2019 IB2 HL Chemistry Prelim Exam Paper 2 – Answers

1. 9.74 tonnes of magnesium is need to react with 1.60 x 10² tonnes of impure titanium (IV) oxide, TiO₂, ore. All the titanium is completely extracted from the sample of impure ore. The following are reactions involved in the extraction process:

Step 1: $TiO_2 + C + 2Cl_2 \rightarrow TiCl_4 + CO_2$

Step 2: $TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$

 $(1 \text{ tonne} = 10^6 \text{ g})$

(a) Write an overall equation for extraction of titanium from TiO_2 .

[1]

$\text{TiO}_2 + \text{C} + 2\text{Cl}_2 + 2\text{Mg} \rightarrow \text{Ti} + \text{CO}_2 + 2\text{MgCl}_2$

(b) Calculate the amount, in mols, of TiO_2 present in the sample of impure ore.

[1]

$$\frac{INVg}{nTiO2} = \frac{2}{1}$$

$$\frac{\frac{9.74 \times 10^6}{24.31}}{nTiO2} = \frac{2}{1} \implies nTiO_2 = \frac{1}{2} \times \frac{9.74 \times 10^6}{24.31} \text{ mol} = 200329.08 \text{ mol} = 2.00 \times 10^5 \text{ mol}$$
[Note: e.c.f. (a) equation]
Some students did not convert tonnes to g, hence, no marks awarded.

Some students uses 1.60 x 10^2 tonnes for calculation. Note that not all 1.60 x 10^2 tonnes are TiO₂. ($\frac{1}{2}$ for nMg) ($\frac{1}{2}$ nTiO₂)

(c) Calculate the mass, in tonnes, of TiO_2 in the sample of impure ore.

[2]

Mass of 200329.08 mol TiO ₂ = 200329.08 x (47.87 + 2x16.00)	(1/2)
= 200329.08 x 79.87 g	
= 15997961 g	
$= 1.60 \times 10^7 \text{ g}$	(1/2)
= 1.60 x10 ¹ tonnes (accept 16 tonnes)	(1)
[Note: e.c.f. (a) equation]	
If student did not convert to g, and get 16 tonnes, only award 1.5. Student must e	ensure units
consistency in their calculation.	
Some students uses the wrong Ar for Ti.	

(d) Calculate the percentage by mass of TiO_2 in the sample.

[1]

% by mass of TiO₂ in the sample = $\frac{1.60 \times 10^1}{1.60 \times 10^2} \times 100 = 10.0\%$ [Note: e.c.f. (a) equation]

Ecf is allowed as long as student uses the answer (in tonnes) calculated in part (c) for calculation of % by mass here.

(e) (i) Titanium (IV) oxide, TiO₂, is a solid, however titanium (IV) chloride, TiCl₄, is a liquid at room temperature.

Suggest a reason for this difference between the two compounds, in terms of [2] structure and bonding.

TiCl₄ is a <u>simple molecular structure</u>, <u>weak intermolecular forces of attraction</u> between the molecules./ Owtte

 TiO_2 is an <u>giant ionic compound</u>, with <u>strong ionic bonds</u> / strong electrostatic forces of attraction between oppositely charged ions/ owtte

5 points : 2 structure, 2 bonding, strength comparison. 2 points stated 0.5, 3 - 1, 4 - 1.5, 5 - full marks

> (ii) Titanium (IV) chloride is relatively stable in aqueous solutions. However, it dissolves in concentrated hydrochloric acid to form an acidic solution of the hexachlorotitanate (IV) complex ion.

Draw the structure of the complex ion, suggest its molecular geometry and bond angle.





Ti²⁺ : 1s² 2s² 2p⁶ 3s² 3p⁶ 3d²

Zn²⁺: 1s² 2s² 2p⁶ 3s² 3p⁶ 3d¹⁰

Write atom configuration, fill in 4s before 3d. Followed by removing electrons from 4s, followed by 3d to obtain the configuration.

(ii) Suggest why titanium has variable oxidation states.

Ti has **partially filled d–orbitals** / incomplete filled d shells($\frac{1}{2}$) this is not at its highest oxidation state/ **able to lose** multiple **electrons form 3d and 4s** / energy needed to remove the electrons form the partially filled d shells is almost equal($\frac{1}{2}$), which allows multiple oxidation states. (accept answers OWTTE)

(g) Magnesium is a s-block element.

(i) Define what is meant by 's'.

[1]

Only s orbital in the highest main energy level contains electrons. [1]

Majority of the student did not answer to the question to define s in the term **s-block element**, and hence give definition of what an s orbital is.

(iii) Sketch on the axes below, the first six ionisation energies (IE), in logarithmic scale, [1] of the element, magnesium.



Some students drew the first IE trend across the period, instead of **successive IE trend**.



- 2. Chlorofluorocarbons, CFCs, have been used previously for a wide range of applications including cleaning solvents and refrigerant. However, they break down easily in the stratosphere that lead to ozone (O₃) depletion.
 - (a) The following equations illustrate the process of ozone depletion.

 $CCl_2F_2 \xrightarrow{hv} \bullet CClF_2 + Cl \bullet \qquad -(1)$ $Cl \bullet + O_3 \rightarrow ClO \bullet + O_2 \qquad -(2)$ $ClO \bullet + O \bullet \rightarrow Cl \bullet + O_2 \qquad -(3)$

(i) Identify the type of processes shown in the three equations by completing the table [2] below:

Process	Equation(s)
initiation	1 (1)
propagation	2,3 (1)
termination	

Concept:

initiation: produce first radicals propagation: radicals produce more radicals termination: radicals combine and no more radicals are formed. Hence eqn (3) is not a termination step \Rightarrow common mistake.

(ii) Cl in equation (1) is the reactive species in this process. State the name of such [1] species and explain its reactivity.

Cl is a (free) radical \checkmark and it is reactive due to its unpaired electron \checkmark

Comments:

Qn says "explain" so give a reason: Saying it's highly reactive is not explaining. Also common mistake: "Cl is highly electronegative": What is the relevance/link?

(b) The hydroflurocarbon, F_3CCFH_2 , is a suitable replacement for CFCs. It is prepared industrially by reacting hydrogen fluoride with $Cl_2C=CClH$. HCl is the by-product.



 $Cl_2C=CClH + 4HF \rightarrow F_3CCFH_2 + 3HCl$

(iii) Explain how HF can act as a *nucleophile* in this reaction.

The F in the molecule has a lone pair of electrons \checkmark that it can donate \checkmark (to the δ + charged carbon atom) and form a (covalent) bond.

Comments:

Qn says "explain how" and italicised the word 'nucleophile'. So take the cue and explain how a nucleophile reacts.

(iv) Draw an isomer of F_3CCFH_2 that can be produced from this reaction.



(c) The breakdown of ozone, O_3 is shown in this equation:

 O_3 (g) $\longrightarrow O \bullet$ (g) + O_2 (g) $\Delta H = +107.5 \text{ kJ mol}^{-1}$

(i) Use relevant data from section 11 of the data booklet to determine the bond energy [1] between oxygen atoms in ozone.

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\Delta H_r = \sum BE (reactants) - \sum BE (products)
+107.5 = 2(BE between bonds in ozone) - (498)
BE = +302.8 kJ mol<sup>-1</sup>
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<u>Comments:</u> Bond in O₂ is O=O (498) not O–O (144) \Rightarrow common mistake.

(ii) Compare the value in (i) and that in the O_2 molecule. Deduce the relative bond [2] strengths in O_2 and O_3 .

bond energy between oxygen atoms in O₃ (303) is <u>smaller</u> than that in O₂ (498). \checkmark O₃ has <u>weaker</u> bond strength than that of O₂. \checkmark

[ECF from (i)]

(d) Ozone, O₃, can be represented in a cyclic or bent structure as shown below.





(i) Determine the hybridization of the oxygen atoms in the two structures.



(ii) Calculate and indicate within the boxes, the formal charges of all the oxygen atoms [2] on both structures.



(e) Hence, based on your answers for (c) and (d), suggest which of the two is the most [2] probable structure of ozone?

3. The following equation shows the molar coefficients of the dynamic equilibrium between haemoglobin and oxygen in the blood stream.

$$Hb(aq) + 4O_2(aq) \rightleftharpoons Hb(O_2)_4(aq)$$

[1]

(a) Define the term *dynamic equilibrium*.

Dynamic equilibrium refers to a <u>reversible process</u> \checkmark at equilibrium in which the <u>rate of forward and</u> reverse processes is equal \checkmark (but not equal to zero)/

A state of <u>dynamic equilibrium</u> is when the <u>rates of the forward and reverse reactions are equal</u> and both are <u>not zero</u>.

Marks is awarded for **rate of forward reaction = rate of backward reaction**. Not rate of forward and backward reaction are constant. Constant rate does not mean forward and backward rate are equal. Some students wrote concentration remain constant. However, when a reaction goes to completion and has stopped, the concentration will remain constant.

(b) Deduce the equilibrium expression for the reaction and state its units.

[2]

```
K_{\rm C} = \frac{[{\rm Hb}({\rm O}_2)_4]}{[{\rm Hb}][{\rm O}_2]^4} \checkmark [1]
Units: mol<sup>-4</sup> dm<sup>12</sup> √ [1]
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Some students confused the units of rate, rate constant and $K_{\mbox{\scriptsize c}}$

(c) At standard conditions, the equilibrium concentration of Hb and Hb(O₂)₄ are equal when concentration of O₂ is 7.6×10^{-6} mol dm⁻³. Calculate the equilibrium constant, K_c , of the [2] reaction.



(d) The graph below shows the changes occurring to an equilibrium system in a closed vessel, containing N_2O_4 and NO_2 , reacting according to the equation:



 $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

Majority of the student did not start the graph at the correct point.

Only when the graph starts at the correct point, marks are awarded for correct shape, and the ratio.

The volume of the reaction vessel is decreased at time, t min. Sketch clearly (in the correct proportion) on the graph above, the change in concentration From the equation: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

- With decrease in volume, there is an increase in pressure. 1/2
- With an increased pressure, it <u>favours the reverse reaction</u>/ equilibrium shifts to the <u>left to</u> reduce the total mols of gas 1/2
- At the new equilibrium, there is an <u>increase concentration of reactant</u>, N₂O₄, and <u>decrease</u> <u>concentration of product</u>, NO₂. ¹/₂
- (e) Suggest how would the K_c be affected if the concentration of NO₂ introduced were to [1] decrease by 0.2 times at the same temperature?



Many students were misled by the question. K_c is **only** dependent on temperature.

4. For the reaction between bromate ions, BrO₃⁻, and bromide ions, Br⁻, in an acidic environment, the reaction proceeds as shown.

 $5Br^{-}(aq) + BrO_{3}^{-}(aq) + 6H^{+}(aq) \rightarrow 3Br_{2}(aq) + 3H_{2}O(l)$

[2]

The rate equation is experimentally determined as Rate = $k[H^+]^2[BrO_3^-]^1[Br^-]^1$

(a) Based on the rate equation, sketch the following graphs below



(b) A student designed a series of experiments to study the rate equation for the Br⁻/BrO₃⁻ reaction using the variables as given in the following table.

Experiment	[H ⁺] / mol dm ⁻³	[BrO ₃ ⁻]/mol dm ⁻³	[Br [_]]/ mol dm ^{_3}	Rate/mol dm ⁻³ s ⁻¹
1	0.01	0.02	0.01	0.4
2	0.005	0.02	0.01	x
3	0.005	0.02	У	2x
4	0.01	Z	0.01	1.0

Using relevant values form the table and the rate equation given above, deduce the values for **x**, **y** and **z**.

Compare 1, 2, reaction is 2^{nd} order wrt to $[H^+] \Rightarrow [H^+]$ decrease 2 times, rate will decrease 4 times. x = 0.4/4 = 0.1

Compare 2, 3, reaction is 1st order wrt to $[Br^-] \Rightarrow$ rate decrease 2 times, y/0.01 = 2 y = **0.02**

Compare 1, 4, reaction is 1^{st} order wrt to $[BrO_3^-] \Rightarrow$ rate decrease 1/0.4 = 2.5 times z/0.02 = 2.5 z = 0.05

(1) for each correct answer.

(c) Comment on the significance of the rate constant, *k*, in the rate equation.

[1]

[3]

The rate constant, k, gives a <u>direct measure of the relative reaction rate</u>.

[A very small value for the rate constant equates to a very slow reaction in general. A large value for the rate constant means a large value for the rate and that the reaction is rapid]

(d) In order to determine the activation energy, E_a, of the reaction, the student conducted a series of experiments by changing the temperature and calculating the rates of the reaction at those temperatures. He obtained the following graph.



Using the data from the graph and the values from section 1 and 2 of the data [3] booklet, calculate the activation energy, E_a, of the reaction.

|--|

(accept other relevant values for the x and y coordinates) (1)
E_a= 8.31 x 7142.85 = 59 257 J mol⁻¹ ✓ (1) = 59.3 kJ mol⁻¹ ✓ (accept values between 58–60) (1)
<u>Comments:</u>

Remember: gradient = - E_a/R; units of E_a will be in J mol⁻¹ due to units of R.
Check the axes for factors such as 10⁻³ ⇒ common mistake to miss out

- Read coordinates carefully to arrive at final answer within the range.
 - (ii) Describe qualitatively the relationship between the rate constant, k, and the [1] temperature, T.

as <u>temperature/T increases</u> \checkmark rate constant/<u>k increases</u> <u>exponentially</u> \checkmark *both points needed for full marks*.

Comments:

 $k = Ae^{-Ea/RT} \Rightarrow$ relationship is exponential.

- 5. Nitric acid, HNO₃, is a strong acid while nitrous acid, HNO₂, is a weak acid.
 - (a) Distinguish between the terms *strong* and *weak acid* and construct the equations to show [2] the dissociation of each acid in aqueous solution.

Strong acid dissociates completely in water/solution to produce H ⁺ (aq)/hydrogen ions/protons. [½] HNO ₃ (aq) \rightarrow H ⁺ (aq) + NO ₃ ⁻ (aq) [½] Weak acid dissociates partially in water/solution to produce H ⁺ (aq)/hydrogen ions/protons. [½] HNO ₂ (aq) \rightleftharpoons H ⁺ (aq) + NO ₂ ⁻ (aq) [½]
Important to memorise the definition of strong and weak acid.
Equation stated must make reference to the acid HNO_3 and HNO_2 , and not HA. For weak acid, reversible arrow must be used.
(b) Describe one chemical method that could be used to distinguish between nitric acid and [2] nitrous acid solutions of the same concentration.
1. Reaction with reactive metal (No. Mr) or metal corbonate (No. CO.) [1]
Nitric acid – faster rate of effervescence/disappearance of solid [½]
Nitrous acid – slower rate of effervescence/disappearance of solid [1/2]
OK 2 Reaction with alkali [1]
Nitric acid – larger temperature change [½]

Clear observations for each substance must be written. Do not just write faster and slower rate of reaction.

Nitrous acid – smaller temperature change [1/2]

(OWTTE)

- (c) A student conducted two titration experiments to determine the volume of 0.20 mol dm⁻³ sodium hydroxide solution required to completely neutralise separate samples of the acid.
 - (i) Calculate the volume of sodium hydroxide solution required to completely neutralise [1] 25.0 cm³ of 0.10 mol dm⁻³ nitric acid.

 $nHNO_3 = (0.0250)(0.10) = 0.0025 \text{ mol} [1/2]$ nNaOH = 0.0025 mol $vNaOH = (0.0025)/(0.20) = 0.0125 \text{ dm}^3 = 12.5 \text{ cm}^3 [1/2]$

(ii) The student made the following hypothesis: "Since nitrous acid is a weak acid, 25.0 cm³ of 0.10 mol dm⁻³ of nitrous acid requires a smaller volume of sodium hydroxide solution for complete neutralisation."
 Comment if this is a valid hypothesis.

[1]

Not valid. $\checkmark [1/2]$ Nitrous acid will require <u>same volume</u> of sodium hydroxide as nitric acid / nitrous acid reacts with 12.5 cm³ sodium hydroxide. $\checkmark [1/2]$ OR Neutralization volume is determined by the mol ratios of the acid and base and not by the strength of the acids. $\checkmark [1/2]$ OR OWTTE

(iii) Using section 22 of the data booklet, identify a suitable indicator that can be used [1] to determine the end point in both titrations.

Phenolphthalein [1]

Phenol red is not allowed as the pH range is 6.8 to 8.4. For a weak acid–strong base titration, equivalence pH is above 7. Phenol red will show colour change earlier, before equivalence volume is reached.

(iv) Using relevant equation(s), describe how an indicator, HIn, works.

[2]



- (d) The pH of 25.0 cm³ of 0.10 mol dm⁻³ of nitrous acid, HNO₂, is 2.17 at 298 K.
 - (i) Write an expression for the *acid dissociation constant*, *K*_a, of nitrous acid, and [2] determine the value of K_a for this acid at 298 K, stating its units.



1Z	$(10^{-2.17})^2$		[4]
$\kappa_a = 1$	(0.10)	$= 4.57 \times 10^{-1}$ mol dm $^{\circ}$	[1]

(ii) The dissociation of nitrous acid into its ions in aqueous solution is an endothermic [2] process. State and explain the effect of increasing temperature on its pH value.

When temperature increases, position of equilibrium ($HNO_2(aq) \rightleftharpoons H^+(aq) + NO_2^-(aq)$) shifts to the right [0.5] to favour the forward endothermic process to decrease temperature/reduce heat [0.5]. [H⁺] increases [0.5], pH decreases [0.5]. [1]

- (e) Solution A contains n moles of nitrous acid. The addition of some sodium hydroxide to A neutralises half of the nitrous acid present to produce solution B.
 - (i) Using your answer in part (d)(i), determine the pH of solution **B**.

[1]

 $pH = pK_a = -log (4.57088 \times 10^{-4}) = 3.34$ [1] The solution is at maximum buffer capacity.

(ii) Solution **B** can act as a buffer. Write an equation to show how solution **B** can act as [1] a buffer when a small amount of hydrochloric acid is added.

 NO_2^- (aq) + H⁺ (aq) \rightarrow HNO₂ (aq) Reversible arrow is not allowed as the process is a neutralisation reaction. Equation is a must to show.

6. (a) Besides ozone, chlorine dioxide (ClO₂) is also used in water treatment. In the laboratory, ClO₂ can be prepared by oxidsing of sodium chlorite ● (NaClO₂) with Cl₂. Cl₂ is reduced to Cl⁻ ● in the process.

	(i)	Determine the oxidation state of chlorine in ClO_2 and in ClO_2^- .	[1]
ClO ₂	+4	: ClO_2^- +3	

(ii)	Identify the reducing agent in this reaction.	[1]

 $NaClO_2$ or ClO_2^- or sodium chlorite.

(iii) Given the following electrode potential, [1] $CIO_2(aq) + e^- \rightleftharpoons CIO_2^-(aq) \qquad E^{\theta} = +0.95 V$ use relevant data from section 24 of the data booklet to calculate the $\mathsf{E}^{\theta}_{\text{cell}}$ of the reaction.

 $E^{\circ} = E^{\circ}_{red} - E^{\circ}_{ox} = +1.36 - (+0.95) = +0.41 \text{ V} (1)$

Comments:

read (a) stem to know reaction: **1** E_{ox} **2**: E_{red}

- (b) Another method of producing ClO₂ is to electrolyse an aqueous solution of sodium chlorite (NaClO₂) using inert electrodes. ⇒ ions present, Na⁺, ClO₂⁻, H₂O
 - (i) Deduce the reaction occurring at the cathode and anode by writing a balanced half– [2] equation at each electrode.

anode: $CIO_2^- \rightarrow CIO_2^- + e \checkmark$ (1) cathode: $2H_2O + 2e \rightarrow H_2 + 2OH^- \checkmark$ (2) (must be balanced for full marks and use " \rightarrow ")	
Method: 1. analyse which ions go to the anode and ca	ithode
Anode: CIO ₂ ⁻ and H ₂ O	<u>Cathode:</u> Na⁺and H₂O
$ $ ClO ₂ (aq) + e ⁻ \Rightarrow $\frac{ClO_2^-}{2}$ (aq) E ^{θ} = +0.95 V \checkmark	Na^+ + e \Rightarrow Na E ^θ = − 2.71V
less +ve	$♦$ $\frac{2H_2O}{P}$ + 2e \Rightarrow H ₂ + 2OH ⁻ E ^θ = -0.83V ✓
\bullet O ₂ + 4H ⁺ + 4e \rightleftharpoons 2H ₂ O E ^θ = +1.23V	more +ve
2. less +ve E^{θ} undergoes oxidation at anode:	
more type E^{θ} undergoes reduction at catho	de
Comments.	
Must know these half, equations for evidet	ion / reduction of water m
• Wust know these half—equations for oxidat	
A poorly done question due to either not re	eading question carefully or not knowing the method
to approach it.	
(ii) Construct the overall balanced equ	ation for the electrolysis process. [1]
(1) x 2 + (2):	
$2\text{CIO}_2^- + 2\text{H}_2\text{O} \rightarrow 2\text{CIO}_2 + \text{H}_2 + 2\text{OH}^-$	

(iii) Explain the reaction occurring at the anode by stating relevant E^{θ} values from [2] section 24 of the data booklet.

At anode:		
CIO_2 + $e^- \rightleftharpoons CIO_2^-$	$E^{\theta} = +0.95 \text{ V}$	
$1/_2O_2 + 2H^+ + 2e \rightleftharpoons H_2O$	$E^{\theta} = +1.23 \text{ V}$ quote values (1)	
Since $E^{\theta}(ClO_2/ClO_2^{-})$ is <u>less positive</u> than that of O_2/H_2O , ClO_2^{-} is preferentially oxidized. (1).		

(iii) Describe the observation(s) at the cathode.

[1]

effervescence (H₂) is seen.

7. (a) Compound **A**, C₂H₃CONH₂, is a suspected carcinogen. It is formed in starchy foods when [1] they are heated at high temperatures such as those found in frying and roasting.



compound A

Name the functional groups in compound A.

alkenyl, carboxamide.

Comments:

- Use functional group <u>names</u> such as the above and hydroxyl, phenyl.
 *Alkene, amine, amide, alcohol
- Learn to distinguish between amine and carboxamide.
 N bonded to C=O is a carboxamide. Not ketone and amine separately (⇒ common mistake!).
 E.g. R' can be any alkyl group or H atom in the following carboxamide.

- (b) Through a series of intermediate steps, compound **A** can be reduced to compound **B**, $C_{3}H_{7}NH_{2}$.
 - (i) Draw the structure of compound **B**.

[1]

CH₃–CH₂–CH₂–NH₂

(ii) A student attempted the reduction of compound **A** and obtained the IR spectrum of [2] the product **B**, as shown below.

Justify with two pieces of evidence that compound **A** is reduced to **B**.



Any two of the following three answers + quote values: No/absence of peaks at about 1620–1680 cm⁻¹ indicates no C=C / alkene present ✓ No/absence of peak at about 1700–1750 cm⁻¹ indicates no C=O / amide present ✓ Two medium peaks at 3500 cm⁻¹ indicates N–H bond is present ✓

(c) Compound **A** has a relative molecular mass of 71.

It can be reduced to another compound **C** with a molecular ion peak that occurs at m/z value 73. There are also base peaks found at m/z value 29 and m/z value 16.

(i) Compound **C** does not decolourise bromine water. Comment on this observation. [1]

C is **not** an alkene / does not contain double bond (C=C).

Comments:

For negative test, say what is not present / absent.

Saying it's an "alkane" is non-conclusive because compound can be anything other than alkene.

(ii) Suggest the formula of the species at m/z value 29 and at m/z value 16.

 $m/z 29 = C_2H_5^+ \checkmark$, $m/z 16 = NH_2^+ \checkmark$ (ZERO marks without +ve sign)

Comments:

- common mistake to omit + sign! [concept: Charged species is detected in mass spectrum]
- strictly speaking, m/z 29 cannot be CHO⁺ since A is <u>not</u> a ketone that can be reduced to a 2° alcohol.
 - (iii) Hence, deduce the structural formula of compound **C**.

[1]



(i) Other than propan–1–ol, identify a suitable 3–carbon compound that can be converted to propanoic acid.

Propanal, sodium propanoate/propanoate salt, propane nitrile.

Comments:

- propanal is <u>not</u> propan–1–al
- propanoate salt: $C_2H_5COO^- + H^+ \rightarrow C_2H_5COOH$
- propane nitrile: C_2H_5CN reacts with aqueous H⁺/heat to from C_2H_5COOH
 - (ii) Explain the mechanism of the reaction of 1–chloropropane to form propan–1–ol [2] using curly arrows to represent the movement of electron pairs.

Clear S_N2 mechanism (since primary RX) represented. Draw $S_N1 \Rightarrow$ zero mark. 1. C^{δ_+} , Cl^{δ_-} shown 2. Attack of OH⁻ from opposite side of Cl 3. 2 curly arrows (1) from lone pair on :OH– to C^{δ_+} (2) from C–Cl bond to Cl 4. pentavalent transition state 5. final product includes Cl⁻ ion HO----Cl CH₂CH₃ Trigonal bipyramidal transition state

(d) Liquid propan–1–ol readily undergoes combustion.

(i) Construct a balanced equation with state symbols for the combustion of propan-1-ol.

(ii) Given that the enthalpy change of formation of liquid propan-1-ol is [2] -303 kJ mol⁻¹, use relevant data from section 12 the data booklet to determine the enthalpy change of combustion of propan-1-ol.

$$\frac{Using (1)}{\Delta H} = 3(-393.5) + 4(-285.8) - (-303) = -2020.7 \text{ kJ mol}^{-1}$$

$$\swarrow$$

$$\frac{Comments:}{\checkmark}$$
For students who used eqn (2), ΔH calucated is for 2 mol of propan-1-ol. Hence need to divide by 2 to get final answer.

(iii) Use your answer in (ii) to calculate the mass of propan-1-ol needed to boil 100 cm³ of water in a calorimeter at 25 °C. It is found that this process is only 80%

[3]



(iv) State one assumption used in the calculation in (iii).

Any one of the following:

- All the heat evolved during the combustion reaction is absorbed by the water
- The heat absorbed by the calorimeter is negligible
- Only complete combustion takes place
- No loss of fuel through vaporisation

Comments:

Not appropriate to state assumption that density of water is 1 g cm⁻³ because there is only water in the calorimeter. This assumption is appropriate if solution is not purely water e.g. salt solution.