OCR
Oxford Cambridge and RSA

Wednesday 19 June 2019 – Morning

A Level Chemistry A

H432/03 Unified chemistry

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry A (sent with general stationery)

You may use:
- a scientific or graphical calculator

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H432/03

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **20** pages.

2

Answer **all** the questions.

1 These short questions are from different areas of chemistry.

(a) Explain why a CF_4 molecule has polar bonds but does **not** have an overall dipole.

F is more electronegative than C but CF_4 is symmetrical so the dipoles cancel out

[2]

(b) Explain why a small proportion of molecules in water have a relative molecular mass of 20.

Molecules contain = ^2H (deuterium)

^3H (tritium)

[1]

(c) What is the partial pressure of O_2 (in Pa) in a gas mixture containing 21% O_2 by volume and with a total pressure of 1.0×10^5 Pa?

partial pressure = mol fraction x total pressure

$0.21 \times 1.00 \times 10^5 = 2.1 \times 10^4$ Pa

21% = 0.21 = mol fraction

partial pressure of O_2 = 2.1×10^4 Pa **[1]**

(d) What mass of carbon dioxide (in g) is formed by the complete combustion of $42.0\,m^3$ (measured at RTP) of propane?

$\frac{42 \times 10^3}{24} = 1750$ mol of C_3H_8

mol = vol (dm^3) / molar volume = 24 dm^3 at RTP

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

$(1750 \times 3) \times (12 + (16 \times 2)) = 2.31 \times 10^5$ g

mass = 2.31×10^5 g **[2]**

(e) A reaction is first order with respect to H^+. At a pH of 1, the initial rate is 2.4×10^{-3} mol dm^{-3} s^{-1}.

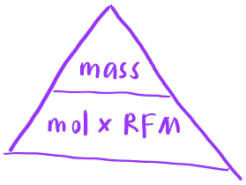
What is the initial rate at a pH of 3?

$\frac{2.4 \times 10^{-3}}{10^2} = 2.4 \times 10^{-5}$ mol dm^{-3} s^{-1}

initial rate = 2.4×10^{-5} mol dm^{-3} s^{-1} **[1]**

3

(f) What is the number of oxygen atoms in 4.26 g of P_2O_5?



$\frac{4.26}{(31 \times 2) + (16 \times 5)} = 0.03$ mol of P_2O_5

$(3 \times 0.03) \times 6.02 \times 10^{23} = 9.03 \times 10^{22}$

number of oxygen atoms = 9.03×10^{22} **[2]**

2 Benzoic acid, C_6H_5COOH, is added to some foods as a preservative.

A student prepares benzoic acid as outlined below.

Step 1 The student mixes 4.00 cm^3 of phenylmethanol, $C_6H_5CH_2OH$, (density = 1.04 $g\,cm^{-3}$) with sodium carbonate and aqueous potassium manganate(VII), as an oxidising agent. The mixture is heated under reflux.

Step 2 The resulting mixture is cooled and then acidified with concentrated HCl. Impure crystals of benzoic acid appear.

Step 3 The student recrystallises the impure crystals to obtain 1.59 g of pure benzoic acid.

(a) In **Step 1**, sodium carbonate, Na_2CO_3, makes the reaction mixture alkaline.

Write an ionic equation to show how carbonate ions form an alkaline solution in water.

$CO_3^{2-} + H_2O \longrightarrow OH^- + HCO_3^-$ (OH⁻) ..... **[1]**

(b) In **Step 2**, explain why the mixture must be acidified so that crystals of benzoic acid appear.

H^+ reacts with $C_6H_5COO^-$:

$H^+ + C_6H_5COO^- \rightarrow C_6H_5COOH$ ..... **[1]**

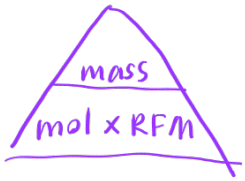
(c) Write the overall equation for the preparation of benzoic acid from phenylmethanol.

Use [O] for the oxidising agent.

$C_6H_5CH_2OH + 2[O] \longrightarrow C_6H_5COOH + H_2O$ ..... **[1]**

(d) Calculate the percentage yield of benzoic acid.

Give your answer to **3** significant figures.



$\frac{4 \times 1.04}{((12\times6)+5+12+2+16+1)} = 0.0385$ mol of $C_6H_5CH_2OH$

$\frac{1.59}{((12\times6)+5+12+(16\times2)+1)} = 0.013$ mol of C_6H_5COOH

$\frac{0.013}{0.0385} \times 100 = 33.8\%$ (3sf)

percentage yield = 33.8 % **[3]**

(e) In **Step 3**, describe how the student can recrystallise the impure crystals to obtain pure benzoic acid.

Dissolve in a minimal amount of hot solvent. Cool, filter, and leave to dry.

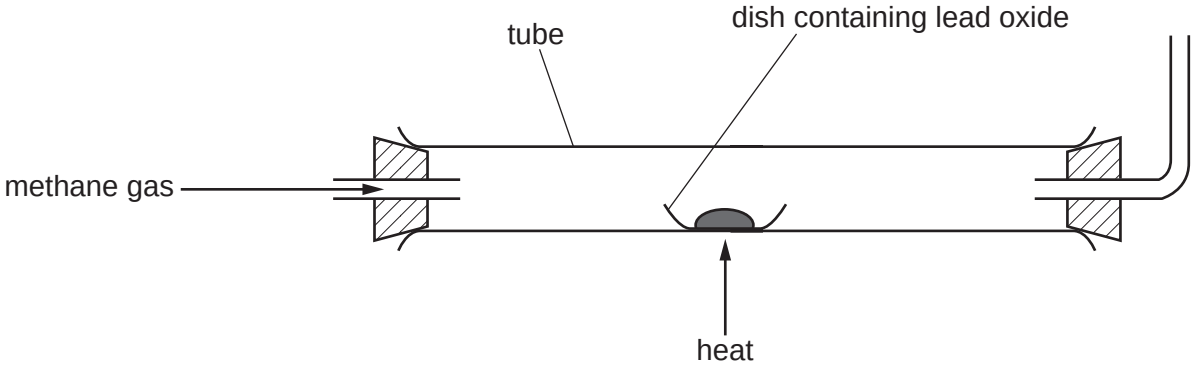
[2]

3 This question is about elements and compounds in Group 14 (Group 4) of the periodic table.

(a) There are four oxides of lead: PbO, PbO_2, Pb_2O_3 and Pb_3O_4.

A student carries out an experiment to identify an unknown lead oxide, which is one of the four oxides of lead shown above.

The student plans to reduce the unknown lead oxide to lead by heating the lead oxide in a stream of methane gas, CH_4. The apparatus is shown below.



Student's method

- Weigh an empty dish.
  Add the lead oxide to the dish and reweigh.
- Set up the apparatus and pass methane gas through the tube as shown.
  Heat the dish for 10 minutes.
- Pass cold air through the tube to cool the dish and contents.
- Weigh the dish and contents.

(i) Write the equation for the reduction of Pb_2O_3 with CH_4.

$4Pb_2O_3 + 3CH_4 \longrightarrow 8Pb + 3CO_2 + 6H_2O$ **[1]**

(ii) The student uses safety glasses and a lab coat.

State, with a reason, **one** other important safety precaution the student should take when carrying out this experiment.

Compounds may be toxic / poisonous / flammable so use a fume cupboard. Lead is toxic / poisonous so wear gloves. Methane is flammable so keep away from flame. **[1]**

(iii) The student was not sure that all the oxygen had been removed from the lead oxide.

Suggest **two** modifications that the student could make to their method to be confident that all the oxygen had been removed. Explain your reasoning.

1 Heat to a constant mass

pass methane through tube as it cools

2 spread / break up lead oxide

use excess methane

Bubble gas through lime water **[2]**

(iv) The student makes suitable modifications to the method and repeats the experiment to obtain the accurate results shown below.

Mass of dish / g	8.364
Mass of dish + lead oxide / g	11.818
Mass of dish + lead at end of experiment / g	11.496

Calculate the empirical formula of the lead oxide.

11.818 − 11.496 = 0.322

11.496 − 8.364 = 3.132

Pb	:	O
3.132	:	0.322
$\frac{3.132}{207.2}$	:	$\frac{0.322}{16}$
0.0151	:	0.020125
3	:	4

empirical formula = Pb_3O_4 **[2]**

(b) SiO_2 and CO_2 are oxides of other Group 14 (Group 4) elements.

Solid SiO_2 melts at 2156 °C. Solid CO_2 melts at −56 °C.

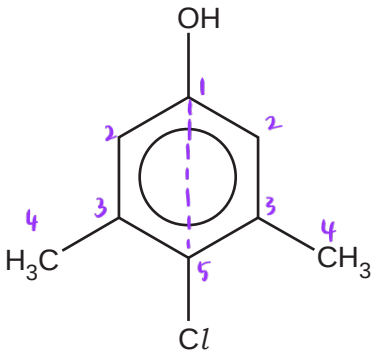
Suggest the type of lattice structure in solid SiO_2 and in solid CO_2 and explain the difference in melting points in terms of the types of force within each lattice structure.

Structure in SiO_2(s) giant

Structure in CO_2(s) simple molecular

Explanation london forces in CO_2. Covalent bonds in SiO_2 stronger than intermolecular forces in CO_2. **[4]**

4 Dettol® is a disinfectant containing the antiseptic chloroxylenol, shown below.



chloroxylenol

(a) Chloroxylenol is a weak Brønsted–Lowry acid.

(i) What is the systematic name of chloroxylenol?

4 - chloro - 3,5 - dimethylphenol

..... **[1]**

(ii) Predict the number of peaks in a ^{13}C NMR spectrum of chloroxylenol.

5

..... **[1]**

(iii) Name the functional group responsible for the acidity of chloroxylenol and describe a simple test which would confirm the presence of this group.

Functional group ..... phenol .....

Test ..... indicator turns red/orange (pH < 7) and no reaction with Na_2CO_3 .....

..... **[2]**

(iv) A student measures the pH of the contents in a bottle of Dettol® as 5.14.

The label on the bottle shows the percentage of chloroxylenol in Dettol® as 4.80% i.e. 100 cm^3 of Dettol® contains 4.80 g of chloroxylenol.

Assume the following:

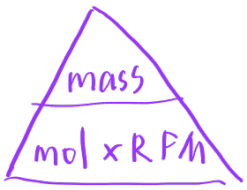
- Chloroxylenol is the only acidic component in Dettol®.
- Chloroxylenol is a weak monobasic acid.
- The density of Dettol® is 1.00 g cm^{-3}.

Write the equation, using molecular formulae, for the acid dissociation of chloroxylenol.

Calculate the acid dissociation constant, K_a, for chloroxylenol.

$C_8H_9ClO \rightleftharpoons H^+ + C_8H_8ClO^-$

$RFM = (12\times8) + 9 + 35.5 + 16 = 156.5\ g\,mol^{-1}$



$K_a = \frac{[H^+]^2}{[HA]}$

$[H^+] = 10^{-pH}$

$\frac{4.8}{156.5} = 0.03067\ mol$

$\frac{0.03067}{100\times10^{-3}} = 0.3067\ mol\,dm^{-3} = [HA]$

$[H^+] = 10^{-5.14} = 7.244\times10^{-6}\ mol\,dm^{-3}$

$K_a = \frac{[7.244\times10^{-6}]^2}{[0.3067]}$

$K_a = 1.71\times10^{-10}\ mol\,dm^{-3}$

$K_a =$ 1.71×10^{-10} ..... $mol\,dm^{-3}$ **[5]**

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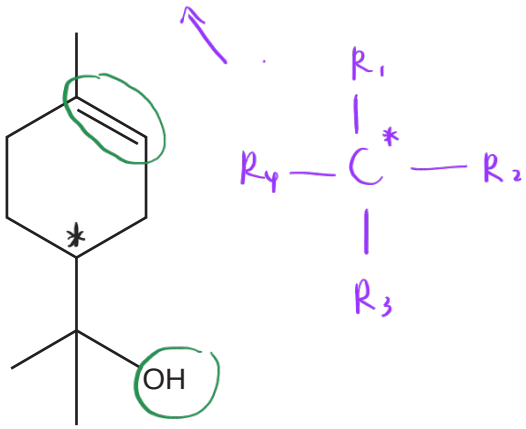
(b) Dettol® contains other chemicals including α-terpineol, shown below.

(i) α-Terpineol is a chiral compound.

Show with an asterisk, (*), the chiral centre(s) in the structure of α-terpineol.



α-terpineol

[1]

(ii) α-Terpineol meets the requirements for *E*/*Z* isomerism.
However, only one *E*/*Z* isomer of α-terpineol exists.

Explain
- why α-terpineol meets the requirements for *E*/*Z* isomerism
- whether α-terpineol is an *E*- or *Z*- isomer
- why only one *E*/*Z* isomer of α-terpineol exists.

• C = C double bond, each C attached to 2 different groups

• E/Z isomerism linked to high priority groups. Z-isomer groups are on the same side

• ring would be strained

[4]

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(iii) α-Terpineol contains two functional groups.

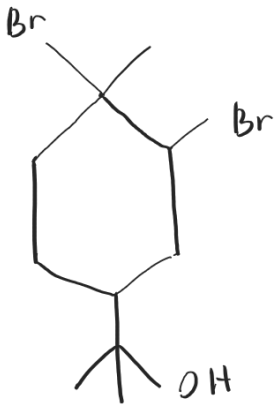
For each functional group, choose a reagent that reacts with that group **only**.
Draw the structures for the organic products of the reactions.

Show structures for organic compounds.

Reagent(s) Br_2

Name of functional group that reacts alkene

Structure of organic product

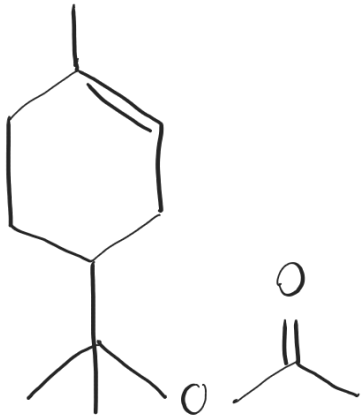


electrophilic addition mechanism

Reagent(s) CH_3COOH, H^+ catalyst

Name of functional group that reacts 3^o alcohol

Structure of organic product



esterification

[4]

5 This question is about copper(II) sulfate, $CuSO_4$, and sodium thiosulfate, $Na_2S_2O_3$.

(a) The enthalpy change of reaction, $\Delta_r H$, for converting anhydrous copper(II) sulfate to hydrated copper(II) sulfate is difficult to measure directly by experiment.

$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4 \bullet 5H_2O(s)$ $\Delta_r H$ **reaction 5.1**

The enthalpy changes of solution of anhydrous and hydrated copper(II) sulfate can be measured by experiment. The reactions are shown below.

In the equations, 'aq' represents an excess of water.

$CuSO_4(s) + aq \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq)$ $\Delta_{sol}H(CuSO_4(s))$ **reaction 5.2**

$CuSO_4 \bullet 5H_2O(s) + aq \rightarrow Cu^{2+}(aq) + SO_4^{2-}(aq)$ $\Delta_{sol}H(CuSO_4 \bullet 5H_2O(s))$ **reaction 5.3**

Experiment 1
A student carries out an experiment to find $\Delta_{sol}H(CuSO_4(s))$ for **reaction 5.2**.

Student's method
- Weigh a bottle containing $CuSO_4(s)$ and weigh a polystyrene cup.
- Add about 50 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $CuSO_4(s)$, stir the mixture, and measure the final temperature.
- Weigh the empty bottle and weigh the polystyrene cup with final solution.

Mass readings

Mass of bottle + $CuSO_4(s)$ / g	28.04
Mass of empty bottle / g	20.06
Mass of polystyrene cup / g	23.43
Mass of polystyrene cup + final solution / g	74.13

Temperature readings

Initial temperature of water / °C	20.5
Temperature of final solution / °C	34.0

Experiment 2
The student carries out a second experiment with $CuSO_4 \bullet 5H_2O$ (**reaction 5.3**). The student uses the same method as in **Experiment 1**.

The student calculates $\Delta_{sol}H(CuSO_4 \bullet 5H_2O(s))$ as +8.43 kJ mol^{-1}.

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(i)* Calculate $\Delta_{sol}H(CuSO_4(s))$ for **reaction 5.2** and determine the enthalpy change of **reaction 5.1**, $\Delta_r H$.

Assume that the specific heat capacity, *c*, of the solution is the same as for water.

Show your working, including an energy cycle linking the enthalpy changes. **[6]**

$E = mc\Delta T$

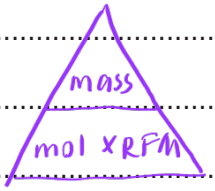
$74.13 - 23.43 = 50.7\,g$ (mass of solution)

$\Delta T = 34.0 - 20.5 = 13.5\,^{\circ}C$

$E = 50.7 \times 4.18 \times 13.5 = 2861\,J = 2.861\,kJ$

$28.04 - 20.06 = 7.98\,g$

$\frac{7.98}{(63.5 + 32 + (16 \times 4))} = 0.05$ mol of $CuSO_4$



$\frac{2.861}{0.05} = -57.22\,kJ\,mol^{-1}$ $\Delta_{sol}H(CuSO_4(s))$

$-57.22 - 8.43 = -65.65\,kJ\,mol^{-1}$

$= \Delta_r H$

Additional answer space if required

(ii) The thermometer had an uncertainty in each temperature reading of ±0.1 °C.

The student calculates a 20% uncertainty in the temperature change in **Experiment 2**. (x2 in temp change)

Calculate the temperature change in **Experiment 2**.

$(0.1 \times 2) \times \frac{100}{20} = 1.0\ °C$

temperature change = 1.0 °C **[1]**

(b) The standard enthalpy change of reaction, $\Delta_r H^{\ominus}$, and the standard free energy change, $\Delta G^{\ominus}$, for converting anhydrous sodium thiosulfate to hydrated sodium thiosulfate are shown below.

$Na_2S_2O_3(s) + 5H_2O(l) \rightarrow Na_2S_2O_3 \cdot 5H_2O(s)$

$\Delta_r H^{\ominus} = -55.8\ kJ\,mol^{-1}$
$\Delta G^{\ominus} = -16.1\ kJ\,mol^{-1}$

Standard entropies are given in the table.

Compound	$S^{\ominus}$ / $JK^{-1}mol^{-1}$
$Na_2S_2O_3 \cdot 5H_2O(s)$	372.4
$H_2O(l)$	69.9

Determine the **standard** entropy, $S^{\ominus}$, of anhydrous sodium thiosulfate, $Na_2S_2O_3(s)$.

Give your answer to **3** significant figures.

$\Delta G = \Delta H - T\Delta S$

$-16.1 = -55.8 - 298(\Delta S)$

$39.7 = -298(\Delta S)$

$-0.133 = \Delta S = -133\ JK^{-1}mol^{-1}$

$kJK^{-1}mol^{-1}$

$\Delta S = 372.4 - (5 \times 69.9) = 22.9\ JK^{-1}mol^{-1}$

$\Delta S = 22.9 - (-133) = 156\ JK^{-1}mol^{-1}$

$S^{\ominus}$ = 156 $JK^{-1}mol^{-1}$ **[4]**

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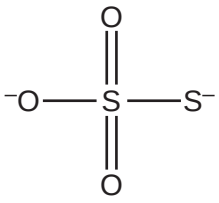
(c) Sodium thiosulfate contains the thiosulfate ion, $S_2O_3^{2-}$.
The displayed formula of $S_2O_3^{2-}$ can be shown as below.



thiosulfate ion

(i) Predict the O–S–S bond angle and name of the shape of the thiosulfate ion.

Bond angle 109.5°

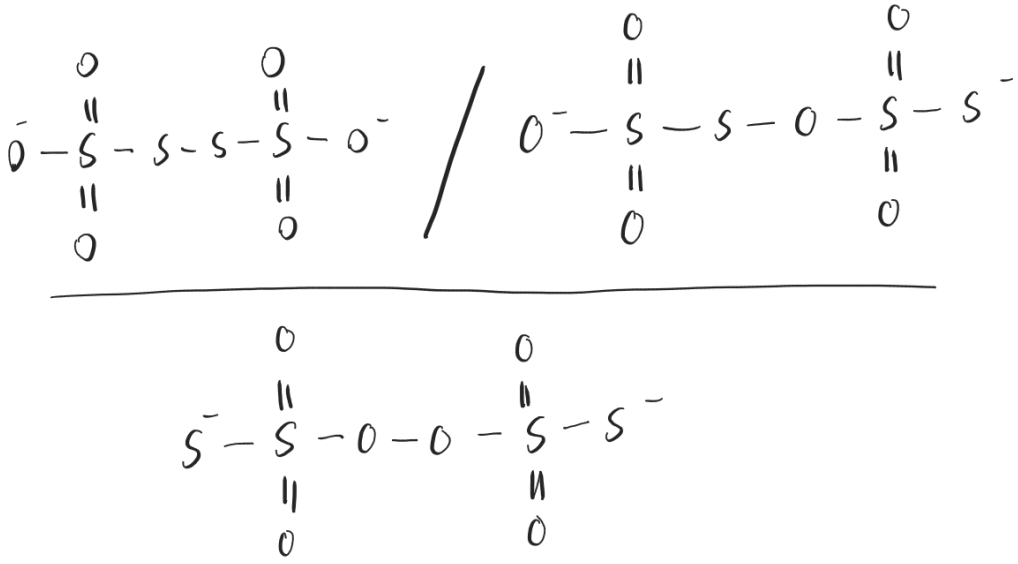
Name of shape tetrahedral

[1]

(ii) In some of its reactions, the thiosulfate ion forms the tetrathionate ion, $S_4O_6^{2-}$.

The $S_4O_6^{2-}$ ion is a 'dimer' of $S_2O_3^{2-}$.

Draw a displayed formula for the $S_4O_6^{2-}$ ion.



[1]

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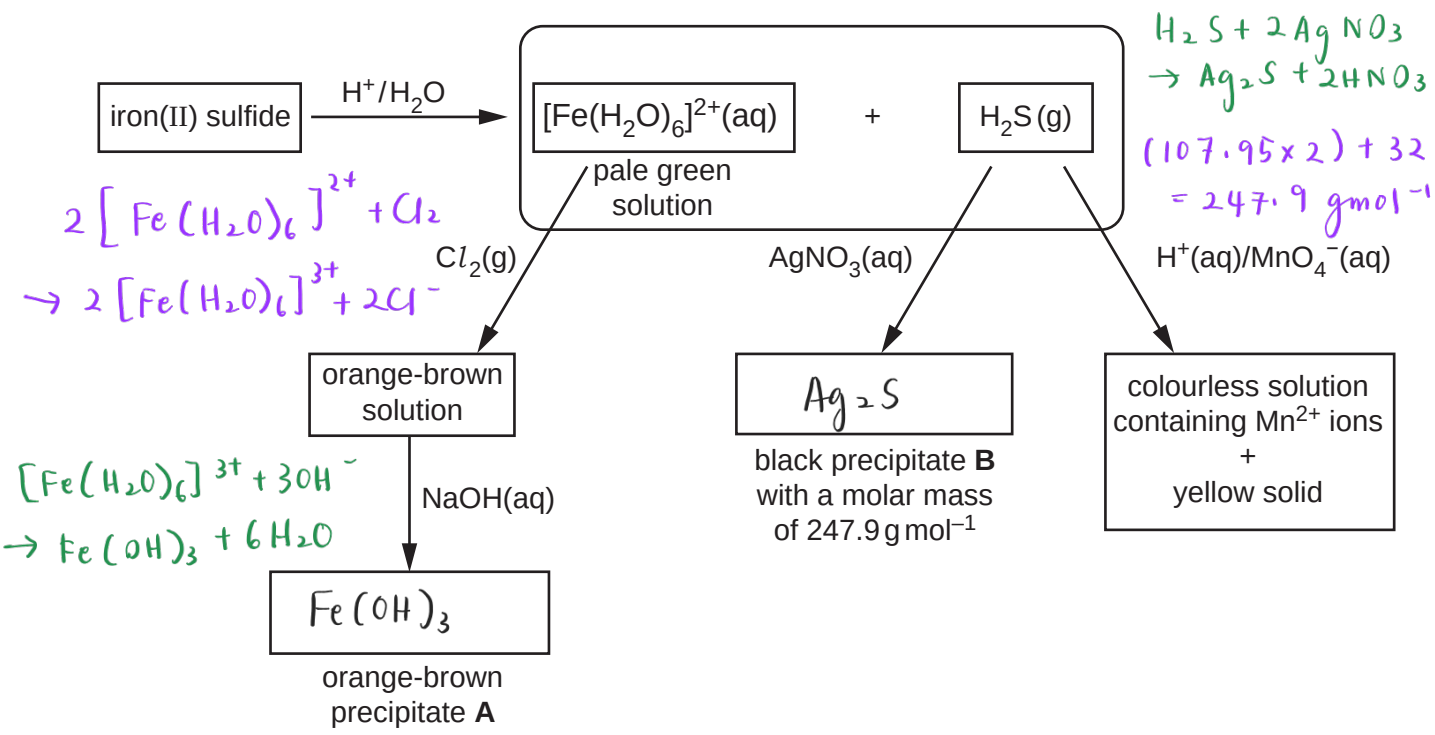
6 This question is about reactions of iron compounds.

(a) A student carries out the reactions in the flowchart, starting with iron(II) sulfide.



(i) In the boxes, write the formulae of **A** and **B**. **[2]**

(ii) The student thinks that the reaction of iron(II) sulfide with H^+/H_2O is a redox reaction.

Explain, with reasons, whether the student is correct.

Student is incorrect as no oxidation number change

e.g. Fe stays +2

[1]

(iii) Write the equation for the reaction of $[Fe(H_2O)_6]^{2+}(aq)$ with $Cl_2(g)$.

$2[Fe(H_2O)_6]^{2+} + Cl_2 \rightarrow 2[Fe(H_2O)_6]^{3+} + 2Cl^-$ **[1]**

(iv) Construct an equation for the reaction of $H_2S(g)$ with $H^+(aq)/MnO_4^-(aq)$.

$5H_2S + 2MnO_4^- + 6H^+ \rightarrow 2Mn^{2+} + 5S + 8H_2O$ **[2]**

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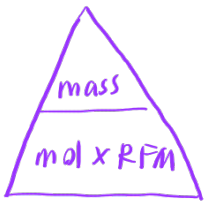
(b)* Compound **C** is a hydrated ionic compound with the empirical formula: $FeH_{18}N_3O_{18}$.

A student investigates the thermal decomposition of compound **C** as outlined below.

Stage 1
The student gently heats 0.00300 mol of compound **C** to remove the water of crystallisation. 0.486 g of water is collected, leaving 0.00300 mol of the anhydrous compound **D**.

Stage 2
The student strongly heats 0.00300 mol of compound **D**, which decomposes to form a solid oxide **E** (molar mass of 159.6 g mol^{-1}) and 270 cm^3 of a gas mixture, measured at RTP, containing gases **F** and **G**.



Stage 3
The student cools the 270 cm^3 gas mixture of **F** and **G**.
- Gas **F** is a compound that condenses to form 0.414 g of a liquid.
- Gas **G** remains and has a volume of 54 cm^3, measured at RTP.
  Gas **G** is tested and it relights a glowing splint. ↖ O_2

$\frac{\text{vol}}{\text{molar vol (24000 cm}^3\text{)}} = \text{mol}$

Determine the formulae of **C**, **D**, **E**, **F** and **G**.

Show all your working and equations for the reactions. **[6]**

$\frac{0.486}{18} = 0.027$ mol of H_2O

$0.027 : 0.003$ $\quad 1 : 9$ ↖ a H_2O

C : $Fe(NO_3)_3 \cdot 9H_2O$

D : $Fe(NO_3)_3$

E : Fe_2O_3 ← $(55.8 \times 2) + (16 \times 3) = 159.6$ g mol^{-1}

$\frac{270 - 54}{24000} = 0.009$ mol of F

$\frac{0.414}{0.009} = 46$ g mol^{-1} $= NO_2 = F$

G = O_2

Additional answer space if required.

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END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).