



SUBJECT: **Chemistry**
DATE: 18th May 2023
TIME: 4:00 p.m. to 7:05 p.m.

Useful informationIdeal gas constant = $8.314 \text{ JK}^{-1}\text{mol}^{-1}$

Relative atomic masses: H = 1, C = 12, N = 14, O = 16, Na = 23, Cl = 35.5

A Periodic Table is included.

SECTION A**Answer ALL questions in this section.**

1. (a) Write the electron configuration in terms of s and p orbitals of the element which has 13 protons.

_____ (1)

- (b) In which period of the Periodic Table would you find the element which has the atomic number 16?

_____ (1)

- (c) Explain in terms of sub-atomic particles (protons, electrons and neutrons), the difference between ${}^6\text{Li}$ and ${}^7\text{Li}$.

_____ (1)

(Total: 3 marks)

2. Give the composition (the number of protons, neutrons and electrons) of the ions of sodium-23 (Na^+) and chlorine-37 (Cl^-).

_____ (3)

(Total: 3 marks)

Please turn the page.

3. (a) State the general trend in the first ionization energies of the Period 3 elements, sodium to chlorine.

_____ (1)

- (b) Identify an element which deviates from this general trend.

_____ (1)

- (c) Explain why the element which you mentioned in part 3(b) deviates from the general trend.

_____ (2)

(Total: 4 marks)

4. (a) Write a balanced ionic half-equation which shows the reaction of chlorine as an oxidizing agent.

_____ (1)

- (b) Explain in terms of oxidizing power why bromine displaces iodine from potassium iodide but does **not** displace chlorine from potassium chloride.

_____ (1)

- (c) Write a fully balanced ionic equation which represents the reaction between bromine and potassium iodide.

_____ (2)

(Total: 4 marks)

5. (a) Explain the term 'boiling point of a liquid'.

_____ (1)

- (b) The molar mass of water is 18 g and that of methane is 16 g. One notes that the boiling point of water is 100 °C and that of methane is -162 °C. Explain the difference in the boiling points of water and methane.

_____ (2)

- (c) How do impurities affect the boiling point of a liquid?

_____ (1)

(Total: 4 marks)

6. (a) Explain the bonding in a macromolecular crystal and in a molecular crystal.

(1½)

(b) Which of the two crystals mentioned in part 6(a) would have the higher melting point?

(½)

(c) Name an element which exists as a macromolecular crystal at room temperature.

(1)

(d) Name an element which consists of molecular crystals at room temperature.

(1)

(Total: 4 marks)

7. (a) Which of the following contains the fewer molecules: 1 g of hydrogen (H₂) or 8 g of oxygen (O₂)? Explain.

(1½)

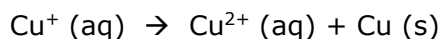
(b) An organic compound X contains the elements carbon, oxygen and hydrogen only. A sample of X was found to contain 62.07% carbon and 27.60% oxygen by mass. The molar mass of the compound X is 58 g. What is the molecular formula of the organic compound X?

(2½)

(Total: 4 marks)

Please turn the page.

8. Copper(I) ions are said to be unstable in aqueous solutions. This change is represented by the following ionic equation:



- (a) Define the term disproportionation.

_____ (1)

- (b) Explain in terms of oxidation numbers, why the above reaction is a disproportionation reaction.

_____ (2)

- (c) Consider the following reaction: Cu^{2+} reacts with I^- to give CuI and I_2
Is this a disproportionation reaction? Explain your answer.

_____ (1)

(Total: 4 marks)

SECTION B

Answer ALL questions in this section.

9. The ideal gas equation shows the relationship between the volume of a gas, the pressure it exerts and its temperature.

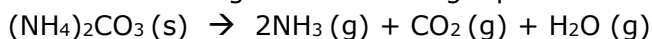
- (a) Write the ideal gas equation.

_____ (1)

- (b) A gas burner underneath a hot air balloon heats the air inside it. Explain why the balloon floats in air in terms of changes in temperature and volume.

_____ (2)

- (c) In a lab experiment, 0.8 g of ammonium carbonate decompose completely to ammonia, water and carbon dioxide according to the following equation:



Calculate the total volume of gas (in dm^3) formed at a temperature of $250\text{ }^\circ\text{C}$ and a pressure of $1 \times 10^6 \text{ Nm}^{-2}$.

(3)

(Total: 6 marks)

10. The enthalpies of formation of hydrocarbons are difficult or impossible to measure by practical means. However, they can be measured by the use of Hess's cycles.

(a) State Hess's law.

(2)

- (b) The standard enthalpies of combustion of carbon, hydrogen and ethyne are -394 kJmol^{-1} , -286 kJmol^{-1} and -1300 kJmol^{-1} respectively. These values can be used to determine the standard enthalpy of formation of ethyne (C_2H_2).

Draw a Hess's cycle to show how the enthalpy of formation of ethyne can be calculated from the given information.

(2)

- (c) Calculate the enthalpy of formation of ethyne.

(2)

(Total: 6 marks)

Please turn the page.

11. The amino acid 2-aminopropanoic acid is a chiral molecule.

- (a) Draw the two optical isomers of this amino acid using the standard convention of solid, wedged, and dashed lines.

(1)

- (b) Circle a chiral carbon atom in one of your drawn structures.

(½)

- (c) Describe how molecules with this type of isomerism can be distinguished from each other by physical means.

(1)

- (d) Discuss the biological importance of this type of isomerism with reference to ibuprofen.

(1)

- (e) Amino acids are the building blocks of polypeptides and proteins. The peptide linkage between one monomer and another is similar to that present in polyamides such as nylon-66.

- (i) Draw the repeating unit of nylon-66.

(2)

- (ii) Circle the amide linkage in your diagram.

(½)

(Total: 6 marks)

12. A student carried out a redox titration to determine the concentration of an iodine solution, where 25.00 cm³ of the iodine solution required 22.50 cm³ of 0.200 mol dm⁻³ sodium thiosulfate solution for complete reaction. The thiosulfate ions (S₂O₃²⁻) form tetrathionate (S₄O₆²⁻) ions in this reaction.

(a) Write a balanced half ionic equation to show the oxidation of the thiosulfate ion.

_____ (1/2)

(b) Write a fully balanced ionic equation to show the reaction between iodine and thiosulfate ions.

_____ (1)

(c) Explain in terms of oxidation numbers, why the iodine is the oxidiser in this reaction.

_____ (1)

(d) Calculate the number of moles of thiosulfate ions which reacted with 25 cm³ of the iodine solution.

_____ (1)

(e) Calculate the concentration of the iodine solution.

_____ (2 1/2)

(Total: 6 marks)

Please turn the page.

13. The collision theory explains how collisions between molecules result in chemical change.

(a) Describe the concept of the collision theory.

(1½)

(b) What is the role of a catalyst in a reaction?

(1½)

(c) In the space below, sketch a graph which shows the distribution of molecular energies for a sample of gas.

In your sketch:

- (i) label the axes appropriately;
- (ii) mark the activation energy for a non-catalysed reaction and label it E_a ;
- (iii) shade the area which represents the fraction of molecules that will react in a non-catalysed reaction;
- (iv) mark the activation energy for a catalyzed reaction E_a (cat); and
- (v) mark with dots the area representing the fraction of molecules which react in the catalyzed reaction.

(3)

(Total: 6 marks)

SECTION C

Answer any TWO questions from this section. Write your answers on the lined pages of this booklet.

14. (a) Chemical equilibria are dynamic.
- State the condition that must be satisfied in order to have chemical equilibrium. (1)
 - State why equilibrium reactions are also called reversible reactions. (1)
 - Describe dynamic equilibrium. (2)
- (b) At 2000 °C, carbon dioxide decomposes into carbon monoxide and oxygen. This is a reversible reaction.
- Write the equation, including state symbols, for this reaction. (2)
 - Is this a homogeneous or a heterogeneous equilibrium? Explain. (2)
 - The amounts of each component in a 1 dm³ container at 2000 °C after equilibrium was reached were: 0.246 moles of carbon dioxide, 4.30 × 10⁻³ moles of carbon monoxide and 2.15 × 10⁻³ moles of oxygen. Calculate the equilibrium constant K_c at 2000 °C. Indicate the units. (4)
- (c) Nitrogen gas and hydrogen gas react together to produce ammonia gas. This is a reversible reaction. Consider the values of the equilibrium constant K_c at different temperatures for this reaction in the table below.

Temperature (°C)	K _c
300	1.34 × 10 ⁻⁹
400	3.67 × 10 ⁻¹¹
500	2.46 × 10 ⁻¹²
600	2.99 × 10 ⁻¹³

- Write the equation, including state symbols, for this reaction. (1)
- Write the expression for K_c for this reversible reaction and indicate its units. (2)
- The value of K_c changes with an increase in temperature. Indicate the change in terms of yield of ammonia with increase in temperature. (2)
- Considering the conclusion in part (c)(iii), predict whether the forward reaction (nitrogen reacts with hydrogen to give ammonia) is exothermic or endothermic. Explain your answer. (3)

(Total: 20 marks)

15. (a) In 1884, the Swedish chemist Svante Arrhenius, proposed the concept of acid and base according to the theory of ionisation. This concept is applicable to compounds that are soluble in water (i.e., where water is the solvent) only. It includes many common acids and bases, but other acids and bases do not fit into this Arrhenius concept.
- Define the terms Arrhenius acid and Arrhenius base. (2)
 - K_w is known as the ionic product of water. Give the expression for K_w. (1)
 - State the numerical value of K_w at 25 °C and give its units. (2)
 - Considering a 0.05 mol dm⁻³ sodium hydroxide solution and using the expression for K_w, find its pH. (5)

Question continues on the next page.

- (b) Apart from the Arrhenius definitions, there is the Brønsted-Lowry theory for acids and bases.
- (i) Define a Brønsted-Lowry acid and base. (2)
- (ii) Consider the following two reactions:
- $$\text{CH}_3\text{COOH (aq)} + \text{H}_2\text{O (l)} \rightleftharpoons \text{CH}_3\text{COO}^- \text{ (aq)} + \text{H}_3\text{O}^+ \text{ (aq)}$$
- $$\text{NH}_3 \text{ (aq)} + \text{H}_2\text{O (l)} \rightleftharpoons \text{NH}_4^+ \text{ (aq)} + \text{OH}^- \text{ (aq)}$$
- Identify the acid, the base, the conjugate acid and the conjugate base in each case. (4)
- (iii) Considering the above two reactions, comment on the acid-base nature of water. (2)
- (c) While 0.02 mol dm^{-3} hydrochloric acid $[\text{HCl (aq)}]$ and 0.02 mol dm^{-3} ethanoic acid $[\text{CH}_3\text{COOH (aq)}]$ have the same concentration, hydrochloric acid is a strong acid while ethanoic acid is a weak acid. Explain. (2)

(Total: 20 marks)

16. (a) The Periodic Table has the s-block, the p-block and the d-block. The d-block elements are located between the s-block and p-block.
- (i) Distinguish between an s-block, a p-block and a d-block element. (3)
- (ii) State the s-block elements in period 4 of the Periodic Table. (1)
- (iii) State the first and last elements of the p-block in period 4. (1)
- (iv) State the first and last elements of the d-block in period 4. (1)
- (v) State the difference between d-block elements and transition metals. (2)
- (vi) Zinc resides in the d-block but is not a transition metal. Explain. (2)
- (vii) Would scandium (atomic number 21) which forms only Sc^{3+} be classified as a transition metal? Explain. (2)
- (b) This is the definition of the term 'coordination compound' in the Britannica:
- coordination compound**, any of a class of substances with chemical structures in which a central metal atom is surrounded by nonmetal atoms or groups of atoms, called ligands, joined to it by chemical bonds. ...
- <https://www.britannica.com/science/coordination-compound>
- (i) Some ligands are H_2O , NH_3 and Cl^- . What makes them suitable as ligands? (1)
- (ii) The bonding between the central metal and the ligand can be explained in terms of dative covalent (coordinate) bonding. This is different from a 'normal' covalent bond. Explain. (2)
- (c) Consider the following complex ions: $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Cu}(\text{NH}_3)_2]^+$. In each case give the name, the charge on the central ion, and the coordination number. (5)

(Total: 20 marks)

17. Explain each of the following statements.

In all cases, unless otherwise indicated, give relevant equations, state the conditions and indicate the organic products that are produced.

- (a) We can distinguish between aldehydes and ketones through Fehling's test. Chemical equations are **not** necessary. (3)
- (b) Primary alcohols can be oxidised to aldehydes, while aldehydes can then be oxidized to carboxylic acids. (6)
- (c) The reduction of aldehydes and ketones give different types of alcohol. (5)
- (d) Propanol and ethanoic acid react together to give an ester. Name the ester. (6)

(Total: 20 marks)

