

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

(SBIOS\_7\_Y1)

Summer 2008

**Chemistry – Old Syllabus**

(Time: 3 Hours)

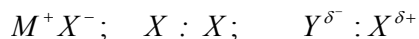
Answer **FIVE** questions. Question 1 is compulsory. Answer **TWO** questions from Section B and **ONE** question from Section C, and **ONE** from either Section B or C.  
Use separate answer books for each section.

Examiners: Dr. R. Hourihane  
Prof. G. Walsh

**Section A**

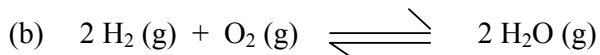
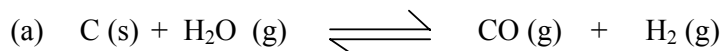
Q1. Attempt 10 parts. All parts carry two marks.

- (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:



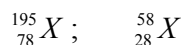
(viii) What is the trend in the following properties going across a period in the periodic table?

(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.

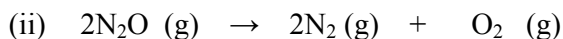
## Section B

- 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  $\text{N}_2\text{O}$  is  $0.37\text{M/s}$  what is the rate of appearance of each of the products? (6 marks)

(c) Nitrosyl bromide decomposes at  $10^\circ\text{C}$  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  $2^{\text{nd}}$  order kinetics.

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

(iii) What are the units for a  $2^{\text{nd}}$  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  $\text{HCl}$ ;
  - (ii) a  $0.075 \text{ mol dm}^{-3}$  solution of  $\text{H}_2\text{SO}_4$ ;
  - (iii) a solution containing 0.385g of  $\text{HNO}_3$  per  $100\text{cm}^3$  of solution;
  - (iv) a solution containing 0.032g of  $\text{NaOH}$  per  $\text{dm}^3$  of solution. (8 marks)

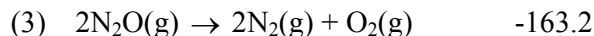
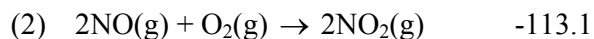
- (b) Use the  $\text{pK}_a$  data in the following table to arrange the acids in order of increasing acid strength (weakest acid first). Explain the reasons for your answer. (5 marks)

Acid	$\text{C}_4\text{H}_9\text{COOH}$	$\text{HCl}$	$\text{HNO}_2$	$\text{H}_2\text{PO}_4^-$	$\text{CH}_3\text{COOH}$	$\text{C}_6\text{H}_5\text{OH}$
$\text{pK}_a$	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 ( $\text{HNO}_2$ ) and determine the  $\text{pK}_b$  of the conjugate base. (2 marks)
- (e) Determine the pH of a buffer mixture prepared by mixing  $100\text{cm}^3$  of a  $0.05 \text{ mol dm}^{-3}$  ethanoic acid ( $\text{CH}_3\text{COOH}$ ) solution with  $100\text{cm}^3$  of a  $0.01 \text{ mol dm}^{-3}$  sodium ethanoate ( $\text{CH}_3\text{COONa}$ ) solution. (3 marks)

- Q6. (a) (i) State Hess's Law.

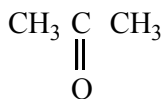
(ii) Given the following data:  $\Delta H / \text{kJ}$



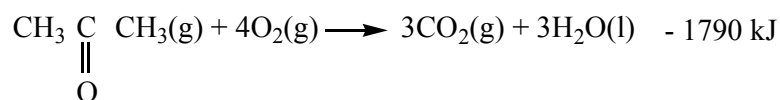
Use Hess's Law to calculate  $\Delta H$  for the reaction:



(b) The following reaction of 1 mol of acetone



liberates 1790 kJ.  $\Delta H^\circ = -1790 \text{ kJ}$



(i) Name the type of reaction.

(ii) Why is the  $\Delta H^\circ$  value negative?

(iii) Using the information together with the attached table of enthalpy of formation values, calculate the enthalpy of formation of acetone.

(7 marks)

(c) (i) Enthalpy is a state function, what is meant by this?

(ii) Name and give the symbol for two other state functions.

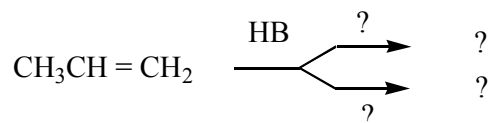
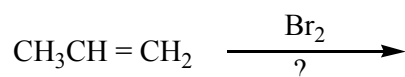
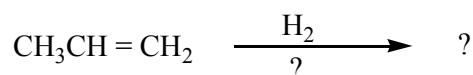
(iii) If a function is not a state function, what might it be?

(5 marks)

## Section C

- Q7. (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)

- Q8. (a) Alkenes are of great importance in the organic chemical industry.
- (i) Name three methods by which alkenes may be synthesised in the laboratory.
- (ii) Give a general reaction equation for two of the three methods named above. (5 marks)
- (b) (i) Alkenes react primarily by addition reactions. Explain what is meant by this. (2 Marks)
- (ii) In each of the following reactions:
- Predict and name the product
  - Name the type of reaction
  - Give the reaction conditions where appropriate



(10 marks)

- (c) Explain why alkenes have relatively low melting and boiling points compared to other compounds of similar molecular mass. (3 marks)

T-42

Table 5.3 Standard Enthalpies of Formation

TABLE 5.3 Standard Enthalpies of Formation,  $\Delta H_f^\circ$ , at 298 K

Substance	Formula	$\Delta H_f^\circ$ (kJ/mol)	Substance	Formula	$\Delta H_f^\circ$ (kJ/mol)
Acetylene	$C_2H_2$	226.7	Ethanol (drunk)	$C_2H_5OH$	-123.0
Ammonia	$NH_3$	-46.11	Hydrogen fluoride	$HF(g)$	-269.4
Benzene	$C_6H_6$	49.0	Hydrogen iodide	$HI(g)$	-25.9
Carbon monoxide	$CO(g)$	-110.5	Methane	$CH_4(g)$	-74.8
Carbon dioxide	$CO_2(g)$	-393.5	Methanol	$CH_3OH(l)$	-239.0
Carbon disulfide	$CS_2(l)$	-117.3	Propane	$C_3H_8(g)$	-103.85
Carbon tetrachloride	$CCl_4(l)$	-138.1	Styrene (drunk)	$C_8H_8$	-127.0
Ethane	$C_2H_6$	-84.68	Sulfuric acid (drunk)	$H_2SO_4(l)$	-813.9
Ethanol	$C_2H_5OH(l)$	-237.2	Sulfuric acid (conc.)	$H_2SO_4(aq)$	-813.9
Hydrogen	$H_2(g)$	0.00	Sulfuric acid (solid)	$H_2SO_4(s)$	-813.9
Hydrogen chloride	$HCl(g)$	-92.31	Sulfuric acid (solid)	$H_2SO_4(s)$	-813.9
Hydrogen bromide	$HBr(g)$	-36.4	Sulfuric acid (solid)	$H_2SO_4(s)$	-813.9

Source: The following data are from the NIST Chemistry WebBook, NIST Standard Reference Database Number 69, Version 2.1, July 1999.

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# 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		
C-F	485	N-Cl	200	O-I	234	Br-F	237
C-Cl	328	N-Br	243	S-H	339	Br-Cl	218
C-Br	276			S-F	327	Br-Br	193
C-I	240	H-H	436	S-Cl	253		
C-S	259	H-F	567	S-Br	218	I-Cl	208
		H-Cl	431	S-S	266	I-Br	175
Si-H	323	H-Br	366			I-I	151
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						