RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME					
CLASS	2	1	J		
CENTRE NUMBER	S				

INDEX NUMBER ☐☐☐☐

H2 CHEMISTRY
9729/02

Paper 2 Structured Questions

14 September 2022

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number, class and name on all the work that you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions in the spaces provided on the Question Paper. If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

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

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

For Examiner's Use								
Question Number	1	2	3	4	5			
Marks	9	17	14	14	21			
significant figures			**units**				**Total**	75

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

1 Ammonium salts are typically used in instant cold packs. The cold pack contains water and an inner pouch containing an ammonium salt. A crushing action causes the inner pouch to break and release the salt, which quickly dissolves to lower the pack's temperature.

To determine whether ammonium nitrate or ammonium chloride is more effective as the cold pack ingredient, a student decided to conduct an experiment to find out the enthalpy changes of solution of the two salts.

He first added ammonium nitrate to water and determined the temperature change by plotting a suitable graph to correct for heat transfer.

In a preliminary investigation, the enthalpy change of solution of ammonium nitrate was found to be approximately +26.0 kJ mol^{-1}.

(a) Define the term *enthalpy change of solution*.

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.... [1]

(b) **(i)** The student was told to use 50.0 cm^3 of water to conduct the experiment. Suggest a minimum mass of ammonium nitrate that could be used to effect a temperature change of 5.0 °C. Justify your choice with relevant calculations.

You should assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.

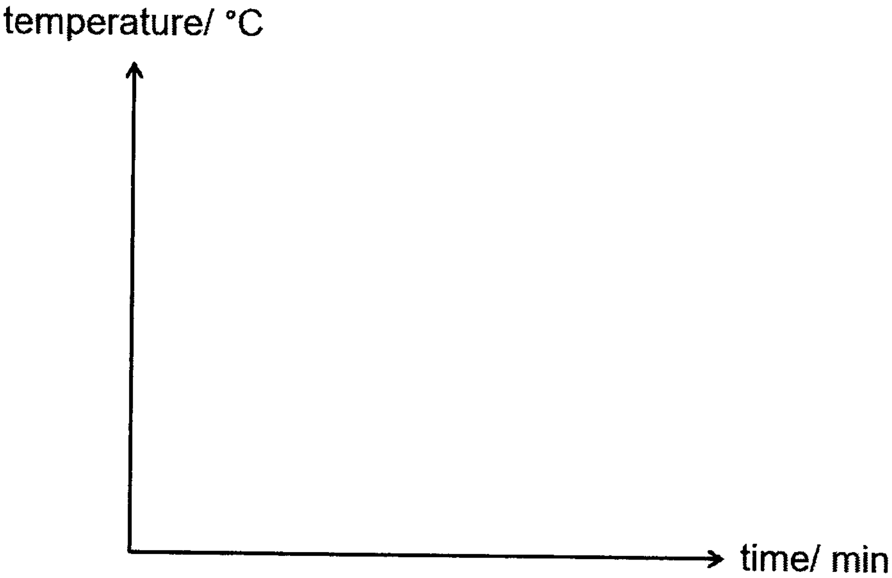
[1]

(ii) The student carried out the following procedure to find the enthalpy change of solution of ammonium nitrate.

1. Weigh accurately about 4.00 g of ammonium nitrate in a weighing bottle.
2. Using a 50 cm^3 measuring cylinder, add 50.0 cm^3 of deionised water into a polystyrene cup.
3. Stir the contents in the polystyrene cup gently with the thermometer and record the temperature every 0.5 minute.
4. At exactly 3.0 minutes, add the ammonium nitrate into the water. Do not read the temperature at this time.
5. Stir the mixture thoroughly and continue to record the temperature every 0.5 minute from 3.5 minutes to 9.0 minutes until constant temperature is reached.
6. Reweigh the weighing bottle with the residual ammonium nitrate.

Sketch the graph of temperature against time that you expect to obtain from the experiment.

Indicate clearly on the graph how the temperature change, ΔT, can be determined.



[2]

(c) Given the following data, draw an energy level diagram to determine the standard enthalpy change of solution of ammonium chloride.

Lattice energy of ammonium chloride = –705 kJ mol^{-1}

Enthalpy change of hydration of NH_4^+ = –307 kJ mol^{-1}

Enthalpy change of hydration of Cl^- = –381 kJ mol^{-1}

[3]

(d) Explain how the magnitude of enthalpy change of hydration of chloride ions differs from that of bromide ions.

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.... [2]

[Total: 9]

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

Cobalt is a transition element that is used in the manufacture of magnetic alloys and catalysts.

(a) Define the term *transition element.*

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.... [1]

(b) The melting point of cobalt is 1495 °C while the melting point of calcium is 843 °C.

Explain this in terms of structure and bonding of both elements.

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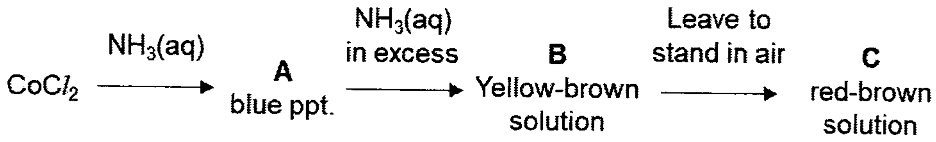
.... [2]

(c) Aqueous cobalt(II) chloride, $CoCl_2$, is a pink solution which gives the following reactions:



(i) State the electronic configuration of the cobalt species in compound **A**.

.... [1]

(ii) Given the following information:

$[Co(NH_3)_6]^{3+} + e^- \rightleftharpoons [Co(NH_3)_6]^{2+}$ $E^\ominus = +0.11$ V

By using relevant $E^\ominus$ values, account for the observation when solution **B** is left to stand in air.

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.... [2]

(iii) Construct a labelled diagram to describe how the $E^\ominus$ value of the equation $[Co(NH_3)_6]^{3+} + e^- \rightleftharpoons [Co(NH_3)_6]^{2+}$ can be measured.

[3]

(iv) Indicate the direction of electron flow in your diagram above.

[1]

(d) **D** is a cobalt(III) complex with the formula $Co(NH_3)_aCl_3$.

In a ligand exchange reaction, 3.501 g of **D** is dissolved in 500 cm^3 of water. 25.0 cm^3 of this solution requires 18.75 cm^3 of 0.0400 mol dm^{-3} of EDTA(aq) for complete reaction.

In another experiment, when excess $AgNO_3$(aq) is added to 23.340 g of **D**, 14.340 g of solid $AgCl$ is formed.

(i) Given that 1 mole of **D** reacts with 1 mole of EDTA, show that the molar mass of **D** is 233.4 g mol^{-1}.

[2]

(ii) Show that 1 mole of **D** will form 1 mole of $AgCl$ when reacted with excess $AgNO_3$.

[1]

(iii) Deduce the value of **a**. Hence, state the formula of the cation in **D**.

[2]

(iv) When **D** undergoes reduction, followed by exposure to excess carbon monoxide gas, an octahedral complex **E**, $Co(CO)_4Cl_2$, is formed.

Given that **E** has no net dipole moment, Draw the shape of **E**, showing the arrangement of the ligands.

[2]

[Total: 17]

3 **(a)** Hydration of alkenes can be carried out by reacting alkenes with borane, BH_3, followed by treatment with alkaline hydrogen peroxide, H_2O_2. The product is an alcohol.

An example is shown below in Fig. 3.1.

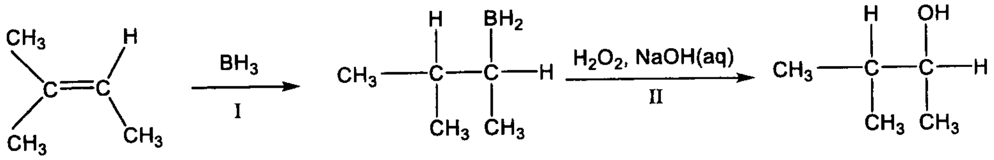

Fig. 3.1

(i) The product of the reaction in Fig. 3.1 exhibits stereoisomerism. State the type of stereoisomerism and draw the structure of each stereoisomer.

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[2]

(ii) Step I occurs via a mechanism similar to electrophilic addition and it involves the BH_3 acting as an electrophile.

Explain what is meant by the term *electrophile*.

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.... [1]

(iii) It is suggested that the mechanism for step I goes through the formation of a transition state as shown in Fig. 3.2.

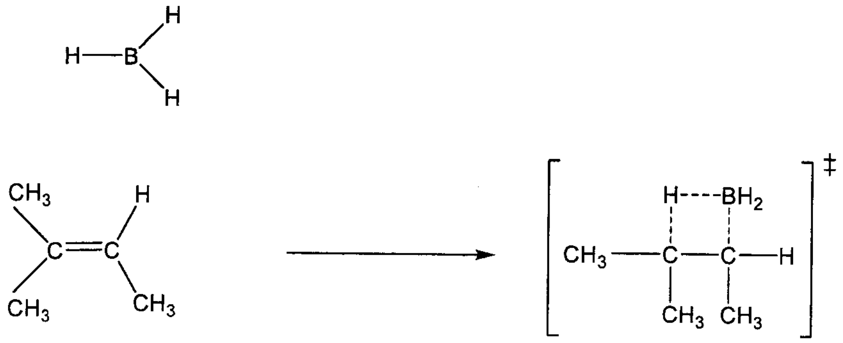
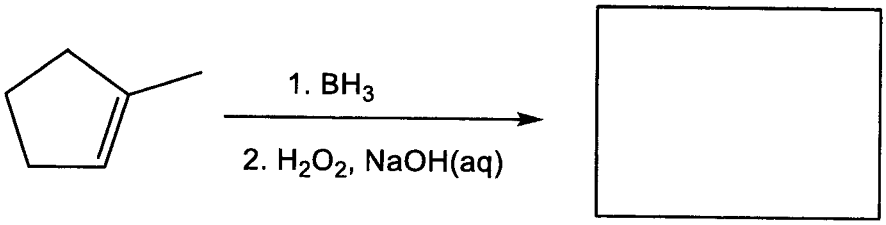


Fig. 3.2

Given that boron is less electronegative than hydrogen, complete Fig. 3.2 to suggest the mechanism for step I. Show relevant dipoles and use curly arrows to indicate the movement of electron pairs.

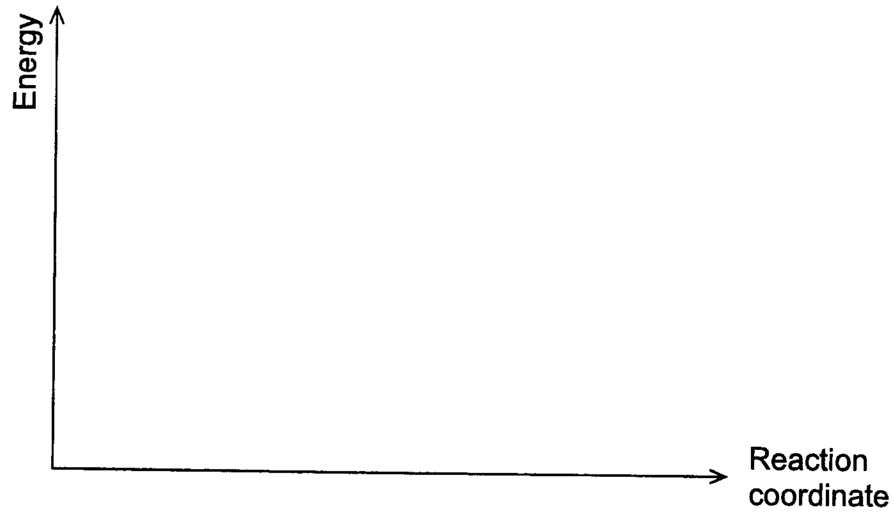
[2]

(iv) Predict the major product for the following reaction.



[1]

(b) Alkenes undergo electrophilic addition with halogens in an exothermic reaction. Draw the labelled energy profile diagram for the reaction between ethene and liquid bromine.



[2]

(c) Methanol is a colourless and flammable liquid which can be a possible alternative fuel for motor vehicles. The boiling points of methanol and two of its analogues are given in the Table 3.1 below.

Table 3.1

compound	M_r	boiling point/ °C
CH_3OH	32.0	65
CH_3SH	48.1	6
CH_3SeH	95.0	25

Explain the difference in boiling points of the three compounds in terms of structure and bonding.

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.... [3]

(d) One alternative fuel technology involves the conversion of liquid methanol into hydrogen gas, as shown in the equation below.

$$CH_3OH(l) \rightarrow 2H_2(g) + CO(g)$$

Given that the standard enthalpy change, $\Delta H^{\ominus}$, for this reaction is +129 kJ mol^{-1} and the standard entropy change, $\Delta S^{\ominus}$, is +332 J K^{-1} mol^{-1},

(i) Explain the sign of $\Delta S^{\ominus}$.

....

....

.... [1]

(ii) With the aid of calculations, show whether the reaction is spontaneous at 130 °C.

[2]

[Total: 14]

4 **(a)** The following equilibrium exist in a sample of aluminium chloride vapour.

$$Al_2Cl_6(g) \rightleftharpoons 2AlCl_3(g) \qquad \Delta H = +63 \text{ kJ mol}^{-1}$$

When 1.50 g of aluminium chloride was introduced into an evacuated steel vessel of 250 cm^3 capacity and heated to 327 °C, the pressure inside the flask rose to 1.60×10^5 Pa.

(i) Assuming the gaseous mixture behaves ideally, calculate the average M_r of the mixture.

[1]

(ii) The M_r of $AlCl_3$ and Al_2Cl_6 are 133.5 and 267 respectively. Using your answer in **(a)(i)** and the above information, calculate the mole fraction of $AlCl_3$ and Al_2Cl_6 respectively, giving your answers to 1 decimal place.

[1]

(iii) Hence, calculate the K_p of the reaction, stating its units.

[3]

(b) Predict the effect of increasing the temperature on the K_p of the above reaction. Explain your answer.

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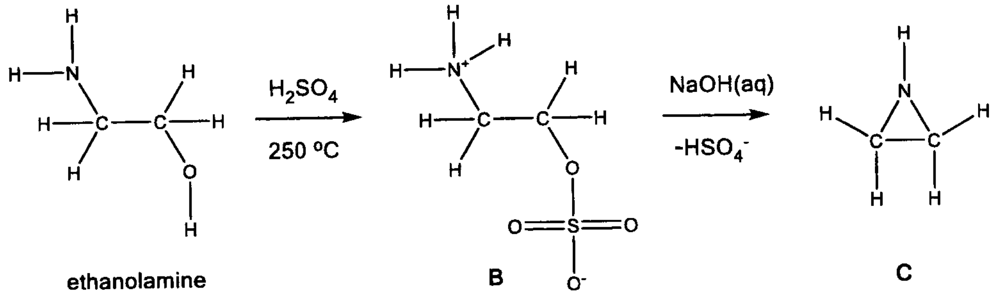
.... [2]

(c) The Wenker synthesis is an organic reaction used to convert a beta amino alcohol, such as ethanolamine, to an aziridine, a three-membered heterocycle which is useful as a starting material in medicinal chemistry.



Ethanolamine will react with sulfuric acid, a strong acid, to form **B**. The monoester is then reacted with sodium hydroxide in the second step to form aziridine **C**.

(i) Write a balanced overall equation for the Wenker synthesis of aziridine **C** from ethanolamine.

.... [1]

(ii) From your equation, name the type of reaction that occurs in the Wenker synthesis.

.... [1]

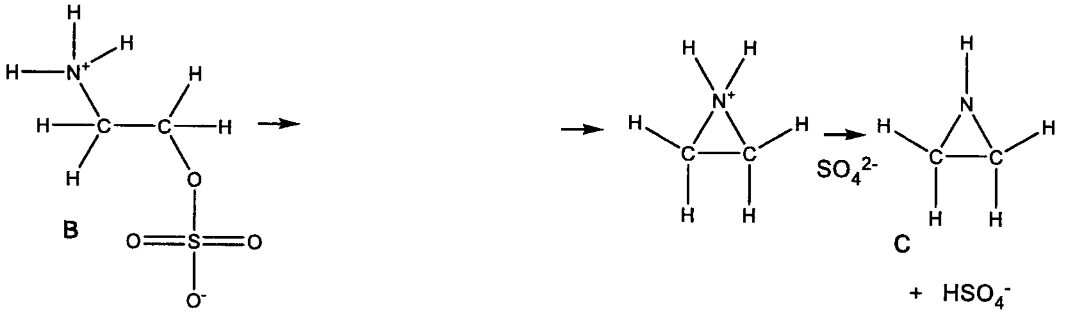
(d) The mechanism of the Wenker synthesis is thought to involve the following steps.

1. Protonation of ethanolamine to form cation **A** with an overall 2+ charge
2. Bond formation on **A** using sulfate anion with simultaneous C–O bond cleavage to give **B**
3. Deprotonation of **B** using OH^-
4. Intramolecular formation of three-membered ring involving the formation of C–N bond and heterolytic bond cleavage of C–O bond
5. Deprotonation to form **C**

(i) Given that sulfuric acid is a strong acid, suggest the structure of cation **A**.

[1]

(ii) Use the information given above in step 3 and 4 to complete the mechanism below for the formation of aziridine from compound **B**. Show all charges, partial charges and relevant lone pairs and show the movement of electron pairs by using curly arrows.



[3]

(iii) Name the type of reaction that occurred during the intramolecular cyclisation.

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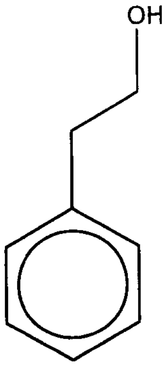
[1]

[Total: 14]

5 Organic chemicals are often used as flavour enhancers. 2-phenylethanol and butanoic acid are commonly used as rose flavour and butter flavour respectively.

(a) 2-phenylethanol, concentrated sulfuric acid and concentrated nitric acid can react together in the laboratory to form 2-(nitrophenyl)ethanol, as described below.



2-phenylethanol

Preparation of 2-(nitrophenyl)ethanol

1. Place 20 g of 2-phenylethanol into a 500 cm^3 conical flask.
2. Add slowly 40 cm^3 of concentrated sulfuric acid to the conical flask. Cool the mixture by immersing the flask in ice water.
3. Mix 15 cm^3 of concentrated nitric acid with 15 cm^3 of concentrated sulfuric acid in an ice bath. This is the nitrating mixture.
4. Using a glass pipette, transfer slowly the nitrating mixture to the contents in the conical flask. After the transfer, stir the reaction mixture in the ice bath for 15 minutes.
5. Carefully pour the reaction into a crushed ice mixture in a 250 cm^3 beaker. Solid crude 2-(nitrophenyl)ethanol will form.

(i) Draw the structural formula of the major organic products that will be formed.

[2]

(ii) The overall reaction may be considered to take place in two stages, the first between inorganic reagents only and the second involving 2-phenylethanol.

Write a balanced equation for **each** of these stages.

Stage I ....

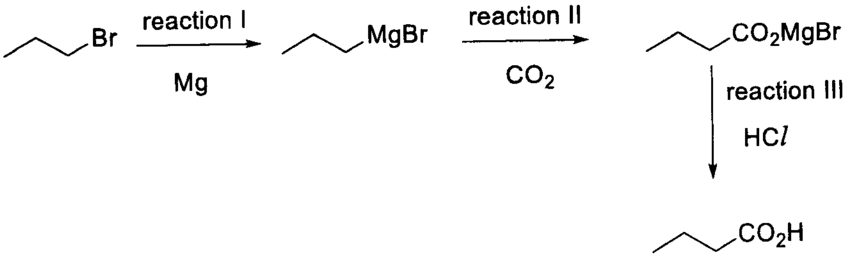
Stage II .... [2]

(iii) When the concentrated sulfuric acid is added to the reaction mixture (step 2), cooling is necessary. An organic by-product may be produced if the temperature is not controlled carefully.

Identify the organic by-product.

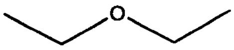
[1]

(b) Butanoic acid can be synthesised in the laboratory using the Grignard reaction, as described below.



Data on these four compounds are given in Table 1.1.

Table 1.1

compound	boiling point/ °C	density/ g cm^{-3}	molar mass/ g mol^{-1}	solubility in diethyl ether	solubility in water
butanoic acid	164	1.14	88	soluble	moderate
1-bromopropane	71	1.35	123	soluble	insoluble
magnesium	1091	1.74	24.3	-	-
diethyl ether 	35	0.71	74	-	insoluble
water	100	1.00	18	insoluble	-

Preparation of butanoic acid

1. Place 1.5 g of magnesium, 60 cm^3 of diethyl ether in a 100 cm^3 round bottom flask attached to a reflux condenser. Add 5 cm^3 of 1-bromopropane to start the reaction. Keep the contents well mixed.
2. After 10 minutes, bubble carbon dioxide gas through the reaction mixture for 15 minutes.
3. Transfer the reaction mixture to a 250 cm^3 conical flask and add 60 cm^3 of 3.0 mol dm^{-3} HC*l* to the reaction mixture.

Purification of butanoic acid

4. Transfer the mixture into a separatory funnel. Shake well. The mixture will separate into two distinct layers. Reject the aqueous layer.
5. Return the organic diethyl ether layer to the funnel. Add 20 cm^3 of 3.0 mol dm^{-3} NaOH, and shake. Separate and keep the aqueous layer containing the alkali. Reject the organic layer.

6. Return the aqueous layer to the funnel. Add 20 cm^3 of 3.0 mol dm^{-3} HC*l*, and shake. Separate and keep the organic diethyl ether layer. Reject the aqueous layer.
7. Transfer the organic diethyl ether layer into a 100 cm^3 conical flask. Add some granular anhydrous calcium chloride. Swirl the mixture until the liquid is clear.
8. Filter the pure butanoic acid into a clean round bottom flask and distil it. Collect the fraction by boiling over a suitable range.

(i) Suggest the type of reaction which occurs in reaction III.

.... [1]

(ii) One of the reagents, magnesium or 1-bromopropane, will be present in an excess in this preparation.

Use the data above to determine, by calculation, which reagent is in excess.

[2]

(iii) In step 3, effervescence was observed when HC*l* was added. Write an equation to show the formation of the gas.

.... [1]

(iv) In step 4, the reaction mixture will separate to give two layers.

Will butanoic acid mostly be in the upper or lower layer?

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Explain your answer.

....

.... [2]

(v) After separating butanoic acid from the aqueous layer, there will still be a very small amount of unwanted organic impurity present. To remove this, the reaction mixture is shaken with NaOH (step 5).

Suggest the identity of the organic impurity.

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Suggest why the aqueous layer is retained and how the impurity will be removed.

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.... [3]

(vi) Suggest what is removed when the impure butanoic acid is then treated with calcium chloride (step 7).

.... [1]

(vii) The final step in the process of purification is distillation of the pure product (step 8). Suggest a suitable range of temperature for the collection of the required fraction.

from ....°C to ....°C [1]

(c) Butanoic acid is a weak acid in water, with a p*K*a value of 4.82.

(i) Calculate the pH of a 0.20 mol dm^{-3} solution of butanoic acid.

[2]

(d) Deuterated water is a form of water that contains deuterium (^2H or D) instead of hydrogen. At 25 °C, the pK_w of deuterated water is 14.95.

(i) Calculate the pH of neutral deuterated water at 25 °C.

.... [1]

(ii) Considering the ionic products (K_W) of water and deuterated water, deduce whether the O–H bond or O–D bond is likely to be a stronger bond.

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.... [2]

[Total: 21]

Additional answer space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

RIVER VALLEY HIGH SCHOOL
JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME									
CLASS	2	1	J						
CENTRE NUMBER	S					INDEX NUMBER			

H2 CHEMISTRY
9729/03

Paper 3 Free Response

20 September 2022
2 hours

Candidates answer on the Question Paper.
Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and index number in the spaces at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper. If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

Section A
Answer **all** the questions.

Section B
Answer **one** question. **Circle** the question number of the question you attempted.

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

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

For Examiner's Use								
Question number	1	2	3	4	5	units	s.f.	Total
Marks	17	20	23	20	20			80

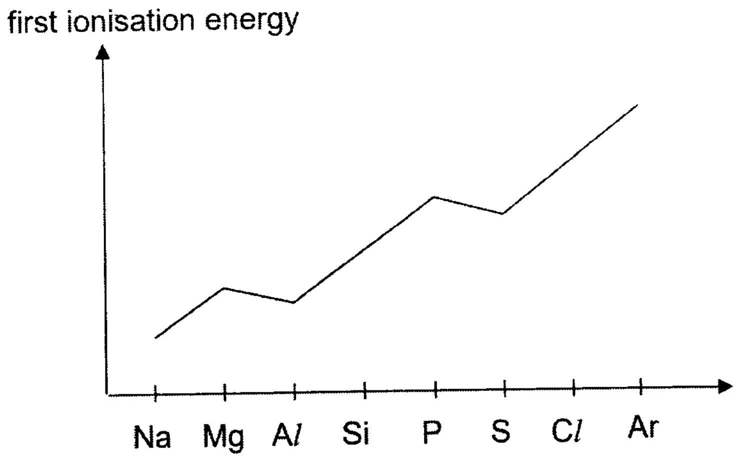
This document consists of **28** printed pages.

Section A

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

1 In the third period of the Periodic Table, there is considerable variation of chemical and physical properties from sodium to argon.

(a) The graph below shows the first ionisation energy from sodium to argon.



(i) Write an equation to represent the first ionisation energy of sulfur. [1]

(ii) Account for the difference in first ionisation energy of Mg and A*l*. [1]

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(b) Calcium carbonate decomposes when heated to about 700 °C. Copper(II) carbonate also undergoes a similar decomposition reaction when heated.

(i) Write a balanced equation for the thermal decomposition of copper carbonate. [1]

(ii) By quoting relevant values from the *Data Booklet*, state and explain if the thermal decomposition temperature of copper(II) carbonate is expected to be lower or higher than that of calcium carbonate. [2]

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(c) Write equations, including state symbols, for the reactions of the following compounds with water. In each case, state the pH of the resultant solution.

(i) Na_2O [1]

(ii) $SiCl_4$ [1]

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(d) When sodium burns in oxygen, it forms a mixture of sodium oxide, Na_2O, and sodium peroxide, Na_2O_2.

(i) Explain the difference in the electrical conductivity of sodium and sodium oxide in their solid states. [2]

(ii) The peroxide anion in sodium peroxide contains an O#O bond.

Draw a 'dot-and-cross' diagram for sodium peroxide. [1]

(iii) When sodium peroxide is added to water, hydrogen peroxide is produced.

Explain, in terms of structure and bonding, why hydrogen peroxide is a liquid while sodium peroxide is a solid at room temperature. [2]

(e) Some Pb metal and a solution of $Cr^{3+}(aq)$ were mixed and allowed to reach equilibrium.

$$Pb(s) + 2Cr^{3+}(aq) \rightleftharpoons Pb^{2+}(aq) + 2Cr^{2+}(aq)$$

The equilibrium concentrations of $Cr^{3+}(aq)$ and $Cr^{2+}(aq)$ were as follows.

$[Cr^{3+}(aq)] = 0.200 \text{ mol dm}^{-3}$

$[Cr^{2+}(aq)] = 2.96 \times 10^{-4} \text{ mol dm}^{-3}$

(i) Write the K_c expression for this reaction. [1]

(ii) Calculate K_c for this reaction. [2]

(iii) State and explain how the addition of water will affect the position of equilibrium for this reaction. [2]

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[Total: 17]

2 This question is about the chemistry of aluminium and iron.

(a) Anodising is a process used to increase the thickness of the oxide layer on the surface of metal parts. Aluminium is a reactive metal that is readily oxidised by oxygen. This forms a layer of aluminium oxide, Al_2O_3, making it resistant to corrosion.

(i) Draw a labelled diagram of the electrolysis cell used to anodise an iPhone, which is made of aluminium. You should include H_2SO_4(aq) as the electrolyte. [2]

(ii) Write chemical equations, with state symbols, to show the reactions occurring at the anode during anodising. [2]

(iii) The iPhone has a surface area of 96.2 cm^2 to be anodised. Calculate the time needed to form a 0.3 mm protective layer of Al_2O_3 on the iPhone if a current of 2.0 A is passed through the set-up.

(Density of Al_2O_3 = 3.95 g cm^{-3}) [3]

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(b) Many chemical reactions such as the reaction between peroxodisulfate and iodide ions occur very slowly at room temperature.

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

To speed up rate of reaction, a homogeneous catalyst is usually used.

Use appropriate equations to show the catalytic role of iron(III) ions in the reaction between $S_2O_8^{2-}$ and I^-. [2]

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(c) **(i)** When aqueous bromine is added to aqueous sodium thiosulfate, $Na_2S_2O_3$, a sulfur-containing product is formed. Upon addition of aqueous barium nitrate, a white precipitate forms which is insoluble in excess dilute nitric acid.

Identify the white precipitate. [1]

(ii) When aqueous bromine is replaced with iodine in the same experiment in in **(c)(i)**, no white precipitate is observed. Instead, the sulfur-containing product formed is sodium tetrathionate, $Na_2S_4O_6$.

By considering the change in oxidation state of sulfur, explain the difference between the reactions of the two halogens with $S_2O_3^{2-}$. [2]

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(d) Compound **P** ($C_6H_9O_2N$) does not rotate plane-polarised light and is insoluble in both aqueous hydrochloric acid and sodium hydroxide at room temperature.

When heated with aqueous sodium hydroxide, compound **P** gives three products: compound **Q**, the salt of a carboxylic acid, **R** ($C_4H_6O_4$) and ammonia gas.

1 mole of compound **R** reacts with 1 mole of aqueous sodium carbonate. On treatment with warm alkaline aqueous iodine followed by acidification, compound **Q** gives methanoic acid and a pale yellow precipitate.

The reaction of compound **P** with lithium aluminium hydride forms **Q** and **S** ($C_4H_{11}NO$). Both compounds **Q** and **S** contain a common functional group.

Deduce the structures of compounds **P**, **Q**, **R** and **S**. Explain your reasoning. [8]

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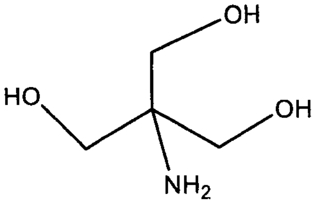
[Total: 20]

3 **(a)** Tris(hydroxymethyl)aminomethane, TRIS, is used extensively as a component of buffer solutions for solutions of nucleic acids.



TRIS

(i) Name all the functional groups in TRIS. [1]

(ii) Explain how TRIS acts as a Lewis base in the presence of hydrochloric acid. [2]

(b) To make a TRIS HC*l* buffer, 121.14 g of TRIS was dissolved in 800 cm^3 of deionised water. The pH was adjusted to 7.5 with an appropriate volume of concentrated hydrochloric acid, before the final volume was made up to 1 dm^3 with deionised water.

The protonated form of TRIS is $TRISH^+$. The value of K_a for $TRISH^+$ is 8.32×10^{-9}.

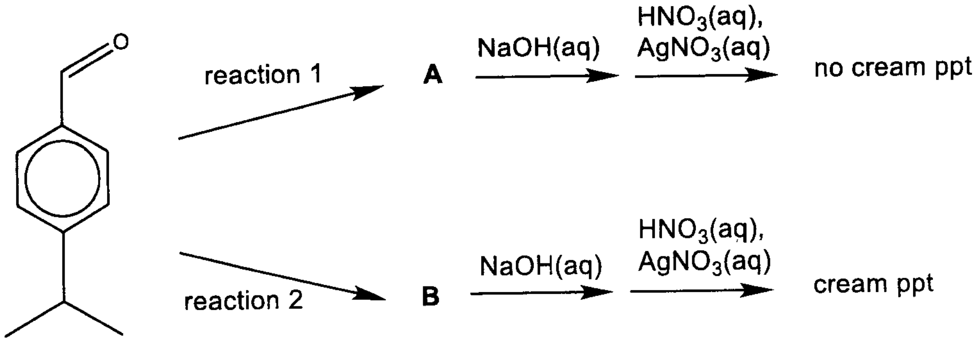
(i) Calculate the pH of TRIS if the final volume was made up to 1 dm^3 without adding concentrated hydrochloric acid. [3]

(ii) Calculate the ratio of $\frac{[TRIS]}{[TRISH^+]}$ at pH 7.5. [1]

(iii) The concentration of hydrochloric used is 11.0 mol dm^{-3}.

Using your answer in **(b)(ii)**, calculate the volume of hydrochloric acid required to form the buffer. [2]

(c) Cuminaldehyde is a component in cumin essential oil extract. It can react with halogens under different conditions to give a mixture of monohalogenated isomers, of which isomers **A** and **B** are major products.

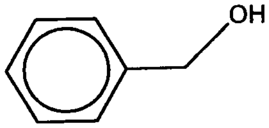


cuminaldehyde

(i) Suggest structures for compounds **A** and **B**. [2]

(ii) Explain clearly how the formation of cream precipitate confirms the functional group in compound **B**. [2]

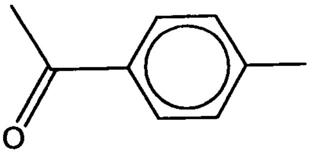
(iii) Cuminaldehyde can be obtained from phenylmethanol in a two-step synthesis.



phenylmethanol

Suggest the reagents and conditions for the two-step synthesis. [2]

(iv) Describe a simple chemical test, with appropriate observations, which would distinguish between compound **D** and cuminaldehyde.



Compound **D** [2]

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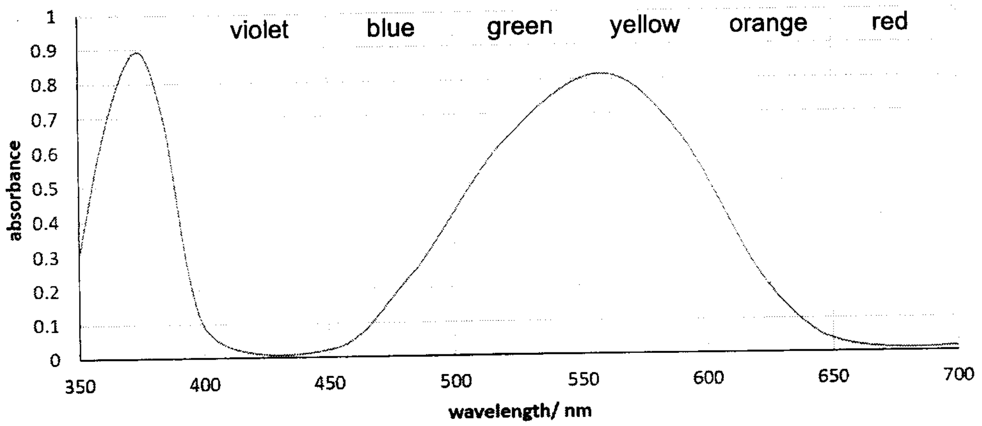
(d) The diagram below shows the UV-visible absorption spectrum of an aqueous transition metal complex ion, [**M**(H_2O)$_6$]$^{3+}$(aq). Absorbance on the vertical axis is a measure of the amount of light absorbed.



(i) Explain why transition metals form coloured complexes. [3]

(ii) State the expected colour of the complex ion, [**M**(H_2O)$_6$]$^{3+}$. Explain your answer. [1]

(iii) The solution turns colourless when [**M**(H_2O)$_6$]$^{3+}$ is oxidised to [**M**(H_2O)$_6$]$^{4+}$. Given that **M** is a transition element from Period 4, deduce the electronic configuration of the transition metal, **M**, at ground state. [1]

(iv) When F^- is added to [**M**(H_2O)$_6$]$^{3+}$, [**M**F_6]$^{3-}$ is formed and the solution also turned colourless. Suggest a reason for this observation. [1]

[Total: 23]

Section B

Answer **one** question from this section.

4 **(a)** Acetals are a common protecting group for carbonyl compounds in organic synthesis. Acetalisation is an acid-catalysed condensation under heated conditions. An example is shown in Fig 4.1.

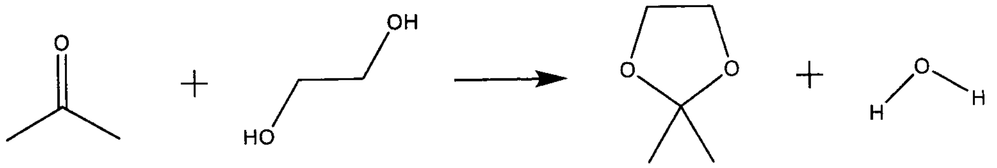


Fig 4.1

(i) The C#C bond length in propanone is 152 pm which is shorter than the C#C bond length of 154 pm in propane.

Suggest the reason and explain for the difference. [2]

(ii) Fig 4.2 shows part of the mechanism in the acetalisation of propanone. Copy and suggest the mechanism by drawing appropriate curly arrows and lone pairs of electrons on intermediate **Q**.

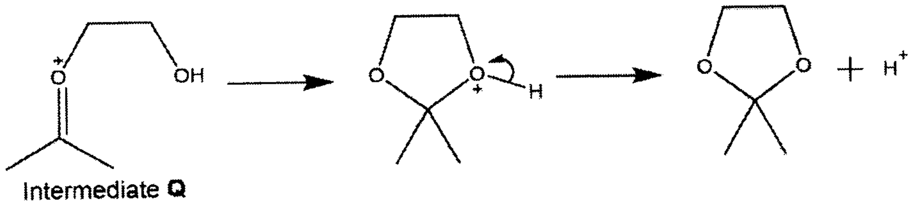
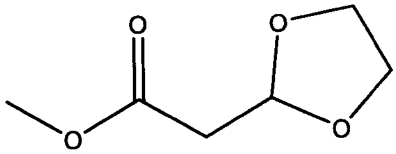


Fig 4.2 [2]

(iii) Compound **R** is a cyclic acetal formed from acetalisation process depicted in Fig 4.1.

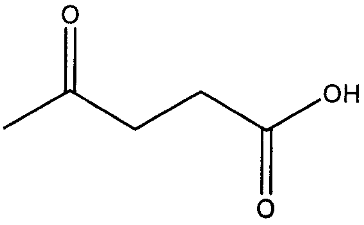


R

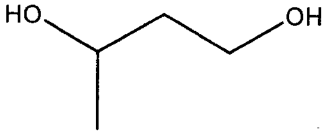
Suggest possible structures for the two reactants used in the formation of **R**. [2]

(iv) When 4-oxopentanoic acid and butane-1,3-diol are subject to the same reaction conditions as Fig 4.1, a mixture of 8 products are formed.

- Products **S** and **T** are structural isomers with molecular formula of $C_9H_{16}O_4$.
- **S** is acidic while **T** is neutral.
- **U** is neutral and has molecular formula of $C_{13}H_{22}O_5$.



4-oxopentanoic acid



butane-1,3-diol

Suggest possible structures for compound **S**, **T** and **U**. [3]

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(b) Ethene is used to produce ethane-1,2-diol. Fig 4.3 shows reactions involving ethene under different conditions.

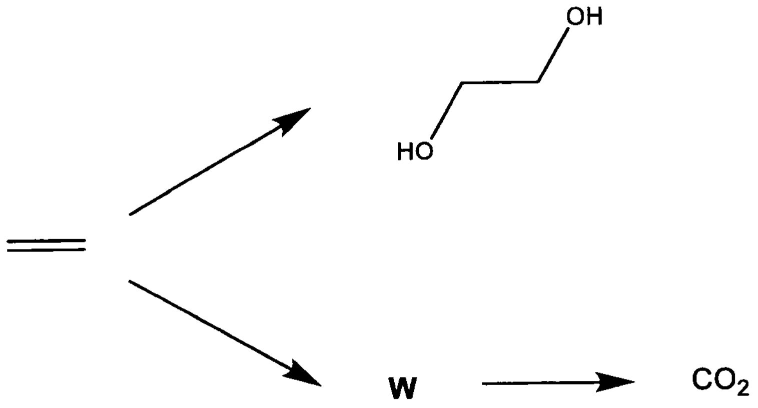

Fig 4.3

(i) State the reagent and condition to convert ethene into ethan-1,2-diol. [1]

(ii) Draw the displayed formula for intermediate **W**. [1]

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(c) Propanone undergoes acid-catalysed reaction with iodine in aqueous solution as shown in equation 1.

Equation 1 $CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+} CH_3COCH_2I(aq) + HI(aq)$

Four experiments were carried out to investigate the order of reaction with respect to propanone, iodine and acid respectively.

Experiment	$[CH_3COCH_3]$/ mol dm^{-3}	$[I_2]$/ mol dm^{-3}	$[H^+]$/ mol dm^{-3}
1	0.10	0.005	0.001
2	0.10	0.005	0.002

The change in concentration of iodine remaining for this reaction was measured using a photoelectric colorimeter. The reaction mixture was placed into a colorimeter. The absorbance of light at 470 nm was recorded at 15 second intervals. The absorbance measured was directly proportional to the concentration of iodine present in the sample.

The results of these experiments are shown in Fig 4.4.

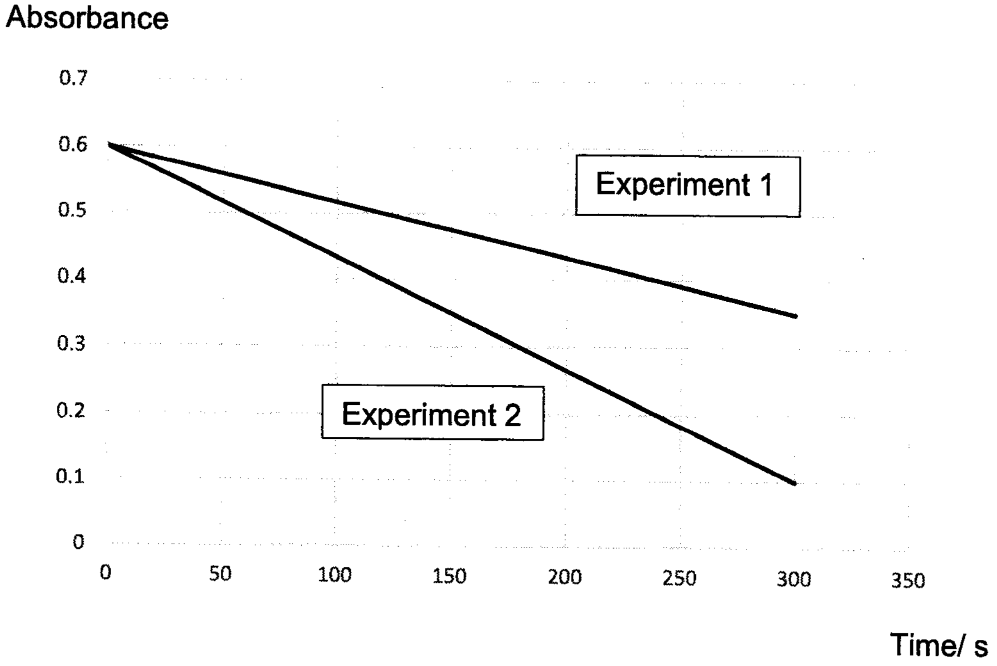

Fig 4.4

(i) Explain why CH_3COCH_3 is used in excess in experiment 1 and 2. [1]

(ii) With reference to Fig 4.4, deduce the order of reaction with respect to I_2(aq). Explain your reasoning. [1]

(iii) Hence, sketch a graph to describe the relationship between the rate of reaction and time in experiment 1. [1]

(iv) With reference to Fig 4.4, determine the order of reaction with respect to H^+(aq). Explain your reasoning and include any calculations where necessary. [2]

(v) The experiment was repeated to find the initial rate of reaction at different initial concentrations of CH_3COCH_3(aq), I_2(aq) and H^+(aq). The results of these experiments are shown in Table 4.1.

Table 4.1

Expt	Initial [CH_3COCH_3(aq)]/ mol dm^{-3}	Initial [I_2(aq)]/ mol dm^{-3}	Initial [H^+(aq)]/ mol dm^{-3}	Initial rate of reaction/ mol dm^{-3} s^{-1}
3	0.001	0.003	0.002	2.45×10^{-8}
4	0.003	0.002	0.001	3.68×10^{-8}

Determine the order of reaction with respect to CH_3COCH_3(aq). [1]

(vi) Outline a suitable experiment involving continuous method to determine rate constant, *k*. [3]

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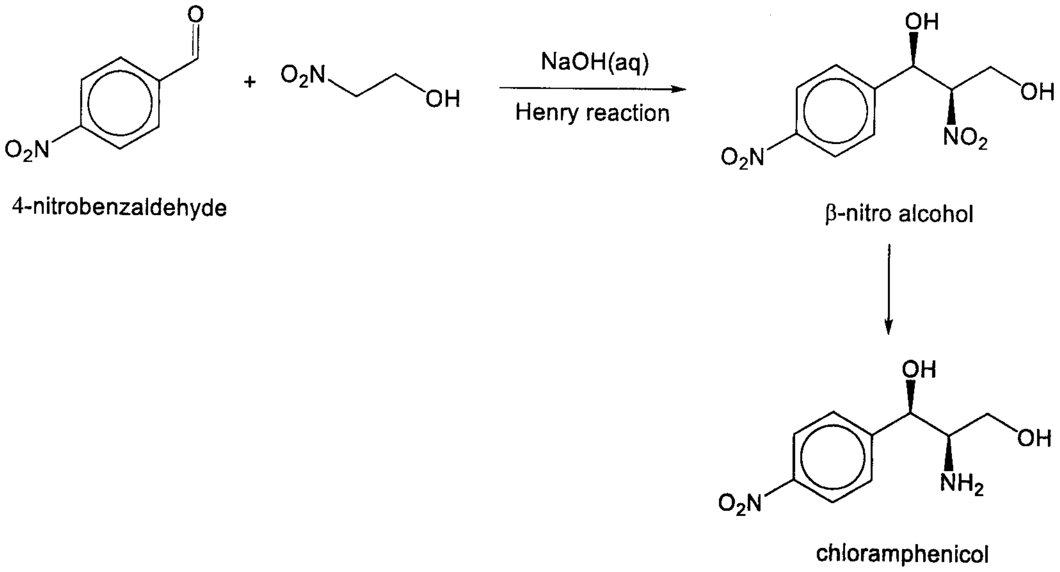
[Total: 20]

5 Chloramphenicol is an antibiotic useful for the treatment of several bacterial infections such as conjunctivitis. Chloramphenicol can be synthesised via the Henry reaction where 4-nitrobenzaldehyde and a nitroalkane are reacted, in the presence of a base, to form β-nitro alcohols. The β-nitro alcohol then undergoes further reaction to form chloramphenicol.

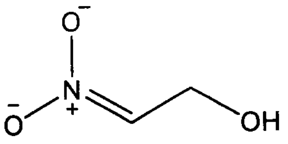


(a) **(i)** Define the term *bond energy*. [1]

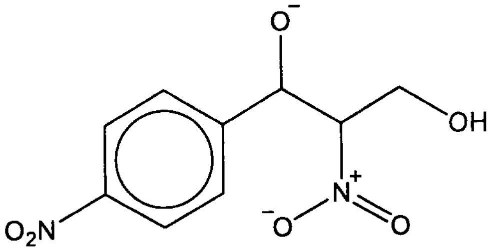
(ii) Use bond energy values from the *Data Booklet* to calculate the enthalpy change of reaction for the formation of β-nitro alcohol shown above. [2]

(b) **(i)** The mechanism for the Henry reaction is thought to involve the reaction of nitro-enolate ion with C∃O of the 4-nitrobenzaldehyde to form an alkoxide ion in a concerted step. The lone pair of electrons on the oxygen atom in nitro-enolate ion can increase the reactivity of the carbon-nitrogen double bond towards electrophilic reagents.

The structure of the nitro-enolate and alkoxide ions are given below.



nitro-enolate ion



alkoxide ion

Suggest this mechanism, showing all relevant charges, dipoles, lone pairs, and curly arrows. [2]

(ii) Name the type of reaction to convert β-nitro alcohol into chloramphenicol. [1]

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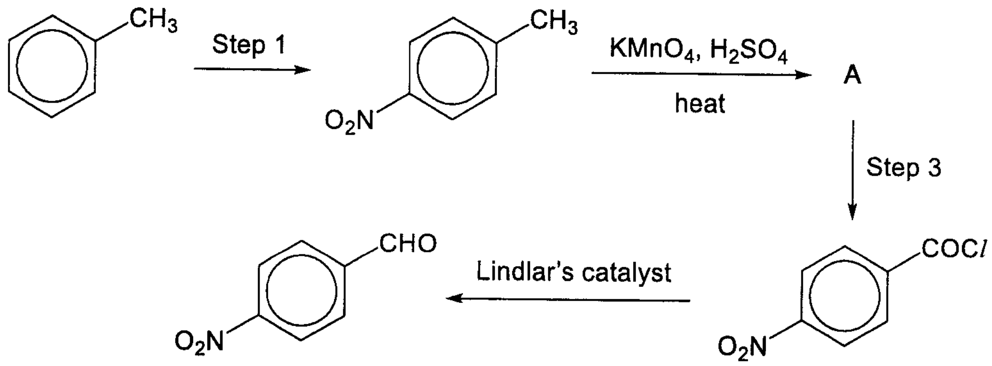
(c) The starting material, 4-nitrobenzaldehyde, can be synthesised from methylbenzene as shown below.



(i) Draw the structure for **A**. [1]

(ii) Suggest the reagents and conditions for Steps 1 and 3. [2]

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(d) The β-nitro alcohol formed in the Henry reaction is a versatile compound. It can be dehydrated to give a mixture of two alkenes **D** and **E**, with the molecular formula $C_9H_8N_2O_5$.

(i) Suggest the reagent and condition for the dehydration reaction. [1]

(ii) Draw the skeletal structures of **D** and **E**. Label the major product and explain your reasoning. [3]

(iii) Draw a labelled diagram to show all the valence orbitals of carbon atoms in the C∃C bond in an alkene and show how the orbitals overlap to form the C∃C bond. State the type of hybridisation involved. [2]

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(e) Silver nitrite, $AgNO_2$, is a sparingly soluble salt used in the synthesis of nitroalkanes.

(i) Write an expression for the solubility product, K_{sp}, of $AgNO_2$. [1]

(ii) Given the solubility of $AgNO_2$ in water at 0 °C is 0.155 g in 100 cm^3 of water, calculate the K_{sp} of $AgNO_2$, stating its units. [2]

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(f) Acidified potassium manganate(VII) is reacted with sodium nitrite, $NaNO_2$.

Using the *Data Booklet* and the information below,

$$NO_3^- + 2H^+ + 2e^- \rightleftharpoons NO_2^- + H_2O \qquad E^\ominus = +0.42\text{ V}$$

(i) Calculate the $E^\ominus_{cell}$ of the reaction. [1]

(ii) Hence, calculate the standard Gibbs free energy, $\Delta G^\ominus$, of the reaction. [1]

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[Turn over

[Total: 20]

Additional answer space

If you use the following page to complete the answer to any question, the question number must be clearly shown.

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RIVER VALLEY HIGH SCHOOL

JC 2 PRELIMINARY EXAMINATION

H2 CHEMISTRY 9729 Paper 4

19 AUGUST 2022

2 HOURS 30 MINUTES

NAME ______________________

CLASS 21J (   )

INDEX NO. ______________________

INSTRUCTIONS TO CANDIDATES

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Read these notes carefully.

Write your name, class and index number in the spaces at the top of this page.
Give details of the practical shift and laboratory where appropriate, in the boxes provided.
Write in dark blue or black pen.
You may use a 2B pencil for any diagram or graph.
Do not use staples, paper clips, highlighters, 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.

Shift
Laboratory

For Examiner's Use	
s.f.	
Units	
Total	55

This Question Paper consists of **19** printed pages and **1** blank page.

Answer **all** the questions in the spaces provided.

1 Investigation of the oxidising ability of substances

FA 1 is an aqueous solution of iron(II) sulfate.
FA 2 is made by dissolving 0.750 g of $KMnO_4$ in deionised water and made up to 250 cm^3 in a volumetric flask.
FA 3 is 0.500 mol dm^{-3} compound **A**.
FA 4 is 1 mol dm^{-3} sulfuric acid.

You will perform tests to:

- investigate the oxidising ability of three substances
- carry out a titration to determine the concentration of iron(II) sulfate in **FA 1**.

(a) **(i)** Carry out the following tests. Carefully record your observations in Table 1.1. The volumes given below are approximate and should be estimated rather than measured.

In this section, there is only one gas evolved. You only need to carry out the identification test and identify the gas once.

Table 1.1

	Test	Observations
1	To a 1 cm depth of **FA 1** in a test-tube, add 1 cm depth of **FA 4**, then gradually add **FA 2** till 1 drop in excess.	
2	To a 1 cm depth of **FA 3** in a test-tube, add 1 cm depth of **FA 2**.	
3	To a 1 cm depth of **FA 1** in a test-tube, add about 1 cm depth of **FA 4**, followed by 1 cm depth of **FA 3**. To a portion of resulting solution, add aqueous sodium hydroxide till excess.	

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(ii) Explain the chemistry involved for all the observations in Test 1.

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(iii) Write two equations to show the changes to Fe^{2+} ions in Test 3.

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(iv) Using the results in Test 3, state the stronger oxidising agent.

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(b) **(i)** **Titration of FA 1 against FA 2**

1. Fill a burette with **FA 2**.
2. Use the pipette to transfer 25.0 cm^3 of **FA 1** into a 250 cm^3 conical flask.
3. Use a measuring cylinder to add 20.0 cm^3 of **FA 4** into the same conical flask.
4. Titrate the mixture in the conical flask until the end-point is reached.
5. Record your titration results, to an appropriate level of precision, in the space provided below.
6. Repeat points 2 to 5 until consistent results are obtained.

Titration results

8	
9	
10	
11	
12	

Difference in titres

(ii) From your titrations, obtain a suitable volume of **FA 2** to be used in your calculations. Show clearly how you obtained this volume.

volume of **FA 2** used = ...

13	

(c) **(i)** Calculate the amount of MnO_4^- used in the titration.
[Ar: K, 39.1; Mn, 54.9; O,16.0]

amount of MnO_4^- = ...

14

(ii) Given that 1 mole of MnO_4^- reacts with 5 moles of Fe^{2+}, calculate the molar concentration of iron(II) sulfate in **FA 1**.

molar concentration of iron(II) sulfate = ...

15

(d) A student plans to titrate 25.0 cm^3 of aqueous solution containing iron(II) chloride with **FA 2** as the titrant. This iron(II) chloride solution has similar molar concentration as iron(II) sulfate in **FA 1**.

Without changing the identity of the chemicals used, suggest a modification to improve the experiment. Explain your answer.

You are not required to show any calculations.

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16

(e) In a series of titrations, a student pipetted 25.0 cm^3 of **FA 1** into the conical flask and added varying volumes of **FA 3** from the burette to form a mixture. This mixture was titrated with **FA 2** till end-point was reached. The results are shown below in Table 1.2.

Table 1.2

experiment	1	2	3	4	5
volume of **FA 3** added /cm^3	5.00	10.00	15.00	20.00	25.00
volume of **FA 2** used /cm^3	15.45	10.55	5.70	1.25	3.45

(i) Explain why the volumes of **FA 2** obtained decrease as V_{FA3} increases from 5.00 cm^3 to 20.00 cm^3.

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(ii) Considering the chemistry involved, deduce whether the volume of **FA 2** used in **experiment 5** is an anomaly.

Explain your answer.

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(iii) Calculate the highest percentage uncertainty in the volume of **FA 2** used as shown in Table 1.2.

percentage uncertainty = ... **20**

[Total: 20]

2 Investigation of the kinetics of the reaction between iron(III) ions and iodide ions

In acidic solutions, iron(III) ions are reduced by iodide ions to form iron(II) ions. The iodide ions are oxidised to iodine.

$$2Fe^{3+}(aq) + 2I^{-}(aq) \rightarrow 2Fe^{2+}(aq) + I_2(aq)$$

The rate of this reaction can be investigated by using starch indicator, which turns blue-black in the presence of iodine. Sodium thiosulfate is added to the reaction mixture to react with iodine as it is formed. The blue-black colour is seen when all the thiosulfate has reacted.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^{-}(aq) + S_4O_6^{2-}(aq)$$

You will perform a series of four experiments to investigate how the rate of reaction is affected by changing the concentration of the iodide ions.

For each experiment, you will note the volume of **FA 5** added, $V_{FA\,5}$, the volume of water added, V_{H_2O}, and the time taken, t, for the reaction mixture to turn blue-black.

In this series of experiments, the rate equation for the reaction can be simplified to rate = $k'[I^-]^m$, where $\boldsymbol{m}$ is the rate order with respect to I^- and k' is $k[Fe^{3+}]$.

The simplified rate equation can be further manipulated to derive the following relationship:

$$\lg\left(\frac{3600}{\text{reaction time}}\right) = \boldsymbol{m} \times \lg(V_{FA\,5}) + \text{constant}$$

FA 5 is 0.0500 mol dm^{-3} potassium iodide, KI.
FA 6 is 0.0500 mol dm^{-3} iron(III) chloride, $FeCl_3$.
FA 7 is 0.0050 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 8 is starch indicator.

(a) In the space provided on page 8, prepare a table in which to record for your experiment:

- all values of $V_{FA\,5}$ and V_{H_2O} to an appropriate level of precision
- all values of t
- all calculated values of lg($V_{FA\,5}$) and lg(rate) to three significant figures.

Experiment 1

1. Use a 25.00 cm^3 measuring cylinder to place 20.00 cm^3 of **FA 5** in a 100 cm^3 beaker.
2. Use appropriate measuring cylinders to add the following to the same beaker.
    - 20.0 cm^3 of **FA 7**
    - 10.0 cm^3 of **FA 8**
3. Use an appropriate measuring cylinder to measure 10.0 cm^3 of **FA 6**.
4. Add this **FA 6** to the same 100 cm^3 beaker and start timing immediately.
5. Stir the mixture and place the beaker on a white tile.
6. Stop timing as soon as the solution turns blue-black.
7. Record this reaction time to the nearest 0.1 second.
8. Wash the beaker and dry it with a paper towel.

Experiment 2

1. Use the same 25.00 cm^3 measuring cylinder to measure 10.00 cm^3 of **FA 5** and make up the volume to 20.00 cm^3 using deionised water.
2. Place this solution in a 100 cm^3 beaker.
3. Use appropriate measuring cylinders to add the following to the same beaker.
    - 20.0 cm^3 of **FA 7**
    - 10.0 cm^3 of **FA 8**
4. Use an appropriate measuring cylinder to measure 10.0 cm^3 of **FA 6**.
5. Add this **FA 6** to the same 100 cm^3 beaker and start timing immediately.
6. Stir the mixture and place the beaker on a white tile.
7. Stop timing as soon as the solution turns blue-black.
8. Record this reaction time to the nearest 0.1 second.
9. Wash the beaker and dry it with a paper towel.

Experiments 3 and 4

Carry out two further experiments to investigate how the reaction time changes with different volumes of aqueous potassium iodide, **FA 5**.

The combined volume of **FA 5** and deionised water must always be 20.00 cm^3.

Do not use a volume of **FA 5** that is less than 6.00 cm^3.

Results

The rate of the reaction is defined as shown.

$$\text{rate} = \frac{3600}{\text{reaction time}}$$

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(b) Plot a graph of $\lg(\frac{3600}{\text{reaction time}})$, on the y-axis, against the $\lg(V_{\text{FA 5}})$, on the x-axis, on the grid. Draw a straight line of best fit through the points.

Your scale should allow $\lg(V_{\text{FA 5}})$ of 0.700 and $\lg(\frac{3600}{\text{reaction time}})$ of 1.30 to be plotted.

26	
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28	

(c) **(i)** Calculate the gradient of the line to three significant figures, and hence suggest the rate order, ***m***, showing clearly how you did this.

gradient = ...

m = ...

29	

(ii) Using your graph, calculate the expected reaction time if 7.9 cm^3 of **FA 5** is used. Show your working clearly.

reaction time = ...

30

(d) **(i)** Using data from **Experiments 1** and **2**, show by calculation that the volume of aqueous potassium iodide, **FA 5**, used was directly proportional to the concentration of iodide ions.

31

(ii) Explain, by referring to your table of results, how the rate of reaction is affected by an increase in the concentration of aqueous potassium iodide, **FA 5**.

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(e) Thiosulfate ions can reduce iron(III) ions and also react with acid to form sulfur, sulfur dioxide and water.

(i) Write an ionic equation, with state symbols, for the reaction between thiosulfate ions and hydrogen ions in aqueous solution.

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(ii) A student carried out the same investigation as in **(a)** but the solutions were mixed in a different order. The student kept the **FA 5** and an appropriate volume of deionised water in the measuring cylinder and all the other reactants in the 100 cm^3 beaker. The student then transferred the solution from the measuring cylinder into the 100 cm^3 beaker and started timing.

State and explain whether the student's method is

- better than that in **(a)**,
- as good as that in **(a)**, or
- not as good as that in **(a)**.

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[Total: 14]

3 Investigation of an inorganic compound

FA 9 is an aqueous solution of an inorganic compound, MY_2, which contains a cation and an anion (Y^-), both listed in Qualitative Analysis Notes.

FA 10 is a saturated solution of a sodium salt, NaY.

You will perform tests to:
- investigate the effect of reagents on **FA 9**
- identify the anion present in **FA 9**.

(a) Carry out the following tests. Carefully record your observations in Table 3.1. The volumes given below are approximate and should be estimated rather than measured.

Table 3.1

	Test	Observations
1	Place a test-tube containing 2 cm depth of **FA 9** in an almost boiling water bath for a few minutes.	
2	To a 2 cm depth of **FA 9** in a test-tube, add gradually add 2 cm depth of **FA 10**. Pour half of this mixture into another test-tube and place it in the almost boiling water bath for a few minutes for comparison.	
3	To a 1 cm depth of **FA 9** in a boiling-tube, gradually add 3 cm depth of aqueous sodium hydroxide. Filter the resultant mixture and collect the filtrate. Keep the filtrate for Test 4.	
4	To a 1 cm depth of filtrate in a test-tube, add 1 cm depth of nitric acid, followed by $AgNO_3(aq)$. To a portion of the resultant mixture, add $NH_3(aq)$.	

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(b) **(i)** State the identity of the cation in **FA 9**.

Cation ....

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(ii) Table 3.1 Test 4 confirms the identity of the anion in **FA 9**. Explain why the filtrate from Test 3 was used instead of **FA 9**.

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(c) When solid MY_2 is dissolved in water, the cation could exist either as a blue soluble complex or a yellow soluble complex. The complexes are $[M(H_2O)_6]^{2+}$ and $[MY_4]^{n-}$, and they can be converted from one form to the other.

Equation 1 $[M(H_2O)_6]^{2+}(aq) + 4Y^{-}(aq) \ll [MY_4]^{n-}(aq) + 6H_2O(l)$

(i) Consider your observations in Table 3.1 Test 2, identify the yellow complex and explain your answer.

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(ii) Considering the information provided and your answer in **3(b)(i)**, explain the chemistry involved that account for the change(s) observed in Table 3.1 Test 1.

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[Total: 9]

4 Planning

The reaction between an acid and a metal hydroxide is exothermic. It is possible to make use of this fact to determine the equivalence-point of a neutralisation reaction without the use of an indicator. This process is known as thermometric titration, and can be used to calculate the molar concentration of an acid solution.

Portions of acid are progressively added to the hydroxide solution until the equivalence-point is reached and passed. The temperature is monitored throughout the experiment.

The data obtained is plotted and two best-fit graph lines are drawn. One line is drawn using data before the equivalence-point and the second line using the remaining data. These lines are then extrapolated (extended) until they meet.

(a) **(i)** Aqueous hydrochloric acid is neutralised by the addition of aqueous barium hydroxide. The enthalpy change of neutralisation has the symbol ΔH_{neut}.

Write an ionic equation for the reaction for which the enthalpy change is ΔH_{neut}. You should include state symbols in your equation.

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(ii) A student carried out a thermometric titration by adding 1.50 mol dm^{-3} hydrochloric acid to 1.00 mol dm^{-3} barium hydroxide, $Ba(OH)_2$.

Given that the magnitude of ΔH_{neut} is about 57 kJ mol^{-1}, show that 25.0 cm^3 of barium hydroxide used will give a temperature change of 11.7 °C.

You should assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of solution by 1.0 °C.

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(b) Using the information provided, you are required to write a plan for a thermometric titration in which hydrochloric acid is added to aqueous barium hydroxide.

You may assume that you are provided with:

- 1.00 mol dm^{-3} $Ba(OH)_2(aq)$,
- hydrochloric acid of approximate concentration 1.50 mol dm^{-3},
- the equipment normally found in a school or college laboratory.

Your plan should include:

- brief, but specific, details of the apparatus you would use, bearing in mind the levels of precision they offer;
- an outline of how accurate results would be obtained;
- how you would recognise that the equivalence-point had been passed.

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(c) **(i)** On the axes provided, sketch the graph you would expect to obtain.

You should consider your answer in **(a)(ii)** and label the graph.

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(ii) Explain the shape of your graph in **(c)(i)**.

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(iii) The exact concentration of HC*l* provided is higher than 1.50 mol dm^{-3}.

On the same axes provided in **(c)(i)**, sketch the graph you would expect to obtain.

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[Total: 12]

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9 Qualitative Analysis Notes

[ppt. = precipitate]

9(a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+ (aq)	ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white. ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium(III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(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^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(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^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

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9(b) Reactions of anions

anion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives pale cream ppt. with Ag^+(aq) (partially soluble in NH_3(aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^- (aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-} (aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-} (aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in dilute strong acids)

9(c) Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	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_2	greenish yellow gas	pale yellow	pale yellow
bromine, Br_2	reddish brown gas / liquid	orange	orange-red
iodine, I_2	black solid / purple gas	brown	purple

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