

Cork Institute of Technology
Higher Certificate in Science in Applied Biology – Stage 1
(NFQ – Level 6)
Summer 2006
Chemistry
(Time: 3 Hours)

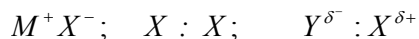
Answer **FIVE** questions. Question 1 is compulsory. Answer **TWO** questions from Section B and **ONE** question from Section C, and **ONE** from either Section B or C.
Use separate answer books for each section.

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Section A

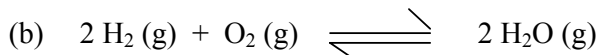
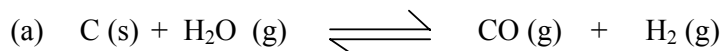
Q1. Attempt 10 parts. All parts carry two marks.

- (i) The following three illustrations describe three types of bonds. Label the diagrams



- (ii) What type of intermolecular/particle force can exist between non polar atoms or molecules? Give an example.
- (iii) What shapes would you expect for molecules with the following number of electron domains/pairs: 3 ; 5 ; 2 ?
- (iv) Which orbital in each of the following pairs is higher in energy:
5p or 5d; 4s or 3p; 6s or 4d.
- (v) Write the appropriate equilibrium constant expression K_c for each of the following:
- (a) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$
- (b) $2 Fe Cl_3 (s) + 3H_2O(g) \rightleftharpoons Fe_2O_3(s) + 6 HCl(g)$
- (vi) When the following reactions come to equilibrium, does the reaction mixture contain mostly reactants or mostly products
- (a) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad K_c = 1.2 \times 10^9$
- (b) $2 HCl (g) \rightleftharpoons H_2(g) + Cl_2(g) \quad K_c = 2.0 \times 10^{-17}$

(vii) For each of the following equilibria, use Le Châtelier's principle to predict the direction of the reaction when the volume is increased:



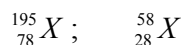
(viii) What is the trend in the following properties going across a period in the periodic table?

(a) atomic radius

(b) ionisation potential

(ix) Chlorine has two naturally occurring isotopes; $^{35}_{17}\text{Cl}$ which has an abundance of 75.77 % and an isotopic mass of 34.969 amu and $^{37}_{17}\text{Cl}$ with an abundance of 24.23 % and an isotopic mass of 36.966 amu. What is the atomic mass of Cl?

(x) Identify 'X' in each of the following cases;



(xi) What is Calorimetry?

Give an equation which may be used to calculate the enthalpy of a reaction based on information generated from a calorimetry process.

(xii) Distinguish between an intensive and an extensive state function. Give an example of each.

(xiii) Identify by structure, the Markovnikov and the anti-Markovnikov addition products in the following reaction.



(xiv) What is a functional group? Give two examples.

(xv) Draw structures for both the *cis* and *trans* isomers of 2-Butene.

Section B

- Q2. (a) The ground state electron configuration of a multielectron atom is written by following a series of 3 rules (principles).
- (i) What are these rules collectively called?
 - (ii) Define the three rules.
 - (iii) Applying these rules, give the expected ground state electron configuration for the following elements:
 N^7 ; Cr^{24} (6 marks)

- (b) (i) What are quantum numbers? How many of them are there and what does each one specify?
- (ii) Give all possible quantum numbers associated with the L shell ($n = 2$ level). (6 marks)

- (c) (i) Distinguish between atomic radii and ionic radii. (2 marks)
- (ii) Which atoms or ions in each of the following pairs would you expect to be larger? Explain.
- (a) O or O^{2-}
 - (b) Fe or Fe^{3+}
 - (c) O or S (6 marks)

- Q3. (a) Distinguish between
- (i) ionic and covalent bonds
 - (ii) ionisation energy and electron affinity. (4 marks)

- (b) Explain why energy is usually released when an electron is added to a neutral atom but absorbed when an electron is removed from a neutral atom? Identify groups in the periodic table which best illustrate this point. (6 marks)

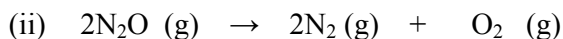
- (c) Draw the Lewis Structure for each of the following, giving as many resonance structures as you can where appropriate.
- (i) CBr_4
 - (ii) O_2^{2-}
 - (iii) NO^+
 - (iv) SO_3

Hence or otherwise predict the shape of each species. (10 marks)

Q4. (a) What is meant by the term initial rate? Explain how it may be determined.

(4 marks)

(b) For each of the following gas phase reactions, indicate how the rate of disappearance of each reactant is related to the rate of appearance of each product.



In the case of (ii) above, if the rate of disappearance of N_2O is 0.37M/s what is the rate of appearance of each of the products? (6 marks)

(c) Nitrosyl bromide decomposes at 10°C according to the following reaction:



Using the kinetic data outlined in the table below

Time/min	0	10	20	30	40
[NOBr],M	0.0400	0.0303	0.0244	0.0204	0.0175

(i) Prove that the reaction obeys 2^{nd} order kinetics.

(ii) Determine a value for the specific rate constant.

(iii) What are the units for a 2^{nd} order rate constant?

(10 marks)

- Q5. (a) Determine the pH of each of the following strong acid or base solutions:
- (i) a $2.5 \times 10^{-4} \text{ mol dm}^{-3}$ solution of HCl ;
 - (ii) a $0.075 \text{ mol dm}^{-3}$ solution of H_2SO_4 ;
 - (iii) a solution containing 0.385g of HNO_3 per 100cm^3 of solution;
 - (iv) a solution containing 0.032g of NaOH per dm^3 of solution. (8 marks)
- (b) Use the pK_a data in the following table to arrange the acids in order of increasing acid strength (weakest acid first). Explain the reasons for your answer. (5 marks)

Acid	$\text{C}_4\text{H}_9\text{COOH}$	HCl	HNO_2	H_2PO_4^-	CH_3COOH	$\text{C}_6\text{H}_5\text{OH}$
pK_a	4.86	-7.0	3.34	7.21	4.75	9.89

- (c) Determine the acid dissociation constant (K_a) of pentanoic acid ($\text{C}_4\text{H}_9\text{COOH}$). (2 marks)
 - (d) Give the chemical formula for the conjugate base of nitrous acid (HNO_2) and determine the pK_b of the conjugate base. (2 marks)
 - (e) Determine the pH of a buffer mixture prepared by mixing 100cm^3 of a 0.05 mol dm^{-3} ethanoic acid (CH_3COOH) solution with 100cm^3 of a 0.01 mol dm^{-3} sodium ethanoate (CH_3COONa) solution. (3 marks)
- Q6. (i) What is recrystallisation? (2 marks)
- (ii) Describe the process in detail. (5 marks)
 - (iii) List three characteristics of an ideal recrystallisation solvent. Give an example. (3 marks)
 - (iv) The purity of a recrystallised material may be determined by its melting point (m.p). Explain what is meant by melting point and melting point range. (3 marks)
 - (v) How would you know from the m.p. value that the sample was contaminated or wet? (2 marks)
 - (vi) Describe briefly the method of melting point determination. (5 marks)

Section C

- Q7. (a) Menthol is an organic compound containing Carbon, Hydrogen and Oxygen. It can be extracted from peppermint and other mint oils. It has local anaesthetic properties and is widely used to relieve minor throat irritations. Its C: H: O ratio is such that it has the same empirical and molecular formulae.
- (i) Distinguish between an empirical and a molecular formula. (2 marks)
 - (ii) Perform the appropriate calculations to determine the empirical formula of Menthol if the combustion of a 0.1005g sample produces 0.2829g of CO₂ and 0.1159g of water. (6 marks)
 - (iii) Write a balanced equation for the combustion of Menthol in oxygen to produce carbon dioxide and water vapour. (3 marks)
 - (iv) Show the structure of Menthol if its IUPAC name is 5-Methyl-2-Propyl-1-Cyclohexanol. (1 mark)
- (b) (i) Comment briefly on the solubility of alcohols in water and non-polar solvents. (4 marks)
- (ii) Write the reaction equation for the dehydration of 3-Methyl-1-Butanol. Show the reactions conditions. Name and give the structural formula for the product. (4 marks)
- Q8. Despite being unsaturated, aromatic hydrocarbons do not readily react. If benzene is forced to react by increasing the temperature or by the addition of a catalyst, it undergoes electrophilic substitution reactions rather than an addition reaction which would be typical of unsaturated aliphatic molecules.
- (a) Using an example of each type, distinguish clearly between aliphatic and aromatic hydrocarbons. (4 marks)
 - (b) What does the term unsaturated mean in the context of organic molecules? (2 marks)
 - (c) Using the bromination of benzene as an example, discuss the mechanism of a typical electrophilic substitution reaction. Show each step involved in the reaction and explain how the catalyst facilitates the reaction. (8 marks)

- (d) Explain why benzene does not undergo addition reactions. (2 marks)
- (e) Which reaction would you expect to take place more readily, the bromination of benzene or the bromination of aniline ($\text{C}_6\text{H}_5\text{NH}_2$)? Give a reason for your answer. (4 marks)