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# SCHOLARSHIP EXEMPLAR



NEW ZEALAND QUALIFICATIONS AUTHORITY  
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD  
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## Scholarship 2015 Chemistry

9.30 a.m. Friday 27 November 2015

Time allowed: Three hours

Total marks: 32

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

Pull out Resource Sheet S–CHEMR from the centre of this booklet.

You should answer ALL the questions in this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–20 in the correct order and that none of these pages is blank.

You are advised to spend approximately 45 minutes on each question.

**YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.**

Question	Mark
ONE	
TWO	
THREE	
FOUR	
<b>TOTAL</b>	/32

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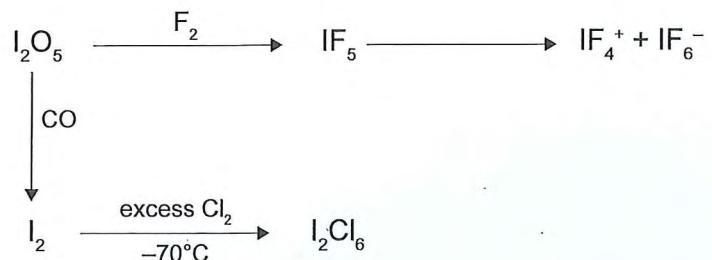
**QUESTION ONE**

Almost all the elements of the periodic table form halides, which may be simple molecular compounds, ionic compounds or infinite atomic arrays. When interhalogen compounds form, there is often more than one possible product, depending on the temperature of the reaction or the relative proportions of the halogens.

- (a)  $\text{IF}_5$  can be formed by the action of  $\text{F}_2$  on diiodine pentoxide,  $\text{I}_2\text{O}_5$ .  $\text{IF}_5$  self-ionises to  $\text{IF}_4^+$  and  $\text{IF}_6^-$ .

$\text{I}_2$  can be extracted from  $\text{I}_2\text{O}_5$  with CO.

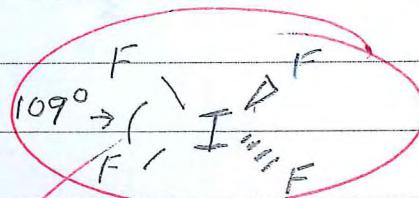
$\text{I}_2\text{Cl}_6$  is produced by reacting  $\text{I}_2$  with excess  $\text{Cl}_2$  at  $-70^\circ\text{C}$ .



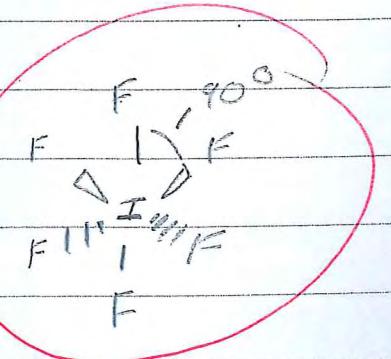
- (i) Predict, with reasoning, the shape of the ions  $\text{IF}_4^+$  and  $\text{IF}_6^-$ .

Include a diagram and suggested bond angles in your answer.

$\text{IF}_4^+$  will be tetrahedral as there are four fluorines around a central iodine and there are no lone pairs to effect the shape of the molecule as iodine is in a 5+ oxidation state

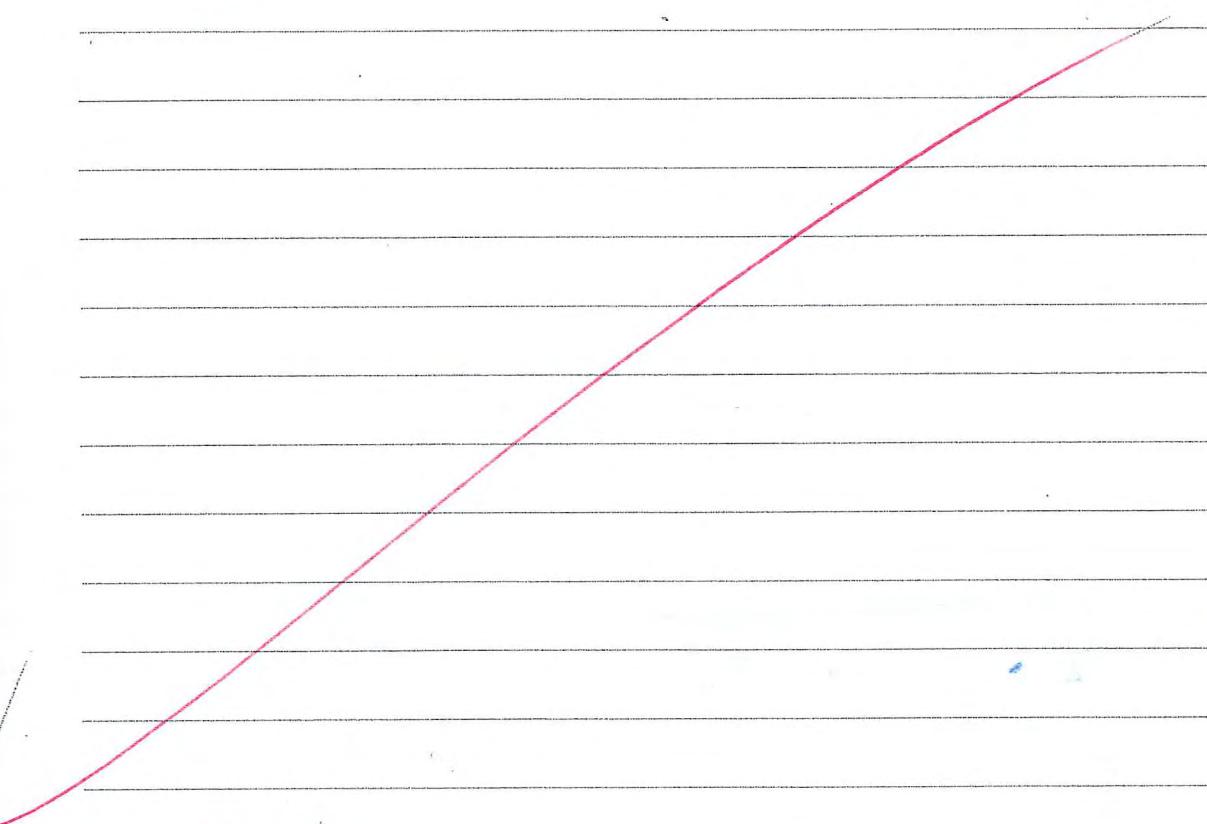
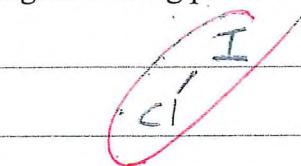


$\text{IF}_6^-$  is octahedral as there are six fluorines and the negative charge is due to an excess of 5 fluorine ions not any intervening lone pairs as iodine is bonded to many fluorines

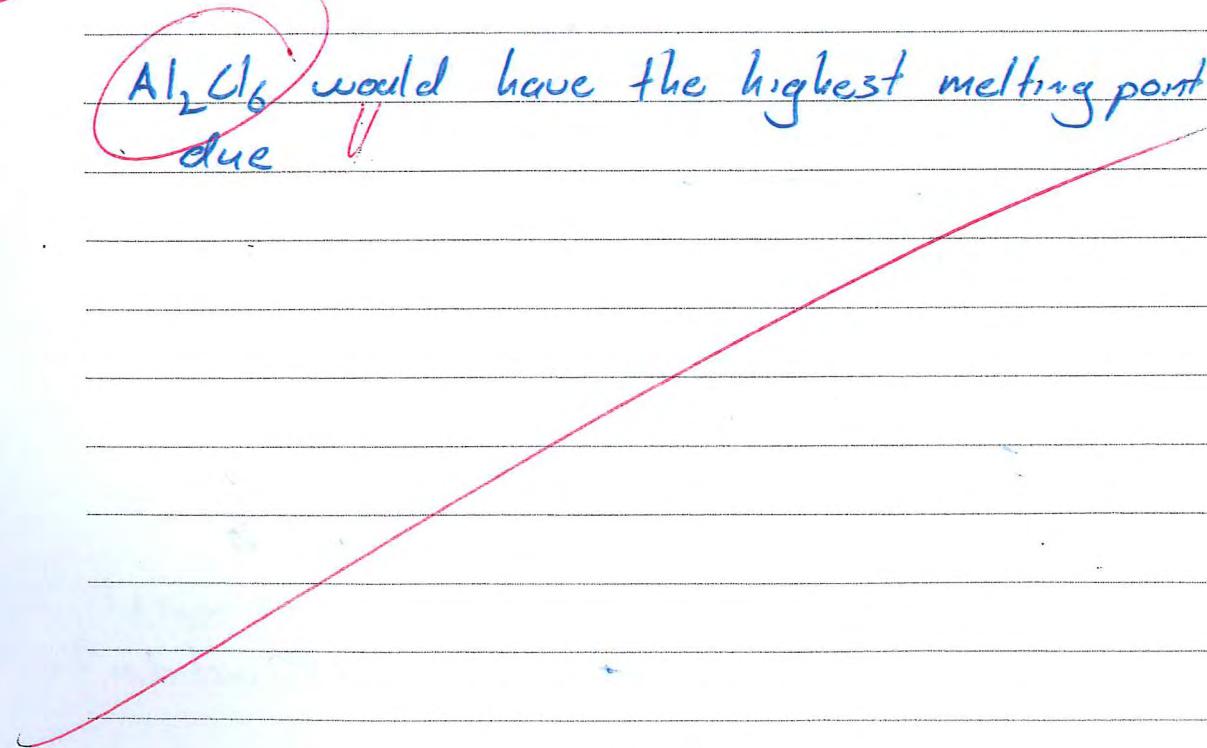


- (ii)  $\text{I}_2\text{Cl}_6$  is a molecular compound. Molecules of  $\text{I}_2\text{Cl}_6$  are symmetrical with no I-I bonds.  $\text{Al}_2\text{Cl}_6$  is also a molecular compound, containing symmetrical molecules with no Al-Al bonds.

Compare and contrast the geometry around the I and Al atoms in these molecules, and predict, on the basis of the molecular structure, which of the compounds would have the higher melting point.



$\text{Al}_2\text{Cl}_6$  would have the highest melting point due



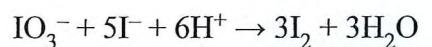
- (b) Diiodine pentoxide ( $I_2O_5$ ) can be used to determine quantitatively the concentration of carbon monoxide in air. The iodine resulting from the reaction of CO and  $I_2O_5$  is titrated with thiosulfate, and the end point is detected by the disappearance of the blue-black colour produced by starch and iodine.

Thiosulfate ions,  $S_2O_3^{2-}$ , are oxidised to tetrathionate ions,  $S_4O_6^{2-}$ , by iodine.

Thiosulfate solutions can be standardised using a primary standard, potassium iodate,  $KIO_3$ .

In order to standardise a thiosulfate solution, a standard solution of potassium iodate was prepared by dissolving 0.5466 g of  $KIO_3(s)$  in sufficient water to make 250.00 mL of solution.

10.00 mL of this  $KIO_3$  solution was pipetted into a conical flask, and 10 mL of 2 mol L<sup>-1</sup> sulfuric acid was added, followed by the slow addition of 10 mL of 0.25 mol L<sup>-1</sup> potassium iodide solution. A red-brown solution is formed. The equation for the reaction is:



The iodine generated was then titrated against the unknown thiosulfate solution using a starch indicator. The average titre for three concordant results was 25.48 mL.

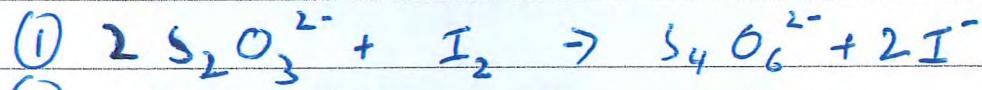
To determine the concentration of carbon monoxide in a sample of air, 23.20 L samples were passed through a series of cold traps to remove nitrogen oxides, water and other interfering compounds. The remaining gas was passed through a sample of acidified  $I_2O_5$ , which reacted quantitatively with the CO fraction of the gas to produce  $I_2$  and  $CO_2$ . The resulting iodine was flushed with nitrogen into a reaction flask, and titrated with the standardised sodium thiosulfate solution described above. The average titre for the samples tested was 17.23 mL.

Determine the concentration of CO in the air sample, in g L<sup>-1</sup>.

$$M(KIO_3) = 214.0 \text{ g mol}^{-1}$$

$$M(CO) = 28.00 \text{ g mol}^{-1}$$

Concentration of thiosulfate



1) Find concentration of thiosulfate

$\Rightarrow$  concentration of iodine

$$\Rightarrow cIO_3^- = \frac{0.5466}{214} \times 0.25 = 0.01021 \text{ mol dm}^{-3}$$

$\therefore$  as KI is in excess  $nI_2 = 3 \times nIO_3^-$

but as volume increases 3x,  $cKI = cI_2$

$$\Rightarrow cI_2 = 0.01021 \text{ mol dm}^{-3}$$

$$\Rightarrow nI_2 = 0.01021 \times \frac{36}{1000} = 3.063 \times 10^{-4} \text{ mol}$$

Two thiosulfates react with one iodine  $\Rightarrow$

$$\therefore nS_2O_3^{2-} = 6.126 \times 10^{-4} \text{ mol}$$

$$\therefore cS_2O_3^{2-} = 6.126 \times 10^{-4} \times \frac{25.48}{1000} = 0.0240 \text{ mol dm}^{-3}$$

- 2) In the second titration, 17.23 mL of 0.0240 mol dm<sup>-3</sup> thiosulfate is used

$$\Rightarrow nS_2O_3^{2-} = 17.23 \times 10^{-3} \times 0.0240 = 4.135 \times 10^{-4}$$

$$\therefore nI_2 = \frac{1}{2} nS_2O_3^{2-}$$

$$= 2.068 \times 10^{-4} \text{ mol}$$

$$\text{from (1), } nCO = 3nI_2$$

$$\Rightarrow nCO = 6.203 \times 10^{-4} \text{ mol}$$

$$\therefore mCO = 6.203 \times 10^{-4} \times 28$$

$$= 0.017368 \text{ g}$$

$\therefore$  concentration of CO

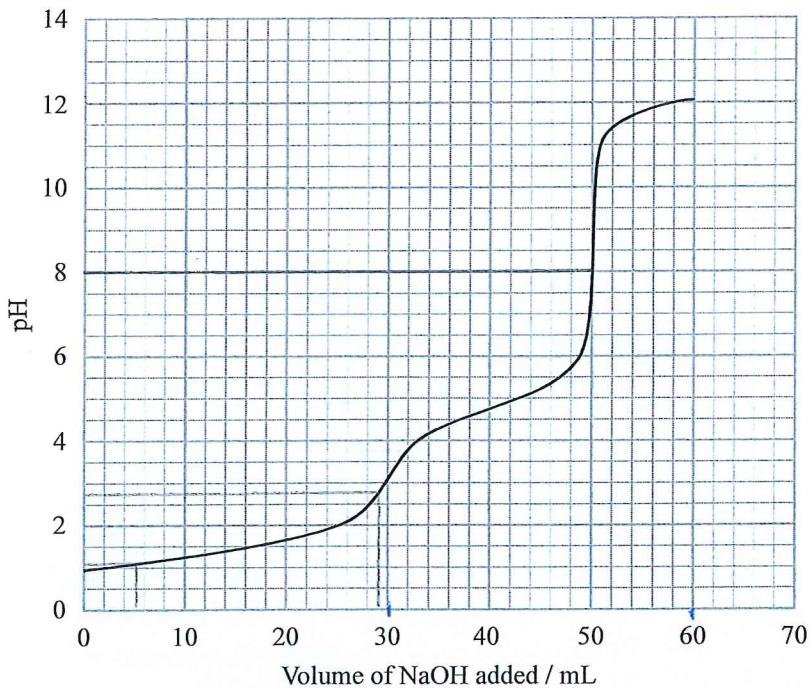
$$= \frac{0.017368}{23.2} = 7.49 \times 10^{-3} \text{ g L}^{-1} //$$

Assuming in all cases that all the reactants were reacted and 100% efficiency //

**QUESTION TWO**

A mixture of 15.00 mL of 0.200 mol L<sup>-1</sup> HCl and 10.00 mL of 0.200 mol L<sup>-1</sup> CH<sub>3</sub>COOH is titrated against 0.100 mol L<sup>-1</sup> NaOH solution.

The titration curve shows two equivalence points, one at 30.0 mL and one at 50.0 mL of added NaOH.



- (a) (i) Calculate the pH after the addition of 5 mL, 29 mL, and 50 mL of NaOH.

Comment on the validity of any assumptions made for the calculations.

Note: The pK<sub>a</sub> of the acid should be approximated from the graph.

$$\text{pH} = \text{pK}_a + \log(\text{base}/\text{acid})$$

The first equivalence point is that due to CH<sub>3</sub>COOH and the second is due to HCl, as the second closely matches the form produced by adding strong base to strong acid.

At equivalence,  $\text{base} = \text{acid} \Rightarrow \log \frac{\text{base}}{\text{acid}} = 0$   
therefore pH = pK<sub>a</sub>

⇒ reading from graph pK<sub>a</sub> = 3

$$\text{pK}_{a_2} = 8$$

3 refers to the HCl/CH<sub>3</sub>COOH, 8 refers to the NaOH //

Therefore for 5 and 29,  $\text{pH} = 3$

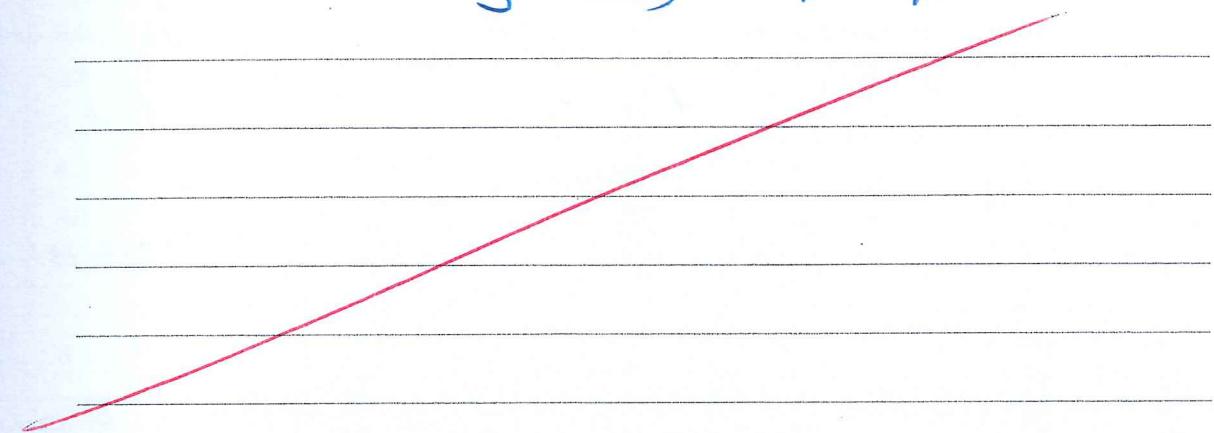
$$\Rightarrow @ 5, \text{pH} = 3 + \log \left( \frac{5 \times 1}{25 \times 2} \right) \\ = 2.00$$

$$@ 29, \text{pH} = 3 + \log \left( \frac{29 \times 1}{25 \times 2} \right) \\ = 2.76$$

80.50 mL, pH = 8.00

50 mL is an equivalence point //

$$8 + \log \left( \frac{50 \times 1}{25 \times 2} \right) = 8 = \text{pK}_a = \text{pH} //$$



- (ii) Account for the variation in pH, in terms of the species present in the solution, between the addition of 30 mL and 60 mL of NaOH solution.

Include balanced equations in your discussion.

Between 30 and 50 mL there is a partial buffer region. This is caused by the buffer effect of the CH<sub>3</sub>COOH superimposed onto the curve produced by HCl reacting with NaOH.  $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$  produces the overall equation  $\text{CH}_3\text{COOH} + \text{OH}^- \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_2\text{O}$ , removing OH<sup>-</sup> ions and producing the observed delay in the increase of pH which occurs at 50 mL, when both all the CH<sub>3</sub>COOH, and the H<sub>3</sub>O<sup>+</sup> produced by ionisation of HCl and CH<sub>3</sub>COOH has reacted with OH<sup>-</sup> at 50 mL of NaOH there is no longer any //

There is more space for your answer to this question on the following page.

unreacted  $\text{H}_3\text{O}^+$  as sufficient NaOH has been added to ~~not~~ remove it. The ~~low~~ pH is the slightly basic pH at this point is due to the conjugate bases formed earlier (primarily  $\text{CH}_3\text{COO}^-$ ). Following from this point, pH increases further as the only species which effects pH is  $\text{OH}^-$ , as it is in excess and therefore removes any  $\text{H}_3\text{O}^+$  in the solution. Rate of pH increase slows as more NaOH is added due to pH being a logarithmic scale ( $10 \times$  the  $\text{OH}^-$  increases pH by 1). Prior to the endpoint of the titration at slightly less than 50 mL of NaOH neutralisation occurs, as <sup>than NaOH</sup> slightly more acid must be present to compensate for conjugate bases. //

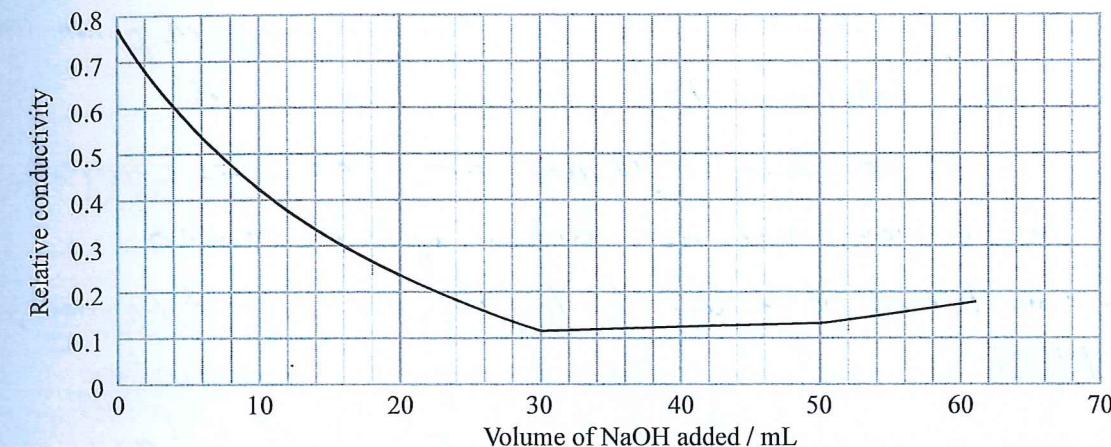
e2

- (b) Solutions of mixed strong and weak acids are often analysed using a conductometric titration. In a conductometric titration, the equivalence points are determined by monitoring changes in the conductivity of the solution. These changes depend on the concentration and the relative conductivities of the ions in solution.

The relative conductivities of some ionic species are shown in the table below.

Ionic species	Relative conductivity
$\text{Na}^+, \text{Cl}^-, \text{CH}_3\text{COO}^-$	1
$\text{OH}^-$	3
$\text{H}_3\text{O}^+$	5

The conductivity curve for the titration described in part (a) is given below.



Account for the shape of the conductivity curve as the volume of NaOH increases from 0 mL to 60 mL by commenting on why the conductivity decreases or increases in each phase of the plot. Link your answers to the relative concentrations of the species present in the solution in the reaction flask.

It can be assumed that the total conductivity in a solution is the sum of the conductivities of the ions present.

Initially the conductivity is high as the maximum possible  $\text{H}_3\text{O}^+$  is present, as no acids have reacted as no ~~OH~~ NaOH has been added. As NaOH is added  $\text{H}_3\text{O}^+$  decreases ( $\text{OH}^- + \text{H}_3\text{O}^+ \rightleftharpoons 2\text{H}_2\text{O}$ ) so conductivity decreases, rapidly initially then slowing toward 30 mL of NaOH. The rate of decrease slows as despite the constant removal of  $\text{H}_3\text{O}^+$  other slightly conductive species are being formed and added. //

There is more space for your answer to this question on the following pages.

particularly  $\text{Na}^+$  from the reaction  $\text{NaOH} + \text{H}_3\text{O}^+ \rightarrow 2\text{H}_2\text{O} + \text{Na}^+$ , and  $\text{CH}_3\text{COO}^-$  from the gradual increase in ionisation of ethanoic acid, as  $\text{H}_3\text{O}^+$  is removed from the products of  $\text{CH}_3\text{COOH} + \text{H}_3\text{O}^+ \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_2\text{O}^+$ , more products are formed as the forward reaction is favored and therefore more  $\text{CH}_3\text{COO}^-$  is present. These two species slow the decrease of conductivity due to the removal of  $\text{H}_3\text{O}^+$ . [Note that  $[\text{Cl}^-]$  will not change until a large excess of  $\text{Ag}^+$  forms] The minimum conductivity results from the first equivalence point where the total conductivity is lowest due to the interaction of decreasing  $\text{H}_3\text{O}^+$  and lack of other charged particles which have not formed yet. Between 50mL NaOH and 60mL NaOH is the largest increase in ~~conductivity~~ conductivity due to there being no further decrease in conductivity due to loss of  $\text{H}_3\text{O}^+$ , but an increase in the concentrations of both  $\text{OH}^-$  and  $\text{Na}^+$  as the base is in excess //

## QUESTION THREE

- (a) A solution is made by adding 42.69 g of a mixture of the aldehydes methanal, HCHO, and ethanal,  $\text{CH}_3\text{CHO}$ , to 76.59 g of water.

Addition of excess ammoniacal silver nitrate solution to 2.18 g of the mixed aldehyde solution results in the precipitation of 4.64 g of silver metal.

Determine, by carrying out the appropriate calculation, the mass, in g, of each of the aldehydes, methanal, and ethanal, in the mixture.

$$M(\text{Ag}) = 107.9 \text{ g mol}^{-1} \quad M(\text{HCHO}) = 30.03 \text{ g mol}^{-1} \quad M(\text{CH}_3\text{CHO}) = 44.05 \text{ g mol}^{-1}$$

$$n_{\text{Ag}} = \frac{4.64}{107.9} = 0.0430 \text{ mol}$$

$\text{X CHO}$  reacts 1:1 with silver ions 1  
~~2.18/0.0430 = 50.91~~

The solution is  $\frac{42.69}{119.28} \times 100 = 35.789\% \text{ aldehyde}$

$\Rightarrow \text{moles aldehydes} = \text{moles silver}$

~~2.18~~ find m of aldehydes

$$2.18 \times 0.35789\dots = 0.7802 \text{ g aldehydes}$$

so to find mass of each aldehyde in the sample (2.18g)

$$\Rightarrow n_T = \frac{m_1}{M_1} + \frac{m_2}{M_2}$$

$$\Rightarrow 0.043 = x \div 30.03 + (0.7802 - x) \div 44.05 \quad (x = \text{mass HCHO})$$

$$\Rightarrow 0.043 = \frac{44.05x - 30.03x + 23.429}{1322.8}$$

$$\Rightarrow 14.02x = 0.043 \times 1322.8 - 23.429$$

$$= 33.45$$

$$x = 2.$$

see end of paper

(b)

**INFORMATION**

The reaction of an alkene with acidified potassium permanganate results in the breaking of the double bond. The reaction product depends on the number of hydrogen atoms present on the double-bonded carbon atoms. If there are no hydrogen atoms, a ketone is formed; if one hydrogen atom is present, a carboxylic acid is formed; if there are two hydrogen atoms present, carbon dioxide gas is produced. Oxalic acid (ethanedioic acid) also reacts with warmed, acidified, potassium permanganate to give two mole equivalents of  $\text{CO}_2$  gas..

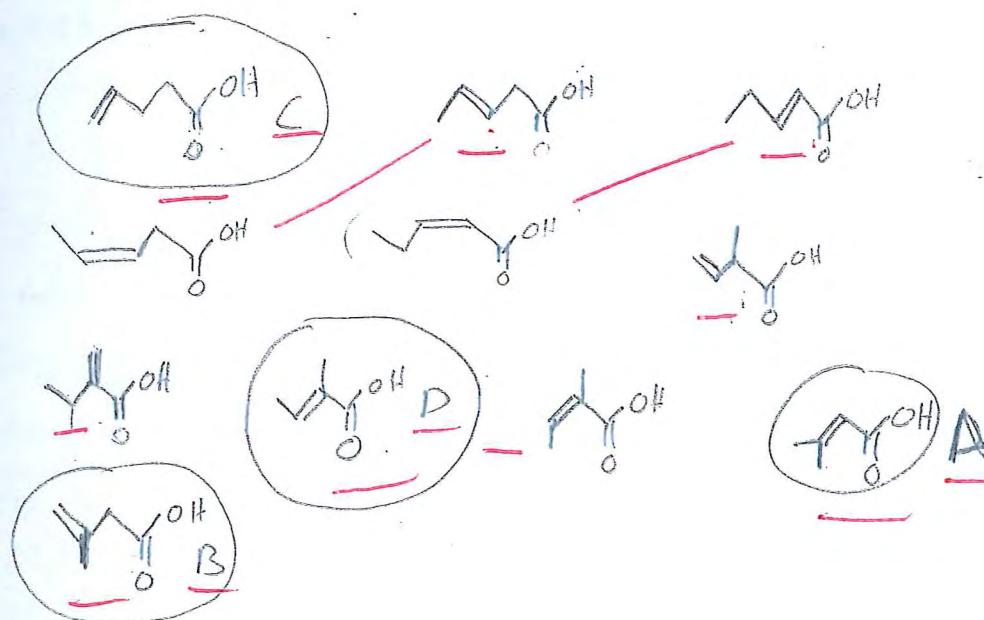
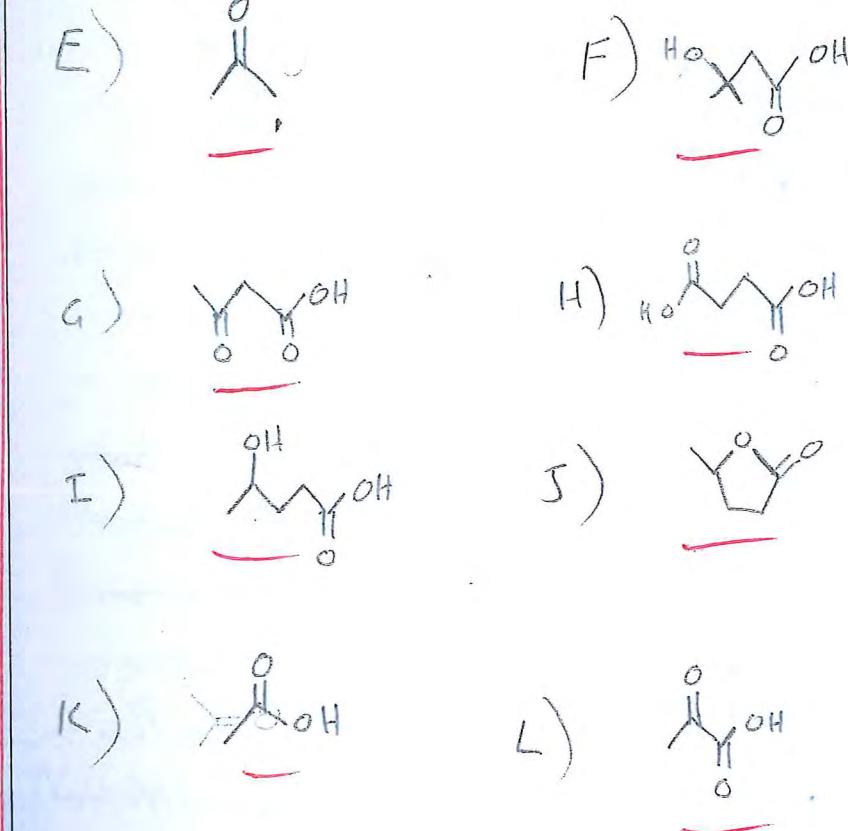
Four compounds, **A**, **B**, **C**, and **D**, have the molecular formula  $\text{C}_5\text{H}_8\text{O}_2$ . They all turn moist blue litmus paper red. Spectral data indicate that none of the compounds is cyclic. Each compound is reacted with warmed, acidified, potassium permanganate and, for some compounds or reaction products, further reactions are carried out as outlined below.

- Compound **A**, on reaction with warmed, acidified, potassium permanganate, produces Compound **E**,  $\text{C}_3\text{H}_6\text{O}$ , and a colourless gas is observed. Compound **E** does not react with sodium carbonate solution. Compound **A** also reacts with water in the presence of an acid catalyst to give Compound **F**,  $\text{C}_5\text{H}_{10}\text{O}_3$ , as the major product. Compound **F** is not optically active, and does not react with acidified potassium dichromate.
- Compound **B**, on reaction with warmed, acidified, potassium permanganate, produces a colourless solution containing Compound **G**, and a colourless gas is observed. Compound **B** reacts with water in the presence of an acid catalyst to give Compound **F** as the major product.
- Compound **C**, on reaction with warmed, acidified, potassium permanganate, produces a colourless solution containing Compound **H**. Bubbles of gas are also observed. Compound **H** does not exist as enantiomers. One mole of Compound **H** reacts with 2 mol equivalents of a standard solution of sodium hydroxide. Compound **C** reacts with water in the presence of an acid catalyst to give Compound **I**,  $\text{C}_5\text{H}_{10}\text{O}_3$ , as the major product. Compound **I** exists as enantiomers, and in the presence of concentrated sulfuric acid, produces Compound **J**,  $\text{C}_5\text{H}_8\text{O}_2$ . Compound **J** is neutral to litmus paper, and does not rapidly decolourise bromine water.
- Compound **D** reacts with warmed acidified potassium permanganate to give a colourless solution containing two compounds, **K** and **L**. Titration of this mixture requires 2 mol equivalents of a standard solution of sodium hydroxide. Compound **K** distils first from the mixture of compounds. Neither compound reacts further with Tollens' reagent.

Draw the structures of ALL the possible isomers of  $\text{C}_5\text{H}_8\text{O}_2$  that turn moist blue litmus paper red, and select the best match for Compounds **A**, **B**, **C**, and **D**.

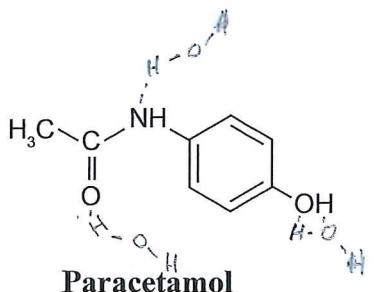
Draw structures for all the reaction products **E** to **L**. Ignore any geometric isomer possibilities.

*Extra pages for planning/working are provided at the back of this booklet.*

Isomers of  $\text{C}_5\text{H}_8\text{O}_2$ :Structures **E** to **L**:

## QUESTION FOUR

- (a) The structural formulae for the molecules of three common pain relievers found on the market today are shown below.



In order for the pain relievers to have their physiological effect, they need to be carried in the bloodstream. Blood is mostly water. Of the three pain relievers, paracetamol is the most soluble at 13 mg mL<sup>-1</sup>, aspirin is slightly less at 3 mg mL<sup>-1</sup>, while ibuprofen has limited solubility at 0.021 mg mL<sup>-1</sup>. The solubility of aspirin and ibuprofen can be increased by supplying each as its calcium salt.

\* Read circled section first

Account for the trend in the solubilities of the pain relievers described above.

$$M(\text{paracetamol}) = 151.2 \text{ g mol}^{-1}, M(\text{ibuprofen}) = 206.3 \text{ g mol}^{-1}, M(\text{aspirin}) = 180.2 \text{ g mol}^{-1}$$

~~Ibuprofen is by far the least soluble as it has the least polar groups and the largest molar mass, so in relation to its size has ~~ext~~ a low number of polar regions. Its only polar section is its carboxylic acid group, as the other ~~ch~~ carbon chain and the arene ring is non polar, so little numbers of water molecules are able to <sup>form</sup> bonds to it in a solution. Its high molar mass decreases the ~~solubility~~ ~~in~~ grams~~

~~Paracetamol is more soluble than aspirin due to a combination of factors. Foremost it has ~~the~~ polar groups to aspirin's two (one long & better distribution of polar regions (1 and 4 compared to (and 2) so ~~the~~ water can form hydrogen bonds easily along the molecule rather than only on one side ~~it~~ in Aspirin makes paracetamol more soluble as it does not have~~

\* ~~to~~ the benzene ring //

one side polar, one side non polar as in Aspirin and particularly in Ibuprofen, which due to its structure would form bilayers and micelles for easier than properly dissolving.

Paracetamol also has a greater ~~charge~~ polarity in its polar regions as ~~amide~~ peptide links and phenol groups have slightly greater dipole moments than ester and carboxylic acids.

The position of ~~per~~ functional groups in Aspirin and Paracetamol, particularly paracetamol may also increase solubility by activating the benzene rings and hence changing ~~per~~ charge distribution due to their inductive effect.

Solubility also decreases with size, due to the non polar groups which are responsible for the increased Mr not contributing more hydrogen bonds.

Supplying Aspirin and Ibuprofen as salts increases solubility by increasing dipole moment in the carboxylic acid groups by changing them into carbocations which are more polar due to the removal of the H<sup>+</sup> in the carboxylic acid (also

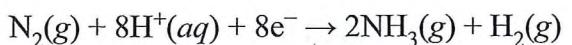
as carboxylic acids are weak acids they only rarely form carbocations naturally as they do not dissociate fully) making the slightly polar -OH group into a very polar -O<sup>-</sup> group, which increases solubility. Paracetamol does not form these salts as phenol <sup>is less</sup> ~~is~~ ~~reactive~~ likely to form salts and no carboxylic acid group is present.

Paracetamol could also be seen to 'be soluble enough' without a need for modification //

Water is a polar solvent and therefore the more polar a substance is the more soluble it will be //

- (b) Nitrogenase is an enzyme present in rhizobia (soil bacteria) that live in the root nodules of legumes. Nitrogenase catalyses the reduction of dinitrogen, N<sub>2</sub>, to two equivalents of ammonia, with additional production of one equivalent of dihydrogen, H<sub>2</sub>.

A balanced half-equation for this reaction is:



Discuss the enthalpy and entropy of this half-reaction, with reference to the data below.

Bond Dissociation Reaction	Bond Dissociation Enthalpy (kJ mol <sup>-1</sup> )
N <sub>2</sub> → 2N	945
H <sub>2</sub> → 2H	436
NH <sub>3</sub> → NH <sub>2</sub> + H	444
NH <sub>2</sub> → NH + H	385
NH → N + H	351

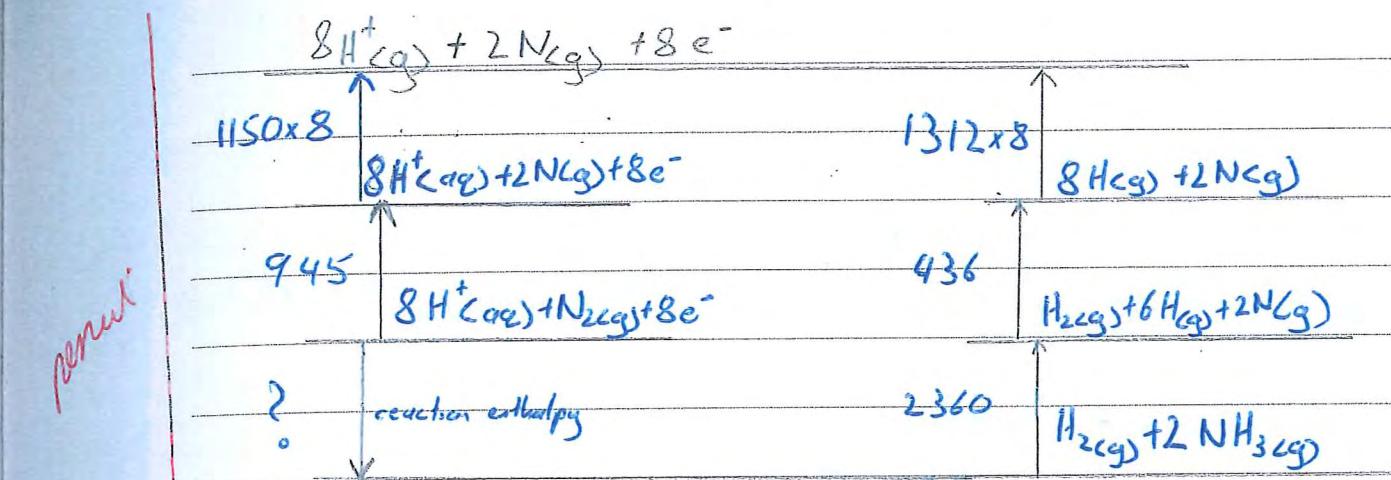
Atom	First Ionisation Enthalpy (kJ mol <sup>-1</sup> )
H	1312

Ion	**Hydration Enthalpy (kJ mol <sup>-1</sup> )
H <sup>+</sup> (g)	-1150

- \*\* Hydration enthalpy is the enthalpy change when 1 mole of gaseous ions dissolve in sufficient water to give an infinitely dilute solution. It is a measure of the energy released when attractions are set up between positive or negative ions and water molecules.

The entropy for this reaction is very favorable as one mole of gas on the reactant side produce three moles of gas on the product side, which is favorable as the reactants are more ordered than the products and therefore the reaction favors the forward reaction. //

With reference to bond and ionisation energies, calculation is required. The reaction can be approximated to a Born-Haber cycle as on the following page



$$[2\text{N} + 6\text{H} \Rightarrow (351 + 385 + 444) \times 2 = 2360 \text{ kJ}]$$

⇒ over the course of the reaction 3147 kJ mol<sup>-1</sup> is released, making the <sup>forward</sup> reaction highly ~~exothermic~~ exothermic and therefore very favorable as the ~~reactants are in~~ products are in a higher energy state than the reactants //

QUESTION  
NUMBER

Extra paper if required.  
Write the question number(s) if applicable.

3a  $0.0430 = \frac{x}{30.03} + \frac{0.780-x}{44.05}$

$x = \text{mass HCHO}$

$$\therefore 0.0430 = \frac{44.05x - 30.03x + 23.43}{1322.82}$$

$$\therefore 56.88 = 14.02x + 23.43$$

$$\therefore 14.02x = 33.45$$

$$x = 2.386 \text{ g (green)}$$

ASSESSOR'S  
USE ONLYQUESTION  
NUMBER

Extra paper if required.  
Write the question number(s) if applicable.

ASSESSOR'S  
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## **Scholarship [21]**

### Question 1 [4]

Attempted to draw the shapes of  $\text{IF}_4^+$  and  $\text{IF}_6^-$  without first drawing Lewis structures. Was unable to compare the geometry around both I and Al atoms to predict the shape of the molecular compounds  $\text{I}_2\text{Cl}_6$  and  $\text{Al}_2\text{Cl}_6$ . The correct method was used in the titration calculation, however, an incorrect ratio was used to calculate the concentration of carbon monoxide (CO).

### Question 2 [5]

The candidate was able to analyse the data given to correctly calculate the pH after 29 mL, however, no assumptions were given.

A well-developed discussion was given accounting for variation in the pH, in terms of the species present for three of the sections of the titration curve. The discussion showed a recognition of the species present in the solution and linked this to the different parts of the conductivity curve.

### Question 3 [6]

The candidate did not recognise the oxidation-reduction reaction involved, however recognised some steps of the calculation.

The candidate correctly identified all isomers and products.

### Question 4 [6]

The candidate gave a logical and concise discussion of factors which affect solubility.

Enthalpy calculation were correct and some analysis of the thermodynamics of the reaction was given.