

# Cork Institute of Technology

Higher Certificate in Science in Applied Biology – Stage 1

(National Certificate in Science in Applied Biology – Stage 1)

(NFQ – Level 6)

Summer 2005

**Chemistry**

(Time: 3 Hours)

## Instructions

Answer **FIVE** questions in total.

**Section A is compulsory.**

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

Examiners: Dr. R. Hourihane

Dr. M. Sheahan

Dr. T. Beresford

## Section A

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

- (i) Give the expected ground state configuration for each of the following elements: Ti, Cu and N.
- (ii) Which of the following combinations of quantum numbers are not allowed?  
  
(a)  $n = 3, l = 0, m_l = -1$ ;    (b)  $n = 3, l = 1, m_l = 1$ ;    (c)  $n = 4, l = 4, m_l = 0$
- (iii) Which atom in each of the following pairs has the larger radius?  
  
Na or K;                      Li or Ba
- (iv) What is lattice energy?
- (v) What are intramolecular forces? Give two examples of these forces.
- (vi) Which of the following bonds are polar?  
  
B — Cl;      Cl — Cl;      P — F;      O — Br
- (vii) Distinguish clearly between the terms heat capacity and specific heat capacity.
- (viii) What is the change in internal energy of a system that does 7.02 kJ of work and absorbs 888J of heat?

- (ix) What is the order with respect to each species and the overall reaction order in a reaction defined by the rate law?  $\text{Rate} = k [\text{NO}]^2 [\text{O}_2]$
- (x) Give the units for the rate constant of a second order reaction.
- (xi) Will the  $K_c$  value for the decomposition reaction  $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$  increase, decrease or remain the same if  $\text{NO}_2$  is removed as it is formed from the reaction mixture? Justify your answer.
- (xii) The equilibrium constant ( $K_c$ ) for the reaction  $2\text{SO}_3(\text{g}) \rightleftharpoons 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g})$  is  $2.4 \times 10^{-3}$  at  $200^\circ\text{C}$ . Write an expression for  $K_c$  for the reverse reaction and determine its value at  $200^\circ\text{C}$ .
- (xiii) What is a saturated hydrocarbon? Give an example.
- (xiv) Using the IUPAC rules, name the following molecule and identify its functional group:  $(\text{CH}_3)_2\text{CH}(\text{CH}_2)_2\text{CH}(\text{OH})\text{CH}_3$ . Give one example of another functional group.

## Section B

- Q2. (a) Name the three subatomic particles. Give the charge, mass and location within the atom of all three. (6 marks)

- (b) (i) What is an isotope? How could one tell from the periodic table that an isotope of any element exists? (2 marks)

- (ii) Magnesium has three naturally occurring isotopes:

$^{24}\text{Mg}$ (23.983 a.m.u)	78.99%
$^{25}\text{Mg}$ (24.986 a.m.u)	10.00%
$^{26}\text{Mg}$ (25.982 a.m.u)	11.01%

Calculate the average atomic mass of Magnesium correct to 2 significant figures. (5 marks)

- (c) For the listed elements, predict the most common ion formed in each case. Justify your predictions using electron configurations and the periodic table.

Na, Ca, Cl and Fe (7 marks)

Q3. (a) (i) List the steps in the procedure for drawing Lewis structures. (3 marks)

(ii) Applying the rules listed in (i) above, draw Lewis structures for  $\text{NH}_3$ ,  $\text{PCl}_5$ , and  $\text{BrO}_3^-$ . Hence or otherwise, predict the shape of each of the three species. (7 marks)

(b) Ionic and covalent compounds differ significantly from each other. Distinguish between them under the following headings:

- (i) Appearance
- (ii) Solubility in aqueous and organic solvents
- (iii) Boiling points and melting points
- (iv) Most common ions produced
- (v) Groups from the periodic table involved in each type of bond. (7 marks)

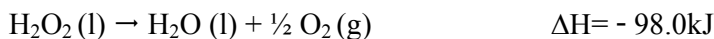
(c) Why are monoatomic cations smaller than their corresponding neutral atoms while the reverse is true for monoatomic anions? (3 marks)

Q4. (a) (i) State Hess's Law. (2 marks)

(ii) Hydrogen Peroxide ( $\text{H}_2\text{O}_2$ ) is a colorless liquid whose solutions are used as bleach and as an antiseptic. It can be prepared from Hydrogen and Oxygen in the following reaction:

$$\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}_2(\text{l})$$

Apply Hess's law to calculate the enthalpy change for this reaction using the following data:



(b) Heat is defined as the energy that flows into or out of a system because of a difference in temperature between the system and its surroundings. Enthalpy is an extensive property (of a substance) and it is a state function. Enthalpies of different reactions are only comparable when they are quoted in their standard state.

Clearly explain each of the underlined terms.

Examples may be used to support your answer. (12 marks)

- Q5. (a) Write an expression for the Arrhenius equation and label each of the variables in the expression. (4 marks)
- (b) Rate constants for the reaction  $2\text{N}_2\text{O}(\text{g}) \rightarrow 4\text{NO}(\text{g}) + \text{O}_2(\text{g})$  exhibit the following temperature dependence:

Temperature (°C)	$k$ (s <sup>-1</sup> )	Temp. (K)	1 / Temp. (K <sup>-1</sup> )	ln $k$
25	$3.7 \times 10^{-5}$			
45	$5.1 \times 10^{-4}$			
55	$1.7 \times 10^{-3}$			
65	$5.2 \times 10^{-3}$			

- (i) Copy completed table into your answer book. (3 marks)
- (ii) Plot the appropriate graph and determine the activation energy (in kJ mol<sup>-1</sup>) for this reaction.  $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ . (7 marks)
- (c) (i) Distinguish between homogeneous and heterogeneous catalyses. (2 marks)
- (ii) Describe in detail the steps involved in heterogeneous catalysis. Supplement your answer with relevant diagrams. (4 marks)
- Q6. (a) Write a brief but comprehensive note on the effects of (i) concentration changes, (ii) pressure / volume changes and (iii) temperature changes on the composition of an equilibrium mixture. The decomposition reaction of  $\text{CO}_2$  can be used as an example to support your answer



- (b) Phosphorus Pentachloride ( $\text{PCl}_5$ ) decomposes according to the equation



- (i) In an experiment, 1 mole of  $\text{PCl}_5$  is placed in a 1L container and heated to 160°C. The equilibrium concentration of each species was found to be as follows:  
 $[\text{PCl}_5] = 0.865\text{M}$ ;  $[\text{PCl}_3]$  and  $[\text{Cl}_2] = 0.135\text{M}$ .  
 Calculate the value of the equilibrium constant ( $K_c$ ) at 160°C. (4 marks)
- (ii) To establish equilibrium in the same reaction at 250°C ( $K_c = 3.8 \times 10^{-2}$ ), 0.100 moles of  $\text{PCl}_5$  are introduced into a 4L flask. How many moles of each gas should be present when equilibrium is established? Verify your answer by substituting into the  $K_c$  expression. (7 marks)

## Section C

Q7. Alkanes are chemically inert to most reagents; however they do undergo some very important reactions such as oxidation and halogenation. The oxidation (combustion) of methane is a common source of heat in many homes while the haloalkanes (halogenated alkanes) are common industrial chemicals.

(a) Write a balanced equation for the combustion reaction of methane. (2 marks)

(b) Using the chlorination of methane as an example of a halogenation reaction:

(i) Name and draw structural formulae for all possible products generated in this reaction. (8 marks)

(ii) Indicate the conditions necessary for the reaction to occur. (1 mark)

(iii) Define the term 'inert' and explain why the alkanes are relatively inert. (3 marks)

(c) Using the IUPAC system, name the reactant, name and draw structural formula for the product obtained in each of the following reactions:

(i)  $\text{CH}_3\text{CH}=\text{CHCH}_3 + \text{H}_2 \longrightarrow ?$

(ii)  $\text{CH}_3\text{CH}_2\text{CH}=\text{C}(\text{CH}_3)_2 + \text{H}_2 \longrightarrow ?$  (6 marks)

Q8. (a) The enthalpy of neutralization of a strong acid with a strong base may be easily measured by simple calorimetry. Explain each of the underlined terms. (6 marks)

(b) Given the following data, calculate the  $\Delta H_{\text{neutralization}}$  of 1M Hydrochloric acid in kJ / mol.

Volume of acid =  $20\text{cm}^3$

Volume of  $\text{H}_2\text{O}$  added =  $80\text{cm}^3$

Initial temperature =  $16.5^\circ\text{C}$

Final temperature =  $19.0^\circ\text{C}$

Specific Heat capacity  $\text{H}_2\text{O} = 4180 \text{ J kg}^{-1} \text{ K}^{-1}$

Assume the density of the solution =  $1 \text{ g / cm}^3$  (10 marks)

(c) Another enthalpy value is the standard enthalpy of formation. Give the symbol for this quantity. What does the term standard mean in this context? (4 marks)