Candidate Name: _____

Class _____ Adm No _____

millennia institute

2022 Preliminary Examination
Pre-University 3

H2 CHEMISTRY

Paper 1 Multiple Choice

9729/01

21ˢᵗ Sep 2022

1 hour

Additional materials: Multiple Choice Answer Sheet

Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write in soft pencil.

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

Write your name, class and admission number in the spaces provided at the top of this page and on the Multiple Choice Answer Sheet provided.

There are **thirty** questions on 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 Multiple Choice Answer Sheet provided.

Read the instructions on the Multiple Choice 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 question paper.

The use of an approved scientific calculator is expected, where appropriate.

FOR EXAMINER'S USE	
TOTAL (30 marks)	

This question paper consists of **14** printed pages and **2** blank pages.

2

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

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 Which of the following conversions have a percentage yield of 73%?

1 74 g of butan-1-ol (M_r = 74.0) → 52.56 g of butanal (M_r = 72.0)

2 72 g of butanone (M_r = 72.0) → 54.02 g of butan-2-ol (M_r = 74.0)

3 56 g of but-2-ene (M_r = 56.0) → 87.60 g of ethanoic acid (M_r = 60.0)

A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

2 Ferric oxalate, $Fe_2(C_2O_4)_3$, is an ionic salt. A sample of 10.0 cm³ of 0.100 mol dm⁻³ ferric oxalate is titrated against 0.100 mol dm⁻³ acidified $KMnO_4$.

What is the volume of $KMnO_4$ required to reach end point, and the total volume of CO_2 gas evolved at r.t.p.?

	volume of KMnO₄	volume of gas
A	4.0 cm³	72 cm³
B	4.0 cm³	144 cm³
C	12.0 cm³	72 cm³
D	12.0 cm³	144 cm³

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

The silver chloride electrode is a type of reference electrode commonly used in electrochemical measurements. It can be represented as below.

$$AgCl(s) + e^- \rightleftharpoons Ag(s) + Cl^-(aq)$$
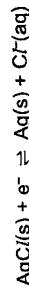
The reduction potential of the Co^{3+}/Co^{2+} half-cell is +1.69 V when it is measured using the $AgCl$/Ag reference electrode at standard conditions.

What is the reduction potential of the $AgCl$/Ag electrode when it is measured against the standard hydrogen electrode as reference?

A -1.89 V   B +0.20 V   C +1.49 V   D +1.89 V

[Turn over

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

Which of the following statements are true?

1 I_2 can reduce $S_2O_3^{2-}$ to $S_4O_6^{2-}$.

2 K is a stronger reducing agent than Ca.

3 When $Br_2(g)$ is bubbled into NaI(aq), an orange solution is produced.

A 1 only

B 2 only

C 1 and 2 only

D 2 and 3 only

5 The first six ionisation energies of an element, **E**, in kJ mol⁻¹ are shown.

578   1817   2745   11577   14842   18379

E forms an oxide when it is heated with oxygen gas.

What is the electronic configuration of **E** in its oxide form?

A $1s^2$

B $1s^2\ 2s^2\ 2p^1$

C $1s^2 2s^2 2p^6$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

6 In which of the following pairs of compounds would the second compound have a higher boiling point than the first compound?

1 CH_3CHO, CH_3CH_2OH

2 AlF_3, $AlCl_3$

3 $CH_3CH_2CH_2CH_2CH_3$, $C(CH_3)_4$

A 1 only

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

7 Information about the properties of some compounds are given below.

compound	boiling point / °C
HF	19.5
NH₃	-33.3
H₂O	100

Which statement about the hydrogen bonding in these compounds is correct?

A HF has a higher boiling point than NH₃ because each HF molecule can form more hydrogen bonds on average compared to each NH₃ molecule.

B H₂O has a higher boiling point than HF because the H–O bond dipole is greater than the H–F bond dipole.

C H₂O has a higher boiling point than HF because hydrogen bonding between two molecules of H₂O causes it to dimerise.

D NH₃ has the lowest boiling point because it forms few hydrogen bonds on average and has the smallest bond dipole.

**8** Covalent bonds involve the overlapping of orbitals.
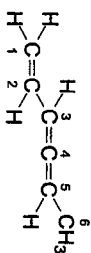
Which statement does **not** describe the molecule above?

A The σ bond between C2–H is formed by 2sp²–1s overlap.

B The σ bond between C3–C4 is formed by 2sp²–2sp² overlap.

C The σ bond between C5–C6 is formed by 2sp²–2sp³ overlap.

D The π bond between C4–C5 is formed by 2p–2p overlap.

9 When glucose is stirred into water and dissolved, strong hydrogen bonds are formed initially between the glucose and water molecules. As more water is added, these same hydrogen bonds are subsequently broken.

Assuming that the rate of energy change remains relatively constant throughout, which of the following graphs best represents the observed temperature changes?
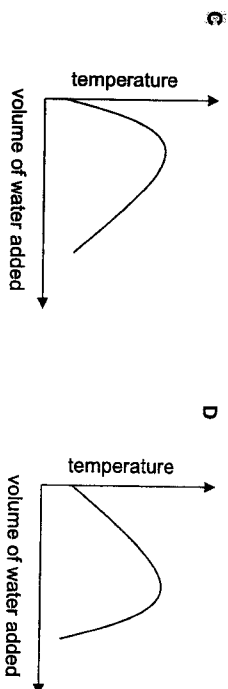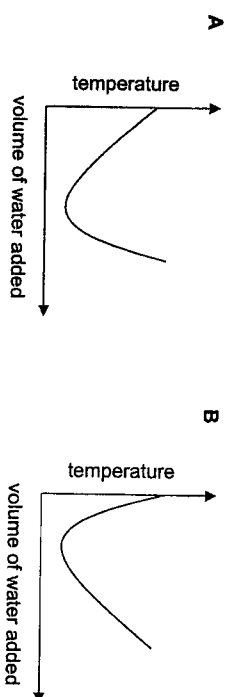
10 The ΔH$_c$ values of some hydrocarbons are given below.

hydrocarbon	ΔH$_c$ / kJ mol⁻¹	M$_r$
CH₄	–889	16.0
C₂H₆	–1560	30.0

What is the ratio of heat generated by CH₄ to C₂H₆ when the same mass of each hydrocarbon is burnt?

A 0.57   **B** 0.94   **C** 1.07   **D** 1.14

11 20 m³ of neon gas at a pressure of 30 kPa and 30 m³ of argon gas at a pressure of 50 kPa were introduced into an evacuated 15 m³ flask at a constant temperature of 300 K. The final pressure in the flask was **F** kPa.

What are the value of **F**?

	F / kPa
A	42
B	80
C	140
D	178

12 Two acid-base reactions are shown below:

Reaction 1: $N_2H_4 + HClO \rightarrow N_2H_5^+ + ClO^-$
Reaction 2: $N_2H_5^+ + NH_3 \rightarrow NH_4^+ + N_2H_4$
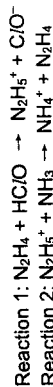
Which of the following statements is **incorrect**?

1   ClO^- is the conjugate base of $HClO$.
2   $N_2H_5^+$ is the Brønsted acid in Reaction 2.
3   N_2H_4 is the Lewis acid in Reaction 1.

A 1 only
B 3 only
C 1 and 2 only
D 2 and 3 only

13 The radioactive decay of an element, **H**, is a first order reaction and produces element **I** as the product:

$$H \rightarrow I$$

1.00 mol of **H** was set aside and allowed to decay. Given that it takes 8 days for 0.75 mol of **I** to be produced, what fraction of **H** remains after 40 days?

A $\left(\frac{1}{2}\right)^1$ **B** $\left(\frac{1}{2}\right)^5$ **C** $\left(\frac{1}{2}\right)^{10}$ **D** $\left(\frac{1}{2}\right)^{25}$

**14** N_2O decomposes in the presence of gold catalyst as follows:

$$2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$$

The following data is obtained from an experiment carried out at 1200 K.

time / s	0	1040	2370	4250	7460
partial pressure of N_2O / kPa	25.0	20.0	15.0	10.0	5.0

Which of the following statements is **incorrect**?

A   The reaction is first order with respect to N_2O.
B   The total pressure upon reaction completion can be determined from the above data.
C   The values of the partial pressures of N_2O are affected by temperature.
D   The value of rate constant of the reaction remains the same even in the absence of gold.

15 $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$
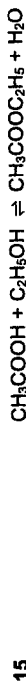
Which of the following conditions will be met when the above reaction has reached dynamic equilibrium?

A   The equilibrium constant K is equal to 1.
B   The reaction between the acid and the alcohol has stopped.
C   The concentrations of the products equal those of the reactants.
D   The rate of production of ethyl ethanoate equals its rate of hydrolysis.

16 The graph below shows the percentage of products present at equilibrium over a range of temperatures and pressures.
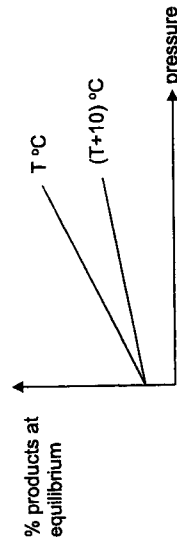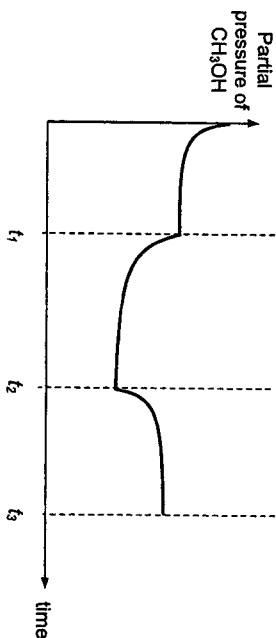

Which of the following reactions could the graph represent?

A $C(s) + O_2(g) \rightleftharpoons 2CO(g)$ $\Delta H = -99$ kJ mol⁻¹
B $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $\Delta H = +20$ kJ mol⁻¹
C $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92$ kJ mol⁻¹
D $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ $\Delta H = +57$ kJ mol⁻¹

[Turn over

17 A synthesis was carried out to produce methanol from hydrogen and carbon monoxide at a high temperature:

$$2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

The partial pressure of $CH_3OH(g)$ was monitored over time, and changes were made to the reaction system at times t_1 and t_2.

What are the possible changes made to the system at t_1 and t_2?

	t_1	t_2
A	CH_3OH was removed	Temperature was increased
B	CO was removed	Temperature was decreased
C	Temperature was increased	CO was removed
D	Temperature was decreased	CH_3OH was added

18 Pure water undergoes slight auto-ionisation:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad K_w \text{ at } 10\,^{\circ}C = 2.9 \times 10^{-15} \text{ mol}^2 \text{ dm}^{-6}$$

Which of the following equations about water at 10 °C is true?

A pH > 7

B pH = 7

C pH < 7

D $[H^+] < [OH^-]$

19 Trimethylamine, $(CH_3)_3N$, has a pK_b of 4.1.

10.0 cm³ of 0.1 mol dm⁻³ $(CH_3)_3N$ was pipetted into a conical flask and titrated against 10.00 cm³ of 0.1 mol dm⁻³ HCl.

Which of the following statements is true about the pH of the reaction mixture?

	before addition of HCl	after adding 10.00 cm³ HCl
A	11.5	5.6
B	11.5	9.9
C	13.8	5.6
D	13.8	9.9

20 The blood buffer system in the human body which maintains the pH of blood at 7.40 can be represented with the following equilibrium:

$$H_2O(l) + CO_2(g) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \qquad K_a = 7.9 \times 10^{-7} \text{ mol dm}^{-3}$$
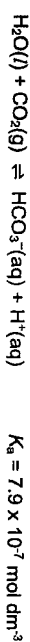
Which of the following statements about the blood buffer system is **not** true?

A During vigorous exercise which produces large amounts of lactic acid in the blood, the body regulates pH by exhaling more CO_2.

B When a person hyperventilates (breathes in and out excessively quickly), the loss of CO_2 causes the pH of blood to increase slightly.

C The pH of blood is 7.40 when the ratio of $[HCO_3^-]:[CO_2]$ is 16:1.

D The blood buffer system is made up of H_2CO_3 and HCO_3^-.

21 Ag_2CO_3 is a sparingly soluble salt with a K_{sp} value of 8.2×10^{-12} mol³ dm⁻⁹.

Which one of the following statements about a solution containing solid Ag_2CO_3 is correct?

A Addition of NaCl(aq) causes more Ag_2CO_3 solid to dissolve.

B Addition of sodium carbonate increases the solubility of Ag_2CO_3.

C Addition of $AgNO_3$ solution decreases the K_{sp} value of Ag_2CO_3.

D Addition of water decreases the solubility of Ag_2CO_3.

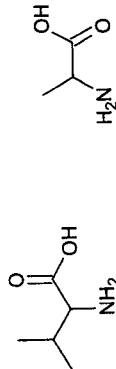**22** Desogestrel is a medication used in birth control pills.
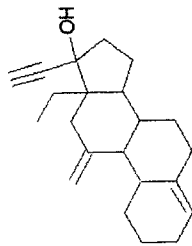
desogestrel

How many stereoisomers does desogestrel have?

A 2^4 B 2^5 C 2^6 D 2^7

23 The structures of two amino acids are given below.

Which of the following statements about the amino acids is correct?

A Both compounds are able to form zwitterions.

B Both compounds are able to react with ethanoic acid in the presence of concentrated sulfuric acid to give an amide.

C Both compounds are able to react with $NaBH_4$ in methanol to give an alcohol.

D Both compounds are soluble in water due to the formation of intermolecular hydrogen bonding.

**24** Benzene, C_6H_6, is a non-polar molecule.

Which of the following statements are true about benzene?

1 Benzene is a good conductor of electricity due to its delocalised π electrons.

2 Benzene undergoes addition reactions readily due to its unsaturated C=C bonds.

3 The enthalpy change of hydrogenation of benzene is less exothermic than that predicted for cyclohexatriene.

4 The C–C bond lengths in benzene are all equivalent and shorter than a typical C–C single bond length.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D 3 and 4 only

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

Compound **J** can be synthesised starting from benzene.

J
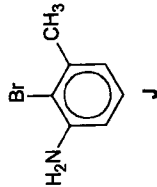
Which of the following synthetic routes will yield the optimum amount of **J**?

A alkylation → bromination → nitration → reduction

B alkylation → nitration → reduction → bromination

C bromination → alkylation → nitration → reduction

D bromination → nitration → alkylation → reduction

[Turn over

26 Alkynes can be deprotonated to form strong nucleophilic ions known as acetylides.

$$H_3C-C{\equiv}C-H \longrightarrow H_3C-C{\equiv}C{:}^- + H^+$$
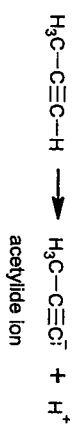
acetylide ion

The acetylide ion can react with carbonyl compounds. An example of such a reaction is shown below:
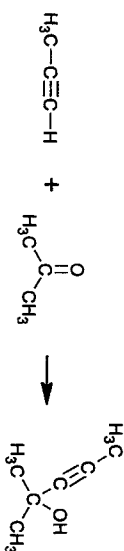
Which of the following reaction schemes does **not** show the correct corresponding product formed?

A

B

C

D
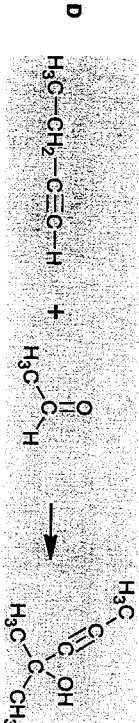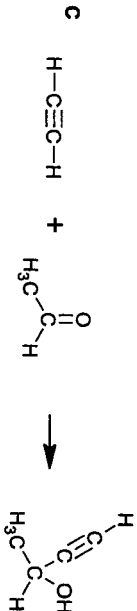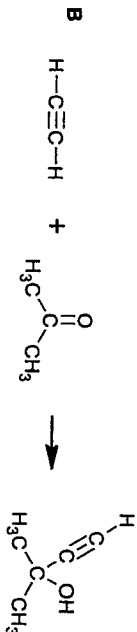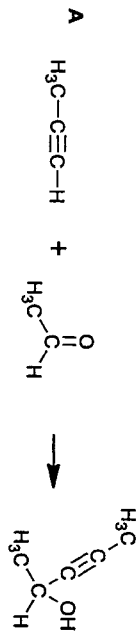
27 Compound **K** has the following structure:

K
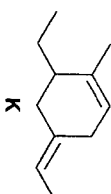
Which of the following statements are correct when **K** is treated with hot acidified KMnO₄?

1   There is only one organic product.

2   The product(s) contain at least one carbonyl functional group.

3   The product(s) contain at least one carboxylic acid functional group.

A   1 only

B   1 and 2 only

C   2 and 3 only

D   1, 2 and 3

28 A Period 3 chloride and Period 3 oxide are dissolved in two separate portions of water to form aqueous solutions.

Both of the resulting solutions can be used to dissolve Al₂O₃ but only one of the two can dissolve SiO₂ slightly.

Which of the following could be the chloride and the oxide used?

	chloride	oxide
1	PCl₅	P₄O₁₀
2	MgCl₂	SO₃
3	SiCl₄	Na₂O

A   2 only

B   3 only

C   1 and 2 only

D   1 and 3 only

15

29 Which of the following correctly describes the complex formed when different reagents are added to solid copper(II) sulfate?

	reagent added	colour of resultant solution	identity of coloured complex ion
A	H_2O	pale blue	$[Cu(H_2O)_6]^+$
B	H_2O, followed by Zn	pink	$[Cu(H_2O)_6]^+$
C	conc. HCl	yellow	$[CuCl_6]^{4-}$
D	excess $NH_3(aq)$	dark blue	$[Cu(NH_3)_4(H_2O)_2]^{2+}$

30 Solid Cr_2O_3 can be used as a catalyst in the synthesis of methanol.

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

Which of the following statements is **false** about the use of Cr_2O_3 in this synthesis?

A Cr_2O_3 functions as a catalyst by increasing the concentration of reactant molecules on its surface.

B Cr_2O_3 lowers the activation energy by using its partially filled 3d orbitals for the adsorption of reactant molecules.

C The Cr atom of Cr_2O_3 is able to form temporary bonds to the reactants.
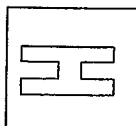
D The oxidation state of Cr is increased after the reaction.

END OF PAPER 1

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BP~844

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H2 CHEMISTRY

Paper 2 Structured Questions

2022 Preliminary Exams
Pre-University 3

9729/02
14 Sep 2022
2 hours

Candidates answer on the Question paper.

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work 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.

Answer all questions.

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.

Question	1	2	3	4	5	Total
Marks	20	13	24	9	9	75

This question paper consists of **16** printed pages and **2** blank pages.

BP~845

Answer all questions in the spaces provided.

1   Many household tools are made from stainless steel as it is highly resistant to corrosion and rust. Stainless steel contains iron, chromium, manganese, nickel, molybdenum, silicon and carbon which interacts with oxygen from water and air to form oxides. Of these elements, chromium has the highest resistance to corrosion.

Despite the high resistance, rusting still occurs in a humid environment. A 'Do-it-Yourself' (DIY) kit has been launched in the market to remove rust from household tools and the set-up is shown in **Figure 1.1**.

Iron sheet

Rusty tool

Na_2CO_3 (aq)

Figure 1.1
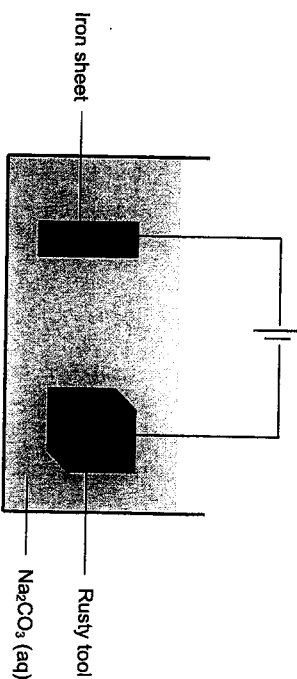
(a) (i) State if the iron sheet is the anode or the cathode. [1]

(ii) *Use of Data Booklet is relevant to this question.*

State and explain the observations found at the iron sheet electrode.

The iron sheet will becomes smaller. (i)

$Fe \rightarrow Fe^{2+} + 2e$ $E^\circ = -0.44$ V

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ $E^\circ = +1.23$ V (ii)
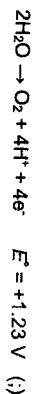
Since $E^\circ_{Fe^{2+}/Fe}$ is more negative than $E^\circ_{(O2/H2O)}$, Fe is preferentially oxidized to Fe^{2+}. (i) [2]

(iii) Suggest why carbonate ions from Na_2CO_3 electrolyte cannot be oxidised at the anode.

Carbon in carbonate is at the maximum oxidation state of +4 or the electrode potential involving carbonate ion is very positive. [1]

(iv) A consumer saw the DIY kit and decided to purchase it and try out on his rusted dumbbell. He prepared the set up as shown in **Figure 1.1** with a 20 A power source and switched it on for 6 hours.

Determine the change in mass of the iron sheet. [2]

$Q = It = 20 \times 6 \times 60 \times 60 = 432000$ C
Amount of electrons = $432000 / 96500 = 4.477$ mol (;)
Amount of Fe = $4.477 / 2 = 2.238$ mol
Mass of Fe = $2.238 \times 55.8 = 125$ g (;) [1]

(b) Fe_2O_3 is the main constituent of the rust found on household items. The standard electrode potentials involving the iron containing species can be found in **Table 1.1**.

Table 1.1

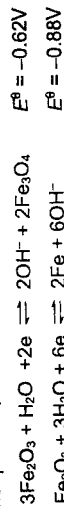| Half-equations	$E^\ominus$/V
$3Fe_2O_3 + H_2O + 2e \rightleftharpoons 2OH^- + 2Fe_3O_4$	-0.62
$Fe_2O_3 + 3H_2O + 6e \rightleftharpoons 2Fe + 6OH^-$	-0.88
$Fe_3O_4 + 4H_2O + 8e \rightleftharpoons 3Fe + 8OH^-$	-0.91

A layer was coated around the rusty tool after using the DIY kit. With reference to the standard electrode potentials given in **Table 1.1**, explain fully whether the layer coated is iron. [2]

Using data from the question,

$3Fe_2O_3 + H_2O + 2e \rightleftharpoons 2OH^- + 2Fe_3O_4$ $E^\ominus = -0.62V$
$Fe_2O_3 + 3H_2O + 6e \rightleftharpoons 2Fe + 6OH^-$ $E^\ominus = -0.88V$

$Fe_3O_4 + 4H_2O + 8e \rightleftharpoons 3Fe + 8OH^-$ $E^\ominus = -0.91V$

The layer is Fe_3O_4. Since $E^\ominus_{Fe2O3/Fe3O4}$ is more positive/less negative than $E^\ominus_{Fe2O3/Fe}$, Fe_2O_3 will be reduced to Fe_3O_4 and not to Fe. (;)
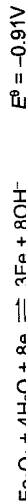
It is not possible to regenerate pure iron as the reduction potential $E^\ominus_{Fe3O4/Fe}$ is the least positive/most negative, thus Fe_3O_4 will not be further reduced. (;)

Hence, the layer coated is Fe_3O_4.

(c) The metal alloy that made up the main components of stainless steel are transition metals.

(i) Define *transition metal*. [1]

[Turn over

A transition element is a **d-block element** which forms **at least one simple ion**, in compounds, with a **partially filled d-subshell**.

(ii) State a physical property of transition metals which makes them a suitable material used for household tools compared to main group metals. [1]

They have high densities

(iii) Iron(III) ions catalyse the reaction between I⁻ ions and $S_2O_8^{2-}$ ions through homogeneous catalysis.

Explain the term *homogeneous catalyst*.

The catalyst is in the **same phase** as the reactants and **it speeds up the rate of reaction by lowering the activation energy** without itself being chemically changed at the end of the reaction. .

(iv) By considering relevant E° values from the Data Booklet, and using balanced equations, determine whether chromium(III) ions are suitable catalyst for the reaction between I⁻ ions and $S_2O_8^{2-}$ ions. [2]

No it is not suitable as the E_{cell} for one of the step is less than zero, making the reaction non-spontaneous. (;)

$2Cr^{3+} + 2I^- \rightarrow I_2 + 2Cr^{2+}$ $E_{cell} = -0.41 - (+0.54) = -0.95$ V(;)
$2Cr^{2+} + S_2O_8^{2-} \rightarrow 2Cr^{3+} + 2SO_4^{2-}$ $E_{cell} = +2.01 - (-0.41) = +2.42$ V

(v) Describe the structure and bonding in the element chromium. Draw a diagram to illustrate your answer. [2]

(;)
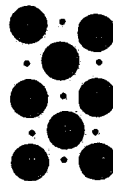
Cr has giant metallic structure held by strong electrostatic forces of attraction between (positive) chromium ions and 'sea' of delocalised electrons. (;)

(d) Chromium(III) oxide has the same acid-base behaviour as aluminium oxide.

(i) State the type of oxide chromium(III) oxide exists as in terms of its acid-base behaviour. [1]

Amphoteric oxide

(ii) By quoting relevant data from the *Data Booklet*, explain why chromium(III) oxide and aluminium oxide have the same acid-base behaviour. [2]

Cr^{3+} has an ionic radius of 0.062 nm while Al^{3+} has an ionic radius of 0.050 nm (∴) while both have the charge of +3. As the charge density of the cations are similar(∴), they have similar degree of covalent character, hence behave similarly.

(iii) *Use of Data Booklet is relevant to this question.*
Describe the observations when dilute NaOH is slowly added to the solution containing chromium(III) ions until in excess.
Grey-green precipitate is formed which dissolves in excess to give a dark green solution. [2]

[Total: 20]

2 (a) An aqueous solution of chlorine dioxide undergoes disproportionation in sodium hydroxide to form chlorate(V) ion, ClO_3^-, and hypochlorite ion, ClO^-. The reaction is catalysed by OBr^- ion.

$$4ClO_2(aq) + 4OH^-(aq) \xrightarrow{OBr^-} 3ClO_3^-(aq) + ClO^-(aq) + 2H_2O(l)$$

To study the kinetics of this reaction at 25 °C, initial rates were measured using various concentrations of ClO_2, OH^- and OBr^-.

experiment	$[ClO_2]/$ mol dm⁻³	$[OH^-]/$ mol dm⁻³	$[OBr^-]/$ mol dm⁻³	initial rate/ mol dm⁻³ s⁻¹
1	0.02	0.05	0.01	2.30 × 10⁻³
2	0.10	0.02	0.03	6.90 × 10⁻²
3	0.02	0.10	0.01	4.60 × 10⁻³
4	0.04	0.02	0.03	1.10 × 10⁻²

(i) Explain, in terms of oxidation numbers, why this reaction is a disproportionation reaction. [2]

The oxidation number of Cl in ClO_2 increases from +4 to +5 in ClO_3^- and decreases from +4 to +1 in ClO^-(∴) Since ClO_2 is oxidised and reduced at the same time(∴), it is a disproportionation reaction.

(ii) Determine the orders of reaction with respect to ClO_2, OH^- and OBr^-. [3]

Comparing experiment 1 and 3, when $[OH^-]$ increases by 2 times, keeping $[ClO_2]$ and $[OBr^-]$ constant, initial rate is increased by 2 times, order of reaction w.r.t OH^- is 1.

Comparing experiment 2 and 4, when $[ClO_2]$ increase by 2.5 times, keeping $[OH^-]$ and $[OBr^-]$ constant, initial rate is increased by 6.27 times, order of reaction w.r.t. ClO_2 is 2.

Let the rate equation be: rate = $k[ClO_2]^2[OH^-][OBr^-]^x$
Using Expt 1 and 4

$$\frac{2.30\times10^{-3}}{1.10\times10^{-2}} = \frac{k(0.02)^2(0.05)(0.01)^x}{k(0.04)^2(0.02)(0.03)^x}$$

$$0.3345 = \left(\frac{0.01}{0.03}\right)^x$$

$$x = 1$$

order of reaction w.r.t. OBr^- is 1.

(iii) Hence, write the rate equation for the reaction. [1]
Rate = $k[ClO_2]^2[OH^-][OBr^-]$

(iv) Calculate the rate constant, k, of the reaction and state its units. [2]
Using Expt 1,
$2.3 \times 10^{-3} = k(0.02)^2 (0.05)(0.01)$
$k = 11500$ (∴) mol³ dm⁹ s⁻¹ (∴)

(v) Determine the initial pH of an aqueous solution of the reaction mixture if the concentration of chlorine dioxide is 0.200 mol dm⁻³ and the concentration of OBr^- is 0.1 mol dm⁻³, given that the initial rate of reaction is 1.45 mol dm⁻³ s⁻¹. [2]

$1.45 = 11500 [0.200]^2[0.1][OH^-]$

$[OH^-] = 0.03152$ mol dm⁻³ (∴)
pOH = -log $[OH^-]$
= 1.50
pH = 14 – 1.50 =12.5(∴)

[Turn over

7

(b) With an appropriate sketch of the Maxwell-Boltzmann distribution, explain how a rise in temperature affects the rate of reaction. [3]

No. of molecules

Proportion of molecules with KE $\geq E_a$ at T_1

Proportion of molecules with KE $\geq E_a$ at T_2

$T_2 > T_1$

T_1

T_2

E_a
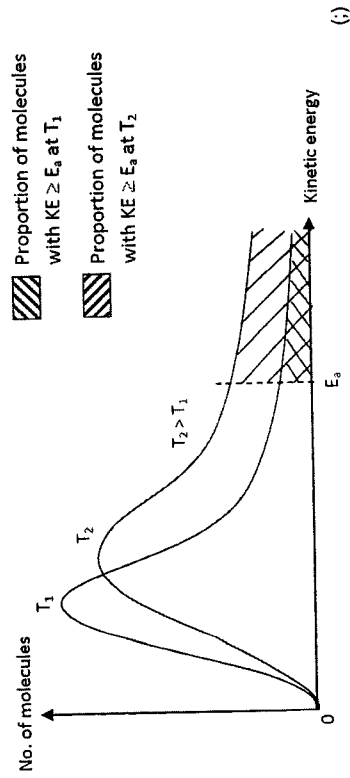
Kinetic energy

At higher temperatures, molecules gain kinetic energy. (;) The fraction of molecules with kinetic energy greater than or equal to activation energy increases. Thus, frequency of effective collision increases, rate increases. (;)

[Total: 13]

8

3 Alpha hydroxy acids (AHA) have a general formula of RCH(OH)COOH. They are a group of plant and animal-derived acids used in a variety of skincare products and are known to tackle hyperpigmentation and signs of skin aging.

(a) (i) Explain why AHAs are generally water-soluble. [2]

Energy given out from the formation of hydrogen bonding between AHA and water is sufficient to overcome the hydrogen bonding between AHA and between water molecules.

(ii) Glycolic acid, $CH_2(OH)COOH$, lactic acid, $CH_3CH(OH)COOH$, and mandelic acid, $C_6H_5CH(OH)COOH$, are examples of AHA.

Suggest, with reasoning, which of the three AHAs is the most soluble in water. [1]

Glycolic acid as it is the most polar with the smallest hydrocarbon chain.

(b) Mandelic acid can be synthesised in the laboratory from benzaldehyde by the following reactions.

CHO

benzaldehyde

step 1

CH(OH)CN

step 2

CH(OH)COOH

mandelic acid
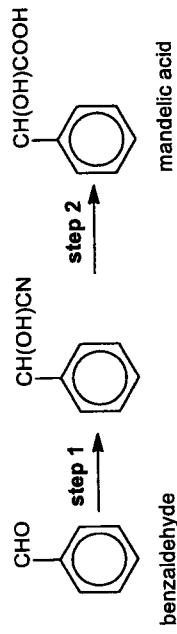
(i) State the reagent and conditions used in step 1. [1]

HCN, trace amount of NaCN, cold

(ii) State the type of reaction that occurs in step 1 and 2. [2]

Step 1: Nucleophilic addition

Step 2: acidic hydrolysis

(iii) Describe the mechanism of the reaction in step 1. Show clearly all charges and the intermediate formed and use curly arrows to indicate the movement of electron pairs. [3]

$HCN \rightleftharpoons H^+ + CN^-$

$NaCN \rightarrow Na^+ + CN^-$

[Turn over
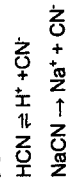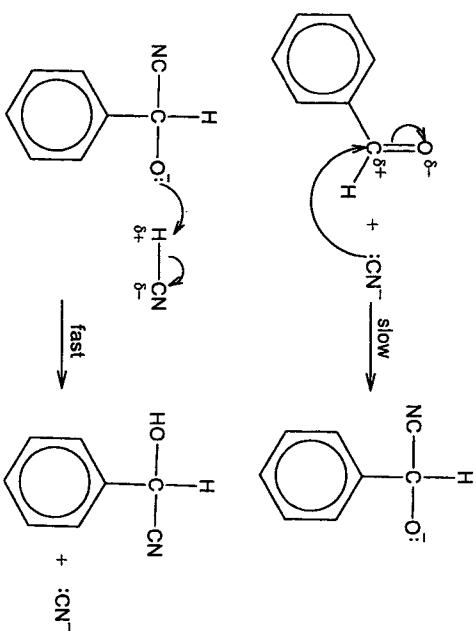
(iv) Predict, with reasoning, whether the product of **step 1** is able to rotate plane-polarised light.

There is a trigonal planar arrangement about the carbonyl carbon (✓). The CN⁻ nucleophile can attack from either side of the plane with equal probability. This results in an equimolar mixture of both enantiomers/ racemic mixture (✓) being formed which does not rotate the plane of polarised light. (✓)

[3]

(v) A scientist carrying out the synthesis of mandelic acid would like to check if all the reactants in **step 1** have been used up.

Devise a suitable chemical test which can help him verify if all the reactants in **step 1** have been used up and include observations in your answer.

Add Tollens' reagent and warm to a small sample of the reaction mixture. (✓)

No silver mirror precipitate will be formed if all the reactants have been used up. (✓)

[2]

(c) Glycolic acid is produced by plants during photorespiration and is recycled by conversion to glycine, H_2NCH_2COOH, within the cytoplasm. The same conversion can be done in the laboratory.

Devise a two-step synthetic route that converts glycolic acid to glycine in a laboratory.

Include the reagents and conditions and the structure of the intermediate product.

$HOCH_2COOH \rightarrow ClCH_2COOH \rightarrow H_2NCH_2COOH$

Step 1: HCl(g) / NaCl, conc H_2SO_4, heat

Step 2: excess concentrated ethanolic NH_3, heat in sealed tube

[3]

(d) A polypeptide made up of 10 amino acid residues is partially hydrolysed to give four smaller fragments. The four fragments are:

ala-gly-ser-gln

lys-trp-arg-pro

gln-his-lys

asp-ala-gly.

Deduce the sequence of the peptide chain. [1]

asp-ala-gly

ala-gly-ser-gln

gln-his-lys

lys-trp-arg-pro

asp-ala-gly-ser-gln- his-lys-trp-arg-pro

(e) Amino acids can be neutral, positively or negatively charged, depending on the pH of the solution.

Amino acid exists as zwitterions at the isoelectric point.

(f) Define *zwitterion*. [1]

Zwitterion is a dipolar ion formed by the intramolecular migration of the proton (H+), from the carboxyl group to the amino group. There is no net charge and is electrically neutral.

(ii) Aspartic acid is an α-amino acid which has the R group –CH_2COOH.
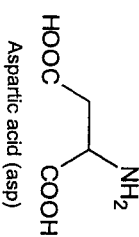
Aspartic acid (asp)

When fully protonated, the pK_a values of the acidic groups are 1.88, 3.65 and 9.60.

Draw the fully protonated aspartic acid and assign the pK_a values. [2]

9.60   3.65   1.88
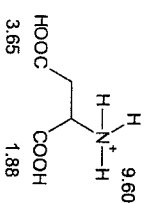
(iii) Hence, draw the major species of aspartic acid at pH 5. [1]
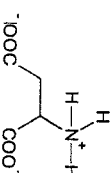
(iv) Aspartic acid was accidentally mixed with lysine at pH 5.

H_3N^+ ... NH_3^+ / COO^-

lysine at pH 5

Electrophoresis is a technique to separate the amino acids in an electric field. The sample was loaded onto an electrophoresis tank buffered at pH 5.0 and an electric field was applied.

On **Figure 3.1**, draw and label the relative positions of lysine and aspartic acid after the electrophoresis.

negative electrode — sample loaded here — positive electrode

Figure 3.1

negative electrode — sample loaded here — positive electrode

lysine ← → aspartic acid

[2]
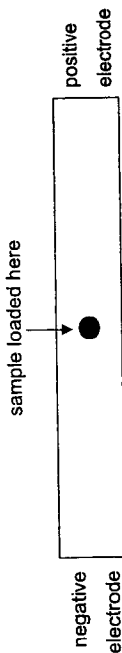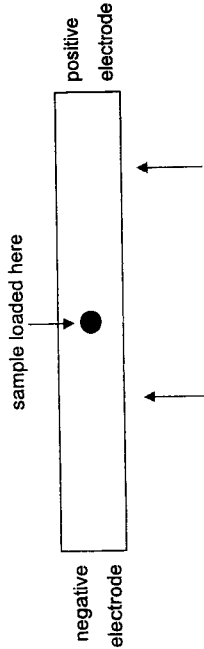
4 (a) Methane, CH$_4$ is the second major greenhouse gas after CO$_2$, exerting a significant influence on the climate and the chemistry of the atmosphere.

Biological methods have also been developed to produce methane from organic acids using bacteria. An example of this reaction where methane is produced from butanoic acid is shown below.

____ CH$_3$CH$_2$CH$_2$COOH(l) + ____ H$_2$O(l) → ____ CH$_4$(g) + ____ CO$_2$(g) ΔH_r
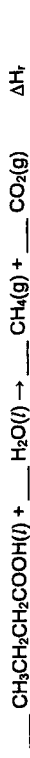
(i) Calculate the average oxidation state of C in each of the following carbon-containing compound.

C in CH$_3$CH$_2$CH$_2$COOH: ....

C in CH$_4$: ....

C in CO$_2$: ....

C in CH$_3$CH$_2$CH$_2$COOH: -1

C in CH$_4$: -4

C in CO$_2$: +4   [1]

(ii) Hence, or otherwise, balance the equation by filling in the stoichiometric coefficient in the above equation where methane is produced from butanoic acid in (a).   [1]

2CH$_3$CH$_2$CH$_2$COOH + 2H$_2$O → 5CH$_4$ + 3CO$_2$
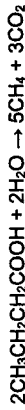
(iii) Using the thermochemical data shown in **Table 4.1**, draw a fully-labelled energy cycle to calculate the standard enthalpy change of reaction, ΔH_r in (a).

Table 4.1

Standard enthalpy change of formation of liquid butanoic acid	−534 kJ mol^{-1}
Standard enthalpy change of combustion of carbon	−394 kJ mol^{-1}
Standard enthalpy change of combustion of hydrogen	−286 kJ mol^{-1}
Standard enthalpy change of formation of methane	−78.4 kJ mol^{-1}

[3]

$\Delta H_{rxn} = -2(-534) - 2(-286) + 5(-78.4) + 3(-394) = +66.0$ kJ mol^{-1}

2CH$_3$CH$_2$CH$_2$COOH(l) + 2H$_2$O(l) $\xrightarrow{\Delta H_r}$ 5CH$_4$(g) + 3CO$_2$(g)

8C(s) + 10H$_2$(g) + 3O$_2$(g)

2(-534)   2(-286)   5(-78.4)   3(-394)
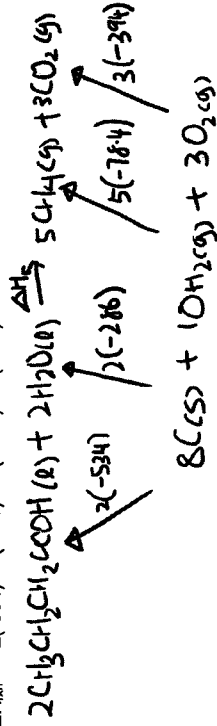
1m for balanced energy cycle

1m for correct substitution of values

1m for final answer

[Total: 24]

[Turn over

(iv) Hence, predict the sign of ΔS for the reaction in (a) and explain the spontaneity of the reaction at high temperatures.
[2]

- ΔH is positive

- ΔS is <u>positive</u> as the <u>number of gaseous particles increases.</u> [1]

- <u>−TΔS is negative</u>

- Since ΔG = ΔH − TΔS

- ⇨ ΔG will <u>only be negative</u> when T is large and the reaction is spontaneous at high temperatures. [1]

(b) Trouton's rule states that the entropy change of vapourisation for liquids such as benzene and hexane at their boiling points is almost the same value at around +85 to +88 J K⁻¹ mol⁻¹.

However, the entropy change of vapourisation for butanoic acid is +130 J K⁻¹ mol⁻¹.

Compare and explain the difference in the entropy change of vapourisation for butanoic acid and benzene.
[2]

ΔS°_{vap}(butanoic acid) is more positive than +85 J mol⁻¹ K⁻¹(;), as hydrogen bonds between butanoic acid molecules in the liquid state reduces its entropy due to the relatively strong intermolecular forces of attraction between the molecules which results in less ways to arrange the molecules. In the gaseous state, the molecules are further apart and would be much more disordered with less significant intermolecular forces of attraction between the molecules. (;)

[Total: 9]

5 Compounds **P, Q, R** and **S** are oxides or chlorides of Period 3 elements.

Table 5.1 shows some properties of the compounds.

Table 5.1

Compounds	Melting point	Solubility in water	pH of solution
P	High	Yes	13
Q	Low	Yes	2
R	High	Yes	6.5
S	High	No	

(a) Based on the information from **Table 5.1**, deduce the identities of compounds **P** and **R** and write the equations to justify the pH of the respective solutions.
[2]

P: Na_2O

$Na_2O + H_2O \rightarrow 2NaOH$

R: $MgCl_2$

$MgCl_2 + 6H_2O \rightarrow [Mg(H_2O)_6]^{2+} + 2Cl^-$

$[Mg(H_2O)_6]^{2+} + H_2O \rightleftharpoons [Mg(H_2O)_5(OH)]^+ + H_3O^+$
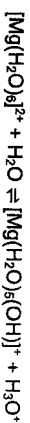
(b) **S** is only soluble in hot concentrated sodium hydroxide.

Identify compound **S** and write the equation for the reaction with hot concentrated sodium hydroxide.
[2]

S is $\underline{SiO_2}$ (as it has a high melting point, insoluble in water and only reacts with hot concentrated NaOH.)

Reaction of **S** with hot NaOH:
$\underline{SiO_2 (s) + 2OH^- (aq) \rightarrow SiO_3^{2-} (aq) + H_2O (l)}$

(c) When water is added to 0.0500 mol of **Q**, the resulting solution requires 0.250 mol of silver nitrate for complete reaction.

Identify compound **Q** and write the equations to show:

- its reaction with water
- the reaction between the resulting solution and silver nitrate [3]

Q is PCl_5

$PCl_5 (s) + 4H_2O(l) \rightarrow H_3PO_4(aq) + 5HCl(aq)$

$HCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + HNO_3(aq)$
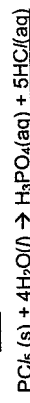
(d) The melting point of compound **P** is 1132 °C while that of potassium carbonate is 891 °C.

Explain the difference in the melting points in terms of structure and bonding. [2]

Na_2O and K_2CO_3 have giant ionic structures held by strong electrostatic forces of attraction between oppositely charged ions.

$L.E. \propto \left| \dfrac{q^+ q^-}{r^+ + r^-} \right|$ Since the charge of cation and anions are the same for both compounds while K^+ is larger in size than Na^+ and CO_3^{2-} is larger than O^{2-}, the magnitude of lattice energy for K_2CO_3 is smaller than Na_2O. Less energy is required to overcome the weaker ionic bonds in K_2CO_3. K_2CO_3 has a lower melting point.

[Total: 9]

END OF PAPER 2

[Turn over

Section A
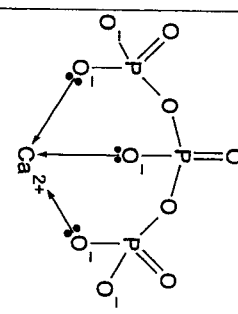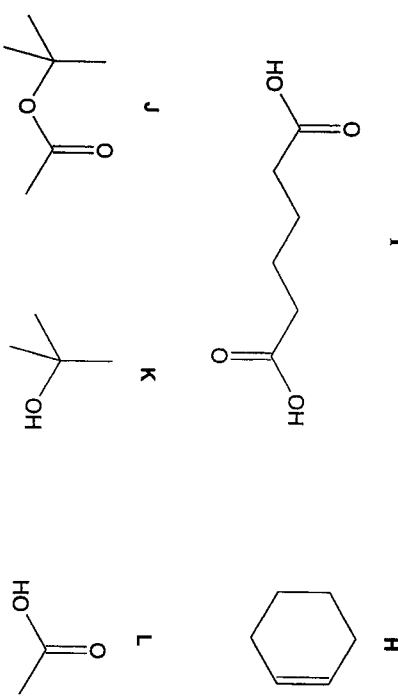
1	(a)	(i)	electron flow / high-resistance voltmeter / Zn / $H_2SO_4(aq)$ / Salt Bridge / V / C / $HNO_3(aq)$	max [1]: battery or mixing of solutions	
			salt bridge		
		(ii)	anode: $Zn \rightarrow Zn^{2+} + 2e^-$	[3] 7 / 7	
			cathode: $NO_3^- + 2H^+ + e^- \rightarrow NO_2 + H_2O$ [1]	[2] 5 / 7	
			sum: $Zn + 2NO_3^- + 4H^+ \rightarrow Zn^{2+} + 2NO_2 + 2H_2O$ or	[1] 3 / 7	
			$Zn + 2HNO_3 + H_2SO_4 \rightarrow ZnSO_4 + 2NO_2 + 2H_2O$ [1]		
		(iii)	$E_{cell} = +0.81 - (-0.76) = +1.57$ V		
		(iv)	concentration of H^+ / NO_3^- higher than 1.00 mol dm^{-3} / temperature higher and reaction is endothermic / NO_2 gas formed escapes the solution [1]		
			equilibrium position of cathode half-equation shifts right, higher E_{cell} [1]		
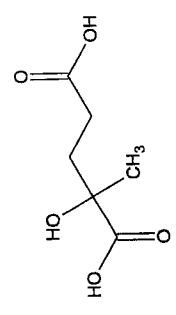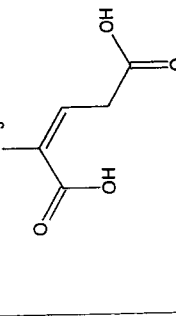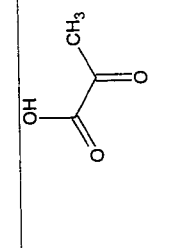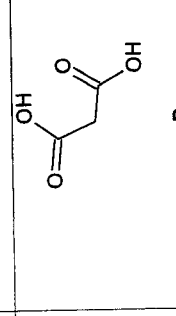
	(b)	(i)			2
		(ii)	$2NO_2(g) \xrightarrow{\Delta H_{reaction}} N_2O_4(g)$		
			$+2(33.2)$ the elements $+9.2$		
		(iii)	$\Delta H_{reaction} = -2(33.2) + 9.2 = -57.2$ kJ mol^{-1}		
			bond is formed between two NO_2		
			energy released / exothermic		
		(iv)	decrease in number of moles of gases [1]		
			decreased ways to arrange molecules (1) and distribute energy (2)		
			decreased disorder (3) hence decreased entropy (4) [1]		
		(v)	$\Delta G = \Delta H - T\Delta S$		
			at high T, $-T\Delta S$ (positive) has larger magnitude than ΔH (negative)		
			$\Delta G > 0$ / more positive		
			at low T, $-T\Delta S$ (positive) has smaller magnitude than ΔH (negative)		
			$\Delta G < 0$ / more negative		

	(vi)		$2NO_2(g)$	$\rightleftharpoons$	$N_2O_4(g)$
		p$_{initial}$ / bar	1.00		0
		p$_{change}$ / bar	−0.702		+0.351
		p$_{final}$ / bar	0.298		0.351

$K_p = \dfrac{p_{N_2O_4}}{p_{NO_2}^2} = \dfrac{0.351}{(0.298)^2} = 3.95$ bar^{-1}

3 (a)

(i) Buffer solutions are solutions which resist pH changes when small amounts of acids or bases are added to it.

(ii) H$^+$ (that tries to leave) are more strongly attracted to the more negatively-charged ion; more difficult dissociation

(iii) $n_{H_2PO_4^-} = \frac{2.00\,g}{136.1\,g/mol} = 0.0147$ mol
hence [H$_2$PO$_4^-$] = 0.0147 mol dm^{-3} [1]
$n_{HPO_4^{2-}} = \frac{1.42g}{142.0\,g/mol} = 0.0100$ mol
hence [HPO$_4^{2-}$] = 0.0100 mol dm^{-3} [1]

$K_a(H_2PO_4^-) = \frac{[H^+][HPO_4^{2-}]}{[H_2PO_4^-]} = 10^{-7.20}$
$\frac{[H^+](0.0100)}{(0.0147)} = 10^{-7.20}$
hence [H$^+$] = 9.275 × 10^{-8} mol dm^{-3} [1]
hence pH = 7.03 [1]

(iv) H$_2$PO$_4^-$ + OH$^-$ → HPO$_4^{2-}$ + H$_2$O

(v) I: 10.0 cm^3

	H$_2$PO$_4^-$	+	OH$^-$	→	HPO$_4^{2-}$	+	H$_2$O
Before rxn /mol	0.00147		0.0001		0.001		
Change	-0.0001		-0.0001		+0.0001		
After rxn /mol	0.00137		0		0.0011		[1]

pH = 7.20 + log $\frac{(0.0011/_V)}{(0.00137/_V)}$ = 7.10 [1]

II: 200 cm^3

	H$_2$PO$_4^-$	+	OH$^-$	→	HPO$_4^{2-}$	+	H$_2$O
Before rxn /mol	0.00147		0.002		0.001		
Change	-0.00147		-0.00147		+0.00147		
After rxn /mol	0		0.000530		0.00247		[1]

[OH$^-$] = $\frac{0.000530}{0.3}$ = 0.001768 [1]
pOH = 2.75
pH = 14 − 2.75 = 11.2 [1]

---

2 (a)

(i) octahedral, 90° [1]

6 electron domains
maximise distance from one another to minimise repulsion [1]

(ii) ligands approach at 3 axes ()

z^2 and x^2-y^2 point at 3 axes, greater electronic repulsion, higher energy
xy, yz and xz point away from the 3 axes / diagonal, less electronic repulsion, lower energy
[2] 6/6
[1] 3/6

(iii) less electronic repulsion
as z^2 is further away from the ligand / z^2 points directly at axial ligands

(iv) Co^{2+}: [Ar] 3d^7
yes, decreased energy of z^2 electron
[2] 4/4
[1] 2/4

Ni^{2+}: [Ar] 3d^8
no net energy change, decreased z^2 electron energy, increased x^2-y^2 electron energy
or even number of electrons

(v) Cu$^+$: [Ar] 3d^{10}
Since the d orbitals are fully-filled, there is no d-d transition. Hence, the complex ions are not coloured.

(b)
Cu^{2+} + 2e$^-$ → Cu   E = +0.34 V
Cu + 4NH$_3$ → [Cu(NH$_3$)$_4$]$^{2+}$ + 2e$^-$ E = +0.05 V

E$_{cell}$ = +0.34 + 0.05 = +0.39 V [1]

ΔG = −nFΔE$_{cell}$ = −(2)(96500)(+0.39) = −75.3 kJ mol^{-1} < 0, hence feasible [1]

(b)	(i)	2Na₂HPO₄ + NaH₂PO₄ → Na₅P₃O₁₀ + 2H₂O	
	(ii)	tetrahedral	
	(iii)		overall 3-charge okay
	(iv)	$[Ca^{2+}]$ present $= \dfrac{5.06 \times 10^{-5}\ g/dm^3}{40.1\ g/mol} = 1.2618 \times 10^{-6}$ mol dm⁻³ [1] $K_{sp}(Ca_3(PO_4)_2) = [Ca^{2+}]^3[PO_4{}^{3-}]^2 = 2.07 \times 10^{-33}$ mol⁵ dm⁻¹⁵ $[Ca^{2+}]^3(6.53 \times 10^{-8})^2 = 2.07 \times 10^{-33}$ hence maximum $[Ca^{2+}]$ allowed in solution $= 7.859254 \times 10^{-7}$ mol dm⁻³ [1] hence $n_{Ca^{2+}}$ to remove $= n_{Na_5P_3O_{10}}$ to add $= 1.2618 \times 10^{-6} - 7.859254 \times 10^{-7}$ $= 4.7587 \times 10^{-7}$ mol mass of Na₅P₃O₁₀ to add $= 4.7587 \times 10^{-7}$ mol $\times 368.0$ g/mol $= 1.75 \times 10^{-4}$ g [1]	

4 (a)

(b)

Information	Deduction
A, C₆H₁₀O₅, is a chiral compound	A has a carbon with 4 different groups / atoms attached to it
When 1 mol of A is reacted with excess solid sodium carbonate at room temperature and pressure, 24 dm³ of CO₂ is formed.	Acid-carbonate reaction; A has 2 -COOH groups
A does not react with hot acidified potassium dichromate(VI)	A cannot be oxidised
A reacts with excess hot concentrated H₂SO₄ to form B, C₆H₆O₄	elimination; A has a tertiary alcohol (since cannot be oxidised but can undergo elimination); B has an alkene group
1 mol of B reacts completely with 2 mol of NaOH(aq)	B has 2 -COOH groups; acid-base reaction
When B is heated with acidified KMnO₄(aq), C, C₃H₄O₃, and D, C₃H₄O₄, are formed.	oxidative cleavage / oxidation
C gives a yellow precipitate with warm aqueous alkaline iodine	C has CH₃CO-; oxidation
Both C and D reacts with magnesium to give effervescence	Both C and D have -COOH group

BP~855

S_N2 (accept only if (ii) is S_N2):

- 3D tetrahedral reactant molecule
- $\delta+$ and $\delta-$
- arrow from N lone pair to C
- arrow from C–Cl bond to Cl

- trigonal bipyramidal transition state with dotted lines
- square brackets, dagger
- C–NH$_3^+$ intermediate

- arrow from Cl⁻ ion lone pair to H
- arrow from N–H bond to N+
- 3D tetrahedral product molecule
- HCl by-product molecule

		no need to name again
		[3] 10/11
		[2] 7/11
		[1] 4/11

(iv)

any one

use limiting amount of (CH$_3$)$_3$Cl / use excess NH$_3$

OR

HCl (if HCl given as answer, no possible method to limit the formation)

(b) (i)

ion-dipole

| [1] correct 2 species [1] dipoles on HF, correctly labelled |

(ii) HF is a Brønsted acid as it lost / released H⁺

(iii) anode: 2F⁻ → F$_2$ + 2e⁻
cathode: 2H⁺ + 2e⁻ → H$_2$

| electrode labels required |

(iv) $\eta_{KHF_2} = \dfrac{355\,g}{78.1\,g/mol} = 4.545$ mol

$\eta_{HF} = \dfrac{145\,g}{20.0\,g/mol} = 7.25$ mol [1]

from KHF$_2$:

Section B

A

B

C

D

5 (a) (i) $p_TV_T = p_1V_1 + p_2V_2$
$p_T(200) = 155(150) + 80(120)$ [1] sub
$p_T = 164$ kPa [1] ans

(ii) nucleophilic substitution, S_N1

3 electron-donating methyl groups
disperse positive charge
stabilising the carbocation

3 methyl groups
sterically hinder
nucleophile approach from opposite C–Cl

		[2] 4/4
		[1] 2/4

(iii) S_N1:

- 3D tetrahedral reactant molecule
- $\delta+$ and $\delta-$
- arrow from C–Cl bond to Cl
- slow

- trigonal planar intermediate with C+
- arrow from N lone pair to C+
- C–NH$_3^+$ intermediate

- arrow from Cl⁻ ion lone pair to H
- arrow from N–H bond to N+
- 3D tetrahedral product molecule
- HCl by-product molecule

	no need to name again
	[3] 10/11
	[2] 7/11
	[1] 4/11

HCl

(v)

η_{H+} discharged = η_{F-} discharged = 4.545 mol

from HF:

η_{H+} discharged = η_{F-} discharged = 7.25 mol

hence total η_{H+} discharged = total η_{F-} discharged
= 4.545 mol + 7.25 mol = 11.795 mol [1]

pV = nRT

volume of each gas H_2 and F_2, $V = \frac{nRT}{p} = \frac{(5.8977)(8.31)(223)}{101325} = 0.108\ m^3$ [1]

since $\frac{\eta_{H_2}}{\eta_{H+}} = \frac{\eta_{F_2}}{\eta_{F-}} = \frac{1}{2}$, $\eta_{H_2} = \eta_{F_2} = \frac{11.795\ mol}{2} = 5.8977\ mol$

[0] wrong gas
[2] 4 / 4
[1] 2 / 4

(vi)

H_2	F_2	HF
1s 1s	2p 2p	1s 2p

H_2
less electrons
weaker
instantaneous dipole – induced dipole forces of attraction between molecules
more ideal gas

[1] correct orbital overlaps for all 3 molecules
[1] correct orbital labels × 6

6 (a) (i)

name of mechanism: electrophilic substitution

electrophile generation:

$AlCl_3$ + [Cl–C(=O)–CH₃] → $AlCl_4^-$ + [CH₃–C⁺=O]

1m for correct name and correct generation of electrophile (ignore arrows)

benzene attack electrophile:

deprotonation:

→ + $AlCl_3$ + HCl

[2] 7 / 8
[1] 3 / 8

(iii)

- arrow from circle to C+
- slow
- positive charge with break
- side chain attached
- arrow from Cl⁻ lone pair / bond pair to H
- arrow from C–H bond to ring
- restored delocalisation
- HCl

[2] 4 / 4
[1] 2 / 4

hydrocarbon substituent is electron-donating
increasing electron density
of delocalised π electrons in benzene

[2] 2 / 4
[1] 2 / 4

(iii)
more reactive towards (subsequent) electrophilic substitution / benzene becomes a stronger nucleophile to attack electrophile (again)

M: [structure]   **N:** N_2

(b)	(i)	increasing atomic radii down Group 2 [1] although nuclear charge and shielding increases distance of valence electrons from nucleus increases weaker electrostatic forces of attraction between them [1]	
	(ii)	more thermally-stable carbonates down Group 2 [1] lower charge density of Group 2 ions polarises carbonate ion less stronger C–O bond, require more energy to break [1]	
	(iii)	mass of CO_2 = 1.02 g – 0.505 g = 0.515 g $\eta_{CO_2} = \frac{0.515\,g}{44.0\,g/mol} = 0.0117$ mol $= \eta_{XCO_3}$ [1] M_r of $XCO_3 = \frac{1.02}{0.0117} = 87.1$ M_r of X^{2+} = 87.1 – 60.0 = 27.1 [1] nearest Group 2 element is Mg [1]	

(c)	(i)	$UO_2 + 4HF \rightarrow UF_4 + 2H_2O$ [1] $UF_4 + F_2 \rightarrow UF_6$ $UO_2 + 4HF + F_2 \rightarrow UF_6 + 2H_2O$ [1]	*Award 2m if only correct final equation shown.*
	(ii)	UO_2 was oxidised to UF_6 the oxidation state of U increased from +4 (in UO_2) to +6 (in UF_6) [1] F_2 was reduced to UF_6 the oxidation state of F decreased from 0 (in F_2) to –1 (in UF_6) [1]	
	(iii)	M_r of $^{235}UF_6$ = 349 M_r of $^{238}UF_6$ = 352 let abundance of $^{235}UF_6 = x$ $349x + 352(1 - x) = 351.95$ $x \times 100\% = 1.67\%$ [1]	
	(iv)	Since % abundance is less than 2% it cannot be used. [1]	

Candidate Name: _____

H
millennia
institute
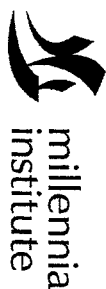
2022 Preliminary Examinations
Pre-University 3

H2 CHEMISTRY   9729/04

Paper 4 Practical   31 Aug 2022

                                               2 hours 30 min

Candidates answer on the Question paper.

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work 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.

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 at the back of the Question Paper.

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.

Question	1	2	3	4	Total
Marks	13	17	12	13	55

---

1 **Determination of amount of water of crystallization in CuSO₄.nH₂O**

Copper is a transition metal capable of exhibiting variable oxidation states. Compounds containing Cu^{2+} ions tend to be relatively stable.

Cu^{2+} ions react with excess potassium iodide, KI, to produce iodine, I_2, and a stable precipitate, CuI. To determine the concentration of Cu^{2+} via iodometric titration, all the Cu^{2+} ions are reduced to Cu^+ ions. A brown suspension, made up of an off-white precipitate of CuI in a brown solution of I_2, will be produced.

equation 1 $2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$

I_2 has a relatively low solubility in water. However, the presence of an excess of I^- ions in the reaction mixture allows the soluble tri-iodide ion, I_3^-, to form as shown by equation 2. This ensures that the I_2 formed as shown in equation 1 is fully dissolved.

equation 2 $I_2 + I^- \rightarrow I_3^-$

The I_3^- ions formed may be titrated against a standard solution of $Na_2S_2O_3$ as shown in equation 3.

equation 3 $I_3^- + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 3I^-$

The solution should be titrated immediately after addition of KI because the I_2 may be adsorbed onto the CuI precipitate, rendering the end-point less sharp.

You are provided with:

FA 1 is solid hydrated copper(II) sulfate, $CuSO_4.nH_2O$, where n is an integer

FA 2 is 0.10 mol dm⁻³ sodium thiosulfate, $Na_2S_2O_3$

FA 3 is 1.00 mol dm⁻³ potassium iodide, KI

FA 4 is 10% potassium thiocyanate, KSCN

Starch indicator

The presence of thiocyanate ion, SCN^-, in the titration mixture near to the end-point will have an impact on the accuracy of the results. The procedure described is designed to improve on the accuracy.

In this experiment, you will determine the amount of water of crystallisation in 1 mol of $CuSO_4.nH_2O$. You will titrate **FA 1** against **FA 2**.

(a) Procedure

Preparation of solution of FA 1

1. Weigh accurately about 5.0 g of **FA 1** in a weighing bottle. Record your readings in an appropriate manner in the space provided below.

2. Transfer all the solid into a 250 cm³ beaker. Dissolve this solid in about 100 cm³ of deionised water.

3. Transfer the solution to a 250 cm³ volumetric flask. Rinse the beaker with deionised water several times, adding each rinsing to the volumetric flask.

4. Make up the solution to 250 cm³ with deionised water. Stopper, invert and shake well to obtain a homogenous solution. Label this solution as **FA 1 solution.**

Results

Mass of empty weighing bottle /g	4.10
Mass of weighing bottle + FA1 /g	9.11
Mass of weighing bottle + residual FA1 /g	4.11
Mass of FA1 /g	5.00

M1: All masses consistently recorded to 2 (or 3) decimal places and correct mass headers   **M1**

M2: Mass of FA 1 used correctly calculated and Mass of FA 1 used 5.00 ±0.05   **M2**

[2]

(b) Titration

1. Fill the burette with **FA 2.**

2. Use a pipette to transfer 25.0 cm³ of **FA 1** solution into a 250 cm³ conical flask.

3. Use a measuring cylinder to add about 15 cm³ of **FA 3** into this flask.

4. Titrate **FA 1** against **FA 2.** Near the end-point, when the brown suspension becomes pale yellow, add about 10 drops of starch solution.

5. Continue adding **FA 2** until the blue-black colour **just** disappears. Add 10 cm³ of **FA 4** using a measuring cylinder.

6. Continue adding **FA 2** slowly. The end-point is reached when the **solution** first becomes colourless. The white precipitate remains.

7. Record your titration results in the space provided on page **4.** Make certain that your recorded results show the precision of your working.

8. Repeat the titration as many times as you think necessary to obtain consistent results.

(i) Results

Initial burette reading / cm³	0.00	0.00	
Final burette reading / cm³	21.00	21.00	
Volume of FA2 added / cm³	21.00	21.00	
	✓	✓	

M3 M4 M5

M3: A table including the appropriate header and units for:

• Initial burette readings
• Final burette readings
• volume added

M4: All accurate burette readings are recorded to the nearest 0.05 cm³.
Do not award this mark if: 50.00cm³ is used as an initial burette reading

M5: Accuracy: Titre/mass ratio: 4.05 ± 0.50

[3]

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

Volume of FA2 = $\frac{21.00+21.00}{2}$ = 21.00 cm³

M6: Correct calculation of the average of two consistent readings within 0.10 cm³ difference   **M6**

Volume of **FA 2** = ... [1]

(c) Calculations

(i) Calculate the amount of iodine, I_2, liberated from 25.0 cm³ of **FA 1** solution.

amount of $S_2O_3^{2-}$ = $\frac{21.00}{1000}$ × 0.10 = 0.00210 mol
amount of I_2 = ½ × 0.00210 = 0.00105 mol

amount of I_2 liberated from 25.0 cm³ of **FA 1** solution = ...[1]   **M7**

[Turn over

(ii) Hence, calculate the amount of copper(II) ions, Cu^{2+}, in 25.0 cm^3 of FA 1 solution.

Amount of Cu^{2+} in 25.0 cm^3 = 2 × 0.00105 = 0.00210 mol

amount of Cu^{2+} in 25.0 cm^3 of FA 1 solution = ...[1]   **M8**

(iii) Determine the amount of $CuSO_4 \cdot nH_2O$ in 250 cm^3 of FA 1 solution.

Amount of Cu^{2+} in 250 cm^3 = 10 × 0.00210 = 0.0210 mol = Amount of $CuSO_4 \cdot nH_2O$

amount of $CuSO_4 \cdot nH_2O$ in 250 cm^3 of FA 1 solution = ...[1]   **M9**

(iv) Calculate the M_r of $CuSO_4 \cdot nH_2O$, and hence the value of n.

[A_r: H, 1.0; O, 16.0; S, 32.1; Cu, 63.5]

$M_r = \dfrac{5.00}{0.0210} = 238.1$

$M_r = 238.1$

$n = \dfrac{238.1 - 63.5 - 32.1 - 16.0 \times 4}{1.0 \times 2 + 16.0} = 4.36 \approx 4$ (nearest integer)

M_r of $CuSO_4 \cdot nH_2O$ = ...   **M10**

value of n = ...[2]   **M11**

(d) Starch forms a dark blue-black complex with the tri-iodide ion, I_3^-. The starch indicator is not added at the beginning of the titration as the resulting complex at high I_3^- concentration is relatively stable, dissociating only slowly.

Predict and explain the effect of adding the starch indicator at the start of the titration on the M_r of $CuSO_4 \cdot nH_2O$ determined in (c)(iv).

Due to the slow release of I_3^- from the starch-I_3^- complex, the end point would have exceeded the equivalence point, resulting in a larger titre value.   **M12**

This leads to larger amount of $CuSO_4 \cdot nH_2O$ hence the M_r would have been smaller than the actual value.   **M13**

[2]

[Total: 13]

[Turn over

---

2 Investigation of the effect of concentration changes on the rate of a reaction

Iodate(V) ions, IO_3^-, also react with sulfite ions, SO_3^{2-}, in the presence of acid to produce iodine:

$$IO_3^-(aq) + SO_3^{2-}(aq) + H^+(aq) \rightarrow I_2(aq) + \text{other products}$$
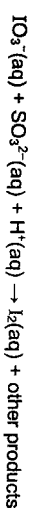
The rate of this reaction is affected by the concentration of acid present in the reaction mixture. In the presence of starch, the iodine produced will give a dark blue colour. Therefore, the effect of the concentration of the acid on the initial rate of the reaction can be studied by measuring the time taken for a fixed amount of iodine to be produced.

You are also provided with:

FA 5 is 0.0500 mol dm^{-3} dilute sulfuric acid, H_2SO_4
FA 6 is 0.0400 mol dm^{-3} sodium sulfite, Na_2SO_3
FA 7 is 3.50 g dm^{-3} aqueous potassium iodate(V), KIO_3
Starch solution (from **Question 1**)

(a) You are required to perform a series of five 'iodine clock' experiments, by varying the concentration of acid and measuring the time, t, taken for the dark blue colour to appear.

- For each experiment, **solution 1** will contain the same volume of FA 6 but a different volume of FA 5. You will need to ensure that the total volume of **solution 1** is kept constant at 50 cm^3 by adding deionised water as required.

- For each experiment, prepare **solution 2** as described in (a)(i).

Note: Use separate measuring apparatus to prepare **solutions 1 and 2**.

For each experiment, you will note the volume of FA 5, $V_{FA 5}$, and the time taken, t, for the reaction mixture to turn dark blue.

You will then calculate the following values to 3 significant figures:

- $1/t$,
- $\lg(1/t)$,
- $\lg(V_{FA 5})$.

In the space provided on page 9, prepare a table in which to record, to an appropriate level of precision:

- all volumes used to prepare **solution 1**,
- all values of t,
- all calculated values of $1/t$, $\lg(1/t)$ and $\lg(V_{FA 5})$.

(i) **Experiment 1**

Solution 1
- Pour 10.0 cm³ of **FA 6** to a 50 cm³ measuring cylinder and make up the volume to 50.0 cm³ by adding **FA 5**.

Solution 2
- Pour 10.0 cm³ of **FA 7** to a 10 cm³ measuring cylinder.

1. Transfer **solution 1** into a 100 cm³ beaker placed on a white tile.
2. Using a 10 cm³ measuring cylinder, add 5.0 cm³ of the starch indicator to the beaker.
3. Pour **solution 2** from the measuring cylinder **rapidly but carefully** into the beaker containing **solution 1**. Start the stopwatch immediately.
4. Stir the mixture using a glass rod.
5. Stop the stopwatch when the dark blue colour first appears.
6. Record the time taken, t, to the nearest second in your table.
7. Wash the beaker thoroughly with water and dry it.

(ii) **Experiment 2**

8. Prepare a different **solution 1** using 10.0 cm³ of **FA 6** and 10.0 cm³ of **FA 5**. Make up the volume to 50.0 cm³ by adding deionised water.
9. Prepare **solution 2** as described in **experiment 1** above.
10. Repeat steps 1 to 7.

(iii) **Experiment 3 to 5**

Choose **three** other suitable volumes of **FA 5**, between 10.0 cm³ and 40.0 cm³, for use in the remaining three experiments.

In each case,
- Use 10.0 cm³ of **FA 6**, together with your selected volume of **FA 5** and deionised water to prepare 50.0 cm³ of **solution 1**.
- Prepare **solution 2** as described in **experiment 1**.
- Determine the time taken, t, for the solution to turn dark blue.

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

[Turn over]

Results

Volume of FA5 / cm³	Volume of FA6 / cm³	Volume of deionised water / cm³	time /s	$\frac{1}{t}$ / s⁻¹	$\lg \frac{1}{t}$	$\lg (V_{FA5})$
40.0	10.0	0.0	4	0.250	-0.602	1.60
10.0	10.0	30.0	28	0.0357	-1.45	1.00
20.0	10.0	20.0	15	0.0667	-1.18	1.30
25.0	10.0	15.0	12	0.0833	-1.08	1.40
30.0	10.0	10.0	9	0.111	-0.954	1.48

M14: Table with correct headers and units
- volumes of **FA 5**, **FA 6** and deionised water
- time
- $1/t$
- $\lg (1/t)$
- $\lg (V_{FA5})$

M15: Record all data with correct precision
- volumes to 0.5 cm³
- t to nearest second
- calculated values to 3 sf

M16: Complete set of volume of **FA 5** and time readings for 5 experiments and all values of t increase as volume of **FA 5** decreases. Data for experiments 1 and 2 must be included

M17: Choose 3 other well-spaced values for the volume of **FA 5**. All volumes must differ by at least 5 cm³

M18: Correctly calculate $1/t$, $\lg (1/t)$ and $\lg (V_{FA5})$ values for all stated experiments.

[5]

Graphical determination of order of reaction

In a series of experiments, where the same end-point (i.e. appearance of dark blue colour) is timed, while changing the concentration of one of the reactants and keeping the total volume of the mixture constant,
- $1/t$ can provide a measure of its initial rate,
- volume of the reactant that is changed in each experiment, can be used as a measure of its initial concentration.

Since the total volume of the reaction mixture is kept constant and only the concentration of **FA 5** has been changed, the rate equation, where m is the order of reaction with respect to H⁺, can be simplified to

$$\text{rate} = k[H^+]^m$$

By taking logarithms of the factors in this equation and by substituting 1/t for rate and V_{FA4} for concentration respectively,

$$\lg(1/t) = m \times \lg(V_{FA\,5}) + \lg k$$

Therefore, by plotting a graph of $\lg(1/t)$ against $\lg(V_{FA\,5})$, you will be able to draw a straight line of best-fit graph, where m is the gradient of the line.

(b) Plot a graph of $\lg(1/t)$ on the y-axis against $\lg(V_{FA\,5})$ on the x-axis. Draw the best-fit straight line, taking into account all of your plotted points.

[3]

M19
M20
M21
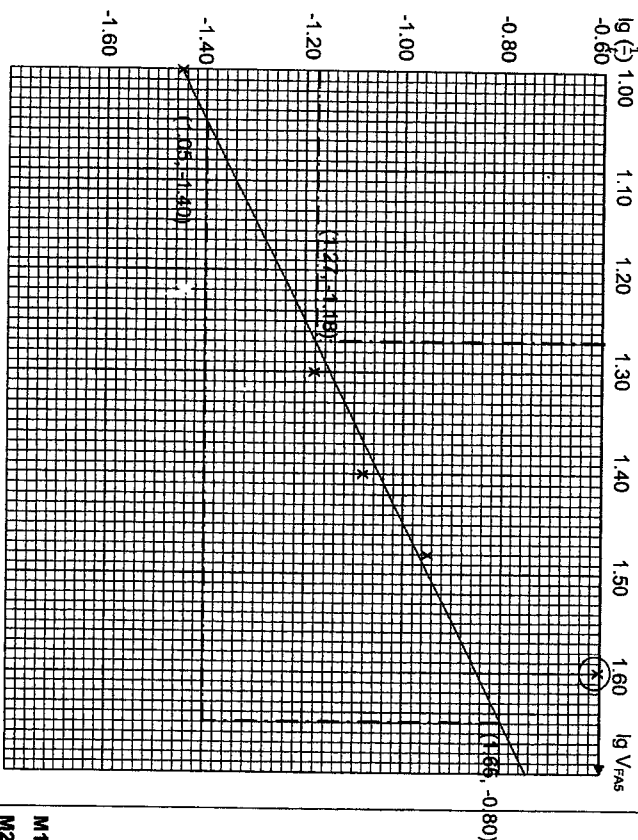
M19: Axes correct way round, with correct labels and appropriate scale. Scale must be chosen so that plotted points occupy at least half the graph grid in both x and y directions
M20: All plotted points correct to within ± ½ small square
M21: A best fit line is drawn with anomalous points excluded

(ii) From your graph, determine the value of m, showing clearly all your working. Give your answer to **3** significant figures and hence state the order of reaction with respect to [H⁺].

Gradient $= \dfrac{(-0.80 - (-1.40))}{1.65 - 1.05} = 1.00 = m$

Correct calculation of gradient of the graph with working shown. The m value is equal to the gradient of the line
Must show accurate coordinates falling on the line with triangle

$m = $ ....

order of reaction with respect to [H⁺] = ... [1]

M22

(c) This experiment is known to be very reliable. When it is performed carefully, it is possible to make a reaction mixture that changes colour after a specified time interval.

Use your graph to determine the volume of **FA 5** which would need to be added in **solution 1** so that the reaction mixture turns dark blue at **15 seconds**.

Show your working clearly.

When t= 15 s, lg (1/t) = lg(1/15) = –1.18

From the graph, lg V_{FA5} = 1.27

V_{FA5} = 18.6 cm³ (3s.f)

- Correct calculation of lg(1/15) = –1.18
- Correct reading of lg($V_{FA\,5}$) value from graph to within ±½ small square.
- Correct calculation of volume of **FA 5** using value for lg($V_{FA\,5}$)

volume of **FA 5** required = ... [2]

M23
M24

(d) State and explain which experiment, from **experiments 1** to **5**, is likely to have the greatest error.

Experiment 1 as time, t, is smallest value and so has greatest % error

[2] for all 3 points correct
[1] for 2 points correct

OR

Selects Experiment 2 and explains that volume of **FA 5** used (20 cm³) is smallest and so has greatest % error

[1]

M25

(e) Calculate the concentration of hydrogen ions, [H⁺], in mol dm⁻³, that is present in the reaction mixture for **experiment 1** at time t = 0 s.
You may assume that the solutions are perfectly mixed and that the reaction has **not** started at t = 0 s.

amount of H⁺ = $0.05 \times 2 \times 40 \times 10^{-3} = 0.00400$ mol   **M26**

[H⁺] = $0.00400 / (65/1000) = 0.0615$ mol dm⁻³   **M27**

[H⁺] = ... mol dm⁻³ [3]   **M28**

M26: correct value
M27: Show correct units and appropriate significant figures in all final answers in **1(c), 2(e)**
M28: Show all relevant workings in **1(c), 2(e)**
M28 deducted for any blank questions

(f) Suppose that the following mistake was made in the preparation of **solution 1** for **experiment 2**:

Kaleyn added 10.0 cm³ of **FA 6** to the 50.0 cm³ measuring cylinder and added **FA 5** up to the 30.0 cm³ mark, instead of 20.0 cm³ mark, on the measuring cylinder. After that, she made up the volume to 50.0 cm³ by adding deionised water.

(i) State and explain how the value of t is affected for **experiment 2** described above.

The value of t will be lower. This is because the [H⁺] is higher than expected, so rate of reaction is faster. [1]   **M29**

(ii) Suggest a modification to the experimental procedure to avoid this error.

Measuring volumes of **FA 5**, **FA 6** and deionized water using separate measuring cylinders to make solution 1. [1]   **M30**

[Total: 17]

3   **Planning**

Like iodine solution, many transition metal complex ions are coloured. It is possible to use this property to determine the concentration of a solution of a coloured complex ion. A few cm³ of the solution is placed inside a machine, known as a spectrometer. This machine measures the amount of light that is absorbed when a specific wavelength of visible light is shone through a coloured solution. It does this by comparing the amount of light passing through the sample with the amount of light passing through the pure solvent. The amount of light absorbed is expressed as an *absorbance value*. The higher the concentration of the solution, the higher the absorbance value, i.e., the absorbance value is directly proportional to the concentration of the solution.

This technique can be used to determine the concentration of a solution of aqueous [Ni(en)₃]²⁺.
A series of known concentration of solution containing [Ni(en)₃]²⁺ is prepared. A spectrometer is used to measure the absorbance of each solution. A graph of absorbance against concentration is then plotted. This graph is known as a calibration line.

The experiment is then repeated using a solution of unknown concentration. By comparing the absorbance of this solution with the calibration line, the concentration of [Ni(en)₃]²⁺ in the unknown solution can be determined.

(a) Explain why transition metal compounds are often coloured.

• As the ligands approach the central metal ions, it results in interelectronic repulsion and splits the d orbitals into 2 energy levels with a small energy gap, ΔE   **M31**
• As the d orbitals are partially filled, when electrons absorb energy from the visible light region of the electromagnetic spectrum corresponding to ΔE, they are promoted from the lower energy d orbital to be promoted to higher energy d orbital.   **M32**
• The colour of the complex is the complementary colour of the light absorbed. [2]

(c) Given that [Ni(en)₃]²⁺ absorbs radiation of a wavelength of about 570 nm, use the information below to predict the colour of [Ni(en)₃]²⁺.

Wavelength range (nm)	Colour	Complementary colour
400 - 450	Violet	Yellow
450 - 490	Blue	Orange
490 - 550	Green	Red
550 - 580	Yellow	Violet
580 - 650	Orange	Blue
650 - 700	Red	Green

violet [1]   **M33**

[Turn over]

(a) Using the information given above, you are required to write a plan to determine the concentration of [Ni(en)$_3$]$^{2+}$ in a solution of **X**.

You may assume that you are provided with:

- solution **X**, of unknown [Ni(en)$_3$]$^{2+}$ concentration less than 2 mol dm^{-3};
- a stock solution containing 5.00 mol dm^{-3} of [Ni(en)$_3$]$^{2+}$;
- access to a spectrometer and instructions for its use;
- graph paper;
- the apparatus and chemicals normally found in a school laboratory.

Your plan should include details of:

- the preparation of 100.0 cm^3 of 2.00 mol dm^{-3} aqueous [Ni(en)$_3$]$^{2+}$ from the stock solution;
- the preparation of a suitable range of diluted solutions of accurate concentrations;
- an outline of how the results would be obtained;
- a sketch of the calibration line you would expect to obtain;
- how the calibration line would be used to determine the concentration of [Ni(en)$_3$]$^{2+}$ in solution **X**.

[9]

- **Calculation of vol of stock solution needed:**
  Vol of stock solution needed = $\frac{100 \times 2}{5}$ = 40 cm^3

- **Procedure for preparation of standard solution of 2.00 mol dm^{-3}**
  1. Fill the 50.00 cm^3 burette with the stock solution of 5.00 mol dm^{-3} [Ni(en)3]$^{2+}$
  2. Run 40.00 cm^3 of the solution into a 100 cm^3 volumetric flask
  3. Top up to the mark with deionised water
  4. Stopper, invert and shake the volumetric flask to obtain a homogeneous solution. Label this solution **P**.

- **Preparation of a suitable range of diluted solutions**
  1. Fill the 50.00 cm^3 burette with solution **P**
  2. Run 15.00 cm^3 of **P** into a 100 cm^3 beaker.
  3. Using another 50.00 cm^3 burette, transfer 5.00 cm^3 of deionised water into the same beaker. Stir the solution with a glass rod to obtain a homogeneous solution.
  4. Repeat steps 2 and 3 with different volumes of solution **P** and deionised water as shown in the table below (Expt 3 to 5).

Expt	Volume of solution P/ cm³	Volume of deionised water /cm³	Conc of [Ni(en)3]²⁺ prepared / mol dm⁻³	Absorbance /A
1	20.00	0.00	2.00	
2	15.00	5.00	1.50	
3	10.00	10.00	1.00	
4	5.00	15.00	0.50	
5	0.00	20.00	0.00	

- **Outline of how the results would be obtained**
  1. Use the spectrometer to measure the absorbance of each of the solutions of different concentrations prepared and record the absorbance value.
  2. Plot a graph of the absorbance against concentration and draw a best-fit line. This is the calibration line.

- **Determining concentration of solution X**
  1. Use the spectrometer to measure and record the absorbance of [Ni(en)$_3$]$^{2+}$ in solution **X**
  2. Using the calibration line drawn, read off the concentration of [Ni(en)$_3$]$^{2+}$ corresponding to the absorbance.

[Total: 12]

1. correct volume of stock solution used to prepare the standard solution.	M34	M34
2. correct procedure for preparing the standard solution, including top up to the mark, stopper and shake	M35	M35

3. use of suitable apparatus with stated capacity for the preparation of standard solution
  o burette for measuring out 40.00 cm³ stock solution
  o 100 cm³ volumetric flask
	M36	M36

4. correct dilution concept for preparation of range of diluted solutions using 2.00 mol dm⁻³ solution	M37	M37
5. select a suitable range of concentrations for the diluted solutions (at least 3 more solutions with concentrations not less than 0.3 mol dm⁻³ apart)	M38	M38
6. measurement of absorbance value using the diluted solutions	M39	M39
7. plotting of graph (mention axis)	M40	M40
8. sketch of the calibration line graph (straight line graph passing through the origin) (if sketch is correct and with appropriate axes, M40+M41)	M41	M41
9. description of use of calibration line to determine concentration of [Ni(en)3]²⁺ in solution **X**	M42	M42

Qualitative Analysis

You are provided with two ionic solids, **FA 8** and **FA 9**.

Perform the tests described in the table below and record your observations in the table. In all the tests, the reagent should be added gradually until no further change is observed, with shaking after each addition. No additional or confirmatory tests for ions present should be attempted.

	observations with **FA 8**	observations with **FA 9**
(a)(i) Add 1 cm³ of dilute hydrochloric acid to ½ spatula of the solid sample in a test tube.	Blue / Blue-green / green solution is observed.	Cream / Off-white ppt is observed. Yellow ppt / solid is formed on warming. (No need to test for SO₂) FYI: $Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + S + SO_2 + H_2O$
(ii) Add 2 cm³ of silver nitrate solution to ½ spatula of the solid sample in a test tube. If need be, filter the resultant mixtures.	White ppt in blue solution formed.	A white / yellow ppt and eventually forms black / brown ppt. Do not accept red-brown ppt Do not accept brown solution Can accept eventually brown ppt
(iii) Add 1 cm³ of potassium iodide solution to ½ spatula of the solid sample in a test tube. If need be, filter the resultant mixtures.	A white / cream ppt is formed in brown solution. FYI: $2CuCl_2 + 4KI \rightarrow 2CuI + I_2 + 2KCl$	A colourless solution is formed.
(iv) Add 1 cm³ of aqueous iodine to ½ spatula of the solid sample in a test tube.		Brown solution decolourises.
(v) Add 1 cm³ of deionised water to ½ spatula of the solid sample in a test tube. To this resultant solution, add aqueous ammonia slowly, with shaking, until no further change is seen.	Blue solution is formed when DI water is added. Blue ppt formed when NH₃(aq) is added dropwise. Ppt soluble in excess NH₃(aq) forming a dark blue solution	

[8]

[Turn over

(b) Suggest the identity of the cation and anion present in **FA 8**. Hence, write a balanced equation for the reaction occurring with **FA 9** in **(a)(ii)**.

cation: Cu^{2+} anion: Cl^- **M51** **M52**

equation: $2AgNO_3(aq) + CuCl_2(aq) \rightarrow Cu(NO_3)_2(aq) + 2AgCl(s)$ [3] **M53**

(c) Based on your observation in **(a)(iii)**, state the type of reaction undergone between potassium iodide and **FA 8**.

Redox   [1] **M54**

(d) Based on your observation in **(a)(iv)**, state the role of **FA 9** in the reaction.

reducing agent   [1] **M55**

[Total: 13]

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Qualitative Analysis Notes

[ppt. = precipitate]

(a) Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH₃(aq)
aluminium, Al³⁺(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH₄⁺(aq)	ammonia produced on heating	–
barium, Ba²⁺(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca²⁺(aq)	white ppt. with high [Ca²⁺(aq)]	no ppt.
chromium(III), Cr³⁺(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu²⁺(aq),	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe²⁺(aq)	green ppt. insoluble in excess	green ppt. insoluble in excess
iron(III), Fe³⁺(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), Mn²⁺(aq)	off-white ppt. insoluble in excess	off-white ppt. insoluble in excess
zinc, Zn²⁺(aq)	white ppt. soluble in excess	white ppt. soluble in excess

(b) Reactions of anions

ions	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 $NO \rightarrow$ (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)

(c) Test for gases

ions	reaction
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

(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

[Turn over

Question	Answer	Marks
1 (a)	All masses consistently recorded to 2 (or 3) decimal places. and correct mass headers	M1
	Mass of empty bottle	
	Mass of bottle + FA 1	
	Mass of bottle + FA 1	
	Mass of bottle + residual of FA 1	
	Mass of FA 1	
	*Inform students to be always reminded to weigh residual mass	
(b)(i)	A table including the appropriate header and units for:	M3
	• Initial burette readings	
	• Final burette readings	
	• volume added	
	All accurate burette readings are recorded to the nearest 0.05 cm³.	M4
	Do not award this mark if: 50.00cm³ is used as an initial burette reading	
	Accuracy	M5
	Titre/mass ratio: 4.05 ± 0.50	
(b)(ii)	Correct calculation of the average of two consistent readings within 0.10 cm³ difference	M6
(c)(i)	amount of I₂ = 0.5 (ans from b(ii)/1000) x 0.10 = A mol	M7
(ii)	amount of Cu²⁺ in 25.0 cm³ = A x 2 = B mol	M8
(iii)	amount of CuSO₄.nH₂O in 250 cm³ = 10 × B = C mol	M9
(iv)	Mr = mass of **FA 1** / C = D Must be 1dp, will affect M27	M10
	n = (D -159.6) / 18.0 n must be an integer	M11
(d)	Due to the slow release of I₃⁻ from the starch-I₃⁻ complex, the end point **would have exceeded the equivalence point**, resulting in a **larger titre value.** This leads to larger amount of CuSO₄.nH₂O hence the **Mr would have been smaller than the actual value.**	M12
	OR	
	The I₂ **is trapped by the starch complex and hence resulting in less I₂** a smaller titre value This leads to a smaller amount of CuSO₄ and hence **Mr will be larger**	M13

Mass of FA 1 used correctly calculated M2
Mass of FA 1 used 5.00 ±0.05

Question	Answer	Marks
2(a)	Table with correct headers and units	M14
	• volumes of **FA 5, FA 6** and deionised water	
	• time	
	• 1/t	
	• lg (1/t)	
	• lg (V_FA 5)	
	Record all data with correct precision	M15
	• volumes to 0.5 cm³	
	• t to nearest second	
	• calculated values to 3 sf	
	Complete set of volume of **FA 5** and time readings for 5 experiments and all values of t increase as volume of **FA 5** decreases. Data for experiments 1 and 2 must be included	M16
	Choose 3 other well-spaced values for the volume of **FA 5**. All volumes must differ by at least 5 cm³	M17
(b)(i)	Correctly calculate 1/t, lg (1/t) and lg (V_FA5) values for all stated experiments.	M18
	Axes correct way round, with correct labels and appropriate scale. Scale must be chosen so that plotted points occupy at least half the graph grid in both x and y directions	M19
	Both accepted, must be in logical numerical sense	
	All plotted points correct to within ± ½ small square	M20
	A best fit line is drawn with anomalous points excluded	M21
(b)(ii)	Correct calculation of gradient of the graph with working shown. The **m** value is equal to the gradient of the line Must show accurate coordinates falling on the line or triangle or best both	M22
(c)	• Correct calculation of lg(1/15) = −1.18	M23
	• Correct reading of lg(V_FA 5) value from graph to within ±½ small square.	M24
	• Correct calculation of volume of **FA 5** using value for lg(V_FA5)	
	[2] for all 3 points correct	
	[1] for 2 points correct	
(d)	Selects Experiment 1 and explains that time, t, is smallest value and so has greatest % error Says that reaction time is fastest and hence it is the most significant	M25
	OR	

	solution P/cm³	deionised water /cm³	prepared /mol dm⁻³
1	20.00	0.00	2.00
2	15.00	5.00	1.50
3	10.00	10.00	1.00
4	5.00	15.00	0.50
5	0.00	20.00	0.00

• Outline of how the results would be obtained
 1. Use the spectrometer to measure the absorbance of each of the solutions of different concentrations prepared and record the absorbance value.
 2. Plot a graph of the absorbance against concentration and draw a best-fit line. This is the calibration line.

• Determining concentration of solution **X**
 1. Use the spectrometer to measure and record the absorbance of $[Ni(en)_3]^{2+}$ in solution **X**
 2. Using the calibration line drawn, read off the concentration of $[Ni(en)_3]^{2+}$ corresponding to the absorbance.

		Mark
1.	correct volume of stock solution used to prepare the standard solution.	M34
2.	correct procedure for preparing the standard solution, including top up to the mark, stopper and shake	M35

3.	use of suitable apparatus with stated capacity for the preparation of standard solution
	  o burette for measuring out 40.00 cm³ stock solution
	  o 100 cm³ volumetric flask
		M36

4.	correct dilution concept for preparation of range of diluted solutions using 2.00 mol dm⁻³ solution	M37
5.	select a suitable range of concentrations for the diluted solutions (at least 3 more solutions with concentrations not less than 0.3 mol dm⁻³ apart)	M38
6.	measurement of absorbance value using the diluted solutions	M39
7.	plotting of graph (mention axis)	M40
8.	sketch of the calibration line graph (straight line graph passing through the origin) (if sketch is correct and with appropriate axes, M40+M41)	M41
9.	description of use of calibration line to determine concentration of $[Ni(en)_3]^{2+}$ in solution **X**	M42

(e)	Selects Experiment 2 and explains that volume of **FA 5** used (20 cm³) is smallest and so has greatest % error	M26
	amount of H⁺ = 0.05 × 2 × 40 × 10⁻³ = 0.00400 mol [H⁺] = 0.00400 / (65/1000) = 0.0615 mol dm⁻³	M27
	Show correct units and appropriate significant figures in all final answers in 1(c), 2(e) **Penalise only if answer is correct** Show all relevant workings in 1(c), 2(e) **M28 deducted for any blank questions**	M28
(f)(i)	The value of t will be lower. This is because the [H⁺] is higher than expected, so rate of reaction is faster.	M29
(ii)	Measuring volumes of **FA 4**, **FA 6** and deionized water separately and mixing to make solution 1	M30

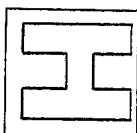| Question	Answer	Marks
3(a)	• presence of partially filled d-orbitals • splitting of d orbitals into 2 groups with a small energy gap • absorbs light energy for electrons from lower energy d orbital to be promoted to higher energy d orbital • light not absorbed is seen as the colour of the complex 2m - all 3 points 1m – any correct 2 points	M31 M32
	violet	M33
(b)		
(c)	• Calculation of vol of stock solution needed: Vol of stock solution needed = $\frac{100\times2}{5}$ = 40 cm³ • Procedure for preparation of standard solution of 2.00 mol dm⁻³ 1. Fill the burette with the stock solution of 5.00 mol dm⁻³ $[Ni(en)_3]^{2+}$ 2. Run 40.00 cm³ of the solution into a 100 cm³ volumetric flask 3. Make up to the mark with deionised water 4. Stopper and shake the volumetric flask to obtain a homogeneous solution. Label this solution **P**. • Preparation of a suitable range of diluted solutions 1. Fill the burette with solution **P** 2. Run 15.00 cm³ of **P** into a 100 cm³ beaker. 3. Using another burette, transfer 5.00 cm³ of deionised water into the same beaker. Stir the solution with a glass rod to obtain a homogeneous solution. 4. Repeat steps 2 and 3 with different volumes of solution **P** and deionised water as shown in the table below (Expt 3 to 5).	

Expt	Volume of	Volume of	Conc of $[Ni(en)_3]^{2+}$	Absorbance /A

4

		observations with FA 8	observations with FA 9
(a)(i)	Add 1 cm³ of dilute hydrochloric acid to ½ spatula of the solid sample in a test tube.	<u>Blue</u> / <u>Blue-green</u> / <u>green</u> solution is observed.	<u>Cream</u> / <u>Off-white</u> ppt is observed (optional) Yellow ppt / solid is formed on ~~warming.~~ (No need to test for SO₂) FYI: $Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + S + SO_2 + H_2O$
(ii)	Add 2 cm³ of silver nitrate solution to ½ spatula of the solid sample in a test tube. If need be, filter the resultant mixtures.	<u>White</u> ppt in blue solution formed.	A <u>white</u> / <u>yellow ppt</u> and eventually forms <u>black</u> / <u>brown</u> ppt. Do not accept red-brown ppt Do not accept brown solution Can accept eventually brown ppt
(iii)	Add 1 cm³ of potassium iodide solution to ½ spatula of the solid sample in a test tube. If need be, filter the resultant mixtures.	A <u>white / cream ppt</u> is formed in <u>brown solution</u>. FYI: $2CuCl_2 + 4KI \rightarrow 2CuI + I_2 + 2KCl$	A <u>colourless</u> solution is formed.
(iv)	Add 1 cm³ of aqueous iodine to ½ spatula of the solid sample in a test tube.	<u>Blue solution</u> is formed.	Brown solution <u>decolourises</u>. Something to the extent of decolourisation
(v)	Add 1 cm³ of deionised water to ½ spatula of the solid sample in a test tube. To this resultant solution, add aqueous ammonia slowly, with shaking, until no further change is seen.	<u>Blue ppt</u> formed. Ppt soluble in excess NH₃(aq) forming a <u>dark blue solution</u>	

Question	Answer	Marks
4(a)	1m for each box	M43 to M50
(b)	cation: Cu²⁺	M51
	anion: Cl⁻ or SO₄²⁻	M52
	equation: $2AgNO_3(aq) + CuCl_2(aq) \rightarrow Cu(NO_3)_2(aq) + 2AgCl(s)$ OR $2AgNO_3(aq) + CuSO_4(aq) \rightarrow Cu(NO_3)_2 + Ag_2SO_4(s)$ Can accept ionic equation	M53
(c)	Redox Not displacement	M54
(d)	reducing agent	M55

NATIONAL JUNIOR COLLEGE

SH2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

	REGISTRATION NUMBER

CHEMISTRY
Paper 1 Multiple Choice

9729/01
15 September 2022
1 hour

Additional Materials: Optical Answer Sheet
                      Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

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

Write your name, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on 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.

Instructions on how to fill in the Optical Mark Sheet

Shade the index number in a 5 digit format on the optical mark sheet:

2nd digit and the last 4 digits of the Registration Number.

Example:

Student	Examples of Registration No.	Shade:
	2105648	**15648**

This document consists of **15** printed pages and **1** blank page.

[Turn over

2

1   Technetium (Tc) is a second row transition element that does not occur naturally on Earth. One of its isotopes has 56 neutrons.

What is the nucleon number of this isotope?

    A   43   **B**   56   **C**   99   **D**   112

2   Which row has the greater number of particles?

    A   1 mol of liquid sulfuric acid

    B   12000 cm^3 of oxygen gas at s.t.p.

    C   32.5 g of zinc

    D   16 g of nitrogen gas

3   Which species will have the smallest deflection when passed through the same electric field?

    A $^{23}Na^+$ **B** $^{11}B^{3+}$ **C** $^{19}F^-$ **D** $^{32}S^{2-}$

4   0.0353 g of a sample of volatile organic compound was completely vaporized at 50 kPa and 300K. The vapour occupied a volume of 40 cm^3. On complete combustion in excess oxygen, 80 cm^3 of carbon dioxide and 80 cm^3 of water vapour were formed. All gaseous volumes were measured under identical conditions.

What would be the molecular formula of the compound?

    A C_2H_2O **B** C_2H_4O **C** C_2H_6O **D** C_3H_8

5   Which species has the most number of unpaired electrons?

    A Co^{2+} **B**   N   **C**   Fe   **D**   S

6   Rubidium and bromine form ions that are isoelectronic.

    1   Ionic radius of rubidium is smaller than its atomic radius.

    2   Ionic radius of bromine is larger than its atomic radius.

    3   Ionic radius of bromine is smaller than that of rubidium.

    Which statements are correct?

    A   1, 2 and 3   **B**   1 and 2 only   **C**   1 and 3 only   **D**   2 and 3 only

7   Which row correctly shows the bond angles for α, β, γ in the molecule below?
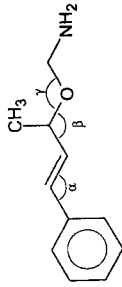
	α	β	γ
A	109.5°	120°	109.5°
B	120°	109.5°	107°
C	120°	107°	105°
D	120°	109.5°	105°

8   In which pair is the melting point of the **second** species higher than that of the **first** species?

A   C and Si

B   K and Rb

C   NaC*l* and NaBr

D   SiC*l*₄ and SiO₂

9   When liquid N_2F_4 is heated, it decomposes into a single product, **B**.

Which statements are correct?

1   N–F bonds are broken during this decomposition.

2   The enthalpy change when N_2F_4 decomposes into **B** is approximately +160 kJ mol⁻¹.

3   Molecules of **B** are non-linear.

A   1, 2 and 3   B   1 and 2 only   C   2 and 3 only   D   1 only

---

10   Three experiments were carried out involving acids and alkalis of the same concentration.
The temperature changes were recorded as shown in the table below.

Volumes of acids and alkalis added together	ΔT/ °C
25.0 cm³ of HC*l*(aq) + 25.0 cm³ of NaOH(aq)	ΔT₁
50.0 cm³ of HC*l*(aq) + 50.0 cm³ of NaOH(aq)	ΔT₂
25.0 cm³ of HC*l*(aq) + 25.0 cm³ of NH₃(aq)	ΔT₃

Which row shows the correct relative magnitude of ΔT values?

A $\Delta T_2 > \Delta T_3 > T_1$ B $\Delta T_1 = \Delta T_2 > \Delta T_3$ C $\Delta T_2 = \Delta T_3 > \Delta T_1$ D $\Delta T_1 = \Delta T_2 = \Delta T_3$

11   Some ΔH values are given below.

	enthalpy change of formation / kJ mol⁻¹
Fe₂O₃	– 824.2
CO	– 110.5
CO₂	– 393.5

In the industrial production of iron, iron(III) oxide is reduced by carbon monoxide.

What is the enthalpy change of reaction for one mole of iron formed?

A   – 24.8 kJ mol⁻¹

B   + 24.8 kJ mol⁻¹

C   – 12.3 kJ mol⁻¹

D   + 541.2 kJ mol⁻¹

[Turn over

12 Nitrogen and hydrogen form ammonia in an exothermic reaction. The rate and yield of the reaction can be altered by changing the experimental conditions.

Which row correctly describes the effect of the changes in condition?

change in condition	effects		
	equilibrium yield	rate of forward reaction	rate of backward reaction
1 increasing temperature	decreases	increases	increases
2 increasing temperature	increases	decreases	increases
3 addition of catalyst	increases	increases	no effect
4 addition of catalyst	no effect	increases	increases

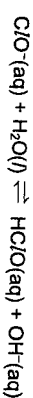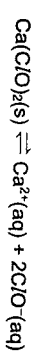**A** 1 and 4 only   **B** 2 and 4 only   **C** 2 and 3 only   **D** 1 and 3 only

13 Four solutions, each of concentration 0.1 mol dm^{-3}, were tested with a pH meter. The results are shown.

solution	pH
CH_3CO_2H	4
HNO_3	1
CH_3NH_2	11
NaOH	14

Which statement is **incorrect**?

A Conjugate base of CH_3CO_2H is less stable than that of HNO_3.

B HNO_3 has a lower pH than CH_3CO_2H because it is more soluble.

C NaOH has a higher concentration of hydroxide ions in solution than CH_3NH_2.

D Mixing equal volume of CH_3NH_2 and HNO_3 form a solution with pH less than 7.

14 Solid calcium hypochlorite pellets, $Ca(ClO)_2(s)$, are added to swimming pools to form $HClO(aq)$ which kills disease-causing bacteria and algae.

$$Ca(ClO)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2ClO^-(aq)$$

$$ClO^-(aq) + H_2O(l) \rightleftharpoons HClO(aq) + OH^-(aq)$$

What is the effect on the solubility of calcium hypochlorite and bacterial growth when pH increases?

	effect on solubility of calcium hypochlorite	effect on bacterial growth
A	decreases	increases
B	decreases	decreases
C	increases	increases
D	increases	decreases

15 A mixture of two oxides of period 3 elements is added to water and the resultant solution has a pH value below 7.

What could be the constituents of the mixture?

A Al_2O_3 and MgO

B Na_2O and MgO

C Na_2O and P_4O_{10}

D SO_3 and P_4O_{10}

16 Anhydrous magnesium nitrate, $Mg(NO_3)_2$, decomposes when heated, giving a white solid and a mixture of two gases, **D** and **E**. **E** is oxygen.

What is the ratio of $\dfrac{\text{mass of } \mathbf{D} \text{ released}}{\text{mass of } \mathbf{E} \text{ released}}$?

A $\dfrac{1}{0.174}$ **B** $\dfrac{1}{0.267}$ **C** $\dfrac{1}{0.348}$ **D** $\dfrac{1}{3.43}$

17 Addition of warm concentrated sulfuric acid, H_2SO_4, to crystals of sodium halides gives the following observations.

compound	observation
NaF	evolution of a colourless gas which etches a damp glass rod
NaCl	evolution of a choking colourless gas which produces a white cloud in contact with ammonia vapour
NaBr	evolution of a brown vapour and of pungent fumes which turn potassium dichromate(VI) paper green
NaI	evolution of a purple vapour and a gas smelling of rotten eggs

Which statements are consistent with the observations?

	hydrogen halide is produced in all four reactions	H_2SO_4 is acting as a reducing agent in all four reactions	SO_2 and H_2S are reduction products of H_2SO_4
A	true	false	true
B	true	true	false
C	false	false	true
D	false	true	true

18 The following electrochemical cell was set up and the E_{cell} value was found to be +0.018 V.

0.5 mol dm⁻³ AgNO₃(aq)   Ag   salt bridge   Ag   1.0 mol dm⁻³ AgNO₃(aq)

F   **G**

Which statement is correct?

A   Electrode potential of $AgNO_3$ / Ag electrode in half-cell **F** is found to be −0.782V.

B   The E_{cell} value becomes less positive when solid sodium chloride is added to half-cell **F**.

C   The E_{cell} value becomes 0.00 V by adding concentrated ammonia gradually to $AgNO_3$ in half-cell **G**.

D   The change in the magnitude of the E_{cell} value is the same when same number of moles of iodide or bromide is added to half-cell **G** separately.

---

19 Which statement about the anodising of aluminium using dilute sulfuric acid is correct?

A   Water is reduced at the cathode.

B   Oxygen is produced at the cathode.

C   The Al object to be anodised is the negative electrode.

D   The mass of the anode increases.

20 Consider the following reaction scheme.

Cu pink solid $\xrightarrow[\text{heat step 1}]{\text{conc. } H_2SO_4}$ **K** yellow solution $\xrightarrow[\text{step 3}]{\text{aq } NH_3}$ **L** dark blue solution

K yellow solution $\xrightarrow[\text{step 2}]{\text{conc } HCl}$ **H** blue solution + **J** gas

H blue solution $\xrightarrow[\text{step 4}]{\text{KI(aq) + filter}}$ **M** white solid + **N** brown solution

Which statement is correct?

A $[Cu(OH)_4]^{2-}$ is the dark blue complex in **L**.

B   Infinite dilution of solution **K** gives a pale yellow solution.

C   Cation in compounds **K** and **M** has the same oxidation state.

D   Step 4 involves both redox and precipitation reactions.

21 Fe^{2+} ion forms a red octahedral complex with *ortho*-phenanthroline molecules. Various samples containing different volumes of 1×10^{-5} mol dm^{-3} Fe^{2+} and 3×10^{-5} mol dm^{-3} *ortho*-phenanthroline were prepared. The following graph was obtained when the colour intensity of the samples was measured using a colorimeter.
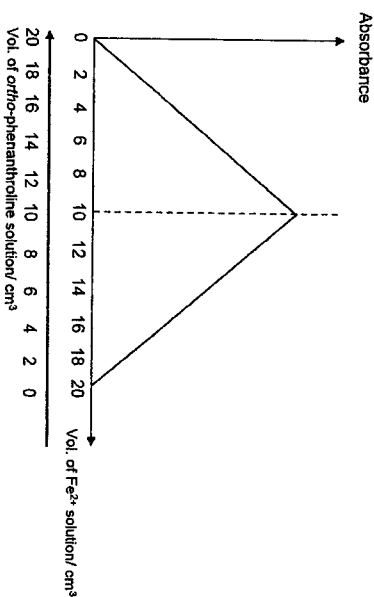
Which statement about the complex ion is correct?

A The complex ion absorbs red light.

B The overall charge of the complex ion is −4.

C The co-ordination number of the Fe^{2+} ion is 3.

D *Ortho*-phenanthroline is a bidentate ligand.

22 One molecule of dodecane, $C_{12}H_{26}$, is cracked to produce three products, **R**, **S** and **T**. **R** is a straight chain alkane. **S** and **T** are straight chain alkenes with different M_r values.

Which statements about **R**, **S** and **T** are correct?

1 If **S** and **T** are but-1-ene and ethene respectively, **R** will be hexane.

2 If **R** is butane, only one, either **S** or **T**, exhibits cis-trans isomerism.

3 **R** could be octane.

**A** 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

23 Adrenalin is a stimulant produced in the adrenal glands. It has the following structure.
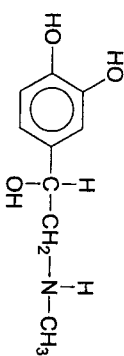
Which statement about adrenalin is correct?

A One mole of adrenalin can only react with one mole of ethanoyl chloride.

B One mole of adrenalin reacts with two moles of hydrogen chloride.

C It gives effervescence with potassium carbonate.

D It reacts with ethanoic acid to form amide.

24 The following compounds are found in essential oils extracted from herbs and spices.
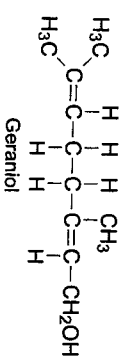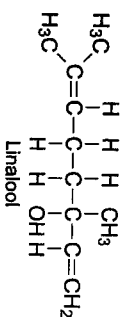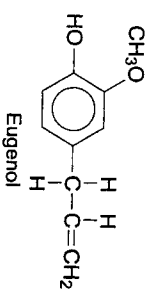
Which statement is **incorrect**?

A Both Linalool and Geraniol exhibit stereoisomerism.

B One mole of Eugenol reacts with at least two moles of Br_2 in the absence of light.

C Linalool gives yellow precipitate with warm alkaline $I_2(aq)$.

D Geraniol decolorises cold acidified $KMnO_4$.

11

25 Which reactions of propan-1-ol produce water as a by-product?

1 passing propan-1-ol vapour over hot Al_2O_3

2 mixing propan-1-ol with warm ethanoic acid and a few drops of concentrated H_2SO_4

3 warming propan-1-ol with HCN

**A** 1, 2 and 3   **B** 1 and 2 only   **C** 2 and 3 only   **D** 1 only

26 Hex-2-ene can be made by the reaction shown.

Which statement about this reaction is correct?

A $(CH_3)_3CO^-$ is behaving as a Lewis base.

B $(CH_3)_3CO^-$ is behaving as an oxidising agent.

C The C–I bond breaks via homolytic fission.

D This is a nucleophilic substitution reaction.

12

27 Maltol, vanillin and cinnamaldehyde are some naturally occurring flavouring agents.

maltol   vanillin   cinnamaldehyde
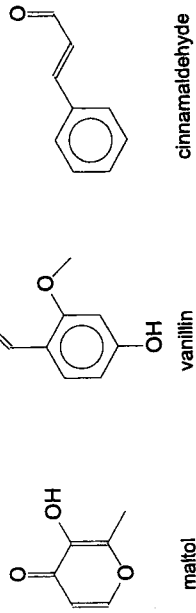
Which pair of reagents would enable the three compounds to be distinguished from one another?

	reagent 1	reagent 2
A	2,4-dinitrophenylhydrazine	hot acidified $K_2Cr_2O_7$
B	$[Ag(NH_3)_2]^+$ solution	neutral aqueous $FeCl_3$
C	Fehling's solution	hot acidified $KMnO_4$
D	anhydrous $SOCl_2$	aqueous Br_2

[Turn over

28 The following compounds were treated with hot acidified KMnO₄ (aq).

Which compound gives an organic product that is **different** from the other three?

A   CH₃COCl

B   CH₃CH₂OCOCH₃

C   CH₃CH=CHOH

D   CH₃CH₂COOCH₃

29 Amino acid Y has three pKₐ values given below:
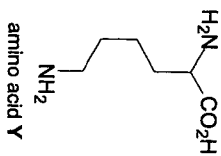
amino acid Y

	α-carboxyl group	α-amino group	Side chain
pKₐ	2.15	9.16	10.67

What is the net charge of the predominant species of amino acid Y at pH 7?

A   +2   B   +1   C   0   D   −1

30 Heptapeptide **X** contains seven amino acid residues. When **X** is partially hydrolysed, the following dipeptide and tripeptide fragments are produced.
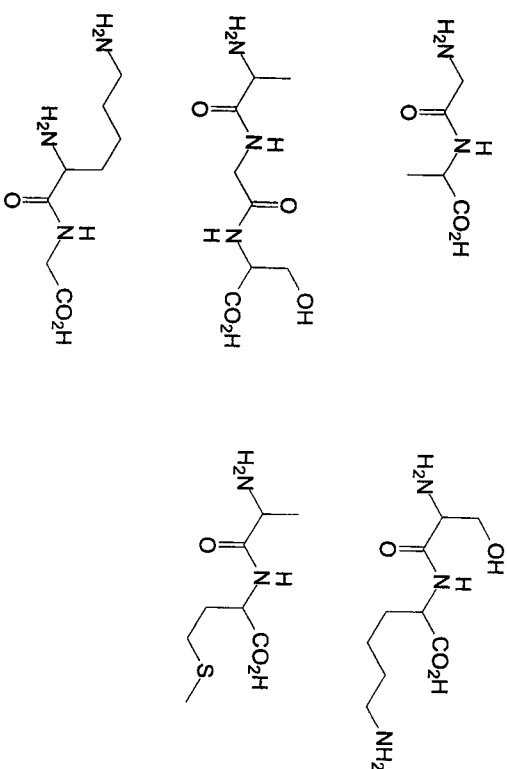
Which of the four heptapeptides on page 15 is the formula of **X**?

15

A

B

C

D

16

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