

Chemistry, 2007 EC, entrance exam

Grade 12 · Chemistry · 2007 E.C.

MARKING KEY — CONFIDENTIAL

Time allowed: 120 minutes

Questions: 71

Total marks: 71

1. According to valence bond theory. Which orbitals on bromine atoms overlap in the formation of the bond in Br_2 ? (1)
- A. 3s
B. 3P
C. 4s
D. ✓ 4P

Answer: D

Bromine has the valence electron configuration $4s^2 4p^5$, so each bromine atom has one half-filled 4p orbital that overlaps with the other to form the single covalent bond in Br_2 .

2. The type of compound that is most likely to contain a covalent bond is one that is (1)
- A. A solid metal
B. ✓ **Composed of only non-metals**
C. Composed of a metal from the far left and a non-metal from far right of the periodic table
D. Held together by the electrostatic forces between oppositely charged ions.

Answer: B

Covalent bonds form primarily between non-metal atoms through the sharing of electron pairs, whereas bonds between metals and non-metals are typically ionic.

3. The first step of the scientific method involves (1)
- A. Forming a hypothesis
B. ✓ **Making observations.**
C. Performing an experiment.
D. Predicting the result of an experiment

Answer: B

The scientific method typically begins with making observations about a phenomenon, which then leads to asking questions and formulating a hypothesis.

4. The process of solute particles being surrounded by solvent particles is known as (1)
- A. Saturation
B. Agglomeration
C. ✓ **Solvation**
D. Dehydration

Answer: C

Solvation is the process in which solute ions or molecules are surrounded and stabilized by solvent molecules (called hydration when the solvent is water).

5. Which one of the following represents an acceptable possible set of quantum numbers (in the order n, l, m_l, m_s) for an electron in an atom? (1)
- A. 2, 1, 0, 0
B. 2, 0, 2, +1/2
C. ✓ **2, 1, -1, 1/2**
D. 2, 0, 1, -1/2

Answer: C

For $n = 2$, l can be 1, m_l can range from -1 to +1 (so -1 is allowed), and m_s can be +1/2. The other options violate quantum number rules: spin cannot be 0 (A), and when $l = 0$, m_l must be 0 (B and D).

6. Of the three types of radioactivity characterized by Rutherford, which of the following are particles? (1)
- A. γ - rays
B. β - rays
C. ✓ α - rays and β - rays
D. α - rays, β - rays, and γ - rays

Answer: C

Alpha rays (helium-4 nuclei) and beta rays (high-speed electrons) are particle radiation, whereas gamma rays are high-energy electromagnetic waves.

7. Which kind of energy is converted in a galvanic cell? (1)
- A. ✓ **Chemical energy is converted into electrical energy.**
B. Chemical energy is converted to heat.
C. Chemical energy is obtained from heat.
D. Electrical energy is converted into chemical energy.

Answer: A

A galvanic (voltaic) cell uses a spontaneous chemical redox reaction to generate electrical energy, whereas an electrolytic cell converts electrical energy into chemical energy.

8. The conversion of nitrogen gas to nitrates by bacteria is called (1)
- A. Nitrification
B. ✓ **Nitrogen fixation**
C. Excretion
D. Denitrification

Answer: B

Nitrogen fixation is the biological process by which atmospheric nitrogen gas (N_2) is converted into biologically accessible forms such as ammonia and nitrates.

9. According to the Arrhenius concept, an acid is a substance that (1)
- A. Is capable of donating one or more H^+ to any solvent.
B. ✓ **Causes an increase in the concentration of H^+ in aqueous solutions.**
C. Can accept a pair of electrons to form a coordinate covalent bond.
D. Reacts with the solvent to form the cation formed by auto ionization of that solvent.

Answer: B

According to the Arrhenius definition, an acid is a substance that dissociates in water to increase the concentration of hydrogen ions (H^+).

10. A system which can exchange both matter and energy with its surroundings is said to be a/an (1)
- A. Isolated system
B. ✓ **Open system**
C. Ideal system
D. Closed system

Answer: B

An open system can freely exchange both matter and energy with its surroundings, unlike a closed system (energy only) or an isolated system (neither).

11. At which point can only the solid and liquid phases coexist in the phase diagram of water given below? (1)

[Figure: A scanned phase diagram. The vertical axis is labelled "Pressure", the horizontal axis "Temperature"; no numerical scale is marked on either axis. Three boundary curves meet at a single point labelled 3 in the middle of the plot (the triple point). From point 3 one line runs up and to the LEFT with a negative slope, passing through a marked point labelled 4 part-way along it and ending at a marked point labelled 7 high on the left, near the pressure axis. From point 3 a second line runs up and to the RIGHT, passing through a marked point labelled 5 and ending at a marked point labelled 8 at the top right. A third, gently curving line runs from point 3 down and to the left, flattening out and meeting the pressure axis low down. Three further points are marked away from any line: point 1 lies in the region to the left of the 7-4-3 line and above the low curved line; point 2 lies in the upper middle region, to the right of the 7-4-3 line and above the 3-5-8 line; point 6 lies below and to the right of point 3, under the 3-5-8 line. Points 4 and 5 sit ON their respective lines; points 1, 2 and 6 sit inside regions.]

- A. 3
C. 5
B. ✓ 4
D. 8

Answer: B

Point 4 lies directly on the melting/freezing curve separating the solid and liquid regions, where both phases coexist in equilibrium. In contrast, point 3 is the triple point where three phases coexist, and point 5 is on the liquid-vapor boundary.

12. What type of solute-solvent interaction should be the most important in a solution of iodine in carbon tetrachloride? (1)

- A. ✓ London forces
C. Ion-dipole forces
B. Ionic bonding
D. Dipole-dipole forces

Answer: A

Both iodine (I₂) and carbon tetrachloride (CCl₄) are nonpolar molecules, meaning the only intermolecular forces between them are London dispersion forces.

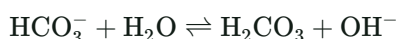
13. The distance between two carbon atoms in a diamond is 154 pm. What is the distance between the carbon atoms in millimetres? (1)

- A. 7.7×10^{-5}
C. ✓ 1.54×10^{-7}
B. 7.7×10^{-7}
D. 1.54×10^{-9}

Answer: C

Since 1 pm equals 10^{-12} m and 1 mm equals 10^{-3} m, 1 pm = 10^{-9} mm. Thus, 154 pm = 154×10^{-9} mm = 1.54×10^{-7} mm.

14. For the acid-base equilibrium. (1)



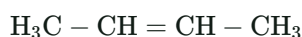
The Brønsted- Lowry acids are

- A. H₂O and OH⁻
C. ✓ H₂O and H₂CO₃
B. HCO₃⁻ and OH⁻
D. HCO₃⁻ and H₂CO₃

Answer: C

A Brønsted-Lowry acid is a proton donor. In the forward reaction, H₂O donates a proton to HCO₃⁻, and in the reverse reaction, H₂CO₃ donates a proton to OH⁻.

15. How many sigma and Pi bonds are present in the following molecule? (1)



- A. 8σ bonds and 1π bond
C. 10σ bonds and 2π bond
B. 8σ bonds and 2π bonds
D. ✓ 11σ bonds and 1π bond

Answer: D

2-butene (H₃C-CH=CH-CH₃) contains eight C-H single bonds, two C-C single bonds, and one C=C double bond (one sigma and one pi). Summing these gives 8 + 2 + 1 = 11 sigma bonds and 1 pi bond.

16. How many orbital are there in an atom with $n = 4$?

(1)

- A. 2
C. ✓ 16
- B. 8
D. 25

Answer: C

The total number of orbitals in a shell with principal quantum number n is given by n^2 . For $n = 4$, there are $4^2 = 16$ orbitals (one 4s, three 4p, five 4d, and seven 4f).

17. The most abundant metal on the surface of the earth is

(1)

- A. Fe
C. Ca
- B. ✓ Al
D. Na

Answer: B

Aluminium (Al) is the most abundant metallic element in the Earth's crust (constituting about 8% by mass), followed by iron.

18. Which of the following is correct?

(1)

- A. ✓ $1\text{L} = 1\text{dm}^3$
B. $1\text{L} = 10\text{dm}^3$
C. $10\text{L} = 1\text{cm}^3$
D. $1\text{L} = 0.1\text{dm}^3$

Answer: A

By definition, one liter (1 L) is equal to one cubic decimeter (1 dm³), which is also equivalent to 1000 cm³.

19. The decreasing order of electrochemical characteristics of some metals is given as: $\text{Mg} > \text{Al} > \text{Zn} > \text{Cu} > \text{Ag}$. What will happen if a copper spoon is used to stir a solution of aluminium nitrate ($\text{Al}(\text{NO}_3)_3$)?

(1)

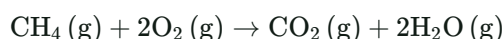
- A. ✓ **There is no reaction**
- B. The solution becomes blue
- C. The spoon will get coated with aluminium
- D. An alloy of copper and aluminium is formed.

Answer: A

Copper is less reactive (lower in the activity series) than aluminium, so it cannot reduce Al^{3+} ions or displace aluminium from solution, resulting in no reaction.

20. What hybridization change does the carbon atom undergo in the combustion of methane?

(1)



- A. $sp \rightarrow ?sp^2$ B. $sp^2 \rightarrow \text{diamond} sp^3$
C. $\checkmark \text{ } sp^3 \rightarrow \text{diamond} sp$ D. $sp^2 \rightarrow \text{diamond} sp$

Answer: C

In methane (CH_4), carbon has four single bonds with tetrahedral geometry and sp^3 hybridization. In carbon dioxide (CO_2), carbon has two double bonds with linear geometry and sp hybridization.

21. Which of the following ionic compounds has the greatest lattice energy?

(1)

- A. ✓ LiF B. LiCl
C. LiBr D. LiI

Answer: A

Lattice energy is inversely proportional to the sum of the ionic radii of the cation and anion. Since all four compounds share the Li^+ cation, LiF has the highest lattice energy because F^- has the smallest ionic radius among the halide ions.

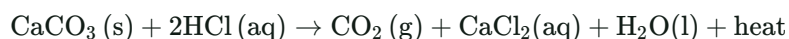
22. Consider the three electromagnetic waves shown below. Which of the electromagnetic waves has the highest frequency? (1)
[Figure: A scanned drawing of FOUR sinusoidal waves stacked vertically, all spanning the same horizontal width and each labelled with a numeral on its left. Wave 1 (top): about 7 complete cycles, small amplitude. Wave 2: about 7 complete cycles, noticeably larger amplitude than wave 1. Wave 3: about 4 to 5 complete cycles, large amplitude, the longest wavelength of the four. Wave 4 (bottom): roughly 15 tightly packed cycles, small amplitude, by far the shortest wavelength. No axes, units or values are marked.]

A. 1
B. 2
C. 3
D. ✓ 4

Answer: D

Frequency is inversely proportional to wavelength ($f = c/\lambda$). Wave 4 has the shortest wavelength (highest number of cycles in the given space), and therefore possesses the highest frequency.

23. Considering the reaction below, in which of the following will the effect of concentration and temperature simultaneously cause an increase in the rate at which products are formed? (1)



A. Decrease $[\text{HCl}]$ and decrease temperature.
B. ✓ Increase $[\text{HCl}]$ and increase temperature.
C. Increase $[\text{HCl}]$ and decrease temperature.
D. Grind up the CaCO_3 and decrease temperature.

Answer: B

Increasing the concentration of a reactant (HCl) increases the collision frequency between reacting particles, and increasing the temperature increases both collision frequency and the fraction of collisions having energy greater than the activation energy, both accelerating the rate of product formation.

24. The wave number of an electromagnetic radiation is $1 \times 10^5 \text{ cm}^{-1}$. The frequency of the radiation would be (1)

A. $3 \times 10^8 \text{ s}^{-1}$
B. $3 \times 10^6 \text{ s}^{-1}$
C. $3 \times 10^{10} \text{ s}^{-1}$
D. ✓ $3 \times 10^{15} \text{ s}^{-1}$

Answer: D

Frequency is related to wave number by $\nu = c \cdot \bar{\nu}$. Using $c = 3 \times 10^{10} \text{ cm/s}$, $\nu = (3 \times 10^{10} \text{ cm/s}) \times (1 \times 10^5 \text{ cm}^{-1}) = 3 \times 10^{15} \text{ s}^{-1}$.

25. For the gas phase reaction (1)



the value of K changes with the

A. Change in pressure
B. Introduction of NO
C. Change in concentration of N_2
D. ✓ Change in temperature.

Answer: D

The equilibrium constant K is a function of temperature only. Changes in concentration, pressure, or volume will shift the equilibrium position according to Le Chatelier's principle, but they do not alter the value of K .

26. In the reaction ($2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$, $K_{\text{eq}} = 100$). What will be the concentration of O_2 , if the concentration of SO_2 is the same as that of SO_3 ? (1)

A. $[\text{O}_2] = [\text{SO}_2]$
B. ✓ $[\text{O}_2] = 0.01 \text{ M}$
C. $[\text{O}_2] = 100 \text{ M}$
D. $[\text{O}_2] = 0.1 \text{ M}$

Answer: B

The equilibrium expression is $K_{\text{eq}} = [\text{SO}_3]^2 / ([\text{SO}_2]^2 [\text{O}_2])$. Since $[\text{SO}_2] = [\text{SO}_3]$, their terms cancel, leaving $K_{\text{eq}} = 1/[\text{O}_2] = 100$, so $[\text{O}_2] = 1/100 = 0.01 \text{ M}$.

27. The decomposition of nitrosyl chloride was studied as

(1)



The following data were obtained where $\text{Rate} = -\Delta[\text{NOCl}]/\Delta t$. What is the rate law in the above decomposition?

[Figure: A bordered two-column data table sitting between the "Rate" line and the question sentence. Left column heading: $[\text{NOCl}]_0$ (molecules/cm³). Right column heading: Initial Rate (molecules/cm³.s). Four data rows, in this printed order: 3.0×10^{16} and 5.98×10^4 ; 2.0×10^{16} and 2.66×10^4 ; 1.0×10^{16} and 6.64×10^3 ; 4.0×10^{16} and 1.66×10^5 .]

A. ✓ $r = k[\text{NOCl}]^2$

B. $r = K[\text{NOCl}]$

C. $r = K[\text{NOCl}][\text{NO}]$

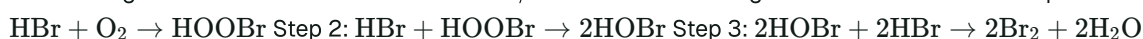
D. $r = k[\text{NOCl}][\text{Cl}]$

Answer: A

Comparing the runs where $[\text{NOCl}]$ doubles from 1.0×10^{16} to 2.0×10^{16} , the rate quadruples from 6.64×10^3 to 2.66×10^4 , which demonstrates a second-order dependence: $r = k[\text{NOCl}]^2$.

28. Considering the mechanism for a reaction below, which of the following statements is correct? Step 1:

(1)



A. Br_2 is a reactant

B. HBr is a product

C. HOBr is a catalyst

D. ✓ **HOBr is a reaction intermediate**

Answer: D

HOBr is formed in Step 1 and subsequently consumed in Step 2, which is the definition of a reaction intermediate. Br_2 is an overall product, HBr is an overall reactant, and HOBr is also an intermediate, not a catalyst.

29. The acid-base indicator bromocresol green is a weak acid. The yellow acid and blue base forms of the indicator are present in equal concentrations in a solution when the pH is 4.68. What is the pK_a of bromocresol green?

(1)

A. 4.48

B. ✓ **4.68**

C. 5.68

D. 6.68

Answer: B

According to the Henderson-Hasselbalch equation, $\text{pH} = \text{pK}_a + \log([\text{In}^-]/[\text{HIn}])$. When the acid and base forms are present in equal concentrations, the ratio is 1, so $\log(1) = 0$ and $\text{pH} = \text{pK}_a = 4.68$.

30. A lipid is any substance of biochemical origin that is

(1)

A. Soluble in both water and non-polar solvents.

B. Insoluble in both water and non-polar solvents.

C. Soluble in water but insoluble in non-polar solvents.

D. ✓ **Soluble in non-polar solvents and insoluble in water.**

Answer: D

Lipids are a diverse group of naturally occurring organic molecules that are hydrophobic (insoluble in water) and soluble in non-polar organic solvents like ether, chloroform, and benzene.

31. A solution in an electrolytic cell contains Cu^{2+} ($E^0 = 0.34\text{V}$), Ag^+ ($E^0 = 0.80\text{V}$), and Zn^{2+} ($E^0 = 0.76\text{V}$). If the voltage is initially very low and slowly increased, in which order will the metals be plated out on to the cathode?

(1)

A. $\text{Zn}^{2+} > \text{Cu}^{2+} > \text{Ag}^+$

B. $\text{Cu}^{2+} > \text{Zn}^{2+} > \text{Ag}^+$

C. $\text{Ag}^+ > \text{Zn}^{2+} > \text{Cu}^{2+}$

D. ✓ **$\text{Ag}^+ > \text{Cu}^{2+} > \text{Zn}^{2+}$**

Answer: D

During electrolysis, the cation with the most positive standard reduction potential is reduced first at the cathode. Since Ag^+ (+0.80 V) > Cu^{2+} (+0.34 V) > Zn^{2+} (-0.76 V), the metals plate out in the order $\text{Ag}^+ > \text{Cu}^{2+} > \text{Zn}^{2+}$.

38. Which of the following compound does NOT follow the octet rule?

(1)

- A. CS₂
C. IBr
B. PBr₃
D. ✓ BrF₅

Answer: D

In BrF_5 , bromine has 5 single bonds and 1 lone pair, expanding its valence shell to 12 electrons and thus violating the octet rule.

39. Chemically, fats and oils are

(1)

- A. Acids
B. Alcohols
C. ✓ Esters
D. Alkenes

Answer: C

Fats and oils are triglycerides, which are chemically triesters formed from glycerol and three fatty acid molecules.

40. The reaction $A + 3B \rightarrow 2C + D$ is first order with respect to reactant A and second order with respect to reactant B. If the concentration of A is doubled and the concentration of B is halved, the rate of the reaction would be a factor of _____.

(1)

- A. Increases, 2
B. ✓ Decreases, 2
C. Increases, 4
D. Decreases, 4

Answer: B

The rate law is $\text{Rate} = k[A][B]^2$. Doubling $[A]$ multiplies the rate by 2, and halving $[B]$ multiplies the rate by $(1/2)^2 = 1/4$; the overall effect is $2 * (1/4) = 1/2$, meaning the rate decreases by a factor of 2.

41. The molecular geometry of H_3O^+ ion is

(1)

- A. Linear
B. Tetrahedral
C. Bent
D. ✓ **Trigonal pyramidal**

Answer: D

The hydronium ion (H_3O^+) has 3 bonding pairs and 1 lone pair on the oxygen atom, giving it a trigonal pyramidal molecular geometry.

42. What is the final concentration of Cl^- ion when 250ml of 0.20M CaCl_2 solution is mixed with 250ml of 0.4M KCl solution? (Assume additive volumes)

(1)

- A. 1.6M
B. ✓ 0.4M
C. 0.20M
D. 0.60M

Answer: B

The moles of chloride from CaCl_2 are $0.250 \text{ L} \times 0.20 \text{ M} \times 2 = 0.10 \text{ mol}$, and from KCl are $0.250 \text{ L} \times 0.4 \text{ M} \times 1 = 0.10 \text{ mol}$. The total concentration in 0.500 L is $(0.10 + 0.10) / 0.500 = 0.40 \text{ M}$.

43. Which of the following is used in the reaction called saponification?

(1)

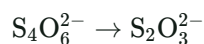
- A. ✓ Strong base
B. Strong acid
C. Hydrogen
D. Nickel

Answer: A

Saponification is the alkaline hydrolysis of fats and oils using a strong base such as NaOH or KOH to produce soap and glycerol.

44. How many electrons will appear when the following half-reaction is balanced?

(1)



- A. 3
C. 4
B. ✓ 2
D. 1

Answer: B

Balancing the sulfur atoms gives $\text{S4O6}^{2-} \rightarrow 2\text{S2O3}^{2-}$. The oxygen atoms are balanced (6 on each side), and adding 2 electrons to the left balances the charge (-2 on the left, -4 on the right).

45. PKa values of three acids x, y and z are 4.5, 3.5 and 6.5, respectively. Which of the following represents the correct order of acid strength? (1)

A. $x > y > z$ B. $z > x > y$
C. ✓ $y > x > z$ D. $z > y > x$

Answer: C

Acid strength is inversely related to pKa, meaning a smaller pKa corresponds to a stronger acid. Since $y (3.5) < x (4.5) < z (6.5)$, the order of acid strength is $y > x > z$.

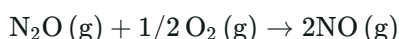
46. Standard electrode potential for $\text{Sn}^{4+}/\text{Sn}^{2+}$ couple is +0.15V and that for the Cr^{3+}/Cr couple is -0.74V. These two couples in their standard state are connected to make a spontaneous reaction. The cell potential will be (1)

A. +1.83V B. +1.19V
C. ✓ +0.89V D. +0.18V

Answer: C

For a spontaneous cell, the couple with the higher standard reduction potential acts as the cathode. Thus, $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} = +0.15 \text{ V} - (-0.74 \text{ V}) = +0.89 \text{ V}$.

47. The enthalpies of formation of gaseous N_2O and NO at 298K are 82 and 90KJ/mol, respectively. The enthalpy change for the reaction (1)



is

A. -8KJ B. ✓ 98KJ
C. -74KJ D. 8KJ

Answer: B

The standard enthalpy change is $\Delta H^\circ_{\text{rxn}} = 2\Delta H^\circ_{\text{f}}(\text{NO}) - \Delta H^\circ_{\text{f}}(\text{N}_2\text{O}) - 1/2\Delta H^\circ_{\text{f}}(\text{O}_2) = 2(90 \text{ kJ/mol}) - 82 \text{ kJ/mol} - 0 = 98 \text{ kJ}$.

48. The following data were collected at the end point of a titration performed to find the molarity of an HCl solution. Volume of acid (HCl) used = 14.4ml Volume of base (NaOH) used = 22.4ml Molarity of standard base (NaOH) = 0.20M On the basis of the above data, what is the molarity of the acid solution? (1)

A. 1.6M B. 0.64M
C. ✓ 0.31M D. 0.13M

Answer: C

Using the stoichiometric relationship $M_a V_a = M_b V_b$ for a monoprotic acid-base titration, $M_a = (0.20 \text{ M} \times 22.4 \text{ mL}) / 14.4 \text{ mL} = 0.31 \text{ M}$.

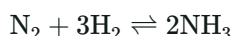
49. The hybridization of the central atom in the XeF_4 molecule is (1)

A. Sp^2 B. Sp^3
C. Sp^3d D. ✓ Sp^3d^2

Answer: D

Xenon in XeF_4 has 4 bonding pairs and 2 lone pairs, yielding a steric number of 6. A steric number of 6 corresponds to sp^3d^2 hybridization (square planar geometry).

50. For the reaction. (1)



The rate of disappearance of H_2 is $0.01 \text{ mol L}^{-1} \text{ min}^{-1}$. The rate of appearance of NH_3 would be

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, rate of appearance of $\text{NH}_3 = (2/3) \times (\text{rate of disappearance of } \text{H}_2) = (2/3) \times 0.01 \text{ mol L}^{-1} \text{ min}^{-1} \approx 0.007 \text{ mol L}^{-1} \text{ min}^{-1}$.

51. Bakelite is obtained from phenol by reacting with (1)

- A. ✓ HCHO B. $(\text{CH}_2\text{OH})_2$
C. CH_3CHO D. CH_3COCH_3

Answer: A

Bakelite is a thermosetting phenol-formaldehyde polymer prepared by the condensation reaction of phenol with formaldehyde (HCHO).

52. In which one of the following numbers are all of the zeros significant? (1)

- A. ✓ 100.09009 B. 0.14329
C. 0.1 D. 0.003002

Answer: A

In 100.09009, all zeros are captive (located between non-zero digits), making every zero significant. In the other options, leading zeros are not significant.

53. An aqueous solution contains 0.100M NaOH at 25.0°C . The PH of the solution is? (1)

- A. 0.1 B. 1
C. 7 D. ✓ 13

Answer: D

For 0.100 M NaOH, a strong base, $[\text{OH}^-] = 0.100 \text{ M}$, giving $\text{pOH} = -\log(0.100) = 1.0$. Therefore, $\text{pH} = 14 - \text{pOH} = 13$.

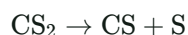
54. The solubility of oxygen gas in water at 25°C and 1.0 atm pressure of oxygen is 0.41g/L. the solubility of oxygen in water at 3.0 atm and 25°C is g/L. (1)

- A. 0.014 B. 0.31
C. 0.041 D. ✓ 0.123

Answer: D

According to Henry's law, gas solubility is directly proportional to partial pressure ($S \propto P$). With an initial solubility of 0.041 g/L at 1.0 atm, tripling the pressure to 3.0 atm increases the solubility to $3 \times 0.041 = 0.123 \text{ g/L}$.

55. The decomposition of carbon disulphide, CS_2 , to carbon mono sulphide, CS, and sulphur is first order with $K = 2.8 \times 10^{-7} \text{ s}^{-1}$ at 1000°C . What is the half-life of the reaction below at 1000°C ? (1)



- A. $5.0 \times 10^7 \text{ s}$ B. $4.7 \times 10^{-6} \text{ s}$
C. $3.8 \times 10^5 \text{ s}$ D. ✓ 2.5×10^6

Answer: D

For a first-order reaction, the half-life is given by $t_{1/2} = \ln(2)/k = 0.693 / (2.8 \times 10^{-7} \text{ s}^{-1}) \approx 2.5 \times 10^6 \text{ s}$.

56. The PK_a of a weak monoprotic acid is 4.8. What should be the ratio of $[\text{Acid}]/[\text{Salt}]$ of a buffer, if $\text{PH} = 5.8$ is required? (1)

- A. ✓ 0.1 B. 1
C. 2 D. 10

Answer: A

Using the Henderson-Hasselbalch equation, $\text{pH} = \text{pK}_a + \log([\text{Salt}]/[\text{Acid}])$, so $5.8 = 4.8 + \log([\text{Salt}]/[\text{Acid}])$, which gives $[\text{Salt}]/[\text{Acid}] = 10$, and thus the inverted ratio $[\text{Acid}]/[\text{Salt}] = 0.1$.

57. The dissolution of water in octane (C_8H_{18}) is prevented by (1)
- A. Dipole-dipole attraction between octane molecules.
 - B. ✓ **Hydrogen bonding between water molecules.**
 - C. London dispersion forces between octane molecules.
 - D. Repulsion between like charged water and octane molecules.

Answer: B

Water is a polar molecule held together by strong hydrogen bonds, which cannot be effectively replaced by the weak dispersion forces between water and nonpolar octane molecules.

58. At 445^0C , K_c for the following reaction is 0.020. (1)



A mixture of H_2 , I_2 , and HI in a vessel at 445^0C has the following concentrations: $[HI] = 2.0M$, $[H_2] = 0.5M$ and $[I_2] = 0.10M$, which one of the following statements concerning the reaction quotient, Q_c , is true for the above system?

- A. Q_c is less than K_c ; more HI will be produced.
- B. Q_c is greater than K_c ; more HI will be produced.
- C. ✓ **Q_c is less than K_c ; more H_2 and I_2 will be produced.**
- D. Q_c is greater than K_c ; more H_2 and I_2 will be produced.

Answer: C

The reaction quotient is $Q_c = [H_2][I_2]/[HI]^2 = (0.5 \times 0.10)/(2.0)^2 = 0.0125$. Since $Q_c < K_c$ (0.020), the system will shift to the right, producing more H_2 and I_2 .

59. Natural rubber is a polymer of (1)
- | | |
|--------------|----------------------|
| A. Butadiene | B. ✓ Isoprene |
| C. Neoprene | D. Styrene |

Answer: B

Natural rubber is cis-1,4-polyisoprene, formed by the polymerization of isoprene (2-methylbuta-1,3-diene).

60. Which of the following statements is true? (1)
- A. All forms of electromagnetic radiation are visible.
 - B. Radio waves have shorter wavelength than visible light.
 - C. Ultraviolet light has longer wavelengths than visible light.
 - D. ✓ **The frequency of radiation increases as the wavelength decreases.**

Answer: D

Since the speed of light is constant ($c = \lambda\nu$), frequency (ν) is inversely proportional to wavelength (λ), meaning frequency increases as wavelength decreases.

61. If the enthalpy change for a certain reaction $A \rightarrow B$ is $-2KJ$ at $300K$, what would be the entropy change in the surroundings? (1)
- | | |
|----------------------------------|--------------------------|
| A. ✓ $6.67J/K$ | B. $40J/K$ |
| C. $-3.6 \times 10^6 J/K$ | D. $3.6 \times 10^6 J/K$ |

Answer: A

The entropy change of the surroundings is given by $\Delta S_{surr} = -\Delta H_{sys} / T = -(-2000 J) / 300 K = +6.67 J/K$.

62. During the electrolysis of an aqueous solution of copper sulphate using platinum electrodes, the reaction takes place at the anode is (1)



Answer: C

With inert platinum electrodes, water is oxidized at the anode rather than the electrode itself or sulfate ions, producing oxygen gas:
 $2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + \text{O}_2 + 4\text{e}^-$.

63. What is the major product of the reaction? (1)

[Figure: The stem carries a reaction scheme: a benzene ring (hexagon with three inner double-bond lines) drawn on the left. At the ring carbon on the upper right an acetyl group is attached, drawn as a bond up to a carbon that carries a double-bonded O above it and a plain bond out to the right (a methyl). At the ring carbon immediately below that one (the ortho position) a bond runs down-right to the label Br. To the right of the structure a long horizontal reaction arrow points right, with NaOH written above it and nothing written below it. The four options are pictures, all built on the same benzene ring with a substituent at the top-right ring carbon and another at the ortho position below it. A: top-right substituent is a carbon double-bonded to O above and single-bonded out to the right to the label ON; ortho substituent is Br. B: top-right substituent is a carbon double-bonded to O above and single-bonded to OH; ortho substituent is OH. C: top-right substituent is a carbon double-bonded to O above and single-bonded to ON; ortho substituent is OH. D: top-right substituent is a single carbon carrying three OH labels (one drawn up-left, one up-right, one to the right); ortho substituent is Br.]

- A. $\checkmark$ [structure] benzene ring carrying a C(=O)-ON group and, on the adjacent (ortho) ring carbon, Br
 B. [structure] benzene ring carrying a C(=O)-OH group and, on the adjacent (ortho) ring carbon, OH
 C. [structure] benzene ring carrying a C(=O)-ON group and, on the adjacent (ortho) ring carbon, OH
 D. [structure] benzene ring carrying a carbon bearing three OH groups and, on the adjacent (ortho) ring carbon, Br

Answer: A

Base-promoted saponification converts the ester into the sodium carboxylate salt (-COONa). The aryl bromide bond is unreactive under these conditions because aryl halides do not readily undergo nucleophilic aromatic substitution without strong electron-withdrawing groups.

64. Which of the following is an acceptable IUPAC name for the organic compound shown below? (1)

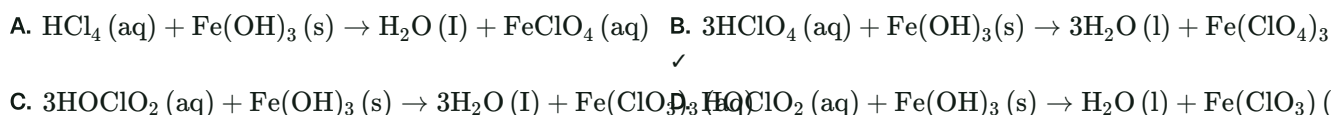
[Figure: A scanned skeletal (zig-zag) structure of a carboxylic acid, drawn left to right. At the far left a carbon bears two methyl groups drawn as short bonds going up-left and down-left (an isopropyl end). From that branch carbon the chain zig-zags right through four further vertices (up, down, up, down) and ends at a carbon that carries a double-bonded O drawn above it and a bond to the right to the label OH. Counting the branch carbon plus one of its two methyls into the longest chain gives an eight-carbon acid chain with a methyl substituent on the carbon next to the far end. No numbers, stereochemistry or other labels are drawn.]

- A. Octanoic acid B. 7-methyl heptanoic acid
 C. δ - methyl heptanoic acid D. $\checkmark$ 7 - methyl octanoic acid

Answer: D

The longest continuous carbon chain containing the carboxylic acid group has 8 carbons, making it an octanoic acid. Numbering starts at the carboxylic carbon (C-1), placing the methyl branch at carbon 7, yielding 7-methyloctanoic acid.

65. Which of the following describes the balanced molecular equation when perchloric acids is mixed with solid iron (III) hydroxide? (1)

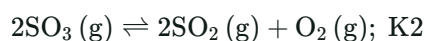
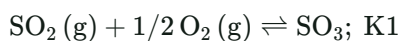


Answer: B

Perchloric acid has the formula HClO_4 and iron(III) hydroxide is $\text{Fe}(\text{OH})_3$. Three moles of monoprotic HClO_4 neutralize one mole of $\text{Fe}(\text{OH})_3$ to form $\text{Fe}(\text{ClO}_4)_3$ and 3 moles of water.

66. At 298 K the following two gaseous equilibrium involving SO_2 , SO_3 and O_2 are established.

(1)



Which of the following equilibrium expression is correct?

A. $K_1 = K_2$

B. $K_2 = K_1^2$

C. ✓ $K_2 = 1/K_1^2$

D. $K_2 = 1/K_1$

Answer: C

The second reaction is obtained by reversing the first reaction and multiplying its coefficients by 2. Therefore, its equilibrium constant is related by $K_2 = (1/K_1)^2 = 1/K_1^2$.

67. A compound is formed by the combination of V and X as follows. What is empirical formula for the compound?

(1)

[Figure: A small, low-resolution scanned strip showing five Lewis electron-dot symbols side by side, each a capital letter surrounded by dots. Left to right: V with a single dot above it (1 valence electron); W with two dots above it (2 valence electrons); X with two dots above, one dot to the left, one dot to the right and one dot below (5 valence electrons); Y with two dots above, one dot to the left, one dot to the right and two dots below (6 valence electrons); Z with two dots above, two dots to the left, one dot to the right and two dots below (7 valence electrons). Only V and X are referred to in the question.]

A. VX

B. V_2X

C. ✓ V_3X

D. VX_2

Answer: C

Element V has 1 valence electron and forms a +1 cation (or 1 covalent bond), whereas element X has 5 valence electrons and requires 3 electrons to complete its octet (valency of 3). Combining them gives the empirical formula V_3X .

68. ΔH for solid to liquid transitions for compound A is 2.73 Kcal/mol and for compound B is 3.0 Kcal/mol. The melting point for compound A is 0°C and the melting point for compound B is 30°C . the entropy changes ΔS_A and ΔS_B at the two transition temperatures are related as

(1)

A. $\Delta S_A = \Delta S_B$

B. $\Delta S_A < \Delta S_B$

C. ✓ $\Delta S_B < \Delta S_A$

D. $\Delta S_A = 300\Delta S_B/273$

Answer: C

69. Which of the following metals forms a volatile compound that is taken as an advantage for its extraction?

(1)

A. CO

B. Fe

C. ✓ Ni

D. W

Answer: C

In the Mond process, nickel is purified by reacting it with carbon monoxide to form volatile nickel tetracarbonyl, $\text{Ni}(\text{CO})_4$, which boils at 43°C and is subsequently thermally decomposed to yield pure nickel.

70. A 0.1M solution of HCl is dissolved in water. What species of ions are present at equilibrium, and what will be their equilibrium concentrations?

(1)

A. ✓ $[\text{H}_3\text{O}^+] = 0.1\text{M}$ $[\text{OH}^-] = 10^{-13}\text{M}$ $[\text{Cl}^-] = 0.1\text{M}$

B. $[\text{H}_3\text{O}^+] = 0.1\text{M}$ $[\text{OH}^-] = 0.1\text{M}$ $[\text{Cl}^-] = 0.1\text{M}$

C. $[\text{H}_3\text{O}^+] = 0.1\text{M}$ $[\text{OH}^-] = 10^{-13}\text{M}$ $[\text{Cl}^-] = 0\text{M}$

D. $[\text{H}_3\text{O}^+] = 10^{-13}\text{M}$ $[\text{Cl}^-] = 0.1\text{M}$ $[\text{OH}^-] = 0.1\text{M}$

Answer: A

HCl is a strong acid that completely dissociates in water, giving $[\text{H}_3\text{O}^+] = [\text{Cl}^-] = 0.1\text{M}$. Using the ion-product of water, $[\text{OH}^-] = K_w/[\text{H}_3\text{O}^+] = 10^{-14}/0.1 = 10^{-13}\text{M}$.

71. The following bases and their conjugate acids (as the chlorides) are available in the laboratory: NH_3 ($K_b = 1.8 \times 10^{-5}$), $\text{C}_6\text{H}_5\text{NCH}_3\text{CH}_2\text{NH}_2$ ($K_b = 6.4 \times 10^{-4}$) and CH_3NH_2 ($K_b = 4.4 \times 10^{-4}$). Which of these acid-base pairs are the best to prepare a buffer solution having a PH of about 9? (1)
- A. ✓ NH_3 + conjugate acid B. $\text{C}_6\text{H}_5\text{N}$ + conjugate acid
C. CH_3NH_2 + conjugate acid D. $\text{CH}_3\text{CH}_2\text{NH}_2$ + conjugate acid

Answer: A

A buffer functions best when $\text{pH} \approx \text{p}K_a$. For NH_3 , $K_b = 1.8 \times 10^{-5}$ gives $\text{p}K_b = 4.74$, so its conjugate acid NH_4^+ has $\text{p}K_a = 14 - 4.74 = 9.26$, which is closest to the desired pH of 9.

— END OF MARKING KEY —

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