.12 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 1.445 \text{ mol O}$$

$$\frac{0.4129 \text{ mol Re}}{0.4129} : \frac{1.445 \text{ mol O}}{0.4129} = 1.000 \text{ mol Re} : 3.500 \text{ mol O}$$

$2(1.0 \text{ mol Re} : 3.5 \text{ mol O}) = 2 \text{ mol Re} : 7 \text{ mol O} \rightarrow Re_2O_7$

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 mol O

$2(2.0 \text{ mol H} : 1.0 \text{ mol N} : 1.5 \text{ mol O}) = 4 \text{ mol H} : 2 \text{ mol N} : 3 \text{ mol O}$
$\rightarrow H_4N_2O_3 = NH_4NO_3$

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 mol O

$2(1.0 \text{ mol Fe} : 1.5 \text{ mol Cr} : 6.0 \text{ mol O}) = 2 \text{ mol Fe} : 3 \text{ mol Cr} : 12 \text{ mol O}$
$\rightarrow Fe_2Cr_3O_{12} = Fe_2(CrO_4)_3$

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 mol H

$3(1.67 \text{ mol C} : 1.00 \text{ mol N} : 2.99 \text{ mol H}) = 5 \text{ mol C} : 3 \text{ mol N} : 9 \text{ mol H}$
$\rightarrow C_5N_3H_9 = C_5H_9N_3$

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.

$$55.81 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 4.647 \text{ mol C}$$

$$3.90 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 3.86 \text{ mol H}$$

$$29.43 \text{ g F} \times \frac{1 \text{ mol F}}{19.00 \text{ g F}} = 1.549 \text{ mol F}$$

$$10.85 \text{ g N} \times \frac{1 \text{ mol N}}{14.01 \text{ g N}} = 0.7744 \text{ mol N}$$

$$\frac{4.647 \text{ mol C}}{0.7744} : \frac{3.86 \text{ mol H}}{0.7744} : \frac{1.549 \text{ mol F}}{0.7744} : \frac{0.7744 \text{ mol N}}{0.7744} = 6.000 \text{ mol C} :$$

$4.98 \text{ mol H} ; 2.000 \text{ mol F} : 1.000 \text{ mol N} \rightarrow C_6H_5F_2N = C_6H_3F_2NH_2$

---

157. a. Given: empirical formula: C_2H_4S; molar mass = 179
Unknown: molecular formula of compound

$$\text{molar mass } C_2H_4S = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 1 \text{ mol S} \times \frac{32.07 \text{ g S}}{1 \text{ mol S}} = 60.13 \text{ g}$$

$$x = \frac{179 \text{ g}}{60.13 \text{ g}} = 2.98 \cong 3; C_{2x}H_{4x}S_x = C_6H_{12}S_3$$

b. Given: empirical formula: C_2H_4O; molar mass = 176
Unknown: molecular formula of compound

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

$$+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 44.06 \text{ g}$$

$$x = \frac{176 \text{ g}}{44.06 \text{ g}} = 3.99 \cong 4; C_{2x}H_{4x}O_x = C_8H_{16}O_4$$

c. Given: empirical formula: $C_2H_3O_2$; molar mass = 119
Unknown: molecular formula of compound

$$\text{molar mass } C_2H_3O_2 = 2 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 3 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

$$+ 2 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 59.058$$

$$x = \frac{119 \text{ g}}{59.05 \text{ g}} = 2.02 \cong 2; C_{2x}H_{3x}O_{2x} = C_4H_6O_4$$

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

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

$$+ 1 \text{ mol O} \times \frac{16.00 \text{ g O}}{1 \text{ mol O}} = 42.04 \text{ g}$$

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

---

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.

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

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

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

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

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.

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

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

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

$$\frac{4.540 \text{ mol C}}{2.270} : \frac{2.06 \text{ mol H}}{2.270} : \frac{2.270 \text{ mol O}}{2.270} = 2.000 \text{ mol C}: 3.99 \text{ mol H} :$$

1.000 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

Unknown: molecular formula of compound

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

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

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

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

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

1.000 mol O

empirical formula = C_3H_4O

$$\text{molar mass } C_3H_4O = 3 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 4 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$$

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

$$x = \frac{168.19 \text{ g}}{56.07 \text{ g}} = 3.000; C_{3x}H_{4x}O_x = C_9H_{12}O_3$$

---

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 $\rightarrow K_2S_2O_5$

---

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 0) = 3 mol Pb : 4 mol O $\rightarrow Pb_3O_4$

161. Given: 0.70 g Cr; 0.65 g S; 1.30 g O; molar mass = 392.2

Unknown: molecular formula of compound

$0.70 \text{ g Cr} \times \frac{1 \text{ mol Cr}}{52.00 \text{ g Cr}} = 0.013 \text{ mol Cr}$

$0.65 \text{ g S} \times \frac{1 \text{ mol S}}{32.07 \text{ g S}} = 0.0203 \text{ mol S}$

$1.30 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.812 \text{ mol O}$

$\frac{0.0135 \text{ mol Cr}}{0.0135} : \frac{0.0203 \text{ mol S}}{0.0135} : \frac{0.0812 \text{ mol O}}{0.0135} = 1.0 \text{ mol Cr} : 1.5 \text{ mol S} :$

6.0 mol O

2(1.0 mol Cr : 1.5 mol S : 6.0 mol O) = 2 mol Cr : 3 mol S : 12 mol O
$\rightarrow Cr_2S_3O_{12} = Cr_2(SO_4)_3$

---

162. Given: 60.68% C; 3.40% H; 35.92% O

Unknown: empirical formula of compound

100.00 compound contain 60.68 g C, 3.40 g H, and 35.92 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 mol C : 1.50 mol H : 1.00 mol O) = 9 mol C : 6 mol H : 4 mol O
$\rightarrow C_9H_6O_4$

---

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 mol N

3(1.66 mol C : 3.00 mol H : 1.00 mol N) = 5 mol C : 9 mol H : 3 mol N

empirical formula = $C_5H_9N_3$

molar mass $C_5H_9N_3 = 5 \text{ mol C} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} + 9 \text{ mol H} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}}$

$+ 3 \text{ mol N} \times \frac{14.01 \text{ g N}}{1 \text{ mol N}} = 111.17 \text{ g}$

$\frac{111 \text{ g}}{111.17 \text{ g}} = 0.998 \cong 1$

molecular formula = $C_5H_9N_3$

165. Given: balanced equation; 4.0 mol H_2
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 H_2SO_4

$$18 \text{ mol Al} \times \frac{3 \text{ mol } H_2SO_4}{2 \text{ mol Al}} = 27 \text{ mol } H_2SO_4$$

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

$$18 \text{ mol Al} \times \frac{1 \text{ mol } Al_2(SO_4)_3}{2 \text{ mol Al}} = 9 \text{ mol } Al_2(SO_4)_3$$

$$18 \text{ mol Al} \times \frac{3 \text{ mol } H_2}{2 \text{ mol Al}} = 27 \text{ mol } H_2$$

---

168. a. Given: balanced equation; 3.85 mol C_3H_8
Unknown: moles of CO_2 and H_2O

$$3.85 \text{ mol } C_3H_8 \times \frac{3 \text{ mol } CO_2}{1 \text{ mol } C_3H_8} = 11.6 \text{ mol } CO_2$$

$$3.85 \text{ mol } C_3H_8 \times \frac{4 \text{ mol } H_2O}{1 \text{ mol } C_3H_8} = 15.4 \text{ mol } H_2O$$

b. Given: balanced equation; 0.647 mol O_2
Unknown: moles of CO_2, H_2O, and C_3H_8

$$0.647 \text{ mol } O_2 \times \frac{3 \text{ mol } CO_2}{5 \text{ mol } O_2} = 0.388 \text{ mol } CO_2$$

$$0.647 \text{ mol } O_2 \times \frac{4 \text{ mol } H_2O}{5 \text{ mol } O_2} = 0.518 \text{ mol } H_2O$$

$$0.647 \text{ mol } O_2 \times \frac{1 \text{ mol } C_3H_8}{5 \text{ mol } O_2} = 0.129 \text{ mol } C_3H_8$$

---

169. a. Given: balanced equation; 3.25 mol P_4O_{10}
Unknown: mass of P

$$3.25 \text{ mol } P_4O_{10} \times \frac{4 \text{ mol P}}{1 \text{ mol } P_4O_{10}} \times \frac{30.97 \text{ g P}}{1 \text{ mol P}} = 403 \text{ g P}$$

b. Given: balanced equation; 0.489 mol P
Unknown: mass of O_2 and P_4O_{10}

$$0.489 \text{ mol P} \times \frac{5 \text{ mol } O_2}{4 \text{ mol P}} \times \frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} = 19.6 \text{ g } O_2$$

$$0.489 \text{ mol P} \times \frac{1 \text{ mol } P_4O_{10}}{4 \text{ mol P}} \times \frac{283.88 \text{ g } P_4O_{10}}{1 \text{ mol } P_4O_{10}} = 34.7 \text{ g } P_4O_{10}$$

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

$$1.840 \text{ mol } H_2O_2 \times \frac{1 \text{ mol } O_2}{2 \text{ mol } H_2O_2} \times \frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} = 29.44 \text{ g } O_2$$

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

$$5.0 \text{ mol } O_2 \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = 180 \text{ g } H_2O$$

---

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

$$100.0 \text{ g } NaNO_3 \times \frac{1 \text{ mol } NaNO_3}{85.01 \text{ g } NaNO_3} \times \frac{1 \text{ mol } Na_2CO_3}{2 \text{ mol } NaNO_3} = 0.5882 \text{ mol } Na_2CO_3$$

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

$$7.50 \text{ g } Na_2CO_3 \times \frac{1 \text{ mol } Na_2CO_3}{105.99 \text{ g } Na_2CO_3} \times \frac{1 \text{ mol } CO_2}{1 \text{ mol } Na_2CO_3} = 0.0708 \text{ mol } CO_2$$

---

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

$$625 \text{ g } Fe_3O_4 \times \frac{1 \text{ mol } Fe_3O_4}{231.55 \text{ g } Fe_3O_4} \times \frac{4 \text{ mol } H_2}{1 \text{ mol } Fe_3O_4} = 10.8 \text{ mol } H_2$$

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

$$90. \text{ g } CaC_2 \times \frac{1 \text{ mol } CaC_2}{64.10 \text{ g } CaC_2} \times \frac{1 \text{ mol } C_2H_2}{1 \text{ mol } CaC_2} \times \frac{26.04 \text{ g } C_2H_2}{1 \text{ mol } C_2H_2} = 37 \text{ g } C_2H_2$$

---

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 $(NH_4)_2SO_4$

$$30.0 \text{ mol } NH_3 \times \frac{1 \text{ mol } (NH_4)_2SO_4}{2 \text{ mol } NH_3} = 15.0 \text{ mol } (NH_4)_2SO_4$$

---

177. a. Given: balanced equation; 150 g Fe_2O_3
Unknown: mass Al

$$150 \text{ g } Fe_2O_3 \times \frac{1 \text{ mol } Fe_2O_3}{159.70 \text{ g } Fe_2O_3} \times \frac{2 \text{ mol Al}}{1 \text{ mol } Fe_2O_3} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 51 \text{ g Al}$$

b. Given: balanced equation; 0.905 mol Al_2O_3
Unknown: mass Fe

$$0.905 \text{ mol } Al_2O_3 \times \frac{2 \text{ mol Fe}}{1 \text{ mol } Al_2O_3} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 101 \text{ g Fe}$$

c. Given: balanced equation; 99.0 g Al
Unknown: moles Fe_2O_3

$$99.0 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{1 \text{ mol } Fe_2O_3}{2 \text{ mol Al}} = 1.83 \text{ mol } Fe_2O_3$$

---

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_2SO_4

$$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$$

$$1.27 \text{ g KOH} \times \frac{1 \text{ mol KOH}}{56.11 \text{ g KOH}} \times \frac{1 \text{ mol } H_2SO_4}{2 \text{ mol KOH}} \times \frac{98.09 \text{ g } H_2SO_4}{1 \text{ mol } H_2SO_4}$$

$$= 1.11 \text{ g } H_2SO_4$$

---

180. a. Given: reactants and products
Unknown: balanced equation

$$H_3PO_4 + 2NH_3 \rightarrow (NH_4)_2HPO_4$$

b. Given: 10.00 g NH_3
Unknown: moles $(NH_4)_2HPO_4$

$$10.00 \text{ g } NH_3 \times \frac{1 \text{ mol } NH_3}{17.04 \text{ g } NH_3} \times \frac{1 \text{ mol } (NH_4)_2HPO_4}{2 \text{ mol } NH_3} = 0.293 \text{ mol } (NH_4)_2HPO_4$$

c. Given: 2800 kg H_3PO_4
Unknown: mass NH_3

$$2800 \text{ kg } H_3PO_4 \times \frac{1 \text{ mol } H_3PO_4}{98.00 \text{ g } H_3PO_4} \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } H_3PO_4} \times \frac{17.04 \text{ g } NH_3}{1 \text{ mol } NH_3}$$

$$= 970 \text{ kg } NH_3$$

181. a. Given: balanced equation; 30.0 mol $Zn_3(C_6H_5O_7)_2$
Unknown: moles $ZnCO_3$ and $C_6H_8O_7$

$$30.0 \text{ mol } Zn_3(C_6H_5O_7)_2 \times \frac{3 \text{ mol } ZnCO_3}{1 \text{ mol } Zn_3(C_6H_5O_7)_2} = 90.0 \text{ mol } ZnCO_3$$

$$30.0 \text{ mol } Zn_3(C_6H_5O_7)_2 \times \frac{2 \text{ mol } C_6H_8O_7}{1 \text{ mol } Zn_3(C_6H_5O_7)_2} = 60.0 \text{ mol } C_6H_8O_7$$

b. Given: balanced equation; 500. mol $C_6H_8O_7$
Unknown: mass in kg of H_2O and CO_2

$$500. \text{ mol } C_6H_8O_7 \times \frac{3 \text{ mol } H_2O}{2 \text{ mol } C_6H_8O_7} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 13.5 \text{ kg } H_2O$$

$$500. \text{ mol } C_6H_8O_7 \times \frac{3 \text{ mol } CO_2}{2 \text{ mol } C_6H_8O_7} \times \frac{44.01 \text{ g } CO_2}{1 \text{ mol } CO_2} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 33.0 \text{ kg } CO_2$$

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182. a. Given: balanced equation; 52.5 g C_3H_7COOH
Unknown: mass $C_3H_7COOCH_3$

$$52.5 \text{ g } C_3H_7COOH \times \frac{1 \text{ mol } C_3H_7COOH}{88.12 \text{ g } C_3H_7COOH} \times \frac{1 \text{ mol } C_3H_7COOCH_3}{1 \text{ mol } C_3H_7COOH}$$
$$\times \frac{102.15 \text{ g } C_3H_7COOCH_3}{1 \text{ mol } C_3H_7COOCH_3} = 60.9 \text{ g } C_3H_7COOCH_3$$

b. Given: balanced equation; 5800. g CH_3OH
Unknown: mass H_2O

$$5800. \text{ g } CH_3OH \times \frac{1 \text{ mol } CH_3OH}{32.05 \text{ g } CH_3OH} \times \frac{1 \text{ mol } H_2O}{1 \text{ mol } CH_3OH} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = 3261 \text{ g } H_2O$$

---

183. a. Given: balanced equation; 36.0 g NH_4NO_3
Unknown: moles N_2

$$36.0 \text{ g } NH_4NO_3 \times \frac{1 \text{ mol } NH_4NO_3}{80.06 \text{ g } NH_4NO_3} \times \frac{2 \text{ mol } N_2}{2 \text{ mol } NH_4NO_3} = 0.450 \text{ mol } N_2$$

b. Given: balanced equation; 7.35 mol H_2O
Unknown: mass NH_4NO_3

$$7.35 \text{ mol } H_2O \times \frac{2 \text{ mol } NH_4NO_3}{4 \text{ mol } H_2O} \times \frac{80.06 \text{ g } NH_4NO_3}{1 \text{ mol } NH_4NO_3} = 294 \text{ g } NH_4NO_3$$

---

184. Given: 1.23 mg $Pb(NO_3)_2$
Unknown: mass KNO_3

$$Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$$

$$1.23 \text{ mg } Pb(NO_3)_2 \times \frac{1 \text{ mol } Pb(NO_3)_2}{331.22 \text{ g } Pb(NO_3)_2} \times \frac{2 \text{ mol } KNO_3}{1 \text{ mol } Pb(NO_3)_2}$$
$$\times \frac{101.11 \text{ g } KNO_3}{1 \text{ mol } KNO_3} = 0.751 \text{ mg } KNO_3$$

---

185. Given: balanced equation; 0.34 kg Pb
Unknown: moles $PbSO_4$

$$0.34 \text{ kg Pb} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol Pb}}{207.2 \text{ g Pb}} \times \frac{2 \text{ mol } PbSO_4}{1 \text{ mol Pb}} = 3.3 \text{ mol } PbSO_4$$

186. Given: 20.0 mol CO_2
Unknown: mass H_2O

$CO_2 + 2LiOH \rightarrow H_2O + Li_2CO_3$

$$20.0 \text{ mol } CO_2 \times \frac{1 \text{ mol } H_2O}{1 \text{ mol } CO_2} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = 360. \text{ g } H_2O$$

---

187. a. Given: balanced equation; 1.00×10^2 g P_4O_{10}
Unknown: mass H_2O

$$1.00 \times 10^2 \text{ g } P_4O_{10} \times \frac{1 \text{ mol } P_4O_{10}}{283.88 \text{ g } P_4O_{10}} \times \frac{6 \text{ mol } H_2O}{1 \text{ mol } P_4O_{10}} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O}$$

$= 38.1 \text{ g } H_2O$

b. Given: balanced equation; 0.614 mol H_2O
Unknown: mass H_3PO_4

$$0.614 \text{ mol } H_2O \times \frac{4 \text{ mol } H_3PO_4}{6 \text{ mol } H_2O} \times \frac{98.00 \text{ g } H_3PO_4}{1 \text{ mol } H_3PO_4} = 40.1 \text{ g } H_3PO_4$$

c. Given: mass of H_2O
Unknown: moles H_2O

$$(63.70 \text{ g} - 56.64 \text{ g}) \; H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} = 0.392 \text{ mol } H_2O$$

---

188. Given: 95.0 g H_2O
Unknown: mass C_2H_5OH

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

$$95.0 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} \times \frac{1 \text{ mol } C_2H_5OH}{3 \text{ mol } H_2O} \times \frac{46.08 \text{ g } C_2H_5OH}{1 \text{ mol } C_2H_5OH}$$

$= 81.0 \text{ g } C_2H_5OH$

---

189. Given: balanced equation; 50.0 g SO_2
Unknown: mass H_2SO_4 and O_2

$$50.0 \text{ g } SO_2 \times \frac{1 \text{ mol } SO_2}{64.07 \text{ g } SO_2} \times \frac{2 \text{ mol } H_2SO_4}{2 \text{ mol } SO_2} \times \frac{98.09 \text{ g } H_2SO_4}{1 \text{ mol } H_2SO_4} = 76.5 \text{ g } H_2SO_4$$

$$50.0 \text{ g } SO_2 \times \frac{1 \text{ mol } SO_2}{64.07 \text{ g } SO_2} \times \frac{1 \text{ mol } O_2}{2 \text{ mol } SO_2} \times \frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} = 12.5 \text{ g } O_2$$

---

190. Given: 5.00 g $NaHCO_3$
Unknown: mass CO_2

$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

$$5.00 \text{ g } NaHCO_3 \times \frac{1 \text{ mol } NaHCO_3}{84.01 \text{ g } NaHCO_3} \times \frac{1 \text{ mol } CO_2}{2 \text{ mol } NaHCO_3} \times \frac{44.01 \text{ g } CO_2}{1 \text{ mol } CO_2}$$

$= 1.31 \text{ g } CO_2$

---

191. c. Given: 20 000 mol N_2H_4
Unknown: mol N_2

$$20\,000 \text{ mol } N_2H_4 \times \frac{3 \text{ mol } N_2}{2 \text{ mol } N_2H_4} = 30\,000 \text{ mol } N_2$$

d. Given: 450. kg N_2O_4
Unknown: mass H_2O

$$450. \text{ kg } N_2O_4 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } N_2O_4}{92.02 \text{ g } N_2O_4} \times \frac{4 \text{ mol } H_2O}{1 \text{ mol } N_2O_4} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O}$$

$= 3.52 \times 10^5 \text{ g } H_2O$

192. Given: 517.84 g HgO
Unknown: mol O_2

$$2HgO \rightarrow 2Hg + O_2$$

$$517.84 \text{ g HgO} \times \frac{1 \text{ mol HgO}}{216.59 \text{ g HgO}} \times \frac{1 \text{ mol } O_2}{2 \text{ mol HgO}} = 1.1954 \text{ mol } O_2$$

---

193. Given: 58.0 g Cl_2
Unknown: mass Fe

$$2Fe + 3Cl_2 \rightarrow 2FeCl_3$$

$$58.0 \text{ g } Cl_2 \times \frac{1 \text{ mol } Cl_2}{70.90 \text{ g } Cl_2} \times \frac{2 \text{ mol Fe}}{3 \text{ mol } Cl_2} \times \frac{55.85 \text{ g Fe}}{1 \text{ mol Fe}} = 30.5 \text{ g Fe}$$

---

194. Given: balanced equation; 5.00 mg Na_2S
Unknown: mass CdS in mg

$$5.00 \text{ mg } Na_2S \times \frac{1 \text{ mol } Na_2S}{78.05 \text{ g } Na_2S} \times \frac{1 \text{ mol CdS}}{1 \text{ mol } Na_2S} \times \frac{144.48 \text{ g CdS}}{1 \text{ mol CdS}} = 9.26 \text{ mg CdS}$$

---

195. a. Given: balanced equation; 4.44 mol $KMnO_4$
Unknown: mol CO_2

$$4.44 \text{ mol } KMnO_4 \times \frac{5 \text{ mol } CO_2}{14 \text{ mol } KMnO_4} = 1.59 \text{ mol } CO_2$$

b. Given: 5.21 g H_2O
Unknown: mol $C_3H_5(OH)_3$

$$5.21 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} \times \frac{4 \text{ mol } C_3H_5(OH)_3}{16 \text{ mol } H_2O} = 0.0723 \text{ mol } C_3H_5(OH)_3$$

c. Given: 3.39 mol K_2CO_3
Unknown: mass Mn_2O_3 in grams

$$3.39 \text{ mol } K_2CO_3 \times \frac{7 \text{ mol } Mn_2O_3}{7 \text{ mol } K_2CO_3} \times \frac{157.88 \text{ g } Mn_2O_3}{1 \text{ mol } Mn_2O_3} = 535 \text{ g } Mn_2O_3$$

d. Given: 50.0 g $KMnO_4$
Unknown: mass $C_3H_5(OH)_3$ and CO_2 in grams

$$50.0 \text{ g } KMnO_4 \times \frac{1 \text{ mol } KMnO_4}{158.04 \text{ g } KMnO_4} \times \frac{4 \text{ mol } C_3H_5(OH)_3}{14 \text{ mol } KMnO_4}$$

$$\times \frac{92.11 \text{ g } C_3H_5(OH)_3}{1 \text{ mol } C_3H_5(OH)_3} = 8.33 \text{ g } C_3H_5(OH)_3$$

$$50.0 \text{ g } KMnO_4 \times \frac{1 \text{ mol } KMnO_4}{158.04 \text{ g } KMnO_4} \times \frac{5 \text{ mol } CO_2}{14 \text{ mol } KMnO_4} \times \frac{44.01 \text{ g } CO_2}{1 \text{ mol } CO_2}$$

$$= 4.97 \text{ g } CO_2$$

---

196. a. Given: balanced equation; 5.00×10^3 kg $CaCl_2$
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_4ClO_4

$$1.50 \times 10^5 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3 \text{ mol } NH_4ClO_4}{3 \text{ mol Al}} \times \frac{117.50 \text{ g } NH_4ClO_4}{1 \text{ mol } NH_4ClO_4}$$

$$= 6.53 \times 10^5 \text{ g } NH_4ClO_4$$

b. Given: balanced equation; 620 kg NH_4ClO_4
Unknown: mass NO

$$620 \text{ kg } NH_4ClO_4 \times \frac{1 \text{ mol } NH_4ClO_4}{117.50 \text{ g } NH_4ClO_4} \times \frac{3 \text{ mol NO}}{3 \text{ mol } NH_4ClO_4} \times \frac{30.01 \text{ g NO}}{1 \text{ mol NO}}$$

$$= 160 \text{ kg NO}$$

---

198. a. Given: balanced equation; 2.50×10^5 kg H_2SO_4
Unknown: moles H_3PO_4

$$2.50 \times 10^5 \text{ kg } H_2SO_4 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } H_2SO_4}{98.09 \text{ g } H_2SO_4} \times \frac{2 \text{ mol } H_3PO_4}{3 \text{ mol } H_2SO_4}$$

$$= 1.70 \times 10^6 \text{ mol } H_3PO_4$$

b. Given: balanced equation; 400. kg $Ca_3(PO_4)_2$
Unknown: mass $CaSO_4 \bullet 2H_2O$

$$400 \text{ kg } Ca(PO_4)_2 \times \frac{1 \text{ mol } Ca_3(PO_4)_2}{310.18 \text{ g } Ca_3(PO_4)_2} \times \frac{3 \text{ mol } CaSO_4 \bullet 2H_2O}{1 \text{ mol } Ca_3(PO_4)_2}$$

$$\times \frac{172.19 \text{ g } CaSO_4 \bullet 2H_2O}{1 \text{ mol } CaSO_4 \bullet 2H_2O} = 666 \text{ kg } CaSO_4 \bullet 2H_2O$$

c. Given: balanced equation; 68 metric tons rock; 78.8% $Ca_3(PO_4)_2$
Unknown: mass H_3PO_4 in metric tons

$$68 \text{ metric tons rock} \times \frac{0.788 \text{ g } Ca_3(PO_4)_2}{1 \text{ g rock}} \times \frac{1 \text{ mol } Ca_3(PO_4)_2}{310.18 \text{ g } Ca_3(PO_4)_2}$$

$$\times \frac{2 \text{ mol } H_3PO_4}{1 \text{ mol } Ca_3(PO_4)_2} \times \frac{98.00 \text{ g } H_3PO_4}{1 \text{ mol } H_3PO_4} = 34 \text{ metric tons } H_3PO_4$$

---

199. Given: balanced equation; mass Fe = $3.19\% \times 1650$ kg
Unknown: mass of steel scrap after 1 yr

$0.0319 \times 1650 \text{ kg Fe} = 52.6 \text{ kg Fe}$

$$52.6 \text{ kg Fe} \times \frac{\text{mol Fe}}{55.85 \text{ g Fe}} \times \frac{2 \text{ mol } Fe_2O_3}{4 \text{ mol Fe}} \times \frac{159.70 \text{ g } Fe_2O_3}{1 \text{ mol } Fe_2O_3} = 75.2 \text{ kg } Fe_2O_3$$

$1650 \text{ kg} - 52.6 \text{ kg} + 75.2 \text{ kg} = 1670 \text{ kg}$

---

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 O_2 needed; 0.030 mol O_2 available

limiting reactant: O_2

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 Cl_2 needed; 950. g Cl_2 available; limiting reactant is $ZrSiO_4$

$$862\text{ g }ZrSiO_4 \times \frac{1\text{ mol }ZrSiO_4}{183.31\text{ g }ZrSiO_4} \times \frac{1\text{ mol }ZrCl_4}{1\text{ mol }ZrSiO_4} \times \frac{233.02\text{ g }ZrCl_4}{1\text{ mol }ZrCl_4}$$

$= 1.10 \times 10^3$ g $ZrCl_4$

---

202. Given: 1.72 mol ZnS; 3.04 mol O_2
Unknown: balanced equation; limiting reactant

$$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$$

$$1.72\text{ mol ZnS} \times \frac{3\text{ mol }O_2}{2\text{ mol ZnS}} = 2.58\text{ mol }O_2$$

2.58 mol O_2 needed; 3.04 mol O_2 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 O_2 needed; 0.26 mol O_2 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_2O_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: O_2

$$6.38 \times 10^{-3}\text{ mol }O_2 \times \frac{2\text{ mol }Al_2O_3}{3\text{ mol }O_2} = 4.25 \times 10^{-3}\text{ mol }Al_2O_3$$

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 O_2 needed; 2.55 O_2 available; limiting reactant: O_2

---

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 O_2 needed; 56 g O_2 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 O_2 needed; 12.0 g O_2 available; limiting reactant: CuS

$$18.7\text{ g CuS} \times \frac{1\text{ mol CuS}}{95.62\text{ CuS}} \times \frac{2\text{ mol CuO}}{2\text{ mol CuS}} \times \frac{79.55\text{ g CuO}}{1\text{ mol CuO}} = 15.6\text{ g CuO}$$

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 $CuSo_4$ needed; 0.158 mol $CuSO_4$ 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 HNO_3

35 g HNO_3 needed; 26 HNO_3 available; limiting reactant: HNO_3

$$26 \text{ g } HNO_3 \times \frac{1 \text{ mol } HNO_3}{63.02 \text{ g } HNO_3} \times \frac{1 \text{ mol } Ba(NO_3)_2}{2 \text{ mol } HNO_3} \times \frac{261.35 \text{ g } Ba(NO_3)_2}{1 \text{ mol } Ba(NO_3)_2}$$

$= 54$ g $Ba(NO_3)_2$

---

207. a. Given: balanced equation; 560 g MgI_2; 360 g Br_2
Unknown: excess reactant; remaining mass

$$560 \text{ g } MgI_2 \times \frac{1 \text{ mol } MgI_2}{278.11 \text{ g } MgI_2} \times \frac{1 \text{ mol } Br_2}{1 \text{ mol } MgI_2} \times \frac{159.80 \text{ g } Br_2}{1 \text{ mol } Br_2} = 322 \text{ g } Br_2$$

Br_2 is in excess; 360 g Br_2 – 322 g Br_2 = 38 g Br_2 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 $Ni(NO_3)_2$

---

209. Given: 1.60 mol CS_2; 5.60 mol O_2
Unknown: balanced equation; moles of excess, reactant

$$CS_2(g) + 3O_2(g) \rightarrow 2SO_2(g) + CO_2(g)$$

$$1.60 \text{ mol } CS_2 \times \frac{3 \text{ mol } O_2}{1 \text{ mol } CS_2} = 4.80 \text{ mol } O_2$$

5.60 mol O_2 – 4.80 mol O_2 = 0.80 mol O_2 excess

210. a. Given: balanced equation; 0.91 g $HgCl_2$
Unknown: mass $Hg(NH_2)Cl$

$$0.91 \text{ g } HgCl_2 \times \frac{1 \text{ mol } HgCl_2}{271.49 \text{ g } HgCl_2} \times \frac{1 \text{ mol } Hg(NH_2)Cl}{1 \text{ mol } HgCl_2} \times \frac{252.07 \text{ g } Hg(NH_2)Cl}{1 \text{ mol } Hg(NH_2)Cl} = 0.84 \text{ g } Hg(NH_2)Cl$$

b. Given: balanced equation; 0.91 g $HgCl_2$; 0.15 g NH_3
Unknown: mass $Hg(NH_2)Cl$

$$0.91 \text{ g } HgCl_2 \times \frac{1 \text{ mol } HgCl_2}{271.49 \text{ g } HgCl_2} \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } HgCl_2} \times \frac{17.04 \text{ g } NH_3}{1 \text{ mol } NH_3} = 0.11 \text{ g } NH_3$$

0.11 g NH_3 needed; 0.15 g NH_3 available; limiting reactant: $HgCl_2$

$$0.91 \text{ g } HgCl_2 \times \frac{1 \text{ mol } HgCl_2}{271.49 \text{ g } HgCl_2} \times \frac{1 \text{ mol } Hg(NH_2)Cl}{1 \text{ mol } HgCl_2} \times \frac{252.07 \text{ g } Hg(NH_2)Cl}{1 \text{ mol } Hg(NH_2)Cl} = 0.84 \text{ g } Hg(NH_2)Cl$$

---

211. b. Given: balanced equation from **a**; 0.57 mol Al; 0.37 mol NaOH; excess water
Unknown: moles H_2

$$0.57 \text{ mol Al} \times \frac{2 \text{ mol NaOH}}{2 \text{ mol Al}} = 0.57 \text{ mol NaOH}$$

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 NO_2
Unknown: moles of HNO_3 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 HNO_3
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 HNO_3 needed; 23.23 g HNO_3 available: Cu is in excess.

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213. a. Given: balanced equation; 2.90 mol NH_3; 3.75 mol O_2
Unknown: moles of NO and H_2O

$$2.90 \text{ mol } NH_3 \times \frac{5 \text{ mol } O_2}{4 \text{ mol } NH_3} = 3.62 \text{ mol } O_2\text{; } NH_3 \text{ is limiting.}$$

$$2.90 \text{ mol } NH_3 \times \frac{4 \text{ mol NO}}{4 \text{ mol } NH_3} = 2.90 \text{ mol NO}$$

$$2.90 \text{ mol } NH_3 \times \frac{6 \text{ mol } H_2O}{4 \text{ mol } NH_3} = 4.35 \text{ mol } H_2O$$

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

Unknown: limiting reactant

$$4.20 \times 10^4 \text{ g } NH_3 \times \frac{1 \text{ mol } NH_3}{17.04 \text{ g } NH_3} \times \frac{5 \text{ mol } O_2}{4 \text{ mol } NH_3} \times \frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2}$$

$= 9.86 \times 10^4$ 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

$$869 \text{ kg } NH_3 \times \frac{1 \text{ mol } NH_3}{17.04 \text{ g } NH_3} \times \frac{4 \text{ mol NO}}{4 \text{ mol } NH_3} \times \frac{30.01 \text{ g NO}}{1 \text{ mol NO}}$$

$= 1.53 \times 10^3$ kg NO

214. Given: balanced equation; 620 g C_2H_5OH; 1020 g CuO

Unknown: mass CH_3CHO; mass excess reactant left

$$620 \text{ g } C_2H_5OH \times \frac{1 \text{ mol } C_2H_5OH}{46.08 \text{ g } C_2H_5OH} \times \frac{1 \text{ mol CuO}}{1 \text{ mol } C_2H_5OH} \times \frac{79.55 \text{ g CuO}}{1 \text{ mol CuO}}$$

= 1070 g CuO

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

$$1020 \text{ g CuO} \times \frac{1 \text{ mol CuO}}{79.55 \text{ g CuO}} \times \frac{1 \text{ mol } CH_3CHO}{1 \text{ mol CuO}} \times \frac{44.06 \text{ g } CH_3CHO}{1 \text{ mol } CH_3CHO}$$

= 565 g CH_3CHO

$$1020 \text{ g CuO} \times \frac{1 \text{ mol CuO}}{79.55 \text{ g CuO}} \times \frac{1 \text{ mol } C_2H_5OH}{1 \text{ mol CuO}} \times \frac{46.08 \text{ g } C_2H_5OH}{1 \text{ mol } C_2H_5OH}$$

= 591 g C_2H_5OH

620 g C_2H_5OH – 591 g C_2H_5OH = 29 g C_2H_5OH 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 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

$$25.0 \text{ g } Na_2SO_3 \times \frac{1 \text{ mol } Na_2SO_3}{126.05 \text{ g } Na_2SO_3} \times \frac{2 \text{ mol HCl}}{1 \text{ mol } Na_2SO_3} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 14.5 \text{ g HCl}$$

14.5 g HCl needed; 22.0 g HCl available; limiting reactant: Na_2SO_3

$$25.0 \text{ g } Na_2SO_3 \times \frac{1 \text{ mol } Na_2SO_3}{126.05 \text{ g } Na_2SO_3} \times \frac{1 \text{ mol } SO_2}{1 \text{ mol } Na_2SO_3} \times \frac{64.07 \text{ g } SO_2}{1 \text{ mol } SO_2}$$

= 12.7 g SO_2

217. a. Given: balanced equation; 27.5 g TbF_3; 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 TbF_3; Ca is limiting

Unknown: mass TbF_3 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 g TbF_3 – 25.0 g TbF_3 = 2.5 g TbF_3 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

$$\frac{0.00089 \text{ g}}{0.00192 \text{ g}} \times 100 = 46\% \text{ yield}$$

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219. a. Given: balanced equation; 8.87 g As_2O_3; actual yield As = 5.33 g

Unknown: percent yield

$$\text{theoretical yield} = 8.87 \text{ g } As_2O_3 \times \frac{1 \text{ mol } As_2O_3}{197.84 \text{ g } As_2O_3} \times \frac{4 \text{ mol As}}{2 \text{ mol } As_2O_3}$$

$$\times \frac{74.92 \text{ g As}}{1 \text{ mol As}} = 6.72 \text{ g As}$$

$$\frac{5.33 \text{ g As}}{6.72 \text{ g As}} \times 100 = 79.3\% \text{ yield}$$

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 C_2H_5OH; actual yield $CH_3COOC_2H_5$ = 2.98 mol; balanced equation
Unknown: percent yield

theoretical yield $CH_3COOC_2H_5$ =

$$4.29\ \text{mol}\ C_2H_5OH \times \frac{1\ \text{mol}\ CH_3COOC_2H_5}{1\ \text{mol}\ C_2H_5OH} = 4.29\ \text{mol}\ CH_3COOC_2H_5$$

$$\frac{2.98\ \text{mol}\ CH_3COOC_2H_5}{4.29\ \text{mol}\ CH_3COOC_2H_5} \times 100 = 69.5\%\ \text{yield}$$

d. Given: balanced equation; 0.58 mol C_2H_5OH; 0.82 mol CH_3COOH; actual yield $CH_3COOC_2H_5$ = 0.46 mol
Unknown: percent yield

$$0.58\ \text{mol}\ C_2H_5OH \times \frac{1\ \text{mol}\ CH_3COOH}{1\ \text{mol}\ C_2H_5OH} = 0.58\ \text{mol}\ CH_3COOH$$

C_2H_5OH is limiting.

$$0.58\ \text{mol}\ C_2H_5OH \times \frac{1\ \text{mol}\ CH_3COOC_2H_5}{1\ \text{mol}\ C_2H_5OH} = 0.58\ \text{mol}\ CH_3COOC_2H_5$$

$$\frac{0.46\ \text{mol}}{0.58\ \text{mol}} \times 100 = 79\%\ \text{yield}$$

---

221. a. Given: balanced equation; 0.0251 mol A; actual yield C = 0.0349 mol
Unknown: percent yield

$$\text{theoretical yield C} = 0.0251\ \text{mol A} \times \frac{4\ \text{mol C}}{2\ \text{mol A}} = 0.0502\ \text{mol C}$$

$$\frac{0.0349\ \text{mol}}{0.0502\ \text{mol}} \times 100 = 69.5\%\ \text{yield}$$

b. Given: balanced equation; 1.19 mol A; actual yield D = 1.41 mol
Unknown: percent yield

$$\text{theoretical yield D} = 1.19\ \text{mol A} \times \frac{3\ \text{mol D}}{2\ \text{mol A}} = 1.785\ \text{mol D}$$

$$\frac{1.41\ \text{mol}}{1.785\ \text{mol}} \times 100 = 79.0\%\ \text{yield}$$

c. Given: balanced equation; 189 mol B; actual yield D = 39 mol
Unknown: percent yield

$$\text{theoretical yield D} = 189\ \text{mol B} \times \frac{3\ \text{mol D}}{7\ \text{mol B}} = 81.0\ \text{mol D}$$

$$\frac{39\ \text{mol}}{81.0\ \text{mol}} \times 100 = 48\%\ \text{yield}$$

d. Given: balanced equation; 3500 mol B; actual yield C = 1700 mol
Unknown: percent yield

$$\text{theoretical yield C} = 3500 \text{ mol B} \times \frac{4 \text{ mol C}}{7 \text{ mol B}} = 2.0 \times 10^3 \text{ mol C}$$

$$\frac{1.7 \times 10^3 \text{ mol}}{2.0 \times 10^3 \text{ mol}} \times 100 = 85\% \text{ C}$$

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222. a. Given: balanced equation; 57 mol $Ca_3(PO_4)_2$; actual yield $CaSiO_3$ = 101 mol
Unknown: percent yield

$$\text{theoretical yield } CaSiO_3 = 57 \text{ mol } Ca_3(PO_4)_2 \times \frac{3 \text{ mol } CaSiO_3}{1 \text{ mol } Ca_3(PO_4)_2}$$
$$= 170 \text{ mol } CaSiO_3$$

$$\frac{101 \text{ mol}}{170 \text{ mol}} \times 100 = 59\% \text{ yield}$$

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 $Ca_3(PO_4)_2$
Unknown: actual mol P

$$1.4 \times 10^5 \text{ mol } Ca_3(PO_4)_2 \times \frac{2 \text{ mol P}}{1 \text{ mol } Ca_3(PO_4)_2} \times 0.815 = 2.3 \times 10^5 \text{ mol}$$

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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 CS_2; actual yield CCl_4 = 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 Cl_2; actual yield S_2Cl_2 = 39.5 g

Unknown: percent yield

$$\text{theoretical yield} = 67.5 \text{ g } Cl_2 \times \frac{1 \text{ mol } Cl_2}{70.90 \text{ g } Cl_2} \times \frac{1 \text{ mol } S_2Cl_2}{3 \text{ mol } Cl_2} \times \frac{135.04 \text{ g } S_2Cl_2}{1 \text{ mol } S_2Cl_2} = 42.8 \text{ g } S_2Cl_2$$

$$\frac{39.5 \text{ g}}{42.8 \text{ g}} \times 100 = 92.2\% \text{ yield}$$

c. Given: balanced equation; 83.3% yield; actual yield CCl_4 = 5.00×10^4 kg

Unknown: kg CS_2 and S_2Cl_2

$$5.00 \times 10^4 \text{ kg } CCl_4 \times \frac{100\%}{83.3\%} \times \frac{1 \text{ mol } CCl_4}{153.81 \text{ g } CCl_4} \times \frac{1 \text{ mol } CS_2}{1 \text{ mol } CCl_4} \times \frac{76.15 \text{ g } CS_2}{1 \text{ mol } CS_2} = 2.97 \times 10^4 \text{ kg } CS_2$$

$$5.00 \times 10^4 \text{ kg } CCl_4 \times \frac{83.3\%}{100\%} \times \frac{1 \text{ mol } CCl_4}{153.81 \text{ g } CCl_4} \times \frac{1 \text{ mol } S_2Cl_2}{1 \text{ mol } CCl_4} \times \frac{135.04 \text{ g } S_2Cl_2}{1 \text{ mol } S_2Cl_2} = 3.66 \times 10^4 \text{ kg } S_2Cl_2$$

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225. a. Given: balanced equation; 0.38 g NO_2; actual yield N_2O_5 = 0.36 g

Unknown: percent yield

$$0.38 \text{ g } NO_2 \times \frac{1 \text{ mol } NO_2}{46.01 \text{ g } NO_2} \times \frac{1 \text{ mol } N_2O_5}{2 \text{ mol } NO_2} \times \frac{108.02 \text{ g } N_2O_5}{1 \text{ mol } N_2O_5} = 0.45 \text{ g } N_2O_5$$

$$\frac{0.36 \text{ g}}{0.45 \text{ g}} \times 100 = 80.\% \text{ g yield}$$

b. Given: balanced equation; 6.0 mol NO_2; 61.1% yield

Unknown: mass N_2O_5

$$6.0 \text{ mol } NO_2 \times \frac{1 \text{ mol } N_2O_5}{2 \text{ mol } NO_2} \times \frac{108.02 \text{ g } N_2O_5}{1 \text{ mol } N_2O_5} = 320 \text{ g } N_2O_5$$

$$320 \text{ g } N_2O_5 \times \frac{61.1\%}{100\%} = 2.0 \times 10^2 \text{ g } N_2O_5$$

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226. Given: balanced equation; 30.0 g NaCl; 0.250 mol H_2SO_4; actual yield HCl = 14.6 g

Unknown: percent yield

$$30.0 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58.44 \text{ g NaCl}} \times \frac{1 \text{ mol } H_2SO_4}{2 \text{ mol NaCl}} = 0.257 \text{ mol } H_2SO_4$$

0.250 mol H_2SO_4 available, 0.257 mol H_2SO_4 needed; H_2SO_4 is limiting.

$$0.250 \text{ mol } H_2SO_4 \times \frac{2 \text{ mol HCl}}{1 \text{ mol } H_2SO_4} \times \frac{36.46 \text{ g HCl}}{1 \text{ mol HCl}} = 18.2 \text{ g HCl}$$

$$\frac{14.6 \text{ g}}{18.2 \text{ g}} \times 100 = 80.2\% \text{ yield}$$

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

$$\frac{x}{0.910 \text{ kg Au}} = \frac{100\%}{0.001\%}; x = 9 \times 10^4 \text{ kg ore}$$

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228. a. Given: balanced equation; 2.00 g CO; actual yield I_2 = 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

$100.0\% - 87.6\% = 12.4\%$ unreacted

0.124×2.00 g CO = 0.248 g CO

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229. a. Given: balanced equation; 1.2 kg Cl_2; 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 Cl_2

$$25 \text{ metric tons NaClO} \times \frac{100\%}{91.8\%} \times \frac{1 \text{ mol NaClO}}{65.46 \text{ g NaClO}} \times \frac{1 \text{ mol Cl}_2}{1 \text{ mol NaClO}}$$

$$\times \frac{70.90 \text{ g Cl}_2}{1 \text{ mol Cl}_2} = 29 \text{ metric tons Cl}_2$$

c. Given: balanced equation; 81.8% yield; 1 mol Cl_2
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

$$\frac{370 \text{ kg NaClO}}{1 \text{ h}} \times \frac{100\%}{79.5\%} \times \frac{1 \text{ mol NaClO}}{65.46 \text{ g NaClO}} \times \frac{2 \text{ mol NaOH}}{1 \text{ mol NaClO}}$$

$$\times \frac{40.00 \text{ g NaOH}}{1 \text{ mol NaOH}} = 568 \text{ kg NaOH/h}$$

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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 Mg_3N_2
Unknown: percent yield

$$\text{theoretical yield} = 0.097 \text{ mol Mg} \times \frac{1 \text{ mol } Mg_3N_2}{3 \text{ mol Mg}} = 0.032 \text{ mol } Mg_3N_2$$

$$\frac{0.027 \text{ mol}}{0.032 \text{ mol}} \times 100 = 84\% \text{ yield}$$

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231. a. Given: balanced equation; 0.89 g C_3H_7OH; actual yield C_2H_5COOH = 0.88 g
Unknown: percent yield

$$\text{theoretical yield} = 0.89 \text{ g } C_3H_7OH \times \frac{1 \text{ mol } C_3H_7OH}{60.11 \text{ g } C_3H_7OH}$$

$$\times \frac{3 \text{ mol } C_2H_5COOH}{3 \text{ mol } C_3H_7OH} \times \frac{74.09 \text{ g } C_2H_5COOH}{1 \text{ mol } C_2H_5COOH} = 1.1 \text{ g } C_2H_5COOH$$

$$\frac{0.88 \text{ g}}{1.1 \text{ g}} \times 100 = 80.\% \text{ yield}$$

b. Given: balanced equation; actual yield C_2H_5COOH = 1.50 mol; 136 g C_3H_7OH
Unknown: percent yield

$$\text{theoretical yield} = 136 \text{ g } C_3H_7OH \times \frac{1 \text{ mol } C_3H_7OH}{60.11 \text{ g } C_3H_7OH}$$

$$\times \frac{3 \text{ mol } C_2H_5COOH}{3 \text{ mol } C_3H_7OH} = 2.26 \text{ mol } C_2H_5COOH$$

$$\frac{1.50 \text{ mol}}{2.26 \text{ mol}} \times 100 = 66.4\% \text{ yield}$$

c. Given: balanced equation; 116 g $Na_2Cr_2O_7$; actual yield C_2H_5COOH = 28.1 g
Unknown: percent yield

$$\text{theoretical yield} = 116 \text{ g } Na_2Cr_2O_7 \times \frac{1 \text{ mol } Na_2Cr_2O_7}{261.98 \text{ g } Na_2Cr_2O_7}$$

$$\times \frac{3 \text{ mol } C_2H_5COOH}{2 \text{ mol } Na_2Cr_2O_7} \times \frac{74.09 \text{ g } C_2H_5COOH}{1 \text{ mol } C_2H_5COOH} = 49.2 \text{ g } C_2H_5COOH$$

$$\frac{28.1 \text{ g}}{49.2 \text{ g}} \times 100 = 57.1\% \text{ yield}$$

232. Given: unbalanced equation; 850. g C_3H_6; 300. g NH_3; excess O_2; actual yield C_3H_3N = 850. g

Unknown: balanced equation; limiting reactant; percent yield

$2C_3H_6(g) + 2NH_3(g) + 3O_2(g) \rightarrow 2C_3H_3N(g) + 6H_2O(g)$

$$850.\text{ g } C_3H_6 \times \frac{1 \text{ mol } C_3H_6}{42.09 \text{ g } C_3H_6} \times \frac{2 \text{ mol } NH_3}{2 \text{ mol } C_3H_6} \times \frac{17.04 \text{ g } NH_3}{1 \text{ mol } NH_3} = 344 \text{ g } NH_3$$

300 g NH_3 available, 344 g NH_3 needed; NH_3 is limiting.

$$300.\text{ g } NH_3 \times \frac{1 \text{ mol } NH_3}{17.04 \text{ g } NH_3} \times \frac{2 \text{ mol } C_3H_3N}{2 \text{ mol } NH_3} \times \frac{53.07 \text{ g } C_3H_3N}{1 \text{ mol } C_3H_3N}$$

$$= 934 \text{ g } C_3H_3N$$

$$\frac{850.\text{ g}}{934 \text{ g}} \times 100 = 91.0\% \text{ yield}$$

---

233. a. Given: 430 kg H_2; reactants and product

Unknown: balanced equation; mass CH_3OH

$CO + 2H_2 \rightarrow CH_3OH$

$$430.\text{ kg } H_2 \times \frac{1 \text{ mol } H_2}{2.02 \text{ g } H_2} \times \frac{1 \text{ mol } CH_3OH}{2 \text{ mol } H_2} \times \frac{32.05 \text{ g } CH_3OH}{1 \text{ mol } CH_3OH}$$

$$= 3.41 \times 10^3 \text{ kg } CH_3OH$$

b. Given: balanced equation and theoretical yield from **a**; actual yield CH_3OH = 3.12×10^3 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 $C_6H_{10}O_4$; actual yield $C_6H_{16}N_2$ = 578 g

Unknown: percent yield

$$750.\text{ g } C_6H_{10}O_4 \times \frac{1 \text{ mol } C_6H_{10}O_4}{146.16 \text{ g } C_6H_{10}O_4} \times \frac{1 \text{ mol } C_6H_{16}N_2}{1 \text{ mol } C_6H_{10}O_4}$$

$$\times \frac{116.24 \text{ g } C_6H_{16}N_2}{1 \text{ mol } C_6H_{16}N_2} = 596 \text{ g } C_6H_{16}N_2$$

$$\frac{578 \text{ g}}{596 \text{ g}} \times 100 = 97.0\% \text{ yield}$$

---

235. Given: unbalanced equation; 1.37×10^4 g CO_2; 63.4% yield

Unknown: balanced equation; mass O_2

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

$$1.37 \times 10^4 \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{6 \text{ mol } O_2}{6 \text{ mol } CO_2} \times \frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2}$$

$$= 9.96 \times 10^3 \text{ g } O_2$$

$$9.96 \times 10^3 \text{ g } O_2 \times \frac{63.4\%}{100\%} = 6.32 \times 10^3 \text{ g } O_2$$

---

236. Given: balanced equation; 2.67×10^2 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 atm; V_1 = 25 mL; P_2 = 6.0 atom

Unknown: V_2

$$V_2 = \frac{P_1V_1}{P_2} = 3.0 \text{ atm} \times \frac{25 \text{ mL}}{6.0 \text{ atm}} = 13 \text{ mL}$$

b. Given: P_1 = 99.97 kPa; V_1 = 550. mL; V_2 = 275 mL

Unknown: P_2

$$P_2 = \frac{P_1V_1}{V_2} = \frac{99.97 \text{ kPa} \times 550. \text{ mL}}{275 \text{ mL}} = 200. \text{ kPa}$$

c. Given: P_1 = 0.89 atm; P_2 = 3.56 atm; V_2 = 20.0 L

Unknown: V_1

$$V_1 = \frac{P_2V_2}{P_1} = \frac{3.56 \text{ atm} \times 20.0 \text{ L}}{0.89 \text{ atm}} = 80. \text{ L}$$

d. Given: V_1 = 800. mL; P_2 = 500. kPa; V_2 = 160. mL

Unknown: P_1

$$P_1 = \frac{P_2V_2}{V_1} = \frac{500. \text{ kPa} \times 160. \text{ mL}}{800. \text{ mL}} = 100. \text{ kPa}$$

e. Given: P_1 = 0.040 atm; P_2 = 250 atm; $V_2 = 1.0 \times 10^{-2}$ L

Unknown: V_1

$$V_1 = \frac{P_2V_2}{P_1} = \frac{250 \text{ atm} \times 1.0 \times 10^{-2} \text{ L}}{0.040 \text{ atm}} = 63 \text{ L}$$

---

238. Given: P_1 = 1.8 atm; V_1 = 2.8 L; P_2 = 1.2 atm

Unknown: V_2

$$V_2 = \frac{P_1V_1}{P_2} = \frac{1.8 \text{ atm} \times 2.8 \text{ L}}{1.2 \text{ atm}} = 4.2 \text{ L}$$

---

239. Given: P_1 = 99.3 kPa; V_1 = 48.0 L; V_2 = 16.0 L

Unknown: P_2

$$P_2 = \frac{P_1V_1}{V_2} = \frac{99.3 \text{ kPa} \times 48.0 \text{ L}}{16.0 \text{ L}} = 298 \text{ kPa}$$

---

240. Given: P_1 = 0.989 atm; V_1 = 59.0 mL; P_2 = 0.967 atm

Unknown: V_2

$$V_2 = \frac{P_1V_1}{P_2} = \frac{0.989 \text{ atm} \times 59.0 \text{ mL}}{0.967 \text{ atm}} = 60.3 \text{ mL}$$

---

241. Given: P_1 = 6.5 atm; V_1 = 2.2 L; P_2 = 1.15 atm

Unknown: V_2

$$V_2 = \frac{P_1V_1}{P_2} = \frac{6.5 \text{ atm} \times 2.2 \text{ L}}{1.15 \text{ atm}} = 12 \text{ L}$$

242. a. Given: $V_1 = 40.0$ mL; $T_1 = 280.$ K; $T_2 = 350.$ K

Unknown: V_2

$$V_2 = \frac{V_1T_2}{T_1} = \frac{40.0 \text{ mL} \times 350 \text{ K}}{280. \text{ K}} = 50.0 \text{ mL}$$

b. Given: $V_1 = 0.606$ L; $T_1 = 300.$ K; $V_2 = 0.404$ L

Unknown: T_2

$$T_2 = \frac{V_2T_1}{V_1} = \frac{0.404 \text{ L} \times 300. \text{ K}}{0.606 \text{ L}} = 200. \text{ K}$$

c. Given: $T_1 = 292$ K; $V_2 = 250.$ mL; $T_2 = 365$ K

Unknown: V_1

$$V_1 = \frac{V_2T_1}{T_2} = \frac{250. \text{ mL} \times 292 \text{ K}}{365 \text{ K}} = 200. \text{ mL}$$

d. Given: $V_1 = 100.$ mL; $V_2 = 125$ mL; $T_2 = 305$ K

Unknown: T_1

$$T_1 = \frac{T_2V_1}{V_2} = \frac{305 \text{ K} \times 100. \text{ mL}}{125 \text{ mL}} = 244 \text{ K}$$

e. Given: $V_1 = 0.0024$ L; $T_1 = 22°C$; $T_2 = -14°C$; K = 273 + °C

Unknown: V_2

$$V_2 = \frac{V_1T_2}{T_1} = \frac{0.0024 \text{ L} \times (273 - 14) \text{ K}}{(273 + 22) \text{ K}} = \frac{0.0024 \text{ L} \times 259 \text{ K}}{259 \text{ K}} = 0.0021 \text{ L}$$

---

243. Given: $V_1 = 2.75$ L; $T_1 = 18°C$; $T_2 = 45°C$; K = 273 + °C

Unknown: V_2

$$V_2 = \frac{V_1T_2}{T_1} = \frac{2.75 \text{ L} \times (273 + 45) \text{ K}}{(273 + 18) \text{ K}} = \frac{2.75 \text{ L} \times 318 \text{ K}}{291 \text{ K}} = 3.01 \text{ L}$$

---

244. Given: $V_1 = 0.43$ mL; $T_1 = 24°C$; $V_2 = 0.57$ mL; K = 273 + °C

Unknown: T_2

$$T_2 = \frac{T_1V_2}{V_1} = \frac{(273 + 24) \text{ K} \times 0.57 \text{ mL}}{0.43 \text{ mL}} = 394 \text{ K}$$

394 K – 273 = 121°C

---

245. a. Given: $P_1 = 1.50$ atm; $T_1 = 273$ K; $T_2 = 410$ K

Unknown: P_2

$$P_2 = \frac{P_1T_2}{T_1} = \frac{1.50 \text{ atm} \times 410 \text{ K}}{273 \text{ K}} = 2.25 \text{ atm}$$

b. Given: $P_1 = 0.208$ atm; $T_1 = 300.$ K; $P_2 = 0.156$ atm

Unknown: T_2

$$T_2 = \frac{T_1P_2}{P_1} = \frac{300. \text{ K} \times 0.156 \text{ atm}}{0.208 \text{ atm}} = 225 \text{ K}$$

c. Given: $T_1 = 52°C$; $P_2 = 99.7$ kPa; $T_2 = 77°C$; $K = 273 + °C$
Unknown: P_1

$$P_1 = \frac{P_2T_1}{T_2} = \frac{99.7 \text{ kPa} \times (52 + 273) \text{ K}}{(77 + 273) \text{ K}} = \frac{99.7 \text{ kPa} \times 325 \text{ K}}{350. \text{ K}} = 92.6 \text{ kPa}$$

d. Given: $P_1 = 5.20$ atm; $P_2 = 4.16$ atm; $T_2 = -13°C$; $K = 273 + °C$
Unknown: T_1

$$T_1 = \frac{P_1T_2}{P_1} = \frac{5.20 \text{ atm} \times (273 - 13) \text{ K}}{4.16 \text{ atm}} = \frac{5.20 \text{ atm} \times 260. \text{ K}}{4.16 \text{ atm}} = 325 \text{ K}$$

325 K – 273 = 52°C

e. Given: $P_1 = 8.33 \times 10^{-4}$ atm; $T_1 = -84°C$; $P_2 = 3.92 \times 10^{-3}$ atm; $K = 273 + °C$
Unknown: T_2

$$T_2 = \frac{T_1P_2}{P_1} = \frac{(273 - 84) \text{ K} \times 3.92 \times 10^{-3} \text{ atm}}{8.33 \times 10^{-4} \text{ atm}} = \frac{189 \text{ K} \times 3.92 \times 10^{-3}}{8.33 \times 10^{-4}}$$

= 889 K

889 K – 273 = 616°C

---

246. Given: $P_1 = 4.882$ atm; $P_2 = 4.690$ atm; $T_2 = 8°C$; $K = 273 + °C$
Unknown: T_1

$$T_1 = \frac{P_1T_2}{P_2} = \frac{4.882 \text{ atm} \times (273 + 8) \text{ K}}{4.690 \text{ atm}} = \frac{4.882 \text{ atm} \times 281 \text{ K}}{4.690 \text{ atm}} = 293 \text{ K}$$

293 K – 273 = 20.°C

---

247. Given: $P_1 = 107$ kPa; $T_1 = 22°C$; $T_2 = 45°C$; $K = 273 + °C$
Unknown: P_2

$$P_2 = \frac{P_1T_2}{T_1} = \frac{107 \text{ kPa} \times (273 + 45) \text{ K}}{(273 + 22) \text{ K}} = \frac{107 \text{ kPa} \times 318 \text{ K}}{295 \text{ K}} = 115 \text{ kPa}$$

---

248. a. Given: $P_1 = 99.3$ kPa; $V_1 = 225$ mL; $T_1 = 15°C$; $P_2 = 102.8$ kPa; $T_2 = 24°C$
Unknown: V_2

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{99.3 \text{ kPa} \times 225 \text{ mL} \times (273 + 24) \text{ K}}{(273 + 15) \text{ K} \times 102.8 \text{ kPa}} = 224 \text{ mL}$$

b. Given: $P_1 = 0.959$ atm; $V_1 = 3.50$ L; $T_1 = 45°C$; $V_2 = 3.70$ L; $T_2 = 37°C$
Unknown: P_2

$$P_2 = \frac{P_1V_1T_2}{T_1V_2} = \frac{0.959 \text{ atm} \times 3.50 \text{ L} \times (273 + 37) \text{ K}}{(273 + 45) \text{ K} \times 3.70 \text{ L}} = 0.884 \text{ atm}$$

c. Given: $P_1 = 0.0036$ atm; $V_1 = 62$ mL; $T_1 = 373$ K; $P_2 = 0.0029$ atm; $V_2 = 64$ mL
Unknown: T_2

$$T_2 = \frac{T_1P_2V_2}{P_1V_1} = \frac{373 \text{ K} \times 0.0029 \text{ atm} \times 64 \text{ mL}}{0.0036 \text{ atm} \times 62 \text{ mL}} = 310 \text{ K}$$

d. Given: P_1 = 100. kPa; V_1 = 43.2 mL; T_1 = 19°C; P_2 = 101.3 kPa; T_2 = 0°C

Unknown: V_2

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{100.\text{ kPa} \times 43.2\text{ mL} \times (273 + 0)\text{ K}}{(273 + 19)\text{ K} \times 101.3\text{ kPa}} = 39.9\text{ mL}$$

249. Given: V_1 = 450. mL; P_1 = 100. kPa; T_1 = 17°C; T_2 = 0°C; P_2 = 101.3 kPa

Unknown: V_2

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{100.\text{ kPa} \times 450.\text{ mL} \times (273 + 0)\text{ K}}{(273 + 17)\text{ K} \times 101.3\text{ kPa}} = 418\text{ mL}$$

250. Given: T = 27°C; H_2S gas: P_T = 207.33 kPa; V = 15 mL

Unknown: P_{H_2O}; P_{H_2S}

Per Table A-8: P_{H_2O} = 3.57 kPa

$P_{H_2S} = P_T - P_{H_2O}$ = 207.33 kPa – 3.57 kPa = 203.76 kPa

251. Given: T = 10°C; P_T = 105.5 kPa; V = 1.93 L;

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Unknown: V_{H_2} at STP

Per Table A-8: P_{H_2O} = 1.23 kPa

$P_{H_2} = P_T - P_{H_2O}$ = 105.5 kPa – 1.23 kPa = 104.3 kPa

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{104.3\text{ kPa} \times 1.93\text{ L} \times (273 + 0)\text{ K}}{(273 + 10)\text{ K} \times 101.3\text{ kPa}} = 1.92\text{ L}$$

252. Given: V_1 = 338 mL CH_4 at T_1 = 19°C, P_1 = 0.9566 atm; T_2 = 26°C, P_2 = 0.989

Unknown: V_2 of CH_4

$P_{1(H_2O)}$ = 2.19 kPa; $P_{2(H_2O)}$ = 3.36 kPa

$$P_{1(CH_4)} = 0.9566\text{ atm} - \left(2.19\text{ kPa} \times \frac{1\text{ atm}}{101.3\text{ kPa}}\right) = 0.935\text{ atm}$$

$$P_{2(CH_4)} = 0.989\text{ atm} - \left(3.36\text{ kPa} \times \frac{1\text{ atm}}{101.3\text{ kPa}}\right) = 0.956\text{ atm}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{0.935\text{ atm} \times 338\text{ mL} \times (273 + 26)\text{ K}}{(273 + 19)\text{ K} \times 0.956\text{ atm}} = 339\text{ mL}$$

$V_2 > V_1$; Student 2 collected more.

253. T is constant; $P_1V_1 = P_2V_2$

a. Given: P_1 = 127.3 kPa; V_1 = 796 cm^3; V_2 = 965 cm^3

Unknown: P_2

$$P_2 = \frac{P_1V_1}{V_2} = \frac{127.3\text{ kPa} \times 796\text{ cm}^3}{965\text{ cm}^3} = 105\text{ kPa}$$

b. Given: $P_1 = 7.1 \times 10^2$ atm; $P_2 = 9.6 \times 10^{-1}$ atm; $V_2 = 3.7 \times 10^3$ mL

Unknown: V_1

$$V_1 = \frac{P_2V_2}{P_1} = \frac{9.6 \times 10^{-1} \text{ atm} \times 3.7 \times 10^3 \text{ mL}}{7.1 \times 10^2 \text{ atm}} = 5.0 \text{ mL}$$

c. Given: $V_1 = 1.77$ L; $P_2 = 30.79$ kPa; $V_2 = 2.44$ L

Unknown: P_1

$$P_1 = \frac{P_2V_2}{V_1} = \frac{30.79 \text{ kPa} \times 2.44 \text{ L}}{1.77 \text{ L}} = 42.4 \text{ kPa}$$

d. Given: $P_1 = 114$ kPa; $V_1 = 2.93$ dm^3; $P_2 = 4.93 \times 10^4$ kPa

Unknown: V_2

$$V_2 = \frac{P_1V_1}{P_2} = \frac{114 \text{ kPa} \times 2.93 \text{ dm}^3}{4.93 \times 10^4 \text{ kPa}} = 6.78 \times 10^{-3} \text{ dm}^3$$

e. Given: $P_1 = 1.00$ atm; $V_1 = 120.$ mL; $V_2 = 97.0$ mL

Unknown: P_2

$$P_2 = \frac{P_1V_1}{V_2} = \frac{1.00 \text{ atm} \times 120. \text{ mL}}{97.0 \text{ mL}} = 1.24 \text{ atm}$$

f. Given: $P_1 = 0.77$ atm; $V_2 = 3.6$ m^3; $P_2 = 1.90$ atm

Unknown: V_2

$$V_2 = \frac{P_1V_1}{P_2} = \frac{0.77 \text{ atm} \times 3.6 \text{ m}^3}{1.90 \text{ atm}} = 1.5 \text{ m}^3$$

---

254. Given: $V_1 = 0.722$ m^3; $P_1 = 10.6$ atm; $P_2 = 0.96$ atm; $P_1V_1 = P_2V_2$

Unknown: V_2

$$V_2 = \frac{P_1V_1}{P_2} = \frac{10.6 \text{ atm} \times 0.722 \text{ m}^3}{0.96 \text{ atm}} = 8.0 \text{ m}^3$$

---

255. Given: $V_1 = 7.50 \times 10^3$ L; $V_2 = 195$ L; $P_2 = 0.993$ atm; $P_1V_1 = P_2V_2$

Unknown: P_1

$$P_1 = \frac{P_2V_2}{V_1} = \frac{0.993 \text{ atm} \times 195 \text{ L}}{7.50 \times 10^3 \text{ L}} = 0.0258 \text{ atm}$$

---

256. Given: $V_1 = 5.70 \times 10^{-1}$ dm^3; $P_1 = 1.05$ atm; $P_2 = 7.47$ atm; $P_1V_1 = P_2V_2$

Unknown: V_2

$$V_2 = \frac{P_1V_1}{P_2} = \frac{1.05 \text{ atm} \times 5.70 \times 10^{-1} \text{ dm}^3}{7.47 \text{ atm}} = 8.01 \times 10^{-2} \text{ dm}^3$$

257. P is constant; $\frac{V_1}{T_1} = \frac{V_2}{T_2}$;
K = 273 + °C

a. Given: V_1 = 26.5 mL; V_2 = 32.9 mL; T_2 = 290. K
Unknown: T_1

$$T_1 = \frac{T_2V_1}{V_2} = \frac{290.\ \text{K} \times 26.5\ \text{mL}}{32.9\ \text{mL}} = 234\ \text{K}$$

b. Given: T_1 = 100°C; V_2 = 0.83 dm^3; T_2 = 29°C
Unknown: V_1

$$V_1 = \frac{T_1V_2}{T_2} = \frac{(273 + 100)\ \text{K} \times 0.83\ \text{dm}^3}{(273 + 29)\ \text{K}} = 1.0\ \text{dm}^3$$

c. Given: $V_1 = 7.44 \times 10^4\ \text{mm}^3$; T_1 = 870°C; $V_2 = 2.59 \times 10^2\ \text{mm}^3$
Unknown: T_2 in °C

$$T_2 = \frac{T_1V_2}{V_1} = \frac{(870. + 273)\ \text{K} \times 2.59 \times 10^2\ \text{mm}^3}{7.44 \times 10^4\ \text{mm}^3} = 3.98\ \text{K}$$

3.98 K – 273.15 = –269.17°C

d. Given: $V_1 = 5.63 \times 10^{-2}$ L; T_1 = 132 K; T_2 = 190. K
Unknown: V_2

$$V_2 = \frac{V_1T_2}{T_1} = \frac{5.63 \times 10^{-2}\ \text{L} \times 190.\ \text{K}}{132\ \text{K}} = 8.10 \times 10^{-2}\ \text{L}$$

e. Given: T_1 = 243 K; V_2 = 819 cm^3; T_2 = 409 K
Unknown: V_1

$$V_1 = \frac{V_2T_1}{T_2} = \frac{819\ \text{cm}^3 \times 243\ \text{K}}{409\ \text{K}} = 487\ \text{cm}^3$$

f. Given: V_1 = 679 m^3; T_1 = –3°C; T_2 = –246°C
Unknown: V_2

$$V_2 = \frac{V_1T_2}{T_1} = \frac{679\ \text{m}^3 \times (273 - 246)\ \text{K}}{(273 - 3)\ \text{K}} = 67.9\ \text{m}^3$$

---

258. Given: V_1 = 1.15 cm^3; T_1 = 22°C; T_2 = 99°C; $\frac{V_1}{T_1} = \frac{V_2}{T_2}$; K = 273 + °C
Unknown: V_2

$$V_2 = \frac{V_1T_2}{T_1} = \frac{1.15\ \text{cm}^3 \times (273 + 99)\ \text{K}}{(273 + 22)\ \text{K}} = 1.45\ \text{cm}^3$$

---

259. Given: V_1 = 6.75 dm^3; T_1 = 40.°C; V_2 = 5.03 dm^3; $\frac{V_1}{T_1} = \frac{V_2}{T_2}$; K = 273 + °C
Unknown: T_2

$$T_2 = \frac{V_2T_1}{V_1} = \frac{5.03\ \text{dm}^3 \times (273 + 40.)\ \text{K}}{6.75\ \text{dm}^3} = 233\ \text{K}$$

233 K – 273 = –40.°C

260. V is constant; $\frac{P_1}{T_1} = \frac{P_2}{T_2}$; K = 273 + °C

a. Given: $P_1 = 0.777$ atm; $P_2 = 5.6$ atm; $T_2 = 192°C$

Unknown: T_1 in °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 K – 273 = –208°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: $T_1 = -76°C$; $P_2 = 3.97$ atm; $T_2 = 27°C$

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; $T_1 = 46°C$; $P_2 = 706$ atm

Unknown: T_2 in °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. K – 273 = 297°C

e. Given: $T_1 = -37°C$; $P_2 = 350.$ atm; $T_2 = 2050°C$

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: $T_1 = 22°C$; $P_1 = 0.982$ atm; $T_2 = -3°C$; $\frac{P_1}{T_1} = \frac{P_2}{T_2}$; K = 273 + °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; $T_1 = 33°C$; $T_2 = 0°C$; $\frac{P_1}{T_1} = \frac{P_2}{T_2}$; K = 273 + °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. $\frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$; $\quad V_2 = \frac{V_1P_1T_2}{T_1P_2} = \frac{1.65\ \text{L} \times 1.03\ \text{atm} \times (273 + 46)\ \text{K}}{(273 + 19)\ \text{K} \times 0.920\ \text{atm}} = 2.02\ \text{L}$

K = 273 + °C

a. Given: P_1 = 1.03 atm;
V_1 = 1.65 L;
T_1 = 19°C;
P_2 = 0.920 atm;
T_2 = 46°C

Unknown: V_2

b. Given: P_1 = 107.0 kPa;
V_1 = 3.79 dm^3;
T_1 = 73°C;
V_2 = 7.58 dm^3;
T_2 = 217°C

Unknown: P_2

$$P_2 = \frac{V_1P_1T_2}{T_1V_2} = \frac{3.79\ \text{dm}^3 \times 107.0\ \text{kPa} \times (273 + 217)\ \text{K}}{(273 + 73)\ \text{K} \times 7.58\ \text{dm}^3} = 75.8\ \text{kPa}$$

c. Given: P_1 = 0.029 atm;
V_1 = 249 mL;
P_2 = 0.098 atm;
V_2 = 197 mL;
T_2 = 293 K

Unknown: T_1

$$T_1 = \frac{V_1P_1T_2}{V_2P_2} = \frac{249\ \text{mL} \times 0.029\ \text{atm} \times 293\ \text{K}}{197\ \text{mL} \times 0.098\ \text{atm}} = 110\ \text{K}$$

d. Given: P_1 = 113 kPa;
T_1 = 12°C;
P_2 = 149 kPa;
V_2 = 3.18 × 10^3 mm^3;
T_2 = –18°C

Unknown: V_1

$$V_1 = \frac{V_2P_2T_1}{T_2P_1} = \frac{3.18 \times 10^3\ \text{mm}^3 \times 149\ \text{kPa} \times (273 + 12)\ \text{K}}{(273 - 18)\ \text{K} \times 113\ \text{kPa}}$$

$$= 4.69 \times 10^3\ \text{mm}^3$$

e. Given: P_1 = 1.15 atm;
V_1 = 0.93 m^3;
T_1 = –22°C;
P_2 = 1.01 atm;
V_2 = 0.85 m^3

Unknown: T_2

$$T_2 = \frac{V_2P_2T_1}{V_1P_1} = \frac{0.85\ \text{m}^3 \times 1.01\ \text{atm} \times (273 - 22)\ \text{K}}{0.93\ \text{m}^3 \times 1.15\ \text{atm}} = 210\ \text{K}$$

201 K – 273 = –72°C

f. Given: V_1 = 156 cm^3;
T_1 = 195 K;
P_2 = 2.25 atm;
V_2 = 468 cm^3;
T_2 = 585 K

Unknown: P_1

$$P_1 = \frac{V_2P_2T_1}{T_2V_1} = \frac{468\ \text{cm}^3 \times 2.25\ \text{atm} \times 195\ \text{K}}{585\ \text{K} \times 156\ \text{cm}^3} = 2.25\ \text{atm}$$

---

265. Given: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$;
K = 273 + °C;
V_1 = 392 cm^3;
P_1 = 0.987 atm;
T_1 = 21°C;
T_2 = 13°C;
P_2 = 0.992 atm

Unknown: V_2

$$V_2 = \frac{V_1P_1T_2}{T_1P_2} = \frac{392\ \text{cm}^3 \times 0.987\ \text{atm} \times (273 + 13)\ \text{K}}{(273 + 21)\ \text{K} \times 0.992\ \text{atm}} = 379\ \text{cm}^3$$

266. Given: $P_T = 0.989$ atm; $T = 17°C$

Unknown: P_{H_2}

from Table A-8: $P_{H_2O} = 1.94 \text{ kPa} \times \dfrac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.0192 \text{ atm}$

$P_{H_2} = P_T - P_{H_2O} = 0.989 \text{ atm} - 0.0192 \text{ atm} = 0.970 \text{ atm or } 98.3 \text{ kPa}$

---

267. Given: $P_1 = 1.77$ atm; $V_1 = 1.00$ L; $V_2 = 1.50$ L; $P_2 = 0.487$ 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: $T_1 = 10.°C$; $P_T = 1.02$ atm; $V_1 = 293$ mL; $\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2}$; $P_2 = 1.00$ atm; $T_2 = 0°C$; K = 273

Unknown: V_{O_2} at STP (V_2)

From Table A-8: $P_{H_2O} = 1.23 \text{ kPa} \times \dfrac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.0121 \text{ atm}$

$P_{O_2} = P_T - P_{H_2O} = 1.02 \text{ atm} - 0.0121 \text{ atm} = 1.01 \text{ atm} = P_1$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.01 \text{ atm} \times 293 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 10) \text{ K} \times 1.00 \text{ atm}} = 285 \text{ mL}$$

---

269. Given: $P_1 = 101.3$ kPa; $T_1 = 20°C$; $V_1 = 325 \text{ cm}^3$; $P_2 = 76.24$ kPa; $T_2 = 10°C$; gases are air over water; K = 273 + °C; $P_T = P_{air} + P_{H_2O}$; $P_{H_2O(20°C)} = 2.34$ kPa; $P_{H_2O(10°C)} = 1.23$ kPa

Unknown: V_2; V of water lost

$P_{A_1} = P_1 - P_{H_2O(20°C)} = 101.3 \text{ kPa} - 2.34 \text{ kPa} = 99.0 \text{ kPa}$

In sealed bottle on mountain: $P_{A_2} = P_{A_1} + P_{H_2O(10°C)}$

$= 99.0 \text{ kPa} + 1.23 \text{ kPa} = 100.2 \text{ kPa}$

$$V_2 = \frac{P_{A_2}V_1T_2}{T_1P_2} = \frac{100.2 \text{ kPa} \times 325 \text{ cm}^3 \times (273 + 10) \text{ K}}{(273 + 20) \text{ K} \times 76.24 \text{ kPa}} = 413 \text{ cm}^3$$

$V_{H_2O} = 413 \text{ cm}^3 - 325 \text{ cm}^3 = 88 \text{ cm}^3 \ H_2O$

---

270. Given: 1°C change in T produces a change of 0.20 cm^3 in V; $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$; K = 273 + °C

Unknown: V at 20.°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: $V_1 = 62.25$ mL; $T = 22°C$; $P_T = 97.7$ kPa; $V_2 = 50.00$ mL; $P_{H_2O} = 2.64$ kPa

Unknown: P_2

$P_{N_2} = P_T - P_{H_2O} = 97.7 \text{ kPa} - 2.64 \text{ kPa} = 95.1 \text{ kPa}$

$$P_2 = \frac{P_{N_2}V_1}{V_2} = \frac{95.1 \text{ kPa} \times 62.25 \text{ mL}}{50.00 \text{ mL}} = 118 \text{ kPa}$$

272. Given: $V_1 = 844$ mL;
$T_1 = 0.00°C$;
$P_1 = 1.000$ atm;
$P_T = 1.017$ atm;
$P_{H_2O} = 3.17$ kPa;
$T_2 = 25°C$;
$P_T = 1.017$ atm;
$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$;
K = 273 + °C

Unknown: V_2; V_T at 25°C and 1.017 atm

$$P_2 = P_{NF_3} = P_T - P_{H_2O} = 1.017 \text{ atm} - 3.17 \text{ kPa}\left(\frac{1 \text{ atm}}{101.3 \text{ kPa}}\right) = 0.9857 \text{ atm}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.000 \text{ atm} \times 844 \text{ mL} \times (273 + 25) \text{ K}}{(273 + 0) \text{ K} \times 0.9857 \text{ atm}} = 935 \text{ mL}$$

273. Given: $V_1 = 2.94$ kL;
$P_1 = 1.06$ atm;
$T_1 = 32°C$;
$P_2 = 0.092$ atm;
$T_2 = -35°C$;
$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$;
K = 273 + °C

Unknown: V_2

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.06 \text{ atm} \times 2.94 \text{ kL} \times (273 - 35) \text{ K}}{(273 + 32) \text{ K} \times 0.092 \text{ atm}} = 26.4 \text{ kL}$$

274. Given: $P_1 = 2.96$ atm;
$T_1 = 17°C$;
$T_2 = 95°C$;
$\frac{P_1}{T_1} = \frac{P_2}{T_2}$;
K = 273 + °C

Unknown: P_2

$$P_2 = \frac{P_1T_2}{T_1} = \frac{2.96 \text{ atm} \times (273 + 95) \text{ K}}{(273 + 17) \text{ K}} = 3.76 \text{ atm}$$

275. Given: $T_1 = 39°C$;
$V_2 = 108$ mL;
$T_2 = 21°C$;
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$;
K = 273 + °C

Unknown: V_1

$$V_1 = \frac{V_2T_1}{T_2} = \frac{108 \text{ mL} \times (273 + 39) \text{ K}}{(273 + 21) \text{ K}} = 115 \text{ mL}$$

276. Given: $V_1 = 624$ L;
$P_1 = 1.40$ atm;
$V_2 = 80.0$ L;
$P_1V_1 = P_2V_2$

Unknown: P_2

$$P_2 = \frac{P_1V_1}{V_2} = \frac{1.40 \text{ atm} \times 624 \text{ L}}{80.0 \text{ L}} = 10.9 \text{ atm}$$

277. a. Given: $P = 1.09$ atm;
$n = 0.0881$ mol;
$T = 302$ K

Unknown: V in L

$$V = \frac{nRT}{P} = \frac{0.0881 \text{ mol} \bullet 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times 302 \text{ K}}{1.09 \text{ atm}} = 2.00 \text{ L}$$

b. Given: $P = 94.9$ kPa;
$V = 0.0350$ L;
$T = 55°C$

Unknown: n

$$n = \frac{PV}{RT} = \frac{94.9 \text{ kPa} \times 0.0350 \text{ L}}{8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 55) \text{ K}} = 1.22 \times 10^{-3} \text{ mol}$$

c. Given: $V = 15.7$ L; $n = 0.815$ mol; $T = -20.°C$
Unknown: P in kPa

$$P = \frac{nRT}{V} = \frac{0.815 \text{ mol} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 - 20) \text{ K}}{15.7 \text{ L}} = 109 \text{ kPa}$$

d. Given: $P = 0.500$ atm; $V = 629$ mL; $n = 0.0337$ mol
Unknown: T in K

$$T = \frac{PV}{nR} = \frac{0.500 \text{ atm} \times 629 \text{ mL} \times 1 \text{ L}}{0.0337 \text{ mol} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times 1000 \text{ mL}} = 114 \text{ K}$$

e. Given: $P = 0.950$ atm; $n = 0.0818$ mol; $T = 19°C$
Unknown: V in L

$$V = \frac{nRT}{P} = \frac{0.0818 \text{ mol} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 19) \text{ K}}{0.950 \text{ atm}} = 2.06 \text{ L}$$

f. Given: $P = 107$ kPa; $V = 39.0$ mL; $T = 27°C$
Unknown: n

$$n = \frac{PV}{RT} = \frac{107 \text{ kPa} \times 39.0 \text{ mL} \times 1 \text{ L}}{8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 27) \text{ K} \times 1000 \text{ mL}} = 1.67 \times 10^{-3} \text{ mol}$$

---

278. Given: $V = 425$ mL; $T = 24°C$, $P = 0.899$ atm
Unknown: n

$$n = \frac{PV}{RT} = \frac{0.899 \text{ atm} \times 425 \text{ mL} \times 1 \text{ L}}{0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 24) \text{ K} \times 1000 \text{ mL}} = 1.57 \times 10^{-2} \text{ mol}$$

---

279. Given: $m = 0.116$ g; $V = 25.0$ mL; $T = 127°C$; $P = 155.3$ kPa; $PV = \frac{mRT}{M}$
Unknown: M

$$M = \frac{mRT}{PV} = \frac{0.116 \text{ g} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 127) \text{ K} \times 1000 \text{ mL}}{155.3 \text{ kPa} \times 25.0 \text{ mL} \times 1 \text{ L}} = 99.4 \text{ g/mol}$$

---

280. Given: CO_2 gas; $V = 7.10$ L; $P = 1.11$ atm; $T = 31°C$; $PV = \frac{mRT}{M}$
Unknown: m

$M = 1$ atom C $\times$ 12.01 amu/atom + 2 atoms O $\times$ 16.00 amu/atom = 44.01 amu; $M = 44.01$ g/mol

$$m = \frac{MPV}{RT} = \frac{44.01 \text{ g/mol} \times 1.11 \text{ atm} \times 7.10 \text{ L}}{0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 31) \text{ K}} = 13.9 \text{ g}$$

---

281. Given: $T = 72°C$; $P = 144.5$ kPa; SiF_4 gas; $D = \frac{MP}{RT}$
Unknown: D

$$D = \frac{MP}{RT} = \frac{104.09 \text{ g/mol} \times 144.5 \text{ kPa}}{8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 72) \text{ K}} = 5.24 \text{ g/L}$$

---

282. Given: $D = 1.13$ g/L; $P = 1.09$ atm; N_2 gas; $D = \frac{MP}{RT}$
Unknown: T

$$T = \frac{MP}{DR} = \frac{28.02 \text{ g/mol} \times 1.09 \text{ atm}}{1.13 \text{ g/L} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}}} = 329 \text{ K}$$

283. a. Given: $P = 0.0477$ atm; $V = 15\ 200$ L; $T = -15°C$

Unknown: n

$$n = \frac{PV}{RT} = \frac{0.0477 \text{ atm} \times 15\ 200 \text{ L}}{0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 - 15) \text{ K}} = 34.2 \text{ mol}$$

b. Given: $V = 0.119$ mL; $n = 0.000\ 350$ mol; $T = 0°C$

Unknown: P in kPa

$$P = \frac{nRT}{V} = \frac{0.000\ 350 \text{ mol} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 0) \text{ K} \times 1000 \text{ mL}}{0.119 \text{ mL} \times 1 \text{ L}}$$

$$= 6.68 \times 10^3 \text{ kPa}$$

c. Given: $P = 500.0$ kPa; $V = 250.$ mL; $n = 0.120$ mol

Unknown: T in °C

$$T = \frac{PV}{nR} = \frac{500.0 \text{ kPa} \times 250. \text{ mL} \times 1 \text{ L}}{0.120 \text{ mol} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times 1000 \text{ mL}} = 125 \text{ K}$$

$$125 \text{ K} - 273 = -148°\text{C}$$

d. Given: $P = 19.5$ atm; $n = 4.7 \times 10^4$ mol; $T = 300.$ °C

Unknown: V

$$V = \frac{nRT}{P} = \frac{4.7 \times 10^4 \text{ mol} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 300) \text{ K}}{19.5 \text{ atm}} = 1.1 \times 10^5 \text{ L}$$

---

284. Given: $PV = \frac{mRT}{M}$

a. Given: $P = 0.955$ atm; $V = 3.77$ L; $m = 8.23$ g; $T = 25°C$

Unknown: M

$$M = \frac{mRT}{PV} = \frac{8.23 \text{ g} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 25) \text{ K}}{0.955 \text{ atm} \times 3.77 \text{ L}} = 55.9 \text{ g/mol}$$

b. Given: $P = 105.0$ kPa; $V = 50.0$ mL; $M = 48.02$ g/mol; $T = 0°C$

Unknown: m

$$m = \frac{PVM}{RT} = \frac{105.0 \text{ kPa} \times 50.0 \text{ mL} \times 48.02 \text{ g/mol} \times 1 \text{ L}}{8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 0) \text{ K} \times 1000 \text{ mL}} = 0.111 \text{ g}$$

c. Given: $P = 0.782$ atm; $m = 3.20 \times 10^{-3}$ g; $M = 2.02$ g/mol; $T = -5°C$

Unknown: V in L

$$V = \frac{mRT}{PM} = \frac{3.20 \times 10^{-3} \text{ g} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 - 5) \text{ K}}{0.782 \text{ atm} \times 2.02 \text{ g/mol}} = 4.46 \times 10^{-2} \text{ L}$$

d. Given: $V = 2.00$ L; $m = 7.19$ g; $M = 159.8$ g/mol; $T = 185°C$

Unknown: P in atm

$$P = \frac{mRT}{MV} = \frac{7.19 \text{ g} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 185) \text{ K}}{159.8 \text{ g/mol} \times 2.00 \text{ L}} = 0.846 \text{ atm}$$

e. Given: $P = 107.2$ kPa; $V = 26.1$ mL; $m = 0.414$ g; $T = 45°C$
Unknown: M

$$M = \frac{mRT}{PV} = \frac{0.414 \text{ g} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 45) \text{ K} \times 1000 \text{ mL}}{107.2 \text{ kPa} \times 26.1 \text{ mL} \times 1 \text{ L}}$$
$$= 391 \text{ g/mol}$$

---

285. Given: $n = 1.00$ mol; $T = 25°C$; $P = 0.915$ kPa
Unknown: V

$$V = \frac{nRT}{P} = \frac{1.00 \text{ mol} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 25) \text{ K}}{0.915 \text{ kPa}} = 2.71 \times 10^3 \text{ L}$$

---

286. $D = \frac{MP}{RT}$

a. Given: $P = 1.12$ atm; $D = 2.40$ g/L; $T = 2°C$
Unknown: M

$$M = \frac{DRT}{P} = \frac{2.40 \text{ g/L} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 2) \text{ K}}{1.12 \text{ atm}} = 48.4 \text{ g/mol}$$

b. Given: $P = 7.50$ atm; $M = 30.07$ g/mol; $T = 20.°C$
Unknown: D in g/L

$$D = \frac{30.07 \text{ g/mol} \times 7.50 \text{ atm}}{0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 20.) \text{ K}} = 9.38 \text{ g/L}$$

c. Given: $P = 97.4$ kPa; $M = 104.09$ g/mol; $D = 4.37$ g/L
Unknown: T in °C

$$T = \frac{MP}{DR} = \frac{104.09 \text{ g/mol} \times 97.4 \text{ kPa}}{4.37 \text{ g/L} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}}} = 279 \text{ K}$$

279 K – 273 = 6°C

d. Given: $M = 77.95$ g/mol; $D = 6.27$ g/L; $T = 66°C$
Unknown: P in atm

$$P = \frac{DRT}{M} = \frac{6.27 \text{ g/L} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 66) \text{ K}}{77.95 \text{ g/mol}} = 2.24 \text{ atm}$$

---

287. Given: $m = 1.36$ kg; N_2O gas; $V = 25.0$ L; $T = 59°C$
Unknown: P in atm

$$P = \frac{mRT}{MV} = \frac{1.36 \text{ kg} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 59) \text{ K} \times 1000 \text{ g}}{44.02 \text{ g/mol} \times 25.0 \text{ L} \times 1 \text{ kg}} = 33.7 \text{ atm}$$

---

288. Given: $AlCl_3$ vapor; $T = 225°C$; $P = 0.939$ atm
Unknown: D

$$D = \frac{MP}{RT} = \frac{133.33 \text{ g/mol} \times 0.939 \text{ atm}}{0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 225) \text{ K}} = 3.06 \text{ g/L}$$

---

289. Given: $D = 0.0262$ g/mL; $P = 0.918$ atm; $T = 10.°C$
Unknown: M

$$M = \frac{DRT}{P} = \frac{0.0262 \text{ g/mL} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 10) \text{ K} \times 1000 \text{ mL}}{0.918 \text{ atm} \times 1 \text{ L}}$$
$$= 663 \text{ g/mol}$$

290. Given: $m = 11.7\text{g}$; He gas; $P = 0.262$ atm; $T = -50.°\text{C}$

Unknown: V

$$V = \frac{mRT}{MP} = \frac{11.9\text{ g} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 - 50)\text{ K}}{4.00\text{ g/mol} \times 0.262\text{ atm}} = 208\text{ L}$$

291. Given: $T = 15°\text{C}$; $P_{H_2O} = 1.5988$ kPa; $P_T = 100.0$ kPa; C_2H_6 gas; $V = 245$ mL

Unknown: n

$$P_{C_2H_6} = P_T - P_{H_2O} = 100.0\text{ kPa} - 1.5988\text{ kPa} = 98.4\text{ kPa}$$

$$n = \frac{PV}{RT} = \frac{98.4\text{ kPa} \times 245\text{ mL} \times 1\text{ L}}{8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 15)\text{ K} \times 1000\text{ mL}} = 0.0101\text{ mol}$$

292. Given: $V = 3.75$ L; NO gas; $T = 19°\text{C}$; $P = 1.10$ atm

Unknown: m

$$m = \frac{MPV}{RT} = \frac{30.01\text{ g/mol} \times 1.10\text{ atm} \times 3.75\text{ L}}{0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 19)\text{ K}} = 5.16\text{ g}$$

293. Given: theoretical yield $NH_3 = 8.83$ g; actual yield NH_3 10.24 L; $T_1 = 52°\text{C}$; $P_1 = 105.3$ kPa; 1 mole gas at STP = 22.4 L; STP = 0°C, 101.3 kPa

Unknown: percent yield

$$V_{STP} = \frac{P_1V_1T_{STP}}{T_1P_{STP}} = \frac{105.3\text{ kPa} \times 10.24\text{ L} \times (273 + 0)\text{ K}}{(273 + 52)\text{ K} \times 101.3\text{ kPa}} = 8.94\text{ L}$$

$$8.94\text{ L} \times \frac{1\text{ mol}}{22.4\text{ L}} \times \frac{17.04\text{ g}}{1\text{ mol}} = 6.80\text{ g actual yield}$$

$$\frac{6.80\text{ g}}{8.83\text{ g}} \times 100 = 77.0\%\text{ yield}$$

294. Given: $D = 0.405$ g/L; $P = 0.889$ atm; $T = 7°\text{C}$

Unknown: molar mass

$$M = \frac{DRT}{P} = \frac{0.405\text{ g/L} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 7)\text{ K}}{0.889\text{ atm}} = 10.5\text{ g/mol}$$

295. Given: $V = 90.0$ L; $P = 1780$ kPa; $T = 18°\text{C}$; mass empty tank = 39.2 kg ; mass tank + gas = 50.5 kg

Unknown: molar mass (M) of gas

$$m = 50.5\text{ kg} - 39.2\text{ kg} = 11.3\text{ kg}$$

$$M = \frac{mRT}{PV} = \frac{11.3\text{ kg} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 18)\text{ K} \times 1000\text{ g}}{1780\text{ kPa} \times 90.0\text{ L} \times 1\text{ kg}} = 171\text{ g/mol}$$

296. Given: $V = 1.20 \times 10^3$ L; $m = 12.0$ kg; HCl gas; $T = 18°\text{C}$

Unknown: P

$$P = \frac{mRT}{MV} = \frac{12.0\text{ kg} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 18)\text{ K} \times 1000\text{ g}}{36.46\text{ g/mol} \times 1.20 \times 10^3\text{ L} \times 1\text{ kg}} = 6.55\text{ atm}$$

297. Given: $T = 20.°\text{C}$; Ne gas; $D = 2.70$ g/L

Unknown: P in kPa

$$P = \frac{DRT}{M} = \frac{2.70\text{ g/L} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 20)\text{ K}}{20.18\text{ g/mol}} = 326\text{ kPa}$$

298. Given: $V = 658$ mL; $m = 1.50$ g; Ne gas; $P = 4.50 \times 10^2$ kPa

Unknown: T

$$T = \frac{MPV}{mR} = \frac{20.18 \text{ g/mol} \times 4.50 \times 10^2 \text{ kPa} \times 658 \text{ mL} \times 1 \text{ L}}{1.50 \text{ g} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times 1000 \text{ mL}} = 479 \text{ K}$$

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299. Given: $m = 1.00$ g; H_2 gas; $P = 6.75$ millibars; 1 bar = 100 kPa = 0.9869 atm; $T_1 = -75°C$; $T_2 = -8°C$

Unknown : V at T_1 and T_2

$$V = \frac{TmR}{MP} = \frac{(273 - 75) \text{ K} \times 1.00 \text{ g} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}}}{2.02 \text{ g/mol} \times 0.675 \text{ kPa}} = 1210 \text{ L at } -75°\text{C}$$

$$V = \frac{TmR}{MP} = \frac{(273 - 8) \text{ K} \times 1.00 \text{ g} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}}}{2.02 \text{ g/mol} \times 0.675 \text{ kPa}} = 1620 \text{ L at } -8°\text{C}$$

---

300. Given: $n = 3.95$ mol; $V = 850.$ mL; $T = 15°C$

Unknown: P in kPa

$$P = \frac{nRT}{V} = \frac{3.95 \text{ mol} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 15) \text{ K} \times 1000 \text{ mL}}{850. \text{ mL} \times 1 \text{ L}} = 1.11 \times 10^4 \text{ kPa}$$

---

301. Given: $n = 0.00660$ mol; $P = 0.907$ atm; $T = 9°C$

Unknown: V in mL

$$V = \frac{nRT}{P} = \frac{0.00660 \text{ mol} \times 0.0821 \frac{\text{L} \bullet \text{atm}}{\text{mol} \bullet \text{K}} \times (273 + 9) \text{ K} \times 1000 \text{ mL}}{0.907 \text{ atm} \times 1 \text{ L}} = 168 \text{ mL}$$

---

302. Given: $m = 8.47$ kg; SO_2 gas; $P = 89.4$ kPa; $T = 40.°C$

Unknown: V

$$V = \frac{mRT}{MP} = \frac{8.47 \text{ kg} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 40) \text{ K} \times 1000 \text{ g}}{64.07 \text{ g/mol} \times 89.4 \text{ kPa} \times 1 \text{ kg}} = 3.85 \times 10^3 \text{ L}$$

---

303. Given: $m = 908$ g; He gas; $P = 128.3$ kPa; $T = 2°C$

Unknown: V

$$V = \frac{mRT}{MP} = \frac{908 \text{ g} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 2) \text{ K}}{4.00 \text{ g/mol} \times 128.3 \text{ kPa}} = 4.05 \times 10^3 \text{ L}$$

---

304. Given: $D = 1.162$ g/L; $T = 27°C$; $P = 100.0$ kPa

Unknown: M

$$M = \frac{DRT}{P} = \frac{1.162 \text{ g/L} \times 8.314 \frac{\text{L} \bullet \text{kPa}}{\text{mol} \bullet \text{K}} \times (273 + 27) \text{ K}}{100.0 \text{ kPa}} = 29.0 \text{ g/mol}$$

---

305. Given: balanced equation; 2800 L NH_3

Unknown: V of NO; V of O_2

$$2800 \text{ L } NH_3 \times \frac{5 \text{ L } O_2}{4 \text{ L } NH_3} = 3500 \text{ L } O_2$$

$$2800 \text{ L } NH_3 \times \frac{4 \text{ L NO}}{4 \text{ L } NH_3} = 2800 \text{ L NO}$$

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306. Given: balanced equation; 3.60×10^4 mL F_2

Unknown: V of O_3: V of HF

$$3.60 \times 10^4 \text{ mL } F_2 \times \frac{1 \text{ mL } O_3}{3 \text{ mL } F_2} = 1.20 \times 10^4 \text{ mL } O_3$$

$$3.60 \times 10^4 \text{ mL } F_2 \times \frac{6 \text{ mL HF}}{3 \text{ mL } F_2} = 7.20 \times 10^4 \text{ mL HF}$$

307. Given: balanced equation; P_1 = 2.26 atm; T_1 = 40°C; V_1 = 55.8 mL
Unknown: V_{CO_2} produced at STP

$$V_2 \text{ (at STP)} = \frac{P_1V_1T_2}{T_1P_2} = \frac{2.26 \text{ atm} \times 55.8 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 40) \text{ K} \times 1.00 \text{ atm}} = 110. \text{ mL}$$

$$110. \text{ mL } O_2 \times \frac{2 \text{ mol } CO_2}{3 \text{ mol } O_2} = 73.3 \text{ mL } CO_2$$

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308. Given: reactants and products: V_1 (of N_2O_5 at STP) = 5.00 L; T_2 = 64.5°C; P_2 = 1.76 atm
Unknown: balanced equation; V_2 for N_2O_5; V of NO_2

$$2N_2O_5 \rightarrow 4NO_2 + O_2$$

$$V_2 = \frac{V_1P_1T_2}{T_1P_2} = \frac{5.00 \text{ L} \times 1.00 \text{ atm} \times (273 + 64.5) \text{ K}}{(273 + 0) \text{ K} \times 1.76 \text{ atm}} = 3.51 \text{ L } N_2O_5$$

$$3.51 \text{ L } N_2O_5 \times \frac{4 \text{ L } NO_2}{2 \text{ L } N_2O_5} = 7.02 \text{ } NO_2$$

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309. Given: balanced equation

a. Given: excess Al; STP; mass $AlCl_3$ = 7.15 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.°C; P = 0.945 atm
Unknown: V of Cl_2

$$1.559 \text{ kg Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{3 \text{ mol } Cl_2}{2 \text{ mol Al}} \times \frac{22.4 \text{ L } Cl_2}{1 \text{ mol } Cl_2} = 1940 \text{ L } Cl_2$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00 \text{ atm} \times 1940 \text{ L} \times (273 + 20) \text{ K}}{(273 + 0) \text{ K} \times 0.945 \text{ atm}} = 2.21 \times 10^3 \text{ L } Cl_2$$

d. Given: excess Al; 920. 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 mL Cl_2; T_1 = 37°C; P_1 = 5.00 atm
Unknown: mass Al in g

Find V at STP:

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{5.00 \text{ atm} \times 1.049 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 37) \text{ K} \times 1.00 \text{ atm}} = 4.62 \text{ mL}$$

$$4.62 \text{ mL } Cl_2 \times \frac{1 \text{ mol } Cl_2}{22\,400 \text{ mL } Cl_2} \times \frac{2 \text{ mol Al}}{3 \text{ mol } Cl_2} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}} = 3.71 \times 10^{-3} \text{ g Al}$$

f. Given: 500.00 kg Al; T_2 = 15°C; P_2 = 83.0 kPa
Unknown: V of Cl_2 in m^3

$$500.00 \text{ kg Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3 \text{ mol } Cl_2}{2 \text{ mol Al}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} \times \frac{1 \text{ m}^3}{1000 \text{ L}}$$

$$= 623 \text{ m}^3 \text{ } Cl_2 \text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{101.3 \text{ kPa} \times 623 \text{ m}^3 \times (273 + 15) \text{ K}}{(273 + 0) \text{ K} \times 83.0 \text{ kPa}} = 802 \text{ m}^3$$

310. a. Given: balanced equation; STP; 57.0 mL H_2
Unknown: V of N_2

$$57.0\text{ mL } H_2 \times \frac{1\text{ mL } N_2}{3\text{ mL } H_2} = 19.0\text{ mL } N_2$$

b. Given: balanced equation; STP; 6.39×10^4 L H_2
Unknown: V of NH_3

$$6.39 \times 10^4\text{ L } H_2 \times \frac{2\text{ L } NH_3}{3\text{ L } H_2} = 4.26 \times 10^4\text{ L } NH_3$$

c. Given: balanced equation; 20.0 mol N_2; STP
Unknown: V of NH_3

$$20.0\text{ mol } N_2 \times \frac{2\text{ mol } NH_3}{1\text{ mol } N_2} \times \frac{22.4\text{ L } NH_3}{1\text{ mol } NH_3} = 896\text{ L } NH_3$$

d. Given: balanced equation; V_1 = 800. L NH_3; T_1 = 55°C; P_1 = 0.900 atm
Unknown: V of H_2 at STP

V of NH_3 at STP =

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{0.900\text{ atm} \times 800.\text{ L } NH_3 \times (273 + 0)\text{ K}}{(273 + 55)\text{ K} \times 1.00\text{ atm}} = 599\text{ L } NH_3$$

$$599\text{ L } NH_3 \times \frac{3\text{ L } H_2}{2\text{ L } NH_3} = 899\text{ L } H_2$$

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311. a. Given: balanced equation; $V_{C_3H_8}$ = 3 L at STP; T_2 = 250.°C; P_2 = 1.00 atm
Unknown: V of H_2O

$$3.0\text{ L } C_3H_8 \times \frac{4\text{ L } H_2O}{1\text{ L } C_3H_8} = 12\text{ L } H_2O\text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00\text{ atm} \times 12\text{ L} \times (273 + 250)\text{ K}}{(273 + 0)\text{ K} \times 1.00\text{ atm}} = 23\text{ L}$$

b. Given: balanced equation; 640. L CO_2
Unknown: V of O_2

$$640.\text{ L } CO_2 \times \frac{5\text{ L } O_2}{3\text{ L } CO_2} = 1070\text{ L } O_2$$

c. Given: 465 mL O_2 at STP; balanced equation; T_2 = 37°C; P_2 = 0.973 atm
Unknown: V_2 of CO_2

$$465\text{ mL } O_2 \times \frac{3\text{ mL } CO_2}{5\text{ mL } O_2} = 279\text{ mL } CO_2\text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00\text{ atm} \times 279\text{ mL} \times (273 + 37)\text{ K}}{(273 + 0)\text{ K} \times 0.973\text{ atm}} = 326\text{ mL}$$

d. Given: 2.50 L of C_3H_8 at STP; balanced equation; T_2 = 175°C; P_2 = 1.14 atm
Unknown: V of products at T_2 and P_2 (V_2)

$$2.50\text{ L } C_3H_8 \times \frac{3\text{ L } CO_2}{1\text{ L } C_3H_8} = 7.50\text{ L } CO_2\text{ at STP}$$

$$2.50\text{ L } C_3H_8 \times \frac{4\text{ L } H_2O}{1\text{ L } C_3H_8} = 10.0\text{ L } H_2O$$

V_1 at STP = 750 L + 10.0 L = 17.5 L

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00\text{ atm} \times 17.5\text{ L} \times (273 + 175)\text{ K}}{(273 + 0)\text{ K} \times 1.14\text{ atm}} = 25.2\text{ L}$$

312. Given: balanced equation; V_1 = 3500. L CO; T_1 = 20.°C; P_1 = 0.953 atm

Unknown: V of O_2 at STP

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{0.953\text{ atm} \times 3500.\text{ L} \times (273 + 0)\text{ K}}{(273 + 20)\text{ K} \times 1.00\text{ atm}} = 3110\text{ L CO at STP}$$

$$V\text{ of }O_2 = 3110\text{ L CO} \times \frac{1\text{ L }O_2}{2\text{ L CO}} = 1550\text{ L }O_2$$

313. Given: balanced equation; V_1 = 1.00 L HF; P_1 = 3.48 atm; T_1 = 25°C; T_2 = 15°C; P_2 = 0.940 atm

Unknown: V of SiF_4 at V_2 and P_2

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{3.48\text{ atm} \times 1.00\text{ L} \times (273 + 15)\text{ K}}{(273 + 25)\text{ K} \times 0.940\text{ atm}} = 3.58\text{ L HF}$$

$$3.58\text{ L HF} \times \frac{1\text{ L }SiF_4}{4\text{ L HF}} = 0.894\text{ L }SiF_4$$

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.°C; P_1 = 1.00 atm

Unknown: mass Fe

Convert to STP:

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00\text{ atm} \times 500.\text{ L} \times (273 + 0)\text{ K}}{(273 + 250)\text{ K} \times 1.00\text{ atm}} = 261\text{ L}$$

$$261\text{ L }H_2O \times \frac{1\text{ mol}}{22.4\text{ L}} \times \frac{3\text{ mol Fe}}{4\text{ mol }H_2O} \times \frac{55.85\text{ g Fe}}{1\text{ mol Fe}} = 488\text{ g Fe}$$

c. Given: 285 g Fe_3O_4

Unknown: V of H_2 at 20.°C and 1.06 atm

$$285\text{ g }Fe_3O_4 \times \frac{1\text{ mol }Fe_3O_4}{231.55\text{ g }Fe_3O_4} \times \frac{4\text{ mol }H_2}{1\text{ mol }Fe_3O_4} \times \frac{22.4\text{ L}}{1\text{ mol}} = 110.\text{ L }H_2\text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00\text{ atm} \times 110.\text{ L} \times (273 + 20)\text{ K}}{(273 + 0)\text{ K} \times 1.06\text{ atm}} = 111\text{ L}$$

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°C; P_1 = 1.02 atm

Unknown: V of O_2 at STP; mass $C_4H_{10}O$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.02\text{ atm} \times 7.15\text{ L} \times (273 + 0)\text{ K}}{(273 + 125)\text{ K} \times 1.00\text{ atm}} = 5.00\text{ L }CO_2\text{ at STP}$$

$$5.00\text{ L }CO_2 \times \frac{6\text{ L }O_2}{4\text{ L }CO_2} = 7.50\text{ L }O_2$$

$$5.00\text{ L }CO_2 \times \frac{1\text{ mol}}{22.4\text{ L}} \times \frac{1\text{ mol }C_4H_{10}O}{4\text{ mol }CO_2} \times \frac{74.14\text{ g }C_4H_{10}O}{1\text{ mol }C_4H_{10}O} = 4.14\text{ g }C_4H_{10}O$$

317. Given: balanced equation

a. Given: 0.100 mol $C_3H_5N_3O_9$

Unknown: V of products at STP

$$0.100 \text{ mol } C_3H_5N_3O_9 \times \frac{6 \text{ mol } N_2}{4 \text{ mol } C_3H_5N_3O_9} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 3.36 \text{ L } N_2$$

$$0.100 \text{ mol } C_3H_5N_3O_9 \times \frac{12 \text{ mol } CO_2}{4 \text{ mol } C_3H_5N_3O_9} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 6.72 \text{ L } CO_2$$

$$0.100 \text{ mol } C_3H_5N_3O_9 \times \frac{10 \text{ mol } H_2O}{4 \text{ mol } C_3H_5N_3O_9} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 5.60 \text{ L } H_2O$$

$$0.100 \text{ mol } C_3H_5N_3O_9 \times \frac{1 \text{ mol } O_2}{4 \text{ mol } C_3H_5N_3O_9} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 0.560 \text{ L } O_2$$

b. Given: 10.0 g $C_3H_5N_3O_9$

Unknown: total V gases produced at 300.°C and 1.00 atm

V_T from **a** = 3.36 L + 6.72 L + 5.60 L + 0.560 L = 16.24 L

$$10.0 \text{ g } C_3H_5N_3O_9 \times \frac{1 \text{ mol } C_3H_5N_3O_9}{227.11 \text{ g } C_3H_5N_3O_9} \times \frac{16.24 \text{ L gases}}{0.100 \text{ mol } C_3H_5N_3O_9}$$

= 7.15 L gases at STP

$$V_2 = \frac{V_1P_1T_2}{T_1P_2} = \frac{7.15 \text{ L} \times 1.00 \text{ atm} \times (273 + 300) \text{ K}}{(273 + 0) \text{ K} \times 1.00 \text{ atm}} = 15.0 \text{ L gases}$$

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318. Given: balanced equation; 250. mL N_2O at STP

Unknown: mass NH_4NO_3

$$250. \text{ mL } N_2O \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{1 \text{ mol } NH_4NO_3}{1 \text{ mol } N_2O} \times \frac{80.06 \text{ g } NH_4NO_3}{1 \text{ mol } NH_4NO_3}$$

= 0.894 g NH_4NO_3

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319. Given: balanced equation; 8.46 g Ca_3P_2

Unknown: V of PH_3 at 18°C and 102.4 kPa

$$8.46 \text{ g } Ca_3P_2 \times \frac{1 \text{ mol } Ca_3P_2}{182.18 \text{ g } Ca_3P_2} \times \frac{2 \text{ mol } PH_3}{1 \text{ mol } C_3P_2} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 2.08 \text{ L } PH_3 \text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{101.3 \text{ kPa} \times 2.08 \text{ L} \times (273 + 18) \text{ K}}{(273 + 0) \text{ K} \times 102.4 \text{ kPa}} = 2.19 \text{ } PH_3$$

---

320. Given: balanced equation; 6.0×10^3 kg $AlCl_3$

Unknown: mass Al; V of HCl at 4.71 atm + 43°C

$$6.0 \times 10^3 \text{ kg } AlCl_3 \times \frac{1 \text{ mol } AlCl_3}{133.33 \text{ g } AlCl_3} \times \frac{2 \text{ mol Al}}{2 \text{ mol } AlCl_3} \times \frac{26.98 \text{ g Al}}{1 \text{ mol Al}}$$

$= 1.2 \times 10^3$ kg Al

$$6.0 \times 10^3 \text{ kg } AlCl_3 \times \frac{1 \text{ mol } AlCl_3}{133.33 \text{ g } AlCl_3} \times \frac{6 \text{ mol HCl}}{2 \text{ mol } AlCl_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}} \times \frac{1000 \text{ g}}{1 \text{ kg}}$$

$= 3.0 \times 10^6$ L HCl at STP

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00 \text{ atm} \times 3.0 \times 10^6 \text{ L} \times (273 + 43) \text{ K}}{(273 + 0) \text{ K} \times 4.71 \text{ atm}} = 7.4 \times 10^5 \text{ L HCl}$$

---

321. Given: balanced equation; actual yield = 8.50×10^4 kg $(NH_2)_2CO$; 89.5% yield

Unknown: V of NH_3

$$\text{theoretical yield } (NH_2)_2CO = 8.50 \times 10^4 \text{ kg } (NH_2)_2CO \times \frac{100\%}{89.5\%}$$

$= 9.50 \times 10^4$ kg $(NH_2)_2CO$

$$9.50 \times 10^4 \text{ kg } (NH_2)_2CO \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } (NH_2)_2CO}{60.07 \text{ g } (NH_2)_2CO} \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } (NH_2)_2CO}$$

$$\times \frac{22.4 \text{ L}}{1 \text{ mol}} = 7.08 \times 10^7 \text{ L } NH_3$$

322. Given: V_1 = 265 mL O_2; T_1 = 10.°C; P_1 = 0.975 atm; balanced equation

Unknown: mass of BaO_2

$$P_{O_2} = P_T - P_{H_2O} = 0.975 \text{ atm} - 1.23 \text{ kPa} \times \frac{1 \text{ atm}}{101.3 \text{ kPa}} = 0.963 \text{ atm}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{0.963 \text{ atm} \times 265 \text{ mL} \times (273 + 0) \text{ K}}{(273 + 10) \text{ K} \times 1.00 \text{ atm}} = 246 \text{ mL } O_2 \text{ at STP}$$

$$246 \text{ mL } O_2 \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{2 \text{ mol } BaO_2}{1 \text{ mol } O_2} \times \frac{169.33 \text{ g } BaO_2}{1 \text{ mol } BaO_2}$$

$$= 3.72 \text{ g } BaO_2$$

---

323. Given: balanced equation; 15.0 g $KMnO_4$

Unknown: V of Cl_2 at 15°C and 0.959 atm

$$15.0 \text{ g } KMnO_4 \times \frac{1 \text{ mol } KMnO_4}{158.04 \text{ g } KMnO_4} \times \frac{5 \text{ mol } Cl_2}{2 \text{ mol } KMnO_4} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$$

$$= 5.32 \text{ L } Cl_2 \text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00 \text{ atm} \times 5.32 \text{ L} \times (273 + 15) \text{ K}}{(273 + 0) \text{ K} \times 0.959 \text{ atm}} = 5.85 \text{ L } Cl_2$$

---

324. Given: balanced equations; 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 equation; 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 L CO_2

Unknown: V of NH_3 under the same conditions

$$38\,000 \text{ L } CO_2 \times \frac{1 \text{ L } NH_3}{1 \text{ L } CO_2} = 38\,000 \text{ L } NH_3$$

b. Given: 38 000 L CO_2 at 25°C and 1.00 atm

Unknown: mass of $NaHCO_3$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00 \text{ atm} \times 38\,000 \text{ L} \times (273 + 0) \text{ K}}{(273 + 25) \text{ K} \times 1.00 \text{ atm}}$$

$$= 34\,800 \text{ L } CO_2 \text{ at STP}$$

$$34\,800 \text{ L } CO_2 \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{1 \text{ mol } NaHCO_3}{1 \text{ mol } CO_2} \times \frac{84.01 \text{ g } NaHCO_3}{1 \text{ mol } NaHCO_3}$$

$$= 1.30 \times 10^5 \text{ g } NaHCO_3$$

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

$$100.00 \text{ kg } NaHCO_3 \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } NaHCO_3}{84.01 \text{ g } NaHCO_3} \times \frac{1 \text{ mol } CO_2}{1 \text{ mol } NaHCO_3} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$$

$$= 2.67 \times 10^4 \text{ L } CO_2 \text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00 \text{ atm} \times 2.67 \times 10^4 \text{ L} \times (273 + 42) \text{ K}}{(273 + 0) \text{ K} \times 5.50 \text{ atm}} = 5.60 \times 10^3 \text{ L } CO_2$$

---

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

$$4.74 \text{ g } C_4H_{10} \times \frac{1 \text{ mol } C_4H_{10}}{58.14 \text{ g } C_4H_{10}} \times \frac{8 \text{ mol } CO_2}{2 \text{ mol } C_4H_{10}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 7.30 \text{ L } CO_2 \text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00 \text{ atm} \times 7.30 \text{ L} \times (273 + 150) \text{ K}}{(273 + 0) \text{ K} \times 1.14 \text{ atm}} = 9.92 \text{ L } CO_2$$

b. Given: 0.500 g C_4H_{10}
Unknown: V of O_2 at 0.980 atm and 75°C

$$0.500 \text{ g } C_4H_{10} \times \frac{1 \text{ mol } C_4H_{10}}{58.14 \text{ g } C_4H_{10}} \times \frac{13 \text{ mol } O_2}{2 \text{ mol } C_4H_{10}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 1.25 \text{ L } O_2 \text{ at STP}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{1.00 \text{ atm} \times 1.25 \text{ L} \times (273 + 75) \text{ K}}{(273 + 0) \text{ K} \times 0.980 \text{ atm}} = 1.63 \text{ L } O_2$$

c. Given: mass_1 (torch + fuel) = 876.2 g; mass_2 (torch + fuel) = 859.3 g
Unknown: V of CO_2 at STP

mass butane reacted = 876.2 g – 859.3 g = 16.9 g

$$16.9 \text{ g } C_4H_{10} \times \frac{1 \text{ mol } C_4H_{10}}{58.14 \text{ g } C_4H_{10}} \times \frac{8 \text{ mol } CO_2}{2 \text{ mol } C_4H_{10}} \times \frac{22.4 \text{ L}}{1 \text{ mol}} = 26.0 \text{ L } CO_2$$

d. Given: 3720 L of CO_2 at 35°C and 0.993 atm
Unknown: mass H_2O

$$V_2 = \frac{V_1P_1T_2}{T_1P_2} = \frac{3720 \text{ L} \times 0.993 \text{ atm} \times (273 + 0) \text{ K}}{(273 + 35) \text{ K} \times 1.00 \text{ atm}} = 3270 \text{ L } CO_2 \text{ at STP}$$

$$3270 \text{ L } CO_2 \times \frac{1 \text{ mol}}{22.4 \text{ L}} \times \frac{10 \text{ mol } H_2O}{8 \text{ mol } CO_2} \times \frac{18.02 \text{ g } H_2O}{1 \text{ mol } H_2O} = 3290 \text{ g } H_2O$$

---

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

$$\frac{3.50 \text{ g } KIO_3}{(3.50 + 6.23 + 805.05) \text{ g}} \times 100 = 0.430\% \ KIO_3$$

$$\frac{6.23 \text{ g KOH}}{(3.50 + 6.23 + 805.05) \text{ g}} \times 100 = 0.765\% \text{ KOH}$$

330. Given: 0.377 g RbCl to make a 5.00% solution
Unknown: mass of H_2O

$$0.377\text{ g RbCl} \times \frac{100\text{ g solution}}{5\text{ g RbCl}} = 7.54\text{ g solution}$$

$$7.54\text{ g solution} - 0.377\text{ g RbCl} = 7.16\text{ g } H_2O$$

---

331. Given: 30.0 g H_2O; 18.0% $LiNO_3$ solution
Unknown: mass of $LiNO_3$

$$\frac{x}{30.0\text{ g} + x} = 0.18\text{ ; } x = 6.59\text{ g } LiNO_3$$

---

332. Given: 141.6 g $C_3H_5O(COOH)_3$; V of solution = 3500.0 mL
Unknown: molarity

$$141.6\text{ g } C_3H_5O(COOH)_3 \times \frac{1\text{ mol } C_3H_5O(COOH)_3}{192.14\text{ g } C_3H_5O(COOH)_3} = 0.7370\text{ mol } C_3H_5O(COOH)_3$$

$$\frac{0.7370\text{ mol}}{3500.0\text{ mL}} \times \frac{1000\text{ mL}}{1\text{ L}} = 0.2106\text{ M}$$

---

333. Given: 280.0 mg NaCl; 2.00 mL H_2O
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_3COOH; 1000.0 mL solution
Unknown: molarity

$$390.0\text{ g } CH_3COOH \times \frac{1\text{ mol } CH_3COOH}{60.06\text{ g } CH_3COOH} = 6.494\text{ mol } CH_3COOH$$

$$\frac{6.494\text{ mol } CH_3COOH}{1000.0\text{ mL solution}} \times \frac{1000\text{ mL}}{1\text{ L}} = 6.494\text{ M}$$

---

335. Given: 5.000×10^3 L; 0.215 M
Unknown: mass of $C_6H_{12}O_6$

$$0.215\text{ mol/L} \times (5.00 \times 10^3\text{ L}) \times \frac{180.18\text{ g } C_6H_{12}O_6}{1\text{ mol } C_6H_{12}O_6} = 1.94 \times 10^5\text{ g } C_6H_{12}O_6$$

---

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_4Cl

$$\frac{0.875\text{ mol}}{\text{L}} \times 300.\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times \frac{53.50\text{ g } NH_4Cl}{1\text{ mol } NH_4Cl} = 14.0\text{ g } NH_4Cl$$

---

338. Given: 560 g CH_3COCH_3 solute; 620 g H_2O solvent
Unknown: molality

$$560\text{ g } CH_3COCH_3 \times \frac{1\text{ mol } CH_3COCH_3}{58.09\text{ g } CH_3COCH_3} = 9.64\text{ mol } CH_3COCH_3$$

$$\frac{9.64\text{ mol } CH_3COCH_3}{0.620\text{ kg solvent}} = 16\text{ m}$$

339. Given: 12.9 g $C_6H_{12}O_6$ solute; 31.0 g H_2O solvent

Unknown: molality

$$12.9 \text{ g } C_6H_{12}O_6 \times \frac{1 \text{ mol } C_6H_{12}O_6}{180.18 \text{ g } C_6H_{12}O_6} = 0.0716 \text{ mol } C_6H_{12}O_6$$

$$\frac{0.0716 \text{ mol } C_6H_{12}O_6}{31.0 \text{ g solvent}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 2.31 \text{ m}$$

---

340. Given: 125 g solvent; 12.0 m solution

Unknown: moles of solute (CH_3CHOH CH_2CH_3); mass of solute

$$125 \text{ g solvent} \times \frac{12.0 \text{ mol solute}}{1 \text{ kg solvent}} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 1.50 \text{ mol solute}$$

$$1.50 \text{ mol } CH_3CHOHCH_2CH_3 \times \frac{74.14 \text{ g } CH_3CHOHCH_2CH_3}{1 \text{ mol } CH_3CHOHCH_2CH_3}$$

$$= 111 \text{ g } CH_3CHOHCH_2CH_3$$

---

341. a. Given: 12.0% $KMnO_4$; 500.0 g solution

Unknown: mass solute; mass solvent (H_2O)

$$500.0 \text{ g} \times 0.120 = 60.0 \text{ g } KMnO_4$$

$$500.0 \text{ g} - 60.0 \text{ g} = 440.0 \text{ g } H_2O$$

b. Given: 0.60 M $BaCl_2$; 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 ($HOCH_2CHO$ HCH_2OH); 800.0 g H_2O solvent

Unknown: mass glycerol in g

$$\frac{6.20 \text{ mol glycerol}}{1 \text{ kg solvent}} \times 800.0 \text{ g solvent} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 4.96 \text{ mol glyercol}$$

$$4.96 \text{ mol glycerol} \times \frac{92.11 \text{ glycerol}}{1 \text{ mol glycerol}} = 457 \text{ g glycerol}$$

d. Given: 12.27 g solute ($K_2Cr_2O_7$); 650. mL solution

Unknown: molarity

$$\frac{12.27 \text{ g } K_2Cr_2O_7}{650. \text{ mL solution}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ mol } K_2Cr_2O_7}{294.20 \text{ g } K_2Cr_2O_7} = 0.0642 \text{ M } K_2Cr_2O_7$$

e. Given: 288 g $CaCl_2$ solute: 2.04 kg H_2O solvent

Unknown: molality

$$\frac{288 \text{ g } CaCl_2}{2.04 \text{ kg } H_2O} \times \frac{1 \text{ mol } CaCl_2}{110.98 \text{ g } CaCl_2} = 1.27\ m$$

f. Given: 0.160 M NaCl solution; 25.0 mL solution

Unknown: mass solute in g

$$\frac{0.160 \text{ mol NaCl}}{1.00 \text{ L solution}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 25.0 \text{ mL solution} = 0.00400 \text{ mol NaCl}$$

$$0.00400 \text{ mol NaCl} \times \frac{58.44 \text{ g NaCl}}{1 \text{ mol NaCl}} = 0.234 \text{ g NaCl}$$

g. Given: 2.00 *m* $C_6H_{12}O_6$; 1.50 kg H_2O solvent

Unknown: mass of solute and total mass of solution

$$\frac{2.00 \text{ mol } C_6H_{12}O_6}{1.00 \text{ kg } H_2O} \times 1.50 \text{ kg } H_2O = 3.00 \text{ mol } C_6H_{12}O_6$$

$$3.00 \text{ mol } C_6H_{12}O_6 \times \frac{180.18 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} = 541 \text{ g } C_6H_{12}O_6$$

$$1.50 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} + 541 \text{ g} = 2040 \text{ g total}$$

---

342. Given: 2.50 L of 4.25 M solution of H_2SO_4

Unknown: moles of H_2SO_4

$$2.50 \text{ L solution} \times \frac{4.25 \text{ mol } H_2SO_4}{1.00 \text{ L solution}} = 10.6 \text{ mol } H_2SO_4$$

---

343. Given: 71.5 g $C_{18}H_{32}O_2$ solute; 525 g solvent

Unknown: molality

$$71.5 \text{ g } C_{18}H_{32}O_2 \times \frac{1 \text{ mol } C_{18}H_{32}O_2}{280.50 \text{ g } C_{18}H_{32}O_2} = 0.255 \text{ mol } C_{18}H_{32}O_2$$

$$\frac{0.255 \text{ mol } C_{18}H_{32}O_2}{525 \text{ g solvent}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 0.486\ m$$

---

344. Given: 16.2% $Na_2S_2O_3$ solution by mass

a. Unknown: mass $Na_2S_2O_3$ in 80.0 g solution

$$80.0 \text{ g} \times \frac{16.2\%}{100\%} = 13.0 \text{ g } Na_2S_2O_3$$

b. Unknown: moles $Na_2S_2O_3$ in 80.0 g solution

$$80.0 \text{ g} \times \frac{16.2\%}{100\%} Na_2S_2O_3 \times \frac{1 \text{ mol } Na_2S_2O_3}{158.12 \text{ g } Na_2S_2O_3}$$

$$= 0.0820 \text{ mol } Na_2S_2O_3$$

c. Given: 80.0 g of 16.2% $Na_2S_2O_3$ solution (see **b**) diluted to 250.0 mL with H_2O

Unknown: molarity of final solution

$$\frac{0.0820 \text{ mol } Na_2S_2O_3}{250.0 \text{ mL solution}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.328 \text{ M}$$

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

$$\frac{1.50 \text{ mol } NH_2CONH_2}{1.00 \text{ kg solvent}} \times 2250 \text{ g solvent} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 3.38 \text{ mol } NH_2CONH_2$$

$$3.38 \text{ mol } NH_2CONH_2 \times \frac{60.07 \text{ g } NH_2CONH_2}{1 \text{ mol } NH_2CONH_2} = 203 \text{ g } NH_2CONH_2$$

---

348. Given: 21.29 mL of a 3.38 M $Ba(NO_3)_2$ solution

Unknown: mass of $Ba(NO_3)_2$

$$21.29 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{3.38 \text{ mol } Ba(NO_3)_2}{1 \text{ L}} = 0.0720 \text{ mol } Ba(NO_3)_2$$

$$0.0720 \text{ mol } Ba(NO_3)_2 \times \frac{261.35 \text{ g } Ba(NO_3)_2}{1 \text{ mol } Ba(NO_3)_2} = 18.8 \text{ g } Ba(NO_3)_2$$

---

349. Given: 100.0 g of a 3.5% $(NH_4)_2SO_4$ solution

Unknown: description of preparation

$$100.0 \text{ g} \times \frac{3.5\%}{100\%} (NH_4)_2SO_4 = 3.5 \text{ g } (NH_4)_2SO_4$$

100.0 g solution – 3.5 g solute = 96.5 g solvent

Add 3.5 g $(NH_4)_2SO_4$ to 96.5 g H_2O

---

350. Given: 590.0 g water solvent; 0.82 *m* solution

Unknown: mass $CaCl_2$ solute

$$\frac{0.82 \text{ mol } CaCl_2}{1.00 \text{ kg } H_2O} \times 590.0 \text{ g } H_2O \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.48 \text{ mol } CaCl_2$$

$$0.48 \text{ mol } CaCl_2 \times \frac{110.98 \text{ g } CaCl_2}{1 \text{ mol } CaCl_2} = 53 \text{ g } CaCl_2$$

---

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

$$\frac{5.3 \text{ mol solute}}{1.00 \text{ kg } H_2O} \times 125 \text{ g } H_2O \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.662 \text{ mol solute}$$

$$M = \frac{62.0 \text{ g solute}}{0.662 \text{ mol solute}} = 93.7 \text{ g/mol}$$

---

353. Given: 0.9% NaCl

Unknown: masses of NaCl and H_2O to prepare 50. L

$$50. \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.000 \text{ g}}{1 \text{ mL}} = 50\,000 \text{ g} = 50 \text{ kg}$$

$$\frac{0.9\%}{100\%} \times 50 \text{ kg} = 0.45 \text{ kg NaCl}; 50 \text{ kg} - 0.45 = 49.6 \text{ kg } H_2O$$

354. Given: mass beaker = 68.60 g; mass beaker + H_2O = 115.12 g; 4.08 g glucose solute

Unknown: percentage concentration glucose

mass H_2O = 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

$CdCl_2 + Na_2S \rightarrow CdS + 2NaCl$

a. Given: 50.00 mL of a 3.91 M solution

Unknown: moles $CdCl_2$

$$\frac{3.91 \text{ mol } CdCl_2}{1 \text{ L}} \times 50.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.196 \text{ mol } CdCl_2$$

b. Given: 0.196 mol $CdCl_2$ from **a**; balanced equation; excess Na_2S

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 H_2SO_4 solution

Unknown: mass H_2SO_4

$$\frac{5.85 \text{ mol } H_2SO_4}{1.00 \text{ L}} \times 60.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.351 \text{ mol } H_2SO_4$$

$$0.351 \text{ mol } H_2SO_4 \times \frac{98.09 \text{ g } H_2SO_4}{1 \text{ mol } H_2SO_4} = 34.4 \text{ g } H_2SO_4$$

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: $CuSO_4 \bullet 5H_2O$ solute

a. Given: 100. g of a 6.00% $CuSO_4$ solution
Unknown: preparation of solution

$$100. \text{ g} \times \frac{6.00\%}{100\%} CuSO_4 = 6.00 \text{ g } CuSO_4$$

$$6.00 \text{ g } CuSO_4 \times \frac{1 \text{ mol } CuSO_4}{159.62 \text{ g } CuSO_4} \times \frac{1 \text{ mol } CuSO_4 \bullet 5H_2O}{1 \text{ mol } CuSO_4}$$

$$\times \frac{249.72 \text{ g } CuSO_4 \bullet 5H_2O}{1 \text{ mol } CuSO_4 \bullet 5H_2O} = 9.39 \text{ g } CuSO_4 \bullet 5H_2O \text{ in } 100. \text{ g} - 9.39 \text{ g}$$

$$= 90.61 \text{ g } H_2O$$

b. Given: 1.00 L of a 0.800 M $CuSO_4$ solution
Unknown: preparation of solution

$$1.00 \text{ L} \times \frac{0.800 \text{ mol } CuSO_4}{1.00 \text{ L}} \times \frac{1 \text{ mol } CuSO_4 \bullet 5H_2O}{1 \text{ mol } CuSO_4}$$

$$\times \frac{249.72 \text{ g } CuSO_4 \bullet 5H_2O}{1 \text{ mol } CuSO_4 \bullet 5H_2O} = 200. \text{ g } CuSO_4 \bullet 5H_2O \text{ in water to make } 1.00 \text{ L}$$

of solution

c. Given: 3.5 m solution of $CuSO_4$ in 1.0 kg H_2O
Unknown: preparation of solution

$$\frac{3.5 \text{ mol } CuSO_4}{1.0 \text{ kg } H_2O} \times 1.0 \text{ kg } H_2O \times \frac{1 \text{ mol } CuSO_4 \bullet 5H_2O}{1 \text{ mol } CuSO_4} \times \frac{249.72 \text{ g } CuSO_4 \bullet 5H_2O}{1 \text{ mol } CuSO_4 \bullet 5H_2O}$$

$$= 870 \text{ g } CuSO_4 \bullet 5H_2O$$

$$3.5 \text{ mol } CuSO_4 \times \frac{159.62 \text{ g } CuSO_4}{1 \text{ mol } CuSO_4} = 560 \text{ g } CuSO_4$$

$$870 \text{ g } CuSO_4 \bullet 5H_2O - 560 \text{ g } CuSO_4 = 310 \text{ g } H_2O$$

$$1.0 \text{ kg} \times \frac{1000 \text{ g}}{1 \text{ kg}} - 310 \text{ g} = 690 \text{ g added water}$$

---

361. Given: 700.0 mL of 2.50 M $CaCl_2$ solution
Unknown: mass $CaCl_2 \bullet 6H_2O$

$$700.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{2.50 \text{ mol } CaCl_2}{1 \text{ L}} \times \frac{1 \text{ mol } CaCl_2 \bullet 6H_2O}{1 \text{ mol } CaCl_2}$$

$$\times \frac{219.10 \text{ g } CaCl_2 \bullet 6H_2O}{1 \text{ mol } CaCl_2 \bullet 6H_2O} = 383 \text{ g } CaCl_2 \bullet 6H_2O$$

---

362. Given: 1.250 L of 0.00205 M $C_6H_{14}N_4O_2$
Unknown: mass of $C_6H_{14}N_4O_2$

$$1.250 \text{ L} \times \frac{0.00205 \text{ mol } C_6H_{14}N_4O_2}{1 \text{ L}} = 0.00256 \text{ mol } C_6H_{14}N_4O_2$$

$$0.00256 \text{ mol } C_6H_{14}N_4O_2 \times \frac{174.24 \text{ g } C_6H_{14}N_4O_2}{1 \text{ mol } C_6H_{14}N_4O_2} = 0.446 \text{ g } C_6H_{14}N_4O_2$$

363. Given: 2.402 kg $NiSO_4 \cdot 6H_2O$; 25% solution

Unknown: mass of water

$$2.402 \text{ kg } NiSO_4 \cdot 6H_2O \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ mol } NiSO_4 \cdot 6H_2O}{262.88 \text{ g } NiSO_4 \cdot 6H_2O}$$

$$\times \frac{1 \text{ mol } NiSO_4}{1 \text{ mol } NiSO_4 \cdot 6H_2O} \times \frac{154.76 \text{ g } NiSO_4}{1 \text{ mol } NiSO_4} = 1414 \text{ g } NiSO_4$$

$$\frac{1414 \text{ g}}{x + 1414 \text{ g}} = 0.25;\ x = \frac{1414 \text{ g}}{0.25} - 1414 \text{ g} = 4242 \text{ g } H_2O \text{ in solution}$$

$$4242 \text{ g } H_2O - (2402 \text{ g} - 1414 \text{ g}) = 3254 \text{ g } H_2O \text{ added}$$

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364. Given: $KAl(SO_4)_2 \cdot 12H_2O$ solute; 35.0 g of a 15% $KAl(SO_4)_2$ solution

Unknown: mass of solute; mass of H_2O added

$$35.0 \text{ g} \times 0.15 \ KAl(SO_4)_2 = 5.25 \text{ g } KAl(SO_4)_2$$

$$5.25 \text{ g } KAl(SO_4)_2 \times \frac{1 \text{ mol } KAl(SO_4)_2}{258.22 \text{ g } KAl(SO_4)_2} \times \frac{1 \text{ mol } KAl(SO_4)_2 \cdot 12H_2O}{1 \text{ mol } KAl(SO_4)_2}$$

$$\times \frac{474.46 \text{ g } KAl(SO_4)_2 \cdot 12H_2O}{1 \text{ mol } KAl(SO_4)_2 \cdot 12H_2O} = 9.646 \text{ g } KAl(SO_4)_2 \cdot 12H_2O$$

35.0 g solution – 9.646 g solute = 25.35 g water added

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365. a. Given: M_S = 0.500 M KBr; V_S = 20.00 mL; V_D = 100.00 mL; $M_SV_S = M_DV_D$

Unknown: M_D

$$M_D = \frac{M_SV_S}{V_D} = \frac{0.500 \text{ M KBr} \times 20.00 \text{ mL}}{100.00 \text{ mL}} = 0.100 \text{ M KBr}$$

b. Given: M_S = 1.00 M LiOH; M_D = 0.075 M LiOH; V_D = 500.00 mL; $M_SV_S = M_DV_D$

Unknown: V_S

$$V_S = \frac{M_DV_D}{M_S} = \frac{0.075 \text{ M LiOH} \times 500.00 \text{ mL}}{1.00 \text{ M LiOH}} = 38 \text{ mL}$$

c. Given: V_S = 5.00 mL; M_D = 0.0493 M HI; V_D = 100.00 mL; $M_SV_S = M_DV_D$

Unknown: M_S

$$M_S = \frac{M_DV_D}{V_S} = \frac{0.0493 \text{ M HI} \times 100.00 \text{ mL}}{5.00 \text{ mL}} = 0.986 \text{ M HI}$$

d. Given: M_S = 12.0 M HCl; V_S = 0.250 L; M_D = 1.8 M HCl; $M_SV_S = M_DV_D$

Unknown: V_D

$$V_D = \frac{M_SV_S}{M_D} = \frac{12.0 \text{ M HCl} \times 0.250 \text{ L}}{1.8 \text{ M HCl}} = 1.7 \text{ L}$$

e. Given: M_S = 7.44 M NH_3; M_D = 0.093 M NH_3; V_D = 4.00 L; $M_SV_S = M_DV_D$
Unknown: V_S

$$V_S = \frac{M_DV_D}{M_S} = \frac{0.093 \text{ M } NH_3 \times 4.00 \text{ L}}{7.44 \text{ M } NH_3} = 0.050 \text{ L} = 50. \text{ mL}$$

---

366. Given: M_S = 0.0813 M; V_S = 16.5 mL; M_D = 0.0200 M; $M_SV_S = M_DV_D$
Unknown: V_D; V of water added

$$V_D = \frac{M_SV_S}{M_D} = \frac{0.0813 \text{ M} \times 16.5 \text{ mL}}{0.0200 \text{ M}} = 67.1 \text{ mL}$$

67.1 mL – 16.5 mL = 50.6 mL H_2O added

---

367. Given: M_S = 3.79 M NH_4Cl; V_S = 50.00 mL; V_D = 2.00 L; $M_SV_S = M_DV_D$
Unknown: M_D

$$M_D = \frac{M_SV_S}{V_D} = \frac{3.79 \text{ M } NH_4Cl \times 50.00 \text{ mL}}{2000 \text{ mL}} = 0.0948 \text{ M } NH_4Cl$$

---

368. Given: 100.00 mL H_2O added; M_D = 0.046 M KOH; M_S = 2.09 M KOH; $M_SV_S = M_DV_D$
Unknown: V_S

$V_D = V_S + 100.00$ mL

$M_SV_S = M_DV_D$

2.09 M KOH × V_S = 0.046 M KOH (V_S + 100.00 mL)

V_S = 2.3 mL

---

369. a. Given: V_S = 20.00 mL; M_D = 0.50 M; 100.00 mL H_2O added; $M_SV_S = M_DV_D$
Unknown: M_S

$$M_S = \frac{M_DV_D}{V_S} = \frac{0.50 \text{ M} \times (100.00 \text{ mL} + 20.00 \text{ mL})}{20.00 \text{ mL}} = 3.0 \text{ M}$$

b. Given: V_D = 5.00 L; M_D = 3.0 M; M_S = 18.0 M; $M_SV_S = M_DV_D$
Unknown: V_S

$$V_S = \frac{M_DV_D}{M_S} = \frac{3.0 \text{ M} \times 5.00 \text{ L}}{18.0 \text{ M}} = 0.83 \text{ L}$$

c. Given: V = 0.83 L, from **b**; D = 1.84 g/mL
Unknown: mass H_2SO_4

$$m = VD = 0.83 \text{ L} \times 1.84 \frac{\text{g}}{\text{mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1.5 \times 10^3 \text{ g}$$

---

370. Given: V_S = 1.19 mL; M_S = 8.00 M; M_D = 1.50 M; $M_SV_S = M_DV_D$
Unknown: V_D

$$V_D = \frac{M_SV_S}{M_D} = \frac{8.00 \text{ M} \times 1.19 \text{ mL}}{1.50 \text{ M}} = 6.35 \text{ mL}$$

371. Given: M_S = 5.75 M; V_D = 2.00 L; M_D = 1.00 M; $M_SV_S = M_DV_D$
Unknown: V_S

$$V_S = \frac{M_DV_D}{M_S} = \frac{1.00\text{ M} \times 2.00\text{ L}}{5.75\text{ M}} = 0.348\text{ L or } 348\text{ mL}$$

---

372. a. Given: V_S = 25.00 mL; M_D = 0.186 M; 50.00 mL H_2O added; $M_SV_S = M_DV_D$
Unknown: M_S

$$M_S = \frac{M_DV_D}{V_S} = \frac{0.186\text{ M} \times (25.00\text{ mL} + 50.00\text{ mL})}{25.00\text{ mL}} = 0.558\text{ M}$$

---

373. a. Given: 36% HCl solution; D = 1.18 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

$$V_1 = \frac{\text{m}}{\text{D}} = 1.0\text{ kg} \times \frac{1\text{ mL}}{1.18\text{ g}} \times \frac{1000\text{ g}}{1\text{ kg}} = 850\text{ mL}$$

$$V_2 = \frac{100\% \times 1\text{ g}}{36\%} \times \frac{1\text{ mL}}{1.18\text{ g}} = 2.4\text{ mL}$$

$$V_3 = 36.46\text{ g} \times \frac{100\%}{36\%} \times \frac{1\text{ mL}}{1.18\text{ g}} = 86\text{ mL}$$

b. Given: D = 1.42 g/mL; 71% HNO_3 solution; $M_SV_S = M_DV_D$
Unknown: V of HNO_3 to prepare 10.0 L of 2.00 M HNO_3 (V_S)

$$\frac{71\text{ g }HNO_3}{100\text{ g}} \times \frac{1.42\text{ g}}{1\text{ mL}} \times \frac{1\text{ mol }HNO_3}{63.02\text{ g }HNO_3} \times \frac{1000\text{ mL}}{1\text{ L}} = 16\ \frac{\text{mol }HNO_3}{\text{L}}$$

$$= 16\text{ M }HNO_3$$

$$V_S = \frac{M_DV_D}{M_S} = \frac{2.00\text{ M} \times 10.0\text{ L}}{16\text{ M}} = 1.2\text{ L}$$

c. Given: 86 mL contains 1.0 mol (from **a**); $M_SV_S = M_DV_D$; M_D = 3.0 M; V_D = 4.50 L
Unknown: V_S

$$M_S = \frac{1\text{ mol}}{86\text{ mL}} \times \frac{1000\text{ mL}}{1\text{ L}} = 12\text{ M}$$

$$V_S = \frac{M_DV_D}{M_S} = \frac{3.0\text{ M} \times 4.50\text{ L}}{12\text{ M}} = 1.1\text{ L}$$

---

374. Given: M_S = 3.8 M; $V_D = 8\ V_S$; $M_SV_S = M_DV_D$
Unknown: M_D

$$M_D = \frac{M_SV_S}{V_D} = \frac{3.8\text{ M} \times V_S}{8\ V_S} = 0.48\text{ M}$$

375. Given: $M_D = 2.50$ M; $V_D = 480.$ mL; 39 mL H_2O evaporated; $M_SV_S = M_DV_D$
Unknown: M_S

$$M_S = \frac{M_DV_D}{V_S} = \frac{2.50 \text{ M} \times 480. \text{ mL}}{(480. - 39) \text{ mL}} = 2.72 \text{ M}$$

---

376. Given: $M_D = 1.22$ M; $V_D = 25.00$ mL; $M_S = 6.45$ M; $M_SV_S = M_DV_D$
Unknown: V_S; procedure

$$V_S = \frac{M_DV_D}{M_S} = \frac{1.22 \text{ M} \times 25.00 \text{ mL}}{6.45 \text{ M}} = 4.73 \text{ mL}$$

Dilute the 6.45 M acid by adding 4.73 mL of it to enough distilled water to make 25.00 mL of solution.

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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 mL; $V_D =$ 500 mL; $M_SV_S = M_DV_D$
Unknown: M_D

$$M_S = \frac{34 \text{ g } I_2}{25 \text{ mL}} \times \frac{1 \text{ mol } I_2}{253.8 \text{ g } I_2} \times \frac{1000 \text{ mL}}{1\text{L}} = 5.36 \text{ M}$$

$$M_D = \frac{M_SV_S}{V_D} = \frac{5.36 \text{ M} \times 25 \text{ mL}}{500 \text{ mL}} = 0.27 \text{ M}$$

---

379. Given: 85% H_3PO_4 solution; $V = 600.0$ mL; 2.80 M
Unknown: mass of solution

$$600.0 \text{ mL} \times \frac{2.80 \text{ mol}}{1 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.68 \text{ mol } H_3PO_4$$

$$1.68 \text{ mol } H_3PO_4 \times \frac{98.00 \text{ g } H_3PO_4}{1 \text{ mol } H_3PO_4} = 165 \text{ g } H_3PO_4$$

$$\text{mass of solution} = \frac{165 \text{ g } H_3PO_4 \times 100. \text{ g solution}}{85 \text{ g } H_3PO_4} = 190 \text{ g solution}$$

---

380. Given: $M_S = 18.0$ M; $M_D = 4.0$ M; $V_D = 3.00$ L; $M_SV_S = M_DV_D$
Unknown: V_S

$$V_S = \frac{M_DV_D}{M_S} = \frac{4.0 \text{ M} \times 3.00 \text{ L}}{18.0 \text{ M}} = 0.67 \text{ L}$$

---

381. Given: $V_D = 1.00$ L; $M_D = 0.495$ M; $M_S = 3.07$ M; $M_SV_S = M_DV_D$
Unknown: V_S

$$V_S = \frac{M_DV_D}{M_S} = \frac{0.495 \text{ M} \times 1.00 \text{ L}}{3.07 \text{ M}} = 0.161 \text{ L} = 161 \text{ mL}$$

Dilute 161 mL stock urea solution to 1.00 L.

---

382. a. Given: 76.2% $C_6H_{12}O_6$
Unknown: molality

$$\frac{76.2 \text{ g } C_6H_{12}O_6}{(100. - 76.2) \text{ g } H_2O} \times \frac{1 \text{ mol } C_6H_{12}O_6}{180.18 \text{ g } C_6H_{12}O_6} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 17.8 \text{ m}$$

b. Given: 76.2% $C_6H_{12}O_6$; D = 1.42 g/mL; V = 1.00 L

Unknown: mass of $C_6H_{12}O_6$; molarity

$$\frac{1.42 \text{ g}}{1 \text{ mL}} \times 1.00 \text{ L} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{76.2\%}{100\%} = 1080 \text{ g}$$

$$\frac{1080 \text{ g}}{1 \text{ L}} \times \frac{1 \text{ mol } C_6H_{12}O_6}{180.18 \text{ g } C_6H_{12}O_6} = 5.99 \text{ M}$$

---

383. Given: M_D = 0.0890 M; V_S = 10.00 mL; V_D = 50.00 mL; $M_SV_S = M_DV_D$; molar mass Na_2CO_3 = 105.99 g

Unknown: M_S; percentage Na_2CO_3 in 50.00 g of a material used to make 1.000 L stock solution

$$M_S = \frac{M_DV_D}{V_S} = \frac{0.0890 \text{ M} \times 50.00 \text{ mL}}{10.00 \text{ mL}} = 0.445 \text{ M}$$

$$\frac{0.445 \text{ mol}}{1 \text{ L}} \times 1.000 \text{ L} \times \frac{105.99 \text{ g}}{1 \text{ mol}} = 47.17 \text{ g } Na_2CO_3$$

$$\frac{47.17 \text{ g } Na_2CO_3}{50.00 \text{ g sample}} \times 100 = 94.34\% \ Na_2CO_3$$

---

384. Given: V_T of $CuCl_2$ stock solution = 0.600 L; V_S = 20.0 mL; V_D = 150.0 mL; M_D = 0.250 M; $M_SV_S = M_DV_D$

Unknown: mass $CuCl_2$ to make stock solution

$$M_S = \frac{M_DV_D}{V_S} = \frac{0.250 \text{ M} \times 150.0 \text{ mL}}{20.0 \text{ mL}} = 1.88 \text{ M}$$

$$\frac{1.88 \text{ mol } CuCl_2}{1 \text{ L}} \times 0.600 \text{ L} \times \frac{134.45 \text{ g } CuCl_2}{1 \text{ mol } CuCl_2} = 152 \text{ g } CuCl_2$$

---

385. Given: M_S = 2.15 M; M_D = 0.65 M; $M_SV_S = M_DV_D$

Unknown: dilution factor

2.15 M × V = 0.65 × kV; k = 3.3; $V_D = 3.3\ V_S$

$V_D - V_S = 3.3\ V_S - 1.0\ V_S = 2.3\ V_S$; Add 2.3 volumes of H_2O per volume of stock solution.

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386. **a.** Given: 18.2% $Sr(NO_3)_2$ solution; D = 1.02 g/ml V = 80.00 mL

Unknown: mass of $Sr(NO_3)_2$

$$80.00 \text{ mL} \times \frac{1.02 \text{ g}}{1 \text{ mL}} \times \frac{18.2 \text{ g } Sr(NO_3)_2}{100 \text{ g solution}} = 14.9 \text{ g } Sr(NO_3)_2$$

b. Given: 14.9 g $Sr(NO_3)_2$ from **a**

Unknown: moles $Sr(NO_3)_2$

$$14.9 \text{ g } Sr(NO_3)_2 \times \frac{1 \text{ mol } Sr(NO_3)_2}{211.64 \text{ g } Sr(NO_3)_2} = 7.04 \times 10^{-2} \text{ mol } Sr(NO_3)_2$$

c. Given: 7.04×10^{-2} mol $Sr(NO_3)_2$ from **b**; 420.0 mL H_2O added

Unknown: molarity (M_D)

$$M_S = \frac{7.04 \times 10^{-2}\ \text{mol}}{80.0\ \text{mL}} \times \frac{1000\ \text{mL}}{1\ \text{L}} = 0.880\ \text{M}$$

$$M_D = \frac{M_S V_S}{V_D} = \frac{0.880\ \text{M} \times 80.0\ \text{mL}}{(80.0 + 420.0)\ \text{mL}} = 0.141\ \text{M}$$

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387. Given: 60.0 g $C_6H_{12}O_6$ in 80.0 g H_2O; K_f for water = $-1.86°C/m$; $\Delta t_f = K_f m$

Unknown: freezing point

$$60.0\ \text{g}\ C_6H_{12}O_6 \times \frac{1\ \text{mol}\ C_6H_{12}O_6}{180.18\ \text{g}\ C_6H_{12}O_6} = 0.333\ \text{mol}\ C_6H_{12}O_6$$

$$\frac{0.333\ \text{mol}\ C_6H_{12}O_6}{80.0\ \text{g}\ H_2O} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 4.16\ m$$

$$\Delta t_f = K_f m = \frac{-1.86°C}{m} \times 4.16\ m = -7.74°C$$

fp (solution) = fp (solvent) + Δt_f = 0.00°C – 7.74°C = 7.74°C

---

388. Given: 645 g H_2NCONH_2; 980. g H_2O

Unknown: freezing point

$$645\ \text{g}\ H_2NCONH_2 \times \frac{1\ \text{mol}\ H_2NCONH_2}{60.07\ \text{g}\ H_2NCONH_2} = 10.7\ \text{mol}\ H_2NCONH_2$$

$$\frac{10.7\ \text{mol}\ H_2NCONH_2}{980.\ \text{g}\ H_2O} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 10.9\ m$$

$$\Delta t_f = K_f m = -\frac{1.86°C}{m} \times 10.9\ m = -20.3\ °C$$

f_p = 0.0°C – 20.3°C = –20.3°C

---

389. Given: 30.00 g KBr; 100.00 g H_2O

Unknown: boiling point

$$30.00\ \text{g KBr} \times \frac{1\ \text{mol KBr}}{119.00\ \text{g KBr}} = 0.252\ \text{mol KBr}$$

$$\Delta t_b = \frac{0.252\ \text{mol KBr}}{100.00\ \text{g}\ H_2O} \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{2\ \text{mol ions}}{1\ \text{mol KBr}} \times \frac{0.51°C}{\text{mol}} = 2.6\ \text{C}$$

bp = 100.0°C + 2.6°C = 102.6°C

---

390. Given: 385 g $CaCl_2$; 1.230×10^3 g H_2O

Unknown: boiling point

$$385\ \text{g}\ CaCl_2 \times \frac{1\ \text{mol}\ CaCl_2}{110.97\ \text{g}\ CaCl_2} = 3.47\ \text{mol}\ CaCl_2$$

$$\Delta t_b = \frac{3.47\ \text{mol}\ CaCl_2}{1.230 \times 10^3\ \text{g}\ H_2O} \times \frac{10^3\ \text{g}}{1\ \text{kg}} \times \frac{3\ \text{mol ions}}{1\ \text{mol}\ CaCl_2} \times \frac{0.51°C}{m} = 4.3°C$$

bp = 100.0°C + 4.3°C = 104.3°C

---

391. Given: 0.827 g nonelectrolyte; 2.500 g H_2O; fp = –10.18°C

Unknown: molar mass

$$m = \frac{\Delta t_f}{K_f} = \frac{-10.18°C}{-1.86°C/m} = 5.47\ m$$

$$\frac{5.47\ \text{mol}}{1.00\ \text{kg}\ H_2O} \times 2.500\ \text{g}\ H_2O \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.0137\ \text{mol}$$

$$\frac{0.827\ \text{g}}{0.0137\ \text{mol}} = 60.4\ \text{g/mol}$$

392. Given: 0.171 g nonelectrolyte; ether solvent; mass of solution = 2.470 g; bp = 36.43°C

Unknown: molar mass

mass of ether solvent = 2.470 g – 0.171 g = 2.299 g

Δt_b = bp – normal bp = 36.43°C – 34.6°C = 1.83°C

$$m = \frac{\Delta t_b}{K_b} = \frac{1.83°\text{C}}{2.02°\text{C}/m} = 0.906\ m$$

$$\frac{0.906 \text{ mol}}{1.00 \text{ kg ether}} \times 2.299 \text{ g ether} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.00208 \text{ mol}$$

$$\frac{0.171 \text{ g}}{0.00208 \text{ mol}} = 82.2 \text{ g/mol}$$

---

393. Given: 383 g glucose; 400. g H_2O

Unknown: freezing point; boiling point

$$383 \text{ g } C_6H_{12}O_6 \times \frac{1 \text{ mol } C_6H_{12}O_6}{180.18 \text{ g } C_6H_{12}O_6} = 2.13 \text{ mol } C_6H_{12}O_6$$

$$\frac{2.13 \text{ mol}}{400. \text{ g } H_2O} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 5.32 \text{ m}$$

$$\text{fp} = \text{normal fp} + (K_f m) = 0.00°\text{C} + \left(\frac{-1.86°\text{C}}{m} \times 5.32\ m\right) = -9.90°\text{C}$$

$$\text{bp} = \text{normal bp} + (K_b m) = 100.00°\text{C} + \left(\frac{0.51°\text{C}}{m} \times 5.32\ m\right) = 102.7°\text{C}$$

---

394. Given: 72.4 g glycerol; 122.5 g H_2O

Unknown: boiling point

$$72.4 \text{ g glycerol} \times \frac{1 \text{ mol glycerol}}{92.08 \text{ g glycerol}} = 0.786 \text{ mol glycerol}$$

$$\frac{0.786 \text{ mol}}{122.5 \text{ g } H_2O} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 6.42\ m$$

$$\text{bp} = \text{normal bp} + (K_b m) = 100.00°\text{C} + \left(\frac{0.51°\text{C}}{m} \times 6.42\ m\right) = 103.3°\text{C}$$

---

395. Given: 30.20 g $HOCH_2CH_2OH$ solute; 88.40 g phenol

Unknown: boiling point

$$30.20 \text{ g } HOCH_2CH_2OH \times \frac{1 \text{ mol } HOCH_2CH_2OH}{62.08 \text{ g } HOCH_2CH_2OH}$$

$$= 0.4865 \text{ mol } HOCH_2CH_2OH$$

$$\frac{0.4865 \text{ mol}}{88.04 \text{ g}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 5.503\ m$$

$$\text{bp} = \text{normal bp} + (K_b m) = 181.8°\text{C} + \left(\frac{3.60°\text{C}}{m} \times 5.503\ m\right) = 201.6°\text{C}$$

---

396. Given: 450. g H_2O; fp = –4.5°C

Unknown: mass of ethanol solute

$$m = \frac{\text{fp}}{K_f} = \frac{-4.5°\text{C}}{-1.86°\text{C}/m} = 2.4\ m$$

$$\frac{2.4 \text{ mol}}{1 \text{ kg}} \times 450. \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 1.1 \text{ mol}$$

$$1.1 \text{ mol ethanol} \times \frac{46.08 \text{ g ethanol}}{1 \text{ mol ethanol}} = 51 \text{ g ethanol}$$

397. Given: fp = –3.9°C 25.00 g H_2O; 4.27 g solute

Unknown: molar mass of solute

$$m = \frac{\text{fp}}{K_f} = \frac{-3.9°\text{C}}{-1.86°\text{C}/m} = 2.1\ m$$

$$\frac{2.1\ \text{mol}}{1\ \text{kg}\ H_2O} \times 25.00\ \text{g}\ H_2O \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.052\ \text{mol}$$

$$\frac{4.27\ \text{g}}{0.052\ \text{mol}} = 82\ \text{g/mol}$$

---

398. Given: 1.17 g $C_{10}H_8O$; 2.00 mL benzene; T = 20°C; D of benzene = 0.876 g/mL; K_f for benzene = –5.12°C/m; normal fp of benzene = 5.53°C

Unknown: freezing point

$$\text{mass benzene} = 2.00\ \text{mL} \times \frac{0.8769}{1\ \text{mL}} = 1.75\ \text{g}$$

$$\text{mol}\ C_{10}H_8O = 1.17\ \text{g}\ C_{10}H_8O \times \frac{1\ \text{mol}\ C_{10}H_8O}{144.18\ \text{g}\ C_{10}H_8O} = 0.00811\ \text{mol}\ C_{10}H_8O$$

$$\frac{0.00811\ \text{mol}\ C_{10}H_8O}{1.75\ \text{g benzene}} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 4.63\ m$$

$$\text{fp} = \text{normal fp} + (K_f m) = 5.53°\text{C} + \left(\frac{-5.12°\text{C}}{m} \times 4.63\ m\right) = -18.2°\text{C}$$

---

399. Given: 10.44 g solute; 50.00 g CH_3COOH solvent; bp = 159.2°C

Unknown: molar mass

$$m = \frac{\text{bp} - \text{normal bp}}{K_b} = \frac{159.2°\text{C} - 117.9°\text{C}}{3.07°\text{C}/m} = 13.5\ m$$

$$\frac{13.5\ \text{mol}}{1\ \text{kg solvent}} \times 50.00\ \text{g solvent} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.675\ \text{mol}$$

$$\frac{10.44\ \text{g}}{0.675\ \text{mol}} = 15.5\ \text{g/mol}$$

---

400. Given: 0.0355 g solute; 1.000 g camphor solvent; T = 200.0°C; fp = 157.7°C

Unknown: molar mass

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{157.7°\text{C} - 178.8°\text{C}}{-39.7°\text{C}/m} = 0.531\ m$$

$$\frac{0.531\ \text{mol}}{1\ \text{kg solvent}} \times 1.000\ \text{g solvent} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 5.31 \times 10^{-4}\ \text{mol}$$

$$\frac{0.0355\ \text{g}}{5.31 \times 10^{-4}\ \text{mol}} = 66.8\ \text{g/mol}$$

---

401. Given: 22.5 g $C_6H_{12}O_6$; 294 g phenol

Unknown: boiling point

$$22.5\ \text{g}\ C_6H_{12}O_6 \times \frac{1\ \text{mol}\ C_6H_{12}O_6}{180.18\ \text{g}\ C_6H_{12}O_6} = 0.125\ \text{mol}\ C_6H_{12}O_6$$

$$\frac{0.125\ \text{mol}}{294\ \text{g}} \times \frac{1000\ \text{g}}{1\ \text{kg}} = 0.425\ \text{m}$$

$$\text{bp} = 181.8°\text{C} + (3.60°\text{C/m} \times 0.425\ \text{m}) = 183.3°\text{C}$$

---

402. Given: 50.0% solution of ethylene glycol in H_2O

$$\frac{50.0\ \text{g ethylene glycol}}{50.0\ \text{g}\ H_2O} \times \frac{1000\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol ethylene glycol}}{62.08\ \text{g ethylene glycol}} = 16.1\ \text{m}$$

a. Unknown: freezing point

$$\text{fp} = \text{normal fp} + (K_f m) = 0.00°\text{C} + (-1.86°\text{C}/m \times 16.1\ m) = -29.9°\text{C}$$

b. Unknown: boiling point

$$\text{bp} = \text{normal bp} + (K_b m) = 100.00°\text{C} + (0.51°\text{C}/m \times 16.1\ m) = 108.2°\text{C}$$

403. Given: $K_f = -20.0°C/m$; normal fp = 6.6°C; cyclohexane solvent; 1.604 g solute; 10.000 g cyclohexane; fp = –4.4°C

Unknown: molar mass

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-4.4°C - 6.6°C}{-20.0°C/m} = 0.550\ m$$

$$\frac{0.550 \text{ mol}}{1.00 \text{ kg solvent}} \times 10.000 \text{ g solvent} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.00550 \text{ mol}$$

$$\frac{1.604 \text{ g}}{0.00550 \text{ mol}} = 292 \text{ g/mol}$$

---

404. Given: 2.62 kg HNO_3; H_2O solvent; mass of solution = 5.91 kg

Unknown: freezing point

mass H_2O = 5.91 kg – 2.62 kg = 3.29 kg

$$2.62 \text{ kg } HNO_3 \times \frac{1 \text{ mol } HNO_3}{63.02 \text{ g } HNO_3} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 41.6 \text{ mol } HNO_3 = 83.2 \text{ mol ions}$$

$$\frac{83.2 \text{ mol ions}}{3.29 \text{ kg } H_2O} = 25.3\ m$$

fp = normal fp + ($K_f m$) = 0.00°C + (–1.86°C/m × 25.3 m) = –47.1°C

---

405. Given: 0.5190 g naphthalene solvent; mass solution = 0.5959 g; fp = 74.8°C

Unknown: molar mass

mass solute = 0.5959 g – 0.5190 g = 0.0769 g

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{74.8°C - 80.2°C}{-6.94°C/m} = 0.778\ m$$

$$\frac{0.778 \text{ mol}}{1.00 \text{ kg solvent}} \times 0.5190 \text{ g solvent} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 4.04 \times 10^{-4} \text{ mol}$$

$$\frac{0.0769 \text{ g}}{4.04 \times 10^{-4} \text{ mol}} = 190. \text{ g/mol}$$

---

406. Given: 8.69 g $NaCH_3COO$; 15.00 g H_2O

Unknown: boiling point

$$8.69 \text{ g } NaCH_3COO \times \frac{1 \text{ mol } NaCH_3COO}{82.04 \text{ g } NaCH_3COO} \times \frac{2 \text{ mol ions}}{1 \text{ mol } NaCH_3COO}$$

= 0.212 mol ions

$$\frac{0.212 \text{ mol}}{15.00 \text{ g } H_2O} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 14.1\ m$$

bp = normal bp + ($K_b m$) = 100.00°C + (0.51°C/m × 14.1 m) = 107.2°C

---

407. Given: 110.5 g H_2SO_4; 225 g H_2O

Unknown: freezing point

$$110.5 \text{ g } H_2SO_4 \times \frac{1 \text{ mol } H_2SO_4}{98.09 \text{ g } H_2SO_4} \times \frac{3 \text{ mol ions}}{1 \text{ mol } H_2SO_4} = 3.38 \text{ mol ions}$$

$$\frac{3.38 \text{ mol}}{225 \text{ g } H_2O} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 15.0\ m$$

fp = normal fp + ($K_f m$) = 0.00°C + (–1.86°C/m × 15.0 m) = –27.9°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°C/m; normal bp = 80.1°C

Unknown: molar mass; molecular formula

$$m = \frac{\text{bp} - \text{normal bp}}{K_b} = \frac{85.1°\text{C} - 80.1°\text{C}}{2.53°\text{C}/m} = 1.98\ m$$

$$\frac{1.98 \text{ mol}}{1 \text{ Kg solvent}} \times 10.00 \text{ g solvent} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.0198 \text{ mol}$$

$$\frac{4.04 \text{ g}}{0.0198 \text{ mol}} = 204 \text{ g/mol}$$

molar mass C_8H_5 = 101.13 g/mol

$$\frac{204 \text{ g}}{1 \text{ mol}} \times \frac{1 \text{ mol}}{101.13 \text{ g}} = 2.02 \approx 2$$

molecular formula = $C_{8\times2}H_{5\times2} = C_{16}H_{10}$

---

409. Given: $CaCl_2$ solute; 100.00 g H_2O; fp = –5.0°C

Unknown: mass $CaCl_2$; mass $C_6H_{12}O_6$ for same fp

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-5.0°\text{C} - 0.0°\text{C}}{-1.86°\text{C}/m} = 2.7\ m \text{ (ions)}$$

$$\frac{2.7 \text{ mol ions}}{1.0 \text{ kg}} \times \frac{1 \text{ mol } CaCl_2}{3 \text{ mol ions}} = 0.90 \text{ m } CaCl_2$$

$$\frac{0.90 \text{ mol } CaCl_2}{1.0 \text{ kg } H_2O} \times 100.00 \text{ g } H_2O \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.090 \text{ mol } CaCl_2$$

$$0.090 \text{ mol } CaCl_2 \times \frac{110.98 \text{ g } CaCl_2}{1 \text{ mol } CaCl_2} = 10. \text{ g } CaCl_2$$

Because glucose is a nonelectrolyte, m of glucose = 2.7 m

$$\frac{2.7 \text{ mol glucose}}{1.0 \text{ kg } H_2O} \times 100.00 \text{ g } H_2O \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.27 \text{ mol glucose}$$

$$0.27 \text{ mol } C_6H_{12}O_6 \times \frac{180.18 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} = 49 \text{ g glucose}$$

---

410. Given: empirical formula is CH_2O; 0.0866 g solute; 1.000 g ether; bp = 36.5°C

Unknown: molecular formula

$$m = \frac{\text{bp} - \text{normal bp}}{K_b} = \frac{36.5°\text{C} - 34.6°\text{C}}{2.02°\text{C}/m} = 0.941\ m$$

$$\frac{0.941 \text{ mol}}{1.00 \text{ kg solvent}} \times 1.000 \text{ g solvent} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 9.41 \times 10^{-4} \text{ mol}$$

$$\frac{0.0866 \text{ g}}{9.41 \times 10^{-4} \text{ mol}} = 92.0 \text{ g/mol for the molecule}$$

molar mass CH_2O = 30.03 g/mol

$$\frac{92.0 \text{ g/mol}}{30.03 \text{ g.mol}} = 3.06$$

molecular formula = $C_{1\times3}H_{2\times3}O_{1\times3} = C_3H_6O_3$

---

411. Given: 28.6% HCl by mass

Unknown: freezing point

$$\frac{28.6 \text{ g HCl}}{(100.0 \text{ g} - 28.6 \text{ g}) H_2O} \times \frac{1 \text{ mol HCl}}{36.46 \text{ g HCl}} \times \frac{2 \text{ mol ions}}{1 \text{ mol HCl}} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 22.0\ m \text{ ions}$$

$$\text{fp} = \text{normal fp} + (K_f m) = 0.00°\text{C} + (-1.86°\text{C}/m \times 22.0\ m) = -40.9°\text{C}$$

412. Given: 4.510 kg H_2O; fp = –18.0°C; $HOCH_2CH_2OH$ solute

Unknown: mass of solute; boiling point

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-18.0°\text{C} - 0.0°\text{C}}{-1.86°\text{C}/m} = 9.68\ m$$

$$\frac{9.68 \text{ mol}}{1.00 \text{ kg solvent}} \times 4.510 \text{ kg solvent} = 43.7 \text{ mol}$$

$$43.7 \text{ mol } HOCH_2CH_2OH \times \frac{62.08 \text{ g } HOCH_2CH_2OH}{1 \text{ mol } HOCH_2CH_2OH}$$

$$= 2710 \text{ g } HOCH_2CH_2OH = 2.71 \text{ kg } HOCH_2CH_2OH$$

$$\text{bp} = \text{normal bp} \times (K_b m) = 100.00°\text{C} \times (0.51°\text{C}/m \times 9.68\ m) = 104.9°\text{C}$$

---

413. a. Given: 2.00 g solute; 10.00 g H_2O; fp = –4.0°C

Unknown: molality

$$\frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-4.0°\text{C} - 0.0°\text{C}}{-1.86°\text{C}/m} = 2.2\ m$$

b. Given: 2.00 g solute; acetone solvent; bp = 58.9°C; normal bp = 56.00°C; K_b = 1.71°C/m

Unknown: molality

$$\frac{\text{bp} - \text{normal bp}}{K_b} = \frac{58.9°\text{C} - 56.00°\text{C}}{1.71°\text{C}/m} = 1.7\ m$$

---

414. Given: fp = –22.0°C; 100.00 g glycerol solute

Unknown: mass of H_2O

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-22.0°\text{C} - 0.0°\text{C}}{-1.86°\text{C}/m} = 11.8\ m$$

$$100.00 \text{ g } C_3H_5(OH)_3 \times \frac{1 \text{ mol } C_3H_5(OH)_3}{92.11 \text{ g } C_3H_5(OH)_3} = 1.086 \text{ mol } C_3H_5(OH)_3$$

$$1.110 \text{ mol } C_3H_5(OH)_3 \times \frac{1 \text{ kg } H_2O}{11.8 \text{ mol } C_3H_5(OH)_3} \times \frac{1000 \text{ g}}{1 \text{ kg}} = 92.0 \text{ g } H_2O$$

---

415. Given: empirical formula is CH_2O; 0.515 g solute; 1.717 g acetic acid; fp = 8.8°C

Unknown: molar mass; molecular formula

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{8.8°\text{C} - 16.6°\text{C}}{-3.90°\text{C}/m} = 2.0\ m$$

$$\frac{2.0 \text{ mol}}{1.00 \text{ kg acetic acid}} \times 1.717 \text{ g acetic acid} \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.0034 \text{ mol}$$

$$\frac{0.515 \text{ g}}{0.0034 \text{ mol}} = 150 \text{ g/mol}$$

molar mass CH_2O = 30.03 g/mol

$$\frac{150 \text{ g/mol}}{30.03 \text{ g/mol}} = 5.0$$

molecular formula = $C_{1 \times 5}H_{2 \times 5}O_{1 \times 5} = C_5H_{10}O_5$

416. Given: empirical formula is C_2H_2O; 3.775 g solute; 12.00 g H_2O; fp = –4.72°C

Unknown: molar mass; molecular formula

$$m = \frac{\text{fp} - \text{normal fp}}{K_f} = \frac{-4.72°\text{C} - 0.00°\text{C}}{-1.86°\text{C}/m} = 2.54\ m$$

$$\frac{2.54 \text{ mol}}{1.00 \text{ kg } H_2O} \times 12.00 \text{ g } H_2O \times \frac{1 \text{ kg}}{1000 \text{ g}} = 0.0305 \text{ mol}$$

$$\frac{3.775 \text{ g}}{0.0305 \text{ mol}} = 124 \text{ g/mol}$$

molar mass C_2H_2O = 42.04 g/mol

$$\frac{124 \text{ g/mol}}{42.04 \text{ g/mol}} = 2.95 \approx 3$$

molecular formula = $C_{2 \times 3}H_{2 \times 3}O_{1 \times 3} = C_6H_6O_3$

---

417. Given: $[OH^-] = 6.4 \times 10^{-5}$ M

Unknown: $[H_3O^+]$

$[H_3O^+][OH^-] = 1.0 \times 10^{-4}\text{ M}^2$

$$\frac{1.0 \times 10^{-4}\text{ M}^2}{6.4 \times 10^{-5}\text{ M}} = 1.6 \times 10^{-10}\text{ M}$$

---

418. Given: 7.50×10^{-4} M HNO_3

Unknown: $[H_3O^+]$; $[OH^-]$

$$[H_3O^+] = 7.50 \times 10^{-4}\text{ M } HNO_3 \times \frac{1\text{ M } H_3O^+}{1\text{ M } HNO_3} = 7.50 \times 10^{-4}\text{ M}$$

$[H_3O^+][OH^-] = 1.00 \times 10^{-14}\text{ M}^2$

$$[OH^-] = \frac{1.00 \times 10^{-14}\text{ M}^2}{7.50 \times 10^{-4}\text{ M}} = 1.33 \times 10^{-11}\text{ M}$$

---

419. Given: 0.00118 M HBr

Unknown: pH

$\text{pH} = -\log[H_3O^+] = -\log(1.18 \times 10^{-3}) = 2.928$

---

420. **a.** Given: $[H_3O^+]$ = 1.0 M

Unknown: pH

$\text{pH} = -\log(1.0) = 0.0$

b. Given: 2.0 M HCl solution

Unknown: pH

$\text{pH} = -\log(2.0) = -0.30$

c. Given: 10. M HCl solution

Unknown: pH

$\text{pH} = -\log(10.) = -1.00$

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421. **a.** Given: $[OH^-] = 1 \times 10^{-5}$ M

Unknown: pH

$[H_3O^+][OH^-] = 1 \times 10^{-14}\text{ M}^2$

$$[H_3O^+] = \frac{1 \times 10^{-14}\text{ M}^2}{[OH^-]} = \frac{1. \times 10^{-14}\text{ M}^2}{1 \times 10^{-5}\text{ M}} = 1 \times 10^{-9}\text{ M}$$

$\text{pH} = -\log[H_3O^+] = -\log(1 \times 10^{-9}) = 9.0$

b. Given: $[OH^-] = 5 \times 10^{-8}$ M

Unknown: pH

$$[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$$

$$[H_3O^+] = \frac{1 \times 10^{-14}\ M^2}{[OH^-]} = \frac{1 \times 10^{-14}\ M^2}{5 \times 10^{-8}\ M} = 2 \times 10^{-7}\ M$$

$$pH = -\log [H_3O^+] = -\log (2 \times 10^{-7}) = 7 - 0.3 = 6.7$$

c. Given: $[OH^-] = 2.90 \times 10^{-11}$ M

Unknown: pH

$$[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$$

$$[H_3O^+] = \frac{1 \times 10^{-14}\ M^2}{[OH^-]} = \frac{1.00 \times 10^{-14}\ M^2}{2.90 \times 10^{-11}\ M} = 3.45 \times 10^{-4}\ M$$

$$pH = -\log [H_3O^+] = -\log (3.45 \times 10^{-4}) = 3.462$$

---

422. Given: pH = 8.92

Unknown: pOH; $(OH^-]$

$$pH + pOH = 14$$

$$pOH = 14.00 - pH = 14.00 - 8.92 = 5.08$$

$$[OH^-] = \text{antilog} (-pOH) = 1 \times 10^{-5.08} = 8.3 \times 10^{-6}\ M$$

---

423. a. Given: $[H_3O^+] = 2.51 \times 10^{-13}$ M

Unknown: pOH

$$[OH^-] = \frac{1.00 \times 10^{-14}\ M^2}{[H_3O^+]} = \frac{1.00 \times 1.0^{-14}\ M^2}{2.51 \times 10^{-13}\ M} = 3.98 \times 10^{-2}\ M$$

$$pOH = -\log [OH^-] = -\log (3.98 \times 10^{-2}) = 1.400$$

b. Given: $[H_3O^+] = 4.3 \times 10^{-3}$ M

Unknown: pOH

$$[OH^-] = \frac{1.0 \times 10^{-14}\ M^2}{[H_3O^+]} = \frac{1.0 \times 10^{-14}\ M^2}{4.3 \times 10^{-3}\ M} = 2.3 \times 10^{-12}\ M$$

$$pOH = -\log [OH^-] = -\log (2.3 \times 10^{-12}) = 11.64$$

c. Given: $[H_3O^+] = 9.1 \times 10^{-6}$ M

Unknown: pOH

$$[OH^-] = \frac{1.0 \times 10^{-14}\ M^2}{[H_3O^+]} = \frac{1.0 \times 10^{-14}\ M^2}{9.1 \times 10^{-6}\ M} = 1.1 \times 10^{-9}\ M$$

$$pOH = -\log [OH^-] = -\log (1.1 \times 10^{-9}) = 8.96$$

d. Given: $[H_3O^+] = 0.070$ M

Unknown: pOH

$$[OH^-] = \frac{1.0 \times 10^{-14}\ M^2}{[H_3O^+]} = \frac{1.0 \times 10^{-14}\ M^2}{7.0 \times 10^{-2}\ M} = 1.4 \times 10^{-13}\ M$$

$$pOH = -\log [OH^-] = -\log (1.4 \times 10^{-13}) = 12.85$$

---

424. Given: 3.50 g NaOH solute; V = 2.50 L

Unknown: $[OH^-]$; $[H_3O^+]$

$$3.50\ g\ NaOH \times \frac{1\ mol\ NaOH}{40.00\ g\ NaOH} = 0.0875\ mol\ NaOH$$

$$[OH^-] = \frac{0.0875\ mol}{2.50\ L} = 0.0350\ M$$

$$[H_3O^+] = \frac{1.00 \times 10^{-14}\ M^2}{[OH^-]} = \frac{1.00 \times 10^{-14}\ M^2}{3.50 \times 10^{-2}\ M} = 2.86 \times 10^{-13}\ M$$

---

425. Given: $V_1 = 1.00$ L ; $pH_1 = 12.90$; $V_2 = 2.00$ L

Unknown: pH_2

$$[H_3O^+] = \text{antilog} (-pH) = 1 \times 10^{-12.90} = 1.3 \times 10^{-13}\ M$$

$$M_2 = \frac{M_1V_1}{V_2} = \frac{1.3 \times 10^{-13}\ M \times 1.00\ L}{2.00\ L} = 6.5 \times 10^{-14}\ M$$

$$pH_2 = -\log [H_3O^+] = -\log (6.5 \times 10^{-14}) = 13.19$$

426. Unknown: $[H_3O^+]$; $[OH^-]$

a. Given: 0.05 M NaOH

$[OH^-] = 5 \times 10^{-2}$ M

$$[H_3O^+] = \frac{1 \times 10^{-14}\ M^2}{[OH^-]} = \frac{1 \times 10^{-14}\ M^2}{5 \times 10^{-2}\ M} = 2 \times 10^{-13}\ M$$

b. Given: 0.0025 M H_2SO_4

$$[H_3O^+] = 0.0025\ M\ H_2SO \times \frac{2\ M\ H_3O^+}{1\ M\ H_2SO_4} = 0.0050\ M = 5.0 \times 10^{-3}\ M$$

$$[OH^-] = \frac{1.0 \times 10^{-14}\ M^2}{[H_3O^+]} = \frac{1.0 \times 10^{-14}\ M^2}{5.0 \times 10^{-13}\ M} = 2.0 \times 10^{-12}\ M$$

c. Given: 0.013 M LiOH

$[OH–] = 1.3 \times 10^{-2}$ M

$$[H_3O^+] = \frac{1.0 \times 10^{-14}\ M^2}{1.3 \times 10^{-2}\ M} = 7.7 \times 10^{-13}\ M$$

d. Given: 0.150 M HNO_3

$[H_3O^+] = 1.50 \times 10^{-1}$ M

$$[OH^-] = \frac{1.00 \times 10^{-14}\ M^2}{1.50 \times 10^{-1}\ M} = 6.67 \times 10^{-14}\ M$$

e. Given: 0.0200 M Ca $(OH)_2$

$[OH^-] = 2[Ca(OH)_2] = 4.00 \times 10^{-2}$ M

$$[H_3O^+] = \frac{1.00 \times 10^{-14}\ M^2}{4.00 \times 10^{-2}\ M} = 2.50 \times 10^{-13}\ M$$

f. Given: 0.390 M $HClO_4$

$[H_3O^+] = 3.90 \times 10^{-1}$ M

$$[OH^-] = \frac{1.00 \times 10^{-14}\ M^2}{3.90 \times 10^{-1}\ M} = 2.56 \times 10^{-14}\ M$$

---

427. Unknown: pH

a. Given: $[H_3O^+] = 2 \times 10^{-13}$ M

pH = – log (2×10^{-13}) = 12.7

b. Given: $[H_3O^+] = 5.0 \times 10^{-3}$ M

pH = – log (5.0×10^{-3}) = 2.30

c. Given: $[H_3O^+] = 7.7 \times 10^{-13}$ M

pH = – log (7.7×10^{-13}) = 12.11

d. Given: $[H_3O^+] = 1.50 \times 10^{-1}$ M

pH = – log (1.50×10^{-1}) = 0.824

e. Given: $[H_3O^+] = 2.50 \times 10^{-13}$ M

pH = – log (2.50×10^{-13}) = 12.602

f. Given: $[H_3O^+] = 3.90 \times 10^{-1}$ M

pH = – log (3.90×10^{-1}) = 0.409

---

428. Given: 0.160 M KOH

Unknown: $[H_3O^+]$; $[OH^-]$

$[OH^-] = [KOH] = 1.60 \times 10^{-1}$ M

$$[H_3O^+] = \frac{1.00 \times 10^{-14}\ M^2}{1.60 \times 10^{-1}\ M} = 6.25 \times 10^{-14}\ M$$

429. Given: pH = 12.9; NaOH solution

Unknown: molarity

pOH = 14.0 – 12.9 = 1.1

$[NaOH] = [OH^-] = \text{antilog}(-\text{pOH}) = 1.0 \times 10^{-1.1} = 0.08\ M$

---

430. Given: 0.001 25 M HBr; V_1 = 175 mL; V_2 = 3.00 L; $M_1V_1 = M_2V_2$

Unknown: pH before and after dilution

$$M_2 = \frac{M_1V_1}{V_2} = \frac{0.001\,25\ M \times 175\ mL}{3.00\ L} \times \frac{1\ L}{1000\ mL} = 7.29 \times 10^{-5}\ M$$

$[HBr] = [H_3O^+]$

$pH_1 = -\log [H_3O^+] = -\log (1.25 \times 10^{-3}) = 2.903$

$pH_2 = -\log [H_3O^+] = -\log (7.29 \times 10^{-5}) = 4.137$

---

431. Given: NaOH solutions of 0.0001 M and 0.0005 M

Unknown: pH for both solutions

$[NaOH] = [OH^-] = 1 \times 10^{-4}\ M$; $pOH = -\log (1 \times 10^{-4}) = 4.0$

pH = 14.0 – 4.0 = 10.0

$[NaOH] = [OH^-] = 5 \times 10^{-4}\ M$; $pOH = -\log (5 \times 10^{-4}) = 3.3$

pH = 14.0 – 3.3 = 10.7

---

432. Given: V_1 = 15.0 mL; M_1 = 1.0 M HCl; V_2 = 20.0 mL; M_2 = 0.50 M HNO_3; V_F = 1.25 L

a. Unknown: $[H_3O^+]$ and $[OH^-]$ of final solution

$$\text{Before dilution: } 15.0\ mL \times \frac{1.0\ mol}{1\ L} \times \frac{1\ L}{1000\ mL} + 20.0\ mL \times \frac{0.50\ mol}{1\ L} \times \frac{1\ L}{1000\ mL} = 0.0150\ mol + 0.0100\ mol = 0.0250\ mol$$

$$[H_3O^+] = \frac{0.0250\ mol}{(15.0 + 20.0)\ mL} \times \frac{1000\ mL}{1\ L} = 0.714\ M$$

$$\text{After dilution: } [H_3O^+] = M_F = \frac{0.714\ M \times 0.035\ L}{1.25\ L} = 0.020\ M$$

$$[OH^-] = \frac{1.0 \times 10^{-14}\ M^2}{2.0 \times 10^{-2}\ M} = 5.0 \times 10^{-13}\ M$$

b. Unknown: pH of final solution

$pH = -\log [H_3O^+] = -\log (2.0 \times 10^{-2}) = 1.70$

---

433. **a.** Given: 0.001 57 M HNO_3

Unknown: pH

$[H_3O^+] = [HNO_3] = 1.57 \times 10^{-3}\ M$

$pH = -\log [H_3O^+] = -\log (1.57 \times 10^{-3}) = 2.804$

b. Given: V_1 = 500.0 mL; M_1 = 0.001 57 M; V_2 = 447.0 mL

Unknown: pH at V_2

$$M_2 = \frac{M_1V_1}{V_2} = \frac{1.57 \times 10^{-3}\ M \times 500.0\ mL}{447.0\ mL} = 1.76 \times 10^{-3}\ M$$

$pH = -\log [H_3O^+] = -\log (1.76 \times 10^{-3}) = 2.754$

---

434. Given: $[H_3O^+]$ = 0.00035 M

Unknown: $[OH^-]$

$$[OH^-] = \frac{1.0 \times 10^{-14}\ M^2}{3.5 \times 10^{-4}\ M} = 2.9 \times 10^{-11}\ M$$

435. Given: NaOH solute; $pH_1 = 12.14$; $V_1 = 50.00$ mL; $V_2 = 2.000$ L

Unknown: pH_2

$pOH_1 = 14.00 - pH = 14.00 - 12.14 = 1.86$

$[OH^-]_1 = \text{antilog}(-pOH) = 1.0 \times 10^{-1.86} = 1.4 \times 10^{-2}$ M

$$[OH^-]_2 = \frac{[OH^-]_1 V_1}{V_2} = \frac{1.4 \times 10^{-2}\text{ M} \times 50.00\text{ mL}}{2.000\text{ L}} \times \frac{1\text{ L}}{1000\text{ mL}} = 3.5 \times 10^{-4}\text{ M}$$

$pOH_2 = -\log(3.5 \times 10^{-4}) = 3.46$

$pH_2 = 14.00 - 3.46 = 10.54$

---

436. Given: pH = 4.0

Unknown: $[H_3O^+]$; $[OH^-]$

$[H_3O^+] = \text{antilog}(-pH) = \text{antilog}(-4.0) = 1 \times 10^{-4}$ M

$$[OH^-] = \frac{1 \times 10^{-14}\text{ M}^2}{1 \times 10^{-4}\text{ M}} = 1 \times 10^{-10}\text{ M}$$

---

437. Given: 0.000 460 M $Ca(OH)_2$ solution

Unknown: pH

$$[OH^-] = 4.60 \times 10^{-4}\text{ M } Ca(OH)_2 \times \frac{2\text{ M }OH^-}{1\text{ M }Ca(OH)_2} = 9.20 \times 10^{-4}\text{ M}$$

$$[H_3O^+] = \frac{1.00 \times 10^{-14}\text{ M}^2}{9.20 \times 10^{-4}\text{ M}} = 1.09 \times 10^{-11}\text{ M}$$

$pH = -\log(1.09 \times 10^{-11}) = 10.963$

---

438. Given: $Sr(OH)_2$ solute; pH = 11.4; 1.00 L

Unknown: mass $Sr(OH)_2$

$pOH = 14.0 - 11.4 = 2.6$

$[OH^-] = \text{antilog}(-pOH) = \text{antilog}(-2.6) = 10^{-2.6} = 3 \times 10^{-3}$ M

$$[Sr(OH)_2] = 3 \times 10^{-3}\text{ M }OH^- \times \frac{1\text{ M }Sr(OH)_2}{2\text{ M }OH^-} = 2 \times 10^{-3}\text{ M}$$

$$\frac{2 \times 10^{-3}\text{ mol}}{1\text{ L}} \times 1.00\text{ L} = 2 \times 10^{-3}\text{ mol}$$

$$2 \times 10^{-3}\text{ mol }Sr(OH)_2 \times \frac{121.64\text{ g }Sr(OH)_2}{1\text{ mol }Sr(OH)_2} = 0.2\text{ g }Sr(OH)_2$$

---

439. Given: NH_3 solute; pH = 11.00

Unknown: $[H_3O^+]$; $[OH^-]$

$[H_3O^+] = \text{antilog}(-11.00) = 1.0 \times 10^{-11}$ M

$$[OH^-] = \frac{1.0 \times 10^{-14}\text{ M}^2}{1.0 \times 10^{-11}\text{ M}} = 1.0 \times 10^{-3}\text{ M}$$

---

440. **a.** Given: 1.0 M CH_3COOH; pH = 2.40

Unknown: percent ionization

$[H_3O^+] = \text{antilog}(-2.40) = 1.00 \times 10^{-2.40} = 3.98 \times 10^{-3}$ 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; pH = 2.90

Unknown: percent ionization

$[H_3O^+] = \text{antilog}(-2.90) = 1.00 \times 10^{-2.90} = 1.26 \times 10^{-3}$ 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; pH = 3.40

Unknown: percent ionization

$[H_3O^+] = \text{antilog}(-3.40) = 1.00 \times 10^{-3.40} = 3.98 \times 10^{-4}$ 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 HNO_3; 2.00 L

Unknown: pH

$$5.00 \text{ g } HNO_3 \times \frac{1 \text{ mol } HNO_3}{63.02 \text{ g } HNO_3} = 0.0793 \text{ mol } HNO_3$$

$$[H_3O^+] = [HNO_3] = \frac{0.0793 \text{ mol}}{2.00 \text{ L}} = 0.0396 \text{ M}$$

$$pH = -\log(0.0396) = 1.402$$

---

442. Given: stock pH = 1.50; HCl solute

Unknown: pH of diluted solution

$$M_S = [H_3O^+] = [HCl] = \text{antilog}(-1.50) = 1.0 \times 10^{-1.50} \text{ M} = 3.16 \times 10^{-2} \text{ M}$$

a. Given: V_S = 1.00 mL; V_D = 1000. mL

$$M_D = \frac{M_S V_S}{V_D} = \frac{3.16 \times 10^{-2} \text{ M} \times 1.00 \text{ mL}}{1000. \text{ mL}} = 3.16 \times 10^{-5} \text{ M}$$

$$pH = -\log(3.16 \times 10^{-5}) = 4.50$$

b. Given: V_S = 25.00 mL; V_D = 200. mL

$$M_D = \frac{M_S V_S}{V_D} = \frac{3.16 \times 10^{-2} \text{ M} \times 25.00 \text{ mL}}{200. \text{ mL}} = 3.95 \times 10^{-3} \text{ M}$$

$$pH = -\log(3.95 \times 10^{-3}) = 2.40$$

c. Given: V_S = 18.83 mL; V_D = 4.000 L

$$M_D = \frac{M_S V_S}{V_D} = \frac{3.16 \times 10^{-2} \text{ M} \times 18.83 \text{ mL}}{4.000 \text{ L}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.49 \times 10^{-4} \text{ M}$$

$$pH = -\log(1.49 \times 10^{-4}) = 3.83$$

d. Given: V_S = 1.50 L; V_D = 20.0 kL

$$M_D = \frac{M_S V_S}{V_D} = \frac{3.16 \times 10^{-2} \text{ M} \times 1.50 \text{ L}}{20.0 \text{ kL}} \times \frac{1 \text{ kL}}{1000 \text{ L}} = 2.37 \times 10^{-6} \text{ M}$$

$$pH = -\log(2.37 \times 10^{-6}) = 5.63$$

---

443. Given: $[H_3O^+]$ = 10 000 $[OH^-]$; aqueous solution

Unknown: $[H_3O^+]$; $[OH^-]$

$$[H_3O^+][OH^-] = 10\,000\,[OH^-][OH^-] = 1 \times 10^{-14} \text{ M}^2$$

$$[OH^-]^2 = \frac{1 \times 10^{-14} \text{ M}^2}{10^4} = 1 \times 10^{-18} \text{ M}^2$$

$$[OH^-] = 1 \times 10^{-9} \text{ M}$$

$$[H_3O^+] = 10^4\,[OH^-] = 10^4 \times 1 \times 10^{-9} \text{ M} = 1 \times 10^{-5}$$

---

444. Given: KOH solute; pH = 12.90; acid reacts with half of OH^-

Unknown: resulting pH

$$pOH = 14.00 - pH = 14.00 - 12.90 = 1.10$$

$$[OH^-] = \text{antilog}(-1.10) = 1.0 \times 10^{-1.10} = 0.079 \text{ M}$$

after reaction:

$$[OH^-] = \frac{0.079 \text{ M}}{2} = 0.040 \text{ M}$$

$$[H_3O^+] = \frac{1.0 \times 10^{-14} \text{ M}^2}{4.0 \times 10^2 \text{ M}} = 2.5 \times 10^{-13} \text{ M}$$

$$pH = -\log(2.5 \times 10^{-13}) = 12.60$$

---

445. Given: HCl solute; pH = 1.70

Unknown: $[H_3O^+]$; $[HCl]$

$$[H_3O^+] = \text{antilog}(-1.70) = 1.0 \times 10^{-1.70} = 0.020 \text{ M}$$

$$[HCl] = [H_3O^+] = 0.020 \text{ M}$$

446. Given: $Ca(OH)_2$ solute: pH = 10.80

Unknown: molarity

pOH = 14.00 – pH = 14.00 – 10.80 = 3.20

$[OH^-] = \text{antilog}\ (-3.20) = 1.0 \times 10^{-3.20} = 6.3 \times 10^{-4}\ M$

$$[Ca(OH)_2] = 6.3 \times 10^{-4}\ M\ OH^- \times \frac{1\ M\ Ca(OH)_2}{2\ M\ OH^-} = 3.2 \times 10^{-4}\ M$$

---

447. Given: 1.00 M stock HCl

Unknown: pH

$pH = -\log(1.00 \times 10^0) = 0.000$

Given: pH = 4.00; 1.00 L stock HCl

Unknown: V_D

$[H_3O^+] = \text{antilog}\ (-4.00) = 1.0 \times 10^{-4.00} = 1.0 \times 10^{-4}\ M$

$$V_D = \frac{M_S V_S}{M_D} = \frac{1.00\ M \times 1.00\ L}{1.0 \times 10^{-4}\ M} = 1.0 \times 10^{4.}\ L = 10.\ kL$$

Given: 1.00 L of pH 4.00

Unknown: V at pH 6.00

$[H_3O^+]$ at pH 4.00 = 1.0×10^{-4} M

$[H_3O^+]$ at pH 6.00 = antilog (–6.00) = $1.0 \times 10^{-6.00} = 1.0 \times 10^{-6}$ M

$$V = \frac{1.0 \times 10^{-4}\ M \times 1.00\ L}{1.0 \times 10^{-6}\ M} = 1.0 \times 10^2\ L$$

Given: 1.00 L of pH 4.00

Unknown: V at pH 8.00

$[H_3O^+]$ at pH 4.00 = 1.00×10^{-4} M

$[H_3O^+]$ at pH 8.00 = antilog (–8.00) = $1.0 \times 10^{-8.00} = 1.0 \times 10^{-8}$ M

$$V = \frac{1.0 \times 10^{-4}\ M \times 1.00\ L}{1.0 \times 10^{-8}\ M} = 1.0 \times 10^4\ L = 10.\ kL$$

---

448. Given: pH = 1.28; 1.00 L $HClO_3$

Unknown: moles NaOH to react; mass NaOH

$HClO_3 + NaOH \rightarrow NaClO_3 + H_2O$

$[H_3O^+] = \text{antilog}\ (-1.28) = 1.0 \times 10^{-1.28} = 5.2 \times 10^{-2}\ M$

$$\frac{5.2 \times 10^{-2}\ mol}{1.0\ L} \times 1.00\ L\ HClO_3 = 5.2 \times 10^{-2}\ mol\ HClO_3$$

$= 5.2 \times 10^{-2}$ mol NaOH

$$0.052\ mol\ NaOH \times \frac{40.00\ g\ NaOH}{1.0\ mol\ NaOH} = 2.1\ g\ NaOH$$

---

449. Given: NH_3 solute; pH = 11.90; 1.00 L NH_3 solution

Unknown: moles HCl to react

pOH = 14.00 – 11.90 = 2.10

$[OH^-] = \text{antilog}\ (-2.10) = 1.0 \times 10^{-2.10} = 7.9 \times 10^{-3}\ M$

$$\frac{7.9 \times 10^{-3}\ mol}{1.0\ L} \times 1.00\ L = 7.9 \times 10^{-3}\ mol\ OH^- = 7.9 \times 10^{-3}\ mol\ HCl$$

---

450. Given: pH = 3.15

Unknown: $[H_3O^+]$; $[OH^-]$

$[H_3O^+] = \text{antilog}\ (-3.15) = 1.0 \times 10^{-3.15} = 7.1 \times 10^{-4}\ M$

$$[OH^-] = \frac{1.0 \times 10^{-14}\ M^2}{7.1 \times 10^{-4}\ M} = 1.4 \times 10^{-11}\ M$$

451. Given: 20.00 mL HBr; 20.05 mL of 0.1819 M NaOH

Unknown: molarity HBr

$HBr + NaOH \rightarrow NaBr + H_2O$

$$\frac{0.1819 \text{ mol NaOH}}{\text{L}} \times 20.05 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 3.647 \times 10^{-3} \text{ mol NaOH}$$

$$3.647 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol HBr}}{1 \text{ mol NaOH}} = 3.647 \times 10^{-3} \text{ mol HBr}$$

$$\frac{3.647 \times 10^{-3} \text{ mol HBr}}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.1824 \text{ M HBr}$$

---

452. Given: 15.00 mL CH_3COOH; 22.70 mL of 0.550 M NaOH

Unknown: molarity of CH_3COOH

$CH_3COOH + NaOH \rightarrow NaCH_3COO + H_2O$

$$\frac{0.550 \text{ mol NaOH}}{\text{L}} \times 22.70 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.25 \times 10^{-2} \text{ mol NaOH}$$

$$1.25 \times 10^{-2} \text{ mol NaOH} \times \frac{1 \text{ mol } CH_3COOH}{1 \text{ mol NaOH}} = 1.25 \times 10^{-2} \text{ mol } CH_3COOH$$

$$\frac{1.25 \times 10^{-2} \text{ mol } CH_3COOH}{15.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.833 \text{ M } CH_3COOH$$

---

453. Given: 20.00 mL $Sr(OH)_2$; 43.03 mL of 0.1159 M HCl

Unknown: molarity of $Sr(OH)_2$ solution

$Sr(OH)_2 + 2HCl \rightarrow SrCl_2 + 2H_2O$

$$\frac{0.1159 \text{ mol HCl}}{\text{L}} \times 43.03 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 4.987 \times 10^{-3} \text{ mol HCl}$$

$$4.987 \times 10^{-3} \text{ mol HCl} \times \frac{1 \text{ mol } Sr(OH)_2}{2 \text{ mol HCl}} = 2.494 \times 10^{-3} \text{ mol } Sr(OH)_2$$

$$\frac{2.494 \times 10^{-3} \text{ mol } Sr(OH)_2}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.1247 \text{ M } Sr(OH)_2$$

---

454. Given: 35.00 mL NH_3 solution; 54.95 mL of 0.400 M H_2SO_4

Unknown: molarity of NH_3 solution

$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

$$\frac{0.400 \text{ mol } H_2SO_4}{\text{L}} \times 54.95 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.20 \times 10^{-2} \text{ mol } H_2SO_4$$

$$2.20 \times 10^{-2} \text{ mol } H_2SO_4 \times \frac{2 \text{ mol } NH_3}{1 \text{ mol } H_2SO_4} = 4.40 \times 10^{-2} \text{ mol } NH_3$$

$$\frac{4.40 \times 10^{-2} \text{ mol } NH_3}{35.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1.26 \text{ M } NH_3$$

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

$CH_3COOH + NaOH \rightarrow NaCH_3COO + H_2O$

$$\frac{0.218 \text{ mol NaOH}}{\text{L}} \times 28.25 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 6.16 \times 10^{-3} \text{ mol NaOH}$$

$$6.16 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol } CH_3COOH}{1 \text{ mol NaOH}} = 6.16 \times 10^{-3} \text{ mol } CH_3COOH$$

$$\frac{6.16 \times 10^{-3} \text{ mol } CH_3COOH}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.308 \text{ M } CH_3COOH$$

$$\frac{2.000 \text{ g } CH_3COOH}{100.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1 \text{ mol } CH_3COOH}{60.06 \text{ g } CH_3COOH}$$

$$= 0.3333 \text{ M } CH_3COOH$$

$$\frac{0.308 \text{ M}}{0.3333 \text{ M}} \times 100 = 92.5\% \ CH_3COOH$$

---

456. Given: 9.709 g Na_2CO_3 diluted to 1.0000 L; 10.00 mL Na_2CO_3 solution; 16.90 mL of 0.1022 M HCl

Unknown: percentage of Na_2CO_3

$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$

$$\frac{0.1022 \text{ mol HCl}}{\text{L}} \times 16.90 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.727 \times 10^{-3} \text{ mol HCl}$$

$$1.727 \times 10^{-3} \text{ mol HCl} \times \frac{1 \text{ mol } Na_2CO_3}{2 \text{ mol HCl}} = 8.635 \times 10^{-4} \text{ mol } Na_2CO_3$$

$$\frac{8.635 \times 10^{-4} \text{ mol } Na_2CO_3}{10.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 8.635 \times 10^{-2} \text{ M } Na_2CO_3$$

$$\frac{9.709 \text{ g } Na_2CO_3}{1.0000 \text{ L}} \times \frac{1 \text{ mol } Na_2CO_3}{105.99 \text{ g } Na_2CO_3} = 9.160 \times 10^{-2} \text{ M } Na_2CO_3$$

$$\frac{8.635 \times 10^{-2} \text{ M } Na_2CO_3}{9.160 \times 10^{-2} \text{ M } Na_2CO_3} \times 100 = 94.27\% \ Na_2CO_3$$

---

457. Given: 50.00 mL KOH; 27.87 mL of 0.8186 M HCl

Unknown: molarity of KOH

$KOH + HCl \rightarrow KCl + H_2O$

$$\frac{0.8186 \text{ mol HCl}}{\text{L}} \times 27.87 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.281 \times 10^{-2} \text{ mol HCl}$$

$$2.281 \times 10^{-2} \text{ mol HCl} \times \frac{1 \text{ mol KOH}}{1 \text{ mol HCl}} = 2.281 \times 10^{-2} \text{ mol KOH}$$

$$\frac{2.281 \times 10^{-2} \text{ mol KOH}}{50.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.4562 \text{ M KOH}$$

---

458. Given: 15.00 mL CH_3COOH; 34.13 mL of 0.9940 M NaOH

Unknown: molarity of CH_3COOH

$CH_3COOH + NaOH \rightarrow NaCH_3COO + H_2O$

$$\frac{0.9940 \text{ mol NaOH}}{\text{L}} \times 34.13 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 3.393 \times 10^{-2} \text{ mol NaOH}$$

$$3.393 \times 10^{-2} \text{ mol NaOH} \times \frac{1 \text{ mol } CH_3COOH}{1 \text{ mol NaOH}}$$

$$= 3.393 \times 10^{-2} \text{ mol } CH_3COOH$$

$$\frac{3.393 \times 10^{-2} \text{ mol } CH_3COOH}{15.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 2.262 \text{ M } CH_3COOH$$

459. Given: 12.00 mL NH_3 solution; 19.48 mL of 1.499 M HNO_3

Unknown: molarity of NH_3 solution

$NH_3 + HNO_3 \rightarrow NH_4NO_3$

$$\frac{1.499 \text{ mol } HNO_3}{\text{L}} \times 19.48 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.920 \times 10^{-2} \text{ mol } HNO_3$$

$$2.920 \times 10^{-2} \text{ mol } HNO_3 \times \frac{1 \text{ mol } NH_3}{1 \text{ mol } HNO_3} = 2.920 \times 10^{-2} \text{ mol } NH_3$$

$$\frac{2.920 \times 10^{-2} \text{ mol } NH_3}{12.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 2.433 \text{ M } NH_3$$

---

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

$M_A \times V_A = M_B \times 20.00$ mL

$2M_B \times V_A = M_B \times 20.00$ 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

$M_A \times V_A = M_B \times 20.00$ mL

$M_A \times V_A = 4M_A \times 20.00$ 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

$HF + NaOH \rightarrow NaF + H_2O$

$$\frac{0.1500 \text{ mol NaOH}}{\text{L}} \times 13.51 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.026 \times 10^{-3} \text{ mol NaOH}$$

$$2.026 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol HF}}{1 \text{ mol NaOH}} = 2.026 \times 10^{-3} \text{ mol HF}$$

$$\frac{2.026 \times 10^{-3} \text{ mol HF}}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.1013 \text{ M HF}$$

$$\frac{0.1013 \text{ mol HF}}{\text{L}} \times 500.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.05065 \text{ mol HF}$$

$$\frac{0.05065 \text{ mol HF}}{10.00 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 5.065 \text{ M HF}$$

---

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_2SO_4

Unknown: molarity of the H_2SO_4

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

$$\frac{1.209 \text{ mol NaOH}}{\text{L}} \times 42.27 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 5.110 \times 10^{-2} \text{ mol NaOH}$$

$$5.110 \times 10^{-2} \text{ mol NaOH} \times \frac{1 \text{ mol } H_2SO_4}{2 \text{ mol NaOH}} = 2.555 \times 10^{-2} \text{ mol } H_2SO_4$$

$$\frac{2.555 \times 10^{-2} \text{ mol } H_2SO_4}{25.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1.022 \text{ M } H_2SO_4$$

---

464. Given: 1 mol acid: 1 mol base; 0.7025 g $KHC_8H_4O_4$; 20.18 mL KOH

Unknown: molarity of KOH

$$0.7025 \text{ g } KHC_8H_4O_4 \times \frac{1 \text{ mol } KHC_8H_4O_4}{204.23 \text{ g } KHC_8H_4O_4}$$

$$= 3.440 \times 10^{-3} \text{ mol } KHC_8H_4O_4$$

$$3.440 \times 10^{-3} \text{ mol } KHC_8H_4O_4 \times \frac{1 \text{ mol KOH}}{1 \text{ mol } KHC_8H_4O_4} = 3.440 \times 10^{-3} \text{ mol KOH}$$

$$\frac{3.440 \times 10^{-3} \text{ mol KOH}}{20.18 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.1705 \text{ M KOH}$$

---

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

$KOH + HNO_3 \rightarrow KNO_3 + H_2O$

$$\frac{0.6515 \text{ mol } HNO_3}{\text{L}} \times 21.65 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.410 \times 10^{-2} \text{ mol } HNO_3$$

$$1.410 \times 10^{-2} \text{ mol } HNO_3 \times \frac{1 \text{ mol KOH}}{1 \text{ mol } HNO_3} = 1.410 \times 10^{-2} \text{ mol KOH}$$

$$\frac{1.410 \times 10^{-2} \text{ mol KOH}}{41.04 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.3436 \text{ M KOH}$$

---

467. Given: 20.00 mL of 2.00 M H_2SO_4; 1.85 M NaOH

Unknown: *V* of NaOH

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

$$\frac{2.00 \text{ mol } H_2SO_4}{\text{L}} \times 20.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 4.00 \times 10^{-2} \text{ mol } H_2SO_4$$

$$4.00 \times 10^{-2} \text{ mol } H_2SO_4 \times \frac{2 \text{ mol NaOH}}{1 \text{ mol } H_2SO_4} = 8.00 \times 10^{-2} \text{ mol NaOH}$$

$$\frac{8.00 \times 10^{-2} \text{ mol NaOH}}{1.85 \text{ mol/L}} = 0.0432 \text{ L NaOH} = 43.2 \text{ mL NaOH}$$

468. Given: 0.5200 M H_2SO_4; 100.00 mL of 0.1225 M $Sr(OH)_2$

Unknown: V of H_2SO_4

$H_2SO_4 + Sr(OH)_2 \rightarrow SrSO_4 + 2H_2O$

$$\frac{0.1225 \text{ mol } Sr(OH)_2}{\text{L}} \times 100.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.225 \times 10^{-2} \text{ mol } Sr(OH)_2$$

$$1.225 \times 10^{-2} \text{ mol } Sr(OH)_2 \times \frac{1 \text{ mol } H_2SO_4}{1 \text{ mol } Sr(OH)_2} = 1.225 \times 10^{-2} \text{ mol } H_2SO_4$$

$$\frac{1.225 \times 10^{-2} \text{ mol } H_2SO_4}{0.5200 \text{ mol/L}} = 0.02356 \text{ L } H_2SO_4 = 23.56 \text{ mL } H_2SO_4$$

---

469. Given: 4.005 g KOH in 200.00 mL solution; 25.00 mL KOH; 19.93 mL of 0.4388 M HCl

Unknown: moles KOH in 4.005 g; mass KOH; percent KOH

$KOH + HCl \rightarrow KCl + H_2O$

$$\frac{0.4388 \text{ mol HCl}}{\text{L}} \times 19.93 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 8.745 \times 10^{-3} \text{ mol HCl}$$

$$8.745 \times 10^{-3} \text{ mol HCl} \times \frac{1 \text{ mol KOH}}{1 \text{ mol HCl}} = 8.745 \times 10^{-3} \text{ mol KOH in 25.00 mL}$$

$$8.745 \times 10^{-3} \text{ mol KOH} \times \frac{200.00 \text{ mL}}{25.00 \text{ mL}} = 6.996 \times 10^{-2} \text{ mol KOH}$$

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

Unknown: mass of $Mg(OH)_2$ to react

$Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$

$$\frac{3.18 \text{ mol HCl}}{\text{L}} \times 558 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.77 \text{ mol HCl}$$

$$1.77 \text{ mol HCl} \times \frac{1 \text{ mol } Mg(OH)_2}{2 \text{ mol HCl}} = 0.885 \text{ mol } Mg(OH)_2$$

$$0.885 \text{ mol } Mg(OH)_2 \times \frac{58.32 \text{ g } Mg(OH)_2}{1 \text{ mol } Mg(OH)_2} = 51.6 \text{ g } Mg(OH)_2$$

---

471. Given: 12.61 mL NH_3 solution; 5.19 mL of 1.25 M HCl

Unknown: molarity of NH_3 solution

$$\frac{1.25 \text{ mol HCl}}{\text{L}} \times 5.19 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 6.49 \times 10^{-3} \text{ mol HCl}$$

$$6.49 \times 10^{-3} \text{ mol HCl} \times \frac{1 \text{ mol } NH_3}{1 \text{ mol HCl}} = 6.49 \times 10^{-3} \text{ mol } NH_3$$

$$\frac{6.49 \times 10^{-3} \text{ mol } NH_3}{12.61 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.515 \text{ M } NH_3$$

---

472. Given: 5.090 g sample of 92.10% NaOH; 2.811 M diprotic acid

Unknown: V of acid

$$5.090 \text{ g NaOH} \times 0.9210 = 4.688 \text{ g NaOH}$$

$$4.688 \text{ g NaOH} \times \frac{1 \text{ mol NaOH}}{40.00 \text{ g NaOH}} \times \frac{1 \text{ mol acid}}{2 \text{ mol NaOH}} = 0.05860 \text{ mol acid}$$

$$\frac{0.05860 \text{ mol acid}}{2.811 \text{ mol/L}} = 0.02085 \text{ L acid} = 20.85 \text{ mL acid}$$

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

$Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$

$$\frac{0.1529 \text{ mol } Ba(OH)_2}{\text{L}} \times 43.09 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 6.588 \times 10^{-3} \text{ mol } Ba(OH)_2$$

$$6.588 \times 10^{-3} \text{ mol } Ba(OH)_2 \times \frac{2 \text{ mol HCl}}{1 \text{ mol } Ba(OH)_2} = 1.318 \times 10^{-2} \text{ mol HCl}$$

$$\frac{1.318 \times 10^{-2} \text{ mol HCl}}{26.06 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.5058 \text{ M HCl}$$

b. Unknown: molarity of RbOH

$HCl + RbOH \rightarrow RbCl + H_2O$

$$\frac{0.5058 \text{ mol HCl}}{\text{L}} \times 27.05 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.368 \times 10^{-2} \text{ mol HCl}$$

$$1.368 \times 10^{-2} \text{ mol HCl} \times \frac{1 \text{ mol RbOH}}{1 \text{ mol HCl}} = 1.368 \times 10^{-2} \text{ mol RbOH}$$

$$\frac{1.368 \times 10^{-2} \text{ mol RbOH}}{15.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.9120 \text{ M RbOH}$$

---

474. Given: 2800 kg of 6.0 M HCl; D_{HCl} = 1.10 g/mL

Unknown: mass $Ca(OH)_2$

$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$

$$2800 \text{ kg HCl} \times \frac{1 \text{ mL}}{1.10 \text{ g}} \times \frac{1000 \text{ g}}{1 \text{ kg}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2500 \text{ L HCl}$$

$$\frac{6.0 \text{ mol HCl}}{\text{L}} \times 2500 \text{ L} = 1.5 \times 10^{4} \text{ mol HCl}$$

$$1.5 \times 10^{4} \text{ mol HCl} \times \frac{1 \text{ mol } Ca(OH)_2}{2 \text{ mol HCl}} = 7.5 \times 10^{3} \text{ mol } Ca(OH)_2$$

$$7.5 \times 10^{3} \text{ mol } Ca(OH)_2 \times \frac{74.10 \text{ g } Ca(OH)_2}{1 \text{ mol } Ca(OH)_2} = 5.6 \times 10^{5} \text{ g } Ca(OH)_2$$

$$= 560 \text{ kg } Ca(OH)_2$$

---

475. Given: 1.00 mL HNO_3 diluted to 200.00 mL; 10.00 mL of diluted HNO_3; 23.94 mL of 0.0177 M $Ba(OH)_2$

Unknown: molarity of original HNO_3

$Ba(OH)_2 + 2HNO_3 \rightarrow Ba(NO_3)_2 + 2H_2O$

$$\frac{0.0177 \text{ mol } Ba(OH)_2}{\text{L}} \times 23.94 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 4.24 \times 10^{-4} \text{ mol } Ba(OH)_2$$

$$4.24 \times 10^{-4} \text{ mol } Ba(OH)_2 \times \frac{2 \text{ mol } HNO_3}{1 \text{ mol } Ba(OH)_2} = 8.48 \times 10^{-4} \text{ mol } HNO_3$$

$$\frac{8.48 \times 10^{-4} \text{ mol } HNO_3}{10.00 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 8.48 \times 10^{-2} \text{ M } HNO_3$$

$$\frac{8.48 \times 10^{-2} \text{ mol } HNO_3}{1 \text{ L}} \times 200.00 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 1.70 \times 10^{-2} \text{ mol } HNO_3$$

$$\frac{1.70 \times 10^{-2} \text{ mol } HNO_3}{1.00 \text{ mL}} \times \frac{1000 \text{ mL}}{\text{L}} = 17.0 \text{ M } HNO_3$$

476. Given: 4.494 M H_2SO_4; 7.2280 g LiOH

Unknown: V of H_2SO_4

$H_2SO_4 + 2LiOH \rightarrow Li_2SO_4 + 2H_2O$

$$7.2280 \text{ g LiOH} \times \frac{1 \text{ mol LiOH}}{23.95 \text{ g LiOH}} = 0.3018 \text{ mol LiOH}$$

$$0.3018 \text{ mol LiOH} \times \frac{1 \text{ mol } H_2SO_4}{2 \text{ mol LiOH}} = 0.1509 \text{ mol } H_2SO_4$$

$$\frac{0.1509 \text{ mol } H_2SO_4}{4.494 \text{ mol/L}} = 0.03358 \text{ L } H_2SO_4 = 33.58 \text{ mL } H_2SO_4$$

---

477. Given: $5CO_2(g) + Si_3N_4(s) \rightarrow 3SiO(s) + 2N_2O(g) + 5CO(g)$

Unknown: reaction enthalpy for the given reaction

(1) $CO(g) + SiO_2(s) \rightarrow SiO(g) + CO_2(g)$

(2) $8CO_2(g) + Si_3N_4(s) \rightarrow 3SiO_2(s) + 2N_2O(g) + 8CO(g)$

$\Delta H_{reaction\ 1} = +520.9$ kJ

$\Delta H_{reaction\ 2} = +461.05$ kJ

$3[CO(g) + SiO_2(s) \rightarrow SiO(g) + CO_2(g)]$ $\quad \Delta H = 3(+520.9) = +1562.7$ kJ

$8CO_2(g) + Si_3N_4(s) \rightarrow 3SiO_2(g) + 2N_2O(g) + 8CO(g)$ $\quad \Delta H = +461.05$ kJ

$5CO_2(g) + Si_3N_4(s) \rightarrow 3SiO(s) + 2N_2O(g) + 5CO(g)$

$\Delta H = 2024$ kJ

---

478. Given: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Unknown: ΔH

$CaCO_3(s) \rightarrow Ca(s) + C(s) + \frac{3}{2}O_2(g)$ $\quad \Delta H = 1207.6$ kJ/mol

$Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$ $\quad \Delta H = -634.9$ kJ/mol

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H = -393.5$ kJ/mol

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ $\quad \Delta H = 179.2$ kJ/mol

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479. Given: $2FeO(s) + O_2(g) \rightarrow Fe_2O_3(s)$

Unknown: ΔH

$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$ $\quad \Delta H = -1118.4$ kJ/mol

$2[2FeO(s) \rightarrow 2Fe(s) + O_2(g)]$ $\quad \Delta H = 2(+825.5) = +1651.0$

$4FeO(s) + O_2(g) \rightarrow 2Fe_2O_3(s)$ $\quad \Delta H = 533$ kJ/mol

---

480. Given: $NH_3(g) + HF(g) \rightarrow NH_4F(s)$

Unknown: ΔH

$NH_3(g) \rightarrow N(g) + \frac{3}{2}H_2(g)$ $\quad \Delta H = 45.9$ kJ/mol

$HF(g) \rightarrow \frac{1}{2}H_2(g) + F(s)$ $\quad \Delta H = 273.3$ kJ/mol

$N(g) + 2\ H_2(g) + F(s) \rightarrow NH_4F(s)$ $\quad \Delta H = -125$ kJ/mol

$NH_3(g) + HF(g) \rightarrow NH_4F(s)$ $\quad \Delta H = 194$ kJ/mol

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481. Given: $H_2S(g) + O_2(g) \rightarrow H_2O(l) + SO_2(g)$
$\Delta H_{reaction} = -562.1$ kJ/mol
$\Delta S_{reaction} = -0.092\ 78$ kJ/mol • K
$T = 25°C = 298$ K

Unknown: ΔG

$\Delta G = \Delta H - T\Delta S$

$= -562.1 \text{ kJ/mol} - [(298 \text{ K})(-0.092\ 78 \text{ kJ/mol} \bullet \text{K})]$

$= -534.5$ kJ/mol

482. Given: $NaClO_3(s) \rightarrow NaCl(s) + O_2(g)$
$\Delta H_{reaction} = -19.1$ kJ/mol
$\Delta S_{reaction} = 0.1768$ kJ/mol • K
$T = 25°C = 298$ K

Unknown: ΔG

$\Delta G = \Delta H - T\Delta S$

$= -19.1$ kJ/mol $-$ [(298 K)(0.1768 kJ/mol • K)]

$= -71.8$ kJ/mol

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483. Given: $C_2H_6(g) + O_2(g) \rightarrow 2CO_2(g) + 3\ H_2O(l)$
$\Delta H_{reaction} = -1561$ kJ/mol
$\Delta S_{reaction} = -1.4084$ kJ/mol • K
$T = 25°C = 298$ K

Unknown: ΔG for combustion of 1 mole of C_2H_6

$\Delta G = \Delta H - T\Delta S$

$= -1561$ kJ/mol $-$ [(298 K)(-0.4084 kJ/mol • K)]

$= -1683$ kJ/mol

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484. Given: $F_2(g) + H_2O(l) \rightarrow 2HF(g) + O_2(g)$

Unknown: ΔH

$2[H_2 + F_2 \rightarrow 2\ HF]$ $\quad \Delta H = 2(-273.3) = -546.6$ kJ/mol

$2H_2O \rightarrow 2H_2 + O_2$ $\quad \Delta H = +285.8$

$2F_2(g) + 2H_2O(l) \rightarrow 4HF(g) + O_2(g)$ $\quad \Delta H = -260.8$ kJ/mol

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485. Given: $CaO(s) + SO_3(g) \rightarrow CaSO_4(s)$
$H_2O(l) + SO_3(g) \rightarrow H_2SO_4(l)$ $\Delta H = -132.5$ kJ/mol
$H_2SO_4(l) + Ca(g) \rightarrow CaSO_4(s) + H_2(g)$ $\Delta H = -602.5$ kJ/mol
$Ca(s) + O_2(g) \rightarrow CaO(s)$ $\Delta H = -634.9$ kJ/mol
$H_2(g) + O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$ kJ/mol

Unknown: ΔH for reaction of CaO + SO_3

$CaO(s) \rightarrow Ca(s) + \frac{1}{2}O_2(g)$ $\quad \Delta H = +634.9$ kJ/mol

$H_2O(l) + SO_3(g) \rightarrow H_2SO_4(l)$ $\quad \Delta H = -132.5$ kJ/mol

$H_2SO_4(l) + Ca(s) \rightarrow CaSO_4(s) + H_2(g)$ $\quad \Delta H = -602.5$ kJ/mol

$H_2 + \frac{1}{2}O_2 \rightarrow H_2O(l)$ $\quad \Delta H = -285.8$ kJ/mol

$CaO(s) + SO_3(g) \rightarrow CaSO_4(s)$ $\quad \Delta H = -385.9$ kJ/mol

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486. Given: $Na_2O(s) + SO_2(g) \rightarrow Na_2SO_3(s)$

Unknown: ΔH

$Na_2O(s) \rightarrow 2Na(s) + \frac{1}{2}O_2(g)$ $\quad \Delta H = +414.2$ kJ/mol

$SO_2(g) \rightarrow S(s) + O_2(g)$ $\quad \Delta H = +296.8$ kJ/mol

$2Na(s) + S(s) + \frac{3}{2}O_2(g) \rightarrow Na_2SO_3(s)$ $\quad \Delta H = -1101$ kJ/mol

$Na_2O(s) + SO_2(g) \rightarrow Na_2SO_3(s)$ $\quad \Delta H = -390.$ kJ/mol

487. Given: $C_4H_9OH(l) + O_2(g) \rightarrow C_3H_7COOH(l) + H_2O(l)$; $C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$ $\Delta H_c = -2675.9$ kJ/mol; $C_3H_7COOH(l) + 5O_2(g) \rightarrow 4CO_2(g) + 4H_2O(l)$ $\Delta H_c = -2183.6$ kJ/mol

Unknown: ΔH for oxidation of C_4H_9OH to make C_3H_7COOH

$$C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l) \qquad \Delta H_c = -2675.9 \text{ kJ/mol}$$

$$4CO_2(g) + 4H_2O(l) \rightarrow C_3H_7COOH(l) + 5O_2(g) \qquad \Delta H_c = 2183.6 \text{ kJ/mol}$$

$$C_4H_9OH(l) + O_2(g) \rightarrow C_3H_7COOH(l) + H_2O(l) \qquad \Delta H = -492.3 \text{ kJ/mol}$$

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488. Given: $CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)$ $\Delta H = -128.5$ kJ/mol $\Delta S = -70.1$ J/mol•K $T = 25°C = 298$ K

Unknown ΔG

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta S = (-70.1 \text{ J/mol}\bullet\text{K})\left(\frac{\text{kJ}}{1000 \text{ J}}\right) = -0.0701 \text{ kJ/mol}\bullet\text{K}$$

$$\Delta G = -128.5 \text{ kJ/mol} - [(298 \text{ K})(-0.0701 \text{ kJ/mol}\bullet\text{K})]$$

$$= -107.6 \text{ kJ/mol}$$

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489. Given: $NaI(s) + Cl_2(g) \rightarrow NaCl(s) + I_2(l)$ $\Delta S = -79.9$ J/mol•K $\Delta G = -98.0$ kJ/mol $T = 25°C = 298$ K

Unknown: ΔH

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta H + \Delta G + T\Delta S$$

$$\Delta S = (-79.9 \text{ J/mol}\bullet\text{K})\left(\frac{\text{kJ}}{1000 \text{ J}}\right) = -0.0799 \text{ kJ/mol}\bullet\text{K}$$

$$\Delta H = -98.0 \text{ kJ/mol} + [(298 \text{ K})(-0.0799 \text{ kJ/mol}\bullet\text{K})] = -121.8 \text{ kJ/mol}$$

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490. Given: $4HBr(g) + MnO_2(s) \rightarrow MnBr_2(s) + 2H_2O(l) + Br_2(l)$ $\Delta H = -291.3$ kJ/mol; $T = 25°C = 298$ K $\Delta H^o_{f\,HBr} = -36.29$ kJ/mol $\Delta H^o_{f\,MnO_2} = -520.0$ kJ/mol $\Delta H^o_{f\,H_2O} = -285.8$ kJ/mol $\Delta H^o_{f\,Br_2} = 0.00$ kJ/mol

Unknown: ΔH^o_f of $MnBr_2(s) = x$

Net ΔH = [Sum of ΔH_f of products] – [Sum of ΔH_f of reactants]

$$-291.3 = \left[\Delta H_{f\,MnBr_2} + 2\,\Delta H_{f\,H_2O} + \Delta H_{f\,Br_2}\right] - \left[4\,\Delta H_{f\,HBr} + \Delta H_{f\,MnO_2}\right]$$

$$-291.3 = [x + (2)(-258.8) + (0)] - [(4)(-36.29) + (-520)]$$

$$-291.3 = x + 93.56$$

$$-291.3 - 93.56 = x = -384.9 \text{ kJ/mol}$$

491. Given: $CaC_2(s) + 2H_2O(l) \rightarrow C_2H_2(g) + Ca(OH)_2(s)$
$\Delta G = -147.7$ kJ/mol
$\Delta H = -125.6$ kJ/mol
$T = 25°C = 298$ K

Unknown: ΔS

$\Delta G = \Delta H - T\Delta S$

$\Delta S = (\Delta H - \Delta G)/T$
$= [-125.6 \text{ kJ/mol} - (-147.7 \text{ kJ/mol})]/298 \text{ K}$
$= 0.0742 \text{ kJ/mol}$

---

492. Given: $NH_4NO_3(s) \rightarrow N_2O(g) + 2H_2O(g)$
$\Delta S = 446.4$ J/mol•K
$T = 25°C = 298$ K

Unknown: ΔG

$2N(g) + \frac{1}{2}O_2(g) \rightarrow N_2O(g) \quad \Delta H = 82.1 \text{ kJ/mol}$

$2[H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)] \quad \Delta H = (2)(-241.82) = -483.64 \text{ kJ/mol}$

$2[H_2O(l) \rightarrow H_2(g) + \frac{1}{2}O_2(g)] \quad \Delta H = (2)(285.8) = 571.6 \text{ kJ/mol}$

$\underline{NH_4NO_3(s) \rightarrow N_2(g) + 2H_2O(l) + \frac{1}{2}O_2 \quad \Delta H = 365.56 \text{ kJ/mol}}$

$NH_4NO_3(s) \rightarrow N_2O(g) + 2H_2O(g) \quad \Delta H = -35.98 \text{ kJ/mol}$

$\Delta S = (446.4 \text{ J/mol•K})(\text{kJ/1000 J}) = 0.4464 \text{ kJ/mol•K}$

$\Delta G = \Delta H - T\Delta S$

$= -35.98 \text{ kJ/mol} - [(298 \text{ K})(0.4464 \text{ kJ/mol•K})] = -169.0 \text{ kJ/mol}$

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493. a. Unknown: Chemical equations for combustion of (1) 1 mol of methane (CH_4) and (2) 1 mol of propane (C_3H_8)

1. *methane*: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
2. *propane*: $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

b. Unknown: Enthalpy change (ΔH) for each reaction

1. *methane:* $CH_4(g) \rightarrow C(s) + 2H_2(g) \quad \Delta H = 74.9 \text{ kJ/mol}$

$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393.5 \text{ kJ/mol}$

$\underline{2[H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)] \quad \Delta H = (2)(-241.82) = -483.64 \text{ kJ/mol}}$

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \quad \Delta H = -802.2 \text{ kJ/mol}$

2. *propane:* $3[C(s) + O_2(g) \rightarrow CO_2(g)] \quad \Delta H = (3)(-393.5) = -1180.5 \text{ kJ/mol}$

$4[H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)] \quad \Delta H = (4)(-241.82) = -967.28 \text{ kJ/mol}$

$\underline{C_3H_8(g) \rightarrow 3C(s) + 4H_2(g) \quad \Delta H = 104.7 \text{ kJ/mol}}$

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g) \quad \Delta H = -2043 \text{ kJ/mol}$

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:* $(1000 \text{ g/}C_3H_8)\left(\frac{\text{mol } C_3H_8}{44.11 \text{ g } C_3H_8}\right) = 22.67 \text{ mol } C_3H_8$

$(22.67 \text{ mol } C_3H_8)(-2043 \text{ kJ/mol}) = -4.632 \times 10^{4} \text{ kJ/kg}$

494. Given: $C_2H_2(g) + H_2O(l) \rightarrow CH_3CHO(l)$; $C_2H_2(g) + 2O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ $\Delta H = -1299.6$ kJ/mol; $CH_3CHO(l) + 2O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ $\Delta H = -1166.9$ kJ/mol

Unknown: Enthalpy (ΔH) for reaction of acetylene with water

$$C_2H_2(g) + 2O_2(g) \rightarrow 2CO_2(g) + H_2O(l) \quad \Delta H = -1299.6 \text{ kJ/mol}$$
$$2CO_2(g) + 2H_2O(l) \rightarrow CH_3CHO(l) + 2O_2(g) \quad \Delta H = 1166.9 \text{ kJ/mol}$$
$$\overline{C_2H_2(g) + H_2O(l) \rightarrow CH_3CHO(l) \quad \Delta H = -132.7 \text{ kJ/mol}}$$

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495. Given: $C_{10}H_{22}(l) + 15O_2(g) \rightarrow 10CO_2(g) + 11H_2O(l)$ ΔH^o_f for liquid decane ($C_{10}H_{22}$) = –300.9 kJ/mol

Unknown: Enthalpy (ΔH) for combustion of decane

$$10[C(s) + O_2(g) \rightarrow CO_2(g)] \quad \Delta H = (10)(-393.5) = -3935 \text{ kJ/mol}$$
$$11[H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l)] \quad \Delta H = (11)(-285.8) = -3143.8 \text{ kJ/mol}$$
$$C_{10}H_{22}(l) \rightarrow 10C(s) + 11H_2(g) \quad \Delta H = 300.9 \text{ kJ/mol}$$
$$\overline{C_{10}H_{22}(l) + \tfrac{31}{2}O_2(g) \rightarrow 10CO_2(g) + 11H_2O(l) \quad \Delta H = -6777.9 \text{ kJ/mol}}$$

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496. Given: $MgO(s) + 2HCl(g) \rightarrow MgCl_2(s) + H_2O(l)$; $Mg(s) + 2HCl(g) \rightarrow MgCl_2(s) + H_2(g)$ $\Delta H = -456.9$ kJ/mol; $Mg(s) + O_2(g) \rightarrow MgO(s)$ $\Delta H = -601.6$ kJ/mol; $H_2O(l) \rightarrow H_2(g) + O_2(g)$ $\Delta H = +285.8$ kJ/mol

Unknown: Enthalpy (ΔH) of reaction of MgO with HCl

$$Mg(s) + 2HCl(g) \rightarrow MgCl_2(s) + H_2(g) \quad \Delta H = -456.9 \text{ kJ/mol}$$
$$MgO(s) \rightarrow Mg(s) + \tfrac{1}{2}O_2(g) \quad \Delta H = 601.6 \text{ kJ/mol}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \quad \Delta H = -285.8 \text{ kJ/mol}$$
$$\overline{MgO(s) + 2HCl(g) \rightarrow MgCl_2(s) + H_2O(l) \quad \Delta H = -141.1 \text{ kJ/mol}}$$

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497. Given: $2NaOH(s) + 2Na(s) \xrightarrow{\Delta} 2Na_2O(s) + H_2(g)$ $\Delta S = 10.6$ J/mol•K $\Delta H^o{}_{f\,NaOH} = -425.9$ kJ/mol $T = 25^oC = 298$ K

Unknown: ΔG

$$2[2Na(s) + \tfrac{1}{2}O_2(g) \rightarrow Na_2O(s)] \quad \Delta H = (2)(-414.2) = -828.4 \text{ kJ/mol}$$
$$2[NaOH(s) \rightarrow 2Na(s) + O_2(g) + H_2(g)] \quad \Delta H = (2)(425.9 = 851.8 \text{ kJ/mol}$$
$$\overline{2NaOH(s) + 2Na(s) \rightarrow 2Na_2O(s) + H_2(g) \quad \Delta H = 23.4 \text{ kJ/mol}}$$

ΔS = (10.6 J/mol•K)(kJ/1000 J) = 0.0106 kJ/mol

$\Delta G = \Delta H - T\Delta S$
= 23.4 kJ/mol – [(298 K)(0.0106 kJ/mol•K)]
= 20.2 kJ/mol

498. Given: $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$
$T = 25°C = 298\ K$
$\Delta G = -91.2\ kJ/mol$

Unknown: Entropy change (ΔS) in J/mol•K

$\frac{1}{2}N_2(g) + 2H_2(g) + \frac{1}{2}Cl_2(g) \rightarrow NH_4Cl(s) \quad \Delta H = -314.4\ kJ/mol$

$NH_3(g) \rightarrow \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \quad \Delta H = 45.9\ kJ/mol$

$HCl(s) \rightarrow \frac{1}{2}H_2(g) + \frac{1}{2}Cl_2(g) \quad \Delta H = 92.3\ kJ/mol$

$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s) \quad \Delta H = -176.2\ kJ/mol$

$\Delta G = \Delta H - T\Delta S$

$\Delta S = \Delta H - \Delta G/T$

$= (-176.2\ kJ/mol) - (-91.2\ kJ/mol)/298\ K$

$= (-0.285\ kJ/mol \bullet K)\left(\frac{1000\ J}{kJ}\right) = -285\ J/mol \bullet K$

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499. a. Given: $3C(s) + Fe_2O_3(s) \rightarrow 3CO(g) + Fe(s)$
$\Delta H^o_{f CO}(g) = -110.53\ kJ/mol$

Unknown: Enthalpy (ΔH)

$3C(s) + \frac{3}{2}O_2(g) \rightarrow 3CO(g) \quad \Delta H = (3)(-110.53) = -331.59\ kJ/mol$

$Fe_2O_3(s) \rightarrow 2Fe(s) + \frac{3}{2}O_2(g) \quad \Delta H = +1118.4\ kJ/mol$

$3C(s) + Fe_2O_3(s) \rightarrow 3CO(g) + 2Fe(s) \quad \Delta H = 786.8\ kJ/mol$

b. Given: $3Mn(s) + Fe_2O_3(s) \rightarrow 3MnO(s) + 2Fe(s)$
$\Delta H^o_{f MnO}(s) = -384.9\ kJ/mol$

Unknown: ΔH

$3[Mn(s) + \frac{1}{2}O_2(g) \rightarrow MnO(s)] \quad \Delta H = (3)(-384.9) = -1154.7\ kJ/mol$

$Fe_2O_3(s) \rightarrow 2Fe(s) + \frac{3}{2}O_2(g) \quad \Delta H = +1118.4\ kJ/mol$

$3Mn(s) + Fe_2O_3(s) \rightarrow 3MnO(s) + 2Fe(s) \quad \Delta H = -36\ kJ/mol$

c. Given: $12P(s) + 10Fe_2O_3(s) \rightarrow 3P_4O_{10}(s) + 20Fe(s)$
$\Delta H^o_{f P_4O_{10}}(s) = -3009.9\ kJ/mol$

Unknown: ΔH

$3[4P(s) + 5O_2(g) \rightarrow P_4O_{10}(s)] \quad \Delta H = (3)(-3009.9) = -9029.7\ kJ/mol$

$F10[Fe_2O_3(s) \rightarrow 2Fe(s) + \frac{3}{2}O_2(g)] \quad \Delta H = (10)(1118.4) = 11\ 184.\ kJ/mol$

$12P(s) + 10Fe_2O_3(s) \rightarrow 3P_4O_{10}(s) + 20Fe(s) \quad \Delta H = +2154\ kJ/mol$

d. Given: $3Si(s) + 2Fe_2O_3(s) \rightarrow 3\ SiO_2(s) + 4Fe(s)$
$\Delta H^o_{f SiO_2}(s) = -910.9\ kJ/mol$

Unknown: ΔH

$3[Si(s) + O_2(g) \rightarrow SiO_2(s)] \quad \Delta H = (3)(-910.9)\ = 2732.7\ kJ/mol$

$2[Fe_2O_3(s) \rightarrow 2Fe(s) + \frac{3}{2}O_2(g)] \quad \Delta H = (2)(1118.4) = 2236.8\ kJ/mol$

$3Si(s) + 2Fe_2O_3(s) \rightarrow 3SiO_2(s) + 4Fe(s) \quad \Delta H = -496\ kJ/mol$

e. Given: $3S(s) + 2\ Fe_2O_3(s) \rightarrow 3\ SO_2(g) + 4\ Fe(s)$

Unknown: ΔH

$3[S(s) + O_2(g) \rightarrow SO_2(g)] \quad \Delta H = (3)(-296.8) = -890.4\ kJ/mol$

$2[Fe_2O_3(s) \rightarrow 2Fe(s) + \frac{3}{2}O_2(g)] \quad \Delta H = (2)(1118.4) = 2236.8\ kJ/mol$

$3S(s) + 2Fe_2O_3(s) \rightarrow 3SO_2(g) + 4Fe(s) \quad \Delta H\ +1346.4\ kJ/mol$

500. a. Given: $A \rightleftharpoons C + D$
$[A] = 2.24 \times 10^{-2}$ M
$[C] = 6.41 \times 10^{-3}$ M
$[D] = 6.41 \times 10^{-3}$ M
Unknown: K

$$K = \frac{[C][D]}{[A]} = \frac{(6.41 \times 10^{-3}\ M)^2}{2.24 \times 10^{-2}\ M} = 1.83 \times 10^{-3}$$

b. Given: $A + B \rightleftharpoons C + D$
$[A] = 3.23 \times 10^{-5}\ M = [B]$
$[C] = 1.27 \times 10^{-2}\ M = [D]$
Unknown: K

$$K = \frac{[C][D]}{[A][B]} = \frac{(1.27 \times 10^{-2}\ M)^2}{(3.23 \times 10^{-5} M)^2} = 1.55 \times 10^5$$

c. Given: $A + B \rightleftharpoons 2\ C$
$[A] = 7.02 \times 10^{-3}\ M = [B]$
$[C] = 2.16 \times 10^{-2}$ M
Unknown: K

$$K = \frac{[C]^2}{[A][B]} = \frac{(2.16 \times 10^{-2}\ M)^2}{(7.02 \times 10^{-3}\ M)^2} = 9.47$$

d. Given: $2A \rightleftharpoons 2C + D$
$[A] = 6.59 \times 10^{-4}$ M
$[C] = 4.06 \times 10^{-3}$ M
$[D] = 2.03 \times 10^{-3}$ M
Unknown: K

$$K = \frac{[C]^2[D]}{[A]^2} = \frac{(4.06 \times 10^{-3}\ M)^2(2.03 \times 10^{-3}\ M)}{(6.59 \times 10^{-4}\ M)^2} = 7.71 \times 10^{-2}$$

e. Given: $A + B \rightleftharpoons C + D + E$
$[A] = 3.73 \times 10^{-4}\ M = [B]$
$[C] = 9.35 \times 10^{-4}\ M = [D] = [E]$
Unknown: K

$$K = \frac{[C][D][E]}{[A][B]} = \frac{(9.35 \times 10^{-4}\ M)^3}{(3.73 \times 10^{-4}\ M)^2} = 5.88 \times 10^{-3}$$

f. Given: $2A + B \rightleftharpoons 2C$
$[A] = 5.50 \times 10^{-3}$ M
$[B] = 2.25 \times 10^{-3}$ M
$[C] = 1.02 \times 10^{-2}$ M
Unknown: K

$$K = \frac{[C]^2}{[A]^2[B]} = \frac{(1.02 \times 10^{-2}\ M)^2}{(5.50 \times 10^{-3}\ M)^2(2.25 \times 10^{-3}\ M)} = 1.53 \times 10^3$$

501. Given: $2A(g) \rightleftharpoons 2C(g) + D(g)$
$[A] = 1.88 \times 10^{-1}$ M
$[C] = 6.56$ M
$K = 2.403 \times 10^2$
Unknown: [D]

$$K = \frac{[C]^2[D]}{[A]^2}$$

$$[D] = (K)\,[A]^2/[C]^2$$

$$= (2.403 \times 10^2)\,(1.88 \times 10^{-1}\text{ M})^2/(6.56\text{ M})^2$$

$$= 0.197\text{ M}$$

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502. Given: $T = 700$ K
$K = 3.164 \times 10^3$
$C_2H_4(g) + H_2(g) \rightleftharpoons C_2H_6(g)$
Unknown: $[C_2H_4]$ if $[H_2] = 0.0619$ M and $[C_2H_6] = 1.055$ M

$$K = \frac{[C_2H_6]}{[C_2H_4][H_2]}$$

$$[C_2H_4] = \frac{[C_2H_6]}{[H_2]\ (K)} = \frac{1.055\text{ M}}{(0.0619\text{ M})(3.164 \times 10^3)} = 5.39 \times 10^{-3}\text{ M}$$

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503. Given: $A + 2B \rightleftharpoons C + 2D$
$[A] = 0.0567$ M
$[B] = 0.1171$ M
$[C] = 0.000\,3378$ M
$[D] = 0.000\,6756$ 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: $2A \rightleftharpoons 2C + 2D$
$[A] = 0.1077$ M
$[C] = 0.000\,4104$ M
$[D] = 0.000\,4104$ M
Unknown: K

$$K = \frac{[C]^2[D]^2}{[A]^2} = \frac{(0.000\,4104\text{ M})^2(0.000\,4104\text{ M})^2}{0.1077\text{ M}^2} = 2.446 \times 10^{-12}$$

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506. **a.** Given: $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$
$T = 25°C$
$K = 4.282 \times 10^{-2}$
$[CO] = 5.90 \times 10^{-3}\text{ M} = [Cl_2]$
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: $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$
$K = 4.282 \times 10^{-2}$
$[COCl^2] = 0.003\,70$ 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: $A(g) + B(s) \rightleftharpoons C(g) + D(s)$
$K = 1$
$T = 500$ 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]

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508. Given: $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$
$K = 4.251 \times 10^{-2}$
$T = 800$ K
$[H_2O] = 0.1990$ M

Unknown: [CO] and $[H_2]$

C is a solid; [C] = 1

$$K = \frac{[CO][H_2]}{[1][H_2O]}$$

$[CO][H_2] = (K)\ [H_2O]$

$x^2 = (4.251 \times 10^{-2})(0.1990 \text{ M})$

$$x = \sqrt{8.459 \times 10^{-3} \text{ M}}$$

$= 0.0918$ M

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509. **a.** Given: $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$
$T = 500$ K
$K = 1.671 \times 10^4$
$[NO] = 6.200 \times 10^{-2}$ M
$[O^2] = 8.305 \times 10^{-3}$ M

Unknown: $[NO_2]$

$$K = \frac{[NO_2]^2}{[NO]^2[O_2]}$$

$[NO_2]^2 = K[NO]^2[O_2]$

$[NO_2] = \sqrt{K[NO]^2[O_2]}$

$$= \sqrt{(1.671 \times 10^4)(6.200 \times 10^{-2} \text{ M})^2(8.305 \times 10^{-3} \text{ M})}$$

$= 0.7304$ M

b. Given: $T = 1000$ K
$K = 1.315 \times 10^{-2}$
$[NO] = 6.200 \times 10^{-2}$ M
$[O_2] = 8.305 \times 10^{-3}$ M

Unknown: $[NO_2]$

$[NO_2]\ \sqrt{K[NO]^2[O_2]}$

$$= \sqrt{(1.315 \times 10^{-2})(6.200 \times 10^{-2} \text{ M})^2(8.305 \times 10^{-3} \text{ M})}$$

$= 6.479 \times 10^{-4}$ M

---

511. **b.** Given: $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$
$K = 5.628 \times 10^{18}$ $[H_2]_{initial} = [Br_2]_{initial}$
$[HBr] = 0.500$ 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: $N_2F_4(g) \rightleftharpoons 2\ NF_2(g)$
$T = 25°C$
$[N_2F_4] = 0.9989$ M
$[NF_2] = 1.131 \times 10^{-3}$ M
Unknown: K

$$K = \frac{[NF_2]^2}{[N_2F_4]} = \frac{(1.131 \times 10^{-3}\ M)^2}{0.9989\ M} = 1.281 \times 10^{-6}$$

---

513. Given: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$
$T = 25°C$
$[N_2O_4] = 5.95 \times 10^{-1}$ M
$[NO_2] = 5.24 \times 10^{-2}$ M
Unknown: K

$$K = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(5.24 \times 10^{-2}\ M)^2}{(5.95 \times 10^{-1}\ M)} = 4.61 \times 10^{-3}$$

---

514. a. Given: $NaCN(s) + HCl(g) \rightleftharpoons HCN(g) + NaCl(s)$
Unknown: Expression for equilibrium constant (K)

$$K = \frac{[HCN][NaCl]}{[NaCN][HCl]}$$

NaCN and NaCl are solids; therefore their concentrations equal 1.

$$K = \frac{[HCN]}{[HCl]}$$

b. Given: $K = 2.405 \times 10^6$
$[HCN] = 0.8959$ M
Unknown: [HCl]

$$K = \frac{[HCN]}{[HCl]}$$

$$[HCl] = \frac{[HCN]}{K} = \frac{0.8959\ M}{2.405 \times 10^6} = 3.725 \times 10^{-7}\ M$$

---

515. a. Given: $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3\ H_2(g)$
At 1100 K, $K = 3.112 \times 10^2$

b. Temperature = 110 K, $K = 3.112 \times 10^2$
$[H_2] = 1.56$ M
$[CH_4] = 3.70 \times 10^{-2}$ M
$[H_2O] = 8.27 \times 10^{-1}$ M
Unknown: [CO]

$$K = \frac{[CO][H_2]^3}{[CH_4][H_2O]}$$

$$[CO] = (K)\frac{[CH_4][H_2O]}{[H_2]} = \frac{(3.112 \times 10^2)\ (3.70 \times 10^{-2}\ M)(8.27 \times 10^{-1}\ M)}{(1.56\ M)^3}$$

$$= 2.51\ M$$

516. Given: $N_2O_4 \rightleftharpoons NO_2$
$T = 20°C = 293$ K
$[N_2O_4] = 2.55 \times 10^{-3}$ M
$[NO_2] = 10.4 \times 10^{-3}$ M
Unknown: K

$N_2O_4 \rightleftharpoons 2NO_2$

$$K = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(10.4 \times 10^{-3}\text{ M})^2}{(2.55 \times 10^{-3}\text{ M})} = 0.0424$$

---

517. Given: $N_2O_4 \rightleftharpoons NO_2$
$T = 20°C = 293$ K
$[N_2O_4] = 2.67 \times 10^{-3}$ M
$[NO_2] = 10.2 \times 10^{-3}$ M
Unknown: K

$N_2O_4 \rightleftharpoons 2NO_2$

$$K = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(10.2 \times 10^{-3}\text{ M})^2}{2.67 \times 10^{-3}\text{ M}} = 0.0390$$

---

518. Given: $T = 25°C$
$[HCOOH] = 0.025$ M
$[H_3O^+] = 2.03 \times 10^{-3}$ M
Unknown: K_a

$HCOOH + H_2O \rightleftharpoons H_3O^+ + HCOO^-$

$$K_a = \frac{[H_3O^+][HCOO^-]}{[HCOOH]}$$

$[H_3O^+] = [HCOO^-] = 2.03 \times 10^{-3}$ M

$[HCOOH] = 0.025 - 2.03 \times 10^{-3} = 0.022\ 97$ M

$$K_a = \frac{(2.03 \times 10^{-3})^2}{0.022\ 97} = 1.8 \times 10^{-4}$$

---

519. Given: $[HIO_3] = 0.400$ M
pH = 0.726
$T = 25°C$
Unknown: K_a

pH = $-\log [H_3O^+]$

$\log [H_3O^+] = -$pH

$[H_3O^+] = $ antilog ($-$pH)

$[H_3O^+] = 1 \times 10^{-\text{pH}}$

$= 1 \times 10^{-0.726}$

$= 0.1879$ M

$HIO_3 + H_2O \rightleftarrows H_3O^+ + IO_3^-$

$[H_3O^+] = [IO_3^-] = 0.1879$ M

$[HIO_3] = 0.400 - 0.1879 = 0.212$ M

$$K_a = \frac{[H_3O^+][IO_3^-]}{[HIO_3]} = \frac{(0.1879)^2}{0.212} = 0.167$$

520. Given: [HClO] = 0.150 M
pH = 4.55
T = 25°C
Unknown: K_a

$[H_3O^+]$ = antilog (–pH)

$[H_3O^+] = 1 \times 10^{-pH} = 1 \times 10^{-4.55} = 2.8 \times 10^{-5}$

$HClO + H_2O \rightleftharpoons H_3O^+ + ClO^-$

$[H_3O^+] = [ClO^-] = 2.8 \times 10^{-5}$ M

$[HClO] = 0.150 - 2.8 \times 10^{-5} = 0.15$ M

$$K_a = \frac{[H_3O^+][ClO^-]}{[HClO]} = \frac{(2.8 \times 10^{-5})^2}{0.15} = 5.2 \times 10^{-9}$$

---

521. Given: $[CH_3CH_2CH_2NH_2]$ = 0.039 M
$[OH^-] = 3.74 \times 10^{-3}$ M
Unknown: (a) pH of solution; (b) K_b for propylamine

a. $pH = -\log [H_3O^+]$

$[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[H_3O^+] = \frac{1.0 \times 10^{-14}\ M^2}{3.74 \times 10^{-3}\ M} = 2.67 \times 10^{-12}\ M$$

$pH = -\log (2.67 \times 10^{-12}) = 11.573$

b. $CH_3CH_2CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2CH_2NH_3^+ + OH^-$

$$K_b = \frac{[CH_3CH_2CH_2NH_3^+][OH^-]}{[CH_3CH_2CH_2NH_2]}$$

$[OH^-] = [CH_3CH_2CH_2NH_3^+] = 3.74 \times 10^{-3}$ M

$[CH_3CH_2CH_2NH_2] = 0.039 - 3.74 \times 10^{-3}$ M = 0.03526

$$K_b = \frac{(3.74 \times 10^{-3})^2}{0.03526} = 4.0 \times 10^{-4}$$

---

522. Given: K_a of $HNO_2 = 4.6 \times 10^{-4}$
T = 25°C
$[HNO_2]$ = 0.0450 M
Unknown: $[H_3O^+]$

$HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^-$

$$K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2]}$$

$[H_3O^+] = [NO_2^-] = x$

$x^2 = (K_a)[HNO_2] = (4.6 \times 10^{-4})(0.0450\ M) = 2.07 \times 10^{-5}$ M

$x = \sqrt{2.07 \times 10^{-5}\ M} = 4.5 \times 10^{-3}$ M

523. Given: $[HN_3] = 0.102$ M
$[H_3O^+] = 1.39 \times 10^{-3}$ M
$T = 25°C$

Unknown: **a.** pH
b. K_a

a. $pH = -\log [H_3O^+] = -\log (1.39 \times 10^{-3}) = 2.857$

b. $HN_3 + H_2O \rightleftharpoons H_3O^+ + N_3^-$

$$K_a = \frac{[H_3O^+][N_3^-]}{[HN_3]}$$

$[H_3O^+] = [N_3^-] = 1.39 \times 10^{-3}$ M

$[HN_3] = 0.102\text{ M} - 1.39 \times 10^{-3}\text{ M} = 0.10061$ M

$$K_a = \frac{(1.39 \times 10^{-3})^2}{0.10061} = 1.92 \times 10^{-5}$$

---

524. Given: $[BrCH_2COOH] = 0.200$ M
$[H_3O^+] = 0.0192$ M
$T = 25°C$

Unknown: **a.** pH
b. K_a

a. $pH = -\log [H_3O^+] = -\log (0.0192) = 1.717$

b. $BrCH_2COOH + H_2O \rightleftharpoons H_3O^+ + BrCH_2COO^-$

$$K_a = \frac{[H_3O^+][BrCH_2COO^-]}{[BrCH_2COOH]}$$

$[H_3O^+] = [BrCH_2COO^-] = 0.0192$ M

$[BrCH_2COOH] = 0.200\text{ M} - 0.0192\text{ M} = 0.1808$ M

$$K_a = \frac{(0.0192)^2}{0.1808} = 2.04 \times 10^{-3}$$

---

525. a. Given: $B + H_2O \rightleftharpoons BH^+ + OH^-$
$[B]_{initial} = 0.400$ M
$[OH^-] = 2.70 \times 10^{-4}$ M

Unknown: (1) $[H_3O^+]$
(2) pH
(3) K_b

(1) $[H_3O^+][OH^-] = 1.00 \times 10^{-14}\text{ M}^2$

$$[H_3O^+] = \frac{1.00 \times 10^{-14}\text{ M}^2}{2.70 \times 10^{-4}\text{ M}} = 3.70 \times 10^{-11}\text{ M}$$

(2) $pH = -\log (3.70 \times 10^{-11}) = 10.431$

(3) $B + H_2O \rightleftharpoons BH^+ + OH^-$

$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

$[OH^-] = [BH^+] = 2.70 \times 10^{-4}$ M

$[B] = 0.400\text{ M} - 2.70 \times 10^{-4}\text{ M} = 0.399\,73$ M

$$K_b = \frac{(2.70 \times 10^{-4})^2}{0.399\,73} = 1.82 \times 10^{-7}$$

b. Given: $B_{initial}$ = 0.005 50 M
$[OH^-]$ = 8.45 $\times 10^{-4}$ M
Unknown: (1) [B] at equilibrium
(2) K_b
(3) pH

(1) [B] at equilibrium = 0.005 50 M – 8.45 × 10^{-4} M = 4.66 × 10^{-3} M

(2) $B + H_2O \rightleftharpoons BH^+ + OH^-$

$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

$[OH^-] = [BH^+] = 8.45 \times 10^{-4}$ M

$$K_b = \frac{(8.45 \times 10^{-4}\ M)^2}{4.66 \times 10^{-3}\ M} = 1.53 \times 10^{-4}$$

(3) pH = –log $[H_3O^+]$

$[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[H_3O^+] = \frac{1 \times 10^{-14}\ M^2}{8.45 \times 10^{-4}\ M} = 1.18 \times 10^{-11}\ M$$

pH = –log (1.18 × 10^{-11}) = 10.93

c. Given: $[B]_{initial}$ = 0.0350 M
pH = 11.29
Unknown: (1) $[H_3O^+]$
(2) $[OH^-]$
(3) [B] at equilibrium
(4) K_b

(1) $[H_3O^+]$ = antilog (–pH) = $1 \times 10^{-pH} = 1 \times 10^{-11.29} = 5.13 \times 10^{-12}$ M

(2) $[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[OH^-] = \frac{1 \times 10^{-14}\ M^2}{[H_3O^+]} = \frac{1 \times 10^{-14}\ M^2}{5.13 \times 10^{-12}\ M} = 1.9 \times 10^{-3}\ M$$

(3) [B] at equilibrium = 0.0350 M – 1.9 × 10^{-3} M = 0.0331 M

(4) $$K_b = \frac{[BH^+][OH^-]}{[B]}$$

$[OH^-] = [BH^+] = 1.9 \times 10^{-3}$ M

$$K_b = \frac{(1.9 \times 10^{-3})^2}{0.0331} = 1.1 \times 10^{-4}$$

d. Given: [B] at equilibrium = 0.006 28 M
$[OH^-]$ = 0.000 92 M
Unknown: (1) $[B]_{initial}$
(2) K_b
(3) pH

(1) $[B]_{eq} = [B]_{initial} - [OH^-]$

$[B]_{initial} = [B]_{eq} + [OH^-]$ = 0.006 28 M + 0.000 92 M = 7.2 × 10^{-3} M

(2) $$K_b = \frac{[BH^+][OH^-]}{[B]}$$

$[OH^-] = [BH^+]$ = 0.000 92 M

$$K_b = \frac{(0.000\ 92\ M)^2}{0.006\ 28\ M} = 1.35 \times 10^{-4}$$

(3) pH = –log $[H_3O^+]$

$[H_3O^+]\ [OH^-] = 1 \times 10^{-14}\ M^2$

$$[H_3O^+] = \frac{1 \times 10^{14}\ M^2}{0.000\ 92\ M} = 1.1 \times 10^{-11}$$

pH = –log (1.1 × 10^{-11}) = 10.96

526. Given: Solubility of C_6H_5COOH in water = 2.9 g/L
pH = 2.92
T = 25°C

Unknown: K_a

$C_6H_5COOH + H_2O \rightleftharpoons H_3O^+ + C_6H_5COO^-$

pH = –log $[H_3O^+]$

log $[H_3O^+]$ = –pH

$[H_3O^+]$ = antilog (–pH)

$[H_3O^+] = 1 \times 10^{-pH} = 1 \times 10^{-2.92} = 1.2 \times 10^{-3}$ M

$[H_3O^+] = [C_6H_5COO^-] = 1.2 \times 10^{-3}$ M

$$\left(\frac{2.9 \text{ g } C_6H_5COOH}{L}\right)\left(\frac{1 \text{ mol } C_6H_5COOH}{122.11 \text{ g } C_6H_5COOH}\right) = 0.02375 \text{ M}$$

$= [C_6H_5COOH]_{initial}$

$[C_6H_5COOH] = 0.02375 - 1.2 \times 10^{-3} = 0.02255$

$$K_a = \frac{[H_3O^+]\,[C_6H_5COO^-]}{[C_6H_5COOH]} = \frac{(1.2 \times 10^{-2} \text{ M})^2}{0.022\,55 \text{ M}} = 6.4 \times 10^{-5}$$

---

527. Given: $[H_2NCH_2CH_2OH]_{initial}$ = 0.006 50 M
pH = 10.64
T = 25°C

Unknown: **a.** $[H_2NCH_2CH_2OH]$ at equilibrium
b. K_b

a. $H_2NCH_2CH_2OH + H_2O \rightleftharpoons H_3NCH_2CH_2OH^+ + OH^-$

pH = –log $[H_3O^+]$

log $[H_3O^+]$ = –pH

$[H_3O^+]$ = antilog (–pH)

$[H_3O^+] = 1 \times 10^{-pH} = 1 \times 10^{-10.64} = 2.3 \times 10^{-11}$ M

$[H_3O^+][OH^-] = 1 \times 10^{-14}$ M^2

$$[OH^-] = \frac{1 \times 10^{-14} \text{ M}^2}{[H_3O^+]} = \frac{1 \times 10^{-14} \text{ M}^2}{2.3 \times 10^{-11} \text{ M}} = 4.35 \times 10^{-4} \text{ M}$$

$[H_2NCH_2CH_2OH] = 0.006\,50 \text{ M} - 4.35 \times 10^{-4} \text{ M} = 6.06 \times 10^{-3}$ M

$[H_3NCH_2CH_2OH^+] = [OH^-] = 4.35 \times 10^{-4}$ M

b. $$K_b = \frac{[H_3NCH_2CH_2OH^+]\,[OH^-]}{[H_2NCH_2CH_2OH]} = \frac{(4.35 \times 10^{-4} \text{ M})^2}{6.06 \times 10^{-3} \text{ M}} = 3.1 \times 10^{-5}$$

---

528. Given: $[H_2Se]$ = 0.060 M
$[H_3O^+] = 2.72 \times 10^{-3}$ M
T = 25°C

Unknown: K_a

$H_2Se + H_2O \rightleftharpoons H_3O^+ + HSe^-$

$$K_a = \frac{[H_3O^+][HSe^-]}{H_2Se}$$

$[HSe^-] = [H_3O^+] = 2.72 \times 10^{-3}$ M

$H_2Se = 0.060 \text{ M} - 2.72 \times 10^{-3} \text{ M} = 0.05728$ 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

a. $C_5H_5N + H_2O \rightleftharpoons C_5H_5NH^+ + OH^-$

$$K_b = \frac{[C_5H_5NH^+]\ [OH^-]}{C_5H_5N}$$

$[C_5H_5NH^+] = [OH^-] = x$

$x^2 = K_b[C_5H_5N] = (1.78 \times 10^{-9})\ (0.140\ M) = 2.5 \times 10^{-10}$

$x = \sqrt{2.5 \times 10^{-10}} = 1.58 \times 10^{-5}\ M = [OH^-]$

b. $pH = -\log\ [H_3O^+]$

$[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[H_3O^+] = \frac{1 \times 10^{-14}\ M^2}{[OH^-]}$$

$$= \frac{1 \times 10^{-14}\ M^2}{1.58 \times 10^{-5}\ M} = 6.329 \times 10^{-10}\ M$$

$pH = -\log\ [6.329 \times 10^{-10}\ M] = 9.20$

---

530. Given: $[HA] = 0.0208$ M
$pH = 2.17$

Unknown: **a.** $[HA]_{initial}$
b. K_a

a. $[HA] + [H_2O] \rightleftharpoons H_3O^+ + A^-$

$pH = -\log\ [H_3O^+]$

$\log\ [H_3O^+] = -pH$

$[H_3O^+] = \text{antilog}\ (-pH) = 1 \times 10^{-pH} = 1 \times 10^{-2.17} = 6.76 \times 10^{-3}\ M$

$[HA] = [HA]_{initial} - [H_3O^+]$

$[HA]_{initial} = [HA] + [H_3O^+]$

$= 0.0208\ M + 6.76 \times 10^{-3}\ M = 0.02756\ M$

b. $$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

$[H_3O^+] = [A^-] = 6.76 \times 10^{-3}\ M$

$$K_a = \frac{(6.76 \times 10^{-3}\ M)^2}{0.0208\ M} = 2.2 \times 10^{-3}$$

531. Given: Mass of solute ($CH_3COCOOH$) = 438 mg
volume of solvent (H_2O) = 10.00 mL
pH = 1.34

Unknown: K_a

$CH_3COCOOH + H_2O \rightleftharpoons H_3O^+ + CH_3COCOO^-$

$pH = -\log [H_3O^+]$

$\log [H_3O^+] = -pH$

$[H_3O^+] = \text{antilog}(-pH)$

$[H_3O^+] = 1 \times 10^{-pH} = 1 \times 10^{-1.34} = 0.0457 \text{ M}$

$[H_3O^+] = [CH_3COCOO^-] = 0.0457 \text{ M}$

$$\left(\frac{438 \text{ mg } CH_3COCOOH}{10.00 \text{ mL}}\right)\left(\frac{\text{g}}{1000 \text{ mg}}\right)\left(\frac{1000 \text{ mL}}{\text{L}}\right)\left(\frac{1 \text{ mol } CH_3COCOOH}{88.04 \text{ g } CH_3COCOOH}\right)$$

$= 0.4975 \text{ M} = [CH_3COCOOH]_{initial}$

$[CH_3COCOOH] = 0.4975 - .0457 = 0.4518 \text{ M}$

$$K_a = \frac{[H_3O^+][CH_3COCOO^-]}{[CH^3COCOOH]} = \frac{(0.0457 \text{ M})^2}{0.4518 \text{ M}} = 4.63 \times 10^{-3}$$

---

532. Given: $[H_3O^+]$ of solution of acetoacetic acid (CH_3COCH_2COOH) = 4.38×10^{-3} M
$[CH_3COCH_2COOH]$ (nonionized) = 0.0731 M

Unknown: K_a

$CH_3COCH_2COOH + H_2O \rightleftharpoons H_3O^+ \; CH_3COCH_2COO^-$

$$K_a = \frac{[H_3O^+][CH_3COCH_2COO^-]}{[CH_3COCH_2COOH]}$$

$[CH_3COCH_2COO^-] = [H_3O^+] = 4.38 \times 10^{-3} \text{ M}$

$[CH_3COCH_2COOH] = 0.0731 \text{ M} - 4.38 \times 10^{-3} \text{ M} = 0.068\,72 \text{ M}$

$$K_a = \frac{(4.38 \times 10^{-3} \text{ M})^2}{0.0731 \text{ M}} = 2.62 \times 10^{-4}$$

---

533. Given: K_a of $CH_3CHClCOOH$ = 1.48×10^{-3}
$[CH_3CHClCOOH]_{initial}$ = 0.116 M

Unknown: **a.** $[H_3O^+]$
b. pH

a. $CH_3CHClCOOH + H_2O \rightleftharpoons H_3O^+ + CH_3CHClCOO^-$

$$K_a = \frac{[H_3O^+]\,[CH_3CHClCOO^-]}{[CH_3CHClCOOH]}$$

$[H_3O^+] = x = [CH_3CHClCOO^-]$

$[CH_3CHClCOOH] = 0.116 - x$

$$K_a = \frac{(x)(x)}{0.116} - x = \frac{x^2}{0.116 - x}$$

$K_a = 1.48 \times 10^{-3}$

$$1.48 \times 10^{-3} = \frac{x^2}{0.116 - x}$$

By the quadratic equation, x = 0.0124 M.

b. $pH = -\log [H_3O^+] = -\log(0.0124) = 1.907$

534. Given: First ionization: $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$
Ionization = 100%
Second ionization: $HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$
$K_{a2} = 1.3 \times 10^{-2}$
$[H_2SO_4] = 0.0788$ M

Unknown: **a.** total $[H_3O^+]$
b. pH of H_2SO_4 solution

a. $K_{a2} = 1.3 \times 10^{-2} = \dfrac{[H_3O^+][SO_4^{2-}]}{HSO_4^-}$

$[H_3O^+] = 0.0788 + x$

$[SO_4^{2-}] = x$

$[HSO_4^-] = 0.0788 - x$

$$1.3 \times 10^{-2} = \frac{(0.0788 + x)(x)}{(0.0788 - x)}$$

$(1.3 \times 10^{-2})(0.0788 - x) = (0.0788 + x)(x)$

$(1.0244 \times 10^{-3}) - (1.3 \times 10^{-2})\,x = (7.88 \times 10^{-2})\,x + x^2$

$x^2 + (9.18 \times 10^{-2})\,x - (1.0244 \times 10^{-3}) = 0$

By the quadratic formula, x = 0.010 024.

$[H_3O^+] = 0.0788 + 0.01 = 0.0888$

b. pH = $-\log [H_3O^+] = -\log (0.0888) = 1.05$

---

535. Given: $[HOCN] = 0.100$ M
$[H_3O^+] = 5.74 \times 10^{-3}$ M

Unknown: **a.** K_a
b. pH

a. $HOCN + H_2O \rightleftharpoons H_3O^+ + OCN^-$

$$K_a = \frac{[H_3O^+][OCN^-]}{[HOCN]}$$

$[H_3O^+] = [OCN^-] = 5.74 \times 10^{-3}$ M

$[HOCN] = 0.100\text{ M} - 5.74 \times 10^{-3}\text{ M} = 0.094$ M

$$K_a = \frac{(5.74 \times 10^{-3})^2}{0.094} = 3.5 \times 10^{-4}$$

b. pH = $-\log [H_3O^+] = -\log (5.74 \times 10^{-3}) = 2.241$

---

536. Given: $[HCN] = 0.025$ M
$[CN^-] = 3.16 \times 10^{-6}$ M

$HCN + H_2O\ ] \rightleftharpoons H_3O^+ + CN^-$

a. Unknown: $[H_3O^+]$

$[CN^-] = [H_3O^+] = 3.16 \times 10^{-6}$ M

b. Unknown: pH

pH = $-\log [H_3O^+] = -\log (3.16 \times 10^{-6}) = 5.500$

d. Unknown: K_a

$$K_a = \frac{[H_3O^+]\ [CN^-]}{[HCN]}$$

$[HCN] = 0.025\text{ M} - 3.16 \times 10^{-6}\text{ M} = 0.0249$ M

$$K_a = \frac{(3.16 \times 10^{-6}\text{ M})^2}{0.0249\text{ M}} = 4.0 \times 10^{-10}$$

f. Given: $[HCN] = 0.085$ M
Unknown: $[H_3O^+]$

$$K_a = \frac{x^2}{0.085}$$

$x^2 = (K_a)(0.085)$

$$x = \sqrt{(K_a)(0.085)} = \sqrt{(4.0 \times 10^{-10})(0.085)} = \sqrt{3.4 \times 10^{-11}} = 5.8 \times 10^{-6}$$

537. Given: $[CCl_2HCOOH]$ = 1.20 M
$[H_3O^+]$ = 0.182 M

a. Unknown: pH

$pH = -\log [H_3O^+] = -\log (0.182) = 0.740$

b. Unknown: K_a

$CCl_2HCOOH + H_2O \rightleftharpoons H_3O^+ + CCl_2HCOO^-$

$$K_a = \frac{[H_3O^+]\,[CCl_2HCOO^-]}{[CCl_2HCOOH]}$$

$[H_3O^+] = [CCl_2HCOO^-] = 0.182$ M

$[CCl_2HCOOH] = 1.20\text{ M} - 0.182\text{ M} = 1.018$ M

$$K_a = \frac{(0.182)^2}{1.018} = 0.0325$$

---

538. Given: $[C_6H_5OH]$ = 0.215 M
pH = 5.61

Unknown: K_a

$C_6H_5OH + H_2O \rightleftharpoons H_3O^+ + C_6H_5O^-$

$$K_a = \frac{[H_3O^+][C_6H_5O^-]}{[C_6H_5OH]}$$

$pH = -\log [H_3O^+]$

$\log [H_3O^+] = -pH$

$[H_3O^+] = \text{antilog } (-pH)$

$[H_3O^+] = 1 \times 10^{-pH} = 1 \times 10^{-5.61} = 2.45 \times 10^{-6}$ M

$[H_3O^+] = [C_6H_5O^-] = 2.45 \times 10^{-6}$ M

$[C_6H_5OH] = 0.215 - 2.45 \times 10^{-6} = 0.215$ M

$$K_a = \frac{(2.45 \times 10^{-6})^2}{0.215} = 2.80 \times 10^{-11}$$

---

539. Given: Solution of NH_2CH_2COOH is 3.75 g in 250.0 mL H_2O
pH = 0.890

a. Unknown: molarity of NH_2CH_2COOH

$$\left(\frac{3.75 \text{ g } NH_2CH_2COOH}{250 \text{ mL}}\right)\left(\frac{1000 \text{ mL}}{L}\right)\left(\frac{1 \text{ mol } NH_2CH_2COOH}{75.06 \text{ g } NH_2CH_2COOH}\right)$$
$= 0.200$ M NH_2CH_2COOH

b. Unknown: K_a

$NH_2CH_2COOH + H_2O \rightleftharpoons H_3O^+ + NH_2CH_2COO^-$

$$K_a = \frac{[H_3O^+]\,[NH_2CH_2COO^-]}{[NH_2CH_2COOH]}$$

$pH = -\log [H_3O^+]$

$\log [H_3O^+] = -pH$

$[H_3O^+] = \text{antilog}\,(-pH)$

$[H_3O^+] = 1 \times 10^{-pH} = 1 \times 10^{-0.890} = 0.1288\ M$

$[H_3O^+] = [NH_2CH_2COO^-] = 0.1288\ M$

$[NH_2CH_2COOH] = 0.200\ M - 0.1288\ M = 0.0712\ M$

$$K_a = \frac{(0.1288)^2}{0.0712} = 0.233$$

---

540. Given: $(CH_3)_3N + H_2O\ ] \rightleftharpoons CH_3NH^+ + OH^-$
$[(CH_3)_3N] = 0.0750\ M$
$[OH^-] = 2.32 \times 10^{-3}\ M$

Unknown: **a.** pH
b. K_b

a. $[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[H_3O^+] = \frac{1 \times 10^{-14}\ M^2}{[OH^-]} = \frac{1 \times 10^{-14}\ M^2}{2.32 \times 10^{-3}\ M} = 4.31 \times 10^{-12}\ M$$

$pH = -\log [H_3O^+] = -\log (4.31 \times 10^{-12}) = 11.37$

b. $$K_b = \frac{[CH_3NH^+][OH^-]}{[(CH_3)_3N]}$$

$[OH^-] = [CH_3NH^+] = 2.32 \times 10^{-3}\ M$

$[CH_3)_3N] = 0.0750\ M - 2.32 \times 10^{-3}\ M = 0.07268\ M$

$$K_b = \frac{(2.32 \times 10^{-3})^2}{0.07268} = 7.41 \times 10^{-5}$$

---

541. Given: $[(CH_3)_2NH] = 5.00 \times 10^{-3}\ M$
$pH = 11.20$

Unknown: **a.** K_b
b. Which base is stronger: $(CH_3)_2NH$ or $(CH_3)_3N$?

a. $(CH_3)_2NH + H_2O\ ] \rightleftharpoons (CH_3)_2NH_2^+ + OH^-$

$$K_b = \frac{[(CH_3)_2NH_2^+][OH^-]}{[(CH_3)_2NH]}$$

$pH = -\log [H_3O^+]$

$\log [H_3O^+] = -pH$

$[H_3O^+] = \text{antilog}\,(-pH) = 1 \times 10^{-pH} = 1 \times 10^{-11.20} = 6.31 \times 10^{-12}\ M$

$[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[OH^-] = \frac{1 \times 10^{-14}\ M^2}{[H_3O^+]} = \frac{1 \times 10^{-14}\ M^2}{6.31 \times 10^{-12}\ M} = 1.585 \times 10^{-3}\ M$$

$[OH^-] = [(CH_3)_2NH_2^+] = 1.585 \times 10^{-3}\ M$

$[(CH_3)_2NH] = 5.00 \times 10^{-3}\ M - 1.585 \times 10^{-3}\ M = 3.415 \times 10^{-3}\ M$

$$K_b = \frac{(1.585 \times 10^{-3})^2}{3.415 \times 10^{-3}} = 7.36 \times 10^{-4}$$

b. K_b of $(CH_3)_3N = 7.41 \times 10^{-5}$

K_b of $(CH_3)_2NH = 7.36 \times 10^{-4}$

$7.36 \times 10^{-4} > 7.41 \times 10^{-5}$

Therefore $(CH_3)_2NH$ (dimethylamine) is the stronger base.

542. Given: $H_2NNH_2 + H_2O(l) \rightleftharpoons H_2NNH_3^+(aq) + OH^-(aq)$
$H_2NNH_3^+(aq) + H_2O(l) \rightleftharpoons H_3NNH_3^{2+}(aq) + OH^-(aq)$
$K_{b_2} = 8.9 \times 10^{-16}$

a. $[H_2NNH_2] = 0.120$ M
pH = 10.50
Unknown: K_{b_1} (Assume that $[H_2NNH_2]_{\text{initial}}$ does not change.)

$$K_{b_1} = \frac{[H_2NNH_3^+][OH^-]}{[H_2NNH_2]}$$

$[H_3O^+] = \text{antilog}(-\text{pH})$

$[H_3O^+] = 1 \times 10^{-\text{pH}}$

$= 1 \times 10^{-10.50}$

$= 3.16 \times 10^{-11}$ M

$[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[OH^-] = \frac{1 \times 10^{-14}\ M^2}{[H_3O^+]} = \frac{1 \times 10^{-14}\ M^2}{3.16 \times 10^{-11}\ M}$$

$= 3.16 \times 10^{-4}$ M

$[OH^-] = 3.16 \times 10^{-4}\ M = [H_2NNH_3^+]$

$$K_{b_1} = \frac{(3.16 \times 10^{-4})^2}{0.120\ M} = 8.3 \times 10^{-7}$$

b. Given: $[H_2NNH_2] = 0.020$ M
Unknown: $[OH^-]$

$$K_{b_1} = \frac{[H_2NNH_3^+]\ [OH^-]}{[H_2NNH_2]}$$

$$8.3 \times 10^{-7} = \frac{x^2}{0.020}$$

$x = \sqrt{(8.3 \times 10^{-7})(0.020)} = 1.3 \times 10^{-4}\ M = [OH^-]$

c. Unknown: pH of 0.020 M $[H_2NNH_2]$ solution

$[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[H_3O^+] = \frac{1 \times 10^{-14}\ M^2}{[OH^-]} = \frac{1 \times 10^{-14}\ M^2}{1.3 \times 10^{-4}\ M} = 7.7 \times 10^{-11}\ M$$

$\text{pH} = -\log[H_3O^+] = -\log(7.7 \times 10^{-11}) = 10.11$

---

543. Given: Saturated solution: 0.276 g $AgBrO_3$ in 150.0 mL H_2O
Unknown: K_{sp}

$$\text{solubility} = \left(\frac{0.276\ g\ AgBrO_3}{150.0\ mL\ H_2O}\right)\left(\frac{1000\ mL}{L}\right)\left(\frac{1\ mol\ AgBrO_3}{235.74\ g\ AgBrO_3}\right)$$

$= 7.80 \times 10^{-3}$ M $AgBrO_3$

$AgBrO_3(s) \rightleftharpoons Ag^+(aq) + BrO_3^-(aq)$

$K_{sp} = [Ag^+][BrO_3^-]$

$[Ag^+] = 7.80 \times 10^{-3}$ M

$[BrO_3^-] = 7.80 \times 10^{-3}$ M

$K_{sp} = (7.80 \times 10^{-3})^2 = 6.08 \times 10^{-5}$

544. Given: solubility of CaF_2 = 0.0427 g/2.50 L

Unknown: K_{sp}

$$\left(\frac{0.0427 \text{ g } CaF_2}{2.50 \text{ L}}\right)\left(\frac{1 \text{ mol } CaF_2}{78.06 \text{ g } CaF_2}\right) = 2.19 \times 10^{-4} \text{ M } CaF_2$$

$CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$

$K_{sp} = [Ca^{2+}][F^-]^2$

$[Ca^{2+}] = 2.19 \times 10^{-4}$ M

$[F^-] = (2)(2.19 \times 10^{-4}) = 4.38 \times 10^{-4}$ M

$K_{sp} = (2.19 \times 10^{-4})(4.38 \times 10^{-4})^2$

$= 4.20 \times 10^{-11}$

---

545. Given: K_{sp} of $CaSO_4$ = 9.1×10^{-6}

Unknown: $[CaSO_4]$ in a saturated solution

$CaSO_4(s) \rightleftharpoons Ca^{2+}(aq) + SO_4^{2-}(aq)$

$K_{sp} = [Ca^{2+}][SO_4^{2-}]$

$[Ca^{2+}] = [SO_4^{2-}] = x$

$K_{sp} = x^2 = 9.1 \times 10^{-6}$

$x = \sqrt{9.1 \times 10^{-6}}$

$= 3.0 \times 10^{-3} \text{ M} = [CaSO_4]$

---

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}

a. $X_2Y(s) \rightleftharpoons 2X(aq) + Y(aq)$

$K_{sp} = [X]^2[Y]$

$[X] = 2x$

$[Y] = x$

$K_{sp} = 4.25 \times 10^{-7} = (2x)^2(x) = 4x^3$

$x = 4.74 \times 10^{-3} \text{ M} = [X_2Y]$

b. $AZ(s) \rightleftharpoons A(aq) + Z(aq)$

$K_{sp} = [A][Z] = x^2$

$x = \sqrt{4.25 \times 10^{-7}} = 6.52 \times 10^{-4}$ M

547. Given: V NaOH = 0.320 L
[NaOH] = 0.046 M
V $CaCl_2$ = 0.400 L
[$CaCl_2$] = 0.085 M
K_{sp} $Ca(OH)_2$ = 5.5×10^{-6}

Unknown: whether a precipitate of $Ca(OH)_2$ forms

$2NaOH + CaCl_2 \rightarrow 2NaCl + Ca(OH)_2$

$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$

$K_{sp} = [Ca^{2+}][OH^-]^2 = 5.5 \times 10^{-6}$

$$(0.400 \text{ L})\left(\frac{0.085 \text{ mol } Ca^{2+}}{\text{L}}\right) = 0.034 \text{ mol } Ca^{2+}$$

$$(0.320 \text{ L})\left(\frac{0.046 \text{ mol } OH^-}{\text{L}}\right) = 0.0147 \text{ mol } OH^-$$

Total volume = 0.320 L + 0.400 L = 0.720 L

$$\frac{0.034 \text{ mol } Ca^{2+}}{0.720 \text{ L}} = 0.0472 \text{ mol/L } Ca^{2+}$$

$$\frac{0.0147 \text{ mol } OH^-}{0.720 \text{ L}} = 0.0204 \text{ mol/L } OH^-$$

$$[Ca^{2+}][OH^-]^2 = (0.0472)(0.0204)^2$$
$$= 1.9 \times 10^{-5} = \text{ion product}$$

$1.9 \times 10^{-5} > K_{sp}$; precipitation occurs

---

548. Given: V $AgNO_3$ = 0.020 L
[$AgNO_3$] = 0.077 M
V $NaC_2H_3O_2$ = 0.030 L
[$NaC_2H_3O_2$] = 0.043 M
K_{sp} $AgC_2H_3O_2$ = 2.5×10^{-3}

Unknown: whether a precipitate forms

$AgNO_3 + NaC_2H_3O_2 \rightarrow AgC_2H_3O_2 + NaNO_3$

$AgC_2H_3O_2(s) \rightleftharpoons Ag^+(aq) + C_2H_3O_2^-(aq)$

$K_{sp} = [Ag^+][C_2H_3O_2^-] = 2.5 \times 10^{-3}$

$$(0.020 \text{ L})\left(\frac{0.077 \text{ mol } Ag^+}{\text{L}}\right) = 1.54 \times 10^{-3} \text{ mol } Ag^+$$

$$(0.030 \text{ L})\left(\frac{0.043 \text{ mol } C_2H_3O_2}{\text{L}}\right) = 1.29 \times 10^{-3} \text{ mol } C_2H_3O_2$$

Total volume = 0.020 L + 0.030 L = 0.050 L

$$\frac{1.54 \times 10^{-3} \text{ mol } Ag^+}{0.050 \text{ L}} = 0.031 \text{ mol/L } Ag^+$$

$$\frac{1.29 \times 10^{-3} \text{ mol } C_2H_3O_2^-}{0.050 \text{ L}} = 0.026 \text{ mol/L } C_2H_3O_2^-$$

$[Ag^+][C_2H_3O_2^-] = (0.031)(0.026) = 8.1 \times 10^{-4}$ = ion product

$8.1 \times 10^{-4} < 2.5 \times 10^{-3}$; no precipitation

549. Given: V $Pb(C_2H_3O_2)_2$ = 0.100 L
$[Pb(C_2H_3O_2)]$ = 0.036 M
V NaCl = 0.050 L
[NaCl] = 0.074 M
K_{sp} $PbCl_2$ = 1.9×10^{-4}

Unknown: whether a precipitate forms

$Pb(C_2H_3O_2)_2 + 2NaCl \rightarrow PbCl_2 + 2Na(C_2H_3O_2)$

$PbCl_2(s) \rightleftharpoons Pb^+(aq) + 2Cl^-(aq)$

$K_{sp} = [Pb^+][Cl^-]^2 = 1.9 \times 10^{-4}$

$$(0.100\ \text{L})\left(\frac{0.036\ \text{mol Pb}^+}{\text{L}}\right) = 3.6 \times 10^{-3}\ \text{mol Pb}^+$$

$$(0.050\ \text{L})\left(\frac{0.074\ \text{mol Cl}^-}{\text{L}}\right) = 3.7 \times 10^{-3}\ \text{mol Cl}^-$$

Total volume = 0.1 L + 0.05 L = 0.15 L

$$\frac{3.6 \times 10^{-3}\ \text{mol Pb}^+}{0.15\ \text{L}} = 0.024\ \text{mol/L Pb}^+$$

$$\frac{3.7 \times 10^{-3}\ \text{mol Cl}^-}{0.15\ \text{L}} = 0.025\ \text{mol/L Cl}^-$$

$[Pb^+][Cl^-]^2 = (0.024)(0.025)^2 = 1.5 \times 10^{-5}$ = ion product

$1.5 \times 10^{-5} < 1.9 \times 10^{-4}$; no precipitation

---

550. Given: V $(NH_4)_2S$ = 0.020 L
$[(NH_4)_2S]$ = 0.0090 M
V $Al(NO_3)_3$ = 0.120 L
$[Al(NO_3)_3]$ = 0.0082 M
K_{sp} Al_2S_3 = 2.00×10^{-7}

Unknown: whether a precipitate forms

$3(NH_4)_2S + 2Al(NO_3)_3 \rightarrow Al_2S_3 + 6NH_4NO_3$

$Al_2S_3(s) \rightleftharpoons 2Al^{3+}(aq) + 3S^{2-}(aq)$

$K_{sp} = [Al^{3+}]^2[S^{2-}]^3 = 2.00 \times 10^{-7}$

$$(0.120\ \text{L})\left(\frac{0.0082\ \text{mol Al}^{3+}}{\text{L}}\right) = 9.8 \times 10^{-4}\ \text{mol Al}^{3+}$$

$$(0.020\ \text{L})\left(\frac{0.0090\ \text{mol S}^{2-}}{\text{L}}\right) = 1.8 \times 10^{-4}\ \text{mol S}^{2-}$$

Total volume = 0.120 L + 0.020 L = 0.140 L

$$\frac{9.8 \times 10^{-4}\ \text{mol Al}^{3+}}{0.140\ \text{L}} = 7.0 \times 10^{-3}\ \text{mol/L Al}^{3+}$$

$$\frac{1.8 \times 10^{-4}\ \text{mol S}^{2-}}{0.140\ \text{L}} = 1.3 \times 10^{-3}\ \text{mol/L S}^{2-}$$

$[Al^{3+}]^2[S^{2-}]^3 = (7.0 \times 10^{-3})^2(1.3 \times 10^{-3})^3 = 1.1 \times 10^{-13}$ = ion product

$1.1 \times 10^{-13} < 2.00 \times 10^{-7}$; no precipitation

---

551. Given: $[CaCrO_4]$ = 0.010 M

Unknown: K_{sp}

$CaCrO_4(s) \rightleftharpoons Ca^{2+} + CrO_4^{2-}$

$K_{sp} = [Ca^{2+}][CrO_4^{2-}]$

$[Ca^{2+}]$ = 0.010 M

$[CrO_4^{2-}]$ = 0.010 M

$K_{sp} = (0.010)^2 = 1.0 \times 10^{-4}$

552. Given: Solubility of $PbSeO_4$ = 0.001 36 g/10.00 mL

Unknown: K_{sp}

$$\left(\frac{0.001\ 36 \text{ g } PbSeO_4}{10.00 \text{ mL}}\right)\left(\frac{1000 \text{ mL}}{\text{L}}\right)\left(\frac{1 \text{ mol } PbSeO_4}{350.12 \text{ g } PbSeO_4}\right) = 3.88 \times 10^{-4} \text{ M } PbSeO_4$$

$PbSeO_4(s) \rightleftharpoons Pb^{2+}(aq) + SeO_4^{2-}(aq)$

$K_{sp} = [Pb^{2+}][SeO_4^{2-}]$

$[Pb^{2+}] = [SeO_4^{2-}] = 3.88 \times 10^{-4}$ M

$K_{sp} = (3.88 \times 10^{-4})^2 = 1.51 \times 10^{-7}$

---

553. Given: V of CuSCN = 0.0225 L
[CuSCN] = 4.0×10^{-6} M

Unknown: **a.** K_{sp}
b. mass of CuSCN dissolved in 1×10^{-3} L of solution

a. $CuSCN(s) \rightleftharpoons Cu^{1+}(aq) + SCN^{1-}(aq)$

$K_{sp} = [Cu^{1+}][SCN^{1-}]$

$[Cu^{1+}] = [SCN^{1-}] = 4.0 \times 10^{-6}$ M

$K_{sp} = (4.0 \times 10^{-6})^2 = 1.6 \times 10^{-11}$

b. solubility =

$$4.0 \times 10^{-6} \text{ M} = \left(\frac{x \text{ g CuSCN}}{1 \times 10^{3} \text{ L}}\right)\left(\frac{1 \text{ mol CuSCN}}{121.64 \text{ g CuSCN}}\right)$$

$x = (4.0 \times 10^{-6}\text{ M})(1000 \text{ L})(121.64 \text{ g})/1 \text{ mol} = 0.49$ g

---

554. Given: $[Ag_2Cr_2O_7] = 3.684 \times 10^{-3}$ M

Unknown: K_{sp}

$Ag_2Cr_2O_7(s) \rightleftharpoons 2Ag^{+}(aq) + Cr_2O_7^{2-}(aq)$

$K_{sp} = [Ag^{+}]^2[Cr_2O_7^{2-}]$

$[Ag^{+}] = (2)(3.684 \times 10^{-3}\text{ M}) = 7.368 \times 10^{-3}$ M

$[Cr_2O_7^{-}] = 3.684 \times 10^{-3}$ M

$K_{sp} = (7.368 \times 10^{-3})^2(3.684 \times 10^{-3}) = 2.000 \times 10^{-7}$

---

555. Given: K_{sp} $BaSO_3$ = 8.0×10^{-7}

Unknown: **a.** $[BaSO_3]$
b. mass of $BaSO_3$ dissolved in 500. mL H_2O

a. $BaSO_3(s) \rightleftharpoons Ba^{2+}(aq) + SO_3^{2-}(aq)$

$K_{sp} = [Ba^{2+}][SO_3^{2-}]$

$[Ba^{2+}] = [SO_3^{2-}] = x$

$K_{sp} = x^2 = 8.0 \times 10^{-7}$

$x = \sqrt{8.0 \times 10^{-7}} = 8.9 \times 10^{-4}\text{ M} = [BaSO_3]$

b. solubility =

$$8.9 \times 10^{-4} \text{ M} = \left(\frac{x \text{ g } BaSO_3}{500 \text{ mL}}\right)\left(\frac{1000 \text{ mL}}{1 \text{ L}}\right)\left(\frac{1 \text{ mol } BaSO_3}{217.37 \text{ g } BaSO_3}\right)$$

$$x = \frac{(8.9 \times 10^{-4}\text{ M})(500 \text{ mL})(1 \text{ L})(217.37 \text{ g})}{(1000 \text{ mL})(1 \text{ mol})}$$

$= 0.097$ g

---

556. Given: K_{sp} $PbCl_2$ = 1.9×10^{-4}

Unknown: $[PbCl_2]$

$PbCl_2(s) \rightleftharpoons Pb^{2+}(aq) + 2Cl^{-}$

$K_{sp} = [Pb^{2+}][Cl^{-}]^2$

$[Pb^{2+}] = x$

$[Cl^{-}] = 2x$

$K_{sp} = 1.9 \times 10^{-4} = (x)(2x)^2 = 4x^3$

$x = \sqrt[3]{1.9 \times 10^{-4}/4} = 0.036\text{ M} = [PbCl_2]$

557. Given: K_{sp} $BaCO_3$ = 1.2×10^{-8}

Unknown: **a.** $[BaCO_3]$
b. volume of water needed to dissolve 0.10 g $BaCO_3$

a. $BaCO_3(s) \rightleftharpoons Ba^{2+}(aq) + CO_3^{2-}(aq)$

$K_{sp} = [Ba^{2+}][CO_3^{2-}] = 1.2 \times 10^{-8}$

$1.2 \times 10^{-8} = x^2$

$x = 1.1 \times 10^{-4}\ M = [BaCO_3]$

b. solubility =

$$1.1 \times 10^{-4}\ M = \left(\frac{0.10\ g\ BaCO_3}{x}\right)\left(\frac{1\ mol\ BaCO_3}{197.31\ g\ BaCO_3}\right)$$

$$x = (0.10\ g\ BaCO_3)\left(\frac{1\ mol\ BaCO_3}{197.31\ g\ BaCO_3}\right)\left(\frac{1}{1.1 \times 10^{-4}\ M}\right)$$

$x = 4.6\ L$

---

558. Given: K_{sp} $SrSO_4$ = 3.2×10^{-7}

Unknown: **a.** $[SrSO_4]$
b. mass of $SrSO_4$ remaining after 20.0 L saturated solution is evaporated

a. $SrSO_4(s) \rightleftharpoons Sr^{2+}(aq) + SO_4^{2-}(aq)$

$K_{sp} = [Sr^{2+}][SO_4^{2-}] = 3.2 \times 10^{-7}$

$3.2 \times 10^{-7} = x^2$

$x = 5.7 \times 10^{-4}\ M = [SrSO_4]$

b. solubility =

$$5.7 \times 10^{-4}\ M = \left(\frac{x\ g\ SrSO_4}{20.0\ L}\right)\left(\frac{1\ mol\ SrSO_4}{183.65\ g\ SrSO_4}\right)$$

$x = (5.7 \times 10^{-4}\ M)(20.0\ L)(183.65\ g\ SrSO_4/mol)$

$= 2.1\ g$

---

559. Given: K_{sp} $SrSO_3$ = 4.0×10^{-8}
solubility = 1.0000 g/5.0 L H_2O

Unknown: mass of $SrSO_3$ remaining after saturated solution is filtered

$SrSO_3(s) \rightleftharpoons Sr^{2+}(aq) + SO_3^{2-}(aq)$

$K_{sp} = [Sr^{2+}][SO_3^{2-}] = 4.0 \times 10^{-8}$

$4.0 \times 10^{-8} = x^2$

$x = 2.0 \times 10^{-4} = [SrSO_3]$

solubility =

$$2.0 \times 10^{-4}\ M = \left(\frac{x}{5\ L}\right)\left(\frac{1\ mol}{167.66\ g\ SrSO_3}\right)$$

$$x = (2.0 \times 10^{-4}\ M)(5\ L)\left(\frac{167.66\ g\ SrSO_3}{1\ mol}\right)$$

$= 0.17\ g\ SrSO_3$

$1.000\ g - 0.17\ g = 0.83\ g\ SrSO_3$

---

560. Given: K_{sp} $Mn_3(AsO_4)_2$ = 1.9×10^{-11}

Unknown: $[Mn_3(AsO_4)_2]$ in a saturated solution

$Mn_3(AsO_4)_2(s) \rightleftharpoons 3Mn^{2+}(aq) + 2AsO_4^{3-}(aq)$

$K_{sp} = [Mn^{2+}]^3[AsO_4^{3-}]^2$

$[Mn^{2+}] = 3x$

$[AsO_4^{3-}] = 2x$

$K_{sp} = 1.9 \times 10^{-11} = (3x)^3(2x)^2 = 108x^5$

$x = 2.8 \times 10^{-3}\ M = [Mn_3(AsO_4)_2]$

561. Given: V $Sr(NO_3)_2$ = 0.030 L
$[Sr(NO_3)_2]$ = 0.0050 M
V K_2SO_4 = 0.020 L
$[K_2SO_4]$ = 0.010 M
K_{sp} $SrSO_4$ = 3.2 × 10^{-7}

Unknown: **a.** ion product of the ions that can form a precipitate (b) whether a precipitate forms

a. $Sr(NO_3)_2 + K_2SO_4 \rightarrow SrSO_4 + 2KNO_3$

$SrSO_4(s)$ $Sr^{2+}(aq) + SO_4^{2-}(aq)$

$K_{sp} = [Sr^{2+}][SO_4^{2-}] = 3.2 \times 10^{-7}$

$$(0.030\ \text{L})\left(\frac{0.0050\ \text{mol Sr}^{2+}}{\text{L}}\right) = 1.5 \times 10^{-4}\ \text{mol Sr}^{2+}$$

$$(0.020\ \text{L})\left(\frac{0.010\ \text{mol SO}_4^{2-}}{\text{L}}\right) = 2.0 \times 10^{-4}\ \text{mol SO}_4^{2-}$$

Total volume = 0.030 L + 0.020 L = 0.050 L

$$\frac{1.5 \times 10^{-4}\ \text{mol Sr}^{2+}}{0.050\ \text{L}} = 3.0 \times 10^{-3}\ \text{mol/L Sr}^{2+}$$

$$\frac{2.0 \times 10^{-4}\ \text{mol SO}_4^{2-}}{0.050\ \text{L}} = 4.0 \times 10^{-3}\ \text{mol/L SO}_4^{2-}$$

$$[Sr^{2+}][SO_4^{2-}] = (3.0 \times 10^{-3})(4.0 \times 10^{-3})$$
$$= 1.2 \times 10^{-5} = \text{ion product}$$

b. $1.2 \times 10^{-5} > 3.2 \times 10^{-7}$; precipitation occurs

---

562. Given: K_{sp} $PbBr_2$ = 6.3 × 10^{-6}
V $MgBr_2$ = 0.120 L
$[MgBr_2]$ = 0.0035 M
V $Pb(C_2H_3O_2)_2$ = 0.180 L
$[Pb(C_2H_3O_2)_2]$ = 0.0024 M

Unknown: **a.** ion product of Br^- and Pb^{2+} in the mixed solution
b. whether a precipitate forms

a. $MgBr_2 + Pb(C_2H_3O_2)_2 \rightarrow PbBr_2 + Mg(C_2H_3O_2)_2$

$PbBr_2(s)$ $Pb^{2+}(aq) + 2Br^-(aq)$

$K_{sp} = [Pb^{2+}][Br^-]^2 = 6.3 \times 10^{-6}$

$$(0.180\ \text{L})\left(\frac{0.0024\ \text{mol Pb}^{2+}}{\text{L}}\right) = 4.3 \times 10^{-4}\ \text{mol Pb}^{2+}$$

$$(0.120\ \text{L})\left(\frac{0.0035\ \text{mol Br}^{-}}{\text{L}}\right) = 4.2 \times 10^{-4}\ \text{mol Br}^{-}$$

Total volume = 0.180 L + 0.120 L = 0.3 L

$$\frac{4.3 \times 10^{-4}\ \text{mol Pb}^{2+}}{0.3\ \text{L}} = 1.4 \times 10^{-3}\ \text{mol/L Pb}^{2+}$$

$$\frac{4.2 \times 10^{-4}\ \text{mol Br}^{-}}{0.3\ \text{L}} = 1.4 \times 10^{-3}\ \text{mol/L Br}^{-}$$

$[Br^-] = (2)(1.4 \times 10^{-3}) = 2.8 \times 10^{-3}$

$$\text{ion product} = [Pb^{2+}][Br^-]^2 = (1.4 \times 10^{-3})(2.8 \times 10^{-3})^2$$
$$= 1.1 \times 10^{-8}$$

b. $1.1 \times 10^{-8} < 6.3 \times 10^{-6}$; no precipitation occurs

563. Given: K_{sp} $Mg(OH)_2$ = 1.5×10^{-11}

Unknown: **b.** volume of H_2O required to dissolve 0.10 g $Mg(OH)_2$

b. $K_{sp} = [Mg^{2+}][OH^-]^2$

$[Mg^{2+}] = x$

$[OH^-] = 2x$

$K_{sp} = 1.5 \times 10^{-11} = (x)(2x)^2 = 4x^3$

$x = 1.6 \times 10^{-4}\ M = [Mg(OH)_2]$

solubility =

$$1.6 \times 10^{-4}\ M = \left(\frac{0.10\ g\ Mg(OH)_2}{x}\right)\left(\frac{1\ mol\ Mg(OH)_2}{58.3\ g\ Mg(OH)_2}\right)$$

$$x = (0.10\ g\ Mg(OH)_2)\left(\frac{1\ mol\ Mg(OH)_2}{58.3\ g\ Mg(OH)_2}\right)\left(\frac{1}{1.6 \times 10^{-4}\ M}\right)$$

$= 11\ L$

---

564. Given: K_{sp} Li_2CO_3 = 2.51×10^{-2}

Unknown: **a.** $[Li_2CO_3]$
b. mass of Li_2CO_3 dissolved to make 3440 mL of saturated solution

a. $Li_2CO_3\ \ 2Li^+ + CO_3^{2-}$

$K_{sp} = [Li^+]^2[CO_3^{2-}]$

$[Li^+] = 2x$

$[CO_3^{2-}] = x$

$K_{sp} = 2.51 \times 10^{-2} = (2x)^2(x) = 4x^3$

$x = 0.184\ M = [Li_2CO_3]$

b. solubility =

$$0.184\ M = \left(\frac{x}{3440\ mL}\right)\left(\frac{1000\ mL}{L}\right)\left(\frac{1\ mol\ Li_2CO_3}{73.86\ g\ Li_2CO_3}\right)$$

$$x = (0.184\ M)(3440\ mL)\left(\frac{1L}{1000\ mL}\right)\left(\frac{73.86\ g\ Li_2CO_3}{1\ mol}\right)$$

$= 46.8\ g$

---

565. Given: V $Ba(OH)_2$ = 0.050 L
V HCl = 0.03161 L
[HCl] = 0.3417 M

Unknown: K_{sp} $Ba(OH)_2$

$Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$

$BaCl_2\ \ Ba^{2+} + 2Cl^-$

$$(0.03161\ L)\left(\frac{0.3417\ mol\ HCl}{L}\right) = 0.01080\ mol\ HCl$$

$$\left(\frac{1\ mol\ Ba(OH)_2}{2\ mol\ HCl}\right)(0.01080\ mol\ HCl) = 5.400 \times 10^{-3}\ mol\ Ba(OH)_2$$

$$\frac{5.400 \times 10^{-3}\ mol\ Ba(OH)_2}{0.050\ L} = 0.1080\ M\ \ Ba(OH)_2$$

$K_{sp} = [Ba^{2+}][Cl^-]^2$

$[Ba(OH)_2] = 0.1080\ M$

$[Ba^{2+}] = 0.1080\ M$

$[Cl^-] = (2)(0.1080) = 0.2160\ M$

$K_{sp} = (0.1080)(0.2160)^2$

$= 5.040 \times 10^{-3}$

566. $QR \rightarrow Q^+ + R^-$

a. Given: [QR] = 1.0 M
Unknown: K_{sp}

$K_{sp} = [Q^+][R^-]$
$= (1.0)(1.0) = 1.0$

b. Given: [QR] = 0.50 M
Unknown: K_{sp}

$K_{sp} = [Q^+][R^-]$
$= (0.50)(0.50) = 0.25$

c. Given: [QR] = 0.1 M
Unknown: K_{sp}

$K_{sp} = (0.1)(0.1) = 0.01$

d. Given: [QR] = 0.001 M
Unknown: K_{sp}

$K_{sp} = (0.001)(0.001) = 1 \times 10^{-6}$

---

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

a. $QR \rightarrow Q^+ + R^-$

$K_{sp} = [Q^+][R^-] = (0.02)^2 = 4 \times 10^{-4}$

b. $X_2Y \rightarrow 2X^+ + Y^-$

$K_{sp} = [X^+]^2[Y^-]$

$[X^+] = (2)(0.02) = 0.04$ M

$[Y^-] = 0.02$ M

$K_{sp} = (0.04)^2(0.02) = 3 \times 10^{-5}$

c. $KL_2 \rightarrow K^+ + 2L^-$

$K_{sp} = [K^+][L^-]^2$

$[K^+] = 0.02$ M

$[L^-] = (2)(0.02) = 0.04$ M

$K_{sp} = (0.02)(0.04)^2 = 3 \times 10^{-5}$

d. $A_3Z \rightarrow 3A^+ + Z^-$

$K_{sp} = [A^+]^3[Z^-]$

$[A^+] = (3)(0.02) = 0.06$ M

$[Z^-] = 0.02$ M

$K_{sp} = (0.06)^3(0.02) = 4 \times 10^{-6}$

e. $D_2E_3 \rightarrow 2D^+ + 3E^-$

$K_{sp} = [D^+]^2[E^-]^3$

$[D^+] = (2)(0.02) = 0.04$ M

$[E^-] = (3)(0.02) = 0.06$ 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

a. $AgBr(s)\ \ Ag^+(aq) + Br^-(aq)$

$K_{sp} = [Ag^+][Br^-]$

$[Ag^+] = [Br^-] = x$

$K_{sp} = x^2 = 5.0 \times 10^{-13}$

$x = 7.1 \times 10^{-7}\ M = [AgBr]$

b. solubility =

$$7.1 \times 10^{-7}\ M = \left(\frac{x\ AgBr}{10.0\ L}\right)\left(\frac{1\ mol\ AgBr}{187.87\ g\ AgBr}\right)$$

$x = (7.1 \times 10^{-7}\ M)(10.0\ L)(187.87\ g)/1\ mol$

$= 1.3 \times 10^{-3}\ g$

---

569. Given: K_{sp} of $Ca(OH)_2$ = 5.5×10^{-6}

Unknown: **a.** molarity of saturated $Ca(OH)_2$ solution
b. $[OH^-]$
c. pH

a. $Ca(OH)_2(s)\ \ Ca^{2+}(aq) + 2OH^-(aq)$

$K_{sp} = [Ca^{2+}][OH^-]^2$

$[Ca^{2+}] = x$

$[OH^-] = 2x$

$K_{sp} = 5.5 \times 10^{-6} = (x)(2x)^2 = 4x^3$

$x = 0.011\ M = [Ca(OH)_2]$

b. $[OH^-] = (2)(x) = (2)(0.011\ M) = 0.022\ M$

c. $[H_3O^+][OH^-] = 1 \times 10^{-14}\ M^2$

$$[H_3O^+] = \frac{1 \times 10^{-14}\ M^2}{0.022\ M}$$

$= 4.5 \times 10^{-13}$

$pH = -\log\ [H_3O^+]$

$= -\log\ (4.5 \times 10^{-13})$

$= 12.35$

---

570. Given: K_{sp} of $MgCO_3$ = 3.5×10^{-8}

Unknown: mass of $MgCO_3$ dissolved in 4.00 L of water

$MgCO_3(s)\ \ Mg^{2+}(aq) + CO_3^{2-}(aq)$

$K_{sp} = [Mg^{2+}][CO_3^{2-}]$

$[Mg^{2+}] = [CO_3^{2-}] = x$

$K_{sp} = x^2 = 3.5 \times 10^{-8}$

$x = 1.9 \times 10^{-4}\ M = [MgCO_3]$

solubility =

$$1.9 \times 10^{-4}\ M = \left(\frac{x}{4.00\ L}\right)\left(\frac{1\ mol\ MgCO_3}{84.29\ g\ MgCO_3}\right)$$

$x = (1.9 \times 10^{-4}\ M)(4.00\ L)(84.29\ g)/1\ mol$

$= 0.064\ g$

571. *Formula equation:*

$Fe + SnCl_4 \rightarrow FeCl_3 + SnCl_2$

Ionic equation:

$\overset{0}{Fe} + \overset{+4}{Sn}^{4+} + 4\overset{-1}{Cl}^- \rightarrow \overset{+3}{Fe}^{3+} + 3\overset{-1}{Cl}^- + \overset{+2}{Sn}^{2+} + 2\overset{-1}{Cl}^-$

Oxidation half-reaction:

$2[\overset{0}{Fe} \rightarrow \overset{+3}{Fe}^{3+} + 3e^-] = 2Fe \rightarrow 2Fe^{3+} + 6e^-$

Reduction half-reaction:

$3[\overset{+4}{Sn}Cl_4 + 2e^- \rightarrow \overset{+2}{Sn}Cl_2 + 2Cl^-] = 3SnCl_4 + 6e^- \rightarrow 3SnCl_2 + 6Cl^-$

Combine half-reactions:

$$\begin{array}{r}
2Fe \rightarrow 2Fe^{3+} + 6e^- \\
3SnCl_4 + 6e^- \rightarrow 3SnCl_2 + 6Cl^- \\
\hline
3SnCl_4 + 2Fe \rightarrow 3SnCl_2 + 2Fe^{3+} + 6Cl^-
\end{array}$$

Combine ions to form balanced equation:

$2Fe + 3SnCl_4 \rightarrow 2FeCl_3 + 3SnCl_2$

---

572. *Formula equation:*

$H_2O_2 + FeSO_4 + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + H_2O$

Ionic equation:

$\overset{+1}{H}_2\overset{-1}{O}_2 + \overset{+2}{Fe}^{2+} + (\overset{+6}{S}\overset{-2}{O}_4^{2-} + 2\overset{+1}{H}^+ + (\overset{+6}{S}\overset{-2}{O}_4^{2-} \rightarrow 2\overset{+3}{Fe}^{3+} + 3(\overset{+6}{S}\overset{-2}{O}_4^{2-}) + \overset{+1}{H}_2\overset{-2}{O}$

Oxidation half-reaction:

$2\overset{+2}{Fe}^{2+} \rightarrow 2\overset{+3}{Fe}^{3+} + 2e^-$

Reduction half-reaction:

$\overset{+1}{H}_2\overset{-1}{O}_2 + 2H^+ + 2e^- \rightarrow 2\overset{+1}{H}_2\overset{-2}{O}$

Combine half-reactions:

$$\begin{array}{r}
2Fe^{2+} \rightarrow 2F^{3+} + 2e^- \\
H_2O_2 + 2H^+ + 2e^- \rightarrow H_2O + H_2O \\
\hline
H_2O_2 + 2H^+ + 2Fe^{2+} \rightarrow 2Fe^{3+} + 2H_2O
\end{array}$$

Combine ions to form balanced equation:

$H_2O_2 + 2FeSO_4 + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 2H_2O$

573. *Formula equation:*

$$CuS + HNO_3 \rightarrow Cu(NO_3)_2 + NO + S + H_2O$$

Ionic equation:

$$Cu^{2+} + S^{2-} + H^+ + \overset{+5}{N}\overset{-2}{O}{}_3^- \rightarrow Cu^{2+} + 2\overset{+5}{N}\overset{-2}{O}{}_3^- + \overset{+2}{N}\overset{-2}{O} + \overset{0}{S} + \overset{+1}{H_2}\overset{-2}{O}$$

Oxidation half-reaction:

$$3[Cu\overset{-2}{S} \rightarrow 2e^- + Cu^{2+} + \overset{0}{S}] = 3CuS \rightarrow 6e^- + 3Cu^{2+} + 3S$$

Reduction half-reaction:

$$2[4H\overset{+5}{N}O_3 + 3e^- \rightarrow 3NO_3^- + \overset{+2}{N}O + 2H_2O]$$

$$= 8HNO_3 + 6e^- \rightarrow 6NO_3^- + 2NO + 4H_2O$$

Combine half-reactions:

$$\begin{array}{r} 3CuS \rightarrow 6e^- + 3Cu^{2+} + 3S \\ 8HNO_3 + 6e^- \rightarrow 6NO_3^- + 2NO + 4H_2O \\ \hline 3CuS + 8HNO_3 \rightarrow 3Cu^{2+} + 3S + 6NO_3^- + 2NO + 4H_2O \end{array}$$

Combine ions to form balanced equation:

$$3CuS + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 3S + 4H_2O$$

---

574. *Formula equation:*

$$K_2Cr_2O_7 + HI \rightarrow CrI_3 + KI + I_2 + H_2O$$

Ionic equation:

$$2\overset{+1}{K}{}^+ + \overset{+6}{Cr}{}_2\overset{-2}{O}{}_7^{2-} + \overset{+1}{H}\,\overset{-1}{I} \rightarrow \overset{+3}{Cr}{}^{3+} + 3\overset{-1}{I}{}^- + \overset{+1}{K}\,\overset{-1}{I} + \overset{0}{I_2} + \overset{+1}{H_2}\overset{-2}{O}$$

Oxidation half-reaction:

$$3[2\overset{-1}{I}{}^- \rightarrow \overset{0}{I_2} + 2e^-] = 6I^- \rightarrow 3I_2 + 6e^-$$

Reduction half-reaction:

$$K_2\overset{+6}{Cr}{}_2O_7 + 14H^+ + 8I^- + 6e^- \rightarrow 2\overset{+3}{Cr}I_3 + 2KI + 7H_2O$$

Combine half-reactions:

$$\begin{array}{r} 6I^- \rightarrow 3I_2 + 6e^- \\ K_2Cr_2O_7 + 14H^+ + 8I^- + 6e^- \rightarrow 2CrI_3 + 2KI + 7H_2O \\ \hline K_2Cr_2O_7 + 14H^+ + 14I^- \rightarrow 2CrI_3 + 2KI + 3I_2 + 7H_2O \end{array}$$

Combine ions to form balanced equation:

$$K_2Cr_2O_7 + 14HI \rightarrow 2CrI_3 + 2KI + 3I_2 + 7H_2O$$

575. *Formula equation:*

$CO_2 + NH_2OH \rightarrow CO + N_2 + H_2O$

Ionic equation:

$\overset{+4}{C}\overset{-2}{O_2} + \overset{-1}{N}\overset{+1}{H_2}\overset{-2}{O}\overset{+1}{H} \rightarrow \overset{+2}{C}\overset{-2}{O} + \overset{0}{N_2} + \overset{+1}{H_2}\overset{-2}{O}$

Oxidation half-reaction:

$2\overset{-1}{N}H_2OH + 2OH^- \rightarrow \overset{0}{N_2} + 4H_2O + 2e^-$

Reduction half-reaction:

$\overset{+4}{C}O_2 + H_2O + 2e^- \rightarrow \overset{+2}{C}O + 2OH^-$

Combine half-reactions:

$2NH_2OH + 2OH^- \rightarrow N_2 + 4H_2O + 2e^-$

$\underline{CO_2 + H_2O + 2e^- \rightarrow CO + 2OH^-}$

$CO_2 + 2NH_2OH \rightarrow CO + N_2 + 3H_2O$

Combine ions to form balanced equation:

$CO_2 + 2NH_2OH \rightarrow CO + N_2 + 3H_2O$

---

576. *Formula equation:*

$Bi(OH)_3 + K_2SnO_2 \rightarrow Bi + K_2SnO_3$

Ionic equation:

$\overset{+3}{Bi^{3+}} + 3\overset{-2}{O}\overset{+1}{H^-} + 2\overset{+1}{K^+} + \overset{+2}{Sn}\overset{-2}{O_2^{2-}} \rightarrow \overset{0}{Bi} + 2\overset{+1}{K^+} + \overset{+4}{Sn}\overset{-2}{O_3^{2-}}$

Oxidation half-reaction:

$3[2K^+ + \overset{+2}{Sn}O_2^{2-} + H_2O \rightarrow 2K^+ + \overset{+4}{Sn}O_3^{2-} + 2H^+ + 2e^-]$

$= 6K^+ + 3SnO_2^{2-} + 3H_2O \rightarrow 6K^+ + 3SnO_3^{2-} + 6H^+ + 6e^-$

Reduction half-reaction:

$2[\overset{+3}{Bi^{3+}} + 3OH^- + 3H^+ + 3e^- \rightarrow \overset{0}{Bi} + 3H_2O]$

$= 2Bi^{3+} + 6OH^- + 6H^+ + 6e^- \rightarrow 2Bi + 6H_2O$

Combine half-reactions:

$6K^+ + 3SnO_2^{2-} + 3H_2O \rightarrow 6K^+ + 3SnO_3^{2-} + 6H^+ + 6e^-$

$\underline{2Bi^{3+} + 6OH^- + 6H^+ + 6e^- \rightarrow 2Bi + 6H_2O}$

$6K^+ + 2Bi^{3+} + 6OH^- + 3SnO_2^{2-} \rightarrow 6K^+ + 2Bi + H_2O + 3SnO_3^{2-}$

Combine ions to form balanced equation:

$2Bi(OH)_3 + 3K_2SnO_2 \rightarrow 2Bi + 3K_2SnO_3 + 3H_2O$

577. *Formula equation:*

$$Mg + N_2 \rightarrow Mg_3N_2$$

Ionic equation:

$$\overset{0}{Mg} + \overset{0}{N}_2 \rightarrow 3\overset{+2}{Mg}{}^{2+} + 2\overset{-3}{N}{}^{3-}$$

Oxidation half-reaction:

$$3\overset{0}{Mg} \rightarrow 3\overset{+2}{Mg}{}^{2+} + 6e^-$$

Reduction half-reaction:

$$\overset{0}{N}_2 + 6e^- \rightarrow 2\overset{-3}{N}{}^{3-}$$

Combine half-reactions:

$$\begin{array}{r} 3Mg \rightarrow 3Mg^{2+} + 6e^- \\ N_2 + 6e^- \rightarrow 2N^{3-} \\ \hline 3Mg + N_2 \rightarrow 3Mg^{2+} + 2N^{3+} \end{array}$$

Combine ions to form balanced equation:

$$3Mg + N_2 \rightarrow Mg_3N_2$$

---

578. *Formula equation:*

$$SO_2 + Br_2 + H_2O \rightarrow HBr + H_2SO_4$$

Ionic equation:

$$\overset{+4-2}{SO}_2 + \overset{0}{Br}_2 + \overset{+1\,-2}{H_2O} \rightarrow \overset{+1}{H}{}^+ + \overset{-1}{Br}{}^- + 2\overset{+1}{H}{}^+ + \overset{+6-2}{SO}{}_4^{2-}$$

Oxidation half-reaction:

$$\overset{+4}{S}O_2 + 2H_2O \rightarrow \overset{+6}{S}O_4^{2-} + 4H^+ + 2e^-$$

Reduction half-reaction:

$$\overset{0}{Br}_2 + 2e^- \rightarrow 2\overset{-1}{Br}{}^-$$

Combine half-reactions:

$$\begin{array}{r} SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^- \\ Br_2 + 2e^- \rightarrow 2Br^- \\ \hline SO_2 + 2H_2O + Br_2 \rightarrow 2Br^- + SO_4^{2-} + 4H^+ \end{array}$$

Combine ions to form balanced equation:

$$SO_2 + Br_2 + 2H_2O \rightarrow 2HBr + H_2SO_4$$

579. *Formula equation:*

$H_2S + Cl_2 \rightarrow S + HCl$

Ionic equation:

$2\overset{+1}{H}{}_2^{+} + \overset{-2}{S}{}^{2-} + \overset{0}{Cl}_2 \rightarrow \overset{0}{S} + \overset{+1}{H}{}^{+} + \overset{-1}{Cl}{}^{-}$

Oxidation half-reaction:

$\overset{-2}{S}{}^{2-} + 2H^+ \rightarrow \overset{0}{S} + 2H^+ + 2e^-$

Reduction half-reaction:

$\overset{0}{Cl}_2 + 2e^- \rightarrow 2\overset{-1}{Cl}{}^-$

Combine half-reactions:

$$\begin{array}{r} S^{2-} + 2H^+ \rightarrow S + 2H^+ + 2e^- \\ Cl_2 + 2e^- \rightarrow 2Cl^- \\ \hline S^{2-} + 2H^+ + Cl_2 \rightarrow S + 2Cl^- + 2H^+ \end{array}$$

Combine ions to form balanced equation:

$H_2S + Cl_2 \rightarrow S + 2HCl$

---

580. *Formula equation:*

$PbO_2 + HBr \rightarrow PbBr_2 + Br_2 + H_2\overset{-2}{O}$

Ionic equation:

$\overset{+4}{Pb}\overset{-2}{O}_2 + \overset{+1}{H}{}^+ + \overset{-1}{Br}{}^- \rightarrow \overset{+2}{Pb}\overset{-1}{Br}_2 + \overset{0}{Br}_2 + \overset{+1}{H}_2\overset{-2}{O}$

Oxidation half-reaction:

$2\overset{-1}{Br}{}^- \rightarrow \overset{0}{Br}_2 + 2e^-$

Reduction half-reaction:

$2Br^- + \overset{+4}{Pb}O_2 + 4H^+ + 2e^- \rightarrow \overset{+2}{Pb}Br_2 + 2H_2O$

Combine half-reactions:

$$\begin{array}{r} 2Br^- \rightarrow Br_2 + 2e^- \\ 2Br^- + PbO_2 + 4H^+ + 2e^- \rightarrow PbBr_2 + 2H_2O \\ \hline 4Br^- + PbO_2 + 4H^+ \rightarrow PbBr_2 + Br_2 + 2H_2O \end{array}$$

Combine ions to form balanced equation:

$PbO_2 + 4HBbr \rightarrow PbBr_2 + Br_2 + 2H_2O$

581. *Formula equation:*

$$S + HNO_3 \rightarrow NO_2 + H_2SO_4 + H_2O$$

Ionic equation:

$$\overset{0}{S} + \overset{+1+5-2}{HNO_3} \rightarrow \overset{+4-2}{NO_2} + \overset{+1}{2H^+} + \overset{+6-2}{SO_4^{2-}} + \overset{+1\ -2}{H_2O}$$

Oxidation half-reaction:

$$\overset{0}{S} + 4H_2O \rightarrow \overset{+6}{SO_4^{2-}} + 8H^+ + 6e^-$$

Reduction half-reaction:

$$6[H\overset{+5}{N}O_3^- + H^+ + 1e^- \rightarrow \overset{+4}{N}O_2 + H_2O] = 6HNO_3 + 6H^+ + 6e^- \rightarrow 6NO_2 + 6H_2O$$

Combine half-reactions:

$$\begin{array}{r} S + 4H_2O \rightarrow SO_4^{2-} + 8H^+ + 6e^- \\ 6HNO_3 + 6H^+ + 6e^- \rightarrow 6NO_2 + 6H_2O \\ \hline S + 6HNO_3 \rightarrow SO_4^{2-} + 2H^+ + 6NO_2 + 2H_2O \end{array}$$

Combine ions to form balanced equation:

$$S + 6HNO_3 \rightarrow 6NO_2 + H_2SO_4 + 2H_2O$$

---

582. *Formula equation:*

$$NaIO_3 + N_2H_4 + HCl \rightarrow N_2 + NaICl_2 + H_2O$$

Ionic equation:

$$\overset{+1+5-2}{NaIO_3} + \overset{-2\ +1}{N_2H_4} + \overset{+1}{H^+} + \overset{-1}{Cl^-} \rightarrow \overset{0}{N_2} + \overset{+1+1-1}{NaICl_2} + \overset{+1\ -2}{H_2O}$$

Oxidation half-reaction:

$$\overset{-2}{N_2}H_4 \rightarrow \overset{0}{N_2} + 4H^+ + 4e^-$$

Reduction half-reaction:

$$Na\overset{+5}{I}O_3 + 6H^+ + 2Cl^- + 4e^- \rightarrow Na\overset{+1}{I}Cl_2 + 3H_2O$$

Combine half-reactions:

$$\begin{array}{r} N_2H_4 \rightarrow N_2 + 4H^+ + 4e^- \\ NaIO_3 + 6H^+ + 2Cl^- + 4e^- \rightarrow NaICl_2 + 3H_2O \\ \hline NaIO_3 + 2H^+ + 2Cl^- + N_2H_4 \rightarrow NaICl_2 + 3H_2O + N_2 \end{array}$$

Combine ions to form balanced equation:

$$NaIO_3 + N_2H_4 + 2HCl \rightarrow N_2 + NaICl_2 + 3H_2O$$

583. *Formula equation:*

$MnO_2 + H_2O_2 + HCl \rightarrow MnCl_2 + O_2 + H_2O$

Ionic equation:

$\overset{+4}{Mn}\overset{-2}{O_2} + \overset{+1}{H_2}\overset{-1}{O_2} + \overset{+1}{H^+} + \overset{-1}{Cl^-} \rightarrow \overset{+2}{Mn^{2+}} + 2\overset{-1}{Cl^-} + \overset{0}{O_2} + \overset{+1}{H_2}\overset{-2}{O}$

Oxidation half-reaction:

$H_2\overset{-1}{O_2} \rightarrow \overset{0}{O_2} + 2H^+ + 2e^-$

Reduction half-reaction:

$\overset{+4}{Mn}O_2 + 4H^+ + 2Cl^- + 2e^- \rightarrow \overset{+2}{Mn^{2+}} + 2H_2O + 2Cl^-$

Combine half-reactions:

$$\begin{array}{r} H_2O_2 \rightarrow O_2 + 2H^+ + 2e^- \\ MnO_2 + 4H^+ + 2Cl^- + 2e^- \rightarrow Mn^{2+} + 2H_2O + 2Cl^- \\ \hline MnO_2 + 2H^+ + H_2O_2 + 2Cl^- \rightarrow Mn^{2+} + 2H_2O + O_2 + 2Cl^- \end{array}$$

Combine ions to form balanced equation:

$MnO_2 + H_2O_2 + 2HCl \rightarrow MnCl_2 + O_2 + 2H_2O$

---

584. *Formula equation:*

$AsH_3 + NaClO_3 \rightarrow H_3AsO_4 + NaCl$

Ionic equation:

$\overset{-3}{As}\overset{+1}{H_3} + \overset{+1}{Na^+} + \overset{+5}{Cl}\overset{-2}{O_3^-} \rightarrow 3\overset{+1}{H^+} + \overset{+5}{As}\overset{-2}{O_4^{3-}} + \overset{+1}{Na^+} + \overset{-1}{Cl^-}$

Oxidation half-reaction:

$3[\overset{-3}{As}H_3 + 4H_2O \rightarrow \overset{+5}{As}O_4^{3-} + 11H^+ + 8e^-]$

$= 3AsH_3 + 12H_2O \rightarrow 3AsO_4 + 33H^+ + 24e^-$

Reduction half-reaction:

$4[\overset{+5}{Cl}O_3 + 6H^+ + Na^+ + 6e^- \rightarrow \overset{-1}{Cl^-} + 3H_2O + Na^+]$

$= 4ClO_3 + 24H^+ + 4Na^+ + 24e^- \rightarrow 4Cl^- + 12H_2O + 4Na^+$

Combine half-reactions:

$$\begin{array}{r} 3AsH_3 + 12H_2O \rightarrow 3AsO_4 + 33H^+ + 24e^- \\ 4ClO_3 + 24H^+ + 4Na^+ + 24e^- \rightarrow 4Cl^- + 12H_2O + 4Na^+ \\ \hline 3AsH_3 + 4ClO_3 + 4Na^+ \rightarrow 3AsO_4 + 9H^+ + 4Na^+ + 4Cl^- \end{array}$$

Combine ions to form balanced equation:

$3AsH_3 + 4NaClO_3 \rightarrow 3H_3AsO_4 + 4NaCl$

585. *Formula equation:*

$K_2Cr_2O_7 + H_2C_2O_4 + HCl \rightarrow CrCl_3 + CO_2 + KCl + H_2O$

Ionic equation:

$2\overset{+1}{K}{}^+ + \overset{+6}{Cr}_2\overset{-2}{O}{}_7^{2-} + 2\overset{+1}{H}{}^+ + \overset{+3}{C}_2\overset{-2}{O}{}_4^{2-} + \overset{+1}{H}{}^+ + \overset{-1}{Cl}{}^- \rightarrow$

$\overset{+3}{Cr}{}^{3+} + 3\overset{-1}{Cl}{}^- + \overset{+4}{C}\overset{-2}{O}_2 + \overset{+1}{K}{}^+ + \overset{-1}{Cl}{}^- + \overset{+1}{H}_2\overset{-2}{O}$

Oxidation half-reaction:

$3[\overset{+3}{C}_2O_4 \rightarrow 2\overset{+4}{C}O_2 + 2e^-] = 3C_2O_4 \rightarrow 6CO_2 + 6e^-$

Reduction half-reaction:

$\overset{+6}{Cr}_2O_7 + 14H^+ + 6e^- \rightarrow 2\overset{+3}{Cr}{}^{3+} + 7H_2O$

Combine half-reactions:

$$\begin{array}{r} 3C_2O_4 \rightarrow 6CO_2 + 6e^- \\ Cr_2O_7 + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \\ \hline Cr_2O_7 + 14H^+ + 3C_2O_4 \rightarrow 2Cr^{3+} + 6CO_2 + 7H_2O \end{array}$$

Combine ions to form balanced equation:

$K_2Cr_2O_7 + 3H_2C_2O_4 + 8HCl \rightarrow 2CrCl_3 + 6CO_2 + 2KCl + 7H_2O$

---

586. *Formula equation:*

$\overset{+2}{Hg}(\overset{+5}{N}\overset{-2}{O}_3)_2 \rightarrow \overset{+2}{Hg}\overset{-2}{O} + \overset{+4}{N}\overset{-2}{O}_2 + \overset{0}{O}_2$

Oxidation half-reaction:

$2\overset{-2}{O} \rightarrow \overset{0}{O}_2 + 4e^-$

Reduction half-reaction:

$4[\overset{+5}{N} + 1e^- \rightarrow \overset{+4}{N}] = 4N + 4e^- \rightarrow 4N$

Balanced equation:

$2Hg(NO_3)_2 \rightarrow 2HgO + 4NO_2 + O_2$

587. *Formula equation:*

$$HAuCl_4 + N_2H_4 \rightarrow Au + N_2 + HCl$$

Ionic equation:

$$\overset{+1}{H}^+ + \overset{+3}{Au}\overset{-1}{Cl}{}_4^- + \overset{-2}{N}_2\overset{+1}{H}_4 \rightarrow \overset{0}{Au} + \overset{0}{N}_2 + \overset{+1}{H}^+ + \overset{-1}{Cl}{}^-$$

Oxidation half-reaction:

$$3[\overset{-2}{N}_2H_4 \rightarrow \overset{0}{N}_2 + 4H^+ + 4e^-] = 3N_2H_4 \rightarrow 3N_2 + 12H^+ + 12e^-$$

Reduction half-reaction:

$$4[H\overset{+3}{Au}Cl_4 + 3e^- \rightarrow \overset{0}{Au} + 4H^+ + 4Cl^-] = 4HAuCl_4 + 12e^- \rightarrow 4Au + 16Cl + 4H^+$$

Combine half-reactions:

$$3N_2H_4 \rightarrow 3N_2 + 12H^+ + 12e^-$$

$$\underline{4HAuCl_4^- + 12e^- \rightarrow 4Au + 16Cl^- + 4H^+}$$

$$4AuCl_4^- + 3N_2H_4 \rightarrow 4Au + 16Cl^- + 3N_2 + 16H^+$$

Combine ions to form balanced equation:

$$4HAuCl_4 + 3N_2H_4 \rightarrow 4Au + 3N_2 + 16HCl$$

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588. *Formula equation:*

$$Sb_2(SO_4)_3 + KMnO_4 + H_2O \rightarrow H_3SbO_4 + K_2SO_4 + MnSO_4 + H_2SO_4$$

Ionic equation:

$$2\overset{+3}{Sb}{}^{3+} + 3\overset{+6}{S}\overset{-2}{O}{}_4^{2-} + \overset{+1}{K}{}^+ + \overset{+7}{Mn}\overset{-2}{O}{}_4^- + \overset{+1}{H}_2\overset{-2}{O} \rightarrow$$

$$3\overset{+1}{H}{}^+ + \overset{+5}{Sb}\overset{-2}{O}{}_4^{3-} + 2\overset{+1}{K}{}^+ + \overset{+6}{S}\overset{-2}{O}{}_4^{2-} + \overset{+2}{Mn}{}^{2+} + \overset{+6}{S}\overset{-2}{O}{}_4^{2-} + 2\overset{+1}{H}{}^+ + \overset{+6}{S}\overset{-2}{O}{}_4^{2-}$$

Oxidation half-reaction:

$$5[2\overset{+3}{Sb}{}^{3+} + 3SO_4^{2-} + 8H_2O \rightarrow 2\overset{+5}{Sb}O_4^{3-} + 3SO_4^{2-} + 16H^+ + 4e^-]$$

$$= 10Sb^{3+} + 15SO_4^{2-} + 40H_2O \rightarrow 10SbO_4^{3-} + 15SO_4^{2-} + 80H^+ + 20e^-$$

Reduction half-reaction:

$$4[K^+ + \overset{+7}{Mn}O_4^- + 8H^+ + 5e^- \rightarrow K^+ + \overset{+2}{Mn}{}^{2+} + 4H_2O]$$

$$= 4K^+ + 4MnO_4 + 32H^+ + 20e^- \rightarrow 4K^+ + 4Mn^{2+} + 16H_2O$$

Combine half-reactions:

$$10Sb^{3+} + 15SO_4^{2-} + 40H_2O \rightarrow 10SbO_4^{3-} + 15SO_4^{2-} + 80H^+ + 20e^-$$

$$\underline{4MnO_4^- + 4K^+ + 32H^+ + 20e^- \rightarrow 4Mn^{2+} + 4K^+ + 16H_2O}$$

$$10Sb^{3+} + 24H_2O + 4MnO_4^- + 15SO_4^{2-} + 4K^+ \rightarrow$$

$$10SbO_4^{3-} + 48H^+ + 4Mn^{2+} + 15SO_4^{2-} + 4K^+$$

Combine ions to form balanced equation:

$$5Sb_2(SO_4)_3 + 4KMnO_4 + 24H_2O \rightarrow 10H_3SbO_4 + 2K_2SO_4 + 4MnSO_4 + 9H_2SO_4$$

589. *Formula equation:*

$$Mn(NO_3)_2 + NaBiO_3 + HNO_3 \rightarrow Bi(NO_3)_2 + HMnO_4 + NaNO_3 + H_2O$$

Ionic equation:

$$\overset{+2}{Mn^{2+}} + 2\overset{+5}{N}\overset{-2}{O_3^-} + \overset{+1}{Na}\overset{+5}{Bi}\overset{-2}{O_3} + \overset{+1}{H^+} + \overset{+5}{N}\overset{-2}{O_3^-}$$

$$\rightarrow \overset{+2}{Bi^{2+}} + 2\overset{+5}{N}\overset{-2}{O_3^-} + \overset{+1}{H}\overset{+7}{Mn}\overset{-2}{O_4} + \overset{+1}{Na^+} + \overset{+5}{N}\overset{-2}{O_3^-} + \overset{+1}{H_2}\overset{-2}{O}$$

Oxidation half-reaction:

$$3[\overset{+2}{Mn^{2+}} + 4H_2O \rightarrow H\overset{+7}{Mn}O_4 + 7H^+ + 5e^-]$$

$$= 3Mn^{2+} + 12H_2O \rightarrow 3HMnO_4 + 21H^+ + 15e^-$$

Reduction half-reaction:

$$5[Na\overset{+5}{Bi}O_3 + 6H^+ + 3e^- \rightarrow \overset{+2}{Bi^{2+}} + Na^+ + 3H_2O]$$

$$= 5NaBiO_3 + 30H^+ + 15e^- \rightarrow 5Bi^{2+} + 5Na^+ + 15H_2O$$

Combine half-reactions:

$$3Mn^{2+} + 12H_2O \rightarrow 3HMnO_4 + 21H^+ + 15e^-$$

$$\underline{5NaBiO_3 + 30H^+ + 15e^- \rightarrow 5Bi^{2+} + 5Na^+ + 15H_2O}$$

$$3Mn^{2+} + 5NaBiO_3 + 9H^+ \rightarrow 3MnO_4 + 5Na^+ + 5Bi^{2+} + 3H_2O$$

Combine ions to form balanced equation:

$$3Mn(NO_3)_2 + 5NaBiO_3 + 9HNO_3 \rightarrow 5Bi(NO_3)_2 + 3HMnO_4 + 5NaNO_3 + 3H_2O$$

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590. *Formula equation:*

$$H_3AsO_4 + Zn + HCl \rightarrow AsH_3 + ZnCl_2 + H_2O$$

Ionic equation:

$$3\overset{+1}{H^+} + \overset{+5}{As}\overset{-2}{O_4^{3-}} + \overset{0}{Zn} + \overset{+1}{H^+} + \overset{-1}{Cl^-} \rightarrow \overset{-3}{As}\overset{+1}{H_3} + \overset{+2}{Zn^{2+}} + 2\overset{-1}{Cl^-} + \overset{+1}{H_2}\overset{-2}{O}$$

Oxidation half-reaction:

$$4[\overset{0}{Zn} \rightarrow \overset{+2}{Zn^{2+}} + 2e^-] = 4Zn \rightarrow 4Zn^{2+} + 8e^-$$

Reduction half-reaction:

$$\overset{+5}{As}O_4 + 11H^+ + 8Cl^- + 8e^- \rightarrow \overset{-3}{As}H_3 + 4H_2O + 8Cl^-$$

Combine half-reactions:

$$4Zn \rightarrow 4Zn^{2+} + 8e^-$$

$$\underline{AsO_4 + 11H^+ + 8Cl^- + 8e^- \rightarrow AsH_3 + 4H_2O + 8Cl^-}$$

$$AsO_4 + 11H^+ + 4Zn + 8Cl^- \rightarrow AsH_3 + 4H_2O + 4Zn^{2+} + 8Cl^-$$

Combine ions to form balanced equation:

$$H_3AsO_4 + 4Zn + 8HCl \rightarrow AsH_3 + 4ZnCl_2 + 4H_2O$$

591. *Formula equation:*

$$KClO_3 + HCl \rightarrow Cl_2 + H_2O + KCl$$

Ionic equation:

$$K^+ + \overset{+5}{Cl}\overset{-2}{O_3^-} + \overset{+1}{H^+} + \overset{-1}{Cl^-} \rightarrow \overset{0}{Cl_2} + \overset{+1}{H_2}\overset{-2}{O} + \overset{+1}{K^+} + \overset{-1}{Cl^-}$$

Oxidation half-reaction:

$$3[2\overset{-1}{Cl^-} \rightarrow \overset{0}{Cl_2} + 2e^-] = 6Cl^- \rightarrow 3Cl_2 + 6e^-$$

Reduction half-reaction:

$$K^+ + \overset{+5}{Cl}O_3^- + 6H^+ + 6e^- \rightarrow K^+ + \overset{-1}{Cl^-} + 3H_2O$$

Combine half-reactions:

$$\begin{array}{c} 6Cl^- \rightarrow 3Cl_2 + 6e^- \\ K^+ + ClO_3^- + 6H^+ + 6e^- \rightarrow K^+ + Cl^- + 3H_2O \\ \hline K^+ + ClO_3^- + 6H^+ + 6Cl^- \rightarrow K^+ + Cl^- + 3H_2O + 3Cl_2 \end{array}$$

Combine ions to form balanced equation:

$$KClO_3 + 6HCl \rightarrow 3Cl_2 + 3H_2O + KCl$$

---

592. *Formula equation:*

$$KClO_3 + HCl \rightarrow Cl_2 + ClO_2 + H_2O + KCl$$

Ionic equation:

$$\overset{+1}{K}\overset{+5}{Cl}\overset{-2}{O_3} + \overset{+1}{H}\overset{-1}{Cl^-} \rightarrow \overset{0}{Cl_2} + \overset{+4}{Cl}\overset{-2}{O_2} + \overset{+1}{H_2}\overset{-2}{O} + \overset{+1}{K^+} + \overset{-1}{Cl^-}$$

Oxidation half-reaction:

$$2[2H\overset{-1}{Cl} + 2H_2O \rightarrow \overset{+4}{Cl}O_2 + 6H^+ + Cl^- + 5e^-]$$

$$= 4HCl + 4H_2O \rightarrow 2ClO_2 + 12H^+ + 2Cl^- + 10e^-$$

Reduction half-reaction:

$$2K\overset{+5}{Cl}O_3 + 12H^+ + 10e^- \rightarrow \overset{0}{Cl_2} + 2K^+ + 6H_2O$$

Combine half-reactions:

$$\begin{array}{c} 4HCl + 4H_2O \rightarrow 2ClO_2 + 12H^+ + 2Cl^- + 10e^- \\ 2KClO_3 + 12H^+ + 10e^- \rightarrow Cl_2 + 2K^+ + 6H_2O \\ \hline 4HCl + 2KClO_3 \rightarrow 2ClO_2 + 2K^+ + Cl_2 + 2H_2O + 2Cl^- \end{array}$$

Combine ions to form balanced equation:

$$2KClO_3 + 4HCl \rightarrow Cl_2 + 2ClO_2 + 2H_2O + 2KCl$$

593. *Formula equation:*

$MnCl_3 + H_2O \rightarrow MnCl_2 + MnO_2 + HCl$

Ionic equation:

$\overset{+3}{Mn}{}^{3+} + 3\overset{-1}{Cl}{}^- + \overset{+1}{H_2}\overset{-2}{O} \rightarrow \overset{+2}{Mn}{}^{2+} + 2\overset{-1}{Cl}{}^- + \overset{+4}{Mn}\overset{-2}{O_2} + \overset{+1}{H}{}^+ + \overset{-1}{Cl}{}^-$

Oxidation half-reaction:

$\overset{+3}{Mn}{}^{3+} + 3Cl^- + 2H_2O \rightarrow \overset{+4}{Mn}O_2 + 3Cl^- + 4H^+ + 1e^-$

Reduction half-reaction:

$\overset{+3}{Mn}{}^{3+} + 3Cl^- + 1e^- \rightarrow \overset{+2}{Mn}{}^{2+} + 3Cl^-$

Combine half-reactions:

$Mn^{3+} + 3Cl^- + 2H_2O \rightarrow MnO_2 + 3Cl^- + 4H^+ + 1e^-$

$Mn^{3+} + 3Cl^- + 1e^- \rightarrow Mn^{2+} + 3Cl^-$

$2Mn^{3+} + 6Cl^- + 2H_2O \rightarrow Mn^{2+} + 6Cl^- + MnO_2 + 4H^+$

Combine ions to form balanced equation:

$2MnCl_3 + 2H_2O \rightarrow MnCl_2 + MnO_2 + 4HCl$

---

594. *Formula equation:*

$NaOH + H_2O + Al \rightarrow NaAl(OH)_4 + H_2$ (in basic solution)

Ionic equation:

$\overset{+1}{Na}{}^+ + \overset{-2+1}{OH}{}^- + \overset{+1}{H_2}\overset{-2}{O} + \overset{0}{Al} \rightarrow \overset{+1}{Na}{}^+\overset{+3}{Al}(\overset{-2+1}{OH})_4^- + \overset{0}{H_2}$

Oxidation half-reaction:

$2[\overset{0}{Al} + Na^+ + 4OH^- \rightarrow \overset{+3}{Al}(OH)_4^- + Na^+ + 3e^-]$

$= 2Al + 2Na^+ + 8OH^- \rightarrow 2Al(OH)_4^- + 2Na^+ + 6e^-$

Reduction half-reaction:

$3[2\overset{+1}{H_2}O + 2e^- \rightarrow \overset{0}{H_2} + 2OH^-] = 6H_2O + 6e^- \rightarrow 3H_2 + 6OH^-$

Combine half-reactions:

$2Al + 2Na^+ + 8OH^- \rightarrow 2Al(OH)_4^- + 2Na^+ + 6e^-$

$6H_2O + 6e^- \rightarrow 3H_2 + 6OH^-$

$2Al + 2Na^+ + 2OH^- + 6H_2O \rightarrow 2Al(OH)_4^- + 2Na^+ + 3H_2$

Combine ions to form balanced equation:

$2NaOH + 6H_2O + 2Al \rightarrow 2NaAl(OH)_4 + 3H_2$

595. *Formula equation:*

$Br_2 + Ca(OH)_2 \rightarrow CaBr_2 + Ca(BrO_3)_2 + H_2O$ (in basic solution)

Ionic equation:

$$\overset{0}{Br_2} + \overset{+2}{Ca^{2+}} + 2\overset{-2+1}{OH^-} \rightarrow \overset{+2}{Ca^{2+}} + 2\overset{-1}{Br^-} + \overset{+2}{Ca^{2+}} + 2\overset{+5\,-2}{BrO_3^-} + \overset{+1\,-2}{H_2O}$$

Oxidation half-reaction:

$$\overset{0}{Br_2} + 6Ca^{2+} + 12OH^- \rightarrow 2\overset{+5}{Br}O_3^- + 6Ca^{2+} + 6H_2O + 10e^-$$

Reduction half-reaction:

$$5[\overset{0}{Br_2} + 2e^- \rightarrow 2\overset{-1}{Br^-}] = 5Br_2 + 10e \rightarrow 10Br^-$$

Combine half-reactions:

$$Br_2 + Ca^{2+} + 12OH^- \rightarrow 2BrO_3 + Ca^{2+} + 6H_2O + 10e^-$$

$$5Br_2 + 10e^- \rightarrow 10Br^-$$

$$6Br_2 + 12OH^- \rightarrow 10Br^- + 2BrO_3 + 6H_2O$$

Combine ions to form balanced equation:

$6Br_2 + 6Ca(OH)_2 \rightarrow 5CaBr_2 + Ca(BrO_3)_2 + 6H_2O$

---

596. *Formula equation:*

$N_2O + NaClO + NaOH \rightarrow NaCl + NaNO_2 + H_2O$ (in basic solution)

Ionic equation:

$$\overset{+1\,-2}{N_2O} + \overset{+1\,+1\,-2}{NaClO} + \overset{+1}{Na^+}\ \overset{-2+1}{OH^-} \rightarrow \overset{+1}{Na^+} + \overset{-1}{Cl^-} + \overset{+1\,+3-2}{NaNO_2} + \overset{+1\,-2}{H_2O}$$

Oxidation half-reaction:

$$2Na + \overset{+1}{N_2}O + 6OH^- \rightarrow 2Na\overset{+3}{N}O_2 + 3H_2O + 4e^-$$

Reduction half-reaction:

$$2[Na\overset{+1}{Cl}O + H_2O + 2e^- \rightarrow Cl^- + 20H^- + Na^+]$$

$$= 2NaClO + 2H_2O + 4e^- \rightarrow 2Cl^- + 4OH^- + 2Na^+$$

Combine half-reactions:

$$2Na^+ + N_2O + 6OH^- \rightarrow 2NaNO_2 + 3H_2O + 4e^-$$

$$2NaClO + 2H_2O + 4e^- \rightarrow 2Cl^- + 4OH^- + 2Na^+$$

$$2Na^+ + N_2O + 2OH^- + 2NaClO \rightarrow 2NaNO_2 + H_2O + 2Cl^- + 2Na^+$$

Combine ions to form balanced equation:

$N_2O + 2NaClO + 2NaOH \rightarrow 2NaCl + 2NaNO_2 + H_2O$

597. *Formula equation:*

$HBr + MnO_2 \rightarrow MnBr_2 + H_2O + Br_2$

Ionic equation:

$\overset{+1}{H^+} + \overset{-1}{Br^-} + \overset{+4\ -2}{MnO_2} \rightarrow \overset{+2\ -1}{MnBr_2} + \overset{+1\ -2}{H_2O} + \overset{0}{Br_2}$

Oxidation half-reaction:

$2\overset{-1}{Br^-} \rightarrow \overset{0}{Br_2} + 2e^-$

Reduction half-reaction:

$2Br^- + \overset{+4}{Mn}O_2 + 4H^+ + 2e^- \rightarrow \overset{+2}{Mn}Br_2 + 2H_2O$

Combine half-reactions:

$$\begin{array}{r} 2Br^- \rightarrow Br_2 + 2e^- \\ 2Br^- + MnO_2 + 4H^+ + 2e^- \rightarrow MnBr_2 + 2H_2O \\ \hline 4Br^- + MnO_2 + 4H^+ \rightarrow Br_2 + MnBr_2 + 2H_2O \end{array}$$

Combine ions to form balanced equation:

$4HBr + MnO_2 \rightarrow MnBr_2 + 2H_2O + Br_2$

598. *Formula equation:*

$Au + HCl + HNO_3 \rightarrow HAuCl_4 + NO + H_2O$ (in *aqua regia**)

Ionic equation:

$\overset{0}{Au} + \overset{+1}{H^+} + \overset{-1}{Cl^-} + \overset{+1}{H^+} + \overset{+5-2}{NO_3} \rightarrow \overset{+1+3\ -1}{HAuCl_4} + \overset{+2-2}{NO} + \overset{+1\ -2}{H_2O}$

Oxidation half-reaction:

$\overset{0}{Au} + 4Cl^- + H^+ \rightarrow H\overset{+3}{Au}Cl_4 + 3e^-$

Reduction half-reaction:

$\overset{+5}{N}O_3^- + 4H^+ + 3e^- \rightarrow \overset{+2}{N}O + 2H_2O$

Combine half-reactions:

$$\begin{array}{c} Au + 4Cl^- + H^+ \rightarrow HAuCl_4 + 3e^- \\ NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O \\ \hline Au + 4Cl^- + 5H^+ + NO_3^- \rightarrow HAuCl_4 + NO + 2H_2O \end{array}$$

Combine ions to form balanced equation:

$Au + 4HCl + HNO_3 \rightarrow HAuCl_4 + NO + 2H_2O$

*Aqua regia = concentrated HCl + concentrated HNO_3.

599. $\overset{+2}{Cu}{}^{2+} + \overset{0}{Fe} \rightarrow \overset{+2}{Fe}{}^{2+} + \overset{0}{Cu}$

Anode = Fe (oxidation)
Cathode = Cu (reduction)

Half-reactions:

$Fe \rightleftharpoons Fe^{2+} + 2e^-$ $\qquad E^0 = +0.45\ V$

$Cu^{2+} + 2e^- \rightleftharpoons Cu$ $\qquad E^0 = +0.34\ V$

$E^0_{cell} = +0.79\ V$; spontaneous

---

600. $\overset{+2}{Pb}{}^{2+} + \overset{+2}{Fe}{}^{2+} \rightarrow \overset{+3}{Fe}{}^{3+} + \overset{0}{Pb}$

Anode = Fe (oxidation)
Cathode = Pb (reduction)

Half-reactions:

$Fe^{2+} \rightleftharpoons Fe^{3+} + 1e^-$ $\qquad E^0 = -0.77\ V$

$Pb^{2+} + 2e^- \rightleftharpoons Pb$ $\qquad E^0 = -0.13\ V$

$E^0_{cell} = -0.90\ V$; not spontaneous

---

601. $\overset{+2}{Mn}{}^{2+} + 3H_2O + \overset{+2}{Sn}{}^{2+} \rightarrow \overset{+7}{Mn}O_4^- + 8H^+ + \overset{0}{Sn}$

Anode = Mn (oxidation)
Cathode = Sn (reduction)

Half-reactions:

$Mn^{2+} + 4H_2O\ \ MnO_4^- + 8H^+ + 5e^-$ $\qquad E^0 = -1.50\ V$

$Sn^{2+} + 2e^- \rightleftharpoons Sn$ $\qquad E^0 = -0.14\ V$

$E^0_{cell} = -1.64\ V$; not spontaneous

---

602. $\overset{+6}{Mn}O_4^{2-} + \overset{0}{Cl_2} \rightarrow \overset{+7}{Mn}O_4^- + 2\overset{-1}{Cl}{}^-$

Anode = Mn (oxidation)
Cathode = Cl (reduction)

Half-reactions:

$MnO_4^{2-} \rightleftharpoons MnO_4^- + e^-$ $\qquad E^0 = -0.56\ V$

$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ $\qquad E^0 = +1.36\ V$

$E^0_{cell} = +0.80\ V$; spontaneous

603. $\overset{+1}{Hg_2^{2+}} + 2\overset{+6}{Mn}O_4^{2-} \rightarrow 2\overset{0}{Hg} + 2\overset{+7}{Mn}O_4^-$

Anode = Mn (oxidation)
Cathode = Hg (reduction)

Half-reactions:

$MnO_4^{2-} \rightleftharpoons MnO_4^- + e^-$	$E^0 = -0.56$ V
$Hg_2^{2+} + 2e^- \rightleftharpoons 2Hg$	$E^0 = +0.80$ V
	$E^0_{cell} = +0.24$ V; spontaneous

---

604. $2\overset{+1}{Li^+} + \overset{0}{Pb} \rightarrow 2\overset{0}{Li} + \overset{+2}{Pb^{2+}}$

Anode = Pb (oxidation)
Cathode = Li (reduction)

Half-reactions:

$Pb \rightleftharpoons Pb^{2+} + 2e^-$	$E^0 = +0.13$ V
$Li^+ + e^- \rightleftharpoons Li$	$E^0 = -3.04$ V
	$E^0_{cell} = -2.91$ V; not spontaneous

---

605. $\overset{0}{Br_2} + 2\overset{-1}{Cl^-} \rightarrow 2\overset{-1}{Br^-} + \overset{0}{Cl_2}$

Anode = Cl (oxidation)
Cathode = Br (reduction)

Half-reactions:

$2Cl^- \rightleftharpoons Cl_2 + 2e^-$	$E^0 = -1.36$ V
$Br_2 + 2e^- \rightleftharpoons 2Br^-$	$E^0 = +1.07$ V
	$E^0_{cell} = -0.29$ V; not spontaneous

---

606. $\overset{0}{S} + 2\overset{-1}{I^-} \rightarrow \overset{-2}{S^{2-}} + \overset{0}{I_2}$

Anode = I (oxidation)
Cathode = S (reduction)

Half-reactions:

$2I^- \rightleftharpoons I_2 + 2e^-$	$E^0 = -0.54$ V
$S + 2e^- \rightleftharpoons S^{2-}$	$E^0 = -0.48$ V
	$E^0_{cell} = -1.02$ V; not spontaneous

607. $Ca^{2+} + 2e^- \rightleftharpoons Ca$ $E^0 = -2.87$ V

$Fe^{3+} + 3e^- \rightleftharpoons Fe$ $E^0 = -0.04$ V

Anode = Ca (oxidation)
Cathode = Fe (reduction)

Anode reaction:

$Ca \rightleftharpoons Ca^{2+} + 2e^-$

Cathode reaction:

$Fe^{3+} + 3e^- \rightleftharpoons Fe$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = -0.04 - (-2.87) = +2.83$ V

---

608. $Ag^+ + e^- \rightleftharpoons Ag$ $E^0 = +0.80$ V

$S + 2H^+ + 2e^- \rightleftharpoons H_2S$ $E^0 = +0.14$ V

Anode = S (oxidation)
Cathode = Ag (reduction)

Anode reaction:

$H_2S \rightleftharpoons S + 2H^+ + 2e^-$

Cathode reaction:

$Ag^+ + e^- \rightleftharpoons Ag$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +0.80 - (+0.14) = +0.66$ V

---

609. $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ $E^0 = +0.77$ V

$Sn^{2+} + 2e^- \rightleftharpoons Sn$ $E^0 = -0.14$ V

Anode = Sn (oxidation)
Cathode = Fe (reduction)

Anode reaction:

$Sn \rightleftharpoons Sn^{2+} + 2e^-$

Cathode reaction:

$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +0.77 - (-0.14) = +0.91$ V

610. $Cu^{2+} + 2e^- \rightleftharpoons Cu$ $\qquad E^0 = +0.34$ V

$Au^{3+} + 3e^- \rightleftharpoons Au$ $\qquad E^0 = +1.50$ V

Anode = Cu (oxidation)
Cathode = Au (reduction)

Anode reaction:

$Cu \rightleftharpoons Cu^{2+} + 2e^-$

Cathode reaction:

$Au^{3+} + 3e^- \rightleftharpoons Au$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +1.50 - (+0.34) = +1.16$ V

---

611. $\overset{0}{Ba} + \overset{+2}{Sn}{}^{2+} \rightarrow \overset{+2}{Ba}{}^{2+} + \overset{0}{Sn}$

Anode = Ba (oxidation)
Cathode = Sn (reduction)

Half-reactions:

$Ba \rightleftharpoons Ba^{2+} + 2e^-$ $\qquad E^0 = +2.91$ V

$Sn^{2+} + 2e^- \rightleftharpoons Sn$ $\qquad E^0 = -0.14$ V

$E^0_{cell} = +2.77$ V; spontaneous

---

612. $\overset{0}{Ni} + \overset{+2}{Hg}{}^{2+} \rightarrow \overset{+2}{Ni}{}^{2+} + \overset{0}{Hg}$

Anode = Ni (oxidation)
Cathode = Hg (reduction)

Half-reactions:

$Ni \rightleftharpoons Ni^{2+} + 2e^-$ $\qquad E^0 = +0.26$ V

$Hg^{2+} + 2e^- \rightleftharpoons Hg$ $\qquad E^0 = +0.85$ V

$E^0_{cell} = +1.11$ V; spontaneous

---

613. $2\overset{+3}{Cr}{}^{3+} + 7H_2O + 6\overset{+3}{Fe}{}^{3+} \rightarrow \overset{+6}{Cr}{}_2O_7^{2-} + 14H^+ + 6\overset{+2}{Fe}{}^{2+}$

Anode = Cr (oxidation)
Cathode = Fe (reduction)

Half-reactions:

$2Cr^{3+} + 7H_2O \rightleftharpoons Cr_2O_7^{2-} + 14H^+ + 6e^-$ $\qquad E^0 = -1.23$ V

$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ $\qquad E^0 = +0.77$ V

$E^0_{cell} = -0.46$ V; not spontaneous

614. $\overset{0}{Cl_2} + \overset{0}{Sn} \rightarrow 2\overset{-1}{Cl^-} + \overset{+2}{Sn^{2+}}$

Anode = Sn (oxidation)
Cathode = Cl (reduction)

Half-reactions:

$Sn \rightleftharpoons Sn^{2+} + 2e^-$ $\qquad E^0 = +0.14\ V$

$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ $\qquad E^0 = +1.36\ V$

$E^0_{cell} = +1.50\ V$; spontaneous

615. $\overset{0}{Al} + 3\overset{+3}{Ag^+} \rightarrow \overset{+3}{Al^{3+}} + 3\overset{0}{Ag}$

Anode = Al (oxidation)
Cathode = Ag (reduction)

Half-reactions:

$Al \rightleftharpoons Al^{3+} + 3e^-$ $\qquad E^0 = +1.66\ V$

$Ag^+ + e^- \rightleftharpoons Ag$ $\qquad E^0 = +0.80\ V$

$E^0_{cell} = +2.46\ V$; spontaneous

616. $\overset{+1}{Hg_2^{2+}} + \overset{-2}{S^{2-}} \rightarrow 2\overset{0}{Hg} + \overset{0}{S}$

Anode = S (oxidation)
Cathode = Hg (reduction)

Half-reactions:

$S^{2-} \rightleftharpoons S + 2e^-$ $\qquad E^0 = +0.48\ V$

$Hg_2^{2+} + 2e^- \rightleftharpoons 2Hg$ $\qquad E^0 = +0.80\ V$

$E^0_{cell} = +1.28\ V$; spontaneous

617. $\overset{0}{Ba} + 2\overset{+1}{Ag^+} \rightarrow \overset{+2}{Ba^{2+}} + 2\overset{0}{Ag}$

Anode = Ba (oxidation)
Cathode = Ag (reduction)

Half-reactions:

$Ba \rightleftharpoons Ba^{2+} + 2e^-$ $\qquad E^0 = +2.91\ V$

$Ag^+ + e^- \rightleftharpoons Ag$ $\qquad E^0 = +0.80\ V$

$E^0_{cell} = +3.71\ V$; spontaneous

618. $\overset{-1}{2I^-} + \overset{+2}{Ca^{2+}} \rightarrow \overset{0}{I_2} + \overset{0}{Ca}$

Anode = I (oxidation)
Cathode = Ca (reduction)

Half-reactions:

$2I^- \rightleftharpoons I_2 + 2e^-$ $\quad E^0 = -0.54$ V

$Ca^{2+} + 2e^- \rightleftharpoons Ca$ $\quad E^0 = -2.87$ V

$E^0_{cell} = -3.41$ V; not spontaneous

---

619. $\overset{0}{Zn} + 2\overset{+7}{Mn}O_4^- \rightarrow \overset{+2}{Zn^{2+}} + 2\overset{+6}{Mn}O_4^{2-}$

Anode = Zn (oxidation)
Cathode = Mn (reduction)

Half-reactions:

$Zn \rightleftharpoons Zn^{2+} + 2e^-$ $\quad E^0 = +0.76$ V

$MnO_4^- + e^- \rightleftharpoons MnO_4^{2-}$ $\quad E^0 = +0.56$ V

$E^0_{cell} = +1.32$ V; spontaneous

---

620. $2\overset{+3}{Cr^{3+}} + 3\overset{+2}{Mg^{2+}} + 7H_2O \rightarrow \overset{+6}{Cr_2}O_7^{2-} + 14H^+ + 3\overset{0}{Mg}$

Anode = Cr (oxidation)
Cathode = Mg (reduction)

Half-reactions:

$2Cr^{3+} + 7H_2O \rightleftharpoons Cr_2O_7^{2-} + 14H^+ + 6e^-$ $\quad E^0 = -1.23$ V

$Mg^{2+} + 2e^- \rightleftharpoons Mg$ $\quad E^0 = -2.37$ V

$E^0_{cell} = -3.60$ V; not spontaneous

---

621. $Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ $\quad E^0 = +1.36$ V

$Ni^{2+} + 2e^- \rightleftharpoons Ni$ $\quad E^0 = -0.26$ V

Anode = Ni (oxidation)
Cathode = Cl (reduction)

Anode reaction:

$Ni \rightleftharpoons Ni^{2+} + 2e^-$

Cathode reaction:

$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +1.36 - (-0.26) = +1.62$ V

Combine half-reactions:

$Ni \rightleftharpoons Ni^{2+} + 2e^-$

$Cl_2 + 2e^- \rightleftharpoons 2Cl^-$

$Cl_2 + Ni \rightleftharpoons Ni^{2+} + 2Cl^-$

622. $Fe^{3+} + 3e^- \rightleftharpoons Fe$ $\qquad E^0 = -0.04$ V

$Hg^{2+} + 2e^- \rightleftharpoons Hg$ $\qquad E^0 = +0.85$ V

Anode = Fe (oxidation)
Cathode = Hg (reduction)

Anode reaction:

$2[Fe \rightleftharpoons Fe^{3+} + 3e^-] = 2Fe \rightleftharpoons 2Fe^{3+} + 6e^-$

Cathode reaction:

$3[Hg^{2+} + 2e^- \rightleftharpoons Hg] = 3Hg^{2+} + 6e^- \rightleftharpoons 3Hg$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +0.85 - (-0.04) = +0.89$ V

Combine half-reactions:

$2Fe \rightleftharpoons 2Fe^{3+} + 6e^-$

$3Hg^{2+} + 6e^- \rightleftharpoons 3Hg$

$3Hg^{2+} + 2Fe \rightarrow 3Hg + 2Fe^{3+}$

---

623. $MnO_4^- + e^- \rightleftharpoons MnO_4^{2-}$ $\qquad E^0 = +0.56$ V

$Al^{3+} + 3e^- \rightleftharpoons Al$ $\qquad E^0 = -1.66$ V

Anode = Al (oxidation)
Cathode = Mn (reduction)

Anode reaction:

$Al \rightleftharpoons Al^{3+} + 3e^-$

Cathode reaction:

$3[MnO_4^- + e^- \rightleftharpoons MnO_4^{2-}] = 3MnO_4^- + 3e^- \rightleftharpoons 3MnO_4^{2-}$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +0.56 - (-1.66) = +2.22$ V

Combine half-reactions:

$Al \rightleftharpoons Al^{3+} + 3e^-$

$3MnO_4^- + 3e^- \rightleftharpoons 3MnO_4^{2-}$

$3MnO_4^- + Al \rightarrow 3MnO_4^{2-} + Al^{3+}$

624. $MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$ $\quad E^0 = +1.50$ V

$S + 2H^+ + 2e^- \rightleftharpoons H_2S$ $\quad E^0 = +0.14$ V

Anode = S (oxidation)
Cathode = Mn (reduction)

Anode reaction:

$5[H_2S \rightleftharpoons S + 2H^+ + 2e^-] = 5H_2S \rightleftharpoons 5S + 10H^+ + 10e^-$

Cathode reaction:

$2[MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O]$

$= 2MnO_4^- + 16H^+ + 10e^- \rightleftharpoons 2Mn^{2+} + 8H_2O$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +1.50 - (+0.14) = +1.36$ V

Combine half-reactions:

$$\begin{array}{r} 5H_2S \rightleftharpoons 5S + 10H^+ + 10e^- \\ 2MnO_4^- + 16H^+ + 10e^- \rightleftharpoons 2Mn^{2+} + 8H_2O \\ \hline 2MnO_4^- + 6H^+ + 5H_2S \rightarrow 2Mn^{2+} + 8H_2O + 5S \end{array}$$

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625. $Ca^{2+} + 2e^- \rightleftharpoons Ca$ $\quad E^0 = -2.87$ V

$Li^+ + e^- \rightleftharpoons Li$ $\quad E^0 = -3.04$ V

Anode = Li (oxidation)
Cathode = Ca (reduction)

Anode reaction:

$2[Li \rightleftharpoons Li^+ + e^-] = 2Li \rightleftharpoons 2Li^+ + 2e^-$

Cathode reaction:

$Ca^{2+} + 2e^- \rightleftharpoons Ca$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = -2.87 - (-3.04) = +0.17$ V

Combine half-reactions:

$$\begin{array}{l} 2Li \rightleftharpoons 2Li^+ + 2e^- \\ Ca^{2+} + 2e^- \rightleftharpoons Ca \\ \hline Ca^{2+} + 2Li \rightarrow Ca + 2Li^+ \end{array}$$

626. $Br_2 + 2e^- \rightleftharpoons 2Br^-$ $\quad E^0 = +1.07$ V

$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$ $\quad E^0 = +1.50$ V

Anode = Br (oxidation)
Cathode = Mn (reduction)

Anode reaction:

$5[2Br^- \rightleftharpoons Br_2 + 2e^-] = 10Br^- \rightleftharpoons 5Br_2 + 10e^-$

Cathode reaction:

$2[MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O]$

$= 2MnO_4^- + 16H^+ + 10e^- \rightleftharpoons 2Mn^{2+} + 8H_2O$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +1.50 - (+1.07) = +0.43$ V

Combine half-reactions:

$$10Br^- \rightleftharpoons 5Br_2 + 10e^-$$
$$\underline{2MnO_4^- + 16H^+ + 10e^- \rightleftharpoons 2Mn^{2+} + 8H_2O}$$
$$2MnO_4^- + 16H^+ + 10Br^- \rightarrow 2Mn^{2+} + 8H_2O + 5Br_2$$

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627. $Sn^{2+} + 2e^- \rightleftharpoons Sn$ $\quad E^0 = -0.14$ V

$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ $\quad E^0 = +0.77$ V

Anode = Sn (oxidation)
Cathode = Fe (reduction)

Anode reaction:

$Sn \rightleftharpoons Sn^{2+} + 2e^-$

Cathode reaction:

$2[Fe^{3+} + e^- \rightleftharpoons Fe^{2+}] = 2Fe^{3+} + 2e^- \rightleftharpoons 2Fe^{2+}$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +0.77 - (-0.14) = +0.91$ V

Combine half-reactions:

$$Sn \rightleftharpoons Sn^{2+} + 2e^-$$
$$\underline{2Fe^{3+} + 2e^- \rightleftharpoons 2Fe^{2+}}$$
$$2Fe^{3+} + Sn \rightarrow 2Fe^{2+} + Sn^{2+}$$

628. $Zn^{2+} + 2e^- \rightleftharpoons Zn$ $\quad E^0 = -0.76\ V$

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$ $\quad E^0 = +1.23\ V$

Anode = Zn (oxidation)
Cathode = Cr (reduction)

Anode reaction:

$3[Zn \rightleftharpoons Zn^{2+} + 2e^-] = 3Zn \rightleftharpoons 3Zn^{2+} + 6e^-$

Cathode reaction:

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +1.23 - (-0.76) = +1.99\ V$

Combine half-reactions:

$$\begin{array}{r} 3Zn \rightleftharpoons 3Zn^{2+} + 6e^- \\ \underline{Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O} \end{array}$$

$Cr_2O_7^{2-} + 14H^+ + 3Zn \rightarrow 2Cr^{3+} + 7H_2O + 3Zn^{2+}$

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629. $Ba^{2+} + 2e^- \rightleftarrows Ba$ $\quad E^0 = -2.91\ V$

$Ca^{2+} + 2e^- \rightleftarrows Ca$ $\quad E^0 = -2.87\ V$

Anode = Ba (oxidation)
Cathode = Ca (reduction)

Anode reaction:

$Ba \rightleftarrows Ba^{2+} + 2e^-$

Cathode reaction:

$Ca^{2+} + 2e^- \rightleftarrows Ca$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = -2.87 - (-2.91) = +0.04\ V$

Combine half-reactions:

$$\begin{array}{r} Ba \rightleftarrows Ba^{2+} + 2e^- \\ \underline{Ca^{2+} + 2e^- \rightleftarrows Ca} \end{array}$$

$Ca^{2+} + Ba \rightarrow Ca + Ba^{2+}$

630. $Hg_2^{2+} + 2e^- \rightleftharpoons 2Hg$ $\quad E^0 = +0.80\ V$

$Cd^{2+} + 2e^- \rightleftharpoons Cd$ $\quad E^0 = -0.40\ V$

Anode = Cd (oxidation)
Cathode = Hg (reduction)

Anode reaction:

$Cd \rightleftharpoons Cd^{2+} + 2e^-$

Cathode reaction:

$Hg_2^{2+} + 2e^- \rightleftharpoons 2Hg$

$E^0_{cell} = E^0_{cathode} - E^0_{anode} = +0.80 - (-0.40) = +1.20\ V$

Combine half-reactions:

$$\begin{array}{l} \qquad Cd \rightleftharpoons Cd^{2+} + 2e^- \\ \underline{Hg_2^{2+} + 2e^- \rightleftharpoons 2Hg\qquad} \\ Hg_2^{2+} + Cd \rightarrow 2Hg + Cd^{2+} \end{array}$$