

Cork Institute of Technology

Higher Certificate in Science in Applied Biology – Stage 1

(NFQ – Level 6)

Autumn 2006

Chemistry

(Time: 3 Hours)

Instructions: Answer **five** questions in total.

Section A is compulsory.

Answer **TWO** questions from Section B, **ONE** question from Section C and **ONE** question from either Section B or C.

Use **separate** answer books for each section

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Dr M. Sheahan
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Section A

Q1. *Answer any 10 parts; all parts carry equal marks.*

- (i) What is the valence-shell electron configuration of an atom? Pick an element from the periodic table to illustrate the point.
- (ii) List the four quantum numbers by name and symbol.
- (iii) According to the Aufbau principle, which orbital is filled immediately *before* each of the following? $3p$, $4p$, $5p$.
- (iv) Draw the Lewis structure for the following ionic compounds:
 KCl and MgO .
- (v) Using the data provided, calculate the energy change in kJ / mol when lithium atoms lose an electron to bromine atoms to form isolated Li^+ and Br^- ions.
Ionization potential for $\text{Li} = + 520 \text{ kJ/mol}$.
Electron Affinity for $\text{Br} = - 325 \text{ kJ/mol}$
- (vi) Which element in each of the following pairs has the larger (more negative) electron affinity: F or Fe ; Ne or Na ?
- (vii) The underwritten gas phase reaction is first order in H_2 and first order in ICl . Write the rate law to represent this information.
$$\text{H}_2(\text{g}) + 2\text{ICl}(\text{g}) \rightarrow 2\text{HCl}(\text{g}) + \text{I}_2(\text{g})$$
- (viii) What graph should be drawn to prove that a reaction obeys first order kinetics? How would you determine the rate constant from such a plot?
- (ix) Distinguish between ionic and covalent bonds.

- (x) Determine the pH of a solution of the strong acid HNO_3 of concentration $0.025 \text{ mol dm}^{-3}$.
- (xi) The acid dissociation constant (K_a) of ethanoic acid (CH_3COOH) is 1.78×10^{-5} . Determine the pK_a of this acid.
- (xii) For each of the following properties of a system indicate whether it is an intensive property or an extensive property: (i) mass, (ii) temperature, (iii) heat capacity, and (iv) volume.
- (xiii) Distinguish between an exothermic process and an endothermic process.
- (xiv) What is a homologous series? Give two examples.
- (xv) State the Markovnikov Rule.
- (xvi) Give two structural formulae corresponding to the molecular formula C_5H_{10} .
- (20 marks)

Section B

- Q2. (a) (i) What is the difference between a pure covalent bond and a polar covalent bond? Show molecules which illustrates each type of bond.. (3 marks)
- (ii) Use electronegativity data to predict which bond in each of the following pairs is more polar. Show the direction of the electron pull.

$\text{C} - \text{H}$ or $\text{C} - \text{Cl}$

$\text{Si} - \text{Li}$ or $\text{Si} - \text{Cl}$

$\text{N} - \text{Cl}$ or $\text{N} - \text{Mg}$ (4 marks)

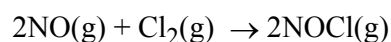
- (b) The table below compares the molecular mass, dipole moment and boiling points of four substances.

| | Molecular Mass (amu) | Dipole Moment (D) | B.p. (K) |
|---|---------------------------------|------------------------------|---------------------|
| $\text{CH}_3\text{CH}_2\text{CH}_3$ | 44.10 | 0.1 | 231 |
| CH_3OCH_3 | 46.07 | 1.3 | 248 |
| CH_3Cl | 50.49 | 1.9 | 249 |
| CH_3CN | 41.05 | 3.9 | 355 |

- (i) Comment on the data and the trend in each property. (5 marks)
- (ii) Identify and describe the type of intermolecular force which is responsible for the trend. (3 marks)
- (iii) What are the most dominant kinds of intermolecular forces in each of the following substances; O_2 , methanol (CH_3OH) and polyethylene ($\text{C}_n\text{H}_{2n+2}$) (3 marks)
- (iv) Rank intermolecular forces in order of increasing strength (2 marks)

- Q3. (a) “The periodic table can be described as a one page chemistry book”.
Write a brief note on the periodic table. In your description (i) name the rows and columns, (ii) explain what similarities elements in the same column share and (iii) locate the position of the metals, non-metals and metalloids in the table.
Identify an element in each category i.e. metals, non-metal, metalloid. (8 marks)
- (b) Properties like atomic radius (AR), ionization potential (IP) and electron affinity (EA) all vary from left to right and from top to bottom of the periodic table.
(i) Give the general trend in each property.
(ii) In the case of ionization potential, explain the observed trend.
(iii) Justify why the IP value of N is greater than that of O. (8 marks)
- (c) Draw the three **2p** orbitals. What distinguishes them from each other? What quantum numbers are associated with the **2p** orbital? (4 marks)

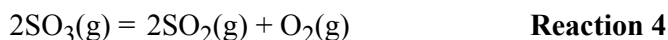
- Q4. (a) (i) What is meant by the order of a reaction?
(ii) What are the units for a first order rate constant? (4 marks)
- (b) The initial rates in the table were determined for the reaction



| Exp. No. | Initial [NO] (mol/dm ³) | Initial [Cl ₂] (mol/dm ³) | Initial Rate (M/s) |
|----------|--|--|-----------------------|
| 1 | 0.13 | 0.20 | 1 x 10 ⁻² |
| 2 | 0.26 | 0.20 | 4 x 10 ⁻² |
| 3 | 0.13 | 0.10 | 5 x 10 ⁻³ |

- (i) Write the rate law for the reaction.
(ii) Calculate a value for the specific rate constant *k*.
(iii) What is the reaction rate when both reactant concentrations are 0.12 mol/dm³? (9 marks)
- (c) (i) List three properties of a catalyst. Support your answer with examples.
(ii) What effect does a catalyst have on the rate, mechanism and activation energy of a chemical reaction? (7 marks)

Q5. (a) Give expressions for the equilibrium constant, K_c , for each of the following reactions:



(4 Marks)

(b) The standard enthalpy change for **Reaction 1** in part (a) is $+57.2 \text{ kJ mol}^{-1}$.

Indicate how (i) the equilibrium constant and (ii) the equilibrium position of this reaction would be influenced by an increase in the temperature of the system.

Explain the reasons for your answers. (5 Marks)

(c) Indicate how (i) the equilibrium constant and (ii) the equilibrium position of **Reaction 2** in part (a) would be influenced by an increase in the total volume of the system.

Explain the reasons for your answers. (5 Marks)

(d) The concentrations of H_2 , I_2 , and HI gases in an equilibrium mixture at 448°C were $6.50 \times 10^{-5} \text{ mol dm}^{-3}$, $1.07 \times 10^{-3} \text{ mol dm}^{-3}$ and $1.87 \times 10^{-3} \text{ mol dm}^{-3}$ respectively.

Determine the equilibrium constant, K_c , for **Reaction 3** in part (a) at 448°C . (4 Marks)

(e) The value of equilibrium constant for **Reaction 4** in part (a) at 827°C is 0.0271.

When the decomposition of $\text{SO}_3(\text{g})$ at 827°C reaches equilibrium, does the equilibrium mixture contain more $\text{SO}_3(\text{g})$ or $\text{SO}_2(\text{g})$? Give a reason for your answer. (2 marks)

Q6. The percentage iron in a soluble iron salt may be determined by gravimetric analysis. This analysis is based on the precipitation of the iron as a hydroxide after treatment with a large excess of ammonium solution. The hydroxide is subsequently converted to an iron oxide (Fe_2O_3) by combustion in a crucible and is weighed in this form.

- (a) Explain the underlined terms. (8 marks)
- (b) Name two other analysis techniques. (2 marks)
- (c) Given that the mass of iron in any mass of Fe_2O_3 can be calculated as follows

$$\text{Mass of iron} = \frac{\text{Mass of Fe}_2\text{O}_3 \times 112}{160}$$

use the underwritten data to determine the percentage of iron in the salt

Mass of Iron salt: 0.8g

Mass of crucible: 34.9g

Mass of crucible + contents after 1st heating: 35.14g

Mass of crucible + contents after 2nd heating: 35.14g. (6 marks)

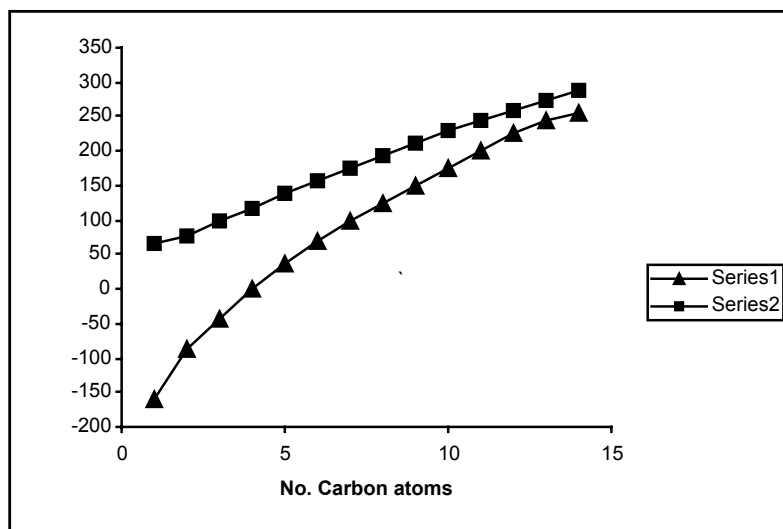
- (d) Calculate the theoretical percentage iron given that the salt used in the analysis is Ferrous ammonium sulfate $[(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}]$. Compare (comment on any differences between) the theoretical value with the value determined from the data supplied. (4 marks)

Section C

- Q7. (a) Write a note, which compares the chlorination (Cl_2) of Methane with the chlorination of 3-Methyl-2-pentene. The note should include the names and structural formulae for all possible products from both reactions. Account for the main differences in reactivity between alkanes and alkenes. (10 marks)
- (b) Show the reaction equation for the synthesis of (i) 2-Methylpentane and (ii) 2,3-Dibromo-4-Methyl-2-Pentene from 4-Methyl-2-Pentyne. Give the reaction conditions and identify the other reagent(s) required in each case. (6 marks)
- (c) Differentiate between an activating group and a deactivating group in benzene chemistry. Give **TWO** example of each type of group. (4 marks)

Q8. (a) The following plots show the boiling points (°C) of the straight-chain alkanes (series 1) and the straight-chain alcohols (series 2) as a function of the number of carbon atoms in the molecule.

- Identify the intermolecular forces that contribute the general trend observed. (2 marks)
- Account for the fact that the alkane curve starts at a much lower point on the temperature scale than the alcohol curve. (3 marks)
- Explain why the plots converge as the numbers of carbon atoms increases. (3 marks)



(b) “The products obtained from the oxidation of an alcohol depend on whether the alcohol is primary, secondary or tertiary and on the reagent(s) used to catalyse the reaction”

- Use appropriate examples (give names & structures) to distinguish between primary, secondary and tertiary alcohols. (6marks)
- Use the IUPAC rules, to name the following alcohols $\text{CH}_3(\text{CH}_2)_5\text{OH}$ and $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$.

Give the structure of the products that may be obtained from the oxidation of these alcohols.

Name and locate the functional group in each product obtained.

Give one difference between these oxidation reactions. (Hint: ranges of product that may be obtained) (6 marks)