GENERAL CHEMISTRY FINAL
Practice Test

1. STATES OF MATTER
1. Oxygen and ozone are

(A) the same substance and the same element.
(B) the same element, but two different substances.
(C) the same substance, but two different elements.
(D) two different substances and two different elements.

2. The density of carbon tetrachloride is 1.60 g·mL⁻¹. How many moles are there in a liter of the pure CCl₄?

<table>
<thead>
<tr>
<th>Molar Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCl₄</td>
</tr>
</tbody>
</table>

(A) 10.4 mol  (C) 23.7 mol
(B) 11.3 mol  (D) 33.7 mol

3. Which substance has the highest boiling point?

(A) CH₄  (B) He  (C) HF  (D) Cl₂

4. The normal boiling point of SO₂ is 263.1 K and that of NH₃ is 239.7 K. At -40 °C which would you predict?

(A) Ammonia has the greater vapor pressure.
(B) Sulfur dioxide has the greater vapor pressure.
(C) The vapor pressures would be equal.
(D) The vapor pressure of NH₃ is 760 mmHg.
(E) The relative vapor pressures are not predictable from the data given.

5. Consider the phase diagram of a pure compound. Which statement applies?

(A) The path A → C represents sublimation.
(B) Following the path A → B → C the compound would first liquefy and then vaporize.
(C) If the compound is in state A, continued reduction of the pressure (at constant temperature) will cause it to melt.
(D) None of these statements is correct.

6. A gas or vapor may be liquefied only at temperatures

(A) equal to the normal boiling point.
(B) at or below the normal boiling point.
(C) above the normal boiling point.
(D) at or below the critical temperature.
(E) above the critical temperature.

7. Carbon dioxide, CO₂, in the form of dry ice would be classified as

(A) an ionic solid.  (C) molecular solid.
(B) a polymeric solid.  (D) a metallic solid.
8. A liter of carbon dioxide gas is compared to a liter of hydrogen gas, both gases at 25 °C and 2 atm. Which statement is correct?

(A) The CO₂ and H₂ molecules have the same average speed.

(B) There are more molecules of H₂ than CO₂ present.

(C) The CO₂ and H₂ molecules hit the walls of the containers with the same frequency.

(D) The CO₂ molecules are on the average moving slower than the H₂ molecules.

(E) The average kinetic energy of the CO₂ molecules is greater than that of the H₂ molecules.

9. If 1 L of a gas at 30 °C and 720 mmHg has a mass of 2.00 g, the mass of a mole of the gas is

(A) 22.4 g.

(B) 44.8 g.

(C) somewhere between 22.4 and 44.8 g.

(D) more than 44.8 g.

10. The Kelvin temperature of one liter of gas is doubled and its pressure is tripled, volume will then be

(A) 1/6 L  
(B) 2/3 L  
(C) 3/2 L  
(D) 6 L

11. Real gases are most like ideal gases at

(A) high pressure and high temperature.

(B) low pressure and low temperature.

(C) high pressure and low temperature.

(D) low pressure and high temperature.

12. Given a mixture of gases: 1.00 g He, 14.0 g N₂ and 10.0 g NO. What is the total pressure at 27.0 °C if the gases are confined in a 2.00 L container?

<table>
<thead>
<tr>
<th>Molar Masses</th>
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</thead>
<tbody>
<tr>
<td>He</td>
</tr>
<tr>
<td>N₂</td>
</tr>
<tr>
<td>NO</td>
</tr>
</tbody>
</table>

(A) 0.310 atm  
(B) 1.24 atm

13. Which conditions favor the high solubility of a gas in a liquid?

(A) high pressure, high temperature

(B) high pressure, low temperature

(C) low pressure, high temperature

(D) low pressure, low temperature

II. SOLUTIONS

14. What mass of MgCl₂ is required to prepare 2.00 L of 0.550 M solution?

<table>
<thead>
<tr>
<th>Molar Mass</th>
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<tbody>
<tr>
<td>MgCl₂</td>
</tr>
</tbody>
</table>

(A) 1.10 g  
(B) 28.9 g  
(C) 86.5 g  
(D) 105 g

15. A stock solution of 12 M H₂SO₄ is available in the laboratory. The preparation of 200 mL of 0.20 M H₂SO₄ (dilute) solution may be accomplished by

(A) mixing 3.3 mL of H₂SO₄ with 200 mL of water.

(B) a six-to-one dilution of stock H₂SO₄ and using 200 mL of this solution.

(C) diluting 3.3 mL of H₂SO₄ (stock) with water to 200 mL total volume.

(D) mixing 1 mL of H₂SO₄ (stock) with 600 mL of water and using 200 mL of this solution.

16. A certain aqueous solution of FeCl₃ has a density of 1.19 g/mL and contains 20.0% FeCl₃. What is the concentration of this solution?

<table>
<thead>
<tr>
<th>Molar Mass</th>
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<tbody>
<tr>
<td>FeCl₃</td>
</tr>
</tbody>
</table>

(A) 0.0282 M  
(B) 0.163 M  
(C) 1.27 M  
(D) 1.47 M  
(E) 7.35 M

17. A 0.1 M aqueous solution is made of each of the substances listed. Which would have the lowest freezing point?

(A) K₂SO₄  
(B) Na₃PO₄  
(C) CaCl₂  
(D) NaCl
18. What is the mole fraction of water in 200. g of 95% (by mass) ethanol, C₂H₅OH?

\[
\text{Molar Mass} \\
\text{C₂H₅OH} & 46 \text{ g mol}^{-1} \\
\]

(A) 0.050  (B) 0.12  (C) 0.56  (D) 0.88

19. Which pair represents compounds each of which dissolves in water to give solutions that are good conductors of electricity?

(A) CH₃CO₂H and NaCl  (C) HF and HCl
(B) NaCl and AgCl  (D) NaCl and H₂SO₄

20. How many moles of HNO₃ must be used to prepare 10 L of solution that has a pH of 2.0?

(A) 2.0  (B) 0.20  (C) 0.10  (D) 0.010

21. A 2.00-g sample of a non-electrolyte is dissolved in 100 g H₂O. If the resulting solution freezes at -0.186 °C, what is the molar mass of the compound?

\[
\begin{array}{|c|}
\hline
\text{Molar Freezing Point Constant} \\
K_f \text{ for water} = 1.86 \text{ °C} \cdot \text{mol}^{-1} \\
\hline
\end{array}
\]

(A) 18.6  (B) 20.0  (C) 186  (D) 200

22. This graph shows how the solubility of ordinary cane sugar (sucrose) in water changes with the temperature. The solubility is expressed as the number of grams of sugar dissolved per 100 g of water in a saturated solution. A solution containing 300 g of sugar per 100 g of water at 40 °C would be

(A) saturated.  (D) impossible.
(B) unsaturated.  (E) dilute.
(C) supersaturated.

23. A bauxite ore is 86.0 percent Al₂O₃ by mass. How many grams of the ore are required to produce 20.0 g of aluminum metal?

\[
\begin{array}{|c|c|c|}
\hline
\text{Molar Masses} & \text{Al} & 27.0 \text{ g mol}^{-1} \\
& \text{Al₂O₃} & 102. \text{ g mol}^{-1} \\
\hline
\end{array}
\]

\[(A) \ 12.3 \ g \quad (B) \ 32.5 \ g \quad (C) \ 57.8 \ g \quad (D) \ 43.9 \ g\]

24. Calcium oxide is made by heating (roasting) limestone strongly

\[
\text{CaCO₃} \rightarrow \text{CaO} + \text{CO₂}
\]

How many liters (STP) of CO₂ is produced when 200 kg of CaCO₃ is roasted?

\[
\begin{array}{|c|c|c|}
\hline
\text{Molar Masses} & \text{CO₂} & 44 \text{ g mol}^{-1} \\
& \text{CaO} & 56 \text{ g mol}^{-1} \\
& \text{CaCO₃} & 100 \text{ g mol}^{-1} \\
\hline
\end{array}
\]

(A) 4,400 L  (C) 44,800 L
(B) 22,400 L  (D) 88,000 L

25. The simplest (empirical) formula of a compound is C₂H₅O. At STP, 11.2 L has a mass of 63 g. What is the correct molecular formula?

\[
\begin{array}{|c|c|}
\hline
\text{Atomic Molar Masses} & \\
\text{C} & 12.0 \text{ g mol}^{-1} \\
\text{H} & 1.0 \text{ g mol}^{-1} \\
\text{O} & 16.0 \text{ g mol}^{-1} \\
\hline
\end{array}
\]

(A) C₄H₄O₂  (C) C₆H₆O₃
(B) C₂H₁₂O₃  (D) C₄H₁₄O₄

26. What is the percentage of nitrogen by mass in (NH₄)₃PO₄?

\[
\begin{array}{|c|c|}
\hline
\text{Atomic Molar Masses} & \\
\text{H} & 1.0 \text{ g mol}^{-1} \\
\text{N} & 14.0 \text{ g mol}^{-1} \\
\text{O} & 16.0 \text{ g mol}^{-1} \\
\text{P} & 31.0 \text{ g mol}^{-1} \\
\hline
\end{array}
\]

(A) 14/62 \times 100\%  (C) 14/113 \times 100\%
(B) 21/80 \times 100\%  (D) 42/149 \times 100\%
17. If 0.50 mol of Na₃PO₄ is mixed with 0.30 mol of BaCl₂, the maximum number of moles of barium phosphate which can be formed is
(A) 0.10  (B) 0.15  (C) 0.30  (D) 0.50

28. The number of atoms in 9.0 g of aluminum is the same as the number of atoms in

<table>
<thead>
<tr>
<th>Atomic Molar Masses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al 27.0 g mol⁻¹</td>
</tr>
<tr>
<td>Mg 24.3 g mol⁻¹</td>
</tr>
</tbody>
</table>

(A) 8.1 g of magnesium.  (D) 18.0 g of magnesium.
(B) 9.0 g of magnesium.  (E) 24.3 g of magnesium.
(C) 12.15 g of magnesium.

29. What volume of 0.060 M H₂SO₄ will neutralize 50.00 mL of 0.24 M NaOH?
(A) 12.5 mL  (B) 25 mL  (C) 100 mL  (D) 200 mL

30. How many moles of H₂O can be produced when 8.0 g of O₂ are used in the reaction, assuming an ample amount of NH₃?

\[4\text{NH}_3(g) + 5\text{O}_2(g) \rightarrow 4\text{NO}(g) + 6\text{H}_2\text{O}(l)\]

<table>
<thead>
<tr>
<th>Molar Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₂ 32.0 g mol⁻¹</td>
</tr>
</tbody>
</table>

(A) 0.28  (B) 0.30  (C) 0.40  (D) 0.60

31. What is the value of \(\Delta H\) for this reaction?

\[3\text{H}_2(g) + \text{O}_3(g) \rightarrow 3\text{H}_2\text{O}(l)\]

\[\text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) \quad \Delta H = -286 \text{ kJ}\]

\[3\text{O}_2(g) \rightarrow 2\text{O}_3(g) \quad \Delta H = +271 \text{ kJ}\]

(A) -15 kJ  (D) -995 kJ
(B) -558 kJ  (E) -1130 kJ
(C) -722 kJ

33. Use this section of a periodic table.

If atoms of R have one "d" type electron, what is the formula for a nitride of element A?

(A) A₃N  (B) A₃N₂  (C) AN  (D) AN₂

34. In which pair of particles is the first member larger than the second member?

(A) Li⁺ ; Be²⁺  (C) Li⁺ ; Na⁺
(B) Li⁺ ; Li  (D) Be ; Mg

35. Among the alkali metals, cesium reacts more rapidly than sodium. To what may this be ascribed?

(A) Cesium has a higher nuclear charge.
(B) The valence electron in cesium is at a greater average distance from the nucleus.
(C) Cesium has a higher atomic weight.
(D) Cesium has more electrons.
(E) Cesium has more neutrons.

36. What do these have in common?

\[{}^{20}\text{Ne} {}^{19}\text{F}^- {}^{24}\text{Mg}^{2+}\]

(A) the same number of protons
(B) the same number of neutrons
(C) the same number of electrons
(D) the same size

37. Which of these atoms has the greatest number of neutrons in its nucleus?

(A) \(^{56}\text{Mn}\)  (B) \(^{52}\text{Fe}\)  (C) \(^{55}\text{Fe}\)  (D) \(^{57}\text{Co}\)
38. Which particle has the smallest mass?
(A) hydrogen atom  (D) proton
(B) alpha particle   (E) neutron
(C) beta particle

39. Which electronic configuration represents an excited state?
(A) [He]2s²2p²         (C) [Ar]4s²
(B) [Ne]3s²3p⁵         (D) [Ne]3s¹3p¹

40. A bismuth atom has one more electron than a lead atom. Into which energy sub-level does this added electron go?
(A) 5p       (B) 6p       (C) 6s       (D) 7s

41. An atom of Mn (atomic number = 25) has two 4s and five 3d electrons. How many unpaired electrons would there be in the Mn²⁺ ion?
(A) 1       (B) 2       (C) 3       (D) 4       (E) 5

42. The element X occurs naturally to the extent of 20.0% ¹²X and 80.0% ¹³X. The atomic mass of X is nearest
(A) 12.2     (B) 12.5     (C) 12.8     (D) 13.0

V. MOLECULAR STRUCTURE

43. In which compound does ionic bonding predominate?
(A) LiBr  (B) CO  (C) H₂O  (D) SiC

44. Which characteristic is generally true of nonmetallic oxides?
(A) They are in general ionic compounds.
(B) They are in general covalent compounds.
(C) They react with water to form bases.
(D) They cannot be prepared directly from the elements.
(E) They react with acids to form a salt and water.

45. According to modern bonding theory the number of sigma (σ) and pi (π) bonds in the ethylene molecule H₂C=CH₂ is
(A) 1 σ and 4 π  (D) 1 π and 5 σ
(B) 1 σ and 5 π  (E) 2 π and 4 σ
(C) 1 π and 4 σ

46. The most reasonable Lewis structure for HOCI is
(A) H : O : Ĉl
(C) H : O : Ĉl
(B) H : Ĉl : O:
(D) H : O : Ĉl

47. The fact that H₂O has a dipole moment suggests that the water molecule is
(A) dimeric.  (C) symmetrical.
(B) bent.     (D) nonpolar.

48. For which molecule can the bonding be described in terms of sp³ hybrid orbitals of the central atom?
(A) SF₆  (B) BF₃  (C) PCl₅  (D) NH₃

49. The molecule :O=C=N−H has been detected in gas clouds between stars. The predicted C−N−H bond angle is about
(A) 60°  (B) 90°  (C) 109°  (D) 120°

50. Which of these is a nonpolar molecule?

51. Which compound is an isomer of CH₃−CH₂−CH₂−OH?
(A) CH₃−CH≡CH−OH
(B) CH₃−O−CH₂−CH₃
(C) HO−CH₂−CH₂−CH₂
(D) H₂C−CH₂
VI. ACIDS AND BASES

52. According to the Brønsted–Lowry definition, which chemical species can function both as an acid and as a base?

(A) Cl⁻    (B) SO₄²⁻  (C) NH₄⁺  (D) HCO₃⁻  
(E) H₃O⁺

53. Which equilibrium can be described as an acid–base reaction using the Lewis acid–base definitions, but not using the Brønsted–Lowry definitions?

(A) NH₃ + CH₃COOH ⇌ CH₃COO⁻ + NH₄⁺  
(B) H₂O + CH₃COOH ⇌ H₂O⁺ + CH₃COO⁻  
(C) 4NH₃ + Cu(H₂O)₄²⁺ ⇌ Cu(NH₃)₄²⁺ + 4H₂O  
(D) 2NH₃ + H₂SO₄ ⇌ 2NH₄⁺ + SO₄²⁻  
(E) Fe(H₂O)₆³⁺ + H₂O ⇌ H₂O⁺ + Fe(H₂O)₅(OH)²⁺

54. Which is the weakest halogen acid?

(A) HF    (B) HCl    (C) HBr    (D) HI

55. The weakest of the bases listed is

<table>
<thead>
<tr>
<th>Acid</th>
<th>Conjugate Base</th>
<th>Kₐ (Ionization Constant of Acid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>Cl⁻</td>
<td>100% ionized</td>
</tr>
<tr>
<td>HSO₄⁻</td>
<td>SO₄²⁻</td>
<td>1.2 × 10⁻²</td>
</tr>
<tr>
<td>H₂S</td>
<td>HS⁻</td>
<td>5.7 × 10⁻⁸</td>
</tr>
<tr>
<td>HS⁻</td>
<td>S²⁻</td>
<td>1.2 × 10⁻¹³</td>
</tr>
</tbody>
</table>

(A) Cl⁻    (B) CN⁻    (C) HS⁻    (D) S²⁻  
(E) SO₄²⁻

56. Which substance dissolves in water to form an acidic solution?

(A) KCl    (B) Na₃PO₄    (C) NH₄Cl    (D) Na₂CO₃

57. A mixture of which pair of 0.1 M aqueous solutions would constitute a buffer?

(A) NaOH and NaCl  
(B) HCl and NaCl  
(C) HCl and NaOH  
(D) NH₃ and NH₄NO₃

58. Which gives an acidic solution in water?

(A) H₂    (B) CH₄    (C) NH₃    (D) CaO  
(E) SO₂

59. A 25.0-mL sample of 0.130 M HCl is mixed with 15.0 mL of 0.240 M of NaOH. The pH of the resulting solution will be nearest

(A) 2.1    (B) 7    (C) 11.9    (D) 13.0

60. Which of the normal atmospheric components will be most readily absorbed by lime water (calcium hydroxide)?

(A) argon  
(B) carbon dioxide  
(C) nitrogen  
(D) oxygen  
(E) water vapor

61. What is the [OH⁻] of a solution which is 0.18 M in ammonium ion and 0.10 M in ammonia?

<table>
<thead>
<tr>
<th>Ionization Constant for Ammonia</th>
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<tbody>
<tr>
<td>K_b = 1.8 × 10⁻⁵</td>
</tr>
</tbody>
</table>

(A) 1.3 × 10⁻³      (B) 1.0 × 10⁻³      (C) 1.3 × 10⁻⁵      (D) 1.0 × 10⁻⁵

VII. EQUILIBRIUM

62. In which reaction will an increase in total pressure at constant temperature favor formation of the products?

(A) CaCO₃(s) ⇌ CaO(s) + CO₂(g)  
(B) H₂(g) + Cl₂(g) ⇌ 2HCl(g)  
(C) 2NO₂(g) + O₂(g) ⇌ 2NO₃(g)  
(D) COCl₂(g) ⇌ CO(g) + Cl₂(g)

63. The equilibrium constant for the gaseous reaction

C + D ⇌ E + 2F

is 3.0 at 50 °C. In a 2.0 L flask at 50 °C are placed 1.0 mol of C, 1.0 mol of D, 1.0 mol of E, and 3.0 mol of F. Initially, the reaction will

(A) proceed at equal rates in both directions.  
(B) proceed more rapidly to form E and F.  
(C) proceed more rapidly to form C and D.  
(D) not occur in either direction.
<table>
<thead>
<tr>
<th>Compound and State</th>
<th>( \Delta G^\circ_{f} ) kJ/mol</th>
</tr>
</thead>
<tbody>
<tr>
<td>H_2O(l)</td>
<td>-237</td>
</tr>
<tr>
<td>H_2O(g)</td>
<td>-229</td>
</tr>
</tbody>
</table>

At 298 K the equilibrium constant for

\[ \text{H}_2\text{O(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightleftharpoons \text{H}_2\text{O(l)} \]

(A) is larger than the \( K_{eq} \) for \( \text{H}_2\text{O(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightleftharpoons \text{H}_2\text{O(l)} \)

(B) will have a value of 1.0 at equilibrium.

(C) cannot be computed since data on \( \text{O}_2 \) and \( \text{H}_2 \) are not provided.

(D) will have the same value as the \( K_{eq} \) for \( \text{H}_2\text{O(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightleftharpoons \text{H}_2\text{O(l)} \)

65. Which factor would cause a change in the equilibrium constant, \( K_c \), for this reaction?

\[ 2\text{NOCl(g)} \rightleftharpoons 2\text{NO(g)} + \text{Cl}_2(g) \]

(A) adding \( \text{NO(g)} \)

(B) decreasing the volume of the reaction vessel

(C) cooling the system

(D) adding an inert gas

66. Calculate \( K_{eq} \) in terms of molar concentration for the reaction

\[ \text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)} \]

when the equilibrium concentration moles per liter are:

\( \text{N}_2 = 0.02, \text{H}_2 = 0.01, \text{NH}_3 = 0.10 \).

(A) \( 2 \times 10^{-6} \)  (B) \( 5 \times 10^{3} \)  (C) \( 5 \times 10^{5} \)  (D) \( 5 \times 10^{7} \)

67. The equilibrium constant for the reaction

\[ 2\text{HBr(g)} \rightleftharpoons \text{H}_2\text{(g)} + \text{Br}_2(g) \]

is 10 at a certain temperature, when concentrations are expressed in moles per liter. Calculate the number of moles of \( \text{HBr(g)} \), present at equilibrium if 100 L of the equilibrium mixture contain 5 mol of \( \text{H}_2\text{(g)} \) and 8 mol of \( \text{Br}_2(g) \).

(A) 0.25  (B) 0.5  (C) 1  (D) 2  (E) 4

68. Which will occur if a 0.1 M solution of a weak acid is diluted to 0.01 M at constant temperature?

(A) [H\(^+\)] will decrease to 0.01 M.

(B) pH will decrease.

(C) Percentage ionization will increase.

(D) \( K_a \) will increase.

69. The solubility of BaCO\(_3\) is \( 7.9 \times 10^{-3} \) g·L\(^{-1}\). Calculate the solubility product, \( K_{sp} \), ignoring hydrolysis.

<table>
<thead>
<tr>
<th>Molar Mass</th>
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</thead>
<tbody>
<tr>
<td>BaCO(_3)</td>
</tr>
</tbody>
</table>

(A) \( 1.6 \times 10^{-2} \)  (C) \( 4.0 \times 10^{-5} \)

(B) \( 1.6 \times 10^{-9} \)  (D) \( 6.2 \times 10^{-5} \)

70. If two salts, \( \text{AX} \) and \( \text{BX}_2 \), have the same \( K_{sp} \) values of \( 4.0 \times 10^{-12} \) at a given temperature, then

(A) their molar solubilities in water are the same.

(B) the salts are more soluble in 0.1 M NaX than in water.

(C) the molar solubility of \( \text{AX} \) in water is less than that of \( \text{BX}_2 \).

(D) addition of NaX will not affect the solubilities of the salts.

VIII. KINETICS AND THERMODYNAMICS

71. What is the standard enthalpy of combustion of \( \text{C}_2\text{H}_6 \) in kJ·mol\(^{-1}\)?

<table>
<thead>
<tr>
<th>Thermochemical Data</th>
<th>( \Delta H^0 ) kJ/mol</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{H}_2\text{O(l)} )</td>
<td>( -286 )</td>
</tr>
<tr>
<td>( \text{C}_2\text{H}_4\text{(g)} + \text{H}_2\text{(g)} \rightarrow \text{C}_2\text{H}_6\text{(g)} )</td>
<td>( -137 )</td>
</tr>
<tr>
<td>( \text{C}_2\text{H}_4\text{(g)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)} + 2\text{H}_2\text{O(l)} )</td>
<td>( -1412 )</td>
</tr>
</tbody>
</table>

(A) \(-1275 \)  (C) \(-31561 \)

(B) \(-1548 \)  (D) \(+1834 \)
72. Calculate the value of $\Delta H$ (in kJ·mol$^{-1}$) for the reaction

$$\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$$

<table>
<thead>
<tr>
<th>Bond Energies (kJ·mol$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H–H</td>
</tr>
<tr>
<td>N≡N</td>
</tr>
<tr>
<td>N–H</td>
</tr>
</tbody>
</table>

(A) 2340 kJ of heat absorbed  
(B) 213 kJ of heat absorbed  
(C) 2340 kJ of heat evolved  
(D) 83 kJ of heat evolved

73. Under which conditions does nitrogen have the largest entropy per mole?

(A) N$_2(g)$ at 50 K and 1 atm  
(B) N$_2(g)$ at 70 K and 1 atm  
(C) N$_2(g)$ at 80 K and 1 atm  
(D) N$_2(g)$ at 80 K and 0.5 atm

74. When Al$_2$O$_3(g)$ is formed from the elements at standard conditions, the values of $\Delta H^0$ and $\Delta G^0$ at 298 K are $-1617$ kJ·mol$^{-1}$ and $-1577$ kJ·mol$^{-1}$, respectively. The standard entropy of formation per mole, in joules per degree, will be

(A) $-315$  
(B) $-157$  
(C) $-93.3$  
(D) $-0.0933$  
(E) $+15.7$

75. A reaction is spontaneous at all temperatures if

(A) $\Delta H$ and $\Delta S$ are both positive.  
(B) $\Delta H$ and $\Delta S$ are both negative.  
(C) $\Delta H$ is positive and $\Delta S$ is negative.  
(D) $\Delta H$ is negative and $\Delta S$ is positive.

76. Which statement concerning the reaction coordinate diagram is true?

(A) The catalyst decreases the activation energy.  
(B) The reaction is endothermic.  
(C) The addition of a catalyst slows this reaction.  
(D) A and B have lower potential energy than C and D.

77. The table presents data for the reaction:

$$2\text{H}_2(g) + 2\text{NO(g)} \rightleftharpoons k_1 \rightarrow 2\text{H}_2\text{O(g)} + \text{N}_2(g)$$

The temperature of the reaction is constant. The initial rate is in arbitrary units.

<table>
<thead>
<tr>
<th>Exp.</th>
<th>[NO] $\times 10^{-3}$</th>
<th>[H$_2$] $\times 10^{-3}$</th>
<th>Initial Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>6.0</td>
<td>1.0</td>
<td>18</td>
</tr>
<tr>
<td>II</td>
<td>6.0</td>
<td>2.0</td>
<td>36</td>
</tr>
<tr>
<td>III</td>
<td>1.0</td>
<td>6.0</td>
<td>3</td>
</tr>
<tr>
<td>IV</td>
<td>2.0</td>
<td>6.0</td>
<td>12</td>
</tr>
</tbody>
</table>

What is the rate law for this reaction?

(A) rate = $k_1$ [H$_2$] [NO]  
(B) rate = $k_1$ [H$_2$]$^2$ [NO]  
(C) rate = $k_1$ [H$_2$]$^2$ [NO]  
(D) rate = $k_1$ [H$_2$] [NO]$^2$
78. Consider the reaction:

\[ 2\text{NO}_2(g) + F_2(g) \rightarrow 2\text{NO}_2F(g) \]

A proposed mechanism for this reaction is

\[ \text{NO}_2 + F_2 \rightarrow \text{NO}_2F + F \quad \text{(slow)} \]
\[ \text{NO}_2 + F \rightarrow \text{NO}_2F \quad \text{(fast)} \]

What is the rate law for this mechanism?

(A) rate = \( k \frac{[\text{NO}_2F]^2}{[\text{NO}_2][F_2]} \)  
(B) rate = \( k [\text{NO}_2][F_2] \)
(C) rate = \( k [\text{NO}_2][F] \)  
(D) rate = \( k [\text{NO}_2][\text{F}] \)

79. A sample of a radioactive isotope initially contains 20 x 10^10 atoms. After 16 days, 5 x 10^10 atoms remain. What is the half-life of the isotope?

(A) 4 days  
(B) 8 days  
(C) 12 days  
(D) 16 days

80. Antimony reacts spontaneously with chlorine to form antimony chloride. The reaction would proceed with reduced velocity if one were to

(A) use smaller particles of antimony.  
(B) use larger particles of antimony.  
(C) increase the pressure on the chlorine gas before the antimony is introduced.  
(D) increase the temperature of the chlorine.  
(E) carry out the reaction in sunlight.

IX. REDOX AND ELECTROCHEMISTRY

81. Which statement is true for the cell as it discharges?

\[ \text{Zn} | \text{Zn}^{2+}(1.0 \text{ M}) || \text{Sn}^{2+}(1.0 \text{ M}) | \text{Sn} \]

(A) Oxidation occurs at the tin electrode.  
(B) Electrons will flow from the tin electrode to the zinc electrode.  
(C) The concentration of \( \text{Zn}^{2+} \) will increase.  
(D) The mass of the tin electrode will decrease.

82. Five metals are represented by the symbols L, M, T, R, Z. When a solution containing all five ions at 1 M concentration is electrolyzed with a small applied voltage, which metal is most likely to be deposited first on the cathode?

<table>
<thead>
<tr>
<th>Unknown Metals</th>
<th>( E^0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>L ( \rightarrow \text{L}^{2+} + 2e^- )</td>
<td>0.76 V</td>
</tr>
<tr>
<td>M ( \rightarrow \text{M}^{2+} + 2e^- )</td>
<td>0.44 V</td>
</tr>
<tr>
<td>T ( \rightarrow \text{T}^{2+} + 2e^- )</td>
<td>0.13 V</td>
</tr>
<tr>
<td>R ( \rightarrow \text{R}^{3+} + 3e^- )</td>
<td>-0.34 V</td>
</tr>
<tr>
<td>Z ( \rightarrow \text{Z}^{+} + e^- )</td>
<td>-0.80 V</td>
</tr>
</tbody>
</table>

83. A solution of CdSO_4 is electrolyzed between inert electrodes. How many hours must a current of 1.75 A flow to deposit 11.8 g of cadmium?

(A) 0.51  
(B) 1.26  
(C) 3.22  
(D) 5.18

84. Calculate the potential of a Daniel cell in which the [Zn^{2+}] is 0.10 M and [Cu^{2+}] is 0.010 M.

(A) 0.38 V  
(B) 0.44 V  
(C) 1.07 V  
(D) 1.13 V

85. Manganese has the oxidation number of +5 in

(A) [MnF_3]^{3-}  
(B) MnO_7  
(C) [MnO_4]^{2-}  
(D) [Mn(CN)_6]^{-}

86. In which group can each substance act as an oxidizing agent?

(A) Cl_2, MnO_2, Cu  
(B) Cl_2, MnO_4, Cu^{2+}  
(C) Cl^-, MnO_4^-, Cu^+  
(D) Cl_2, Mn, Cu^{2+}

87. Which reaction will occur if each substance is in its standard state?

<table>
<thead>
<tr>
<th>Standard Reduction Potentials</th>
<th>( E^0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Ni}^{2+}(aq) + 2e^- \rightarrow \text{Ni(s)} )</td>
<td>-0.25 V</td>
</tr>
<tr>
<td>( \text{Sn}^{4+}(aq) + 2e^- \rightarrow \text{Sn}^{2+}(aq) )</td>
<td>+0.15 V</td>
</tr>
<tr>
<td>( \text{Br}_2(l) + 2e^- \rightarrow 2\text{Br}^-(aq) )</td>
<td>+1.07 V</td>
</tr>
</tbody>
</table>

(A) \( \text{Ni}^{2+} \) will oxidize \( \text{Sn}^{2+} \) to give \( \text{Sn}^{4+} \)  
(B) \( \text{Sn}^{4+} \) will oxidize \( \text{Br}^- \) to give \( \text{Br}_2 \)  
(C) \( \text{Br}_2 \) will oxidize \( \text{Ni(s)} \) to give \( \text{Ni}^{2+} \)  
(D) \( \text{Ni}^{2+} \) will oxidize \( \text{Br}_2 \) to give \( \text{Br}^- \)
88. Complete and balance

\[ \text{MnO}_4^- + ? H^+ + ? \text{Fe}^{2+} \rightarrow ? \text{Mn}^{2+} + ? \text{Fe}^{3+} + ? \text{H}_2\text{O} \]

The coefficient of $H^+$ ions required is

(A) 16  (B) 10  (C) 8  (D) 4  (D) 5

X. DESCRIPTIVE CHEMISTRY AND LABORATORY

89. To protect a buried pipe line from corrosion, a bar of magnesium is buried close to the pipe and connected to the iron. What is the best explanation of this protective action?

(A) Fe loses electrons less readily than Mg, making Mg the anode.

(B) Mg gains electrons more readily than Fe, keeping the Fe from oxidizing.

(C) Mg forms a self-protecting coating over the iron.

(D) Mg is more active than iron and forces the iron to act as an anode.

(E) An electrolytic cell is set up, with $H_2$ gas being evolved at the surface of Mg.

90. Which substance may be most practically collected in space S by the displacement of water?

(A) CuCl₂, solid; solubility = 0.0062 g/100 g H₂O; density = 3.5 g/mL⁻¹

(B) NO₂, gas; solubility = 7.3 mL/100 g H₂O; density = 1.3 g/L⁻¹

(C) P₂H₆, liquid; insoluble; density = 1.01 g/mL⁻¹

(D) Si₃H₈, liquid, decomposed by water; density = 0.74 g/mL⁻¹

(E) CO₂, gas; solubility = 179.7 mL/100 g H₂O; density = 1.96 g/L⁻¹

91. What is the molar mass (in g·mol⁻¹) of anhydrous iron(III) sulfate, to the nearest whole number?

<table>
<thead>
<tr>
<th>Atomic Molar Masses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
</tr>
<tr>
<td>55.8 g·mol⁻¹</td>
</tr>
<tr>
<td>O</td>
</tr>
<tr>
<td>16.0 g·mol⁻¹</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td>32.1 g·mol⁻¹</td>
</tr>
</tbody>
</table>

(A) 104  (B) 152  (C) 248  (D) 336  (E) 400

92. What is the correctly reported mass of water based on this data?

<table>
<thead>
<tr>
<th>Mass of beaker and water</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.62 g</td>
</tr>
<tr>
<td>Mass of beaker only</td>
</tr>
<tr>
<td>28.3220 g</td>
</tr>
</tbody>
</table>

(A) 1.3 g  (B) 1.30 g  (C) 1.298 g  (D) 1.2980 g

93. Some sodium chlorate, NaClO₃, is decomposed by heating and all its oxygen is driven out. What is the best solvent for removing the residue in the test tube?

(A) alcohol  (D) hot water

(B) aqua regia  (E) nitric acid

(C) carbon disulfide

94. When NaOH(aq) is added to a solution, a gas is released that turns moist, red litmus blue. The solution contains

(A) HCl  (C) NH₄Cl

(B) AlCl₃  (D) MgCl₂

95. A student has a salt mixture that contains both barium and copper(II) ions. This mixture dissolves in water forming a clear blue-colored solution. Which anion is absent?

(A) nitrate  (D) perchlorate

(B) chromate  (E) chloride

(C) acetate

96. The addition of a small amount of solid sodium chloride to a saturated solution of lead chloride will

(A) cause no change.

(B) cause more lead chloride to dissolve.

(C) decrease the chloride ion concentration.

(D) cause all the lead chloride to precipitate.

(E) cause some of the lead chloride to precipitate.