

Chemistry, 2009 EC, entrance exam

Grade 12 · Chemistry · 2009 E.C.

MARKING KEY — CONFIDENTIAL

Time allowed: 120 minutes

Questions: 69

Total marks: 69

1. Which of the following covalent bonds is the most polar? (1)

A. ✓ H - F

B. H - C

C. H - H

D. H - N

Answer: A

The polarity of a covalent bond is determined by the difference in electronegativity between the bonded atoms. The electronegativity difference is greatest between hydrogen (2.2) and fluorine (4.0), making the H-F bond the most polar.

2. The force that hold different atoms or ions together are called? (1)

A. Electric forces

B. Physical bonds

C. ✓ Chemical bond

D. Atomic forces

Answer: C

A chemical bond is the attractive force that holds atoms or ions together to create molecules or compounds.

3. How many electrons are shared between two atoms in a double bond? (1)

A. 2

B. 3

C. ✓ 4

D. 6

Answer: C

A covalent bond shares pairs of electrons; a single bond consists of 2 shared electrons, while a double bond consists of 2 pairs, which equals 4 shared electrons.

4. What is the chemical formula of the compound formed by aluminium (III) and sulphate ion, SO_4^{2-} ? (1)

A. AlSO_4 B. Al_2SO_4 C. ✓ $\text{Al}_2(\text{SO}_4)_3$ D. $\text{Al}(\text{SO}_4)_3$ **Answer: C**

Aluminium forms a 3+ cation (Al^{3+}) and sulfate is a 2- polyatomic anion (SO_4^{2-}). To balance the charges to zero, two Al^{3+} ions combine with three SO_4^{2-} ions to give $\text{Al}_2(\text{SO}_4)_3$.

5. Which of the following is the most reasonable valence- bond structure of the nitrosyl chloride (NOCl)? (1)

[Figure: The four options are scanned Lewis (electron-dot) structures, one per option, each drawn on a pale lilac background. Option A: 'O - N - Cl' written with capital letters; the O has a pair of dots above it, a pair of dots to its left (drawn as a colon) and a pair of dots below it, and is joined to N by a single horizontal line; the N has a pair of dots above and a pair of dots below, and is joined to Cl by a short single dash; the Cl has a pair of dots above and a pair of dots below. Option B: 'O = N - Cl'; the O has a pair of dots above and a pair of dots below and is joined to N by a double line (two parallel horizontal strokes); the N has one pair of dots above it only; N is joined to Cl by a short single dash; the Cl has a pair of dots above and a pair of dots below. Option C: ': O - N = Cl'; a pair of dots stands to the left of O, and O also has a pair of dots above and a pair of dots below; O is joined to N by a single short dash; N has a pair of dots above and a pair of dots below; N is joined to Cl by a double line; Cl has a pair of dots above and a pair of dots below. Option D: ': O = N Cl'; a pair of dots stands to the left of O and a pair of dots above it; O is joined to N by a double line; N has a pair of dots above and a pair of dots below; Cl stands with no bond line drawn to N and carries a pair of dots above and a pair of dots below. The tick marking the key sits at the end of option B's line.]

- A. O and N joined by a single bond, N and Cl joined by a single bond; O carries three lone pairs (above, left and below), N carries two lone pairs (above and below), Cl carries two lone pairs (above and below)
- B. **O and N joined by a double bond, N and Cl joined by a single bond; O carries two lone pairs (above and below), N carries one lone pair (above), Cl carries two lone pairs (above and below)**
- C. O and N joined by a single bond, N and Cl joined by a double bond; O carries three lone pairs (left, above and below), N carries two lone pairs (above and below), Cl carries two lone pairs (above and below)
- D. O and N joined by a double bond, no bond drawn between N and Cl; O carries two lone pairs (left and above), N carries two lone pairs (above and below), Cl carries two lone pairs (above and below)

Answer: B

In nitrosyl chloride (NOCl), nitrogen is the central atom bonded to oxygen via a double bond and to chlorine via a single bond (O=N-Cl), giving each atom a complete octet and minimizing formal charges.

6. Which of the following is the correct order for electrons filling in orbitals? (1)

- A. ✓ 3s, 3p, 4s, 3d B. 2p, 3s, 3p, 3d
C. 3p, 4s, 3d, 5s D. 4s, 3d, 4p, 4d

Answer: A

According to the Aufbau principle (the $(n + l)$ rule), the filling order of orbitals is $3s$ ($n+l = 3$), $3p$ ($n+l = 4$), $4s$ ($n+l = 4$, lower n), and then $3d$ ($n+l = 5$).

7. The normal human eye responds to visible light of wavelength ranging from about 390nm to 710nm. What is the frequency range of the human eye? (1)

- A.** $\checkmark 7.7 \times 10^{14} \text{s}^{-1}$ to $4.2 \times 10^{14} \text{s}^{-1}$ **B.** $4.2 \times 10^{14} \text{s}^{-1}$ to $7.7 \times 10^{14} \text{s}^{-1}$
C. $1.3 \times 10^{-15} \text{s}^{-1}$ to $2.4 \times 10^{-15} \text{s}^{-1}$ **D.** $2.4 \times 10^{-15} \text{s}^{-1}$ to $1.3 \times 10^{-15} \text{s}^{-1}$

Answer: A

8. How many different types of orbitals are there in the third energy level? (1)

- A. 2
C. 6
B. ✓ 3
D. 7

Answer: B

In the third principal energy level ($n = 3$), the possible values of the orbital angular momentum quantum number l are 0, 1, and 2, which correspond to three types (subshells) of orbitals: s, p, and d.

9. The Heisenberg uncertainty principle states that (1)
- A. Two atoms of the same element must have the same number of protons.
 - B. No two electrons in the same atom can have the same set of four quantum numbers.
 - C. ✓ **It is impossible to determine both position and momentum of an electron simultaneously.**
 - D. Electrons of atoms in ground state enter energetically equivalent set of orbitals singly before they pair any orbitals of the set.

Answer: C

The Heisenberg uncertainty principle states that it is impossible to know simultaneously both the exact position and momentum of a subatomic particle like an electron.

10. Which of the following transitions will have minimum wavelength? (1)
- A. ✓ **$n_4 \rightarrow n_1$**
 - B. $n_2 \rightarrow n_1$
 - C. $n_4 \rightarrow n_2$
 - D. $n_3 \rightarrow n_1$

Answer: A

Wavelength is inversely proportional to energy. The transition from $n=4$ to $n=1$ has the largest energy difference (15/16 of the Rydberg energy), and therefore produces radiation with the minimum wavelength.

11. What is the energy associated with one photon of a microwave radiation having a frequency of $2.45 \times 10^9 \text{ s}^{-1}$? (1)
- A. $1.62 \times 10^{24} \text{ J}$
 - B. $2.45 \times 10^9 \text{ J}$
 - C. $2.45 \times 10^{-9} \text{ J}$
 - D. ✓ **$1.62 \times 10^{-24} \text{ J}$**

Answer: D

Using Planck's equation $E = h\nu$, $E = (6.626 \times 10^{-34} \text{ J}\cdot\text{s}) \times (2.45 \times 10^9 \text{ s}^{-1}) = 1.62 \times 10^{-24} \text{ J}$.

12. What is the frequency of a radiation (in Hz) from an atom if its wavelength is $1.0 \times 10^{-9} \text{ nm}$? (1)
- A. 3.3×10^{-27}
 - B. 3.0×10^{17}
 - C. 3.0×10^8
 - D. ✓ **3.0×10^{26}**

Answer: D

The wavelength is $1.0 \times 10^{-9} \text{ nm} = 1.0 \times 10^{-18} \text{ m}$. The frequency is $\nu = c/\lambda = (3.0 \times 10^8 \text{ m/s}) / (1.0 \times 10^{-18} \text{ m}) = 3.0 \times 10^{26} \text{ Hz}$.

13. Which of the following particle was discovered by the cathode rays experiment? (1)
- A. ✓ **Electron**
 - B. Neutron
 - C. Nucleus
 - D. Proton

Answer: A

Cathode rays were shown by J.J. Thomson in 1897 to consist of negatively charged particles, leading to the discovery of the electron.

14. Which of the following is NOT a laboratory safety rule? (1)
- A. You should tie back loose hair.
 - B. ✓ **You should never add acid to water.**
 - C. Do not suck solution in the pipette by mouth.
 - D. When lighting a Bunsen Burner, you should light the match stick before turning on the gas.

Answer: B

The proper safety rule is to always add acid to water (never water to acid) because diluting acid is highly exothermic. Therefore, stating that one should 'never add acid to water' is incorrect and not a safety rule.

15. Which of the following is the correct relationship between picometer (PM) and nanometer (nm)? (1)
- A. 1Pm = 10nm
B. 1pm = 100nm
C. 1nm = 10pm
D. ✓ **1nm = 1000pm**

Answer: D

Since $1\text{ nm} = 10^{-9}\text{ m}$ and $1\text{ pm} = 10^{-12}\text{ m}$, 1 nm is equal to 10^3 pm (1000 pm).

16. How many significant figures has the sum of 2.453, 4.6 and 8.14? (1)
- A. 2
B. ✓ **3**
C. 4
D. 5

Answer: B

When adding numbers, the result is rounded to the fewest decimal places. $2.453 + 4.6 + 8.14 = 15.193$, which rounds to 15.2 (one decimal place, limited by 4.6), giving 3 significant figures.

17. Which one of the following measurements has the greatest number of significant figures? (1)
- A. 0.00046
B. ✓ **0.0046**
C. 460
D. 4.6×10^6

Answer: B

18. Which of the following methods is used to convert oils into fats? (1)
- A. Esterification reaction using strong bases like NaOH or KOH
B. Saponification reaction using strong bases like NaOH or KOH
C. Hydrolysis reaction in the presence of water and a catalyst
D. ✓ **Hydrogenation reaction at high temperature and in the presence of a catalyst**

Answer: D

Vegetable oils contain unsaturated fatty acids with double bonds; hydrogenation in the presence of a metal catalyst (such as nickel) at elevated temperature converts them into saturated solid fats.

19. The solubility of compounds containing the carboxylic acid group can be increased by reaction with (1)
- A. Sulphuric acid
B. ✓ **Sodium hydroxide**
C. Water
D. Benzoic acid

Answer: B

Carboxylic acids react with bases like sodium hydroxide to form water-soluble ionic carboxylate salts.

20. What products will be formed when a carboxylic acid reacts with an alcohol? (1)
- A. Ketone and water
B. Amide and water
C. Acid chloride and water
D. ✓ **Ester and water**

Answer: D

The reaction of a carboxylic acid with an alcohol in the presence of an acid catalyst produces an ester and water (esterification), where 'Easter' is a typographical error for ester.

21. Consider the reaction $\text{AB}_3(\text{g}) \rightleftharpoons \text{A}(\text{g}) + 3\text{B}(\text{g})$ What is the equilibrium constant expression if the initial concentration of AB_3 is 0.1M and the equilibrium concentration of A is expressed by x ? (Assume the initial concentrations of A and B are both zero.) (1)

- A. $\frac{x - 3x}{0.1 - x}$ B. $\frac{x \cdot 3}{(0.1 - 3x)^3}$
C. $\frac{x - x^3}{(0.1 - 3x)^3}$ D. $\frac{x(3x)^3}{0.1 - x}$

Answer: D

From the stoichiometry, when $[\text{A}] = x$, $[\text{B}] = 3x$ and $[\text{AB}_3] = 0.1 - x$. The equilibrium expression is $K_c = \frac{[\text{A}][\text{B}]^3}{[\text{AB}_3]} = \frac{x(3x)^3}{(0.1 - x)}$.

22. Consider the following reaction at equilibrium. $2\text{CO}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g}) + \text{O}_2(\text{g})$ $\Delta H^\circ = -514\text{KJ}$ What does Le Chatelier's principle predict when the temperature for the reaction is increased? (1)

- A. The value of the equilibrium constant will increase.
B. **✓ The value of the equilibrium constant will decrease.**
C. The partial pressure of $\text{O}_2(\text{g})$ at equilibrium will increase.
D. The partial pressure of $\text{CO}_2(\text{g})$ at equilibrium will increase.

Answer: B

23. For one component system, when would the degree of freedom becomes one? (1)

- A. When only one phase is present.
B. **✓ When two phases are present at equilibrium.**
C. When three phases are present at equilibrium.
D. At all times.

Answer: B

By Gibbs phase rule, $F = C - P + 2$. For a one-component system ($C = 1$), having $F = 1$ requires $1 = 1 - P + 2$, which gives $P = 2$ phases at equilibrium.

24. Which one of the following is correct when a reaction reaches equilibrium? (1)

- A. The reaction rate for the forward direction is decreased to zero.
B. **✓ The rate of the forward and reverse reaction becomes equal.**
C. The rate of the reverse reaction is reached a maximum.
D. The amounts of reactants and products becomes equal.

Answer: B

Dynamic chemical equilibrium is defined as the state in which the rates of the forward and reverse reactions are equal, keeping the concentrations of reactants and products constant.

25. A possible mechanism for the reaction, $\text{A} + 2\text{B} \rightarrow \text{AB}_2$ is Step: $\text{A} + \text{B} \rightarrow \text{AB}$ Slow Step: $\text{AB} + \text{B} \rightarrow \text{AB}_2$ Fast Overall: $\text{A} + 2\text{B} \rightarrow \text{AB}_2$ According to the mechanism, what will be the rate law? (1)

- A. **✓ Rate = $K[\text{A}][\text{B}]$** B. Rate = $K[\text{B}]^2$
C. Rate = $K[\text{A}][\text{B}]^2$ D. Rate = $K[\text{A}]$

Answer: A

The rate law of an overall reaction is determined by the slow, rate-determining elementary step: $\text{A} + \text{B} \rightarrow \text{AB}$, giving Rate = $k[\text{A}][\text{B}]$.

31. What is the bond order of a superoxide anion, with the chemical formula O_2^- ? (1)
- A. 3
B. 2.5
C. 2
D. ✓ 1.5

Answer: D

The superoxide ion (O_2^-) has 17 total electrons (13 valence electrons), with 8 bonding valence electrons and 5 antibonding valence electrons, yielding a bond order of $(8 - 5) / 2 = 1.5$.

32. What kind of hybrid orbitals are utilized by the carbon atom in CF_4 molecules? (1)
- A. Sp
B. Sp^2
C. ✓ Sp^3
D. Sp^3d

Answer: C

In CF_4 , the central carbon atom forms four single bonds with no lone pairs, corresponding to a steric number of 4 and sp^3 hybridization.

33. Which statement about indicators is always correct? (1)
- A. The mid-point of the PH rage of an indicator is 7.0
B. The PH rage is greater with higher PK_a values.
C. The colour red indicates an acidic solution.
D. ✓ **The PK_a values of the indicator is within its PH range.**

Answer: D

An acid-base indicator changes color over a pH range approximately equal to $\text{pK}_a \pm 1$, meaning its pK_a value always falls within its transition range.

34. The suppression of ionization of a weak acid or a weak base by adding one of its own ions is known as: (1)
- A. Buffer effect
B. Ionization effect
C. ✓ **Common ion effect**
D. Association effect

Answer: C

The suppression of the degree of dissociation of a weak electrolyte by the addition of a strong electrolyte providing a common ion is known as the common ion effect.

35. Nitrous acid, HNO_2 is 0.37% ionized in 3.0M solution. What is the K_a for this acid? (1)
- A. $\frac{3.0(0.0037)^2}{99.63}$
B. $\frac{(0.0037)^2}{0.9963}$
C. ✓ $\frac{3.0(0.0037)^2}{0.9963}$
D. $\frac{0.9963}{(0.0037)^2}$

Answer: C

For a weak acid with degree of ionization $\alpha = 0.0037$ and concentration $C = 3.0 \text{ M}$, $K_a = [\text{H}^+][\text{NO}_2^-]/[\text{HNO}_2] = (C\alpha)^2 / (C(1 - \alpha)) = 3.0(0.0037)^2 / (1 - 0.0037) = 3.0(0.0037)^2 / 0.9963$.

36. Among the following acids, which has the lowest PK_a value? (1)
- A. $\text{CH}_3\text{CH}_2\text{COOH}$
B. ✓ **HCOOH**
C. $(\text{CH}_3)_2\text{CHCOOH}$
D. CH_3COOH

Answer: B

Formic acid (HCOOH) is the strongest acid among the given carboxylic acids because it lacks an electron-donating alkyl group, giving it the lowest pK_a (around 3.75).

37. Which one of the following is a Lewis acid? (1)
- A. NH_3 B. CCl_4
C. ✓ AlCl_3 D. LiCl

Answer: C

AlCl_3 is an electron-deficient molecule with an incomplete octet on the aluminum atom, making it capable of accepting an electron pair as a Lewis acid.

38. Which of the following is the conjugate acid of the HS^- ion? (1)
- A. H_2S^- B. S_2^-
C. S^- D. ✓ H^2S

Answer: D

The conjugate acid of a base is formed by adding a proton (H^+); adding H^+ to HS^- yields H_2S (printed as H^2S).

39. What will be the ratio of the boiling point elevation of a 0.1M solution of sucrose, sodium sulphate and potassium bromide? (1)
- A. 1 : 3 : 1 B. 1 : 1 : 2
C. ✓ 1 : 3 : 2 D. 1 : 2 : 2

Answer: C

Boiling point elevation is proportional to the van 't Hoff factor (i); sucrose is a non-electrolyte ($i = 1$), Na_2SO_4 yields 3 ions ($i = 3$), and KBr yields 2 ions ($i = 2$), giving a ratio of 1 : 3 : 2.

40. When the molecular equation: $\text{CaCl}_2(\text{aq}) + \text{Na}_2\text{CO}_3(\text{aq}) \rightarrow \text{CaCO}_3(\text{s}) + 2\text{NaCl}(\text{aq})$ is written in terms of ionic equation, which one of the following pairs will be the spectator ions? (1)
- A. ✓ Na^+ and Cl^- B. Ca^{2+} and Cl^-
C. Na_3^{2-} and Cl^- D. Ca^{2+} and CO_3^{2-}

Answer: A

In the reaction between CaCl_2 and Na_2CO_3 , Ca^{2+} and CO_3^{2-} precipitate as $\text{CaCO}_3(\text{s})$, while Na^+ and Cl^- remain dissolved in aqueous solution unchanged as spectator ions.

41. If 0.454kg of nitroglycerin explodes according to the following reaction: (1)
- $$2\text{C}_3\text{H}_5(\text{NO}_2)_3 \rightarrow 6\text{CO}_2 + 3\text{N}_2 + 5\text{H}_2$$
- What is the total volume of gases in dm^3 produced at STP?
- A. 44.8 B. 163
C. ✓ 397.7 D. 650

Answer: C

Using the formula $\text{C}_3\text{H}_5(\text{NO}_2)_3$ (molar mass = 179 g/mol), 454 g corresponds to 2.536 mol. According to the equation, 2 moles yield 14 moles of gas (7 moles per mole of reactant), producing 17.75 mol of gas, which occupies $17.75 \times 22.4 \text{ dm}^3 = 397.7 \text{ dm}^3$ at STP.

42. How many grams of methanol would have to be added to water to prepare 150ml of solution which is 2.0M methanol? (1)
- A. 2.4 B. ✓ 9.6
C. 9.6×10^3 D. 4.3×10^2

Answer: B

The molar mass of methanol (CH_3OH) is 32 g/mol. To prepare 0.150 L of a 2.0 M solution, 0.30 moles of methanol are needed, which corresponds to $0.30 \text{ mol} \times 32 \text{ g/mol} = 9.6 \text{ g}$.

43. A certain 500g toothpaste sample has 0.2g of fluoride. What is the concentration of the fluoride in ppm? (1)
- A. 200
B. 250
C. ✓ 400
D. 1000

Answer: C

Concentration in ppm is calculated as (mass of solute / mass of solution) $\times 10^6$, which gives (0.2 g / 500 g) $\times 10^6 = 400$ ppm.

44. What will be the normality of a 2.3M sulphuric acid solution? (1)
- A. 0.23N
B. 0.46N
C. 2.3N
D. ✓ 4.6N

Answer: D

Sulfuric acid (H₂SO₄) is a diprotic acid with an equivalence factor (n) of 2. Therefore, Normality = Molarity $\times n = 2.3 \text{ M} \times 2 = 4.6 \text{ N}$.

45. The solubility of NaCl in water at 20⁰C is 36g in 100g of water. A solution that contains 18g of NaCl in 50g of water at 20⁰C is (1)
- A. ✓ Saturated
B. Unsaturated
C. Supersaturated
D. Dilute

Answer: A

At 20 °C, 18 g of NaCl in 50 g of water corresponds to 36 g of NaCl per 100 g of water, which exactly equals its solubility limit, meaning the solution is saturated.

46. Which of the following pairs of substances are miscible? (1)
- A. Water and gasoline
B. Water and oxygen
C. Water and salt
D. ✓ Water and ethanol

Answer: D

Miscibility refers to the ability of two liquids to mix in all proportions to form a homogeneous solution; water and ethanol form hydrogen bonds and are completely miscible.

47. Which of the following types of solution are possible? 1. Solid dissolved in a liquid 2. Gas dissolved in a gas 3. Gas dissolved in a liquid 4. Solid dissolved in a solid (1)
- A. 1 and 2
B. ✓ 1, 2, 3 and 4
C. 1, 2 and 4
D. 1

Answer: B

All four combinations represent valid solutions: solid in liquid (e.g., salt water), gas in gas (e.g., air), gas in liquid (e.g., soda water), and solid in solid (e.g., metal alloys).

48. The chemical makeup of oil is esters of glycerol with three (1)
- A. Identical saturated fatty acids.
B. Predominantly saturated fatty acids.
C. ✓ Predominantly unsaturated fatty acids.
D. Identical unsaturated fatty acids.

Answer: C

Oils are liquid at room temperature because they are triglycerides formed from glycerol and predominantly unsaturated fatty acids, whereas solid fats contain predominantly saturated fatty acids.

49. Which of the following general class of organic molecules do triglycerides belong to? (1)

- A. Ketones
B. Carboxylic acids
C. ✓ **Esters**
D. Ethers

Answer: C

Triglycerides are triesters formed from the esterification of glycerol with three fatty acid molecules, classifying them as esters.

50. What type of polymerization occurs when amino acids react to form peptides and proteins? (1)

- A. Addition polymerization
B. ✓ **Condensation polymerization**
C. Substitution polymerization
D. Hydration polymerization

Answer: B

When amino acids link together via peptide bonds, a water molecule is eliminated with the formation of each bond, which is characteristic of condensation polymerization.

51. Which of the following is the most abundant polysaccharide? (1)

- A. Amylose
B. ✓ **Cellulose**
C. Starch
D. Sucrose

Answer: B

Cellulose is the most abundant organic polymer and polysaccharide on Earth, serving as the main structural component of plant cell walls. Starch and amylose are storage polysaccharides, and sucrose is a disaccharide.

52. What is the other name for polymethyl methacrylate (PMMA)? (1)

- A. ✓ **Perspex**
B. Teflon
C. Bakelite
D. Nylon- 6

Answer: A

Polymethyl methacrylate (PMMA) is commonly known by trade names such as Perspex, Plexiglas, and Lucite. Teflon is polytetrafluoroethylene, Bakelite is a phenol-formaldehyde resin, and Nylon-6 is polycaprolactam.

53. What is the monomer of polyvinyl chloride (PVC)? (1)

- A. Chloroethane
B. ✓ **Ethylene dichloride**
C. Chloroform
D. Ethyl chloride

Answer: B

54. The second step in the production of sulphuric acid is given by the reaction: $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ (1)
Which conditions would increase the yield of this reaction?

- A. High temperature and low pressure
B. ✓ **Low temperature and high pressure**
C. High temperature and high pressure
D. Low temperature and low pressure

Answer: B

The forward reaction is exothermic and results in a decrease in the number of moles of gas (from 3 moles to 2 moles). By Le Chatelier's principle, lower temperature shifts the equilibrium toward the exothermic direction and higher pressure shifts it toward the side with fewer gas moles, both increasing the yield of SO_3 .

55. Which of the following reactions is used in the production of industrially important chemical? (1)

- A. ✓ $\text{H}_2\text{S}_2\text{O}_7(\text{l}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{H}_2\text{SO}_4(\text{aq})$ B. $3\text{NO}_3(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{HNO}_3(\text{aq}) + \text{NO}_2(\text{g})$
C. $(\text{NH}_4)_2\text{HPO}_4(\text{s}) + \text{NH}_3(\text{g}) \rightarrow \text{NH}_4\text{H}_2\text{PO}_4(\text{s})$ D. $2\text{Cr}(\text{s}) + \text{Al}_2\text{O}_3(\text{s}) \rightarrow \text{Cr}_2\text{O}_3(\text{s}) + 2\text{Al}(\text{s})$

Answer: A

The reaction of oleum ($\text{H}_2\text{S}_2\text{O}_7$) with water is the final step in the Contact Process for the industrial manufacture of sulfuric acid. The other equations are either chemically incorrect or unbalanced representations of industrial processes.

56. Which one of the following metal is used for galvanization of iron sheets? (1)

- A. Nickel B. ✓ **Zinc**
C. Chromium D. Aluminium

Answer: B

Galvanization is the process of applying a protective coating of zinc to iron or steel to prevent corrosion. Zinc acts both as a physical barrier and as a sacrificial anode.

57. In what way is the phosphorous cycle differs from the carbon and nitrogen cycle? (1)

- A. Phosphorus is more abundant than carbon and nitrogen
B. Phosphorus is less important than carbon and nitrogen
C. Phosphorus, once used by an organism does not cycle back to the environment
D. ✓ **The reservoirs for phosphorus exists in mineral form in rocks than in the atmosphere**

Answer: D

Unlike the carbon and nitrogen cycles, the phosphorus cycle lacks a significant gaseous or atmospheric phase. The primary reservoirs of phosphorus are sedimentary rocks and minerals in the lithosphere.

58. Which one of the following is needed for photosynthesis? (1)

- A. ✓ **Carbon dioxide** B. Nitrogen
C. Oxygen D. Phosphorus

Answer: A

Photosynthesis requires carbon dioxide and water in the presence of sunlight and chlorophyll to produce glucose and oxygen. Oxygen is a byproduct of the process, not an input.

59. Consider the reaction: $\text{Cu}^{2+}(\text{aq}) + \text{Fe}(\text{s}) \rightleftharpoons \text{Cu}(\text{s}) + \text{Fe}^{2+}(\text{aq})$, $E^\circ = 0.78\text{V}$ What is the value of E when $[\text{Cu}^{2+}]$ is equal to 0.040M and $[\text{Fe}^{2+}]$ is equal to 0.40M? (1)

- A. 0.72V B. ✓ **0.75V**
C. 0.81V D. 0.84V

Answer: B

Using the Nernst equation at 25 °C, $E = E^\circ - (0.0592 / n) * \log([\text{Fe}^{2+}] / [\text{Cu}^{2+}])$. With $n = 2$ and $Q = 0.40 / 0.040 = 10$, $E = 0.78\text{ V} - (0.0592 / 2) * \log(10) \approx 0.78\text{ V} - 0.03\text{ V} = 0.75\text{ V}$.

60. For the electrochemical cell represented by: $\text{Zn}/\text{ZnSO}_4(\text{aq}) // \text{CuSO}_4(\text{aq})/\text{Cu}(\text{s})$ The standard reduction potentials for Cu^{2+}/Cu and Zn^{2+}/Zn are +0.34 and -0.76V, respectively, what will be the cell reaction that occurs spontaneously and its cell voltage? (1)

- A. $\text{Cu} + \text{Zn}^{2+} = \text{Cu}^{2+} + \text{Zn}$ $E^0(\text{V}) = 1.10$ B. $\text{Zn} + \text{Cu}^{2+} = \text{Zn}^{2+} + \text{Cu}$ $E^0(\text{V}) = 0.42$
C. $\text{Cu}^{2+} + \text{Zn}^{2+} = \text{Zn} + \text{Cu}$ $E^0(\text{V}) = 0.42$ D. ✓ $\text{Cu}^{2+} + \text{Zn} = \text{Cu} + \text{Zn}^{2+}$ $E^0(\text{V}) = 1.10$

Answer: D

Zinc has a more negative standard reduction potential (-0.76 V) than copper (+0.34 V), so zinc acts as the anode (undergoing oxidation) and copper ions act as the cathode (undergoing reduction). The spontaneous reaction is $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$ with a standard cell potential $E^0 = +0.34 \text{ V} - (-0.76 \text{ V}) = +1.10 \text{ V}$.

61. What product(s) is /are formed during the electrolysis of a concentrated aqueous solution of sodium chloride? (1)

- A. $\text{Cl}_2(\text{g})$ B. $\text{Cl}_2(\text{g})$ and $\text{H}_2(\text{g})$
C. $\text{NaOH}(\text{aq})$ and $\text{Cl}_2(\text{g})$ D. ✓ $\text{Cl}_2(\text{g})$, $\text{H}_2(\text{g})$ and $\text{NaOH}(\text{aq})$

Answer: D

During the electrolysis of concentrated aqueous NaCl (brine), chloride ions are oxidized at the anode to produce $\text{Cl}_2(\text{g})$, water is reduced at the cathode to produce $\text{H}_2(\text{g})$ and $\text{OH}^-(\text{aq})$, leaving behind a solution of $\text{NaOH}(\text{aq})$.

62. In the reaction: $\text{Pb} + (\text{s}), \text{PbO}_2 + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow 2\text{PbSO}_4(\text{s}) + 2\text{H}_2\text{O}(\text{l})$ Which substance behaves as the oxidizing agent? (1)

- A. Pb B. PbSO_4
C. ✓ PbO_2 D. H_2SO_4

Answer: C

In PbO_2 , lead has an oxidation state of +4, which is reduced to +2 in PbSO_4 , making PbO_2 the oxidizing agent.

63. What mass of magnesium (Mg) is produced in the electrolysis of molten MgCl_2 , if a current of $7.50 \times 10^2 \text{ A}$ is passed through the molten salt for 1.00 hour? (1)

- A. ✓ $3.4 \times 10^2 \text{ g}$ B. $9.92 \times 10^2 \text{ g}$
C. $1.7 \times 10^2 \text{ g}$ D. $4.96 \times 10^2 \text{ g}$

Answer: A

The total charge passed is $Q = I \times t = 750 \text{ A} \times 3600 \text{ s} = 2.70 \times 10^6 \text{ C}$. The moles of electrons are $Q/F = (2.70 \times 10^6 \text{ C})/(96,500 \text{ C/mol}) \approx 27.98 \text{ mol e}^-$, which reduces to 13.99 mol of Mg (since $\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg}$), giving a mass of $13.99 \text{ mol} \times 24.31 \text{ g/mol} \approx 3.4 \times 10^2 \text{ g}$.

64. Devices in which oxidation- reduction reaction is induced by an electric current are called (1)

- A. Galvanic cells B. ✓ **Electrolytic cells**
C. Voltaic cells D. Electromotive cells

Answer: B

Electrolytic cells use an external electric current to drive a non-spontaneous oxidation-reduction reaction, whereas galvanic (voltaic) cells generate electricity from spontaneous reactions.

65. In the following reaction: $3\text{Cl}^-(\text{aq}) + 4\text{CrO}_4^{2-}(\text{aq}) + 23\text{H}^+(\text{aq}) \rightarrow 3\text{HClO}_2(\text{aq}) + 4\text{Cr}^{3+}(\text{aq}) + 10\text{H}_2\text{O}(\text{l})$ What is the behaviour $\text{Cl}^-(\text{aq})$? (1)
- A. An acid
B. A base
C. An oxidizing agent
D. ✓ **A reducing agent**

Answer: D

The oxidation state of chlorine increases from -1 in $\text{Cl}^-(\text{aq})$ to +3 in $\text{HClO}_2(\text{aq})$; since it undergoes oxidation, $\text{Cl}^-(\text{aq})$ acts as a reducing agent.

66. Based on the following information $\Delta H^\circ(\text{kJ})$ $\text{H}_2(\text{g}) + 1/2\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$ -286 (1)
 $2\text{Na}(\text{s}) + 1/2\text{O}_2(\text{g}) \rightarrow \text{Na}_2\text{O}(\text{s})$ 414 $\text{Na}(\text{s}) + 1/2\text{O}_2(\text{g}) + 1/2\text{H}_2(\text{g}) \rightarrow \text{NaOH}(\text{s})$ -425 What will be the standard enthalpy changes for the reaction? $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{NaOH}(\text{s})$?
- A. -978KJ
B. -722KJ
C. ✓ **-150KJ**
D. +275KJ

Answer: C

Using Hess's law, $\Delta H^\circ = 2\Delta H^\circ_f[\text{NaOH}(\text{s})] - \Delta H^\circ_f[\text{Na}_2\text{O}(\text{s})] - \Delta H^\circ_f[\text{H}_2\text{O}(\text{l})] = 2(-425 \text{ kJ}) - (-414 \text{ kJ}) - (-286 \text{ kJ}) = -850 + 414 + 286 = -150 \text{ kJ}$ (the minus sign for Na_2O 's formation enthalpy was omitted as a typographical error in the table).

67. At what condition(s) is the equation, $\Delta H = \Delta U + P\Delta V$, applicable? (1)
- A. For constant pressure and temperature processes
B. ✓ **Only for constant pressure processes**
C. Only for constant temperature processes
D. Only for constant volume processes

Answer: B

From the definition of enthalpy, $H = U + PV$, the change in enthalpy is $\Delta H = \Delta U + P\Delta V + V\Delta P$; this simplifies to $\Delta H = \Delta U + P\Delta V$ specifically under conditions of constant pressure ($\Delta P = 0$).

68. What is a thermodynamic system that exchanges both energy and matter with the surroundings? (1)
- A. Adiabatic
B. Closed
C. Isolated
D. ✓ **Open**

Answer: D

An open system can freely exchange both energy and matter with its surroundings, whereas a closed system exchanges only energy, and an isolated system exchanges neither.

69. Use the following equilibrium reaction for questions 81 $2\text{C}(\text{s}) + \text{O}_2(\text{g}) = 2\text{CO}(\text{g})$ $\Delta H < 0$ (1)
 What is the equilibrium expression? (M)

- A. $K = \frac{2[\text{CO}]}{2[\text{C}] + [\text{O}_2]}$
B. $K = \frac{[\text{CO}]^2}{[\text{C}]^2[\text{O}_2]}$
C. $K = \frac{2[\text{CO}]}{[\text{O}_2]}$
D. ✓ $K = \frac{[\text{CO}]^2}{[\text{O}_2]}$

Answer: D

Pure solids such as $\text{C}(\text{s})$ have constant concentrations (activity = 1) and are excluded from the equilibrium constant expression, giving $K = [\text{CO}]^2 / [\text{O}_2]$.

— END OF MARKING KEY —