

NANYANG JUNIOR COLLEGE JC 2 PRELIMINARY EXAMINATION Higher 2

# CHEMISTRY

# 9729/01

Paper 1 Multiple Choice

23 September 2019

1 hour

Additional Materials:

Multiple Choice Answer Sheet Data Booklet

### READ THESE INSTRUCTIONS FIRST

Write in soft pencil. Do not use staples, paper clips, glue or correction fluid. Write your name, CT and NRIC / FIN on the Answer Sheet in the spaces provided.

There are **thirty** questions in this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the one you consider correct and record your choice in soft pencil on the separate Answer Sheet.

#### Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet. The use of an approved scientific calculator is expected, where appropriate. 1 4<sup>th</sup> July 2012, the discovery of the Higgs boson validated the Standard Model of elementary particles, a widely accepted framework for understanding sub-atomic particles.

In the Standard Model, nucleons can be further divided into more basic particles, called quarks. Quarks occupy spaces and have charges; some positive, some negative.

Type of particle	Symbol	Size and polarity of electronic charge, e
Up quark	u	+2/3
Down quark	d	-1/3
electron	е	-1
neutrino	Ve	0

The following table list the characteristics of some sub-atomic particles in the Standard Model.

In a radioactive reaction, the following process occurs in the nucleus of an atom.



nucleon A

nucleon B

Which of the following statements are correct?

- 1 The charge of nucleon B is +1.
- 2 Particle C is deflected towards the positive plate in an electric field.
- 3 The process can be described by  $^{22}Ne \rightarrow ^{22}Na$ .
- **A** 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only
- 2 An oxygen candle is used to provide an emergency supply of oxygen in spacecraft. It contains sodium chlorate in a chemical mixture. When ignited, the mixture burns at 600 °C. At this temperature, thermal decomposition of the sodium chlorate occurs, releasing oxygen gas and forming sodium chloride as the only products.

When sodium chlorate decomposes, 0.150 moles of oxygen gas and 0.100 mole of sodium chloride are formed.

What is the oxidation state of chlorine in the chlorate?

	Α	+3	В	+5	С	+6	D	+11
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**3** Cations with a high charge density can polarise adjacent anions. This results in ionic bonds with covalent character. However, if the oxidation state is high enough, a covalent bond will form instead.

Which of the following correctly lists the most ionic and the most covalent halide compounds?

	Most ionic	Most covalent
Α	SnF <sub>2</sub>	PbCl <sub>4</sub>
В	PbF <sub>2</sub>	SnCl <sub>4</sub>
С	SnF₄	PbCl <sub>2</sub>
D	PbF <sub>4</sub>	SnCl <sub>2</sub>

4 Compound Z has the following structure.



compound Z

Which bond angle is not present in a molecule of compound Z?

**A** 105° **B** 109° **C** 120° **D** 180°

### 5 Use of the Data Booklet is relevant to this question.

A mass of 0.253 g of a volatile liquid is injected into a gas syringe at 97 °C. The initial reading of the gas syringe, before the injection of the liquid, is 5 cm<sup>3</sup>. The final reading, after complete vaporisation of the liquid, is 81 cm<sup>3</sup>. The temperature was kept constant at 97 °C.

Atmospheric pressure is 1 atm.

What is the  $M_r$  of the volatile liquid?

Α	26	В	89	С	95	D	101
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6 Use of the Data Booklet is relevant to this question.

For the energy cycle given below, which enthalpy change is correctly stated?



All values are given in kJ mol<sup>-1</sup>.

Α

1 
$$\Delta H_7 = \Delta H_8 - \Delta H_{hyd} (Ca^{2+}) - \Delta H_{hyd} (CO_3^{2-})$$
  
2  $\Delta H_5 = 1740$   
3  $\Delta H_{atm} (Ca) = \Delta H_1 + \Delta H_8 - (\Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6 + \Delta H_7)$   
1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 3 only

7 The set-up shown is used to determine the enthalpy change of reaction for the neutralisation of oxalic acid,  $H_2C_2O_4$ , using a calibration method.

$$\Delta H_{rxn}$$

$$2NaOH(aq) + H_2C_2O_4(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(l)$$

$$\frac{Experiment 1}{}$$

$$50 \text{ cm}^3 \text{ of } 2.0 \text{ mol dm}^{-3} \text{ NaOH}(aq) \text{ was added to } 50 \text{ cm}^3 \text{ of } 2.0 \text{ mol dm}^{-3}$$

$$HC_l(aq).$$

$$\text{Temperature of solution rise by } 10.0 \text{ °C}.$$

$$\frac{Experiment 2}{}$$

- 50 cm<sup>3</sup> of 2.0 mol dm<sup>-3</sup> NaOH(aq) was added to 50 cm<sup>3</sup> of 2.0 mol dm<sup>-3</sup> H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>(aq).
- Temperature of solution rise by 8.5 °C.

Using the results from experiments 1 and 2, and given standard enthalpy change of neutralisation is  $-57.4 \text{ kJ mol}^{-1}$ , what is the correct magnitude for the experimental value of  $\Delta H_{rxn}$  in kJ mol<sup>-1</sup>?

Α	57.4 x 8.5 x 2 10	В	57.4 x 8.5 10 x 2
C	57.4 x 8.5	П	57.4 x 10 x 2
C	10	D	8.5

8 For which of the following processes is the sign of  $\Delta G^{\Theta}$  and  $\Delta S^{\Theta}$  different?

- 1 Addition of silicon chloride to water.
- 2 Bubbling chlorine gas into potassium iodide solution.
- 3 Thermal decomposition of magnesium carbonate.
- **A** 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

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9

Nitrosyl chloride, NOC*l*, is a yellow gas produced by the reaction of colourless nitrogen monoxide gas and chlorine gas.

$$2NO + Cl_2 \rightarrow 2NOCl$$

To investigate the kinetics of the production of nitrosyl chloride, experiments were carried out and the following graphs obtained.



Which of the following can be deduced from these results?

- 1 The reaction is first order with respect to Cl<sub>2</sub>.
- 2 A possible mechanism for the reaction is:

 $NO + Cl_2 \longrightarrow NOCl_2$ 

 $NOCl_2 + NO \longrightarrow 2NOCl$ 

**10** The decomposition of hydrogen peroxide in aqueous solution is a first order process.

If 10 % of the hydrogen peroxide in a solution of concentration 0.10 mol dm<sup>-3</sup> decomposes in 5 minutes at a certain temperature, what is the concentration, in mol dm<sup>-3</sup>, of a 1.00 mol dm<sup>-3</sup> hydrogen peroxide solution after 5 minutes at the same temperature?

<b>A</b> 0	.10	В	0.50	С	0.80	D	0.90
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11 The pH of human blood is constant at about 7.40.

Which ion present in the human body will remove contaminating H<sup>+</sup>(aq) ions from the blood to keep the pH constant?

- **A**  $CO_3^{2-}$  **B**  $HCO_3^{-}$  **C**  $H_2PO_4^{-}$  **D**  $PO_4^{3-}$
- **12** Values of three solubility products are given.

$$K_{sp} (AgIO_3) = 3.2 \times 10^{-8} \text{ mol}^2 \text{ dm}^{-6}$$
  
 $K_{sp} (Ag_2CrO_4) = 9.0 \times 10^{-12} \text{ mol}^3 \text{ dm}^{-9}$   
 $K_{sp} (Ag_3AsO_4) = 1.0 \times 10^{-22} \text{ mol}^4 \text{ dm}^{-12}$ 

A conical flask contains 0.10 mol dm<sup>-3</sup> potassium iodate(V), 0.10 mol dm<sup>-3</sup> potassium chromate(VI) and 0.10 mol dm<sup>-3</sup> potassium arsenate(V), all in solution together.

Drops of aqueous silver nitrate were added incrementally until the first precipitate appears.

What is the concentration of silver ions, in mol dm<sup>-3</sup>, present?

- **A** 9.5 x 10<sup>-6</sup>
- **B** 3.2 x 10<sup>-7</sup>
- **C** 1.0 x 10<sup>-7</sup>
- **D** 3.3 x 10<sup>-8</sup>

**13** Use of the Data Booklet is relevant to this question.

Free energy change of a reduction half-equation is related to the standard electrode potential by the equation.

$$\Delta G^{\Theta} = -nFE^{\Theta}$$

The free energy,  $-\Delta G^{\Theta}/F$ , for the reduction of uranium species are given in the table.

half-equation	−∆ <i>G</i> <sup>θ</sup> /F (V)
$UO_2^{2+} + e^- \implies UO_2^+$	+0.16
$UO_2^+ + 4H^+ + e^- \iff U^{4+} + 2H_2O$	+0.27
$U^{4+} + e^{-} = U^{3+}$	-0.52
U <sup>3+</sup> + 3e <sup>-</sup> = U	-4.98

Units of  $-\Delta G^{\Theta}/F$  are in voltage, V.

Excess magnesium powder was added to 1.0 mol dm<sup>-3</sup> solution of  $UO_2^+$  at 25 °C. What is the stable species of uranium formed?

Α	U	В	U <sup>3+</sup>	С	U <sup>4+</sup>	D	UO2 <sup>2+</sup>
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14 An electrolytic cell is set up for the purification of a mass of impure copper as shown.



The sample of impure Cu is known to contain nickel and silver as minor impurities.

Which of the following factor, when used in a larger quantity, results in more pure copper deposit on the cathode?

- **A** concentration of Cu<sup>2+</sup> electrolyte
- B current
- **C** mass of impure Cu
- D surface area of pure Cu
- **15** In addition to the Group 2 elements, several elements behave similarly in forming only cations with +2 charge.

On losing two electrons, which of the following element acts as the strongest reducing agent?

A Cd B Ni C Sr	D	Zn
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**16** Transition metal ions can react in a number of different ways. Listed are three different reactions of transition metal ions with relevant observations.

Which observation is due to ligand exchange only?

- 1 When a yellow solution of ammonium vanadate(V) is added to zinc powder, the solution changes colour eventually to violet as vanadium(II) ions are made.
- 2 When a purple solution of chromium(III) sulfate is warmed, a green solution containing  $[Cr(H_2O)_5SO_4]^+$  is made.
- 3 When a pink solution of cobalt(II) ions is added to tartrate ions, <sup>−</sup>OOCCH<sub>2</sub>(OH)CH<sub>2</sub>(OH)COO<sup>−</sup>, followed by hydrogen peroxide solution, a green solution of [Co(OOCCH<sub>2</sub>(OH)CH<sub>2</sub>(OH)COO)<sub>3</sub>]<sup>3−</sup> is made which eventually returns to a pink solution again.
- **A** 1, 2 and 3 **B** 1 and 3 only **C** 2 and 3 only **D** 2 only
- 17 An aqueous solution containing both potassium chloride and potassium iodide is treated with an excess of aqueous silver nitrate. The precipitate formed is filtered off and washed with distilled water. The precipitate is then shaken with aqueous ammonia and filtered off again.

Which ion is present in the final filtrate?

- A chloride
- **B** iodide
- **C** potassium
- D silver

- **18** An organic molecule has
  - the composition, by mass, C, 40%; H, 6.7%; O, 53.3%,
  - the ability to rotate plane polarised light,
  - no cyclic structure.

What is the smallest number of carbon atoms this molecule can have?

**A** 1 **B** 2 **C** 3 **D** 4

**19** When heated with chlorine, the hydrocarbon 1,3-diisopropylcyclohexane undergoes free radical substitution. In a propagation step, the free radical X• is formed by the loss of one hydrogen atom.



1,3-diisopropylcyclohexane

How many different forms of X• are theoretically possible?

<b>A</b> 6 <b>B</b> 7 <b>C</b> 8 <b>D</b>	9
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**20** A. Geim and K. Novoselov shared the 2010 Nobel prize for the discovery and characterisation of graphene, which is a single layer of graphite. A graphene sheet is 100 times stronger than steel, and conducts heat and electricity efficiently.

More recently, oxygen atoms have been added to graphene in order to modify its physical properties. A graphene sheet is normally non-polar and impermeable to all gases and liquids. A graphene oxide layer, however, will allow water molecules to pass through.



example of a graphene oxide layer

Which of the following statement is incorrect?

- **A** A graphene sheet is insoluble in water.
- **B** A graphene sheet is very strong as overlapping p-orbitals on the carbon atoms strengthens the C–C bonds.
- **C** All carbon atoms in a graphene oxide layer are on the same plane.
- **D** There are  $\sigma$  bonds formed by  $2sp^2-2sp^3$  overlap in a graphene oxide layer.

21 The following industrial reaction involves benzene and propene.



Which of the following intermediate is likely formed in this reaction.



22 Amines can react in various ways in organic reactions: as nucleophiles, Brønsted bases and oxidising and reducing agent.



In the reaction mechanism shown, what are the ways in which amines react as?

- 1 Nucleophile
- 2 Brønsted base
- 3 Oxidising agent
- **A** 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

**23** A halogenoalkane can react with hydroxide ions, OH<sup>-</sup>, in two ways,

- to form an alcohol in a nucleophilic substitution reaction, or
- to form an alkene in an elimination reaction.



Compound H has the structure shown.



Which of the following halogenoalkane and solvent pair, when reacted with OH<sup>-</sup>, will give the best yield for compound H?

	halogenoalkane	solvent
A	H <sub>3</sub> C	$\begin{array}{c} CH_3\\ HO -                                   $
В	H <sub>3</sub> C Br	$\begin{array}{c} CH_3\\ HO - \begin{array}{c} CH_3\\ - CH_3\\ CH_3\end{array}$
с	H <sub>3</sub> C	H <sub>2</sub> O
D	H <sub>3</sub> C Br	H₂O

24 Vicinal diols are organic compounds where there are two –OH groups on adjacent carbons. On treatment with sodium periodate, NaIO<sub>4</sub>, the carbon-carbon bond between the two diols is cleaved to form aldehydes or ketones.



vicinal diol

A vicinal diol, D, which contains six carbon atoms, reacts with NaIO<sub>4</sub> to form compounds E and F.

Compound E gives a yellow precipitate with alkaline aqueous iodine.

Compound F gives a red-brown precipitate with alkaline Cu<sup>2+</sup> solution.

What is the organic product formed when D is warmed with acidified K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>?

- A HOOCCH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>COCH<sub>3</sub>
- B CH<sub>3</sub>CH(OH)COCH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>
- $C \qquad (CH_3)_2C(OH)COCH_2CH_3$
- D HOOCCOC(CH<sub>3</sub>)<sub>3</sub>
- 25 Which liquid is the best conductor of electricity?
  - A aqueous pyruvic acid,  $CH_3COCO_2H$  with a concentration of 1 mol dm<sup>-3</sup>
  - **B** aqueous propanoic acid, CH<sub>3</sub>CH<sub>2</sub>CO<sub>2</sub>H with a concentration of 1 mol dm<sup>-3</sup>
  - **C** aqueous ethanoic acid,  $CH_3CO_2H$  with a concentration of 1 mol dm<sup>-3</sup>
  - **D** pure ethanoic acid

26 Compound K reacts with hot alkaline aqueous manganate(VII).



compound K

Which of the following compound is formed?



27 Niclosamide is an essential medicine used in the treatment of tapeworm infestations.



Which of the following reducing agent does not react with niclosamide?

- A H<sub>2</sub> with Ni metal
- **B** LiAlH<sub>4</sub> in dry ether
- **C** NaBH<sub>4</sub> in ethanol
- **D** Sn in concentrated HC*l*

**28** One mole of each of the following compounds was boiled with NaOH (aq) for two minutes, and then dilute HNO<sub>3</sub> (aq) and AgNO<sub>3</sub> (aq) were added. The appearance of the precipitate was recorded.



Which of the following statements explain the observations?

- 1 Lone pairs of electrons of Cl in P overlap with  $\pi$ -electrons of the C=O group, electrons delocalised with C=O group disperse the partial positive charge.
- 2 Cl atom causes the C–Cl bond to have a partial positive charge on the carbon atom.
- 3 The  $\pi$ -electron cloud in the aromatic ring of R repels OH<sup>-</sup> nucleophiles.

Α	1, 2 and 3	В	1 and 2 only	С	2 and 3 only	D	3 only
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**29** *Jesuit's bark* was brought to Europe from South America by missionaries and proved useful in the treatment of malaria. Quinine, the active compound, is found in the bark of the cinchona tree and used originally by natives of Peru and Bolivia to treat shivering in cold weather.

Nowadays, a similar alkaloid, chloroquine is commonly used for the treatment of malaria.



- 2 aqueous bromine
- 3 ethanoyl chloride

Α	1, 2 and 3	В	1 and 2 only	С	2 and 3 only	D	1 only
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**30** Coca-Cola<sup>®</sup> No Sugar is a sugar and calorie free drink developed to taste like Coca-Cola classic. It uses the artificial sweetener aspartame.



Aspartame has  $pK_a$  values of 3.2 and 7.9.

Given that Coca-Cola® No Sugar has a pH of 2.5, what is the structure of the major species of aspartame present?





NANYANG JUNIOR COLLEGE JC 2 PRELIMINARY EXAMINATION Higher 2

CANDIDATE NAME

CLASS

TUTOR'S NAME

## CHEMISTRY

Paper 2 Structured Questions

9729/02 17 September 2019 2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

## **READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in. Write in dark blue or black pen. You may use an HB pencil for any diagrams, graphs. Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper. The use of an approved scientific calculator is expected, where appropriate. A Data Booklet is provided.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use			
1	/18		
2	/13		
3	/14		
4	/15		
5	/15		
Total	/75		

This document consists of **20** printed pages.

Answer all questions in the spaces provided.

**1 (a)** Ammonia is one of the world's most produced inorganic chemical due to its many uses. The current method of producing ammonia is the Haber-Bosch process.

 $3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g)$ 

This involves reacting nitrogen and hydrogen in a recycled process as shown. Nitrogen and hydrogen are pumped into the reactor where reaction to form ammonia takes place. The output from the reactor then goes into a condenser.

 $\Delta H < 0$ 



(i) An optimal temperature of 500 °C is used inside the reactor. Explain why this temperature is used.

	[2]
(ii)	Finely divided iron is used as catalyst inside the reactor. Outline the mode of action of the iron catalyst in this reaction.
	[2]

(iii) Using a Boltzmann diagram, explain why rate increases in the presence of catalyst.

(iv) The condenser helps to cool the gases and in doing so, maximises the yield of ammonia. Explain in terms of structure and bonding how this is achieved.

(v) Hydrazoic acid, HN<sub>3</sub>, is a compound of nitrogen and hydrogen like ammonia.

The plots of pV/RT against p for one mole of an ideal gas and one mole of ammonia are given below.



On axes above, sketch a graph to illustrate the behaviour of one mole of hydrazoic acid. Explain your answer.

•••••	 	 •••••
		[0]
••••••	 	 [2]

(b) Globally, approximately 88 % of ammonia is used as fertilisers. Research is actively carried out to seek new uses for ammonia in other areas.

For example, when  $NH_3(aq)$  is added to a solution of  $Zn^{2+}(aq)$ , a solution of  $[Zn(NH_3)_4]^{2+}(aq)$  can be formed. It is then possible to design an electrochemical cell based on the following half equations.

 $Zn^{2+}(aq) + 2e^{-} \rightleftharpoons Zn(s) \qquad E^{\circ} = -0.76V$  $[Zn(NH_3)_4]^{2+}(aq) + 2e^{-} \rightleftharpoons Zn(s) + 4NH_3(aq) \qquad E^{\circ} = -1.04V$ 

(i) Draw a fully labelled diagram of the electrochemical cell that could be set up, showing the polarity of the electrodes during discharge.

[2]

(ii) Write a balanced equation for the overall reaction that occurs during the discharging process. Hence calculate  $\Delta G^{e}$  of the electrochemical cell.

(c) Ammonia is used in the pharmaceutical industry for synthesising of drugs. An example is acetazolamide, a drug used for treating heart failure.



(i) The molecule of acetazolamide contains both  $\sigma$  (sigma) and  $\pi$  (pi) bonds.

With respect to the C=N<sub>a</sub> bond circled, draw a labelled diagram to show how orbitals overlap to form  $\sigma$  (sigma) and  $\pi$  (pi) bonds.

(ii) Suggest how the basicity of N<sub>a</sub> might compare to that of N<sub>b</sub>. Explain your answer with reference to your answer in (c)(i).

[Total:18]

2 Copper has a wide range of common uses, such as electrical wiring and water piping because it is relatively inexpensive and has a high resistance to corrosion.

Copper is also an unreactive metal which does not react directly with dilute acids. Therefore, the enthalpy change of reaction,  $\Delta H_r$ , for the following reaction, cannot be determined directly.

$$Cu(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2(g) \Delta H_r$$

In order to determine a value for  $\Delta H_r$ , you will therefore need to find the enthalpy change of reaction for two reactions that do occur. One of these reactions involve adding a reactive metal M to dilute sulfuric acid.

$$nM(s) + H_2SO_4(aq) \longrightarrow M_nSO_4(aq) + H_2(g) \Delta H_1$$

The other reaction is a displacement of copper from aqueous copper(II) sulfate using metal M.

 $nM(s) + CuSO_4(aq) \longrightarrow M_nSO_4(aq) + Cu(s) \Delta H_2$ 

The value for the enthalpy change of the displacement reaction  $\Delta H_2$  can be determined using a graphical method by finding the maximum temperature change  $\Delta T_{max}$ . The following experiment is carried out and the metal M used in this experiment can be assumed to be in excess.



Determination of  $\Delta T_{max}$ 

- 1 Weigh accurately the mass of the metal powder M.
- 2 Measure 50 cm<sup>3</sup> of 0.3 mol dm<sup>-3</sup> CuSO<sub>4</sub>(aq) and pour it into the polystyrene cup.
- 3 Measure the temperature of CuSO<sub>4</sub>(aq) every half minute.
- 4 At the 3<sup>rd</sup> minute, pour the metal powder M into the polystyrene cup.
- 5 Record the temperature of the solution at the 4<sup>th</sup> minute and thereafter at every half minute until the 10<sup>th</sup> minute.

However, the polystyrene cup used in the experiment can also absorb heat, so a separate experiment is performed to find the heat capacity of the polystyrene cup. This process is known as the calibration of the calorimeter.

One way to do this is to use a common metal of known specific heat capacity. A piece of nickel bar can be heated to around 100 °C and then dropped into the polystyrene cup containing water. The heat capacity of the polystyrene cup can then be calculated from the known specific heat capacity of nickel.

(a) Suggest, with the aid of a labelled diagram, why copper is suitable to be used in electrical wiring.

......[2]

(b) (i) The  $E^{\Theta}$  values of some redox reactions are shown below.

reaction	<i>E</i> <sup>e</sup> / V
$Ag^+ + e^- \rightleftharpoons Ag$	+0.80
Ba²+ + 2e⁻ ≓ Ba	-2.90
Ca²+ + 2e⁻ ≓ Ca	-2.87
Cu²+ + 2e⁻ ≓ Cu	+0.34
$2H^+ + 2e^- \rightleftharpoons H_2$	+0.00
Mg²+ + 2e⁻ ≓ Mg	-2.38

By considering the  $E^{\bullet}$  values given, suggest the most suitable metal from the following list to be used as metal M in both reactions. Give reasons for your choice.

/er	silver	magnesium	calcium	barium
[2]				

(ii) Using the metal you have chosen in (b)(i), construct an energy cycle to show how  $\Delta H_r$  can be calculated from  $\Delta H_1$  and  $\Delta H_2$ .

[1]

(iii) Outline how you would determine the heat capacity of the polystyrene cup, using a nickel bar of approximately 50 g.

You should include brief details of the apparatus you would use, the procedure you would follow, and the measurements you would make.

 [3]

(iv) Sketch, with clearly labelled axes, the graph that you would expect to obtain in the experiment described on page 7 and show how the value of  $\Delta T_{max}$  can be obtained.



(v) The heat capacity of the polystyrene cup was found to be 9.7 J K<sup>-1</sup> in (b)(iii) and the value of  $\Delta T_{max}$  was found to be 34.8 °C in (b)(iv).

Calculate the value of  $\Delta H_2$ .

[2]

(c) Calcium is found in the same Period as copper in the Periodic Table. However, Ca has a significantly larger atomic radius than Cu.

Explain why Cu has a smaller atomic radius.

......[2] [Total:13] **3** The numerical value of the solubility products of some iron containing salts at 298 K are given below.

salt	value of solubility product
iron(II) hydroxide, Fe(OH) <sub>2</sub>	8.0 × 10 <sup>-16</sup>
iron(II) disulfide, FeS <sub>2</sub>	1.3 × 10 <sup>-27</sup>
iron(III) hydroxide, Fe(OH)₃	4.0 × 10 <sup>−38</sup>

In this question, give each of your numerical answers to one decimal place.

- (i) Write an expression for the solubility product of iron(III) hydroxide, stating its units.
   [1]
  - (ii) From the data above, calculate a value for the solubility of iron(III) hydroxide.

(iii) Solid  $Fe(NO_3)_2$  was added to a solution containing 0.25 mol dm<sup>-3</sup> of sodium disulfide and 0.40 mol dm<sup>-3</sup> of sodium hydroxide at 298 K.

Calculate the concentration of disulfide ions remaining in the solution when the first trace of iron(II) hydroxide appears.

When a precipitate is formed,  $\Delta G^{\circ}_{ppt}$  is given by the following expression.

$$\Delta G^{\circ}_{ppt} = 2.303 \text{ RT} \log K_{sp}$$

(b) (i) Use the data above to calculate  $\Delta G^{\circ}_{ppt}$ , in kJ mol<sup>-1</sup>, for FeS<sub>2</sub>.

[1]

[2]

(ii) The standard enthalpy change of formation of the precipitate FeS<sub>2</sub> is  $-178.0 \text{ kJ mol}^{-1}$ . Use your answer in (b)(i) to calculate  $\Delta S^{\circ}_{\text{ppt}}$ .

(iii) Explain the significance of the sign of your answer in (b)(ii).

(c) When  $FeCl_3$  is mixed with  $CaC_2O_4$  in  $NH_4Cl(aq)$ , a yellow salt, X, is formed as one of the products. X has the following composition by mass

C, 19.3 %; Fe, 14.9 %; H, 3.2 %; N, 11.2 %; O, 51.4 %

X is ionic with a formula mass of 373.8. One formula unit of X contains one type of anion and one type of cation in the ratio of 1:3.

(i) Calculate the empirical formula of X.

		[1	[]
(ii)	Suggest the formulae of each of the id	ons present in X.	
	Cation:	Anion:[2	2]
(iii)	Suggest the coordination number of shape.	the iron-containing ion and hence state it	S
	Coordination number:	Shape:[1	]
(iv)	Explain why the salt is yellow in colou	r.	
			•
			•
		[2	2]
		[Total: 14	1]

**4** (a) The Contact Process produces sulfuric acid in high concentrations needed for industrial processes. V<sub>2</sub>O<sub>5</sub> is the catalyst used in this process.

 $SO_2$  is first produced by heating sulfur in oxygen. It is then oxidised to  $SO_3$  by air.

The oxidation of SO<sub>2</sub> to SO<sub>3</sub> is reversible and exothermic.

 $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$   $\Delta H = -197 \text{ kJ mol}^{-1}$ 

(i)  $SO_2$  and  $O_2$  were mixed in a 2:1 mole ratio. Given that the partial pressure of  $SO_2$  in the equilibrium mixture was 24 kPa and the total pressure of the flask was 104 kPa, determine the equilibrium partial pressures of  $O_2$  and  $SO_3$ . Hence, calculate  $K_p$ , giving the units.

[2]

In the next step of the Contact Process, oleum and sulfuric acid are produced according to the equations below.

 $SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7 \text{ (oleum)}$  $H_2S_2O_7 + H_2O \longrightarrow 2H_2SO_4$ 

The oleum produced can react with 4-ethylguaiacol, a key flavour component that gives robusta coffee beans the spicy and earthy notes.



4-ethylguaiacol

Assume that oleum ionises as shown.

$$H_2S_2O_7 \rightleftharpoons HSO_4 + SO_3H^+$$

(ii) Propose a mechanism for this reaction of 4-ethylguaiacol, showing the structure of the intermediate, lone electron pairs, and movement of electrons pairs by using curly arrows.

(b) 4-ethylguaiacol can undergo bromination using the following methods.



(i) Give the structure of monobrominated product B and the ratio of A to B formed in method 1, assuming that  $-OCH_3$  is inert.

(ii) In method 2, the presence of n-bromosuccinimide (NBS) results in side-chain bromination occuring exclusively at the benzylic position, the yield of A is 97 % in this reaction.



The NBS bromination occurs by a radical chain pathway.

- The first step involves a bromine radical abstracting a benzylic hydrogen atom, forming a benzylic radical and HBr.
- This is followed by the benzylic radical reacting with a bromine molecule to yield the product and bromine radical.

Suggest the two-step mechanism, using curly arrows to show the movement of electrons.

[2]

(iii) The bromine molecule that reacts with the benzylic radical in the second step of the mechanism in (b)(ii) is produced by a concurrent reaction of HBr with NBS.

The reaction involves homolytic bond fissions in the molecules.

Using the reaction of HBr with NBS, explain the term, *homolytic fission* and provide a balanced equation for this reaction.

(iv) Method 2 forms A as the only monobrominated product with 97 % yield where bromination occurs exclusively at the benzylic position. Explain why other products do not form in method 2.

(c) Organic reductions commonly use nickel catalyst but not all possible functional groups can be reduced. Heating increases the catalytic ability of nickel.

The following reactions illustrate reductions using different conditions.



(i) Suggest the identities of A and B.

А	В

[2]

(ii) Explain why B only forms at very high temperature.

.....

......[1]

[Total: 15]
**5** Lactones contain the ester functional group and are often used as flavours or fragrances. They could be synthesised using the reaction scheme given below.



(a) (i) The reaction between the carboxylate ion and iodine in step 2 is an electrophilic addition.

Complete the diagram to suggest a mechanism to show how a 5-membered ring lactone is formed. Show all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows. Indicate the slow step of the mechanism.







5-membered ring lactone

[2]

(ii)	Explain why NaHCO <sub>3</sub> is added in step 1.
	[1]
(iii)	Suggest two reasons for the preferential production of the 5-membered ring lactone instead of the 4-membered ring lactone.
	[2]
(iv)	Outline a simple chemical test that could be carried out to see if any 4-membered ring lactone is produced in the reaction mixture in step 2.
	[2]
(v)	With reference to the <i>Data Booklet</i> , explain why the product will be more stable when $Cl_2$ is used in step 2.
	[1]

(b) The 5-membered ring lactone formed in step 2, exists as a mixture of stereoisomers. Draw the structures of each stereoisomer of the 5-membered ring lactone.

(c) The reaction scheme below shows how the 5-membered ring lactone could be synthesised. Suggest the reagents and conditions needed for step 1, 2 and 3. Draw the structures of D and E in the boxes.



[5]

[Total: 15]



NANYANG JUNIOR COLLEGE JC 2 PRELIMINARY EXAMINATION Higher 2

#### CHEMISTRY

Paper 3 Free Response

9729/03 19 September 2019 2 hours

Candidates answer on separate paper.

Additional Materials: Answer Booklet Data Booklet

#### READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in. Write in dark blue or black pen on both sides of the paper. You may use a soft pencil for any diagrams, graphs or rough working. Do not use staples, paper clips, highlighters, glue or correction fluid.

# Section A

Answer **all** questions.

#### Section B

Answer one question.

A Data Booklet is provided. The use of an approved scientific calculator is expected, where appropriate.

At the end of the examination, fasten all your work securely together. The number of marks is given in brackets [ ] at the end of each question or part question.

#### Section A

Answer **all** the questions from this section.

1 (a) When ethanoic acid reacts with ethanol to form ethyl ethanoate and water, the following equilibrium is established.

 $CH_{3}CO_{2}H(I) + CH_{3}CH_{2}OH(I) \rightleftharpoons CH_{3}CO_{2}CH_{2}CH_{3}(I) + H_{2}O(I) \qquad \Delta H = -3.8 \text{ kJ mol}^{-1}$ 

A student mixed 1.48 g of ethanoic acid in a conical flask with 0.92 g of ethanol and 1.80 g of water. He then carefully added 0.98 g of concentrated sulfuric acid to catalyse the reaction. The flask was sealed and placed in a thermostatic water bath set at 25 °C for 5 days.

After 5 days, the student added phenolphthalein indicator to the flask and titrated the entire contents of the conical flask with 0.800 mol  $dm^{-3}$  Ba(OH)<sub>2</sub>. The indicator turned pink when 23.30 cm<sup>3</sup> of Ba(OH)<sub>2</sub> had been added.

- (i) Calculate the amount of  $Ba(OH)_2$  that has reacted with  $H_2SO_4$ . [1]
- (ii) Write a balanced equation for the reaction of ethanoic acid with Ba(OH)<sub>2</sub>. Using your answer in (a)(i), calculate the amount of ethanoic acid present at equilibrium. [2]
- (iii) Write an expression for the equilibrium constant,  $K_c$ , for this reaction and calculate the value of  $K_c$ , stating its units. [3]
- (iv) Suggest and explain what would happen to the position of this equilibrium and the value of  $K_c$  if the temperature is decreased. [2]
- (b) (i) The addition of an acid to water generates heat and this process is termed as dilution. The dilution of ethanoic acid can be represented with the equation below.

$$CH_3COOH(I) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$$

Calculate the enthalpy change of dilution of ethanoic acid given the following:

	$\Delta H_{\rm f}^{ heta}$ / kJ mol <sup>-1</sup>
CH₃COO⁻(aq)	-486
H⁺(aq)	0
CH₃COOH(I)	-485

[1]

[1]

(ii) In the presence of heat, ethyl ethanoate,  $CH_3CO_2CH_2CH_3$  is able to react with  $Ba(OH)_2$  as seen in the equation below:

$$2CH_{3}CO_{2}CH_{2}CH_{3}(I) + Ba(OH)_{2}(aq) \rightarrow (CH_{3}CO_{2}^{-})_{2}Ba^{2+}(aq) + 2C_{2}H_{5}OH(I)$$

State the type of reaction occurring.

(iii) Construct a fully labelled energy level diagram to calculate the enthalpy change of the reaction in (b)(ii).

Your diagram should include the data given in (a), (b)(i) and the following data.

Standard enthalpy change of neutralisation of  $CH_3COOH(aq)$  and  $Ba(OH)_2 = -55 \text{ kJ mol}^{-1}$ 

(c) Suggest a synthesis of phenyl propanoate starting from propane according to the scheme below. State the structure of compound A. Include reagents and conditions for all reactions, and the structures of all other intermediate compounds, in your answer.





[3]

2 Alanine is a non-essential  $\alpha$ -amino acid in humans and widely used for biosynthesis of proteins.



Protonated alanine can be synthesised in the laboratory from ethanol.



- (a) Heating with distillation in step 1 is required for the synthesis of aldehyde to prevent the (i) aldehyde from further oxidising to carboxylic acid. Explain why heating with distillation is suitable in isolating the aldehyde. [1]
  - (ii) Draw the displayed formula of compound B. [2]
  - Describe the mechanism in step 2. (iii)
  - (iv) Protonated glycine can also be synthesised from methanol, CH<sub>3</sub>OH, using the reaction scheme shown above.



Suggest why the relative rate of step 2 will be higher in the synthesis of protonated glycine. [2]

Suggest the reagent and condition for step 3. (v)

[3]

[1]

(b) To prove that the mechanism in step 4 is  $S_N 2$ , two separate experiments were performed and the rate equation was found to be

rate = k[NH<sub>3</sub>][2-bromopropionitrile]

- In experiment 1, the rate of reaction was monitored with increasing concentration of NH<sub>3</sub>.
- In experiment 2, concentration of 0.1 mol dm<sup>-3</sup> of 2-bromopropionitrile was monitored over time.
- (i) Copy the two graph axes below onto your answer booklet. Draw the graph for each experiment and explain the shape of your graphs.



(iii) Suggest why the mechanism in step 4 is unlikely to be  $S_N 1$ . [1]

(c) Protonated alanine (H<sub>2</sub>A) dissociates in two stages as shown below.



The graph below shows how the percentage composition of  $H_2A$ ,  $HA^-$  and  $A^{2-}$  change with pH.



(i) State the values of  $pK_{a1}$  and  $pK_{a2}$  of alanine.

[1]

(ii) A buffer of pH 10.3 is prepared by adding 0.100 mol of protonated alanine (H<sub>2</sub>A) in 1 dm<sup>3</sup> of water and solid NaOH was subsequently added.

Using the graph above, determine the amount of HA<sup>-</sup> and A<sup>2-</sup> present in the buffer and hence, calculate the mass of solid NaOH added. [2]

(iii) Assuming 1 dm<sup>3</sup> of water is added to the buffer prepared in (c)(ii), explain qualitatively if the new buffer will result in a greater or smaller change in pH compared to the original buffer, when same amount of HC*l*(aq) is added.
[2]

(iv) The solubility of alanine under different pH was investigated. The graph below shows the results of solubility against pH.



Isoelectric point is the pH at which the amino acid has a net zero charge.

With reference to the structures of  $H_2A$ ,  $HA^-$  and  $A^{2-}$ , explain

- the low solubility of alanine at its isoelectric point of 6.0.
- the high solubility of alanine at low and high pH.

[4]

[Total: 22]

- **3** This question looks at the chemistry of some compounds formed by transition metal ions and halides.
  - (a) When aqueous potassium iodide is mixed with aqueous copper(II) sulfate, a yellow brown precipitate is formed and the solution loses its blue colour. When the resulting mixture is shaken with hexane, a purple layer is formed which floats on top of the mixture. A white solid, D, remains which has a mass composition made up of one-third copper and two-third iodine.
    - (i) Deduce the empirical formula of white solid D. [1]
    - (ii) Write the electronic configuration of copper in white solid D. [1]
    - (iii) The filled orbitals of copper in white solid D have different shapes. Draw the shape of the orbital present in the largest quantity. [1]
    - (iv) Write an ionic equation, with state symbols, for the reaction of copper(II) sulfate with potassium iodide. Identify clearly the species responsible for the different colours observed during the reaction.
    - (v) Standard redox potentials may be used to predict the feasibility of a reaction. Use  $E^{\theta}$  values from the *Data Booklet* to show that the reaction between aqueous copper(II) sulfate and potassium iodide is unlikely to occur. [1]
    - (vi) By using your answer to (a)(iv), explain clearly in terms of changes in  $E^{\theta}$  values, why this reaction does, in fact, occur. [1]
  - (b) When 1.00 g of a red solid, G, with formula K<sub>x</sub>NiF<sub>6</sub>, was reacted with water, 48 cm<sup>3</sup> of oxygen (measured at 293 K and 1 atm) was evolved and a green acidic solution, H, was formed. H consists of KF, NiF<sub>2</sub> and HF.

Solution H was divided into 2 equal portions.

Titration of one portion with 0.20 mol dm<sup>-3</sup> NaOH required 19.90 cm<sup>3</sup> for neutralisation.

The other portion was electrolysed using a current of 0.40 A and it took 16 minutes to completely deposit the nickel metal at the cathode.

- Using the formula of the complex ion present in red solid G, explain what is meant by the term complex ion. You may assume the oxidation state of the metal in the complex ion is +n.
- (ii) Suggest a reason why the metal is able to form a complex ion identified in (b)(i). [1]
- (iii) Calculate the amount of oxygen evolved.
- (iv) Calculate the amount of hydrogen ions and nickel ions in solution H. [2]
- (v) Using your answers to (b)(iii) and (b)(iv), deduce the value of x with the aid of an equation. [2]
- (vi) Write an equation to suggest the product formed at the other electrode during electrolysis of solution H. Use  $E^{\theta}$  values from the *Data Booklet* to explain why it is formed.

[2]

[1]

(c) A spectrochemical series is a list of ligands based on the strength of their interaction with metal ions. It was first proposed in 1938 based on the results of absorption spectra of cobalt complexes. The ligands are ranked based on the energy gap,  $\Delta E$ , formed between the split d-orbitals when the ligand is bonded to the cobalt metal centre. A partial spectrochemical series listing of ligands is given below.

small  $\Delta E$   $I^- < Br^- < Cl^- < F^- < NCS^- (N-bonded)^* < CH_3CN < NH_3 < H_2NCH_2CH_2NH_2$ 

\*N-bonded means the ligand binds to the metal centre at the nitrogen atom

Ligands on the left of this series are generally regarded as weaker ligands. On the other hand, ligands on the right are stronger ligands.

Propose suitable explanations for the following trends observed in the spectrochemical series.

- (i) Halide ligands decrease in strength down the Group. [1]
- (ii)  $CH_3CN$  is a stronger ligand than  $NCS^-$  (N-bonded). [1]
- (iii) H<sub>2</sub>NCH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub>, a bidentate ligand, is a stronger ligand than NH<sub>3</sub>, a monodentate ligand. Consider the standard Gibbs free energy change for the following ligand exchange reaction in your answer.

 $[Co(NH_3)_6]^{3+}(aq) + 3H_2NCH_2CH_2NH_2(aq) \rightleftharpoons [Co(H_2NCH_2CH_2NH_2)_3]^{3+}(aq) + 6NH_3(aq)$ 

[2]

[Total: 20]

#### Section B

#### Answer **one** question from this section.

4 (a) Samples of anhydrous magnesium ethanoate,  $Mg(CH_3COO)_2$  and barium ethanoate,  $Ba(CH_3COO)_2$ , were heated to a temperature of 600 °C causing them to decompose.

White residues were formed in both cases and a common gaseous product, X, with molecular formula of  $C_3H_6O$  was also given off. X gives a yellow precipitate upon warming with alkaline aqueous iodine. In addition, the decomposition of magnesium ethanoate also produced a second gaseous product, which forms a white precipitate with calcium hydroxide solution.

- (i) Identify the gaseous product, X. [1]
- (ii) Write a balanced equation with state symbols for each decomposition reaction. [2]
- (iii) Account for the difference in the decomposition products. [2]
- (b) During an earthquake, the heat generated by the friction of the fault in the Earth's crust may be large enough to decompose the mineral rocks present in the fault, releasing chemicals like sulfur dioxide,  $SO_2$ , and aluminium oxide,  $Al_2O_3$ .

One method for the removal of sulfur dioxide is to absorb it in a slurry of magnesium oxide, to produce magnesium sulfite, MgSO<sub>3</sub>.

- Based on your knowledge of chemical periodicity, suggest whether Al<sub>2</sub>O<sub>3</sub> can also be used to remove SO<sub>2</sub>.
- (ii) State and explain the pH of the solutions formed when MgO, Al<sub>2</sub>O<sub>3</sub> and SO<sub>3</sub> are separately added to water.
   [3]
- (c) Phenol, phenylmethanol and benzoic acid are three compounds containing benzene rings. None of these compounds is particularly soluble in water. Both phenol and benzoic acid dissolve in NaOH(aq), but only benzoic acid dissolves in Na<sub>2</sub>CO<sub>3</sub>(aq).

State what these observations indicate about the relative acidities of the three compounds, and explain this trend in acidity. [3]

(d) Compound P, C<sub>6</sub>H<sub>11</sub>O<sub>2</sub>C*l*, reacts with 2,4-dinitrophenylhydrazine to form an orange precipitate and decolourises hot, acidified potassium manganate(VII). When compound P is heated with excess aqueous sodium hydroxide, compound Q, C<sub>6</sub>H<sub>12</sub>O<sub>3</sub>, is formed. Aqueous iodine is subsequently added to the hot mixture of this reaction and compound R, C<sub>4</sub>H<sub>4</sub>O<sub>5</sub>Na<sub>2</sub>, is formed. P reacts with excess concentrated sulfuric acid at 170 °C to give three possible isomeric products S, T and U.

S, but not T and U, reacts with excess ammonia to form an amine.

- (i) Suggest the structures of P, Q and R, explaining your reasoning. [6]
- (ii) Describe and explain how the ease of hydrolysis of S differs from that of T and U. [2]

[Total: 20]

- 1 mol of A,  $C_{10}H_{13}OCl$ , reacts with 2 mol of aqueous  $Br_2$  to give P.
- 3 mol of A reacts with 1 mol of methylamine to give R.
   R reacts immediately with cold silver nitrate to give a white precipitate.
- 1 mol of A reacts with 1 mol of sodium hydroxide at room temperature to form a homogeneous solution.
- 1 mol of A reacts with 1 mol of sodium and gives the following compound,



Suggest structures for A and P. Explain all the reactions, taking into account the molar ratios of the reactants when applicable. [7]

- (b) B, a constitutional isomer of A, is also an aromatic compound and reacts very differently with the above mentioned reagents.
  - B does not react with aqueous Br<sub>2</sub>, methylamine or sodium hydroxide.
  - B does not react with hot acidified potassium dichromate(VI) but with hot acidified potassium manganate(VII), B gives C<sub>8</sub>H<sub>5</sub>O<sub>4</sub>C*l*.
  - B does not react with alkaline aqueous iodine.
  - 1 mol of B reacts with 1 mol of sodium.
  - B does not exhibit enantiomerism.
  - (i) Based on the above information, state all the possible functional groups in B. [1]
  - (ii) Hence suggest a structure of B, giving the skeletal formula for the structure. [2]

(c) Anhydrous aluminium chloride,  $AlCl_3$  is a powerful Lewis acid, and is used as a catalyst in Friedel-Crafts alkylation of aromatic compounds.

Anhydrous  $A/Cl_3$  adopts three different structures, depending on the temperature and the state (solid, liquid, gas). Solid  $A/Cl_3$  exists as cubic close packed layers. In the liquid state, aluminium trichloride exists as the dimer  $Al_2Cl_6$ .  $Al_2Cl_6$  dimers are also found in the vapour phase.

- (i) Draw a dot-and-cross diagram for the dimer of aluminium chloride, and state the bond angle about the Al atom. [2]
- (ii) A 0.52 g sample contains a mixture of  $A/Cl_3$  and its dimer. It takes up a volume of 70 cm<sup>3</sup> at a temperature of 150 °C and a pressure of 1 atm. By determining the average  $M_r$  of the mixture, deduce the percentage composition of the aluminium chloride dimer under these conditions. [3]
- (iii) How would you predict the average  $M_r$  of the mixture to change as the temperature is increased? Explain your answer. [1]
- (iv) With the aid of an equation, explain why the hydrated form of aluminium chloride cannot act as a Lewis acid. [2]
- (d) Beryllium dichloride has properties similar to those of aluminium chloride.

Beryllium dichloride and ammonia reacts in the molar ratio 1:2. By considering the number of bonding and non-bonding electron pairs, explain the molar ratio and draw a diagram to show the bonding in the product. [2]

[Total: 20]

NDI	DAT	E

Additional Materials:

NANYANG JUNIOR COLLEGE JC 2 PRELIMINARY EXAMINATION Higher 2

CANDIDATE NAME			
CLASS		TUTOR'S NAME	
CHEMISTRY			9729/04
Paper 4 Practi	cal		19 August 2019
			2 hours 30 minutes
Candidates and	swer on the Question Paper.		

#### **READ THESE INSTRUCTIONS FIRST**

Write your name and class on all the work you hand in. Give details of the practical shift and laboratory where appropriate, in the boxes provided.

As listed in the Confidential Instructions

Write in dark blue or black pen.

You may use an HB pencil for any diagrams, graphs.

Do not use staples, paper clips, glue or correction fluid.

Answer all questions in the spaces provided on the Question Paper. The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

Qualitative Analysis Notes are printed on pages 18 and 19. At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

Shift
Laboratory

For Examiner's Use		
1	/ 28	
2	/ 11	
3	/ 16	
Total	/ 55	

#### 1 Determination of the percentage by mass of ethanedioic acid

**FA 1** is a solution made by dissolving an unknown mass of a mixture of ethanedioic acid,  $H_2C_2O_4$ , and sodium ethanedioate,  $Na_2C_2O_4$ .

In aqueous solution, both ethanedioic acid and sodium ethanedioate release all their ethanedioate ions,  $C_2O_4^{2-}$ . These ions react with manganate(VII) ions as shown.

 $2MnO_4^{-}(aq) + 16H^{+}(aq) + 5C_2O_4^{2-}(aq) \rightarrow 10CO_2(g) + 2Mn^{2+}(aq) + 8H_2O(I)$ 

You will carry out titrations to find the percentage by mass of ethanedioic acid in the mixture.

- FA 2 is 0.0200 mol dm<sup>-3</sup> potassium manganate(VII), KMnO<sub>4</sub>.
- **FA3** is 1.00 mol dm<sup>-3</sup> sulfuric acid, H<sub>2</sub>SO<sub>4</sub>.

#### (a) (i) Titration of FA 1 against FA 2

- 1. Fill a burette with **FA 2**.
- 2. Pipette 25.0 cm<sup>3</sup> of **FA 1** into a conical flask.
- 3. Use the measuring cylinder to add 30.0 cm<sup>3</sup> of **FA 3** to the same conical flask.
- 4. Place the conical flask on the tripod and gauze and heat until the temperature of the solution is approximately 70 °C.
- Carefully remove the flask from the tripod.
   Add a few drops of FA 2 from the burette and swirl the mixture until it turns colourless.
- Note: If the reaction mixture does not decolourise or turns brown, reheat it to about 70 °C.
   Swirl the mixture till it decolourises.
   If the brown colour remains, discard the contents of the flask and begin a new titration.
  - 6. Continue the titration until a permanent pale pink is obtained.
  - 7. Record your titration results, to an appropriate level of precision, in the space provided on page **3**.
  - 8. Repeat points 2 to 7 until consistent results are obtained.

#### **Titration results**

(ii) From your titration results, obtain a suitable volume of **FA 2**, *V*<sub>**FA 2**</sub>, to be used in your calculations. Show clearly how you obtained this volume.

(iii) Calculate the total number of moles of ethanedioate ions present in 25.0 cm<sup>3</sup> of FA 1.

moles of ethandioate ions present = \_\_\_\_\_

[1]

#### (b) Titration of FA 1 against FA 4

A separate experiment was carried out by titrating **FA 1** against **FA 4** containing 0.0400 mol dm<sup>-3</sup> sodium hydroxide from a burette. It was found that 25.0 cm<sup>3</sup> of **FA 1** required **26.75 cm<sup>3</sup>** of **FA 4** for complete reaction.

Calculate the number of moles of ethanedioic acid present in 25.0 cm<sup>3</sup> of **FA1**.

moles of ethandioic acid present =

[Turn Over

[1]

(c) (i) Calculate the mass of sodium ethanedioate,  $Na_2C_2O_4$ , present in 25.0 cm<sup>3</sup> of FA 1. [A<sub>r</sub>: C, 12.0; O, 16.0; Na, 23.0]

mass of sodium ethanedioate present = \_\_\_\_\_

[1]

(ii) Calculate the mass of ethanedioic acid, H<sub>2</sub>C<sub>2</sub>O<sub>4</sub>, present in 25.0 cm<sup>3</sup> of FA 1. Hence calculate the percentage by mass of ethanedioic acid in the solid mixture used to prepare FA 1.
 [A<sub>r</sub>: C, 12.0; O, 16.0; H, 1.0]

percentage by mass of  $H_2C_2O_4 =$  [2]

(d) Explain why the solution in the conical flask was heated to approximatly 70 °C before titration.

.....[1]

(e) Student B suggested improving the accuracy of the titration results by decreasing the concentration of FA 2 to 0.0150 mol dm<sup>-3</sup>.

State and explain if the student's suggestion would make the titration results more accurate.

.....[1]

(f) The **FA 2** that was initially added into the conical flask took some time to decolourise. As the titration continued, the rate of decolourisation changed due to the products formed.

To investigate the kinetics of the reaction in part (a), a separate experiment was carried out to observe the rate of carbon dioxide produced over a period of time.

30.0 cm<sup>3</sup> of **FA 2** was added from a measuring cylinder to a conical flask containing 20.0 cm<sup>3</sup> of **FA 1** and 50.0 cm<sup>3</sup> of **FA 3** and the stop watch was started. The volume of carbon dioxide was collected by downward displacement of water using a measuring cylinder and the volume of gas was recorded at 30 s intervals.

(i) Sketch the graph, in **Fig 1.1**, you would expect to obtain for this experiment and use it to explain why **FA 2** decolourises at different rates throughout the titration.



(ii) A similar experiment described in (f)(i) was carried out using 20.0 cm<sup>3</sup> of FA 1 with 30.0 cm<sup>3</sup> of another oxidising agent, aqueous potassium persulfate,  $K_2S_2O_8$ , in the presence of Fe<sup>3+</sup>(aq) catalyst. The volume of carbon dioxide produced was similarly recorded at 30 s intervals. Sketch in Fig 1.2, a graph you would expect for this new experiment



Time / min



[1]

#### (g) Planning

The kinetics of a chemical reaction can be studied by using the initial rates method. In this method, we note the time taken for a reaction to reach an identification point early in the reaction.

Reaction between iodide ions,  $I^-$ , and persulfate ions,  $S_2O_8^{2-}$  is an example where its initial rate can be determined.

$$2I^{-}(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

If a small and same amount of aqueous sodium thiosulfate is added to every reaction mixture together with starch before the start of the reaction, the iodine produced during the reaction will react immediately with the thiosulfate ions present.

When the small amount of thiosulfate ions have reacted with the iodine produced, a blue-black iodine-starch complex will appear, indicating the experiment has reached the identification point.

By keeping the amount of thiosulfate ions small, the time taken for the reaction to reach the identification point is therefore used to determine the initial rate of that reaction.

The same procedure is repeated with different volumes of reactants and deionised water while keeping the total volume of the reaction mixture constant.

In this question, you are to investigate how the rate of reaction between potassium persulfate and potassium iodide depends on the concentration of potassium persulfate.

(i) You are to plan a series of experiments to determine the time taken for the reaction between potassium persulfate and potassium iodide to reach a same identification point for all the experiments and show how changing the concentration of potassium persulfate will affect the rate of reaction.

You may assume you are provided with:

- 0.60 mol dm<sup>-3</sup> aqueous potassium iodide, KI,
- 0.20 mol dm<sup>-3</sup> aqueous potassium persulfate, K<sub>2</sub>S<sub>2</sub>O<sub>8</sub>,
- 0.020 ml dm<sup>-3</sup> aqueous sodium thiosulfate, Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>,
- starch indicator,
- equipment normally found in a school or college laboratory.

25 cm<sup>3</sup> potassium iodide,

- 40 cm<sup>3</sup> potassium persulfate,
- 10 cm<sup>3</sup> sodium thiosulfate,
- 0 cm<sup>3</sup> deionised water,
- 5 cm<sup>3</sup> starch indicator.

In your plan you should include brief details of:

- the apparatus that you would use,
- the procedure that you would follow,
- how you would ensure your results obtained are reliable,
- a table showing all volumes and precision of each solution you would use and the measurements that you would take.

Table

 • • •
 • • •
 •••
 •••

(ii) Write an ionic equation, including state symbols, for the reaction between the iodine produced and the thiosulfate ions,  $S_2O_3^{2-}$ , present in the reaction mixture.

.....[1]

(iii) Hence calculate the rate of producing iodine if the time taken for experiment 1 was 134 seconds.

(iv) A preliminary experiment carried out by another student, using approximate volumes of solution, showed that the time taken for an experiment to reach identification point doubled when the potassium persulfate was diluted with an equal volume of water.

Sketch with clearly labelled axes, on **Fig 1.3**, an appropriate graph to represent the results of the student's preliminary experiment.



Fig 1.3

[1]

[Total: 28]

#### 2 Determination of the concentration of sodium hydroxide

When hydrochloric acid is mixed with aqueous sodium hydroxide, the neutralisation reaction releases heat causing a rise in the temperature of the solution.

 $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$ 

In this experiment you will mix different volumes of hydrochloric acid and sodium hydroxide but the total volume will be kept constant. For each mixture you will record the temperature rise.

Since the total volume remains the same, the temperature rise is a direct measure of the heat given out by the reaction. The maximum heat given out occurs when all the acid present is exactly neutralised by all the alkali present. By determining the volumes when this occurs, you can determine the concentration of the sodium hydroxide.

**FA 5** is 2.00 mol dm<sup>-3</sup> aqueous hydrochloric acid, HC*l*.

FA 6 is aqueous sodium hydroxide, NaOH.

- (a) Prepare a table in the space provided on page **12** in which to record, to an appropriate level of precision:
  - the volume of FA 5, V<sub>FA 5</sub>,
  - the volume of **FA 6**,  $V_{FA 6}$ ,
  - the initial temperature of **FA 5**, *T*<sub>i</sub>,
  - the maximum temperature of the solution,  $T_{max}$ ,
  - the temperature rise,  $\Delta T$ , where  $\Delta T = T_{max} T_i$ .

#### **Experiment 1**

- 1. Using a measuring cylinder, transfer 40.0 cm<sup>3</sup> of **FA 5** into a polystyrene cup placed in a 250 cm<sup>3</sup> beaker.
- 2. Record the initial temperature of **FA 5**,  $T_i$ , in the space below.
- 3. Using another measuring cylinder, transfer 10.0 cm<sup>3</sup> of **FA 6** into the same cup.
- 4. Stir the mixture thoroughly and record in your table the maximum temperature,  $T_{max}$  of the solution.
- 5. Empty the polystyrene cup, rinse thoroughly with water and shake dry.

#### Experiments 2 to 6

Repeat experiment 1 five times, using 34.0, 28.0, 22.0, 16.0, 10.0 cm<sup>3</sup> respectively, of **FA 5**, at point 1.

In each case, you will need to add sufficient **FA 6** to make sure that the total volume is  $50.0 \text{ cm}^3$ .

Record all required volumes, temperature taken and calculated values in your table.

#### Results

(b) (i) Plot a graph of temperature rise,  $\Delta T$ , on the y-axis against the volume of **FA 5** on the x-axis on page **13**. Draw two best-fit lines taking into account all of your plotted points.



(ii) From your graph, determine the volume of FA 5 required to exactly react with FA 6.

volume of FA 5 =

[4]

(c) (i) Calculate the number of moles of hydrochloric acid present in the volume of FA5 in (b)(ii).

moles of hydrochloric acid in **FA 5** = \_\_\_\_\_[1]

(ii) Calculate the concentration of FA 6.

concentration of **FA 6** = \_\_\_\_\_[1]

(d) A student decided to modify the original experiment. The total volume of the solution was increased to 70 cm<sup>3</sup> and temperature rises were recorded for 15, 20, 25, 30, 40, 45, 50, 55, 60 and 65 cm<sup>3</sup> of **FA 6**.

Discuss how these two changes would affect the accuracy with which the concentration of **FA 6** could be determined.

[2] [Total:11]

#### 3 Investigation of some organic and inorganic reactions

Carry out the following tests. Carefully record your observations in Tables 3.1 and 3.2

Unless otherwise stated, the volumes given below are approximate and should be estimated rather than measured. Test and identify any gases evolved. If there is no observable change, write **no observable change**.

FA 7, FA 8 and FA 9 are all solutions of carbohydrates.

- Sugars and starch are carbohydrates.
- Some sugars contain an aldehyde group and hence act as reducing agents.
- Other sugars do not contain an aldehyde group.

Sandell's solution reacts in a similar way to Fehling's reagent.

You will need to heat Sandell's solution in a hot water bath when using it in tests.

		test	observations		
			FA 7	FA 8	FA 9
(a)	(i)	Add 2 or 3 drops of aqueous iodine.			
	(ii)	Add 2 or 3 drops of acidified potassium manganate(VII) and <b>allow</b> <b>to stand for two minutes.</b>			
	(iii)	Add 3 cm depth of Sandell's solution and place the tube in the hot water bath for two minutes.			

#### Table 3.1

[3]

(iv) Identify the following and explain your reasoning:

the carbohydrate that could be starch:

(v) Describe a different test, other than using Sandell's solution and Fehling's reagent, that could be carried out to identify the presence of an aldehyde group. Describe how the test would be carried out and the expected observation if the result is positive.

#### Do not carry out your test.

test:	
abconvation	
	[1]

**FA 10** and **FA 11** are two of the components of Sandell's solution. Each contains one cation and one anion. Carry out the following tests and record all your observations in the table.

		teet	observa	ations
		lest	FA 10	FA 11
(b)	(i)	Add a few drops of		
		aqueous silver nitrate.		
	(11)	Add a few drops of		
		aqueous barium nitrate or		
		aqueous barium chloride,		
		inen		
		add dilute nitric acid.		
	(iii)	Add a few drops of		
		aqueous iodine.		
	(iv)	Add a 1 cm depth of		
		aqueous iron(II) sulfate.		
	(v)	Add a 1 cm depth of <b>FA 11</b> .		
				[6]

Table 3.2	ble 3.2
-----------	---------

(vi) Identify the ions in FA 10 and FA 11.

FA 10 cation: \_\_\_\_\_\_ anion: \_\_\_\_\_

FA 11 anion:

[2]

(vii) Write an ionic equation, including state symbols, for the reactions of FA 10 in (b)(iii) and (b)(v).

equation for **(b)(iii)**:

equation for **(b)(v)**:

[2]

[Total:16]

# Qualitative Analysis Notes [ppt. = precipitate]

### (a) Reactions of aqueous cations

	reaction with			
cation	NaOH(aq)	NH₃(aq)		
aluminium, A <i>t</i> ³⁺(aq)	white ppt. soluble in excess	white ppt. insoluble in excess		
ammonium, NH₄ <sup>+</sup> (aq)	ammonia produced on heating	_		
barium, Ba <sup>2+</sup> (aq)	no ppt. (if reagents are pure)	no ppt.		
calcium, Ca <sup>2+</sup> (aq)	white ppt. with high [Ca <sup>2+</sup> (aq)]	no ppt.		
chromium(III), Cr <sup>3+</sup> (aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess		
copper(II), Cu <sup>2+</sup> (aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution		
iron(II), Fe <sup>2+</sup> (aq)	green ppt., turning brown on contact with air insoluble in excess	green ppt., turning brown on contact with air insoluble in excess		
iron(III), Fe <sup>3+</sup> (aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess		
magnesium, Mg²⁺(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess		
manganese(II), Mn <sup>2+</sup> (aq)	off-white ppt., rapidly turning brown on contact with air insoluble in excess	off-white ppt., rapidly turning brown on contact with air insoluble in excess		
zinc, Zn <sup>2+</sup> (aq)	white ppt. soluble in excess	white ppt. soluble in excess		

#### (b) Reactions of anions

anion	reaction			
carbonate, $CO_3^{2-}$	CO <sub>2</sub> liberated by dilute acids			
chloride, C <i>l</i> <sup>–</sup> (aq)	gives white ppt. with Ag <sup>+</sup> (aq) (soluble in $NH_3(aq)$ )			
bromide, Br <sup>-</sup> (aq)	gives pale cream ppt. with Ag <sup>+</sup> (aq) (partially soluble in NH <sub>3</sub> (aq))			
iodide, I⁻(aq)	gives yellow ppt. with Ag⁺(aq) (insoluble in NH₃(aq))			
nitrate, NO <sub>3</sub> <sup>-</sup> (aq)	$NH_3$ liberated on heating with $OH^-(aq)$ and $Al$ foil			
nitrite, NO <sub>2</sub> <sup>-</sup> (aq)	NH <sub>3</sub> liberated on heating with OH <sup>-</sup> (aq) and A <i>l</i> foil; NO liberated by dilute acids (colourless NO $\rightarrow$ (pale) brown NO <sub>2</sub> in air)			
sulfate, $SO_4^{2-}$ (aq)	gives white ppt. with Ba <sup>2+</sup> (aq) (insoluble in excess dilute strong acids)			
sulfite, $SO_3^{2-}$ (aq)	SO <sub>2</sub> liberated with dilute acids; gives white ppt. with Ba <sup>2+</sup> (aq) (soluble in dilute strong acids)			

#### 9(c) Tests for gases

gas	test and test result		
ammonia, NH <sub>3</sub>	turns damp red litmus paper blue		
carbon dioxide, CO <sub>2</sub>	gives a white ppt. with limewater (ppt. dissolves with excess CO <sub>2</sub> )		
chlorine, Cl <sub>2</sub>	bleaches damp litmus paper		
hydrogen, H <sub>2</sub>	"pops" with a lighted splint		
oxygen, O <sub>2</sub>	relights a glowing splint		
sulfur dioxide, SO <sub>2</sub>	turns aqueous acidified potassium manganate(VII) from purple to colourless		

### 9(d) Colour of halogens

halogen	colour of element	colour in aqueous solution	colour in hexane	
chlorine, Cl <sub>2</sub>	greenish yellow gas	pale yellow	pale yellow	
bromine, Br <sub>2</sub>	reddish brown gas / liquid	orange	orange-red	
iodine, $I_2$	black solid / purple gas	brown	purple	

#### H2 Chemistry Prelim Exam Answers

1	A	11	В	21	D
2	В	12	С	22	В
3	В	13	A	23	Α
4	В	14	В	24	С
5	D	15	С	25	Α
6	С	16	D	26	D
7	A	17	A	27	С
8	D	18	С	28	С
9	В	19	A	29	С
10	D	20	C	30	В

#### Paper 1 Answer Key

#### **Paper 1 Worked Solutions**

1 **(A)** 

Charge of nucleon A =  $(+^{2}/_{3}) + 2(-^{1}/_{3}) = 0$ Charge of nucleon B =  $2(+^{2}/_{3}) + (-^{1}/_{3}) = +1$ Hence, A is a neutron, B is a proton. Statement 1 is correct.

Statement 2: A neutrino does not have a charge.

Hence the charge of C must be -1. C will be attracted to the positive plate. Statement 2 is correct.

Statement 3:  ${}^{22}_{10}Ne \rightarrow {}^{22}_{11}Na$  is correct.

When a neutron breaks up into a proton, mass number remains constant; proton number increase by 1.

## 2 **(B)**

The ratio of O<sub>2</sub>:  $Cl^{-}$  is 3:2. In chlorates (or any oxoanions), O exist as oxides with OS -2. Hence each O is oxidised from -2 in chlorates to 0 in oxygen gas.

Total number of electrons lost by three  $O_2$  molecules = 3 x 2 x 2 = 12 Total number of electrons gained by two  $Cl^- = 12$ Number of electrons gained by each  $Cl^- = 6$ 

Change in OS of Cl = -6Final OS – Initial OS = -6 Initial OS = -1 – (-6) = +5

# 3 **(B)**

Cations with higher charge and smaller ionic radius have higher charge density, will polarise anion electron cloud more to form a more covalent bond.

For ionic compounds of Group 14 halides, we look for cation with smaller 2+ charge and larger ionic radius (further down the group), hence  $Pb^{2+}$  (...  $PbF_2$ ).

For covalent compounds, we look for cation with larger 4+ charge and smaller ionic radius (up the group), hence  $Sn^{4+}$  ( $\therefore SnCl_4$ ).

(Note: Although not tested here, students should know that anions with larger electron cloud, are more easily polarised, form more covalent bonds. Hence chlorides form more covalent bonds than fluorides.)



There are no sp<sup>3</sup> hybridised carbon atom with 4 bond pairs and 0 lone pairs to give a 109° bond angle.

# 5 **(D)**

At constant temperature and pressure, V  $\alpha$  n.

The initial 5 cm<sup>3</sup> is due to air particles. The final reading of 81 cm<sup>3</sup> includes the volume due to the air particles. After subtracting off 5 cm<sup>3</sup>, the volume due to the volatile liquid only is 76 cm<sup>3</sup>.

$$M_{\rm r} = \frac{\rm mRT}{\rm pV}$$
$$M_{\rm r} = \frac{0.253 \times 8.31 \times (273+97)}{101 \ 325 \times 76 \times 10^{-6}}$$
$$M_{\rm r} = 101.0$$
## 6 **(C)**

This question test how well students know the definitions of the different enthalpy changes.

Statement 1:  $\Delta H_7 \equiv LE(CaCO_3) \text{ and } \Delta H_8 \equiv -\Delta H_{sol}(CaCO_3)$ From  $\Delta H_{sol} = \sum \Delta H_{hyd} - LE$ ,  $LE = \sum \Delta H_{hyd} - \Delta H_{sol}$   $= \Delta H_{hyd} (Ca^{2+}) + \Delta H_{hyd} (CO_3^{2-}) - (-\Delta H_8)$ Hence statement 1 is wrong.

Statement 2:  $\Delta H_7 \equiv 1^{st} + 2^{nd}$  IE of Ca = 590 + 1150 = 1740 Hence statement 2 is correct.

```
Statement 3:

\Delta H_2 \equiv \Delta H_{atm}(Ca)

From Hess's law,

\Delta H_1 = \Delta H_2 + (\Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6 + \Delta H_7) - \Delta H_8

rearrange, \Delta H_2 = \Delta H_1 + \Delta H_8 - (\Delta H_3 + \Delta H_4 + \Delta H_5 + \Delta H_6 + \Delta H_7)

Hence statement 3 is correct.
```

### 7 **(A)**

Calibration methods account for heat loss by assuming a constant heat capacity C of the set-up.

In experiment 1, reaction is a neutralisation reaction. Total amount of heat evolved depends on amount of water formed.  $n(water) = 2.0 \times \frac{50}{1000}$ 

Using heat evolved = heat absorbed and letting C be heat capacity in kJ K<sup>-1</sup>. 2.0 x 50/1000 x 57.4 = C x 10.0 -Eqn  $\bigcirc$ 

For experiment 2, we calculate the enthalpy change of neutralisation for one mole of the weak acid  $H_2C_2O_4$ . n( $H_2C_2O_4$ ) reacted = 2.0 x 50/1000 x  $\frac{1}{2}$  (as NaOH is limiting)

Using heat evolved = heat absorbed 2.0 x 50/1000 x  $\frac{1}{2}$  x  $|\Delta H_{rxn}|$  = C x 8.5 -Eqn ②

Taking Eqn@/Eqn①,  $\frac{2.0 \times 50/1000 \times \frac{1}{2} \times |\Delta H_{rxn}|}{2.0 \times 50/1000 \times 57.4} = \frac{C \times 8.5}{C \times 10.0}$ Hence  $|\Delta H_{rxn}| = \frac{57.4 \times 8.5 \times 2}{10}$ 

D)	
	D)

Statement	Equation	$\Delta G^{\Theta}$	$\Delta S^{\Theta}$
1	$SiCl_4(I) + 2H_2O(I) \rightarrow SiO_2(s) + 4HCI(aq)$	-	+
2	$Cl_2(g)$ + $2l^-(aq) \rightarrow l_2(aq)$ + $2Cl^-(aq)$	-	-
3	$MgCO_3(s) \xrightarrow{\Delta} MgO(s) + CO_2(g)$	+	+

Statement 1 only is correct.

Graph of colour intensity against time shows 1<sup>st</sup> order characteristics with constant halflives. Since NO was used in excess, the variable is [Cl<sub>2</sub>]. As reaction proceeds, rate decreases proportionally (flatter gradient) with decreasing [Cl<sub>2</sub>]. Reaction is 1<sup>st</sup> order wrt Cl<sub>2</sub>.

Graph of rate against [NO]<sup>2</sup> shows a straight line with constant positive gradient passing through origin, rate is directly proportional to [NO]<sup>2</sup>. Hence 2<sup>nd</sup> order wrt to NO.

Statement 1 is correct.

Statement 2 test whether students can draw the link between orders of reaction and stoichiometric coefficient in the mechanism.  $1^{st}$  order wrt to  $Cl_2$  and  $2^{nd}$  order wrt NO tells us one molecule of  $Cl_2$  and two molecule of NO takes part in the reaction up to and including the slow step of the reaction.

Hence, for the given mechanism, when the slow step is the second step, the mechanism will be consistent with the rate equation.

Statement 3 is wrong.

For an overall 3<sup>rd</sup> order reaction, units of  $k = \frac{\text{mol dm}^{-3} \text{min}^{-1}}{\left[\text{mol dm}^{-3}\right] \left[\text{mol dm}^{-3}\right]^2} = \text{mol}^{-2} \text{ dm}^6 \text{min}^{-1}.$ 

At constant temperature, decomposition of hydrogen peroxide is a first order reaction, hence rate is directly proportional to  $[H_2O_2]$ . The time taken to use up 10% of initial amount remains constant. After 5 minutes, 90% of initial  $[H_2O_2]$  will remain.

Prove:

rate =  $k[H_2O_2]$ 

When  $[H_2O_2]=0.10$  mol dm<sup>-3</sup>, rate = 0.1k. 10% of 0.10 mol dm<sup>-3</sup> is 0.01 mol dm<sup>-3</sup>. At a rate of 0.1k, it takes 5 mins to use up 0.01 mol dm<sup>-3</sup> of H<sub>2</sub>O<sub>2</sub>.

When  $[H_2O_2]=1.00$  mol dm<sup>-3</sup>, rate = k. 10% of 1.00 mol dm<sup>-3</sup> is 0.10 mol dm<sup>-3</sup>. When the amount to be used up increase by 10x and the rate also increase by 10x, the increases cancel out and the time taken will remain constant at 5 mins.

### 11 **(B)**

Human blood is buffered by the H<sub>2</sub>CO<sub>3</sub>, HCO<sub>3</sub><sup>-</sup> system.

The weak base will react with and remove small amounts of  $H^+(aq)$  in the blood to maintain a relatively constant pH of 7.4.

 $\mathsf{HCO}_3^- + \mathsf{H}^+ \to \mathsf{H}_2\mathsf{CO}_3$ 

## 12 **(C)**

For precipitation, ionic product  $\geq$  Ksp. Substitute [IO<sub>3</sub><sup>-</sup>] = 0.10 mol dm<sup>-3</sup>, [CrO<sub>4</sub><sup>2-</sup>] = 0.10 mol dm<sup>-3</sup>, [AsO<sub>4</sub><sup>3-</sup>] = 0.10 mol dm<sup>-3</sup> into the corresponding ionic products.

AgIO <sub>3</sub> :	[Ag <sup>+</sup> ] [IO <sub>3</sub> <sup>−</sup> ] ≥ 3.2 x 10 <sup>−8</sup> mol <sup>2</sup> dm <sup>-6</sup>
	[Ag⁺] ≥ 3.2 x 10 <sup>-7</sup> mol dm <sup>-3</sup>

Ag<sub>2</sub>CrO<sub>4</sub>:  $[Ag^+]^2 [CrO_4^{2-}] \ge 9.0 \times 10^{-12} \text{ mol}^3 \text{ dm}^{-9}$  $[Ag^+] \ge 9.5 \times 10^{-6} \text{ mol dm}^{-3}$ 

Ag<sub>3</sub>AsO<sub>4</sub>:  $[Ag^+]^3 [AsO_4^{3-}] \ge 1.0 \times 10^{-22} \text{ mol}^4 \text{ dm}^{-12}$  $[Ag^+] \ge 1.0 \times 10^{-7} \text{ mol dm}^{-3}$ 

The first precipitate is Ag<sub>3</sub>AsO<sub>4</sub> and it appears at the smallest [Ag<sup>+</sup>] of  $1.0 \times 10^{-7}$  mol dm<sup>-3</sup>.

#### 13 **(A)**

Rearranging  $\Delta G^{\Theta} = -nFE^{\Theta}$ ,  $-\Delta G^{\Theta}/F = nE^{\Theta}$ 

A quick calculation of  $E^{\Theta}$  will give the more standard reduction potential values.

half-equation	−∆ <i>G</i> <sup>⊖</sup> /F (V)	E <sup>e</sup> / V
$UO_2^{2+} + e^- \implies UO_2^+$	+0.16	+0.16
$UO_2^+ + 4H^+ + e^- \implies U^{4+} + 2H_2O$	+0.27	+0.27
U <sup>4+</sup> + e <sup>−</sup> → U <sup>3+</sup>	-0.52	-0.52
U <sup>3+</sup> + 3e <sup>−</sup> <del>→</del> U	-4.98	-1.66
Mg²+ + 2e⁻ → Mg		-2.38

Mg metal is a reducing agent that will reduce UO<sub>2</sub><sup>+</sup> and itself oxidised to Mg<sup>2+</sup>.

Using  $E_{cell}^{\Theta} = E_{red}^{\Theta} - E_{oxd}^{\Theta}$ , we can see  $E_{cell}^{\Theta} > 0$  (and reaction will be spontaneous) when  $E_{red}^{\Theta} > E_{Mg2+/Mg}^{\Theta}$ .

Since  $E_{UO2+/U4+}^{\Theta} > E_{U4+/U3+}^{\Theta} > E_{U3+/U}^{\Theta} > E_{Mg2+/Mg}^{\Theta}$ ,  $UO_2^+$  will be reduced by Mg metal all the way to U.

14 **(B)** 

Using the equations Q=It and Q=nzF,

where n = amount of Cu deposited, z = 2 for Cu<sup>2+</sup> + 2e  $\rightarrow$  Cu

 $n = \frac{lt}{zF}$ 

The amount of charge supplied will affect the amount of Cu deposited. The amount of charge, Q, is affected by current used and the length of time for which the current is run.

### 15 **(C)**

The strongest reducing agent has the lowest  $1^{st} + 2^{nd}$  ionisation energies.

IEs decrease down the group and increase across the period. Sr is in group 2, to the left of Cd, both in Period 4. Hence Sr should have lower  $1^{st} + 2^{nd}$  IEs than Cd.

A glance at the data booklet should tell you that the first two IEs of Sr is lower than for both Ni and Zn.

16 **(D)** 

Statement 1:

 $2VO_3^-$  +  $3Zn \rightarrow 2V^{2+}$  +  $3Zn^{2+}$ . Vanadium is reduced from +5 OS in  $VO_3^-$  to +2 in  $V^{2+}$ .

Statement 2:

 $Cr(H_2O)_{6^{3+}} + SO_{4^{2-}} \rightarrow Cr(H_2O)_5(SO_4)^+ + H_2O$ . Chromium undergoes ligand exchange reaction where a water ligand is replaced with a sulfate(VI) ligand. Cr remains +3 cation.

Statement 3:

Tartrate anion  $\neg$ OOCCH<sub>2</sub>(OH)CH<sub>2</sub>(OH)COO<sup>-</sup> has a charge of -2.

In  $[Co(tartrate)_3]^{3-}$ , the oxidation state of Co is +3. Hence Co has been oxidised by hydrogen peroxide from Co(II) to Co(III). Once  $[Co(tartrate)_3]^{3-}$  is formed, it will be reduced back to Co(II) by hydrogen peroxide.  $[Co(II)(tartrate)_3]^{4-}$  is acting as a homogeneous catalyst for the disproportionation of hydrogen peroxide.

	(A)							
	Steps		Cl	-	I-			
	add AgNO <sub>3</sub> (ag	)	AgCI	ppt	Agl ppt			
	Filter + wash v	, /ith H₂O	Resi	due	Residue			
	add NH <sub>3</sub> (aq)		soluble to form Cl <sup>-</sup> inse and Ag(NH <sub>3</sub> ) <sub>2</sub> <sup>+</sup> Ac		insoluble Agl ppt			
	Filter		complexCl <sup>-</sup> and Ag(NH3)2 <sup>+</sup> in filtrate					
	Note: All the K	+ ions should	have been wa	shed off in t	he first filtration			
1.0								
10	(0)							
Eleme	ent	С	Н	0	7			
% ma	SS	40	6.7	53.3				
Amt		3.33	6.7	3.33				
Ratio		1	2	1				
The C atom is unsaturated, no chiral carbon possible. MF is $C_2H_4O_2$ : H O H O      H-C-C-OH HO-C-C-H OH H H H      H O - C-C-H OH H O - C-C-H OH H OH H H H								
MF is ( H H—C— H	С2H4O2: О Н -C—ОН НО—С- , Н	о    _С_н , но-(	ОН Н 	Н Н     -C==С—ОН				
MF is ( H H—C— H All stra	C₂H₄O₂: О Н -C—ОН НО—С- , Н ight chain struct	O II −C−H O , HO−O	ОН Н │	н н -с=с—он				
MF is ( H H H All stra	C₂H₄O₂: O H -C—OH HO—C- j ight chain struct	O II C—H , HO—( tures are not o can give a ch	ОН Н     C=C—H <sub>,</sub> HO- chiral. H· iral carbon.	н н -C=C—он -C <sup></sup> C*-он н н				







The best electrical conductor has the highest ionic concentration, which depends on extent of dissociation of weak acid, in turn due to strength of acid.

Pyruvic acid, with an electron-withdrawing CH<sub>3</sub>CO– acyl group that disperse the negative charge on –COO<sup>–</sup> of conjugate base, is the strongest weak acid.

CH<sub>3</sub>– and CH<sub>3</sub>CH<sub>2</sub>– groups of ethanoic acid and propanoic acid respectively are electrondonating groups that intensify the negative charge on  $-COO^-$  of conjugate base, are weaker acids.

Pure ethanoic acid, like all simple covalent liquids, only undergo auto-ionisation, producing minuscule amounts of ions.





### Paper 2 Answers

1	(a)	(i)	At a low temperature, by Le Chatelier's Principle, the forward exothermic reaction is favoured to produce more heat. Hence the position of equilibrium will shift to the right to increase yield of ammonia. [1] However the system will take a long time to reach equilibrium. Hence an optimal temperature of 500 °C is used to ensure rate of reaction is not too slow and makes the production process become uneconomical. [1]				
		(ii)	The iron catalyst is in solid state while nitrogen and hydrogen are in gaseous state. It functions as a heterogeneous catalyst as it is in a different phase as compared to nitrogen and hydrogen. [1]				
			catalyst. Bonds in the reactant molecules are weakened which lowers the activation energy. New bonds are then formed between adjacent reactant molecules to form the menthol. The product formed will be desorbed from the surface of the catalyst. [1]				
		(iii)	<ul> <li>The catalyst provides an alternative reaction pathway with a lower activation energy, E<sub>a</sub> (c) compared to the uncatalysed reaction, E<sub>a</sub>.</li> </ul>				
			<ul> <li>More molecules will possess energy greater than this lowered activation energy.</li> </ul>				
			<ul> <li>The frequency of effective collisions increases. Hence, according to the Collision Theory, the rate of reaction increases.</li> </ul>				
			3 pts: [2], 2 pts: [1]				
			No. of molecules				
			Key: No of molecules with energy $\geq Ea$ (u) No of molecules with energy $\geq Ea$ (c) Ea (c) $E_a$ (u) catalysed rxn uncatalysed rxn				
			[1] Diagram				

(iv) Ammonia has a simple molecular structure with hydrogen bonding between molecules. Nitrogen and hydrogen have simple molecular structure with instantaneous dipole-induced dipole interactions between molecules. [1] Ammonia has a higher boiling point than nitrogen and hydrogen due to the stronger hydrogen bonds between molecules. The condenser helps to lower temperature so that ammonia is condensed into liquid while nitrogen and hydrogen remains as gases and is recycled back into the reactor. [1] Sketch of HN<sub>3</sub> shows more deviation from ideal gas than ammonia. [1] (v) Both hydrazoic acid and ammonia have simple molecular structure. Hydrazoic acid has a large electron cloud which is more polarisable, resulting in stronger instantaneous dipole-induced dipole interaction between its molecules than the hydrogen bonds between ammonia molecules. The stronger id-id interactions causes hydrazoic acid to deviate more from ideal gas behavior. [1] (b) (i) (e<sup>-</sup>) optional (+)(-) Zn-Zn salt bridge 1.00 moldm<sup>-3</sup> 1.00 moldm<sup>-3</sup> Zn<sup>2+</sup> (aq)  $[Zn(NH_3)_4]^{2+}$  (aq) and 25 °C 1.00 moldm<sup>-3</sup> NH<sub>3</sub> (aq), 25 °C label the electrode and ions in each half cell with concentration and • temperature salt bridge, voltmeter and label the polarity of the electrodes correctly [2]

	(ii)	[R]: $Zn^{2+} + 2e^{-} \rightarrow Zn$ [O]: $Zn + 4NH_3 \rightarrow [Zn(NH_3)_4]^{2+} + 2e^{-}$ Overall: $Zn^{2+} + 4NH_3 \rightarrow [Zn(NH_3)_4]^{2+}$ [1]
		$\Delta G^{\circ} = -nFE^{\circ} = -2 \times 96500 \times 0.28 = -54040 \text{ Jmol}^{-1} = -54.0 \text{ kJ mol}^{-1} [1]$
		Or $\Delta G^{\circ} = -nFE^{\circ} = -2 \times 96500 \times 0.28 / 1000 = -54.04 \text{ kJmol}^{-1} = -54.0 \text{ kJ mol}^{-1}$
(c)	(i)	sp <sup>2</sup> orbital of N and C head-on overlap to form $\sigma$ bond
		$sp^2$ $sp^2$ $sp^2$ $sp^2$ $sp^2$ $p^2$ m $p^2$ m r r r r r r r r
		p orbital of N and C side-way overlap to form $\pi$ bond [1]
	(ii)	$N_a$ is more basic than $N_b$ .
		In N <sub>a</sub> , lone pair of electrons are present in the sp <sup>2</sup> orbital that is pointing away from/perpendicular to the delocalised $\pi$ electron cloud formed with neighboring carbon atom, hence it does not overlap with the delocalised $\pi$ electron cloud and the lone pair are not delocalised, making the lone pair of electrons available for dative bonding with H <sup>+</sup> . [1] N <sub>b</sub> is part of amide. Lone pair of electron in N <sub>b</sub> is present in the unhybridised p orbital of N, which overlaps with $\pi$ electron cloud of C=O (and delocalised $\pi$ electron cloud containing C=N <sub>a</sub> ), resulting in lone pair of electrons on N delocalising into the $\pi$ electron cloud of C=O (and delocalised $\pi$ electron cloud containing C=N <sub>a</sub> ) and are unavailable for forming a dative bond with H <sup>+.</sup> Amides are hence considered to be neutral. [1]
(a)		Sea of delocalised electrons (1) Copper has a giant metallic lattice structure of Cu <sup>2+</sup> cations surrounded by a sea of delocalised valence electrons, which can act as mobile charge carriers to conduct electricity. [1]
	(c) (a)	(ii) (c) (i) (ii) (a)

(b)	(i)	Magnesium.					
		<ul> <li>Mg, Ca and Ba can undergo both reactions but Ag cannot.</li> </ul>					
		The E <sup>e</sup> values for Mg, Ca and Ba are more negative than E <sup>e</sup> (H <sup>+</sup> /H <sub>2</sub> ) and E <sup>e</sup> (Cu <sup>2+</sup> /Cu), hence they can be oxidised in both reactions 1 and 2. Ag cannot be oxidised by Cu <sup>2+</sup> and H <sup>+</sup> since E <sup>e</sup> (Ag <sup>+</sup> /Ag) is more positive. [1] (Accept E <sup>e</sup> <sub>cell</sub> calculation to prove that reactions are feasible / not feasible.)					
		<ul> <li>Ca and Ba are too reactive and will react violently with acid since reducing power increases down the group.</li> </ul>					
		The E <sup>e</sup> (M <sup>2+</sup> /M) values get <u>more negative</u> down the group, implying oxidation of metal becomes more favourable, and the reducing strength of metal increases and the reactivity of group 2 metals with acid increases down the group. Ca and Ba reacts vigorously, but reaction of Mg with cold water is very slow. [1]					
	(ii)	$\Delta H_{\rm r}$					
		$Cu(s) + H_2SO_4(aq) + Mg(s) \longrightarrow CuSO_4(aq) + H_2(g) + Mg(s)$					
		$\Delta H_1$ $\Delta H_2$					
		$MgSO_4(aq) + H_2(g) + Cu(s)$					
		[1] energy cycle					
	(iii)	<ol> <li>Using the electronic balance, <u>measure accurately</u> the mass of the Ni bar.</li> <li>Heat a water bath in a beaker on a hot plate until the water is boiling.</li> <li>Tie the Ni bar using a string and lower it into the boiling water bath for 10 min (or any length of time sufficient for the temperature to equilibrate).</li> <li>Measure the temperature of the water bath using a 1°C thermometer. (accept 0.2 °C division thermometer)</li> <li>Measure 100 cm<sup>3</sup> of water using a 100 cm<sup>3</sup> measuring cylinder and pour it into a polystyrene cup.</li> <li>Measure the initial temperature of the water using a 1°C thermometer. (accept 0.2 °C division thermometer)</li> <li>Remove the Ni bar from the boiling water bath and place it in the polystyrene cup.</li> <li>Measure the highest temperature reached.</li> </ol>					
		<ul> <li>Marking points:</li> <li>Measure mass of Ni bar,</li> <li>and volume of water using measuring cylinder.</li> <li>Use thermometer to measure initial temperature of water bath,</li> <li>and the highest temperature reached.</li> <li>Use of boiling water bath to heat Ni bar</li> <li>and allow time for Ni bar to be heated fully (mention heating for 10 min/time for temperature of Ni bar and water bath to equilibrate)</li> <li>points. [1] for 1-2 point [2] 3-5 points [3] all 6 points</li> </ul>					

	(iv)						
	()						
		$\Delta T$					
		$\downarrow \qquad \qquad$					
		└ + + + + + + + + + → → time / min 0 1 2 3 4 5 6 7 8 9 10					
		0 1 2 3 4 5 6 7 8 9 10					
		[1] Label axes with correct units, correct shape of graph and labelling of $\Lambda T$					
	(v)	Heat evolved = $mc \Lambda T + C \Lambda T$					
	(•)	$= (50 \times 4 \ 18 \times 34 \ 8) + (97 \times 34 \ 8)$					
		= 7610  J[1]					
		- 10100[1]					
		$n(CuSO_4) = 50/1000 \times 0.3 = 0.015 \text{ mol}$					
		$\Lambda H_2 = -7610 / 0.015 \times 10^{-3} = -507 \text{ k/l mol}^{-1} [1]$					
(c)		Cu has more protons, hence it has a higher nuclear charge. However, the					
(-)		additional electrons are added to the penultimate 3d orbitals. The d subshell					
		shield less efficiently than s and p subshells. [1] Hence, Cu has a larger					
		effective nuclear charge. The valence shell of Cu are more strongly attracted					
		to the nucleus and hence Cu has a smaller atomic radius. [1]					

3	(a)	(i)	$K_{sp} = [Fe^{3+}] [OH^{-}]^{3}$ units: mol <sup>4</sup> dm <sup>-12</sup> [1]
		(ii)	$K_{\rm sp} = 4.0 \times 10^{-38}$
			$27x^4 = 4.0 \times 10^{-38}$
			Solubility = $2.0 \times 10^{-10} \text{ mol } \text{dm}^{-3}$ [1]
		(:::)	$\Gamma_{2}$ $\Gamma_{2}$ $\Gamma_{2}$ $\Gamma_{2}$ $\Gamma_{2}$ $\Gamma_{2}$ $\Gamma_{2}$
		(111)	$FeS_2(S) \leftarrow Fe^{-1}(aq) + S_2^{-1}(aq)$
			$r_{sp} = [re_{j}][0_{2}]$
			$[Fe^{2+1}]_{min} = 5.2 \times 10^{-27} \text{ mol dm}^{-3}$
			$Fe(OH)_2(s) \rightleftharpoons Fe^{2+}(aq) + 2OH^-(aq)$
			$K_{sp} = [Fe^{2+}][OH^{-}]^2$
			$8.0 \times 10^{-16} = [Fe^{2+}]_{min}(0.40)^2$
			$[Fe^{2+}]_{min} = 5.0 \times 10^{-15} \text{ mol dm}^{-3}$
			$[1]$ for $2^{10}$ calculation – $1^{31}$ working to prove that FeS <sub>2</sub> is a less soluble sait.
			When the first trace of Fe(OH) <sub>2</sub> appears, $[Fe^{2+}] = 5.0 \times 10^{-15}$ mol dm <sup>-3</sup>
			To calculate the $[S_2^{2-}]$ present:
			$K_{\rm sp} = [{\rm Fe}^{2+}] [{\rm S}_2^{2-}]$
			$5.0 \times 10^{-15} [S_2^{2-}] = 1.3 \times 10^{-27}$
			$[S_2^{2-}] = 2.6 \times 10^{-13} \text{ mol dm}^{-3} [1] \text{ for final answer}$
	(b)	(i)	$\Delta G_{\rm ppt}^{\theta} = 2.303 RT \log K_{\rm sp}$
			$= 2.303 (8.31)(298)\log(1.3 \times 10^{-27})$
			= – 153 333 J mol <sup>-1</sup>
			= $-153.3$ kJ mol <sup>-1</sup> [1] for value & correct dp
			(minus 1 overall if answers in (i) & (ii) are not 1 dp)
		(ii)	$\Delta \boldsymbol{G}^{\theta}_{\text{ppt}} = \Delta \boldsymbol{H}^{\theta}_{\text{ppt}} - T \Delta \boldsymbol{S}^{\theta}_{\text{ppt}}$
			$-153.3 = (-178.0) - 298 \Delta S^{\theta}_{\text{pot}}$
			$\Delta S_{\text{part}}^{\theta} = -0.08277 \text{ kJ mol}^{-1} \text{ K}^{-1}$ (or 8.28 x 10 <sup>-2</sup> kJ mol}^{-1} \text{ K}^{-1})
			$\Lambda S^{\theta}$ = - 82.8 J mol <sup>-1</sup> K <sup>-1</sup> [1] for value & sign [1] for correct units

	(iii)	$\Delta S_{\text{pot}}^{\theta}$ is negative which suggests that there is a decrease in entropy due to the						
		formation of an ordered lattice as the solid precipitate forms (or there are less						
		aqueous particles). There are	less wav	s to arra	nae the	particles.	[1]	
			,		<u>-</u>	[	L · J	
	(1)							
(C)	(1)	Floment	<u> </u>	٦	Ц	NI	0	1
		2/ composition by mass	10.2	ге 14.0	2.2	IN 11.2	51 A	
			19.5	55.8	3.Z 1.0	11.2	16.0	-
		Amount/mol	1 608	0.267	3.21	0.800	3 213	
		Amountmon	1.000	0.207	5.21	0.000	0.210	
		Mole ratio	6	1	12	3	12	
								1
		Empirical formula of Y: C <sub>6</sub>	FeH <sub>12</sub> N <sub>3</sub> C	D <sub>12</sub> [1]				
	(ii)	Anion: [Fe(C <sub>2</sub> O <sub>4</sub> ) <sub>3</sub> ] <sup>3–</sup> [1]	Catio	on: NH <sub>4</sub> +	[1]			
	/iii)	Coordination number: 6	Shar	oo: ootah	odral [1	1		
	(111)		Sha	Je. Uclai		1		
	(iv)	In the presence of $C_2O_4^{2-}$ ligation	ands, the	partially	filled 3	d orbitals	split into	two
	. ,	energy levels, with an energy	gap, ∆E.				•	
			0 1 7					
		The d electrons in the lowe	r energy	level a	bsorbed	d energy	in the vis	ible
		spectrum corresponding to energy gap and become excited to a vacant d orbital						
		at the higher energy level (d-d transition).						
		The complementary colour of violet corresponding to unabsorbed wavelengths						
		of yellow is transmitted.						
		All 3 points - [2] 2 Points - [1]						



![](_page_90_Figure_2.jpeg)

![](_page_91_Figure_2.jpeg)

	(iv)	Add K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> , H <sub>2</sub> SO <sub>4</sub> (aq), heat. [1]				
		If orange $K_2Cr_2O_7$ turns green, 4-membered ring lactone is produced in step 2. If orange $K_2Cr_2O_7$ remains, 4-membered ring lactone is not produced in step 2. [1]				
		$KMnO_4$ is not accepted. Alkene in the carboxylate ion (reactant) could be oxidised by $KMnO_4.$				
	(v)	Bonds formed: BE (C-C <i>l</i> ) = 340 kJ mol <sup>-1</sup> > BE(C-I) = 240 kJ mol <sup>-1</sup> Bonds broken: BE (C <i>l</i> -C <i>l</i> ) = 244 kJ mol <sup>-1</sup> > BE(I-I) = 151 kJ mol <sup>-1</sup> The enthalpy change of reaction will be <u>more exothermic</u> . The product will be of a lower energy level, hence it is more stable. [1]				
(b)		$\begin{array}{c} CH_2CH_3\\ H_3C^{W}\\ H_1^{H}\\ H \end{array} \xrightarrow{O} O \\ H_1^{H}\\ H \end{array} \xrightarrow{O} O \\ H_2^{C}CH_3\\ H \\ H$				
		$H_{3}C^{\text{CH}_{2}CH_{3}} = 0$ $H_{3}C^{\text{CH}_{2}CH_{3}} = 0$ $H_{3}C^{\text{CH}_{2}CH_{3}} = 0$ $H_{3}C^{\text{CH}_{2}CH_{3}} = 0$				
		mirror plane [2]				
(c)		step 1: ethanolic KCN, heat under reflux [1] step 2: HBr(g), room temperature [1] step 3: ethanolic NaOH, heat under reflux [1]				
		CN Or CN Or				
		[1] D E				

# Paper 3 Answers

1	(a)	(i)	Amount of	$Ba(OH)_2 = a$	mount of H <sub>2</sub>	SO4	= 0.98 / 98.1 = 0.00	0999 mol [1]
		(ii)	$2CH_3CO_2H + Ba(OH)_2 \rightarrow (CH_3CO_2)_2Ba + 2H_2O [1]$					
			Amount of = 23.30 / 1 Amount of = 2 × 0.008	Ba(OH) <sub>2</sub> that 000 × 0.800 ethanoic acid 865 = 0.0173	t reacts with - 0.09989 = d = 2 × n(Ba mol [1] alloy	etha 0.0 (OH w ec	anoic acid 0865 mol l) <sub>2</sub> ) ff if equation is not b	palanced
		(iii)	$K_a = \frac{[CH_3]}{[CH_3]}$	COOC <sub>2</sub> H <sub>5</sub> ] [H	H <sub>2</sub> O] [1]			
			<sup>c</sup> [CH <sub>3</sub>	$COOH] [C_2H_3]$	,OH]			
			Initial / mol	CH <sub>3</sub> CO <sub>2</sub> H 1.48 / 60.0 = 0.02466	$C_2H_5OH$ 0.92 / 46.0 =	 	CH <sub>3</sub> CO <sub>2</sub> CH <sub>2</sub> CH <sub>3</sub> 0	H <sub>2</sub> O 1.8 / 18.0 = 0.10
			Change / mol	-0.007366	- 0.007366		+0.007366	+0.007366
			Eqm / mol	0.0173 Allow ecf from (ii)	0.01263		0.007366	0.1073
			[1] for working out the equilibrium amount of $C_2H_5OH$ , $CH_3CO_2C_2H_5$ and $H_2O$ Let V be the volume.					
			$K_{c} = \frac{\left[\frac{0.001700}{V}\right]\left[\frac{0.0170}{V}\right]}{\left[\frac{0.0173}{V}\right]\left[\frac{0.01263}{V}\right]} = 3.62 \text{, no units [1]}$					
		(iv)	By Le Ch exothermic position of	natelier's Prin c reaction wil equilibrium s	nciple, as t l be favoure hifts to the r	emp d to ight	perature is decreas compensate for the . [1]	sed, the forward heat lost, hence
			As forward reaction is favoured, more products are produced, hence value of $K_c$ increases. [1]					

![](_page_94_Figure_2.jpeg)

2	(a)	(i)	Aldehyde is unable to form intermolecular hydrogen bonding between molecules and has a low boiling point compared to an alcohol. Thus, the aldehyde will vaporise quickly (or extracted) once it is formed which subsequently condense and collect in the distillate. [1]				
		(ii)	H = C = H $H = C = N$ $H = C = N$				
			Compound B [1] for correct structure and [1] for displayed formula				
		(iii)	Nucleophilic Addition				
			NaOH + HCN $\rightarrow$ NaCN + H <sub>2</sub> O [1] for equation and name of mechansim				
			$H_{3}C \xrightarrow{I}CN \xrightarrow{I}CN \xrightarrow{I}CN$				
			[1] for correct curly arrow, $\delta$ charges, lone pair and negative charge on CN^ and labelling slow step				
			$\begin{array}{ccc} O \xrightarrow{r} & O H \\ H_{3}C - C & H \\ H_{3}C - C & H \\ C N & H_{3}C - C \\ C N & C N \end{array}$				
			[1] for correct curly arrow, lone pair and negative charge on intermediate and balanced equation				
		(iv)	At step 1, methanol and ethanol are oxidised to methanal and ethanal respectively.				
			There are zero and one electron-donating groups bonded to the C=O group of methanal and ethanal respectively. The carbonyl carbon of methanal is more electron-deficient than that of ethanal. [1] Therefore, the carbonyl carbon of methanal has a larger partial positive charge compared to that of ethanal, making it more susceptible towards nucleophilic attack. [1]				
			or				
			Methanal has two hydrogen atoms bonded to the C=O group compared to one sterically bulky methyl group in ethanal. Hence, CN <sup>-</sup> nucleophile would face more steric hindrance when approaching the carbonyl carbon of the ethanal as compared to methanal. [1]				

![](_page_96_Figure_2.jpeg)

(c)	(i)	At 1 <sup>st</sup> maximum buffering capacity (percentage composition of H <sub>2</sub> A = HA <sup>-</sup> = 50%), pH = $pK_{a1}$					
		At 2 <sup>nd</sup> maximum buffering capacity (percentage composition of HA <sup>-</sup> = A <sup>2-</sup> = 50%), pH = $pK_{a2}$					
		$pK_{a1} = 2.30$ $pK_{a2} = 9.70$					
		[1] for both values					
	(ii)	At pH 10.3, the mixture contain 20% HA <sup>-</sup> and 80% A <sup>2-</sup> .					
		Amount of $HA^- = 0.100 \times 20\% = 0.0200$ mol Amount of $A^{2-} = 0.100 \times 80\% = 0.0800$ mol [1] for both values					
		$ \begin{array}{l} H_2A + OH^- \rightarrow HA^- + H_2O & \dots \ eqn \ 1 \\ HA^- + OH^- \rightarrow A^{2-} + H_2O & \dots \ eqn \ 2 \end{array} $					
		Amount of NaOH required for eqn $1 = 0.1000$ mol Amount of NaOH required for eqn $2 = 0.08000$ mol					
		Total amount of NaOH required = 0.1800 mol					
		Mass of NaOH required = 0.1800 × 40.0 = 7.20 g [1]					
	(iii)	The change in ratio of $\frac{[HA^-]}{[A^2-]}$ is larger when 1 cm <sup>3</sup> HC <i>l</i> (aq) is added. [1] Thus,					
		the new buffer will result in a larger change in pH. [1]					
		or					
		Addition of small amount/volume of acid will have a larger change in concentration of acid and salt. [1] Hence, pH change is larger. [1]					
	(iv)	At isoelectric point, alanine exist as a zwitterion (HA-). There will be strong					
		The amount of energy released when ion-dipole interaction formed between zwitterion and water molecules, may not be sufficient to overcome all the ionic bonding between zwitterions and hydrogen bonding between water molecules. [1]					
		At low and high pH, alanine exist as cation and anion respectively. At low pH, the cations repel each other and at high pH, the anions repel each other. [1] The ions form ion-dipole interaction with the surrounding water molecules and dissolve. The amount of energy released when ion-dipole interaction formed between ions and water molecules, is sufficient to overcome all the ionic bonding between alanine salt and hydrogen bonding between water molecules. [1]					

3	(a)	(i)		Cu	I							
	` '	.,	mass ratio	1	2							
			amt / mal	0.01574	0.01576							
				0.01574	0.01576							
			Simplest ratio	1	1							
			Hence, the empirical formula of D is Cul.									
			[1] Table not req	1] Table not required. Working can be shown as calculation.								
		<i>(</i> ii)	$1e^{2}2e^{2}2n^{6}3e^{2}3n^{6}$	3d10 [1]								
		(")	13 23 2p 03 0p									
		(iii)	There are 3 s orl	oitals, 6 p oi	rbitals and	5 d orbitals.						
			p orbital is dumb	-bell shape	d.							
			$\cap$									
			( )									
			$\times$									
			( )	[1] or	ly diagram	required						
			$\bigcirc$	[1] 01	liy ulayian	riequileu						
		<i>(</i> <b>1</b> )		) <u> </u>	<i>,</i> ,, .							
		(IV)	$2Cu^{2+}$ (aq) + 4l <sup>-</sup> (	$aq) \rightarrow 2Cul$	(s) + I	2 (aq) [1]						
			blue	white soli	d D yello	w/brown solution						
					which	n dissolves in hexane						
					to fo	rm purple laver						
				1								
					γ	]						
				_								
				For	ms a yello	w brown precipitate when mixed.						
			[1] for all colours	i								
		(v)	$E_{cell} = E_R - E_O$									
			$= E(Cu^{2+}/Cu^{+}) -$	E(l <sub>2</sub> /l <sup>-</sup> )								
			= +0.15 - (+0.54)	4)								
			0.39 V < 0 he	", nce not fea	sihla [1]							
			- 0.00 V <0 He		566.[1]							
		() <i></i> !)	A. Cut in man al 1									
		(VI)	As Cu <sup>+</sup> is precipi	tated by loc	lide, [Cu' (a	ad)] decreases, position of equilibrium						
			of $Cu^{2+} + e^{-} =$	t Cu⁺ shi	its to the r	ight and E(Cu <sup>2+</sup> /Cu <sup>+</sup> ) becomes more						
			positive, making	reduction m	nore feasib	le/E <sub>cell</sub> positive hence reaction is more						
			feasible. [1]									

(b)	(i)	The complex ion $[NiF_6]^{x-}$ is a species that contains a central metal ion Ni <sup>n+</sup> surrounded by F <sup>-</sup> anions / ligands which forms coordinate bonds to the metal centre. [1]
	(ii)	Ni <sup>n+</sup> is able to form a stable complex ion because it has energetically accessible vacant d-orbitals to accommodate the lone pairs of electrons donated by the ligands to form the dative bonds [1]
	(iii)	n(O <sub>2</sub> ) = 48 / 24000 = 2.00 x 10 <sup>-3</sup> mol [1]
	(iv)	Note: Solution H was divided into 2 equal portions for analysis.
		$n(H^+ \text{ in } H) = 2 \times n(OH^- \text{ required}) = 2 \times \frac{19.90}{1000} \times 0.20 = 7.96 \times 10^{-3} \text{ mol } [1]$
		Q = I x t = 0.40 x 16 x 60 = 384 C
		Q = nzF $\Rightarrow$ n(Ni <sup>2+</sup> ) = ( 384 / (96500 x 2) ) x 2 = 3.98 x 10 <sup>-3</sup> mol [1]
	(v)	$n_{O_2}: n_{H^+}: n_{Ni^{2+}} = 2.00: 7.96: 3.98 = 1:4:2$ [1]
		$2K_xNiF_6 + 2H_2O \rightarrow 2xKF + 2NiF_2 + O_2 + 4HF$
		Considering the number of F, $12 = 2x + 4 + 4 \Rightarrow x = \frac{12 - 8}{2} = 2$ [1]
		Hence, compound E is $K_2NiF_6$ .
	(vi)	$2 H_2O (I) \rightarrow O_2 (g) + 4H^+ (aq) + 4e^- [1]$ Oxygen gas is produced at the anode.
		$H_2O$ and $F^-$ are attracted to the anode. As the $E^{\theta}(O_2/H_2O) = +1.23$ is less positive than $E^{\theta}(F_2/F^-) = +2.87$ , $H_2O$ is preferentially oxidised to form $O_2$ at the anode. [1]

	(c)	(i)	Down the group, the halide ion increases in size hence the bond length of X $\rightarrow$ Co/M increases. This give rise to less effective orbital overlap and strength					
			of dative bond formed with the metal ion decreases.					
			[1] to adjust points required according to range of students answers					
		(ii)	(A ligand is a species/molecule or anion with at least one lone pair of electrons that it can use to form a dative bond to the transition metal atom/ion.)					
			CH <sub>3</sub> CN contains an electron-donating alkyl group which makes the lone pair on N more available than that in NCS- to be used to form a dative bond to the transition metal centre, hence it is a stronger ligand. [1]					
		(iii)	<ul> <li>ΔH for the reaction is approximately zero as the same (N→Co) bonds are broken and formed.</li> <li>ΔS is positive as the number of particles increase, resulting in more ways to</li> </ul>					
			arrange the particles hence greater disorder. • Since $\Delta G = \Delta H - T\Delta S$ and $- T\Delta S$ is negative, $\Delta G$ is negative and hence ligand exchange of NH <sub>3</sub> with H <sub>2</sub> NCH <sub>2</sub> CH <sub>2</sub> NH <sub>2</sub> is very feasible. 3 points [2]. 2 points [1]					
4	(a)	(i)	Propanone, CH <sub>3</sub> COCH <sub>3</sub> [1]					
		(ii)	$\begin{array}{l} Mg(CH_{3}COO)_{2} \ (s) \rightarrow MgO(s) + CO_{2}(g) + CH_{3}COCH_{3}(g) \ [1] \\ Ba(CH_{3}COO)_{2} \ (s) \rightarrow BaCO_{3}(s) + CH_{3}COCH_{3}(g) \ [1] \end{array}$					
		(iii)	The $Mg^{2+}$ ion is smaller than $Ba^{2+}$ ion, hence its higher charge density [1] enables it to polarise the electron cloud of $CH_3COO^-$ ion and distort the C-O bond to a greater extent resulting in complete decomposition. [1]					
	(b)	(i)	Yes, since $A_2O_3$ is an amphoteric oxide, it can react with an acidic oxide such as $SO_2$ to remove it. [1]					
		(ii)	MgO in water: pH 8 – 9 Weakly alkaline solution formed as Mg(OH) <sub>2</sub> is only slightly soluble in water [1] (due to strong ionic bonds between Mg <sup>2+</sup> and OH <sup>-</sup> ions).					
			$A_2O_3$ in water: pH 7 Solution is neutral as $A_2O_3$ is insoluble in water [1] (due to strong ionic bonds between $A_3^{\beta_+}$ and $O^{2^-}$ ions).					
			SO <sub>3</sub> in water: pH 1 - 2 Solution is acidic due to the formation of strong acid H <sub>2</sub> SO <sub>4</sub> (aq). [1] SO <sub>3</sub> (g) + H <sub>2</sub> O( $l$ ) $\rightarrow$ H <sub>2</sub> SO <sub>4</sub> (aq) H <sub>2</sub> SO <sub>4</sub> $\implies$ H <sup>+</sup> + HSO <sub>4</sub> <sup>-</sup>					
	(c)		The relative acidities of the compounds are in the order: C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> OH < C <sub>6</sub> H <sub>5</sub> OH < C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> H					

	-									
	The acidity of a compound depends on the relative stability of its con base. The more stable the conjugate base, the more acidic the compo- be.									
		The $C_6H_5CO_2^-$ is the most stable as the p orbital of the oxygen atom overlat with the electron cloud of the $-C=O$ bond and the lone pair of electrons the oxygen atom delocalise into the $-C=O$ . The negative charge is dispers over the carbon atom and the two electronegative oxygen atoms, stabilisi the $C_6H_5CO_2^-$ ion. [1]								
		In C <sub>6</sub> H <sub>5</sub> O <sup>-</sup> , the p orbital of the oxygen atom overlaps with the electron cloud of the benzene ring and the lone pair of electrons on oxygen atom delocalise into the benzene ring. This causes the dispersion of the negative charge into the benzene ring, stabilising the phenoxide ion.								
		However the charge dispersion in phenoxide ion is less effective than the dispersion in benzoate ion because the 2 electronegative oxygen atoms in benzoic acids can better accommodate the negative charge. [1]								
		$C_6H_5CH_2O^-$ is destabilised a negative charge on oxygen.	as the electron-donating alkyl group intensifies the [1]							
(d)	(i)									
• •	.,	Chemistry	Deduction							
		P reacts with 2,4-DNPH to form an orange ppt.	P contains either an aldehyde or a ketone functional group and undergoes condensation reaction.							
		P decolourises hot, acidified KMnO <sub>4</sub> .	P may contain primary/secondary alcohol functional group or aldehyde functional group and undergoes oxidation reaction.							
		P is heated with excess NaOH(aq) to form Q. This involves the loss of a C <i>l</i> atom.	P contains an alky chloride and undergoes nucleophilic substitution to form an alcohol Q.							
		$I_2(aq)$ is subsequently added to the hot mixture to form R.	Q contains both $-COCH_3$ and $-CH(OH)CH_3$ groups and gives a positive iodoform test.							
			Note: The loss of 2 C atoms denotes the formation of 2 $CHI_3$ molecules per molecule of P.							
		P reacts with excess conc $H_2SO_4$ at 170 °C.	The alcohol group in P undergoes elimination to form alkenes.							
		P reacts with excess conc $H_2SO_4$ at 170 °C to give three possible isomeric products.	P contains a secondary alcohol functional group. OR The alcohol group in P is not a primary alcohol.							

		[1] for each correct deductio	OR The structure of P is not CH <sub>3</sub> CH(C <i>l</i> )CH(OH)CH <sub>2</sub> COCH <sub>3</sub> . This structure of P will give 4 possible isomeric products. n. Maximum [3].				
		P: $CH_3CH(OH)CH(Cl)CH_2COCH_3$ [1] Q: $CH_3CH(OH)CH(OH)CH_2COCH_3$ [1] R: NaOCOCH(OH)CH_2COO <sup>-</sup> Na <sup>+</sup> [1]					
	(ii)	T and U are cis-trans isome bond, hence they are less si	rs with a C <i>l</i> atom directly attached to the double usceptible to hydrolysis. [1]				
		This is because the p orbital of the C=C bond, resulting delocalising into the C=C character in the C–C $l$ bond,	of the C <i>l</i> atom overlaps with the $\pi$ electron cloud g in a lone pair of electrons in the p orbital bond. This gives rise to partial double bond hence the bond is strengthened. [1]				

![](_page_103_Figure_2.jpeg)

			(accept any of the positional isomers)				
			<ul> <li>B does not react with aqueous Br₂, methylamine or sodium hydroxide.</li> <li>⇒ phenol, alkene, halogenoalkane, carboxylic acid absent. To account for the Cl atom in the molecular formula, an aryl halide must to be present.</li> <li>B does not react with hot acidified potassium dichromate(VI) but with hot acidified potassium manganate(VII), B gives C<sub>8</sub>H<sub>5</sub>O<sub>4</sub>C<i>I</i>.</li> <li>⇒ 1° and 2° alcohols absent. 2 carbon containing side chains present</li> <li>B does not react with alkaline aqueous iodine.</li> <li>⇒ methyl alcohol and ketone absent</li> <li>1 mol of B reacts with 1 mol of sodium.</li> <li>⇒ based on this point and above info, one 3° alcohol present</li> <li>B does not exhibit enantiomerism.</li> <li>B should not have any chiral carbon present</li> </ul>				
(	(c)	(i)					
			** ** ** Bond angle about AI: 109°[1]				
			[1] for diagram: • each atom has 8 electrons around it				
			<ul> <li>distinguish between the electrons of CI and AI</li> </ul>				
			show dative bonds				
		(ii)	$pV = nRT = \frac{m}{M}RT$				
			average M = $\frac{mRT}{mRT} = \frac{0.52 \times 8.31 \times (150+273)}{mRT}$ [1] correct conversion of units				
			$pV = 101325 \times 70 \times 10^{\circ}$ = 257.7 g mol <sup>-1</sup> [1] correct numerical answer				
			Assume that sample contain x mole fraction of Al <sub>2</sub> Cl <sub>6</sub> and $(1 - x)$ of AlCl <sub>3</sub>				
			(1-x)(133.5) + (x)(267) = 257.7 133.5 + 267x - 133.5 x - 257.7				
			x = 0.930				
			Hence the percentage composition of the dimer is <u>93.0 %</u> [1]				
		(iii)	As T increases, $AI_2CI_6$ dimers will dissociate to form $AICI_3$ molecules. Hence average $M_r$ will decrease [1]				
			OR				
			AS T Increase, solid AlCi3 forms liquid Al2Ci6. Hence average <i>Mr</i> will Increase. [1]				

	()	(A Lewis acid is an electron pair acceptor.)				
		$A/CI_3$ (s) + 6H <sub>2</sub> O (I) → $[A/(H_2O)_6]^{3}\ddot{A}$ (aq) + 3C $\Gamma$ (aq) [1] The hydrated form of aluminium chloride exists $[A/(H_2O)_6]^{3}\ddot{A}$ and C $\Gamma$ ions. In $[A/(H_2O)_6]^{3}\ddot{A}$ , A/ is surrounded by six water ligand/molecules and does not have empty orbitals to accept electron pairs and act as a Lewis acid. [1]				
(d)		In BeCl <sub>2</sub> , Be has only 2 bonding electron pairs around it and can accept 4 more electrons to achieve an octet. NH <sub>3</sub> has a lone pair of electrons. [1] for stating the no of electrons pairs for Be and N				
		Hence $BeCl_2$ can form 2 dative bonds with $NH_3$ , accepting 2 lone pairs of electrons from 2 mol of $NH_3$ .				
		$H CI H$ $H - N \rightarrow Be \rightarrow N - H$ $H CI H$ $H CI H$ $[1] accept dot & cross diagram too$				
	(d)	(d)				

# Paper 4 Answers

1	(a)	(i)		1	2			
			Final burette reading / cm <sup>3</sup>	25.35	25.45			
			Initial burette reading / cm <sup>3</sup>	0.00	0.00			
			Volume of <b>FA 2</b> used / cm <sup>3</sup>	25.35	25.45			
			С	orrect head	lers and un	its for table	e [1]	
			Record volu	me and bur	ette readin	gs to 2 d.p	.[1]	
		(ii)	Ave V used = $\frac{25.35 + 25.45}{25.45} = 25.40$	cm <sup>3</sup>				
			2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2					
			Consistent reading	gs used, co	rrect calcul	ation, 2 d.p	o.[1]	
			titre value – ref	erence valu	ue (δ) ≤ 0.2	0 Accuracy	y [1]	
			titre value – ref	erence valu	ue (δ) ≤ 0.4	0 Accuracy	y [1]	
		(iii)	$n = reacted = \frac{0.0200 \times 25.40}{-5.00} = 5.00$	$8 \times 10^{-4} m$	ol			
			<sup>™</sup> <sub>MnO₄</sub> 1000		01			
			$n_{2} = \frac{5}{2}$ present in 25.0 cm <sup>3</sup> = $\frac{5}{2}$ x 5.08	x 10 <sup>-4</sup> = 1.	27 x 10 <sup>-3</sup>	mol		
			2					
	(b)	n	reacted = 0.0400 x 26.75					
		NaOH	$\frac{1}{1000}$ 1000					
			0.0400 x 26.75					
		n <sub>H2C2</sub>	$_{O_4}$ present in 25.0 cm <sup>3</sup> = $\frac{1000}{2}$ = 5.35 x 10 <sup>-4</sup> mol					
			ζ.					
	(c)	(i)	$n_{Na_2C_2O_4}$ in 25.0 cm <sup>3</sup> of <b>FA 1</b> = 1.27 x 10 <sup>-3</sup> -	5.35 x 10 <sup>-4</sup>	= 7.35 x 10	<sup>−4</sup> mol		
			$m_{Na,C,O}$ in 25.0 cm <sup>3</sup> of <b>FA1</b> = 7.35 x 10 <sup>-4</sup> x	134.0 = 9.8	84 x 10 <sup>−2</sup> g			
			1420204					
		(ii)	$m_{H_2C_2O_4}$ present in 25.0 cm <sup>3</sup> = 5.35 x 10 <sup>-4</sup>	x 90.0 = 4.8	315 x 10 <sup>−2</sup> g	1		
			Percentage by mass of $H \subset O$ in mixture	4	.815 x 10 <sup>−2</sup>	·	100	
			Fercentage by mass of $H_2 C_2 C_4$ in mixture	= 9.84 x 1	0 <sup>-2</sup> + 4.815	x 10 <sup>-2</sup>	100	
				= 32.8	35 ≈ 32.9	%		

![](_page_107_Figure_2.jpeg)
(g)	<ul> <li>(g) (i)</li> <li>1. Fill a burette with Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>.</li> <li>2. Using a 50 cm<sup>3</sup> measuring cylinder, measure 40.0 cm<sup>3</sup> of K<sub>2</sub>S<sub>2</sub>A</li> <li>3. Transfer 20.00 cm<sup>3</sup> of Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> from the burette into a 250 cm<sup>3</sup> flask.</li> <li>4. Using a 25.0 cm<sup>3</sup> measuring cylinder, transfer 25.0 cm<sup>3</sup> of KI are of starch indicator into the conical flask.</li> <li>5. Pour the K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> from the measuring cylinder into the conical immediately start the stop watch. Swirl the conical flask and leave table.</li> <li>6. Stop the stop watch when the colour of the mixture turns blue-th 7. Record the timing and wash the conical flask and remove a water.</li> <li>8. Repeat steps 2 to 7, using volume indicated in the table below. using a 50 cm<sup>3</sup> measuring cylinder.</li> </ul>				K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> . 250 cm <sup>3</sup> co f KI and 5.0 onical flash d leave it o blue-black. ove any ex elow. Add v	onical 0 cm <sup>3</sup> < and on the ccess water				
			Expt	V <sub>K2S2O8</sub> / cm <sup>3</sup>	V <sub>deionised</sub> water / cm <sup>3</sup>	V <sub>KI</sub> / cm <sup>3</sup>	V <sub>Na2S2O3</sub> / cm <sup>3</sup>	V <sub>starch</sub> / cm <sup>3</sup>	Time take / s	en
			1	40.0	0.0	25.0	10.00	5.0		
			2	30.0	10.0	25.0	10.00	5.0		
			3	20.0	20.0	25.0	10.00	5.0		
			4	10.0	30.0	25.0	10.00	5.0		
					Ma	ark sche	me			
		i	At and	least 2 mo d equally s	re expts with lo paced out.	ower cor	ncentration	/ vol of	S <sub>2</sub> O <sub>8</sub> <sup>2-</sup>	[1]
		ii	1 e S <sub>2</sub> (	expt has to $D_8^{2-}$	be at least hal	f or less	than half c	of origina	al vol of	[1]
		iii	V <sub>to</sub>	<sub>tal</sub> , V <sub>KI</sub> , V <sub>S2</sub>	<sub>O32</sub> –, V <sub>starch</sub> all	kept cor	istant			[1]
		iv	Bu	rette used asuring cv	to measure S <sub>2</sub>	O₃² <sup>–</sup> ; ure S₂O	<sub>8</sub> 2- and Ha	0		[1]
		v	S <sub>2</sub>	$D_8^{2-}$ must l	be separated fi	rom KI a	nd $S_2O_3^{2-}$	before r	nixing	[1]
		vi	Sta	art timing in	mmediately wh	en mixin	ig occurs;			[1]
		vi	i Ta	p timing w	hen blue-black	appear:	<u>S</u> ised only o			[1]
		vi	ii Pre	ecision of b	ourette to 2 d.p	measu	urina cvlind	$\frac{100}{1}$ er to 1 c	.p.	[1]
			I							





	(ii)	volume of <b>FA 5</b> = $23.5 \text{ cm}^3$
		Reads correctly value of <b>FA 5</b> from intercept to nearest ½ sq [1]
(c)	(i)	$n_{HCI}$ in <b>FA 5</b> = $\frac{23.5 \times 2.00}{1000}$ = 0.0470 mol
	(ii)	$[\mathbf{FA 6}] = \frac{0.0470}{\frac{50.0 - 23.5}{1000}} = 1.77 \text{ mol dm}^{-3}$
(d)	1. lı te ir	Therease in total volume does not affect accuracy as there is no change in Emperature rise, T, as volume increased proportionately with a corresponding Increase in the amt of water / heat produced.
	2. A h	Accuracy increased with more experiments carried out as more data points allelps to draw more accurate best fit lines / get a more accurate intercept.

3								
				Table 3.	1			
			toot	observations				
			lesi	FA 7	FA 8	FA 9		
(a)	(i)	Ado aqu	d 2 or 3 drops of leous iodine.	blue-black / black / dark blue	no observable change / yellow / brown	no observable change / yellow / brown		
	(ii)	Add 2 or 3 drops of acidified potassium manganate(VII) and allow to stand for two minutes.		no observable change / remains purple / pink	purple / pink / KMnO4 / MnO4 <sup></sup> decolourise	no observable change / remains purple / pink		
	(iii)	Add a 3 cm depth of Sandell's solution and place the tube in the hot water bath for two minutes.		no observable change / solution remains blue	blue solution turns brick red / orange / red brown / orangebrown / yellowbrown / brown ppt	no observable change / solution remains blue		
		(iv) (v)	Starch in <b>FA 7</b> re Aldehyde in <b>FA 8</b> Add 1 cm <sup>3</sup> of To and <b>FA 9</b> and wa Silver mirror / gre	eacted with iodine to form a blue-black iodine-starch complex <b>8</b> is oxidised by KMnO <sub>4</sub> / Sandell's solution to carboxylic acid. ollens' reagent to separate test tubes containing <b>FA 7</b> , <b>FA 8</b> <i>r</i> arm in a water bath. ey / black ppt appears for solution containing aldehyde ( <b>FA 8)</b> .				

		toot	observations			
		lesi	FA 10	FA 11		
(b)	(i)	Add a few drops of aqueous silver nitrate.	No observable change / no ppt / solution remains blue / solution turns more pale (blue)	brown ppt (dissolve in excess)		
	(ii)	Add a few drops of aqueous barium nitrate or aqueous barium chloride, then	White ppt	No ppt / no observable change		
		add dilute nitric acid.	Ppt insoluble in excess acid / no observable change / white ppt remains	No observable change		
	(iii)	Add a few drops of aqueous iodine.	white / cream ppt in yellow / brown solution	Brown solution decolourised		
	(iv)	Add a 1 cm depth of aqueous iron(II) sulfate.	No observable change / no ppt / solution remains blue / solution turns more pale (blue)	Green ppt formed (turns brown)		
	(v)	Add a 1 cm depth of <b>FA 11</b> .	Light blue ppt formed			

Table 3	3.2
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	(vi)	Identify the ions in <b>FA 10</b> and <b>FA 11</b> .
		<b>FA 10</b> cation $\underline{Cu^{2+}}$ anion $\underline{SO_4^{2-}}$
		<b>FA 11</b> anion <u>OH</u> <sup>-</sup>
	(vii)	Equation for (b)(iii) : $2Cu^{2+}(aq) + 4I^{-}(aq) \rightarrow 2CuI(s) + I_2(aq)$
		Note: $I_2 + I^- \Leftrightarrow I_3^-$
		Equation for (b)(v) : $Cu^{2+}$ (ag) + 2 $OH^{-}$ (ag) $\rightarrow Cu(OH)_{2}$ (s)