

Chemistry, 2011 EC, entrance exam

Grade 12 · Chemistry · 2011 E.C.

MARKING KEY — CONFIDENTIAL

Time allowed: 120 minutes

Questions: 77

Total marks: 77

1. What aspect of the modern view of atomic structure was proved by Rutherford's gold foil experiment? (1)
- A. ✓ **The existence of the nucleus.** B. The charge on an electron.
C. The charge on an α particle. D. The existence of electrons.

Answer: A

Rutherford's gold foil experiment showed that alpha particles could be deflected at large angles, proving the existence of a dense, positively charged nucleus at the center of the atom.

2. Which of these compounds is propanoic acid? (1)
- A. $\text{CH}_3\text{CH}_2\text{COOCH}_3$ B. $\text{CH}_3\text{CH}_2\text{COH}$
C. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ D. ✓ **$\text{CH}_3\text{CH}_2\text{COOH}$**

Answer: D

Propanoic acid is a three-carbon carboxylic acid with the molecular formula $\text{CH}_3\text{--CH}_2\text{--COOH}$.

3. Fats and oils can be classified as_____. (1)
- A. carbohydrates B. acids
C. ✓ **esters** D. alcohols

Answer: C

Fats and oils are triglycerides, which are esters formed from glycerol (a triol) and three fatty acid molecules.

4. What does it mean by $\Delta H = \text{negative}$ for a given process? (1)
- A. The process is endothermic B. ✓ **The process is exothermic**
C. The process is adiabatic D. The process is equithermic

Answer: B

A negative change in enthalpy ($\Delta H < 0$) indicates that heat is released to the surroundings, which is the definition of an exothermic process.

5. The oxidation state of chlorine in HClO_4 is: (1)
- A. +1 B. +3
C. +5 D. ✓ **+7**

Answer: D

In HClO_4 , hydrogen has an oxidation state of +1 and oxygen is -2. Setting the sum equal to zero: $(+1) + \text{Cl} + 4(-2) = 0$, which gives $\text{Cl} = +7$.

11. Which of the four colligative properties arises in systems where there is an equilibrium between a liquid solution phase and a second liquid phase? (1)
- A. Vapour pressure lowering
B. Boiling point elevation
C. Freezing point depression
D. ✓ **Osmotic pressure**

Answer: D

Osmotic pressure involves an equilibrium established between two liquid phases (the pure solvent and the solution) across a semipermeable membrane.

12. Which of the following can function as both a Brønsted-Lowry acid and Brønsted-Lowry base? (1)
- A. H_2SO_4
B. ✓ **HSO_3^-**
C. SO_4^{2-}
D. H^+

Answer: B

The hydrogen sulfite ion (HSO_3^-) is amphiprotic; it can donate a proton to act as an acid, forming SO_3^{2-} , or accept a proton to act as a base, forming H_2SO_3 .

13. What makes the phosphorus cycle different from the carbon and nitrogen cycles? (1)
- A. Phosphorus is found in the atmosphere in the gaseous state.
B. Carbon and nitrogen are released at lower rate compared to phosphate salts.
C. Phosphorus salts are released at higher rate compared to carbon and nitrogen cycles.
D. ✓ **Carbon and nitrogen are found in the atmosphere in the gaseous state.**

Answer: D

Unlike the carbon and nitrogen cycles, the phosphorus cycle has no significant gaseous atmospheric component; phosphorus remains primarily in solid rock and aqueous solution phases.

14. When Na_2CrO_4 solution is acidified, which of the following is formed? (1)
- A. Cr (metal)
B. Cr_2O_3
C. CrO_4^{2-}
D. ✓ **$\text{Cr}_2\text{O}_7^{2-}$**

Answer: D

Acidifying a yellow chromate solution (CrO_4^{2-}) shifts the equilibrium to form orange dichromate ($\text{Cr}_2\text{O}_7^{2-}$).

15. Nylon is a/an___? (1)
- A. Amide
B. Peptide
C. ✓ **Polyamide**
D. Polyester

Answer: C

Nylon is a synthetic polymer characterized by repeating amide linkages ($-\text{CO}-\text{NH}-$), making it a polyamide.

16. Which of the following is NOT a component of polysaccharides? (1)
- A. Glucose
B. ✓ **Sucrose**
C. Cellulose
D. Glycogen

Answer: B

Sucrose is a disaccharide, while cellulose and glycogen are polysaccharides, and glucose is the monosaccharide monomer (component) of those polysaccharides.

17. Which of the following is the SI measurement unit of electric current?

(1)

- A. ✓ Ampere
B. Watt
C. Volt
D. Coulomb

Answer: A

The Ampere (A) is the SI base unit of electric current, whereas the Watt is for power, the Volt is for potential difference, and the Coulomb is for electric charge.

18. What is the first step in a scientific investigation?

(1)

- A. Ask questions
B. ✓ **Make observations**
C. Do research
D. Draw conclusions

Answer: B

In a scientific investigation, the process typically starts with making observations about phenomena, which then leads to asking questions and forming hypotheses.

19. In the electromagnetic spectrum with wavelengths shown (in micrometers, μm), which bracketed section of the spectrum represents visible light?

(1)

[Figure: A horizontal axis labeled 'wavelength (μm)' with tick marks at 0.2, 0.4, 0.6, 0.8, 1, 2, 4, 8, 10, 12, and 20. Above the axis are four curly brackets indicating intervals: bracket 'x' spans from 0.4 to 0.8 μm ; bracket 'y' spans from 0.8 to 4 μm ; bracket 'z' spans from 4 to 12 μm ; bracket 'o' spans from 12 to 20 μm .]

- A. o B. ✓ x
C. y D. z

Answer: B

Visible light lies in the wavelength range of approximately 0.4 to $0.8\text{ }\mu\text{m}$ (400 to 800 nm), which corresponds to interval 'x' on the diagram.

20. Which of the orbitals in the figure below has (have) an angular momentum quantum number of $l = 2$?

(1)

[Figure: Four electron density cross-section diagrams labeled I, II, III, and IV. I and III are spherically symmetric showing concentric circular rings (s orbitals). II shows a four-lobed cloverleaf pattern (d orbital). IV shows two vertically aligned lobes with a nodal plane between them (p orbital).]

- A. I
C. ✓ II
B. I and III
D. I and IV

Answer: C

An angular momentum quantum number of $l = 2$ corresponds to d-orbitals, which typically have a four-lobed cloverleaf pattern shown in diagram II.

21. Which groups in the periodic table form ionic bonds?

(1)

- B. ✓ Groups 1(1A) & 17(7A), Groups 2 (2A) & 16(6A)**

Answer: B

Ionic bonds are formed between highly electropositive metals (such as Group 1 and Group 2) and highly electronegative non-metals (such as Group 16 and Group 17).

22. There is a progressive decrease in the bond angle in the series of molecules CCl_4 , PCl_3 , and H_2O . According to the VSEPR model, this is best explained by: (1)
- A. Increasing electronegativity of the central atom
- B. ✓ **Increasing number of lone pair electrons**
- C. Decreasing size of the central atom
- D. Decreasing bond strength

Answer: B

In the series CCl_4 (0 lone pairs), PCl_3 (1 lone pair), and H_2O (2 lone pairs), the increasing number of non-bonding lone pairs on the central atom causes greater electron repulsion, thereby compressing the bonding angles.

23. For the reaction, $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$, the rate of disappearance of H_2 is $0.01 \text{ mol L}^{-1} \text{ min}^{-1}$. What is the rate of appearance of NH_3 ? (1)
- A. $0.01 \text{ mol L}^{-1} \text{ min}^{-1}$
- B. $0.02 \text{ mol L}^{-1} \text{ min}^{-1}$
- C. ✓ **$0.007 \text{ mol L}^{-1} \text{ min}^{-1}$**
- D. $0.002 \text{ mol L}^{-1} \text{ min}^{-1}$

Answer: C

From the stoichiometry of the reaction, the rate of appearance of NH_3 is equal to two-thirds of the rate of disappearance of H_2 , which is $2/3 \times 0.01 \approx 0.007 \text{ mol L}^{-1} \text{ min}^{-1}$.

24. The appropriate unit for a first order rate constant are? (1)
- A. M/s
- B. $1/\text{M s}$
- C. $1/\text{M}^2 \text{ s}$
- D. ✓ **$1/\text{s}$**

Answer: D

For a first-order reaction, the rate law is $\text{Rate} = k[\text{A}]$. Thus, the unit of k is $(\text{M/s}) / \text{M}$, which simplifies to $1/\text{s}$ or s^{-1} .

25. $2\text{X}_{(g)} \rightleftharpoons 3\text{Y}_{(g)} + \text{Z}_{(g)}$ $\Delta H_{(\text{forward rxn})} > 0$ (1)
- The molar equilibrium concentrations for the reaction mixture represented above at 298 K are $[\text{X}] = 4.0 \text{ M}$, $[\text{Y}] = 5.0 \text{ M}$, and $[\text{Z}] = 2.0 \text{ M}$. What is the value of the equilibrium constant, K_{eq} , for the reaction at 298 K?
- A. 0.06
- B. 2.50
- C. ✓ **16.0**
- D. 62.5

Answer: C

The equilibrium expression is $K_{eq} = \frac{[\text{Y}]^3[\text{Z}]}{[\text{X}]^2}$. Substituting the given values yields $K_{eq} = \frac{5.0^3 \times 2.0}{4.0^2} = \frac{250}{16} = 15.625$, which rounds to 16.0.

26. What is the IUPAC name for the following carboxylic acid? (1)
- [Figure: A chemical structural formula: a central carbon is single-bonded to a CH_3 group to the left, a CH_3 group above, a CH_3 group below, and a $-\text{CH}_2-$ group to the right. The $-\text{CH}_2-$ group is single-bonded to a carbonyl carbon ($\text{C}=\text{O}$), which is single-bonded to an $-\text{OH}$ group.]
- A. ✓ **3,3-dimethylbutanoic acid**
- B. 2-methylpentanoic acid
- C. 2,2-dimethylbutanoic acid
- D. 3-methylpentanoic acid

Answer: A

The longest continuous carbon chain containing the principal functional group (carboxylic acid) has four carbon atoms, making it a butanoic acid. Since there are two methyl groups at the C-3 position, the IUPAC name is 3,3-dimethylbutanoic acid.

27. 4 L of 0.02 M of aqueous solution of NaCl is diluted with 1 L of water. What is the molarity of the solution? (1)
- A. 0.004
B. 0.008
C. 0.012
D. ✓ 0.016

Answer: D

Using the dilution equation $M_1V_1 = M_2V_2$ with $V_1 = 4$ L, $M_1 = 0.02$ M, and $V_2 = 4$ L + 1 L = 5 L, we get $M_2 = (0.02 \times 4)/5 = 0.016$ M.

28. How much water, in liters, must be added to 0.50 liter of 6.0 M HCl to make the solution 2.0 M? (1)
- A. 0.50
B. ✓ 1.0
C. 1.5
D. 2.0

Answer: B

Using the dilution equation, the final volume required is $V_2 = (M_1V_1)/M_2 = (6.0 \text{ M} \times 0.50 \text{ L})/2.0 \text{ M} = 1.5$ L. The volume of water to be added is $V_2 - V_1 = 1.5 \text{ L} - 0.50 \text{ L} = 1.0$ L.

29. What is the pH of a 0.10 M solution of NH_3 , a weak base, whose $K_b = 1.8 \times 10^{-5}$? (1)
- A. 2.89
B. 4.76
C. 9.24
D. ✓ 11.11

Answer: D

For a weak base, $[\text{OH}^-] = \sqrt{K_b \times C_b} = \sqrt{1.8 \times 10^{-5} \times 0.10} \approx 1.34 \times 10^{-3}$ M. This gives a $\text{pOH} \approx 2.87$ and a $\text{pH} = 14 - \text{pOH} \approx 11.13$, which is closest to option D (11.11).

30. Which of the following is the correct reaction taking place at the electrodes during the electrolysis of dilute sodium chloride solution? (1)
- A. Anode: $2 \text{Cl}^- (\text{aq}) \rightarrow \text{Cl}_2 (\text{l}) + 2\text{e}^-$
Cathode: $2 \text{Na}^+ (\text{aq}) + 2\text{e}^- \rightarrow 2 \text{Na} (\text{s})$
- B. ✓ Anode: $2 \text{H}_2\text{O} (\text{l}) \rightarrow \text{O}_2 (\text{g}) + 4 \text{H}^+ (\text{aq}) + 4\text{e}^-$
Cathode: $2 \text{H}_2\text{O} (\text{l}) + 2 \text{e}^- \rightarrow \text{H}_2 (\text{g}) + \text{OH}^- (\text{aq})$
- C. Anode: $2 \text{Cl}^- (\text{aq}) \rightarrow \text{Cl}_2 (\text{l}) + 2\text{e}^-$
Cathode: $2 \text{H}_2\text{O} (\text{l}) + 2 \text{e}^- \rightarrow \text{H}_2 (\text{g}) + \text{OH}^- (\text{aq})$
- D. Anode: $2 \text{H}_2\text{O} (\text{l}) \rightarrow \text{O}_2 (\text{g}) + 4 \text{H}^+ (\text{aq}) + 4\text{e}^-$
Cathode: $2 \text{Na}^+ (\text{aq}) + 2\text{e}^- \rightarrow 2 \text{Na} (\text{s})$

Answer: B

During the electrolysis of a dilute aqueous NaCl solution, water is more easily oxidized and reduced than Cl^- and Na^+ respectively, resulting in the oxidation of water to O_2 at the anode and reduction of water to H_2 at the cathode.

31. Precision refers to _____. (1)
- A. how close a measured number is to the true value
B. how close a measured number is to zero
C. ✓ how close a measured number is to other measured numbers
D. how close a measured number is to the calculated value

Answer: C

Precision describes the reproducibility of measurements, reflecting how closely multiple independent measurements of the same quantity agree with each other, regardless of whether they are close to the true value (which is accuracy).

32. Consider the following two possibilities for electron transfer in a hydrogen atom, given below: (1)

First: The electron drops from the Bohr orbit $n = 3$ to the orbit $n = 2$, followed by the transition from $n = 2$ to $n = 1$

Second: The electron drops from the Bohr orbit $n = 3$ directly to the orbit $n = 1$

Which of the following is correct about the energy change of these transitions?

- A. The sum of the energies for the first transitions is less than the energy of transition of the second.
B. ✓ **The sum of the energies for the first transitions is equal to the energy of transition of the second.**
C. The sum of the energies for the first transitions is greater than the energy of transition of the second.
D. The energies of transitions of the first and the energy of transition of the second can't be compared.

Answer: B

According to the law of conservation of energy and the state-function nature of energy, the change in energy between the initial and final states ($n = 3$ to $n = 1$) is independent of the path taken; thus, the sum of the energies of the two-step transition equals that of the direct single-step transition.

33. Which of the following elements has the highest fifth ionization energy (IE_5)? (1)

- A. Al
B. ✓ **Si**
C. P
D. S

Answer: B

Silicon has four valence electrons, so its fifth ionization energy (IE_5) involves removing an electron from its highly stable, inner noble-gas core ($1s^2 2s^2 2p^6$), leading to an exceptionally large energy requirement compared to the others.

34. Which one of the following type of bonding exists between atoms with very different electro-negativities? (1)

- A. Metallic bonding
B. Hydrogen bonding
C. Network covalent bonding
D. ✓ **Ionic bonding**

Answer: D

Ionic bonding occurs when there is a transfer of electrons between atoms with very different electronegativities, usually between a metal and a nonmetal.

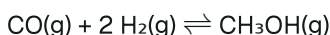
35. Which one of the following reactions at equilibrium would be unaffected by an increase in pressure? (I) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ (II) $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$ (III) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ (IV) $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g)$ (1)

- A. I
B. II
C. ✓ **III**
D. IV

Answer: C

An increase in pressure only affects gas-phase equilibria where there is a change in the number of moles of gas ($\Delta n_g \neq 0$). For reaction III, $\Delta n_g = 2 - (1 + 1) = 0$, so it is unaffected by pressure changes.

36. A sealed isothermal container initially contained 2 moles of CO gas and 3 moles of H_2 gas. The following reversible reaction occurred: (1)



At equilibrium, there was 1 mole of CH_3OH in the container. What was the total number of moles of gas present in the container at equilibrium?

- A. 1
B. 2
C. 4
D. ✓ **3**

Answer: D

For the reaction $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$, forming 1 mol of CH_3OH consumes 1 mol of CO (leaving 1 mol) and 2 mol of H_2 (leaving 1 mol). The total moles of gas at equilibrium is $1 + 1 + 1 = 3$ moles.

37. Hydrolysis of ester leads to the formation of which of the following products in basic medium? (1)
- A. Ether and alcohol
B. Aldehyde and alcohol
C. ✓ **Alcohol and sodium carboxylate**
D. Sodium carboxylate

Answer: C

Saponification, or base-catalyzed ester hydrolysis, yields a carboxylate salt (such as sodium carboxylate when NaOH is used) and an alcohol as products.

38. When a saturated solution of sodium chloride is heated, it becomes (1)
- A. ✓ **Unsaturated**
B. Remains saturated
C. Supersaturated
D. Attains equilibrium conditions

Answer: A

Since the dissolution of sodium chloride is an endothermic process, its solubility increases with increasing temperature. Heating a saturated solution increases its solubility limit, making the solution unsaturated if no more solute is added.

39. The pH of a solution prepared by the addition of 100 mL 0.002 M HCl to 100-mL distilled water is closest to: (1)
- A. 1.0
B. 1.5
C. 2.0
D. ✓ **3.0**

Answer: D

Diluting 100 mL of 0.002 M HCl with 100 mL of water doubles the volume and halves the concentration to 0.001 M. Because HCl is a strong acid, $[H^+] = 10^{-3}$ M, yielding a pH = 3.0.

40. A chemist creates a buffer solution by mixing equal volumes of a 0.2-molar HOCl solution and a 0.2-molar KOCl (1) solution. Which of the following will occur when a small amount of KOH is added to the solution?
- I. The concentration of undissociated HOCl will increase.
II. The concentration of OCl^- ions will increase.
III. The concentration of H^+ ions will increase.
- A. I only
B. ✓ **II only**
C. III only
D. I and III only

Answer: B

When the strong base KOH is added to the buffer, OH^- reacts with the weak acid HOCl to produce water and its conjugate base, OCl^- . Thus, the concentration of OCl^- increases, while the concentration of HOCl decreases and the concentration of H^+ decreases slightly.

41. Based on the information given in the table below, what is the enthalpy change for the reaction: $2 H_2O_2(g) + S(s) \rightarrow SO_2(g) + 2 H_2O(g)$ (1)
- [Figure: A table with two columns and four data rows:
Header: 'Substance' and ' ΔH_f° (kJ/mol)'.
Row 1: $H_2O_2(g)$ | -150
Row 2: $SO_2(g)$ | -300
Row 3: $H_2O(g)$ | -250
Row 4: $S(s)$ | 0]
- A. ✓ **-500 kJ**
B. -200 kJ
C. 200 kJ
D. 400 kJ

Answer: A

Using Hess's Law, $\Delta H^\circ = [\Delta H_f^\circ(SO_2) + 2\Delta H_f^\circ(H_2O)] - [2\Delta H_f^\circ(H_2O_2) + \Delta H_f^\circ(S)] = [-300 + 2(-250)] - [2(-150) + 0] = -800 - (-300) = -500$ kJ.

42. Features common to both galvanic and electrolytic cells include which of the following?

(1)

- I. Oxidation at the anode
- II. Can perform electrolysis
- III. Spontaneous

A. ✓ I only

B. II only

C. III only

D. I and II only

Answer: A

Oxidation always occurs at the anode in all electrochemical cells (both galvanic and electrolytic). However, only galvanic cells are spontaneous, and only electrolytic cells consume electrical energy to perform electrolysis.

43. Which of the following reactions is NOT involved in the contact process, during the production of sulfuric acid?

(1)

- A.** $\text{SO}_2 + \text{O}_2 \rightarrow 2 \text{SO}_3$

B. ✓ $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$

- C. $\text{SO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{S}_2\text{O}_7$

D. $\text{H}_2\text{S}_2\text{O}_7 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$

Answer: B

Directly dissolving SO_3 in water (Option B) is avoided in the contact process because it is highly exothermic and creates an acid mist that is very difficult to condense. Instead, SO_3 is dissolved in concentrated H_2SO_4 to form oleum, which is then diluted with water.

44. Two types of polymer are shown below. Which of the following statements concerning these polymers is correct?

(1)

[Figure: Two schematic drawings of polymer structures labeled X and Y. Diagram X shows three horizontal wavy polymer chains with vertical dashed lines representing weak intermolecular attractions between adjacent chains. Diagram Y shows three horizontal polymer chains connected to each other by solid vertical and angled covalent cross-links, forming a continuous network.]

- C. ✓ X is thermoplastic whereas Y is thermosetting**

Answer: C

Polymer X has linear chains with weak intermolecular forces (dashed lines), which characterizes a thermoplastic polymer. Polymer Y has permanent covalent cross-links forming a 3D network, which characterizes a thermosetting polymer.

45. The energy of an electron in the first Bohr orbit of hydrogen atom is -13.6 eV. The possible value of the excited state for electron in Bohr orbits of hydrogen is_____.

(1)

- A. ✓ -1.51 eV**

B. -6.8 eV

- C. -4.21 eV

D. +6.8 eV

Answer: A

The energy levels in a hydrogen atom are given by $E_n = -13.6 \text{ eV}/n^2$. For the second excited state ($n = 3$), the energy is $E_3 = -13.6 \text{ eV}/9 = -1.51 \text{ eV}$.

46. The sublevel that can be occupied by a maximum of 10 electrons is identified by the letter_____.

(1)

- A. ✓ *d*

B. f

- C. p

D. S

Answer: A

The d sublevel ($l = 2$) consists of 5 orbitals, each of which can hold a maximum of 2 electrons, giving it a maximum capacity of 10 electrons.

47. What is the molecular shape of ICl_4^- ? (1)
- A. Octahedral
B. T-shaped
C. ✓ **Square planar**
D. Trigonal bipyramidal

Answer: C

The central iodine atom in ICl_4^- has 4 bonding pairs and 2 lone pairs (steric number = 6). To minimize electron pair repulsion, the lone pairs occupy opposite axial positions, resulting in a square planar molecular geometry.

48. What hybridization change, if any, occurs at the underlined atom in the following reaction? $\underline{\text{C}}\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$ (1)
- A. ✓ $sp \rightarrow sp^2$
B. $sp^3 \rightarrow sp^3d$
C. $sp^2 \rightarrow sp^3$
D. No hybridization change observed

Answer: A

The carbon atom in CO_2 has two σ -bonds and no lone pairs, so it is sp hybridized. In H_2CO_3 , the carbon atom is bonded to three oxygen atoms (three σ -bonds) with no lone pairs, representing an sp^2 hybridization state.

49. The proposed reaction mechanism between nitrogen monoxide and bromine is give below. $\text{NO} + \text{Br}_2 \rightleftharpoons \text{NOBr}_2$ (fast) $\text{NOBr}_2 + \text{NO} \rightarrow 2\text{NOBr}$ (slow) (1)
- Which of the following rate equations is consistent with the proposed mechanism?
- A. $\text{Rate} = k [\text{NO}]^2$
B. $\text{Rate} = k [\text{NO}][\text{Br}_2]^2$
C. $\text{Rate} = k [\text{NO}][\text{Br}_2]$
D. ✓ $\text{Rate} = k [\text{NO}]^2[\text{Br}_2]$

Answer: D

The rate-determining step is the slow step: $\text{Rate} = k_2[\text{NOBr}_2][\text{NO}]$. From the fast equilibrium of the first step, $[\text{NOBr}_2] = K_{\text{eq}}[\text{NO}][\text{Br}_2]$. Substituting this gives the overall rate law $\text{Rate} = k_2K_{\text{eq}}[\text{NO}]^2[\text{Br}_2] = k[\text{NO}]^2[\text{Br}_2]$.

50. Which one of the following statements regarding a dynamic equilibrium is FALSE? (1)
- A. At equilibrium, there is no net change in the system.
B. ✓ **At equilibrium, the forward and reverse reactions cease to occur.**
C. At equilibrium, the rates of the forward and back reactions are identical.
D. At equilibrium, the concentration of reactants and products stays the same.

Answer: B

In dynamic equilibrium, the forward and reverse reactions do not stop; rather, they continue to occur at equal rates, resulting in no net change in the concentrations of reactants and products.

51. In which of the following cases will the dissolution of sugar be the most rapid? (1)
- A. Sugar crystals in hot water.
B. ✓ **Powdered sugar in hot water.**
C. Sugar crystals in cold water
D. Powdered sugar in cold water.

Answer: B

The rate of dissolution is maximized when the solute has a high surface area (powdered sugar) and the solvent is at a higher temperature (hot water), which increases both kinetic energy and solubility.

52. If a solution of acetic acid (CH_3COOH) has a pH of 3.00, what is its concentration? K_a of acetic acid = 1.74×10^{-5} (1)
- A. 0.0057 M
B. ✓ 0.057 M
C. 0.57 M
D. 5.70 M

Answer: B

Since $\text{pH} = 3.00$, the concentration of hydronium ions is $[\text{H}^+] = 1.0 \times 10^{-3} \text{ M}$. Using the weak acid dissociation expression, $K_a \approx [\text{H}^+]^2 / C$, we find $C \approx (1.0 \times 10^{-3})^2 / (1.74 \times 10^{-5}) \approx 0.057 \text{ M}$.

53. The indicator methyl red is red in a solution of NaH_2PO_4 . Which of the following equations is consistent with this observation? (1)
- A. $\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{PO}_4 + \text{OH}^-$
B. ✓ $\text{H}_2\text{PO}_4^- + \text{H}_2\text{O} \rightleftharpoons \text{HPO}_4^{2-} + \text{H}_3\text{O}^+$
C. $\text{HPO}_4^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{PO}_4^{3-} + \text{H}_3\text{O}^+$
D. $\text{HPO}_4^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{OH}^-$

Answer: B

Methyl red turns red in acidic solutions ($\text{pH} < 4.4$). The dihydrogen phosphate ion (H_2PO_4^-) acts as a weak acid in water, producing hydronium ions (H_3O^+), which lowers the pH and turns the indicator red.

54. A nickel electrode can undergo oxidation to Ni^{2+} ion as follows: (1)
- $\text{Ni (s)} \rightarrow \text{Ni}^{2+} \text{ (aq)} + 2\text{e}^-$ $E^\circ_{\text{red}} = -0.28 \text{ V}$ $2\text{H}_2\text{O(l)} \rightarrow 4\text{H}^+ \text{ (aq)} + \text{O}_2\text{(g)} + 4\text{e}^-$ $E^\circ_{\text{red}} = 1.23 \text{ V}$
- What will happen during the electrolysis of concentrated aqueous solution of NiSO_4 using Ni electrodes?
- (I) Nickel will deposit at the cathode. (II) Nickel will dissolve at the anode. (III) Oxygen will be released at the anode. (IV) Nickel will deposit at the anode.
- A. I only
B. ✓ I, II
C. I, III
D. II, IV

Answer: B

During the electrolysis of aqueous NiSO_4 with Ni electrodes, Ni^{2+} is reduced at the cathode because its reduction potential (-0.28 V) is less negative than that of water (-0.83 V). At the anode, the Ni metal electrode is oxidized (dissolves) because it has a higher oxidation potential ($+0.28 \text{ V}$) than water or sulfate ions.

55. Which of the following is NOT true about the photoelectric effect? (1)
- A. Most metals require ultraviolet light to emit electrons.
B. A bright light causes more electrons to be emitted than a weak light.
C. Higher frequency light emits electrons with higher kinetic energy
D. ✓ A bright light causes less electrons to be emitted than a weak light.

Answer: D

In the photoelectric effect, the intensity (brightness) of light determines the number of photons, so a brighter light causes more (not less) electrons to be emitted, provided the frequency of the light is above the threshold frequency.

56. Which of the following statements is correct about nitrosyl chloride (NOCl)? (1)
- A. ✓ It has a bent or angular geometry with N a central atom.
B. It has a bent or angular geometry with O a central atom.
C. It has a trigonal planar geometry with N a central atom.
D. It has a trigonal planar geometry with O a central atom.

Answer: A

Nitrosyl chloride (NOCl) has nitrogen as the central atom bonded to oxygen and chlorine ($\text{Cl} - \text{N} = \text{O}$) with one lone pair on N. This results in a trigonal planar electron-domain geometry and a bent or angular molecular geometry.

57. The minimum energy required for an effective collision is called_____. (1)
- A. potential energy
B. ✓ activation energy
C. free energy
D. kinetic energy

Answer: B

Activation energy is the minimum kinetic energy that colliding reactant particles must possess in order for a chemical reaction to occur.

58. A sample of solid ammonium carbamate is heated in a closed container at 298 K and allowed to reach equilibrium. (1)
- $\text{NH}_4\text{CO}_2\text{NH}_2 (\text{s}) \rightleftharpoons 2 \text{NH}_3 (\text{g}) + \text{CO}_2 (\text{g})$
- If the total pressure of the system is 0.114 atm, what is the value of equilibrium constant, K_p ?
- A. 1.29×10^{-3}
B. 3.80×10^{-4}
C. 7.60×10^{-3}
D. ✓ 2.19×10^{-4}

Answer: D

Let $P_{\text{CO}_2} = x$, then $P_{\text{NH}_3} = 2x$. The total pressure is $3x = 0.114 \text{ atm}$, which gives $x = 0.038 \text{ atm}$. Thus, $K_p = (P_{\text{NH}_3})^2(P_{\text{CO}_2}) = (2x)^2(x) = 4x^3 = 4(0.038)^3 = 2.19 \times 10^{-4}$.

59. During esterification of carboxylic acid with alcohol which bond of carboxylic acid undergoes cleavage? (1)
- A. C - C
B. C = O
C. ✓ C - O
D. O - H

Answer: C

During the esterification reaction, isotopic labeling studies show that the C-O bond of the carboxylic acid undergoes cleavage, releasing the -OH group, which combines with the hydrogen from the alcohol's O-H group to form water.

60. If 49 grams of H_2SO_4 react with 80.0 grams of NaOH , how much reactant will be left over after the reaction is complete? (1)
- A. 24.5 g H_2SO_4
B. 20.0 g NaOH
C. ✓ 40.0 g NaOH
D. 60.0 g NaOH

Answer: C

According to the reaction $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$, 0.50 moles of H_2SO_4 (49 g) reacts completely with 1.0 mole of NaOH (40.0 g). Since 2.0 moles of NaOH (80.0 g) were provided, 1.0 mole of NaOH (40.0 g) remains unreacted.

61. What is the change in internal energy of a system that releases 12.4 J of heat and does 4.2 J of work on the surroundings (1)
- A. 16.6 J
B. 8.2 J
C. ✓ -16.6 J
D. -8.2 J

Answer: C

According to the first law of thermodynamics, $\Delta U = q + w$. When the system releases heat, $q = -12.4 \text{ J}$, and when the system does work on the surroundings, $w = -4.2 \text{ J}$, giving $\Delta U = -12.4 \text{ J} - 4.2 \text{ J} = -16.6 \text{ J}$.

62. Which one of the following is true? (1)
- A. Entropy increases when a liquid freezes at its melting point.
 - B. ✓ **For spontaneous process $\Delta S > 0$.**
 - C. For a spontaneous process $\Delta G > 0$.
 - D. Entropy of the pure crystalline solid is zero at 0°C .

Answer: B

According to the Second Law of Thermodynamics, for any spontaneous process, the entropy of the universe (system + surroundings) must increase ($\Delta S_{\text{univ}} > 0$).

63. Which of the following has the same number of significant figures as the number 1.00310? (1)
- A. 100
 - B. 1×10^6
 - C. ✓ **199.791**
 - D. 5.119

Answer: C

The number 1.00310 has 6 significant figures. Among the choices, 199.791 also contains exactly 6 significant figures, while option A and B have 1, and option D has 4.

64. When an electron in a hydrogen atom makes the transition from the $n = 4$ state to the $n = 2$ state, blue light with a wavelength of 434 nm is emitted. Which of the following expressions gives the energy released by the transition? (1)
- A. ✓ **$\frac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{(4.34 \times 10^{-7})} \text{ joules}$**
 - B. $\frac{(6.63 \times 10^{-34})}{(4.34 \times 10^{-7})(3.00 \times 10^8)} \text{ joules}$
 - C. $\frac{(6.63 \times 10^{-34})(4.34 \times 10^{-7})}{(3.00 \times 10^8)} \text{ joules}$
 - D. $\frac{(4.34 \times 10^{-7})}{(6.63 \times 10^{-34})(3.00 \times 10^8)} \text{ joules}$

Answer: A

The energy of a photon emitted during a transition is given by $E = hc/\lambda$. Substituting Planck's constant ($h = 6.63 \times 10^{-34} \text{ J s}$), speed of light ($c = 3.00 \times 10^8 \text{ m/s}$), and the wavelength in meters ($\lambda = 434 \text{ nm} = 4.34 \times 10^{-7} \text{ m}$) yields Option A.

65. Arrange the following molecules in the order of increasing stability. (1)
- A. $\text{N}_2^+ < \text{N}_2 < \text{N}_2^- < \text{N}_2^{2-}$
 - B. ✓ **$\text{N}_2^{2-} < \text{N}_2^- = \text{N}_2^+ < \text{N}_2$**
 - C. $\text{N}_2^{2-} < \text{N}_2^- < \text{N}_2 < \text{N}_2^+$
 - D. $\text{N}_2 < \text{N}_2^+ = \text{N}_2^- < \text{N}_2^{2-}$

Answer: B

Stability is determined by bond order: N_2 has a bond order of 3, both N_2^- and N_2^+ have a bond order of 2.5, and N_2^{2-} has a bond order of 2. Higher bond order corresponds to greater stability, which aligns with the order shown in Option B.

66. The reaction below takes place with all of the reactants and products in the gaseous phase. Which of the following is true of the relative rates of disappearance the reactants and appearance of the products? $2 \text{ NOCl} \rightarrow 2 \text{ NO} + \text{Cl}_2$ (1)
- A. NO appears at twice the rate that NOCl disappears.
 - B. Cl_2 appears at the same rate that NOCl disappears.
 - C. NO appears at half the rate that NOCl disappears.
 - D. ✓ **NO appears at the same rate that NOCl disappears.**

Answer: D

In the reaction $2\text{NOCl} \rightarrow 2\text{NO} + \text{Cl}_2$, because the stoichiometric coefficients of NOCl and NO are equal, the rate of disappearance of NOCl is equal to the rate of appearance of NO .

67. In the Figure shown below, what does O denote? (1)

[Figure: A phase diagram plotting pressure on the vertical axis (with values 0.1, 1, and 100 marked) against temperature on the horizontal axis. The diagram is divided into three phase regions: "Solid" on the left, "Liquid" in the upper central region, and "Vapour" on the lower right. Three boundary curves meet at a single intersection point labeled "O": a sublimation curve rising from the origin to point O, a solid-liquid boundary curve with a negative slope extending upward to label B, and a liquid-vapour curve rising to the right toward point A. Dashed horizontal and vertical reference lines connect point O to the pressure value 0.1 and the temperature axis, respectively. Another horizontal dashed line at pressure 1 intersects the solid-liquid line and liquid-vapour line, with vertical dashed lines dropping to the temperature axis.]

- A. Melting point
B. ✓ Triple point
C. Boiling point
D. Vaporization point

Answer: B

Point O in a phase diagram represents the intersection where the solid, liquid, and vapor phase boundaries meet, which is known as the triple point.

68. Given the following unbalanced equation $\text{KMnO}_4 + \text{KI} + \text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + \text{MnSO}_4 + \text{I}_2 + \text{H}_2\text{O}$ (1)
How many grams of KMnO_4 are needed to make 250 mL of 0.20 N solution?

- A. 3.95 g
B. 3.16 g
C. 2.98 g
D. ✓ 1.58 g

Answer: D

In acidic media, KMnO_4 undergoes a 5-electron reduction ($\text{Mn}^{7+} \rightarrow \text{Mn}^{2+}$), so its equivalent mass is $\text{Molar Mass}/5 = 158.0/5 = 31.6 \text{ g/eq}$. Thus, the mass required is $\text{Normality} \times \text{Volume (L)} \times \text{Equivalent Mass} = 0.20 \text{ eq/L} \times 0.250 \text{ L} \times 31.6 \text{ g/eq} = 1.58 \text{ g}$.

69. Consider the following equilibria: (I) $\text{HCO}_3^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 + \text{OH}^-$ (II) $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{NH}_3$ (1)
(III) $\text{HSO}_3^- + \text{H}_3\text{O}^+ \rightleftharpoons \text{H}_2\text{O} + \text{H}_2\text{SO}_3$

In which of the equilibrium (equilibria) does water act as a Brønsted-Lowry base?

- A. I only
B. ✓ II only
C. II and III
D. I, II, III

Answer: B

A Brønsted-Lowry base is a proton acceptor. In equilibrium (II), H_2O accepts a proton from NH_4^+ to become H_3O^+ , thereby acting as a base, whereas in (I) it acts as an acid, and in (III) it is not a reactant.

70. A certain current produces 0.50 g of hydrogen gas in 2.0 hrs. What is the amount of copper liberated from a solution of copper sulfate by the same current flowing for the same time? (1)

- A. 31.8 g
B. 63.6 g
C. ✓ 15.9 g
D. 6.36 g

Answer: C

According to Faraday's laws of electrolysis, the masses of substances liberated by the same current in the same time are proportional to their equivalent weights. The equivalent weight of H_2 is 1.0 g/eq and that of Cu^{2+} is $63.6/2 = 31.8 \text{ g/eq}$. Thus, the mass of copper liberated is $0.50 \text{ g} \times 31.8/1.0 = 15.9 \text{ g}$.

71. For which of the following half-cells is the reduction potential E independent of the pH of the solution? (1)
- A. $[\text{Cr}_2\text{O}_7]^{2-} + 14\text{H}^+ + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ B. $\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$
C. $[\text{NO}_3]^- + \text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons [\text{NO}_2]^- + 2[\text{OH}]^-$ D. ✓ $\text{Co}^{2+} + 2\text{e}^- \rightleftharpoons \text{Co}$

Answer: D

The reduction potential of a half-reaction is independent of pH if the reaction does not involve H^+ or OH^- ions. The reduction of Co^{2+} to Co ($\text{Co}^{2+} + 2\text{e}^- \rightleftharpoons \text{Co}$) has no hydrogen or hydroxide ions involved, making it independent of pH.

72. What is the basis for the Scientific Method? (1)
- A. **To formulate a research problem, test the hypothesis under carefully controlled conditions that challenge the hypothesis**
✓
B. To test hypotheses and if they are disproved, they should be abandoned completely.
C. To test hypotheses in conditions that are favourable to their success.
D. To formulate a research problem and disprove the hypothesis.

Answer: A

The scientific method relies on formulating a hypothesis and testing it under carefully controlled conditions designed to challenge and potentially falsify the hypothesis.

73. Which of the following molecules has the largest dipole moment? (1)
- A. CO B. ✓ HCN
C. HCl D. HF

Answer: B

HCN is a linear molecule with a highly polar triple bond, creating a large separation of charge and resulting in a very large dipole moment (2.98 D), which is significantly higher than that of HF (1.82 D) or HCl (1.11 D).

74. In three different experiments the following results were obtained for the reaction $\text{A} \rightarrow \text{products}$: $[\text{A}]_0 = 1.00 \text{ M}$, $t_{1/2} = 50 \text{ min}$; $[\text{A}]_0 = 2.00 \text{ M}$, $t_{1/2} = 25 \text{ min}$; $[\text{A}]_0 = 0.50 \text{ M}$, $t_{1/2} = 100 \text{ min}$. What is the value of the rate constant for this reaction? (1)
- A. $0.010 \text{ L mol}^{-1} \text{ min}^{-1}$ B. ✓ $0.020 \text{ L mol}^{-1} \text{ min}^{-1}$
C. $0.030 \text{ L mol}^{-1} \text{ min}^{-1}$ D. $0.040 \text{ L mol}^{-1} \text{ min}^{-1}$

Answer: B

The half-life is inversely proportional to the initial concentration, which is characteristic of a second-order reaction. Using the second-order half-life formula, $t_{1/2} = 1/(k[\text{A}]_0)$, we get $k = 1/(50 \text{ min} \times 1.00 \text{ M}) = 0.020 \text{ L mol}^{-1} \text{ min}^{-1}$.

75. Which of the following compounds is the least soluble in water? (1)
- A. $(\text{NH}_4)_2\text{CO}_3$ B. ✓ BaCO_3
C. $\text{Fe}(\text{NO}_3)_3$ D. $\text{Na}_3(\text{PO}_4)$

Answer: B

According to general solubility rules, all nitrates, ammonium salts, and alkali metal (sodium) salts are highly soluble in water. Carbonates are generally insoluble except those of Group 1 elements and ammonium, making barium carbonate (BaCO_3) the least soluble compound among the options.

- 76.** What is the freezing point of a solution of 250 g of CaCl₂ in 1.0 kg of water? (K_f for H₂O = 1.86 °C/m) (1)
- A. - 1.3 °C B. - 6.5 °C
C. - 9.0 °C D. ✓ - 13 °C

Answer: D

Calcium chloride dissociates into three ions ($i = 3$). The molality of the solution is $250 \text{ g}/111 \text{ g/mol}/1.0 \text{ kg} = 2.25 \text{ m}$, giving a freezing point depression of $\Delta T_f = i \cdot K_f \cdot m = 3 \times 1.86 \times 2.25 \approx 12.6^\circ\text{C}$, which corresponds to a freezing point of -13°C .

77. Which of the following metals cannot be electroplated on to the surface of another metal using an aqueous electrolyte? E° (Ni^{2+}/Ni) = -0.28 V; E° (Cu^{2+}/Cu) = 0.34 V, E° (Mg^{2+}/Mg) = -2.37 V; E° (Ag^+/Ag) = 0.80 V (1)
- A. Ni B. Cu
C. ✓ Mg D. Ag

Answer: C

Magnesium has a highly negative standard reduction potential (-2.37 V), which is much lower than that of water. In an aqueous electrolyte, water is preferentially reduced to hydrogen gas at the cathode, making it impossible to electroplate magnesium from an aqueous solution.

— END OF MARKING KEY —