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)

Autumn 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) Identify the element X in each case: $^{24}_{12}X$ and $^{58}_{28}X$.

(ii) Which orbital in each of the following pairs is higher in energy?

a. 5*p* or 5*d*; b. 4*s* or 3*p*; c. 6*s* or 4*d*

(iii) What is the difference between an atoms atomic number and its mass number? Quote an example from the periodic table to support your answer.

(iv) Explain the term resonance with reference to chemical bonds.

(v) Draw Lewis symbols for each of the following elements: Ca, P, Br and Fr.

(vi) Define the term standard enthalpy of formation.

(vii) In each of the following cases, indicate the sign (i.e. > 0 or < 0 or = 0) of q and w respectively and predict whether you expect the internal energy (E) to increase, decrease or remain the same

a. A system releases heat and does work on the surroundings

b. The surroundings do work on the system without a transfer of heat.

(viii) Comment briefly on the following statement "A catalyst increases the rate of a reaction but it is not consumed because it does not participate in the reaction". An example would be helpful in your comment.

(ix) Identify 2 factors, which influence the rate of a chemical reaction.

(x) The kinetic data for the reaction $2N_2O\ (g) \rightarrow 2N_2(g) + O_2(g)$ is shown.

Time (min)	0	60	90	120	180
$[N_2O]$ (M)	0.250	0.218	0.204	0.190	0.166

Without performing calculations, explain how this data would be used to determine the rate (instantaneous rate) of the reaction at 100 minutes?

(xi) Will the pH of a solution of the weak acid Hydrofluoric acid (HF) increases, decreases or remain the same when Sodium Fluoride (NaBr) is added to it? Show the appropriate equations to justify your answer.

(xii) What is the pH of a buffer solution made by dissolving 0.10 moles of Formic acid (HCOOH) and 0.10M Sodium formate (HCOONa) in 1L of water? K_a (HCOOH) = 1.8×10^{-4}.

(xiii) Using the IUPAC system, name and draw 2 possible structural formula which correspond to the molecular formula C_4H_{10} .

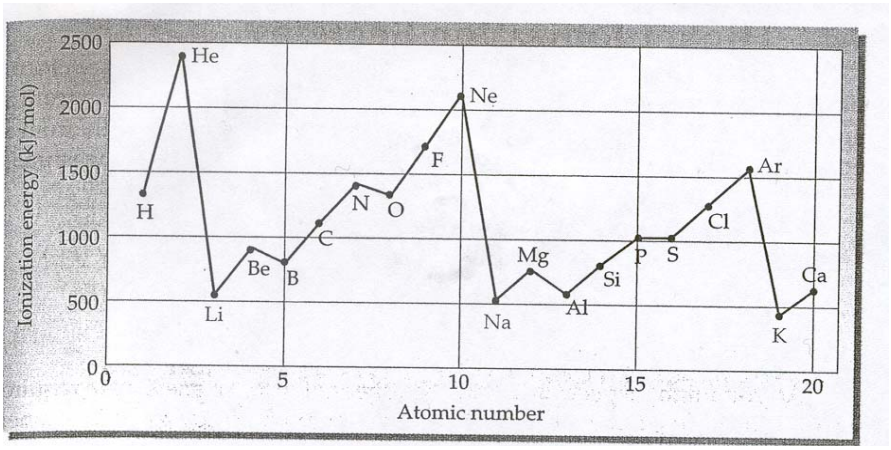
(xiv) Complete the following reaction equation and name the product

$$CH_3C \equiv CCH_2CH_3 \quad + \quad H_2 \quad \longrightarrow \quad ?$$

SECTION B

Q2. (a) (i) Distinguish between ionization potential and electron affinity (2 marks)

(ii) The figure below shows the ionization potential of the first 20 elements of the periodic table. Explain the general trend. Account for minor irregularities especially the group II elements Be and Mg, which have slightly larger values than expected. Also account for irregularities in the group VI elements O and S that have slightly smaller values than might be expected



(6 marks)

(b) Name the four quantum numbers; indicate what each number specifies about the atomic orbital? Give all possible values of each quantum number. (12 marks)

Q3. (a) (i) Name and arrange in order of increasing strength, the different types of intermolecular forces that occur between molecules (3 marks)

(ii) Write a brief note on each type identified. Include in your answer the exact type of force(s) involved and the type(s) of molecules that would typically form each type of intermolecular force (9 marks)

(b) (i) Explain why electronegativity (EN) generally increases from left to right within a period of the periodic table and why EN values may be used to determine bond polarity? (4 marks)

(ii) By performing the appropriate calculations, arrange the following bonds in order of increasing polarity: C — Cl, C—H, C—Mg, C—O, C—S (2 marks)

(iii) Give one example each of a pure covalent bond and an ionic bond. Use EN values to justify your examples (2 marks)

Q4. (a) Write a note, which compares a typical strong acid-strong base titration curve with a weak acid-strong base titration curve. In your answer, include fully labelled sketches of both titration curves (9 marks)

(b) A 1.00g sample of Acetylsalicylic acid (aspirin) is dissolved in 0.300L of water at 25°C.

$CH_3OCOC_6H_4COOH\ (aq) + H_2O\ (l) \leftrightarrows H_3O^+(aq) + CH_3OCOC_6H_4COO^-\ (aq)$

Acetylsalicylic acid

(i) Calculate the pH of the solution given the K_a for aspirin is 3.56×10^{-4} and its molecular mass is 180g. (7 marks)

(ii) Will the pH of the aspirin solution increase or decrease if a few drops of dilute NaOH are added to the solution. Justify your answer by explaining how the equilibrium adjust with the addition of the NaOH. (4 marks)

Q5. (a) Given ΔH°_f for Na_2O (s) is – 415.9 kJ mol^{-1}, use the attached tabulated data to calculate ΔH° for the following reactions

(i) $NH_3\ (g) + HCl\ (g) \rightarrow NH_4Cl\ (s)$

(ii) $Na_2O\ (s) + 2HCl\ (g) \rightarrow 2\ NaCl\ (g) + H_2O\ (l)$ (4 marks)

(b) The catalytic oxidation of ammonia to nitric oxide is represented by the equation: $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$. Perform the appropriate calculations to:

(i) Prove the reaction releases approximately 900kJ (2 marks)

(ii) Determine the enthalpy change (ΔH°_{rxn}) in underwritten reactions

$12NH_3(g) + 15O_2(g) \rightarrow 12NO(g) + 18H_2O(g)$ (2 marks)

$2NO(g) + 3H_2O(g) \rightarrow 2NH_3(g) + 2½O_2(g)$ (2 marks)

(c) Write an equation that can be used to calculate $\Delta S°$ for each of the following reactions. Without performing calculations, indicate whether $\Delta S°$ is less than, greater than or equal to 0 in each case. Justify your answers

(i) $CaCO_3\,(s) \rightarrow CaO\,(s) + CO_2\,(g)$

(ii) $CS_2\,(l) \rightarrow CS_2\,(g)$

(iii) $2Na_2O_2(s) + 2H_2O(l) \rightarrow 4NaOH(aq) + O_2(g)$

(6 marks)

(d) For a reaction to occur spontaneously as written, which of the following must be true? Give a reason your answer

i) The entropy of the system must increase

ii) The enthalpy of the system must decrease

iii) The free energy change (ΔG) must be negative

iv) The value of the reaction quotient Q, must exceed that of the equilibrium constant K_c

(4 marks)

Q6. (a) The first step in the synthesis of nitric acid involves the conversion of ammonia (NH_3) to nitric oxide (NO) at a high temperature

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$

(i) Show how the rate of consumption of O_2 is related to the rate of consumption of NH_3? (2 marks)

(ii) How are the rates of formation of NO and H_2O related to the rate of consumption of NH_3? (2 marks)

(b) At elevated temperatures, nitrous oxide (N_2O) decomposes as follows:

$2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$

Given the reaction data in the table

Time / min	0	60	90	120	180
$[N_2O]$ / M	0.250	0.218	0.204	0.190	0.166

(i) Prove the reaction obeys first order kinetics (8 marks)
(ii) Determine a value for the rate constant (2 marks)
(iii) What is the half-life of this reaction? (2 marks)

(c) The rate of the reaction $A + B_2 + C \rightarrow$ Products is directly proportional to the concentration of B_2, independent of the concentration of A and directly proportional to the concentration of a substance C

(i) Write the appropriate rate law (2 marks)
(ii) Identify the order with respect to each of the three reactants (2 marks)

SECTION C

Q7. (a) Write a comprehensive note, which compares organic and inorganic compounds. In particular account for the differences in properties such as solubility, melting and boiling points and conductivity (8 marks)

(b) Write a note on alcohols, which includes the following information

(i) General structural formula (1 mark)
(ii) The differences between primary, secondary and tertiary alcohols (3 marks)
(iii) Why alcohols possess both acidic and basic properties (2 marks)
(iv) How the melting points, boiling points and solubility of alcohols compare with those of alkanes and alkenes of similar molecular weight (6 marks)

Where appropriate, use examples and structural formulae to support your answer.

Q8. (a) (i) Describe the method of liquid/liquid extraction (6 marks)

(ii) Explain the symbol K_D (2 marks)

(iii) List ideal properties for the extraction solvent (3 marks)

(iv) Identify two extraction solvents and indicate whether they are heavier or lighter than water (4 marks)

(b) The amount of acid extracted can be determined quite readily be determining the amount of acid that remains in the aqueous layer by titration with a standard solution of Sodium Hydroxide. Titres of 5.2cm^3 and 3.8cm^3 NaOH respectively were obtained when a 20cm^3 portion of Trichloroethanoic acid was extracted with 1 x 20cm^3 and 2 x 10cm^3 of extraction solvent. Using this data, comment on whether one or several extractions are best

Note the volume of NaOH required to neutralize 20cm^3 of 0.1M Trichloroacetic acid is 23.9cm^3 (5 marks)

C Thermodynamic Quantities for Selected Substances at 298.15 K (25°C)

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)
Aluminum			
$Al(s)$	0	0	28.32
$AlCl_3(s)$	−705.6	−630.0	109.3
$Al_2O_3(s)$	−1669.8	−1576.5	51.00
Barium			
$Ba(s)$	0	0	63.2
$BaCO_3(s)$	−1216.3	−1137.6	112.1
$BaO(s)$	−553.5	−525.1	70.42
Beryllium			
$Be(s)$	0	0	9.44
$BeO(s)$	−608.4	−579.1	13.77
$Be(OH)_2(s)$	−905.8	−817.9	50.21
Bromine			
$Br(g)$	111.8	82.38	174.9
$Br^-(aq)$	−120.9	−102.8	80.71
$Br_2(g)$	30.71	3.14	245.3
$Br_2(l)$	0	0	152.3
$HBr(g)$	−36.23	−53.22	198.49
Sodium			
$Na(g)$	107.7	77.3	153.7
$Na(s)$	0	0	51.45
$Na^+(aq)$	−240.1	−261.9	59.0
$Na^+(g)$	609.3	574.3	148.0
$NaBr(aq)$	−360.6	−364.7	141
$NaBr(s)$	−361.4	−349.3	86.82
$Na_2CO_3(s)$	−1130.9	−1047.7	136.0
$NaCl(aq)$	−407.1	−393.0	115.5
$NaCl(g)$	−181.4	−201.3	229.8
$NaCl(s)$	−410.9	−384.0	72.33
$NaHCO_3(s)$	−947.7	−851.8	102.1
$NaNO_3(aq)$	−446.2	−372.4	207
$NaNO_3(s)$	−467.9	−367.0	116.5
$NaOH(aq)$	−469.6	−419.2	49.8
$NaOH(s)$	−425.6	−379.5	64.46
$CF_4(g)$	−679.9	−635.1	262.3
$CH_4(g)$	−74.8	−50.8	186.3
$C_2H_2(g)$	226.7	209.2	200.8
$C_2H_4(g)$	52.30	68.11	219.4
$C_2H_6(g)$	−84.68	−32.89	229.5
$C_3H_8(g)$	−103.85	−23.47	269.9
$C_4H_{10}(g)$	−124.73	−15.71	310.0
$C_4H_{10}(l)$	−147.6	−15.0	231.0
$C_6H_6(g)$	82.9	129.7	269.2
$C_6H_6(l)$	49.0	124.5	172.8
$CH_3OH(g)$	−201.2	−161.9	237.6
$CH_3OH(l)$	−238.6	−166.23	126.8
$C_2H_5OH(g)$	−235.1	−168.5	282.7
$C_2H_5OH(l)$	−277.7	−174.76	160.7
$C_6H_{12}O_6(s)$	−1273.02	−910.4	212.1
$CO(g)$	−110.5	−137.2	197.9
$CO_2(g)$	−393.5	−394.4	213.6
$HC_2H_3O_2(l)$	−487.0	−392.4	159.8
Cesium			
$Cs(g)$	76.50	49.53	175.6
$Cs(s)$	0	0	85.15
$CsCl(s)$	−442.8	−414.4	101.2
Chlorine			
$Cl(g)$	121.7	105.7	165.2
$Cl^-(aq)$	−167.2	−131.2	56.5
$Cl_2(g)$	0	0	222.96
$HCl(aq)$	−167.2	−131.2	56.5
$HCl(g)$	−92.30	−95.27	186.69
Chromium			
$Cr(g)$	397.5	352.6	174.2
$Cr(s)$	0	0	23.6
$Cr_2O_3(s)$	−1139.7	−1058.1	81.2

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)
Cobalt			
$Co(g)$	439	393	179
$Co(s)$	0	0	28.4
Copper			
$Cu(g)$	338.4	298.6	166.3
$Cu(s)$	0	0	33.30
$CuCl_2(s)$	−205.9	−161.7	108.1
$CuO(s)$	−156.1	−128.3	42.59
$Cu_2O(s)$	−170.7	−147.9	92.36
Fluorine			
$F(g)$	80.0	61.9	158.7
$F^-(aq)$	−332.6	−278.8	−13.8
$F_2(g)$	0	0	202.7
$HF(g)$	−268.61	−270.70	173.51
Hydrogen			
$H(g)$	217.94	203.26	114.60
$H^+(aq)$	0	0	0
$H^+(g)$	1536.2	1517.0	108.9
$H_2(g)$	0	0	130.58
Iodine			
$I(g)$	106.60	70.16	180.66
$I^-(aq)$	−55.19	−51.57	111.3
$I_2(g)$	62.25	19.37	260.57
$I_2(s)$	0	0	116.73
$HI(g)$	25.94	1.30	206.3
Iron			
$Fe(g)$	415.5	369.8	180.5
$Fe(s)$	0	0	27.15
$Fe^{2+}(aq)$	−87.86	−84.93	113.4
$Fe^{3+}(aq)$	−47.69	−10.54	293.3
$FeCl_2(s)$	−341.8	−302.3	117.9
$FeCl_3(s)$	−400	−334	142.3
$FeO(s)$	−271.9	−255.2	60.75
$Fe_2O_3(s)$	−822.16	−740.98	89.96
$Fe_3O_4(s)$	−1117.1	−1014.2	146.4
$FeS_2(s)$	−171.5	−160.1	52.92
Lead			
$Pb(s)$	0	0	68.85
$PbBr_2(s)$	−277.4	−260.7	161
$PbCO_3(s)$	−699.1	−625.5	131.0
$Pb(NO_3)_2(aq)$	−421.3	−246.9	303.3
$Pb(NO_3)_2(s)$	−451.9	—	—
$PbO(s)$	−217.3	−187.9	68.70
Lithium			
$Li(g)$	159.3	126.6	138.8
$Li(s)$	0	0	29.09
$Li^+(aq)$	−278.5	−273.4	12.2
$Li^+(g)$	685.7	648.5	133.0
$LiCl(s)$	−408.3	−384.0	59.30

Substance	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	S° (J/mol-K)
Magnesium			
$Mg(g)$	147.1	112.5	148.6
$Mg(s)$	0	0	32.51
$MgCl_2(s)$	−641.6	−592.1	89.6
$MgO(s)$	−601.8	−569.6	26.8
$Mg(OH)_2(s)$	−924.7	−833.7	63.24
Manganese			
$Mn(g)$	280.7	238.5	173.6
$Mn(s)$	0	0	32.0
$MnO(s)$	−385.2	−362.9	59.7
$MnO_2(s)$	−519.6	−464.8	53.14
$MnO_4^-(aq)$	−541.4	−447.2	191.2
Mercury			
$Hg(g)$	60.83	31.76	174.89
$Hg(l)$	0	0	77.40
$HgCl_2(s)$	−230.1	−184.0	144.5
$Hg_2Cl_2(s)$	−264.9	−210.5	192.5
Nickel			
$Ni(g)$	429.7	384.5	182.1
$Ni(s)$	0	0	29.9
$NiCl_2(s)$	−305.3	−259.0	97.65
$NiO(s)$	−239.7	−211.7	37.99
Nitrogen			
$N(g)$	472.7	455.5	153.3
$N_2(g)$	0	0	191.50
$NH_3(aq)$	−80.29	−26.50	111.3
$NH_3(g)$	−46.19	−16.66	192.5
$NH_4^+(aq)$	−132.5	−79.31	113.4
$N_2H_4(g)$	95.40	159.4	238.5
$NH_4CN(s)$	0.0	—	—
$NH_4Cl(s)$	−314.4	−203.0	94.6
$NH_4NO_3(s)$	−365.6	−184.0	151
$NO(g)$	90.37	86.71	210.62
$NO_2(g)$	33.84	51.84	240.45
$N_2O(g)$	81.6	103.59	220.0
$N_2O_4(g)$	9.66	98.28	304.3
$NOCl(g)$	52.6	66.3	264
$HNO_3(aq)$	−206.6	−110.5	146
$HNO_3(g)$	−134.3	−73.94	266.4
Oxygen			
$O(g)$	247.5	230.1	161.0
$O_2(g)$	0	0	205.0
$O_3(g)$	142.3	163.4	237.6
$OH^-(aq)$	−230.0	−157.3	−10.7
$H_2O(g)$	−241.82	−228.57	188.83
$H_2O(l)$	−285.83	−237.13	69.91
$H_2O_2(g)$	−136.10	−105.48	232.9
$H_2O_2(l)$	−187.8	−120.4	109.6