

Cork Institute of Technology
Bachelor of Science in Applied BioSciences – Stage 1
(NFQ Level 7)
Autumn 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

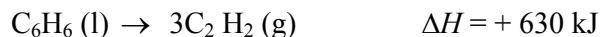
Section A

Attempt 10 parts. All carry equal marks.

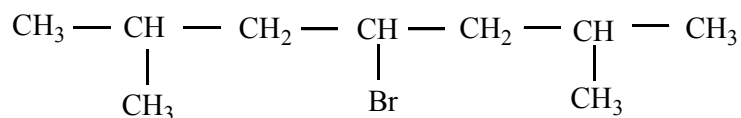
- Q1.** (i) List the three sub-atomic particles, give the charge and mass in each case.
- (ii) What is an ionic bond? Which groups in the periodic table are most likely to participate in this type of bonding?
- (iii) What isotope is used as the standard in establishing the atomic mass scale?
- (iv) The atomic mass of boron is reported as 10.81, yet no atom of boron can have a mass of this value. Explain.
- (v) Write the equilibrium expression for each of the following reactions:
- $\text{CH}_4(\text{g}) + 2\text{H}_2\text{S}(\text{g}) \rightleftharpoons \text{CS}_2(\text{g}) + 4\text{H}_2(\text{g})$
- $\text{FeO}(\text{s}) + \text{H}_2(\text{g}) \rightleftharpoons \text{Fe}(\text{s}) + \text{H}_2\text{O}(\text{g})$
- (vi) At 1000 K, $K_p = 1.85$ for the reaction
- $\text{SO}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightleftharpoons \text{SO}_3(\text{g})$
- (a) What is the K_p value for the reverse reaction?
- (b) What is the K_p value if the above reaction is doubled?
- (vii) A number of experiments are performed for the reaction $\text{A} \rightarrow \text{B} + \text{C}$
The rate law has the form $\text{Rate} = K [\text{A}]^x$
What is the value of x if
- (a) There is no rate change when the concentration of A is tripled
- (b) The rate increases by a factor of 9 when the concentration of A is tripled
- (viii) Calculate ΔE and determine whether the process is endothermic or exothermic for the following scenario:

The system releases 57.5 kJ of heat while doing 13.5 kJ of work on the surroundings

- (ix) Consider the following reaction:



- (a) What is the enthalpy change for the reverse reaction?
- (b) What is the ΔH value for the formation of 1 mole of acetylene (C_2H_2)?
- (x) The specific heat capacity of iron metal is $0.45 \text{ J g}^{-1} \text{ K}^{-1}$. How many J of heat are needed to raise the temperature of a 1.05 kg block of iron from 25°C to 88.5°C ?
- (xi) What three factors determine whether a collision between two molecules will lead to a chemical reaction?
- (xii) Name the following symbols that are encountered in rate equations:
- $$[A]_0 \quad t_{1/2} \quad [A]_t \quad K$$
- (xiii) Distinguish between a primary, secondary and tertiary alcohol.
- (xiv) Name the following organic molecule:



- (xv) Draw the structural formula of the following compound:

4,4 dimethyl hexyne

(20 Marks)

Section B

- Q2. (a) What is meant by the term ‘atomic radius of an atom’? How does this value differ from that of the ion? (Consider both + and -) (3 marks)
- (b) (i) Atomic radii values are approximate values only, outline one more reliable method which is often used to determine the atomic radius of an atom.
- (ii) What is the difference between a bonding radius and a non-bonding radius?
- (iii) If the distance between *W* atoms in tungsten metal is 2.74 \AA , what is the atomic radius of a tungsten atom in this environment? (7 marks)
- (c) Other atomic properties like ionisation potential and electron affinity vary as one moves across a period or down a group of the periodic table.
- (i) Define both named properties
- (ii) How does each vary across a period or down a group of the periodic table?
- (iii) Why are ionisation energies always positive values?
- (iv) Why does F have a larger first ionisation energy than O?
- (v) What is the general relationship between the size of an atom and its first ionisation energy? (10 marks)

- Q3. (a) (i) What is meant by the term covalent bond?
- (ii) A substance XY, forms from two different elements and boils at -33°C . Is XY likely to be ionic or covalent in nature? Give two reasons to support your claims. (4 marks)
- (b) Electronegativity values range from 0 to 4.
- (i) What is electronegativity a measure of?
- (ii) How do values vary across the periodic table? Explain.
- (iii) Using electronegativity values, predict which of the following bonds are polar: (1) B – F; (2) Cl – Cl; (3) Se – O; (4) H – I. Indicate the direction of the polarity. (6 marks)
- (c) Draw the following Lewis structures for the following:
- (i) CO
- (ii) SF₂
- (iii) SO₄²⁻
- (iv) NH₂ OH
- Predict the shapes and resonance structures where appropriate. (10 marks)

- Q4. (a) Calculate the pH of each of the solutions (i) – (iv), and the $[H^+]$ of solution (v).
 (i) 0.500 M HCl
 (ii) 0.045 M Sr (OH)₂
 (iii) 2.250 g of LiOH in 250 ml of water
 (iv) 0.095 M propionic acid (HC₃H₅O₂), $K_a = 1.3 \times 10^{-5}$
 (v) A solution with a pH of 3 (8 marks)

- (b) Identify the acid, base, conjugate acid and conjugate base in each of the following reactions:
 (i) $NH_4^+(aq) + CN^-(aq) \rightleftharpoons HCN(aq) + NH_3(aq)$
 (ii) $(CH_3)_3N(aq) + H_2O(l) \rightleftharpoons (CH_3)_3NH^+ + OH^-(aq)$
 (iii) $HCHO_2(aq) + PO_4^{3-}(aq) \rightleftharpoons CHO_2^-(aq) + HPO_4^{2-}(aq)$ (6 marks)
- (c) What would be the effect of adding 0.05 M NaOH to the benzoic acid / benzoate buffer where $[C_6H_5COOH] = 0.12$ M and $[C_6H_5COO^-] = 0.12$ M, $K_a = 6.3 \times 10^{-5}$ (6 marks)

- Q5. (a) From the following data for the first-order gas phase isomerisation of CH₃CN at 215°C, calculate the first order rate constant and the half life for the reaction.

Time / s	Pressure CH ₃ CN / ton
0	502
2,000	335
5,000	180
8,000	95.5
12,000	41.7
15,000	22.4

(12 marks)

- (b) (i) For the following gas phase reaction, write the rate expression in terms of appearance of each product and relative to the disappearance of each reactant.
 $2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$

- (ii) If the rate at which Nitrogen (N_2) appears is $6.0 \times 10^{-5} \text{ M/s}$ at a particular instant, at what rate is hydrogen (H_2) disappearing at this same time?

(4 marks)

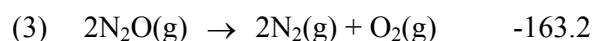
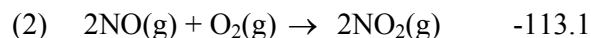
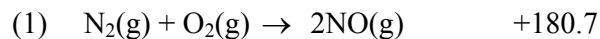
- (c) Distinguish between average rate and instantaneous rate.

A diagram is required.

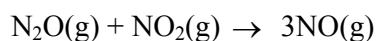
(4 marks)

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

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

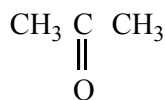


Use Hess's Law to calculate ΔH for the reaction:

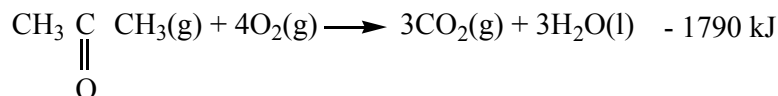


(8 marks)

- (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 ΔH° 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. (a) The concentration of an unknown material can be determined by measuring the amount of visible or ultra violet light it absorbs. This is best done by plotting a calibration curve using absorption values measured for a series of solutions of known concentration.

Using the data in the following table:

- (i) Plot the appropriate calibration curve.
- (ii) Determine the concentration of the unknown solution.

Absorbance @ 525 nm	Concentration / ppm
0.027	2
0.059	4
0.125	8
0.195	12
0.261	16
0.324	20
0.375	24
0.267	Unknown solution

(10 marks)

- (b) (i) The absorbance values were determined at 525 nm.
What is the name given to this wavelength value? (2 marks)
- (ii) What does the concentration unit ppm mean? (2 marks)
- (iii) The standard solutions were prepared from a 100 ppm stock solution.
Explain how the 4 ppm standard might be prepared if 100 ml of standard solution are required. (4 marks)
- (iv) What law is being obeyed in this scenario? (2 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)

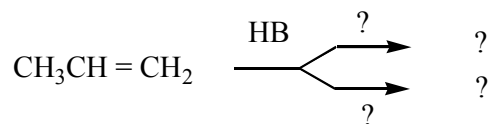
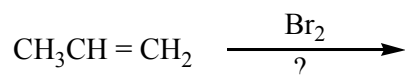
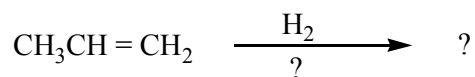
(b) (i) Alkenes react primarily by addition reactions. Explain what is meant by this. (2 Marks)

(ii) In each of the following reactions:

(1) Predict the product and name

(2) Name the type of reaction

(3) 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)

Table 5.3 Standard Enthalpies of Formation

TABLE 5.3 Standard Enthalpies of Formation, ΔH_f° , at 298 K

Substance	Formula	ΔH_f° (kJ/mol)	Substance	Formula	ΔH_f° (kJ/mol)
Acetylene	$C_2H_2(g)$	226.7	Hydrogen chloride	$HCl(g)$	-92.30
Ammonia	$NH_3(g)$	-46.19	Hydrogen fluoride	$HF(g)$	-268.6
Benzene	$C_6H_6(l)$	49.0	Hydrogen iodide	$HI(g)$	25.9
Calcium carbonate	$CaCO_3(s)$	-1207.1	Methane	$CH_4(g)$	-74.8
Calcium oxide	$CaO(s)$	-635.5	Methanol	$CH_3OH(l)$	-238.6
Carbon dioxide	$CO_2(g)$	-393.5	Propane	$C_3H_8(g)$	-103.85
Carbon monoxide	$CO(g)$	-110.5	Silver chloride	$AgCl(s)$	-127.0
Diamond	$C(s)$	1.88	Sodium bicarbonate	$NaHCO_3(s)$	-947.7
Ethane	$C_2H_6(g)$	-84.68	Sodium carbonate	$Na_2CO_3(s)$	-1130.9
Ethanol	$C_2H_5OH(l)$	-277.7	Sodium chloride	$NaCl(s)$	-410.9
Ethylene	$C_2H_4(g)$	52.30	Sucrose	$C_{12}H_{22}O_{11}(s)$	-2271
Glucose	$C_6H_{12}O_6(s)$	-1273	Water	$H_2O(l)$	-285.8
Hydrogen bromide	$HBr(g)$	-36.23	Water vapor	$H_2O(g)$	-241.8

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