

Chemistry, 2012 EC, entrance exam, version 1

Grade 12 · Chemistry · 2012 E.C.

MARKING KEY — CONFIDENTIAL

Time allowed: 120 minutes

Questions: 77

Total marks: 77

1. According to World Health Organization (WHO), the standard for the concentration of alcohol used to prevent COVID-19 virus is 70%. How much water has to be added to prepare the standard alcohol for 1L of 96% alcohol? (1)
- A. 1371.4 ml
B. 371.4 L
C. ✓ 371.4 ml
D. 30 ml

Answer: C

Using the dilution formula $C_1V_1 = C_2V_2$, the final volume required is $V_2 = (96\% \times 1000 \text{ mL})/70\% = 1371.4 \text{ mL}$. Thus, the volume of water that must be added to the 1 L of alcohol is $1371.4 \text{ mL} - 1000 \text{ mL} = 371.4 \text{ mL}$.

2. In which of the following solvents would you expect the solubility of NaCl to be greatest? (1)
- A. Carbon tetrachloride (CCl₄)
B. ✓ Water (H₂O)
C. Methanol (CH₃OH)
D. Methanol (CH₃OH)

Answer: B

NaCl is an ionic compound and dissolves best in highly polar solvents that can effectively solvate its ions through strong ion-dipole interactions. Water has a much higher dielectric constant and polarity compared to carbon tetrachloride and methanol.

3. Which of the following substances might stabilize a colloidal suspension of oil in water? (1)
- A. ✓ Sodium stearate NaCO₂(CH₂)₁₆CH₃
B. Sodium bicarbonate (NaHCO₃)
C. H₂O
D. CaCl₂

Answer: A

Sodium stearate is an emulsifying agent (soap) containing a hydrophobic non-polar hydrocarbon tail that interacts with the oil and a hydrophilic polar head group that interacts with water, thereby stabilizing the colloidal suspension of oil in water.

4. How many moles of unknown weak acid (HA) in a 100 L solution are required to produce a solution with pH = 2? (1)
- K_a of the unknown weak acid (HA) = 5×10^{-3} .
- A. 3×10^{-3}
B. 0.3×10^{-3}
C. ✓ 3
D. 0.3

Answer: C

A pH of 2 corresponds to $[H^+] = 10^{-2} \text{ M} = 0.01 \text{ M}$. Since $K_a = \frac{[H^+]^2}{[HA]_0 - [H^+]}$, we have $5 \times 10^{-3} = \frac{(0.01)^2}{[HA]_0 - 0.01}$, giving $[HA]_0 = 0.03 \text{ M}$. For a 100 L solution, the required amount is $0.03 \text{ M} \times 100 \text{ L} = 3 \text{ moles}$.

5. If different processes are used to bring about the same change the enthalpy changes during these processes are the same, this is the statement of (1)
- A. ✓ Hess's law
B. Standard Enthalpy
C. 1st law thermodynamics
D. 2nd law thermodynamics

Answer: A

Hess's law states that the total enthalpy change for a chemical reaction is the same regardless of whether the reaction takes place in one step or in several steps.

6. Which of the following 0.1 M solutions has the lowest pH? (1)
- A. NaNO_2 B. KClO_4
C. ✓ NH_4Cl D. NH_3

Answer: C

NH_4Cl is a salt of a strong acid (HCl) and a weak base (NH_3). Its cation, NH_4^+ , undergoes hydrolysis in water to produce hydronium ions, making the solution acidic ($\text{pH} < 7$), which is lower than the neutral KClO_4 or basic NaNO_2 and NH_3 solutions.

7. The pH of a 0.1 M weak base B is 9. What is the K_b for B? (1)
- A. 9.2×10^{-4} B. 2×10^{-6}
C. 1×10^{-4} D. ✓ 1×10^{-9}

Answer: D

A pH of 9 corresponds to a pOH of 5 ($14 - 9$), which means $[\text{OH}^-] = 10^{-5} \text{ M}$. For a weak base B, $K_b = \frac{[\text{OH}^-]^2}{[\text{B}]_0 - [\text{OH}^-]} \approx \frac{(10^{-5})^2}{0.1} = 10^{-9}$.

8. Addition of HCl to an aqueous buffer solution containing NH_3 and NH_4Cl cause which of the following to occur? (1)
- I. pH of the solution increase II. pH of the solution decrease III. NH_4^+ concentration increase IV. NH_3 concentration increase
- A. I B. II
C. I and III D. ✓ II and III

Answer: D

When HCl is added, the hydronium ions react with the weak base NH_3 to form its conjugate acid NH_4^+ , thus increasing the concentration of NH_4^+ (III). Although it is a buffer, the addition of an acid still results in a slight decrease in the pH of the solution (II).

9. What is the equivalence point pH of the solution formed by the titration of 50 mL of 0.15 M CH_3COOH using 25 mL of 0.3 M NaOH ? [Use $\log 7.5 = 0.87$, K_b of acetate ion = 5.6×10^{-10}] (1)
- A. 7.44 B. 6.22
C. 8.44 D. ✓ 8.87

Answer: D

At the equivalence point, the moles of acetate ion formed equal 0.0075 mol in a total volume of 75 mL, giving $[\text{CH}_3\text{COO}^-] = 0.1 \text{ M}$. Using the base dissociation constant $K_b = 5.6 \times 10^{-10}$, the $[\text{OH}^-]$ concentration is calculated as $\sqrt{5.6 \times 10^{-11}} \approx 7.5 \times 10^{-6} \text{ M}$, yielding a pOH of 5.13 and a pH of $14 - 5.13 = 8.87$.

10. The solubility of a particular salt in water is 9.9 g/mL at room temperature. If 11.1 g is completely dissolved in one milliliter of water, the solution is (1)
- A. Saturated B. ✓ Supersaturated
C. Unsaturated D. Dilute

Answer: B

A solution that contains more dissolved solute than its normal maximum solubility under given conditions is referred to as supersaturated; here, 11.1 g is completely dissolved in 1 mL of water, which exceeds the solubility limit of 9.9 g/mL.

11. The hybrid orbitals in a molecule of methane are oriented (1)
- A. ✓ **Towards the corners of a tetrahedron centered on the carbon atom.**
 - B. Towards the corners of a cube centered on the carbon atom.
 - C. Towards the corners of a triangle centered on the carbon atom.
 - D. Towards the corners of a rectangle centered on the carbon atom.

Answer: A

In methane (CH_4), the carbon atom undergoes sp^3 hybridization, resulting in four equivalent hybrid orbitals directed toward the corners of a regular tetrahedron with bond angles of 109.5° .

12. Which one of the following best describes chemical equilibrium? (1)
- A. Concentrations of products are higher than concentration of reactants.
 - B. ✓ **Forward and reverse reactions continue with no effect on the concentration of reactants and products.**
 - C. Reactions stop only when reactants have been converted to products.
 - D. Forward and reverse reactions have stopped so that the concentration of the reactants equals the concentration of products.

Answer: B

Chemical equilibrium is a dynamic process where the forward and reverse reactions continue to occur at equal rates, resulting in no net change in the concentrations of the reactants and products.

13. Based on the Valence shell electron pair repulsion (VSEPR) theory which of the following would have a tetrahedral arrangement of electrons around the central atom? (1)
- | | |
|-----------------------|---------------------------------------|
| A. BH_3 | B. NO_2^- |
| C. CO_3^{2-} | D. ✓ SiH_4 |

Answer: D

SiH_4 has four bonding pairs of electrons and no lone pairs around the central silicon atom, resulting in a tetrahedral electron-pair geometry and molecular shape, whereas the other options have three electron groups (trigonal planar).

14. When the 1s-orbitals of two hydrogen atoms combine to form a hydrogen molecule, then which molecular orbitals are formed? (1)
- A. One bonding molecular orbital only.
 - B. Two bonding molecular orbitals.
 - C. ✓ **One bonding molecular orbital and one antibonding molecular orbital.**
 - D. Two antibonding molecular orbitals.

Answer: C

According to molecular orbital theory, the linear combination of n atomic orbitals always produces n molecular orbitals. Therefore, combining two 1s atomic orbitals forms one bonding molecular orbital (σ_{1s}) and one antibonding molecular orbital (σ_{1s}^*).

15. Which of the following solid substances contains positive ions immersed in a sea of mobile electrons? (1)
- | | |
|-----------------|------------------------------------|
| A. O_2 | B. ✓ Cu |
| C. CuO | D. SiO_2 |

Answer: B

Metallic bonding is characterized by a lattice of positive metal ions (cations) surrounded by a "sea" of delocalized, mobile valence electrons, which is the type of bonding found in copper (Cu).

16. Which one of the following compounds contains both covalent and ionic bond? (1)
- A. CCl_4 B. KCl
C. MgCl_2 D. ✓ **NH_4Cl**

Answer: D

Ammonium chloride (NH_4Cl) contains covalent bonds between the nitrogen and hydrogen atoms within the polyatomic ammonium cation (NH_4^+), and an ionic bond between the NH_4^+ cation and the chloride anion (Cl^-).

17. Oxygen, nitrogen and fluorine bond with hydrogen to form molecules. These molecules are attracted to each other by (1)
- A. Coordinate covalent bonds B. Electro covalent bond
C. Ionic bonds D. ✓ **Hydrogen bonds**

Answer: D

Hydrogen bonding occurs when hydrogen is covalently bonded to highly electronegative atoms like nitrogen, oxygen, or fluorine, leading to strong intermolecular attractions between these polar molecules.

18. Given the reaction: $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$. Which statement best describes the energy changes as bonds are formed and broken in this reaction. (1)
- A. ✓ **The forming of the H-Cl bond releases energy.**
B. The forming of the H-Cl bond absorbs energy.
C. The breaking of the H-H bond releases energy.
D. The breaking of the Cl-Cl bond releases energy.

Answer: A

Bond breaking is always an endothermic process (absorbs energy), whereas bond forming is always an exothermic process (releases energy). Therefore, the formation of the H-Cl bond releases energy.

19. The reaction $\text{CHCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow \text{CCl}_4(\text{g}) + \text{HCl}(\text{g})$ has the rate law: $\text{Rate} = k[\text{CHCl}_3][\text{Cl}_2]$. If the concentration of CHCl_3 is increased by a factor of five while the concentration of Cl_2 is kept the same, the rate will be (1)
- A. Stay the same B. ✓ **Increased by a factor of five**
C. Decreased by a factor of five D. Doubled

Answer: B

According to the given rate law, the reaction is first-order with respect to CHCl_3 . Therefore, increasing the concentration of CHCl_3 by a factor of five will increase the rate of the reaction by the same factor of five.

20. What are the four quantum numbers of $4d^6$ orbital? (Options in table) (1)
- A. $n=4, l=1, m_l=1, m_s=\pm 1/2$ B. ✓ **$n=4, l=2, m_l=-2, m_s=-1/2$**
C. $n=4, l=0, m_l=0, m_s=-1/2$ D. $n=4, l=2, m_l=1, m_s=-1/2$

Answer: B

For a $4d$ subshell, the principal quantum number is $n = 4$ and the angular momentum quantum number is $l = 2$ (for d orbitals). For the $4d^6$ configuration, Hund's rule dictates that the first five electrons fill the five d orbitals singly with parallel spins, and the sixth electron pairs up in the first orbital ($m_l = -2$) with an opposite spin of $m_s = -1/2$.

21. Lava is a foam colloid. The dispersed phase and dispersion medium are respectively: (1)
- A. gas-liquid B. solid-gas
C. liquid-gas D. ✓ **gas-solid**

Answer: D

Lava (and pumice) is classified as a solid foam colloid, where the dispersed phase is a gas (trapped air/gas bubbles) and the dispersion medium is a solid (solidified volcanic rock).

22. Which of the following salts would form an acidic solution? I. KCl II. NaF III. NH_4Cl IV. CaCO_3 (1)
- A. I and III
B. I and IV
C. III and IV
D. ✓ **only III**

Answer: D

NH_4Cl is a salt formed from a strong acid (HCl) and a weak base (NH_3), meaning the NH_4^+ ion undergoes hydrolysis to produce hydronium ions, making the solution acidic. KCl is neutral, while NaF and CaCO_3 are basic salts.

23. Which of the following is a Lewis acid but not a Brønsted acid? (1)
- A. HBr
B. ✓ **BBr_3**
C. NH_3
D. CH_4

Answer: B

BBr_3 is a Lewis acid because the boron atom has an incomplete octet (six valence electrons) and can accept an electron pair. However, it cannot donate a proton (H^+), so it is not a Brønsted acid.

24. What is the percentage dissociation of a 0.1 M unknown weak acid (HA) solution? [Use K_a of HA = 9×10^{-9}] (1)
- A. 9×10^{-9}
B. 3×10^{-9}
C. 9×10^{-2}
D. ✓ **3×10^{-2}**

Answer: D

The degree of dissociation is calculated as $\alpha = \sqrt{(K_a / C)} = \sqrt{(9 \times 10^{-9} / 0.1)} = 3 \times 10^{-4}$. Multiplying by 100% gives the percentage dissociation, which is $3 \times 10^{-2}\%$.

25. A chemist adds water to 120 mL of a 6 M solution of HCl until the final volume is 2 L. What is the molarity of the resulting solution? (1)
- A. 0.94 M
B. 2.3 M
C. ✓ **0.36 M**
D. 8.7 M

Answer: C

Using the dilution formula $M_1V_1 = M_2V_2$: $(6 \text{ M})(0.12 \text{ L}) = M_2(2 \text{ L})$, which yields $M_2 = 0.36 \text{ M}$.

26. Which of the following is the correct increasing order of the atomic size of Mg^+ , Na, Si^{3+} , and Al^{2+} ? (1)
- A. $\text{Na} < \text{Mg}^+ < \text{Al}^{2+} < \text{Si}^{3+}$
B. ✓ **$\text{Si}^{3+} < \text{Al}^{2+} < \text{Mg}^+ < \text{Na}$**
C. $\text{Al}^{2+} < \text{Mg}^+ < \text{Na} < \text{Si}^{3+}$
D. $\text{Si}^{3+} > \text{Al}^{2+} > \text{Na} > \text{Mg}^+$

Answer: B

These four species are isoelectronic (each has 11 electrons). For isoelectronic species, the ionic/atomic radius decreases as the nuclear charge (atomic number) increases because the nucleus pulls the same number of electrons more strongly.

27. The standard enthalpy of formation of Nitrogen (N_2) is? (1)
- A. 1
B. ✓ **0**
C. -1
D. 4

Answer: B

By definition, the standard enthalpy of formation of any pure element in its most stable physical state at standard conditions (such as N_2 gas) is zero.

A pi (π) bond is formed by the sideways (lateral) overlap of parallel atomic orbitals, such as p-orbitals. In contrast, sigma (σ) bonds are formed by head-on or axial overlap of orbitals.

33. Which one is the function of iron in the Haber process? (1)
- A. It shifts the position of equilibrium towards the products.
B. It decreases the rate of reactions.
C. ✓ **It provides an alternative reaction pathway with lower activation energy.**
D. It reduces the enthalpy change of the reaction.

Answer: C

Iron acts as a catalyst in the Haber process, which means it speeds up the chemical reaction by providing an alternative pathway with a lower activation energy. It does not alter the enthalpy change of the reaction or the position of the chemical equilibrium.

34. Which types of solid materials are typically hard, have high melting points and poor electrical conductivities? I. Ionic II. Metallic III. Covalent-network (1)
- A. I and II only
B. ✓ **I and III only**
C. II and III only
D. I, II, and III

Answer: B

Ionic and covalent-network solids typically feature high melting points, high hardness, and poor electrical conductivity in their solid states. Metallic solids, on the other hand, are highly conductive and ductile.

35. For the reaction: $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$, at a certain temperature the equilibrium concentrations in mol/L are $[\text{H}_2]=0.2$, $[\text{I}_2]=0.2$, $[\text{HI}]=2.0$. Then based on this data, which one is the equilibrium constant K_c ? (1)
- A. 0.002
B. 20
C. 10
D. ✓ **100**

Answer: D

The equilibrium constant expression is $K_c = [\text{HI}]^2 / ([\text{H}_2][\text{I}_2])$. Substituting the given concentrations, $K_c = (2.0)^2 / (0.2 \times 0.2) = 4 / 0.04 = 100$.

36. Which statement is correct about the effect of adding a catalyst to a system at equilibrium? I. The rate of the forward reaction increases. II. The rate of reverse reaction increases. III. The yield of the products increases. (1)
- A. I only
B. III only
C. ✓ **I and II only**
D. I, II and III

Answer: C

A catalyst increases the rates of both the forward and reverse reactions by the same factor, helping the system reach equilibrium faster. However, it does not alter the position of the equilibrium or change the final yield of the products.

37. For the reaction: $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$, $K_c = 8 \times 10^{-4} \text{ mol/cm}^3$? Actually units: $8 \times 10^{-4} \text{ mol/cm}^3$? That is huge; likely 8×10^{-4} ? Given options: $[\text{N}_2\text{O}_4]=8 \times 10^{-2} \text{ mol/cm}^3$, find $[\text{NO}_2]$. $K_c = [\text{NO}_2]^2 / [\text{N}_2\text{O}_4] = 8 \times 10^{-4}$? That would give $[\text{NO}_2]^2 = 8 \times 10^{-4} \times 8 \times 10^{-2} = 6.4 \times 10^{-5}$, $[\text{NO}_2]=80$, not matching options. If $K_c=8 \times 10^{-4}$, then $[\text{NO}_2]^2 = 8 \times 10^{-4} \times 8 \times 10^{-2} = 6.4 \times 10^{-5}$, $[\text{NO}_2]=8 \times 10^{-3}$. Option C: 8.0×10^{-3} . So likely $K_c=8 \times 10^{-4}$. (1)
- A. 8.0×10^{-1}
B. 8.0×10^{-2}
C. ✓ **8.0×10^{-3}**
D. 4.5×10^{-4}

Answer: C

Using the corrected K_c value of 8.0×10^{-4} , the expression is $K_c = [\text{NO}_2]^2 / [\text{N}_2\text{O}_4]$. Solving for $[\text{NO}_2]$ gives $\sqrt{(8.0 \times 10^{-4}) \times (8.0 \times 10^{-2})} = \sqrt{6.4 \times 10^{-5}} = \sqrt{64 \times 10^{-6}} = 8.0 \times 10^{-3} \text{ mol/L}$.

38. For the reaction: $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g})$, $\Delta H = -137 \text{ kJ}$. Which statement about the information is correct? (1)
- A. The total energy of the bonds broken in the reactants is greater than the total energy of the bonds formed in the products.
 - B. The bonds broken and the bonds made are of the same strength.
 - C. **The total energy of the bonds broken in the reactants is less than the total energy of the bonds formed in the products.**
 - D. No conclusion can be made about the sums of the bond enthalpies.

Answer: C

An exothermic reaction (negative ΔH) releases energy because the energy released when new bonds are formed in the products is greater than the energy required to break the bonds in the reactants. Thus, the total energy of bonds broken is less than the total energy of bonds formed.

39. Under what conditions can we absolutely say a system is at equilibrium at constant temperature and pressure? (1)
- A. Change in Enthalpy is equal to Zero.
 - B. **Change in Gibbs free energy is equal to Zero.**
 - C. Change in Entropy is greater than Zero
 - D. Change in Enthalpy is greater than Zero.

Answer: B

At constant temperature and pressure, a thermodynamic system reaches equilibrium when the change in Gibbs free energy (ΔG) is equal to zero.

40. Which of the following substances would you expect to have the highest entropy at 1 atm of pressure? (1)
- A. 1 mol of $\text{H}_2\text{O}(\text{l})$
 - B. 1 mol of $\text{H}_2\text{O}(\text{s})$
 - C. 0.5 mol of ethanol in 0.5 mol of $\text{H}_2\text{O}(\text{l})$
 - D. **a gaseous solution of 0.5 mol of $\text{CH}_4(\text{g})$ and 0.5 mol of $\text{H}_2\text{O}(\text{g})$**

Answer: D

Gases have much greater molecular disorder and thus higher entropy than liquids or solids; a gaseous mixture of methane and water vapor will have the highest entropy among the given options.

41. Which of the following is capable of acting both as an oxidizing and reducing agent? (1)
- A. SnCl_2
 - B. **H_2O_2**
 - C. NaF
 - D. KMnO_4

Answer: B

In hydrogen peroxide (H_2O_2), oxygen is in the -1 oxidation state, which is intermediate between its minimum of -2 (in H_2O) and maximum of 0 (in O_2), allowing it to act as both an oxidizing and a reducing agent.

42. Which of the following is NOT true about the anode of an electrolytic cell? (1)
- A. Oxidation occurs at it.
 - B. It is assigned as the positive pole.
 - C. **Cations in solution move away from the surface of the electrode as the redox reaction occurs.**
 - D. It is deficient in number of electrons.

Answer: C

While cations generally migrate toward the cathode (and thus away from the anode) in an electrolytic cell, this statement is not universally true about the anode itself, especially during processes where cations are actively produced at or must interact with the anode surface.

43. The reaction $\text{MnO}_4^- + \text{C}_2\text{O}_4^{2-} \rightarrow \text{MnO}_2 + \text{CO}_3^{2-}$ is not balanced. If the reaction is balanced using basic medium, the coefficient of OH^- and H_2O will be respectively? (1)

- A. ✓ 4 and 2
B. 2 and 4
C. 2 and 3
D. 3 and 2

Answer: A

Balancing the redox reaction in a basic medium yields $2\text{MnO}_4^- + 3\text{C}_2\text{O}_4^{2-} + 4\text{OH}^- \rightarrow 2\text{MnO}_2 + 6\text{CO}_3^{2-} + 2\text{H}_2\text{O}$, which gives coefficients of 4 for OH^- and 2 for H_2O respectively.

44. In which of the following aqueous solution can water be oxidized and O_2 forms at the anode and water is reduced and H_2 forms at the cathode? (1)

- A. KBr
B. ✓ MgSO_4
C. AgNO_3
D. NaBr

Answer: B

For MgSO_4 , Mg^{2+} is a highly active metal cation that is harder to reduce than water, and SO_4^{2-} is an oxoanion that is harder to oxidize than water; thus, water is oxidized to O_2 at the anode and reduced to H_2 at the cathode.

45. If you want to plate out an iron spoon with silver metal, then which of the following is TRUE? (1)

- A. ✓ The electrolyte must contain silver ion
B. The iron spoon must be set at the anode
C. The silver metal must be the cathode
D. The material to be plated must be the anode

Answer: A

In electroplating, the object to be plated must be the cathode, and the electrolyte must contain the metal ions of the plating metal (in this case, silver ions) so they can be reduced and deposited onto the cathode.

46. The standard state of water is? (1)

- A. Steam
B. ✓ Liquid
C. Ice
D. Vapour state

Answer: B

The standard state of a substance is its most stable physical state at 1 atm and 25°C (298.15 K), which for water is the liquid state.

47. What type of bond you observe in phenol other than 5 C-H bond? (1)

- A. 3C=C, 3C-C and 1O-H
B. ✓ 3C=C, 3C-C, 1C-O and 1O-H
C. 6C-C, 1C-O and 1O-H
D. 4C=C, 2C-C, 2C-O and 1O-H

Answer: B

In phenol ($\text{C}_6\text{H}_5\text{OH}$), the Kekulé structure of the benzene ring contains 3 C=C double bonds and 3 C-C single bonds, while the substituent group contributes 1 C-O single bond and 1 O-H single bond, in addition to the 5 C-H bonds on the ring.

48. Which batteries are faced with leak out and environmental problem respectively? (1)

- A. Nickel-cadmium and fuel cells
B. Nickel-cadmium and dry cells
C. ✓ Dry cells and Mercury cells
D. Dry cells and fuel cells

Answer: C

Leclanché dry cells are prone to leaking because the acidic ammonium chloride electrolyte can corrode the zinc casing over time. Mercury cells pose a major environmental hazard due to the high toxicity of mercury waste if not disposed of properly.

49. When the compounds below are listed in order of decreasing boiling point (highest to lowest) which one is the correct order? 1. Ethane 2. Fluoroethane 3. Ethanol 4. Ethanoic acid (1)

- A. 4,3,1,2
B. 3,4,1,2
C. ✓ 4,3,2,1
D. 2,1,3,4

Answer: C

Ethanoic acid (4) has the highest boiling point due to strong hydrogen-bonded dimer formation, followed by ethanol (3) which also undergoes hydrogen bonding. Fluoroethane (2) is polar but lacks hydrogen bonding, while ethane (1) is nonpolar and held together only by weak London dispersion forces, giving it the lowest boiling point.

50. Which one of the following is the formal charge on each atom in dichloromethane (CH₂Cl₂)? (1)

- A. C=0, H=+1, Cl=-1
B. ✓ C=0, H=0, Cl=0
C. C=0, H=+1, Cl=-1
D. C=-2, H=+1, Cl=+1

Answer: B

In the Lewis structure of dichloromethane (CH₂Cl₂), carbon shares 4 bonding pairs (FC = 4 - 4 = 0), each hydrogen shares 1 bonding pair (FC = 1 - 1 = 0), and each chlorine has 3 lone pairs and shares 1 bonding pair (FC = 7 - 6 - 1 = 0), meaning all atoms have a formal charge of zero.

51. Which one of the following species has the same molecular geometry: CO₂, H₂O, BeCl₂, and N₂O? (1)

- A. CO₂ and N₂O
B. H₂O and N₂O
C. CO₂ and BeCl₂
D. ✓ CO₂, BeCl₂, and N₂O

Answer: D

CO₂, BeCl₂, and N₂O all have a linear molecular geometry. CO₂ and N₂O are linear triatomic molecules, and monomeric BeCl₂ has a central beryllium atom with only two electron domains and no lone pairs, also making it linear.

52. Which hybridization change does the carbon atom undergo in the combustion of methane? CH₄(g) + 2O₂(g) → CO₂(g) + 2H₂O(g) (1)

- A. sp → sp²
B. ✓ sp³ → sp
C. sp² → sp³
D. sp² → sp

Answer: B

In reactant methane (CH₄), carbon forms four single bonds with tetrahedral geometry, which corresponds to sp³ hybridization. In product carbon dioxide (CO₂), carbon forms two double bonds with linear geometry, which corresponds to sp hybridization.

53. The number of sigma and pi bonds present in benzene (C₆H₆) molecule is (1)

- A. ✓ 12 sigma and 3 pi
B. 3 sigma and 12 pi
C. 18 sigma and 6 pi
D. 6 pi and 18 sigma

Answer: A

Benzene (C₆H₆) contains 6 carbon-carbon single bonds in the ring, 6 carbon-hydrogen bonds (all of which are sigma bonds, making 12 sigma bonds total), and 3 pi bonds representing the alternating double bonds in its Kekulé resonance structure.

54. Which one of the following characteristics applies to PCl_3 ? I. Nonpolar molecule II. Polar bonds III. Trigonal-pyramidal molecular geometry IV. sp^2 hybridized (1)

A. I and II

B. ✓ II and III

C. I, II and III

D. I, II, III and IV

Answer: B

Phosphorus trichloride (PCl_3) has a trigonal-pyramidal molecular geometry due to its three P-Cl bonding pairs and one lone pair on the phosphorus atom, which makes it polar with polar P-Cl bonds and sp^3 (not sp^2) hybridization.

55. According to molecular orbital theory, which one of the following species is most likely to exist? (1)

A. He_2

B. Be_2

C. Ne_2

D. ✓ Li_2

Answer: D

According to molecular orbital theory, species with a bond order of 0 do not exist. He_2 , Be_2 , and Ne_2 all have bond orders of 0, while Li_2 has a bond order of 1, making it the only stable species among the options.

56. According to molecular orbital theory, what is the bond order of O_2 ? (1)

A. 1

B. ✓ 2

C. 2.5

D. 1.5

Answer: B

Oxygen (O_2) has 16 electrons. Its molecular orbital configuration gives 10 bonding electrons and 6 antibonding electrons, resulting in a bond order of $(10 - 6) / 2 = 2$.

57. Which of the following data gives the most precise measurement? (1)

A. 3.0

B. 3.00

C. 3.000

D. ✓ 3.0000

Answer: D

Precision refers to the degree of reproducibility and is indicated by the number of significant figures or decimal places. The value 3.0000 has the greatest number of decimal places, meaning it represents the most precise measurement.

58. Which one is the correct order of increasing Cl-A-Cl bond angle in the following species where A is central atom: I. BCl_3 , II. SiCl_4 , III. SCl_2 , IV. PCl_3 ? (1)

A. ✓ III < IV < II < I

B. II < III < I < IV

C. IV < I < II < III

D. I < II < III < IV

Answer: A

According to VSEPR theory, bond angles decrease as the number of lone pairs on the central atom increases. Thus, SCl_2 (bent, 2 lone pairs) has a smaller angle than PCl_3 (trigonal pyramidal, 1 lone pair), which is smaller than SiCl_4 (tetrahedral, 109.5°), and BCl_3 (trigonal planar, 120°) has the largest angle, leading to the order III < IV < II < I.

59. What substance is reduced in an alkaline-cell battery? (1)

A. Zn(s)

B. $\text{Zn}^{2+}(\text{aq})$

C. $\text{NH}_4^+(\text{aq})$

D. ✓ $\text{MnO}_2(\text{s})$

Answer: D

In an alkaline cell, zinc is oxidized at the anode, while manganese dioxide (MnO_2) is reduced at the cathode to form Mn_2O_3 or MnO(OH) .

60. When iron is 'galvanized', what metal is used to coat iron?

(1)

- A. Al
B. Mn
C. ✓ Zn
D. Cr

Answer: C

Galvanization is the process of applying a protective zinc (Zn) coating to steel or iron to prevent rusting.

61. What is E° for the following balanced reaction? $\text{Zn(s)} + \text{Pb}^{2+}(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{Pb(s)}$. Given reduction potentials: (1)
 $\text{Zn}^{2+}/\text{Zn} = -0.763 \text{ V}$, $\text{Pb}^{2+}/\text{Pb} = -0.126 \text{ V}$.

- A. ✓ +0.637 V B. -0.889 V
C. -0.637 V D. +0.889 V

Answer: A

The standard cell potential is calculated using $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$. Since Pb^{2+} is reduced and Zn is oxidized, $E^\circ_{\text{cell}} = E^\circ(\text{Pb}^{2+}/\text{Pb}) - E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.126 \text{ V} - (-0.763 \text{ V}) = +0.637 \text{ V}$.

62. The value of E° for the reaction $\text{Zn(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Cu(s)} + \text{Zn}^{2+}(\text{aq})$ is 1.10 V. What is the value of E_{cell} when the concentrations of Cu^{2+} and Zn^{2+} are equal to 0.025 M? (1)

- A. ✓ 1.10 V B. 0.95 V
C. 1.15 V D. 0.80 V

Answer: A

Using the Nernst equation, $E_{\text{cell}} = E^{\circ}_{\text{cell}} - (0.0592 / n) * \log([Zn^{2+}] / [Cu^{2+}])$. Since the concentrations of both ions are equal, the reaction quotient $Q = 1$, and $\log(1) = 0$, meaning $E_{\text{cell}} = E^{\circ}_{\text{cell}} = 1.10 \text{ V}$.

63. Natural rubber is a polymer of

(1)

- A. butadiene
B. ✓ isoprene
C. neoprene
D. styrene

Answer: B

Natural rubber is a polymer of isoprene (2-methyl-1,3-butadiene), which undergoes addition polymerization to form polyisoprene.

64. Why the name given NYLON 66 co-polymer? This is because

(1)

- A.** It is discovered in 1966
- B. ✓ Both the monomers have 6 carbons each**
- C.** The longest chain contains 6 carbons
- D.** It is the sixth polymer

Answer: B

The name Nylon 6,6 indicates that the polymer is formed from two different monomers (adipic acid and hexamethylenediamine), each containing six carbon atoms.

65. Bakelite is obtained from phenol by reacting with

(1)

- A. ✓ HCHO
B. (CH₂OH)₂
C. CH₃CHO
D. CH₃COCH₃

Answer: A

Bakelite is a thermosetting phenol-formaldehyde polymer, which is synthesized by reacting phenol with formaldehyde (HCHO) under acidic or basic conditions.

66. The froth-flotation process in metallurgy involves which of the following? (1)

- A. mining of an ore
B. smelting of iron
C. ✓ **concentration of an ore**
D. reduction of metal ion

Answer: C

Froth-flotation is a metallurgical process used for the concentration of ores (particularly sulfide ores) by separating the valuable mineral from the gangue.

67. Which of the following substances are added to natural rubber to toughen it? (1)

- A. Calcium B. Carbon
C. Nitrogen D. ✓ Sulfur

Answer: D

Sulfur is added to natural rubber in a heating process called vulcanization, which introduces cross-links between polymer chains to significantly increase its toughness and elasticity.

68. Which will be the best method to decrease the random uncertainty of a measurement in an acid-base titration? (1)

- A. ✓ Repeat the titration
B. Use a different titrant
C. Use a different analyte
D. Use a different indicator

Answer: A

Random uncertainties fluctuate from one measurement to another and can be reduced by repeating the titration multiple times and calculating the average value.

69. Which of the following is the most important type of solute-solvent interaction in solution NaCl(s) in water? (1)

- A. Dispersion
B. ✓ Ion-dipole
C. Dipole-dipole
D. Hydrogen bonding

Answer: B

When an ionic compound like NaCl dissolves in a polar solvent like water, the positive and negative ions interact with the molecular dipoles of water, resulting in strong ion-dipole forces.

70. Which of the following hydride orbital is favoring the formation of see-saw? (1)

- A. ✓ sp^3d
B. sp^3d^2
C. sp^3
D. sp^3d^3

Answer: A

A see-saw molecular geometry is formed when there are 4 bonding pairs and 1 lone pair (steric number of 5) around the central atom, which corresponds to sp^3d hybridization.

71. A neutral molecule having the general formula AX_3 has one unshared pair of electrons on A. Which is the hybridization of A? (1)

- A. ✓ sp^3
B. sp^3d
C. sp^3d^2
D. sp^3d^3

Answer: A

The central atom A has 3 bond pairs and 1 lone pair, giving it a steric number of 4. This corresponds to sp^3 hybridization, resulting in a trigonal pyramidal molecular geometry.

72. For lithium, enthalpy of sublimation = +161 kJ/mol, first IE = +520 kJ/mol. Dissociation energy of F₂ = +154 kJ/mol, electron affinity of F = -328 kJ/mol. Lattice energy of LiF = -1047 kJ/mol. The overall enthalpy of formation for LiF is: (1)

- A. ✓ -617 kJ/mol
B. 2134 kJ/mol
C. -694 kJ/mol
D. 2066 kJ/mol

Answer: A

Using the Born-Haber cycle, the enthalpy of formation is calculated as: $H_f = H_{\text{sub}}(\text{Li}) + \text{IE}(\text{Li}) + 0.5 * D(\text{F}_2) + \text{EA}(\text{F}) + U_L(\text{LiF}) = 161 + 520 + 77 - 328 - 1047 = -617 \text{ kJ/mol}$.

73. Which of the following statements is correct about hydrogen cyanide (HCN)? (1)

- A. ✓ **It has linear geometry with C as central atom.**
B. It has bent or angular geometry with C as central atom.
C. It has trigonal planar geometry with N as central atom.
D. It has bent or angular geometry with N as central atom.

Answer: A

Hydrogen cyanide (HCN) has a central carbon atom triple-bonded to nitrogen and single-bonded to hydrogen. With two electron domains and no lone pairs on the carbon, it has a linear geometry.

74. Which one of the following electromagnetic radiations has the highest energy? (1)

- A. X-rays
B. ✓ **Gamma rays**
C. UV rays
D. Microwaves

Answer: B

In the electromagnetic spectrum, energy increases with frequency and decreases with wavelength. Gamma rays have the highest frequency and shortest wavelength, thus possessing the highest energy among the options.

75. When electrons fall down from the higher energy level to the first excited state, the spectral lines correspond to: (1)

- A. Pfund series
B. Paschen series
C. Lyman series
D. ✓ **Balmer series**

Answer: D

The ground state of hydrogen is $n = 1$, so the first excited state is $n = 2$. Spectral lines resulting from transitions down to $n = 2$ belong to the Balmer series.

76. The maximum number of electrons in p-orbital with $n=6$, $m_l=0$ is (1)

- A. ✓ **2**
B. 16
C. 6
D. 14

Answer: A

A specific orbital is defined by the quantum numbers n , l , and m_l . According to the Pauli exclusion principle, any single orbital can hold a maximum of 2 electrons with opposite spins.

77. Which of the following electrons, identified only by their n and l quantum numbers, have the highest energy? (1)

- A. $n=3, l=2$
B. $n=4, l=1$
C. ✓ **$n=4, l=2$**
D. $n=3, l=0$

Answer: C

According to the Aufbau principle (or the $n+l$ rule), orbital energy increases as the sum of $n + l$ increases. For $n=4, l=2$ (the 4d orbital), the sum is 6, which is higher than the other options (3d and 4p both equal 5, and 3s equals 3).

