

Cork Institute of Technology  
Bachelor of Science in Applied BioSciences – Stage 1

(NFQ Level 7)

Summer 2007

**Chemistry**

(Time: 3 Hours)

**Instructions**

Answer **FIVE** questions. Question 1 is compulsory. Attempt two questions from Section B, one question from Section C and one other question from either B or C.

Examiners: Dr. R. Hourihane  
Prof. R. J. Fitzgerald

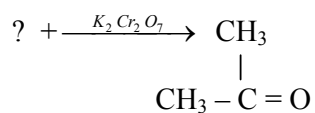
**Section A**

Attempt 10 parts.

All carry equal marks.

- (i) Write the groundstate electronic configuration of each of the following:
- (a) N
  - (b) Cr      Show the orbital occupancy of the valance shell in each case.
- (ii) What is a covalent bond? What groups from the periodic table are most likely to be involved in this type of bond?
- (iii) Give two assumptions made by Daltons atomic theory.
- (iv) The cathode ray experiment led to the discovery of which of the subatomic particles?  
What is the charge on this particle?
- (v) Calculate the pH of a  $0.5 \text{ mol dm}^{-3}$  NaOH solution.
- (vi) Identify the acid, base, conjugate acid and conjugate base in the following reaction:
- $$\text{NH}_4^+ (\text{aq}) + \text{CN}^- (\text{aq}) \rightleftharpoons \text{HCN} (\text{aq}) + \text{NH}_3 (\text{aq})$$
- (vii) Give the composition of a typical buffer mixture material.  
What pH range will it operate over?

- (viii) Define what is meant by standard enthalpy of neutralisation. What is the symbol?
- (ix) Distinguish between open, closed and isolated systems. Give an example of each.
- (x) Define activation energy. Give the symbol.
- (xi) Identify three factors which influence the rate of a chemical reaction.
- (xii) What indicates that an equilibrium has been reached in a chemical reaction?
- (xiii) Does a catalyst affect the equilibrium position?
- (xiv) Name the following organic molecules, using the IUPAC system.  
 $\text{CH}_3 (\text{CH}_2)_5 \text{OH}$   
 $\text{CH}_2 = \text{CH} (\text{CH}_2)_2 \text{CH} = \text{CH} \text{CH}_3$
- (xv) Identify the reactant in each of the following reactions:  
 $? + \text{H}_2\text{O} \rightarrow (\text{CH}_3)_2 \text{C}(\text{OH}) \text{CH}_3$



(20 marks)

## Section B

Q2. (a) The periodic table is the most significant tool that scientists use for organising and remembering chemical facts. It arranges elements in order of increasing atomic number, and mass number too, which tends to increase in a similar manner. Mass numbers are usually non integer values due to the existence of isotopes. The table consists of a series of **rows** and **columns** about which atomic properties tend to vary.

- (i) Explain the underlined terms.
- (ii) Correctly name the terms in bold.
- (iii) List at least three of the atomic properties referred to in the text.
- (iv) How do these properties vary as we progress across or down the table?

(10 marks)

(b) The element lead (Pb) consists of a four naturally occurring isotopes as outlined in the table below:

Isotope	Abundance / %	Atomic mass / a.m.u.
$^{204}\text{Pb}$	1.4	203.973
$^{206}\text{Pb}$	24.1	205.974
$^{207}\text{Pb}$	22.1	206.976
$^{208}\text{Pb}$	52.4	207.977

From the data calculate the atomic mass of lead correct to two decimal places.

(5 marks)

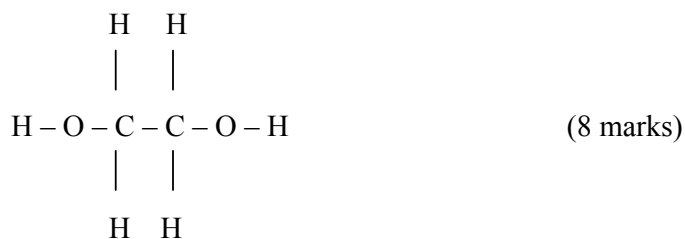
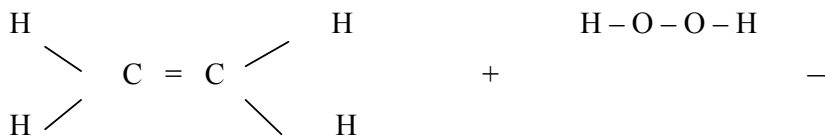
(c) For each of the following elements write the chemical symbol, name the column of the periodic table to which it belongs, and indicate whether it is a metal, non-metal or metalloid.

- (i) Potassium
- (ii) Iodine
- (iii) Magnesium
- (iv) Argon
- (v) Sulphur

(5 marks)

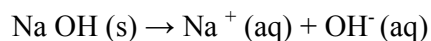
- Q3. (a) (i) What is an intermolecular force?
- (ii) Identify the intermolecular force which operates between
- (a) all molecules
  - (b) polar molecules
  - (c) the hydrogen atom is a polar bond, bonded to a more electronegative atom.
- Which is greatest?
- (iii) Taking HCl (g) as an example identify and discuss the type of intermolecular force that exists between two HCl molecules. Diagrams required. (6 marks)
- (b) (i) List the 4 steps in the formation of an ionic bond.
- (ii) Identify the energies associated with each step.
- (iii) Indicate whether these energies are endothermic or exothermic in each case. (8 marks)
- (c) Draw the Lewis structures and predict the shape of each of the following:
- (i) Na
  - (ii)  $\text{MgCl}_2$
  - (iii)  $\text{SO}_4^{2-}$
  - (iv)  $\text{PCl}_5$
- (6 marks)

- Q4. (a) (i) Explain what is meant by the term bond enthalpy?
- (ii) Using the bond enthalpy values in the attached table, calculate the enthalpy ( $\Delta H$ ) for the following gas-phase reaction.



- (b) (i) Distinguish between heat capacity and specific heat capacity.
- (ii) When a 9.55g sample of solid sodium hydroxide dissolved in 100g of water in a coffee-cup calorimeter, the temperature rises from 23.6°C to 47.4°C.

Calculate  $\Delta H$  (in kJ/mol NaOH) for



You can assume that the specific heat capacity of the solution is the same as pure water.

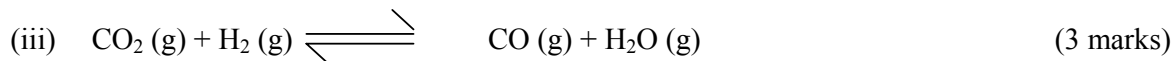
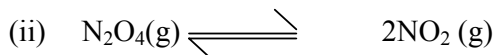
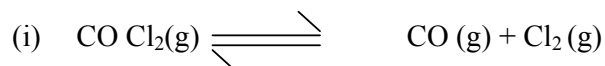
$$(\text{s.h.c H}_2\text{O} = 4.18 \text{ J g}^{-1} \text{ K}^{-1}) \quad (8 \text{ marks})$$

- (c) (i) Distinguish between exothermic and endothermic  $\Delta H$  values.
- (ii) For the two calculations in (a) and (b) above, are they exothermic or endothermic?
- (4 marks)

# Average Bond Enthalpies (kJ/mol)

Single Bonds							
C-H	413	N-H	391	O-H	463	F-F	155
C-C	348	N-N	163	O-O	146	Cl-F	253
C-N	293	N-O	201	O-F	190	Cl-Cl	242
C-O	358	N-F	272	O-Cl	203	Br-F	237
C-F	485	N-Cl	200	O-I	234	Br-Cl	218
C-Cl	328	N-Br	243	S-H	339	Br-Br	193
C-Br	276	H-H	436	S-F	327	I-Cl	208
C-I	240	H-F	567	S-Cl	253	I-Br	175
C-S	259	H-Cl	431	S-Br	218	I-I	151
Si-H	323	H-Br	366	S-S	266		
Si-Si	226	H-I	299				
Si-C	301						
Si-O	368						
Si-Cl	464						
Multiple Bonds							
C=C	614	N=N	418	O <sub>2</sub>	495		
C≡C	839	N≡N	941	S=O	523		
C=N	615	N=O	607	S=S	418		
C≡N	891						
C=O	799						
C≡O	1072						

Q5. (a) Write the equilibrium expression K for each of the following equilibrium reactions:



- (b) For reaction (i) above, if the concentrations of  $\text{COCl}_2$ ,  $\text{CO}$ , and  $\text{Cl}_2$  are  $2.00 \times 10^{-3}\text{M}$ ,  $3.3 \times 10^{-6}\text{M}$  and  $6.62 \times 10^{-6}\text{M}$  respectively is the reaction at equilibrium? If not, indicate the direction that the reaction must proceed to achieve equilibrium.

$K = 2.19 \times 10^{-10}$ . (4 marks)

- (c) Considering reaction (ii) above, what would the effect on the equilibrium position be if the total volume of the container was reduced? How would the concentrations, of each reactant and product, change when equilibrium is re-established? (4 marks)

- (d) In relation to reaction (iii) above,  
Calculate a value for the equilibrium constant given the following data:

Reaction mixture

$\text{CO}_2 = 0.20 \text{ mol}$

$\text{H}_2 = \text{H}_2\text{O} = 0.1600 \text{ mols}$

$\text{CO} = 0.3 \text{ mol}$

Total volume of the container is 3.00L. (5 marks)

- (e) If more  $\text{CO}(\text{g})$  was bubbled into the equilibrium mixture shown in reaction (i) above,  
How would the equilibrium constant and the equilibrium position be effected?

What law/principle is being applied here? (4 marks)

- Q6. (a) Sucrose ( $C_{12}H_{22}O_{11}$ ), which is commonly known as table sugar reacts in dilute acid solutions to form two simple sugars, glucose and fructose, both of which have the formula ( $C_6H_{12}O_6$ ). At  $23^\circ\text{C}$  and  $0.5 \text{ mol dm}^{-3}$  HCl, the following data were obtained for the disappearance of sucrose.

Time/ min	0	39	80	140	210
$[C_{12}H_{22}O_{11}]/\text{M}$	0.316	0.274	0.238	0.190	0.146

- (i) Is this reaction obeying  $1^{\text{st}}$  or  $2^{\text{nd}}$  order kinetics with respect to  $[C_{12}H_{22}O_{11}]$ ?  
(Prove graphically).
- (ii) Determine a value for the specific rate constant.
- (iii) Write a simple rate law for the process. (10 marks)
- (b) A reaction  $A + B \rightarrow C$  obeys the following rate law:  

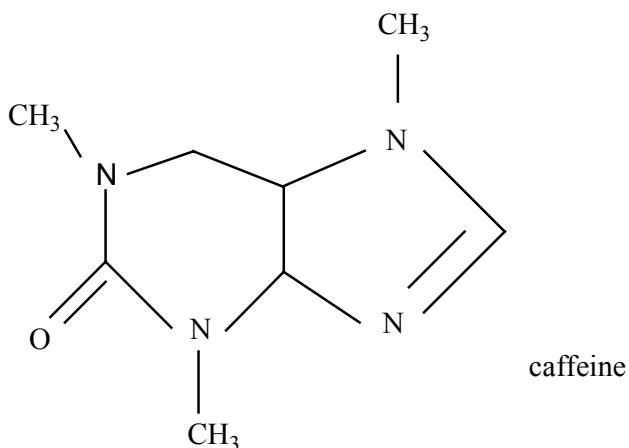
$$\text{Rate} = K[B]^2$$
- (i) If  $[A]$  is doubled, how will the rate change? Will the rate constant change?  
 Explain your answers.
- (ii) What are the reaction orders with respect to A and B? What is the overall reaction order? What are the units of the rate constant? (6 marks)
- (c) For each of the following gas phase reactions, how is the rate of appearance of each product related to rate of disappearance of each reactant?
- (i)  $2\text{HBr(g)} \rightarrow \text{H}_2(\text{g}) + \text{Br}_2(\text{g})$
- (ii)  $2\text{SO}_2(\text{g}) \rightarrow \text{O}_2(\text{g}) + 2\text{SO}_3(\text{g})$  (4 marks)



## Section C

Q7. (i) Caffeine is an alkaloid, what element contained in its structure identifies it as such?

(ii) As a result is it acidic or basic? (3 marks)



(iii) Draw the structure of the caffeine molecule into your answer book. Circle and name the functional groups contained within the structure. (4 marks)

(iv) The experimental procedure for isolating the caffeine from tea leaves can be divided into four stages namely:

- Aqueous extraction
- Precipitation and suction filtration
- Solvent extraction
- Distillation

Write a brief note explaining each of the steps listed above. (7 marks)

(v) The authenticity of the extracted caffeine sample was checked by two methods.

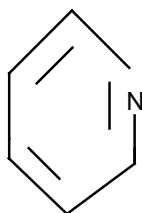
- Name these methods
- Explain one of these methods briefly. (6 marks)

- Q8. (a) (i) Amines are classified as primary ( $1^\circ$ ), secondary ( $2^\circ$ ) or tertiary ( $3^\circ$ ). Distinguish between all three. Give an example in each case.
- (ii) Amines are further classified as aliphatic or aromatic. Distinguish between these two classifications with examples. (7 marks)

(b) Consider the data in the following table.

Molecular wt (amu)	$\text{CH}_3\text{CH}_3$	$\text{CH}_3\text{NH}_2$	$\text{CH}_3\text{OH}$
Boiling pt. ( $^\circ\text{C}$ )	-88.6	-6.3	65.0

- (i) Account for the significant differences in boiling point, of the three compounds, even though they are all of similar molecular weight.
- (ii) What type of bonding is in operation?
- (iii) Predict the solubility of all three in water. Which most soluble? (7 marks)
- (c) (i) Select the stronger base from each of the following pairs of amines.

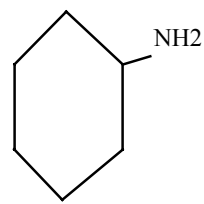


A



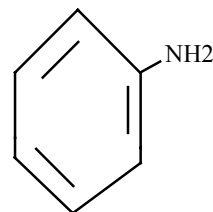
C

OR



B

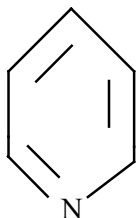
OR



D

Explain briefly your choices.

- (ii) Complete the equation for the following acid base reactions name the salts formed:
- $(\text{CH}_3\text{CH}_2)_2\text{NH} + \text{HCl} \rightarrow$



(6 marks)