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OUTSTANDING SCHOLARSHIP EXEMPLAR



NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

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	
TOTAL	/32

ASSESSOR'S USE ONLY

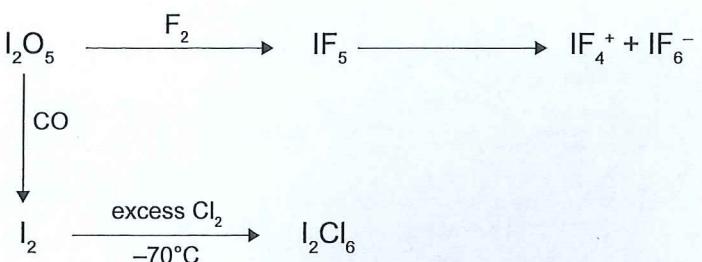
QUESTION ONE

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) IF_5 can be formed by the action of F_2 on diiodine pentoxide, I_2O_5 . IF_5 self-ionises to IF_4^+ and IF_6^- .

I_2 can be extracted from I_2O_5 with CO.

I_2Cl_6 is produced by reacting I_2 with excess Cl_2 at -70°C .

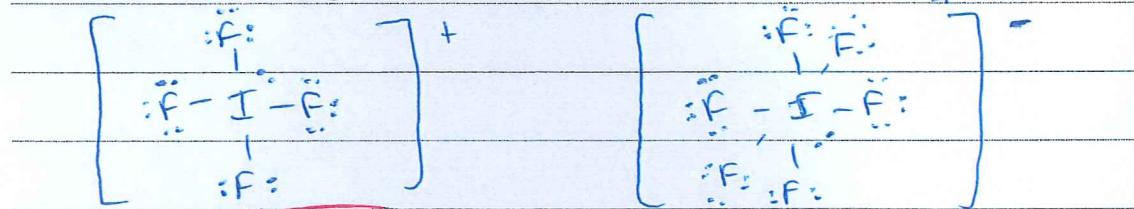


(i) Predict, with reasoning, the shape of the ions IF_4^+ and IF_6^- .

Include a diagram and suggested bond angles in your answer.

$$\text{number of electrons in } \text{IF}_4^+ = 7 + 4 \times 7 - 1 = 34.$$

$$\text{number of electrons in } \text{IF}_6^- = 7 + 6 \times 7 + 1 = 50.$$



IF_4^+ : There are 5 regions of equal electron density around the central bond atom that repel for maximum separation. There are 4 bonding regions, so the shape is distorted tetrahedral and bond angle is 90° and 120° .

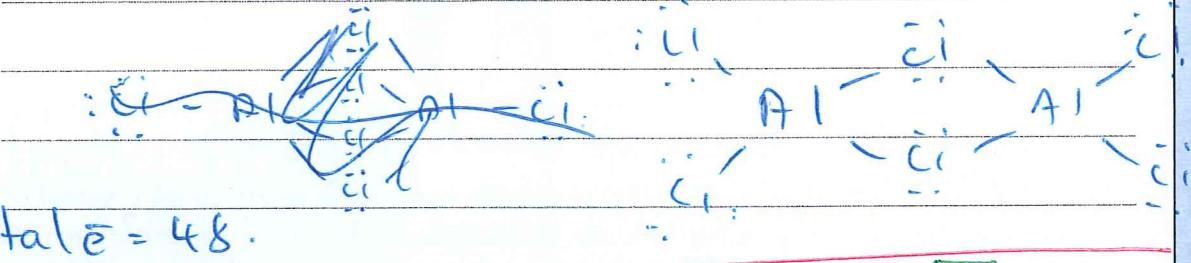
IF_6^- : There are 7 regions of electron density around the central bond atom that repel for maximum separation. There are 6 bonding regions, so the shape is some form of distorted octahedral (?) and bond angle is unknown.

I believe the molecular shape should be IF_4^- (square planar, 90°) and IF_6^+ (octahedral, 90°), and that this is a typo.

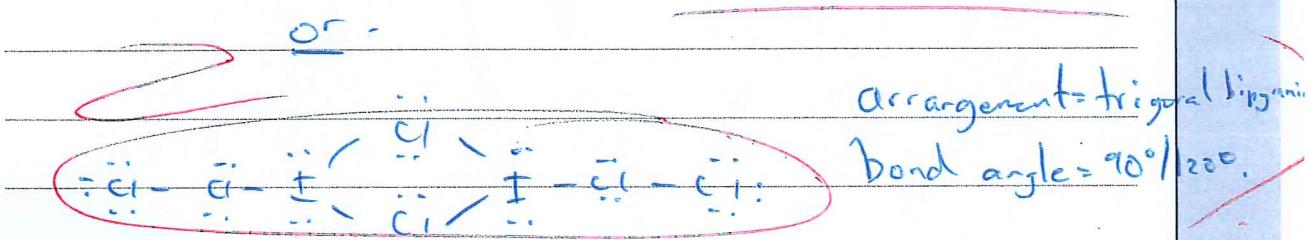
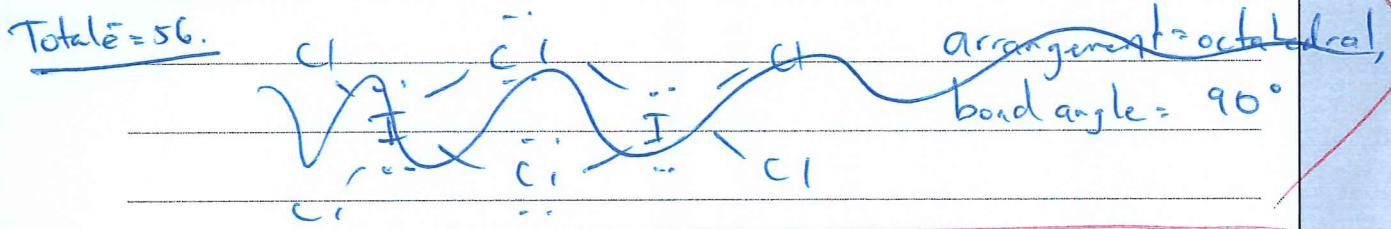
(ii) I_2Cl_6 is a molecular compound. Molecules of I_2Cl_6 are symmetrical with no I-I bonds. Al_2Cl_6 is also a molecular compound, containing symmetrical molecules with no Al-Al bonds.

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.

Al_2Cl_6 is a molecular compound, must contain covalent bonds. Each Al has 3 valence electrons, so must have 5 bonds.



Each Al atom is in tetrahedral arrangement, bond angle 109.5° .



In ~~the~~ case for I_2Cl_6 , the bond angle is smaller than that of Al_2Cl_6 , as there are more regions of electron density around the central bond atom (5) compared to only 4). There are more electrons, (56 compared to 48), and since I can only have 8 in its shell, iodine atom must take the rest. This increased density of negative charge around the iodine atoms (SEE BACK PAPER)

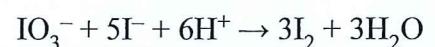
- (b) Diiodine pentoxide (I_2O_5) can be used to determine quantitatively the concentration of carbon monoxide in air. The iodine resulting from the reaction of CO and I_2O_5 is titrated with thiosulfate, and the end point is detected by the disappearance of the blue-black colour produced by starch and 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⁻¹ sulfuric acid was added, followed by the slow addition of 10 mL of 0.25 mol L⁻¹ 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⁻¹.

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

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

$$n(KIO_3) = \frac{0.5466}{214} = 2.55 \times 10^{-3} \text{ mol. (3sf)}$$

~~$$n(KIO_3)_{\text{sample}} = 1.02 \times 10^{-4} \text{ mol}$$~~

$$n(I_2) = 3 \times n(KIO_3)$$

$$= 3 \times 1.02 \times 10^{-4} = 3.07 \times 10^{-4} \text{ mol (unrounded value used)}$$



$$n(S_2O_3^{2-}) = 2 \times n(I_2)$$

$$= 2 \times 3.07 \times 10^{-4}$$

$$= 6.13 \times 10^{-4} \text{ mol (unrounded value used)}$$

$$c(S_2O_3^{2-}) = \frac{6.13 \times 10^{-4}}{0.02548}$$

$$= 0.0241 \text{ mol L}^{-1} \text{ (3sf)}$$



$$n(S_2O_3^{2-}) = 0.01723 + 0.0241 = 4.15 \times 10^{-4} \text{ (3sf) mol}$$

$$n(I_2) = \frac{1}{2} \times n(S_2O_3^{2-})$$

$$= 2.08 \times 10^{-4} \text{ mol}$$

$$n(CO) = 5 \times n(I_2)$$

$$= 1.04 \times 10^{-3} \text{ mol (3sf)}$$

~~$$\text{NCO} = \frac{n}{V} = \frac{1.04 \times 10^{-3}}{23.2}$$~~
~~$$\approx 4.47 \times 10^{-5} \text{ mol L}^{-1} \text{ (3sf)}$$~~

$$n(CO) = 28 \times n(CO)$$

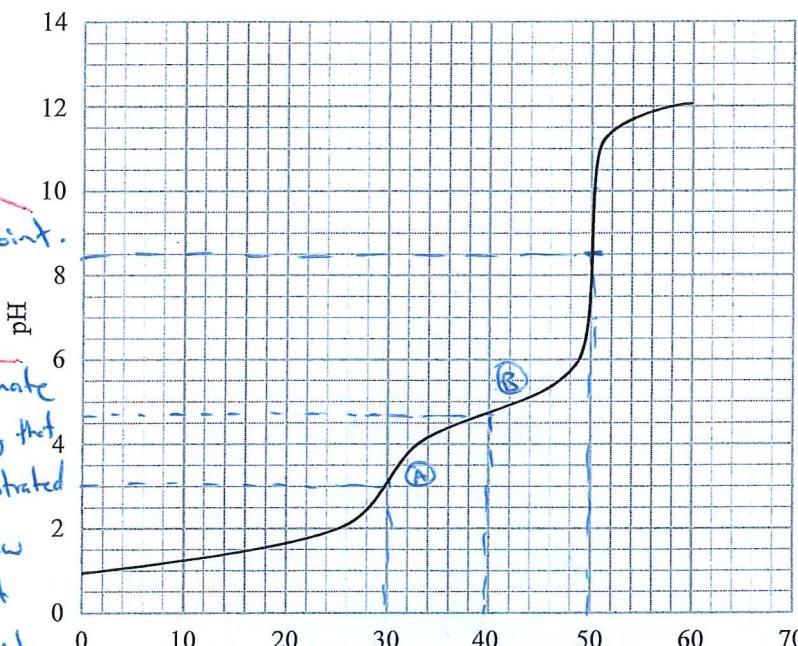
$$= 0.0291 \text{ g (3sf)}$$

$$c(CO) = \frac{n}{V} = \frac{0.0291}{23.2} = 1.25 \times 10^{-3} \text{ (3sf)}$$

QUESTION TWO

A mixture of 15.00 mL of 0.200 mol L⁻¹ HCl and 10.00 mL of 0.200 mol L⁻¹ CH₃COOH is titrated against 0.100 mol L⁻¹ NaOH solution.

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



* we could approximate the pKa by assuming that all the HCl has been titrated at point A, and a new titration starts. Point B is the halfway point, here $pH = pKa$ as $[CH_3COO^-] = [CH_3COOH]$, where we get $pKa \approx 4.75$. I will use $pKa = 4$ as it is more accurately calculated, and does not assume two different titrations.

- (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_a of the acid should be approximated from the graph.

At 50mL: acid is neutralized, only (CH_3COO^-) present.

$$0.05 \times 0.1 = 0.015 + 0.2 + 0.01 \times 0.2, \text{ so } 50\text{mL NaOH is}$$

equivalence point (only CH_3COO^- affects pH).

$$K_b = \frac{[OH^-][CH_3COOH]}{[CH_3COO^-]}$$

$$[CH_3COO^-] = \frac{0.01 + 0.2}{0.05} = 0.0267 \text{ mol L}^{-1}$$

$$\text{assume } [OH^-] = [CH_3COO^-] = 1.58 \times 10^{-6} \text{ (as pH is 8.2 from graph).}$$

$$K_b = 9.41 \times 10^{-11}, K_a = 1.66 \times 10^{-5}, pKa = 3.97 \approx 4. *$$

At 5mL, assume only HCl is being titrated - only one contributing to change in pH as CH_3COOH is weak acid.

$$n(HCl) = 0.015 + 0.2 - 0.005 + 0.1 = 2.5 \times 10^{-3} \text{ mol.}$$

$$c(HCl) = \frac{2.5 \times 10^{-3}}{0.05} \rightarrow 0.05 \text{ mol L}^{-1}$$

$$pH = 1.08 \text{ (3sf)}$$

At 29mL, have to assume only HCl is being titrated as is strongest acid.

$$n(HCl) = 0.015 + 0.2 - 0.029 + 0.1 = 1 \times 10^{-4} \text{ mol.}$$

$$c(HCl) = \frac{1 \times 10^{-4}}{0.054} = 1.85 \times 10^{-6} \text{ mol L}^{-1}$$

$$pH = 5.73$$

At 50mL, acid HCl, CH_3COOH and NaOH have all reacted & neutralized, strongest base is CH_3COO^-

$$K_b = \frac{[OH^-][CH_3COOH]}{[CH_3COO^-]} \text{ assume } [OH^-] = [CH_3COO^-]$$

$$[OH^-] = 1.58 \times 10^{-6}, pH \approx 8.2$$

At 5mL, assuming only HCl is a fair assumption, as a significant concentration of HCl still exists & CH_3COOH is unlikely to have a big effect on pH. At 50mL, the only base/acid is CH_3COO^- as the rest is neutralized.

It is fair to assume $[OH^-] = [CH_3COO^-]$, and this prediction should be valid like the 5mL prediction.

SEE EXTRA PAPER

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.

This assumes that, as HCl is the stronger acid, all the HCl is titrated when volume = 30mL. In reality, some HCl will remain in solution until

volume = 50mL when all acid has been titrated.

At V=30mL, the CH_3COOH becomes the main acid being titrated, solution is acidic as $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$



The pH increases rapidly as much of the acid is neutralized.

However, CH_3COOH is a weak acid, which means that a mixture of CH_3COOH and its conjugate

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

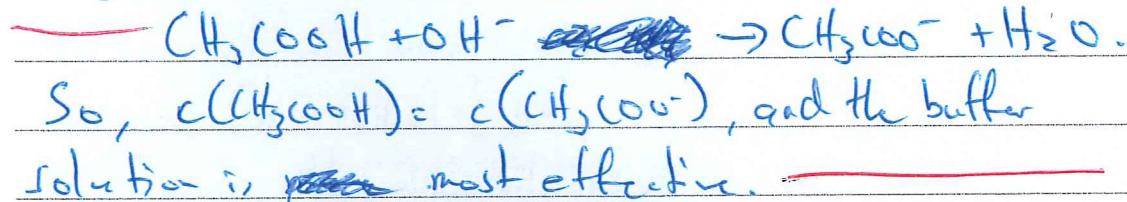
weak base, CH_3COO^- , will act as a buffer solution. Between around 34–46 mL of NaOH added, the solution acts as a buffer solution, where the solution ~~remains~~ is somewhat resistant to pH changes. The best buffer solution is at 40mL, where half of the CH_3COOH has been neutralized:

$$0.01 \times 0.200 - 0.01 \times 0.1 = 0.001 = \frac{0.01 \times 0.200}{2}$$

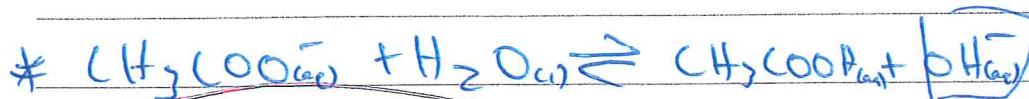
~~etc~~

$$v(\text{CH}_3\text{COOH}) \times c(\text{CH}_3\text{COOH}) = v(\text{NaOH}) \times c(\text{NaOH})$$

The number (CH_3COOH remaining after 10mL since start of $\text{CH}_3\text{COOH} + \text{NaOH}$ titration) is half the original amount of CH_3COOH .



At 50mL NaOH, equivalence is reached, as $n(\text{NaOH}) = n(\text{CH}_3\text{COOH}) + n(\text{HCl})$. The strongest acid/base present is CH_3COO^- (the CH_3COOH has reacted to form CH_3COO^-), which is a weak base, hence the pH is slightly basic. After this, NaOH added is the strongest base, and so the pH is most affected by this, instead of the CH_3COO^- . More NaOH added increases the concentration of OH^- ions, which increases the pH for volume NaOH > 50 .



b

c2

f

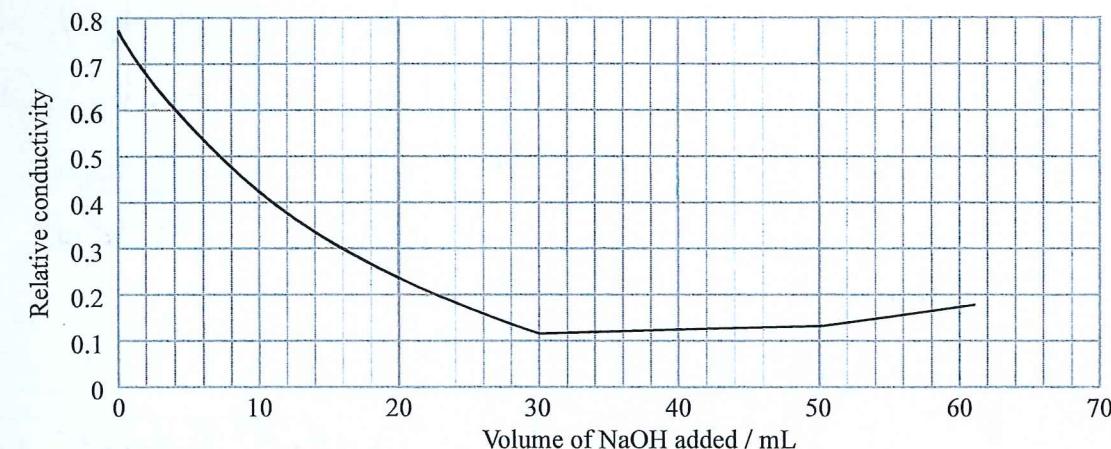
i+

- (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
OH^-	3
H_3O^+	5

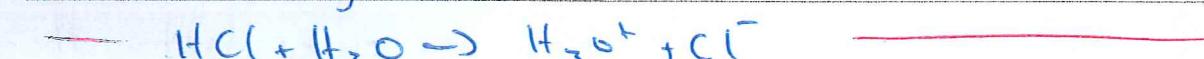
The conductivity curve for the titration described in part (a) is given below.



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.

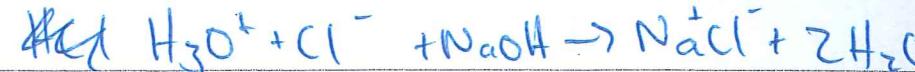
At Volume = 0mL NaOH, there is a high concentration of HCl present, which fully dissociates in water as it is a strong acid.



Therefore, there is a high concentration of the very conductive H_3O^+ ion, and also of the less conductive Cl^- ion, so overall conductivity is very high.

As NaOH is added, HCl is neutralised.

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



The very conductive H_3O^+ ions are neutralized, so conductivity decreases.

This section is curved, because as more HCl is neutralised, $c(\text{HCl})$ decreases, and so more and more NaOH will react with CH_3COOH and less with HCl. However, this effect is very slight, and hence the slight curve. It is so slight, that it can be assumed to not be happening.

At 30mL NaOH added, the conductivity is at its lowest, as the H_3O^+ from HCl dissociation has been neutralised, leaving only slightly conductive Na^+ , Cl^- and a few H_3O^+ and CH_3COO^- ions (from dissociated weak acid) acid CH_3COOH .



Between 30mL added and 50mL added, CH_3COO^- and Na^+ ions are produced as products, so conductivity increases, although very slowly as CH_3COO^- and Na^+ are weak conductors.

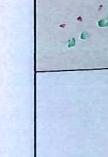


After 50mL added NaOH added, NaOH does not neutralise any acid, as no acid is present. NaOH dissociates to form Na^+ and the moderate conductor OH^- , so conductivity increases, faster than between 30 and 50mL, as OH^- is a better conductor than the ions released between 30 to 50mL.

t1

t2

t3



QUESTION THREE

- (a) A solution is made by adding 42.69 g of a mixture of the aldehydes methanal, HCHO, and ethanal, CH_3CHO , 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.

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



$$n(\text{Ag(s)}) = \frac{4.64}{107.9} = 0.0430 \text{ mol (r,f)}$$

$$n(\text{RCHO}) = \frac{1}{2} \times n(\text{Ag(s)}) \\ = 0.0215 \text{ mol}$$

in 2.18g, there is $(0.218 \times \frac{42.69}{76.59+42.69})$ g of aldehyde
 $= 0.780 \text{ g of aldehyde}$.

let $n(\text{HCHO}) = x$.

$$0.780 = 0.780 = x \times 30.03 + (0.0215 - x) \times 44.05$$

$$-0.167 = 30.03x - 44.05x$$

$$-0.167 = -14.02x$$

$$x = 0.0119 \text{ mol HCHO}$$

$$\text{so } 9.6 \times 10^{-3} \text{ mol CH}_3\text{CHO}$$

In original mixture:

$$0.0119 \times \frac{76.59+42.69}{2.18} \times 30.03 = 19.6 \text{ g HCHO (r,f)}$$

$$0.96 \times 10^{-3} \times \frac{76.59+42.69}{2.18} \times 44.05 = 22.9 \text{ g CH}_3\text{CHO. (r,f)}$$

Difference is due to rounding error

(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 CO_2 gas.

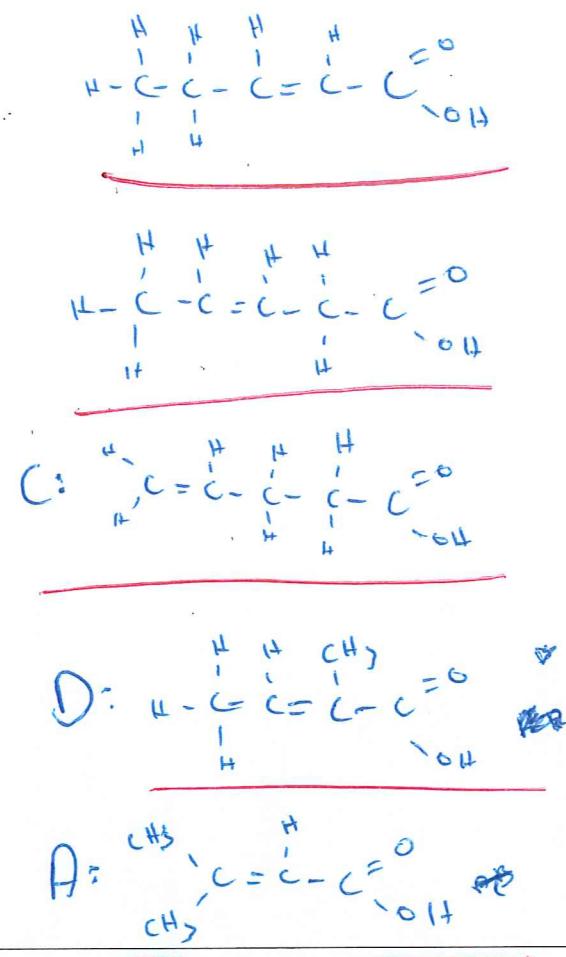
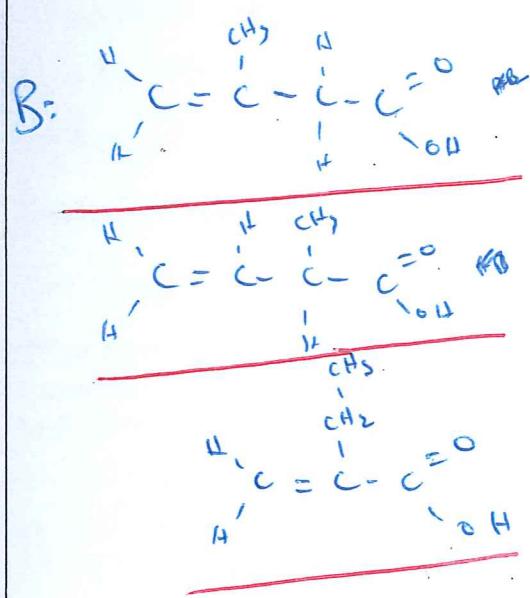
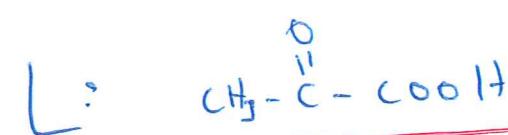
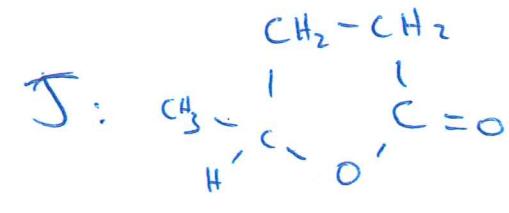
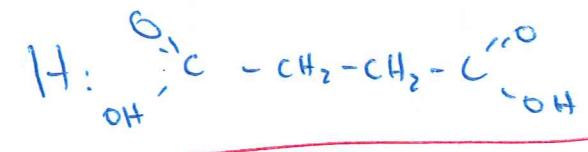
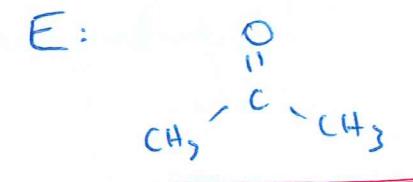
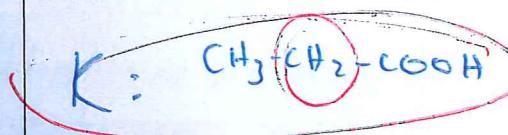
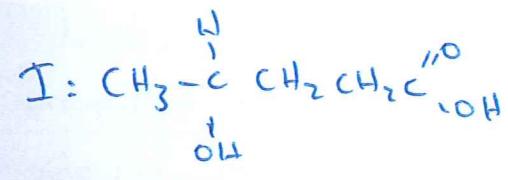
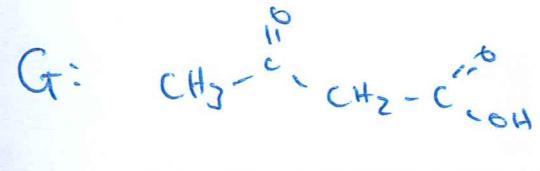
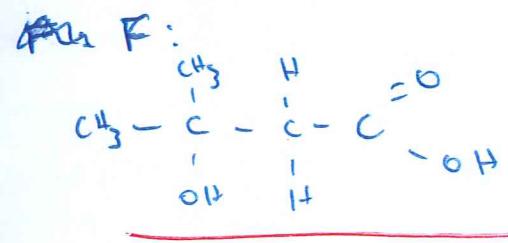
Four compounds, **A**, **B**, **C**, and **D**, have the molecular formula $\text{C}_5\text{H}_8\text{O}_2$. They all turn moist blue litmus paper red. Spectral data indicate that none of the compounds is cyclic. Each compound is reacted with warmed, acidified, potassium permanganate and, for some compounds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

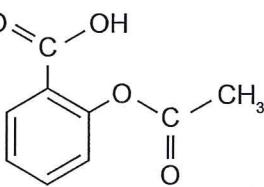
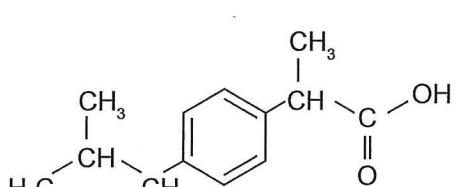
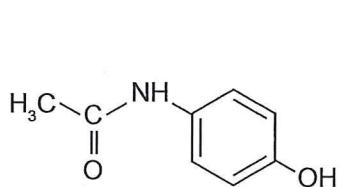
Draw structures for all the reaction products **E** to **L**. Ignore any geometric isomer possibilities.

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^{-1} , aspirin is slightly less at 3 mg mL^{-1} , while ibuprofen has limited solubility at 0.021 mg mL^{-1} . The solubility of aspirin and ibuprofen can be increased by supplying each as its calcium salt.

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

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

Paracetamol is the most soluble. Paracetamol has the lowest molar mass of the three pain relievers, so contains the least number of electrons. It is less likely that there will be a significant instantaneous density of electrons on one side of the molecule (and the effects will be less extreme), so lower temporary dipole-dipole forces exist between molecules so the intermolecular bonds will be easier to break & so more will dissolve.

Paracetamol contains both an OH and NH bond which can form hydrogen bonds with water, forming very strong bonds & pulling the lattice apart, dissolving more. Also, the polar C=O, OH and N-H bonds form bonds with the polar water molecules, so there is overall very strong attraction between water and paracetamol & so a lot dissolves, in the blood.

Aspirin has a slightly higher molar mass than

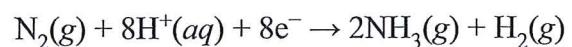
paracetamol, so forms stronger intermolecular weak temporary dipole-dipole forces, meaning it more force is required to dissolve & pull apart aspirin. Aspirin only contains one O-H group that can ~~break~~ ~~form~~ hydrogen bond with water, so these forces are weaker than in paracetamol. Aspirin contains a polar carboxylic acid & ester group, so ~~water~~ ~~water~~ is attracted to the polar water molecules, forming moderate aspirin-water attraction & so a moderate amount ^{of} ~~of~~ ~~dissolve~~ dissolves.

Ibuprofen is a large molecule (largest molar mass) and is also long & not compact, so there is a lot of surface area for instantaneous dipole-dipole attraction to occur, and is harder to dissolve. There is one O-H bond to form hydrogen bonds with water, and Ibuprofen is only slightly polar (only a carboxylic acid group at one end), so there is weak attraction between Ibuprofen & water molecules, and so only a small amount dissolves.

Both Aspirin & Ibuprofen contain COOH groups, and so can form calcium carboxylate salts $(R\text{COO})_2\text{Ca}^{2+}$. There is now a clear positive (Ca^{2+}) and negative (RCOO^-) end to each molecule, which are attracted to the slightly positive & negative ends of each water molecule, so this force is stronger & ~~so~~ so more will dissolve in the water (blood). Paracetamol does not contain a COOH group, so cannot form a calcium salt.

- (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_2 , to two equivalents of ammonia, with additional production of one equivalent of dihydrogen, H_2 .

A balanced half-equation for this reaction is:



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

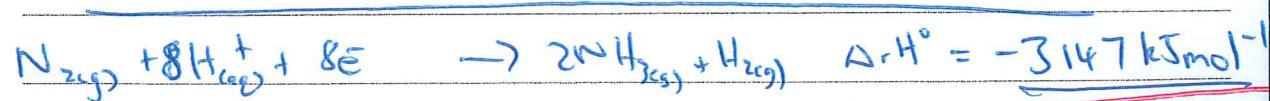
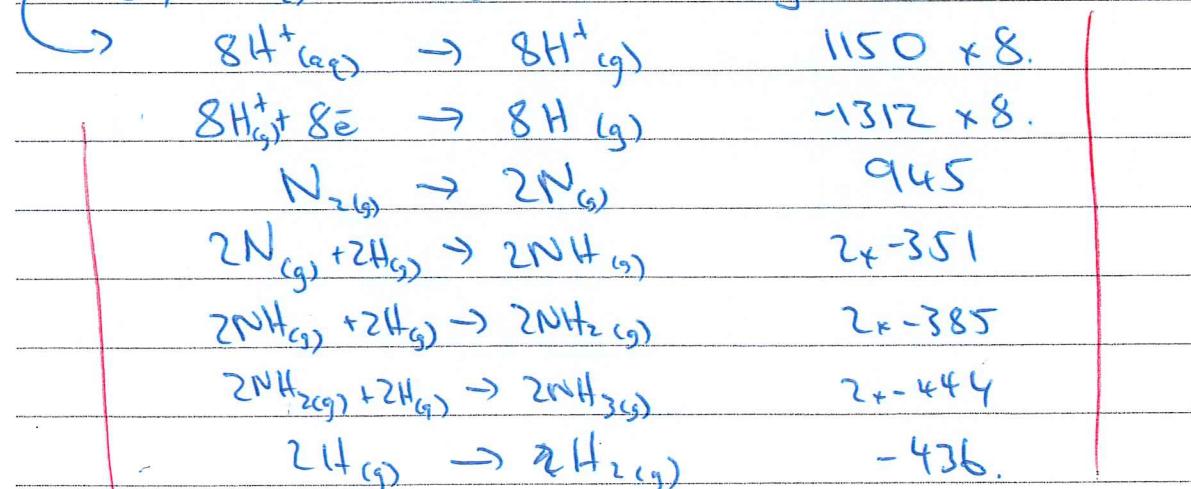
Bond Dissociation Reaction	Bond Dissociation Enthalpy (kJ mol ⁻¹)
N ₂ → 2N	945
H ₂ → 2H	436
NH ₃ → NH ₂ + H	444
NH ₂ → NH + H	385
NH → N + H	351

Atom	First Ionisation Enthalpy (kJ mol ⁻¹)
H	1312

Ion	**Hydration Enthalpy (kJ mol ⁻¹)
$\text{H}^+(g)$	-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.

First, $H^+_{(aq)}$ needs to be dehydrated.



Enthalpy change is very negative, exothermic

In this reaction, 1 mole of reactant forms 3 moles of product, so entropy decreases, as there are less ways for the particles to be arranged. ~~less~~
However, all the products are gaseous, whereas there was an aqueous reactant, so entropy increases. Overall, these changes somewhat cancel out, so there is a negligible ΔS (we need to know the exact changes in entropy for each to determine if it is positive or negative). —

As ΔrH° is negative and ΔS is negligible, the reaction should take place. If ΔS was slightly negative, a very high temperature could mean $\Delta rH^\circ - T\Delta S > 0$, and the reaction would not be spontaneous, ~~at~~ however under normal conditions the reaction should take place as $\Delta rH^\circ - T\Delta S < 0$ as ΔS is negligible.

QUESTION
NUMBER

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

2ai: However, at 29mL, most of the HCl has been titrated already (assuming only 1×10^{-4} mol left), so CH_3COOH is likely to have a significant effect on the pH (lowering it as it is an acid, on the graph the pH is much lower than predicted), so here, this prediction is invalid as the assumptions (that CH_3COOH has no effect) is very unlikely and not true (invalid). 

*on pH
1aiii means that there are more repelling forces closer together. ~~the molecule will be more unstable, so it will have a lower boiling point, as less force is required to break the bonds.~~

However, the lone pairs around the I means that the shape will be T-shaped, and so polar. ~~less~~ compared to the non-polar tetrahedral in Al_2Cl_6 . This means that the intermolecular forces in I_nCl_6 will be stronger, melting point higher. 

QUESTION
NUMBER

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

ASSESSOR'S
USE ONLY

Outstanding Scholarship [27]

Question 1 [5]

Drew Lewis structures and applied knowledge of the Valence Shell Electron Pair Repulsion theory (VSEPR) to compare the shapes of IF_4^+ and IF_6^- . Confused the shape of the I_2Cl_6 molecular compound.
Demonstrated a logical development of ideas using titration data to correctly calculate the concentration of carbon monoxide (CO) in g L^{-1} .

Question 2 [8]

Analysed the data given to correctly calculate the pH after 5 mL, recognising an assumption made for the calculation.
Demonstrated independent reflection and extrapolation with a well-developed discussion accounting for variation in the pH, in terms of the species present, as well as supporting the answer with appropriate equations.
Used convincing communication in a well-developed discussion to show the link between the shape of the conductivity curve to the relative concentrations of the species involved; including appropriate equations.

Question 3 [8]

Demonstrated perception and insight in recognising oxidation-reduction processes to understand the complex situation of correctly calculating the masses of the two aldehydes.
Demonstrated independent reflection and extrapolation by identifying all isomers involved and the majority of products (one minor error was allowed).

Question 4 [6]

Gave a logical and concise discussion of factors which affect solubility. Enthalpy calculations were correct and some analysis of the thermodynamics of the reaction was included.