

SECTION ONE

Questions 5-8 refer to atoms for which the occupied atomic orbitals are shown below.

- (A) $1s \uparrow \quad 2s \uparrow$
 (B) $1s \uparrow \quad 2s \uparrow \quad 2p \uparrow$
 (C) $1s \uparrow \quad 2s \uparrow \quad 2p \uparrow \quad 2p \uparrow$
 (D) $1s \uparrow \quad 2s \uparrow \quad 2p \uparrow \quad 2p \uparrow \quad 2p \uparrow$
 (E) $1s \uparrow \quad 2s \uparrow \quad 2p \uparrow \quad 2p \uparrow \quad 2p \uparrow \quad 3s \uparrow$

5. Represents an atom that is chemically unreactive
 6. Represents an atom in an excited state
 7. Represents an atom that has four valence electrons
 8. Represents an atom of a transition metal

Questions 9-12 refer to aqueous solutions containing 1.0 mole each of the following pairs of substances. Assume all concentrations are 1 M.

- (A) NH_3 and NH_4Cl
 (B) H_2PO_4^- and NaH_2PO_4
 (C) HCl and NaCl
 (D) NaOH and NH_3
 (E) NH_3 and $\text{HC}_2\text{H}_3\text{O}_2$ (acetic acid)
9. The solution with the lowest pH
 10. The most nearly neutral solution
 11. A buffer at a pH > 8
 12. A buffer at a pH < 6

Questions 13-16 refer to the following descriptions of bonding in different types of solids.

- (A) Lattice of positive and negative ions held together by electrostatic forces
 (B) Closely packed lattice with delocalized electrons throughout
 (C) Strong single covalent bonds with weak intermolecular forces
 (D) Strong multiple covalent bonds (including π -bonds) with weak intermolecular forces
 (E) Macromolecules held together with strong polar bonds

13. Calcium chloride, $\text{CaCl}_2(\text{s})$
 14. Gold, $\text{Au}(\text{s})$
 15. Carbon dioxide, $\text{CO}_2(\text{g})$
 16. Methane, $\text{CH}_4(\text{g})$

Questions 17-18 refer to the following elements:

- (A) Lithium
 (B) Nickel
 (C) Bismuth
 (D) Uranium
 (E) Fluorine

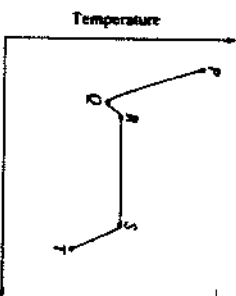
17. Is a gas in its standard state at 298 K
 18. Reacts with water to form a strong base

20. What mass of Au is produced when 0.0500 mol of Au_2S_3 is reduced completely with excess H_2 ?

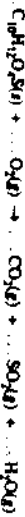
- (A) 9.85 g
 (B) 19.7 g
 (C) 24.5 g
 (D) 39.4 g
 (E) 48.9 g

22. Of the following reactions, which involves the largest decrease in entropy?

- (A) $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
 (B) $2 \text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{CO}_2(\text{g})$
 (C) $\text{Pb}(\text{NO}_3)_2(\text{s}) + 2 \text{KI}(\text{g}) \rightarrow \text{PbI}_2(\text{s}) + 2 \text{KNO}_3(\text{g})$
 (D) $\text{C}_2\text{H}_4(\text{g}) + 5 \text{O}_2(\text{g}) \rightarrow 3 \text{CO}_2(\text{g}) + 4 \text{H}_2\text{O}(\text{g})$
 (E) $4 \text{Li}(\text{s}) + 3 \text{O}_2(\text{g}) \rightarrow 2 \text{Li}_2\text{O}(\text{s})$



25. The cooling curve for a pure substance as it changes from a liquid to a solid is shown above. The solid and the liquid coexist at
 (A) point Q only
 (B) point R only
 (C) all points on the curve between Q and S
 (D) all points on the curve between R and T
 (E) no point on the curve



26. When the equation above is balanced and all coefficients are reduced to their lowest whole-number terms, the coefficient for $\text{O}_2(\text{g})$ is

- (A) 6
 (B) 7
 (C) 12
 (D) 14
 (E) 28



30. Which of the following is true regarding the reaction represented above?

- (A) The oxidation number of O does not change.
 (B) The oxidation number of H changes from -1 to +1.
 (C) The oxidation number of F changes from +1 to -1.
 (D) The oxidation number of Se changes from -2 to +6.
 (E) It is a disproportionation reaction for F.

32. Types of hybridization exhibited by the C atoms in propanoic acid, $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$, include which of the following?

- I. sp
 II. sp^2
 III. sp^3
- (A) I only
 (B) III only
 (C) I and II only
 (D) II and III only
 (E) I, II, and III

Questions 33-35 refer to an electrolytic cell that involves the following half-reactions:



34. Which of the following occurs in the reaction?

- (A) AlF_6^{3-} is reduced at the cathode.
 (B) Al is oxidized at the anode.
 (C) Aluminum is converted from the -3 oxidation state to the 0 oxidation state.
 (D) F^- acts as a reducing agent.
 (E) F^- is reduced at the cathode.

35. A steady current of 10 amperes is passed through an aluminum-production cell for 15 minutes. Which of the following is the correct expression for calculating the number of grams of aluminum produced? (1 Faraday = 96,500 coulombs)

- (A) $\frac{(10)(15)(96,500)}{(27)(60)} \text{ g}$
 (B) $\frac{(10)(15)(27)}{(60)(96,500)} \text{ g}$
 (C) $\frac{(10)(15)(60)(27)}{(96,500)(3)} \text{ g}$
 (D) $\frac{(96,500)(27)}{(10)(15)(60)(3)} \text{ g}$
 (E) $\frac{(96,500)(10)(15)(60)}{(27)(3)} \text{ g}$

Experiment	Initial [NO] (mol L ⁻¹)	Initial [O ₂] (mol L ⁻¹)	Initial Rate of Formation of NO ₂ (mol L ⁻¹ s ⁻¹)
1	0.10	0.10	2.5 × 10 ⁻⁴
2	0.20	0.10	5.0 × 10 ⁻⁴
3	0.20	0.40	8.0 × 10 ⁻⁴

36. The initial-rate data in the table above were obtained for the reaction represented below. What is the experimental rate law for the reaction?

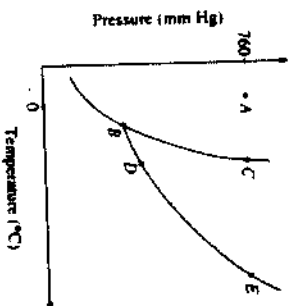


- (A) Rate = $k[\text{NO}][\text{O}_2]$
 (B) Rate = $k[\text{NO}]^2[\text{O}_2]$
 (C) Rate = $k[\text{NO}]^2[\text{O}_2]$
 (D) Rate = $k[\text{NO}]^2[\text{O}_2]^2$
 (E) Rate = $k \frac{[\text{NO}]}{[\text{O}_2]}$

	Ionization Energies for element X (kJ mol ⁻¹)			
	First	Second	Third	Fourth
5N0	1,815	2,740	11,600	14,800

37. The ionization energies for element X are listed in the table above. On the basis of the data, element X is most likely to be

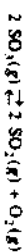
- (A) Na
 (B) Mg
 (C) Al
 (D) Si
 (E) P



38. The phase diagram for a pure substance is shown above. Which point on the diagram corresponds to the equilibrium between the solid and liquid phases at the normal melting point?

- (A) A
 (B) B
 (C) C
 (D) D
 (E) E
39. Of the following molecules, which has the largest dipole moment?

- (A) CO
 (B) CO₂
 (C) O₂
 (D) HF
 (E) F₂



41. After the equilibrium represented above is established, some pure O₂(g) is injected into the reaction vessel at constant temperature. After equilibrium is reestablished, which of the following has a lower value compared to its value at the original equilibrium?
- (A) K_{eq} for the reaction
 (B) The total pressure in the reaction vessel
 (C) The amount of SO₃(g) in the reaction vessel
 (D) The amount of O₂(g) in the reaction vessel
 (E) The amount of SO₂(g) in the reaction vessel



42. When the equation above is balanced and all coefficients reduced to lowest whole number terms, the coefficient for OH⁻(aq) is
- (A) 1
 (B) 2
 (C) 3
 (D) 4
 (E) 6

44. A rigid metal tank contains oxygen gas. Which of the following applies to the gas in the tank when additional oxygen is added at constant temperature?

- (A) The volume of the gas increases.
 (B) The pressure of the gas decreases.
 (C) The average speed of the gas molecules remains the same.
 (D) The total number of gas molecules remains the same.
 (E) The average distance between the gas molecules increases.

47. When helium metal is heated in an atmosphere of chlorine gas, the product of the reaction is found to contain 62.2 percent Hf by mass and 37.4 percent Cl by mass. What is the empirical formula for this compound?

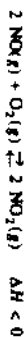
- (A) HfCl
- (B) HfCl₂
- (C) HfCl₃
- (D) HfCl₄
- (E) Hf₂Cl₃

48. If 87.5 percent of a sample of pure ¹³¹I decays in 24 days, what is the half-life of ¹³¹I?

- (A) 6 days
- (B) 8 days
- (C) 12 days
- (D) 14 days
- (E) 21 days

49. In the periodic table, as the atomic number increases from 11 to 17, what happens to the atomic radius?

- (A) It remains constant.
- (B) It increases only.
- (C) It increases, then decreases.
- (D) It decreases only.
- (E) It decreases, then increases.



54. Which of the following changes alone would cause a decrease in the value of K_p for the reaction represented above?

- (A) Decreasing the temperature
- (B) Increasing the temperature
- (C) Decreasing the volume of the reaction vessel
- (D) Increasing the volume of the reaction vessel
- (E) Adding a catalyst

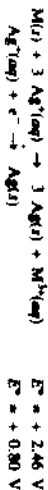


55. According to the balanced equation above, how many moles of HI would be necessary to produce 2.5 mol of I₂, starting with 4.0 mol of K₂MnO₄ and 3.0 mol of H₂SO₄?

- (A) 20
- (B) 10
- (C) 8.0
- (D) 5.0
- (E) 2.5

56. A yellow precipitate forms when 0.5 M NaI(aq) is added to a 0.5 M solution of which of the following salts?

- (A) Pb²⁺(aq)
- (B) Zn²⁺(aq)
- (C) CH₃⁺(aq)
- (D) SO₄²⁻(aq)
- (E) OH⁻(aq)

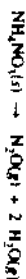


57. According to the information above, what is the standard reduction potential for the half-reaction $\text{M}^{3+}(\text{aq}) + 3 e^- \rightarrow \text{M}(s)$?

- (A) -1.66 V
- (B) -0.06 V
- (C) 0.06 V
- (D) 1.66 V
- (E) 3.26 V

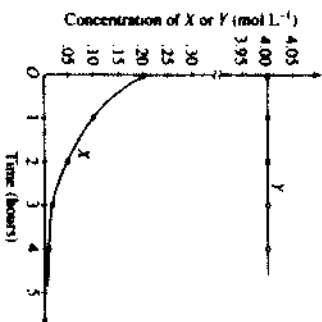
59. A 40.0 mL sample of 0.25 M KOH is added to 60.0 mL of 0.15 M Ba(OH)₂. What is the molar concentration of OH⁻(aq) in the resulting solution? (Assume that the volumes are additive.)

- (A) 0.10 M
- (B) 0.19 M
- (C) 0.28 M
- (D) 0.40 M
- (E) 0.55 M



60. A 0.03 mol sample of NH₄NO₃(s) is placed in a 1.1 L evacuated flask, which is then sealed and heated. The NH₄NO₃(s) decomposes completely according to the balanced equation above. The total pressure in the flask measured at 400 K is closest to which of the following? (The value of the gas constant, R , is 0.082 L atm mol⁻¹ K⁻¹.)

- (A) 3 atm
- (B) 1 atm
- (C) 0.5 atm
- (D) 0.1 atm
- (E) 0.03 atm



63. The graph above shows the results of a study of the reaction of X with a large excess of Y to yield Z. The concentrations of X and Y were measured over a period of time. According to the results, which of the following can be concluded about the rate law for the reaction under the conditions studied?

- (A) It is zero order in [X].
- (B) It is first order in [X].
- (C) It is second order in [X].
- (D) It is first order in [Y].
- (E) The overall order of the reaction is 2.

64. Equal numbers of moles of He(g), Ar(g), and Ne(g) are placed in a glass vessel at room temperature. If the vessel has a pinhole-sized leak, which of the following will be true regarding the relative values of the partial pressures of the gases remaining in the vessel after some of the gas mixture has effused?

- (A) $P_{\text{He}} < P_{\text{Ar}} < P_{\text{Ne}}$
- (B) $P_{\text{He}} < P_{\text{Ne}} < P_{\text{Ar}}$
- (C) $P_{\text{Ar}} < P_{\text{Ne}} < P_{\text{He}}$
- (D) $P_{\text{Ne}} < P_{\text{Ar}} < P_{\text{He}}$
- (E) $P_{\text{He}} = P_{\text{Ar}} = P_{\text{Ne}}$

66. When solid ammonium chloride, $\text{NH}_4\text{Cl}(s)$, is added to water at 25°C , it dissolves and the temperature of the solution decreases. Which of the following is true for the values of ΔH and ΔS for the dissolving process?

- | ΔH | ΔS |
|--------------|---------------|
| (A) Positive | Positive |
| (B) Positive | Negative |
| (C) Positive | Equal to zero |
| (D) Negative | Positive |
| (E) Negative | Negative |

68. In which of the following processes are covalent bonds broken?

- (A) $\text{I}_2(g) \rightarrow \text{I}(g)$
- (B) $\text{CO}_2(g) \rightarrow \text{CO}_2(l)$
- (C) $\text{NaCl}(s) \rightarrow \text{NaCl}(l)$
- (D) C(diamond) \rightarrow C(g)
- (E) $\text{Fe}(s) \rightarrow \text{Fe}(l)$

69. What is the final concentration of barium ions, $[\text{Ba}^{2+}]$, in solution when 100. mL of 0.10 M $\text{BaCl}_2(aq)$ is mixed with 100. mL of 0.050 M $\text{H}_2\text{SO}_4(aq)$?

- (A) 0.00 M
- (B) 0.012 M
- (C) 0.025 M
- (D) 0.075 M
- (E) 0.10 M

73. The volume of distilled water that should be added to 10.0 mL of 6.00 M $\text{HCl}(aq)$ in order to prepare a 0.500 M $\text{HCl}(aq)$ solution is approximately

- (A) 50.0 mL
- (B) 60.0 mL
- (C) 100 mL
- (D) 110 mL
- (E) 120 mL

74. Which of the following gases deviates most from ideal behavior?

- (A) SO_2
- (B) Ne
- (C) CH_4
- (D) N_2
- (E) H_2