YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME					
CG		INDEX NO		H1 GROUP	C / H / E

CHEMISTRY

8873/01

Paper 1 Multiple Choice

17 September 2020

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid/tape.
Write your name and class 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.

This document consists of **11** printed pages and **1** blank pages.

[Turn Over

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

How many molecules are present in 1 cm^3 of oxygen gas under room conditions?

A $\frac{2 \times 6.02 \times 10^{23}}{24000}$

B $\frac{1 \times 24000}{6.02 \times 10^{23}}$

C $\frac{1 \times 6.02 \times 10^{23}}{24000}$

D $\frac{6.02 \times 10^{23} \times 24000}{1 \times 1000}$

2 The proton and an electron moved at the same speed perpendicular to a uniform electric field.

What deflection is observed?

A They are deflected in opposite directions. The proton is deflected most.

B They are deflected in the opposite directions. The electron is deflected most.

C They are deflected in the same direction. The proton is deflected most.

D They are deflected in the same direction. The electron is deflected most.

3 Which molecule contains the same numbers of bonds sigma and pi bonds?

A HCHO B N_2 C HCN D H_2O

4 U_3O_8 is a catalyst, prepared by heating a uranium nitrate salt, $UO_2(NO_3)_2$. This salt decomposes quantitatively to give U_3O_8, NO_2 and O_2 only.

How many moles of O_2 are produced from one mole of the salt?

A $^1/_3$

B $^1/_2$

C $^2/_3$

D 2

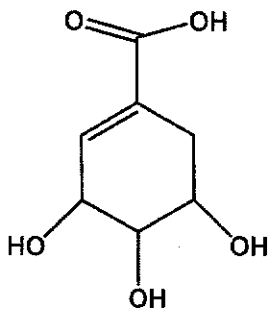
5 5×10^{-3} mol of solution of a metallic salt was found to react exactly with 2.5×10^{-3} mol of aqueous sodium sulfite. In this reaction, the sulfite ion is oxidised as follows:

$$SO_3^{2-}(aq) + H_2O(l) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e$$

What is the new oxidation number of the metal in the salt if its original oxidation number was +3?

A +1 **B** +2 **C** +4 **D** +5

6 Shikimic acid is a naturally occurring compound found in the spice plant star anise, also known as Japanese flower shikimi.



Shikimic acid

What is the percentage composition by mass of carbon in shikimic acid?

A 48.3% **B** 48.8% **C** 49.7% **D** 50%

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

Which of the following ions contains an unpaired electron?

A Ca^{2+}

B Cu^{2+}

C K^+

D Ti^{2+}

8 Which of the following pairs of compounds shows the same shape and similar bond angles?

A $AlCl_3$ and PCl_3

B $BeCl_2$ and CO_2

C SO_2 and CO_2

D $BeCl_2$ and H_2O

9 Which of the following can form hydrogen bonding?

1 NH_4Cl (s)

2 NH_3 (l)

3 $CH_3CH_2CH_2OH$ (l)

A 1 and 2 only

B 2 and 3 only

C 3 only

D All the above

10 Which of the following shows the sequence of the magnitude of lattice energies of the following compounds in ascending order?

I NaCl
II RbCl
III MgS
IV BaS

A I, II, III, IV

B II, I, IV, III

C III, IV, I, II

D IV, III, II, I

11 Which equation correctly describes the reaction whose ΔH_r is the standard enthalpy change of formation of cabon monoxide at 298K?

A $C(g) + O(g) \rightarrow CO(g)$

B $C(g) + \frac{1}{2} O_2(g) \rightarrow CO(g)$

C $C(s) + \frac{1}{2} O_2(g) \rightarrow CO(g)$

D $2C(s) + O_2(g) \rightarrow 2CO(g)$

12 A chemical plant illegally dumped two radioactive isotopes **P** and **Q** in a landfill. The amount of **P** is 4 times the amount of **Q**. The radioactive decay of isotopes follows first-order kinetics. The half-life of **P** is 2 days whereas that of **Q** is 8 days. By the time the authorities found out about this illegal dumping and analysed a sample of the waste, the ratio of **P** to **Q** was found to be **1:2**.

How long was the waste in the landfill before the authorities arrived?

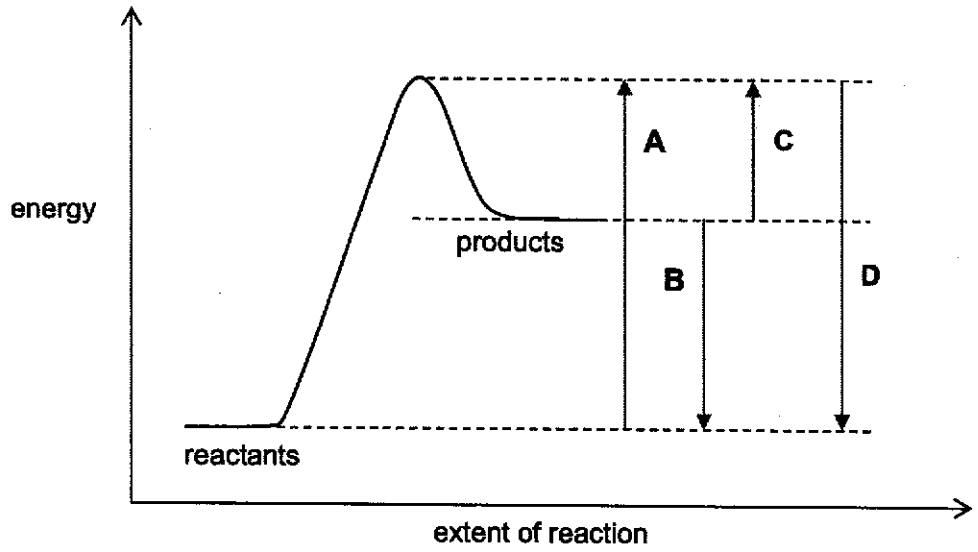
A 8 days

B 16 days

C 32 days

D 64 days

13 Which arrow on the reaction pathway diagram shows the enthalpy change of reaction for the reverse reaction?



14 Hydrogen and nitrogen monoxide can react to form nitrogen and steam.

$$2H_2(g) + 2NO(g) \rightarrow N_2(g) + 2H_2O$$

The rate of this reaction is first order with respect to hydrogen and second order with respect to nitrogen monoxide.

Which of the following conclusions can be drawn from this information?

A The value of rate constant depends on the concentrations of hydrogen and nitrogen monoxide.

B The overall order of reaction is two.

C Doubling the concentration of nitrogen monoxide increases the rate of evolution of nitrogen gas by 4 times.

D Halving the concentration of hydrogen will not change the rate of reaction.

15 The following equilibrium exists in a mixture of concentrated nitric acid and concentrated sulfuric acid.

$$HNO_3 + H_2SO_4 \rightleftharpoons H_2NO_3^+ + HSO_4^-$$

Which of the statements is correct?

A HNO_3 is a stronger acid than H_2SO_4.

B The nitric acid acts as an oxidising agent.

C The sulfuric acid acts as a dehydrating agent.

D HNO_3 and $H_2NO_3^+$ are a conjugate acid–base pair.

16 A mixture was made by adding 10 cm^3 of a solution of pH 1 to 30 cm^3 of another solution of pH 5. What is the final pH of the mixture?

A 1.6

B 2.5

C 3.0

D 4.0

17 The gallium hydrate hydrolyses as shown below.

$[Ga(H_2O)_6]^{3+}$ (aq) $\rightleftharpoons$ $[Ga(H_2O)_5OH]^{2+}$ (aq) + H_3O^+ (aq) $\quad \Delta H$ = positive

Which of the following statements about the equilibrium are **true**?

1 $[Ga(H_2O)_6]^{3+}$ is more stable at low pH values.

2 Increasing the temperature will favour the formation of $[Ga(H_2O)_5OH]^{2+}$

3 Increasing the concentration of $[Ga(H_2O)_6]^{3+}$ will increase K_c as the forward reaction is favoured.

A 1 only

B 1 and 2 only

C 2 and 3 only

D All the above

18 When pressure is increased for a homogeneous gaseous system at equilibrium, the position of equilibrium shifted to the right.

Which of the following could be the units of the equilibrium constant, K_c, for this system?

A $mol^{-1}\ dm^3$

B $mol\ dm^{-3}$

C $mol^2\ dm^{-6}$

D no units

19 Which property decreases from Na_2O to P_4O_{10} for the oxides of period 3 elements?

A melting point

B covalent character

C solubility in aqueous alkali

D pH when mixed with water

20 The proton number of the element **P** is less than 20.

The chloride of element **P** has a simple molecular structure, and is readily hydrolysed in water to give an acidic solution.

The oxide of **P** is insoluble in water.

In which Group of the Periodic Table is **P** likely to be found?

A Group 1

B Group 2

C Group 14

D Group 15

21 Which of the following series does **not** have a decreasing trend?

A atomic radius of P, S and Cl

B melting point of Si, P and S

C ionic radius of Na^+, Mg^{2+} and Al^{3+}

D electrical conductivity of Al, Si and P

22 Which of the following statements are true about the elements in Group 1 of the Periodic Table?

1 The ionic radius increases down the group.

2 The reducing power increases down the group.

3 The electronegativities decrease down the group.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D All the above

23 Sodium hydroxide reacts with chloropropane in a series of steps to produce propanoic acid.

$$CH_3CH_2CH_2Cl \xrightarrow{\text{step 1}} \mathbf{Q} \xrightarrow{\text{step 2}} CH_3CH_2COOH$$

What are the identities of the reagents for step 1 and step 2, and the organic intermediate **Q**?

	step 1	Q	step 2
A	$Cr_2O_7^{2-}$/ H^+	$CH_3CH_2CH_2OH$	$KMnO_4$ / H^+
B	NaOH/ethanol	$CH_3CH{=}CH_2$	H_2SO_4(aq)
C	NaOH(aq)	$CH_3CH_2CH_2OH$	$Cr_2O_7^{2-}$/ H^+
D	$NaBH_4$	$CH_3CH_2CH_2CH_3$	$KMnO_4$ / H^+

24 Which of the following pairs of compounds can be distinguished by using acidified potassium manganate(VII) solution?

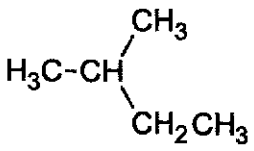
A pentan-2-one and pentan-3-one

B pentan-2-one and pentanal

C propan-1-ol and propan-2-ol

D 2-methylpropan-2-ol and pentan-2-one

25 When 2-methylbutane reacts with limited chlorine gas in the presence of uv light, monochlorinated compounds are formed.



2-methylbutane

Which of the following statements is **not** correct?

1 H_2 molecule is a by-product of the reaction.

2 Four different monochlorinated isomers may be formed.

3 The reaction can take place if heat is used instead of uv light.

A 1 only

B 2 only

C 1 and 2 only

D All the above

26 Alcohols can be classified into primary, secondary and tertiary alcohols. How many structural isomers are there for each type with the formula $C_5H_{12}O$?

	primary	secondary	tertiary
A	3	3	2
B	4	2	2
C	4	3	1
D	5	2	1

27 Which compound can undergo a reaction when treated with hot ethanolic potassium hydroxide?

A CH_2Br_2

B CBr_3CBr_3

C $(CH_3)_2CCBr_2$

D $CH_3CBr_2CH_3$

28 Butanoic acid was heated under reflux with a mixture of ethanol and propanol in the presence of concentrated sulfuric acid. Which of the following is a possible product of this reaction?

A ethyl propanoate

B propyl butanoate

C butyl butanoate

D propyl ethanoate

29 Poly(ethane) cup is attached to the pelvic girdle by bone cement in an artificial hip joint. The formation of the cement is highly exothermic and involves polymerisation of the monomer methyl-2-methylpropenoate, $CH_2=C(CH_3)COOCH_3$.

Which statements about this polymerisation are correct?

1 More energy is released in making two C–C bonds than in breaking a C=C bond.

2 The formation of the cement occurs by condensation polymerisation.

3 The polymer can form strong hydrogen bonds between layers.

A 1 only

B 1 and 2 only

C 2 and 3 only

D All the above

30 Which of the following statement regarding the properties of high density polyethene (HDPE) and low density polyethene (LDPE) is least likely to be correct?

A HDPE is harder than LDPE.

B HDPE has a higher melting point than LDPE.

C HDPE has more branching than LDPE.

D HDPE is less flexible than LDPE.

12

BLANK PAGE

YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME					
CG		INDEX NO		H1 GROUP	C / H / E

CHEMISTRY

8873/02

Paper 2 Structured Questions

1 September 2020

Candidates answer on the Question Paper.

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, index number and CG 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, highlighters, and glue or correction fluid/tape.

Section A
Answer **all** questions.

Section B
Answer **one** question.

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

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

For Examiner's Use	
Paper 1	
	/30
Paper 2	
1	/11
2	/7
3	/11
4	/7
5	/7
6	/17
7 or 8	/20
Penalty	
	/80
Overall (Paper 1 & 2) Percentage (%)	
	/110

This document consists of **24** printed pages.

[Turn over

Section A

Answer **all** the questions in this section, in the spaces provided.

1 The element magnesium, Mg, is a metal which is used in many alloys which are strong and light. Magnesium can exist as a number of different isotopes.

(a) What is meant by the term *isotope*?

.....

.....

[2]

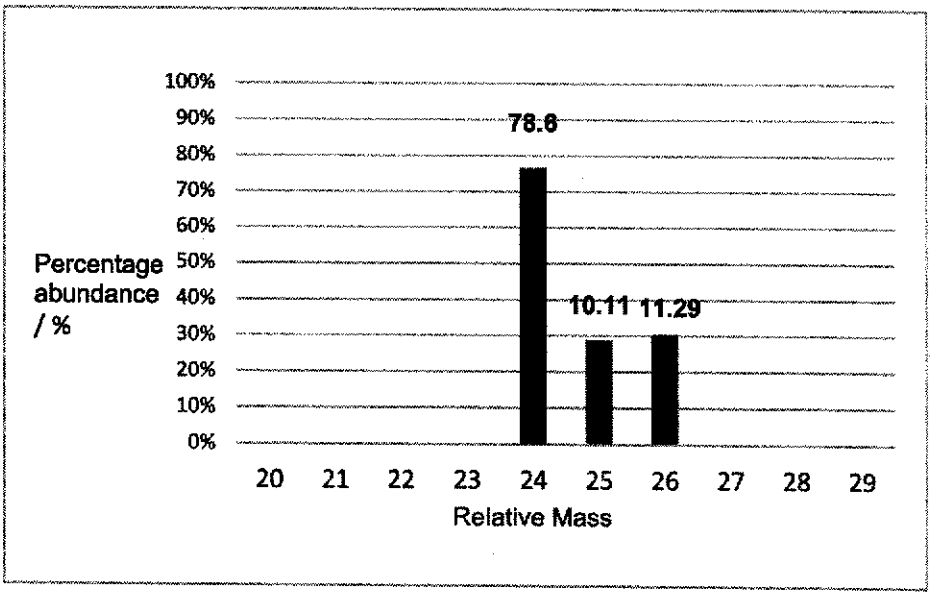
(b) **(i)** Complete the table below for two of the isotopes of magnesium.

isotopic species	number of proton	number of neutrons	number of electrons
$^{24}_{12}Mg$			
		14	11

[2]

(ii) The relative atomic mass of an element can be determined using data from its mass spectrum. The mass spectrum of an element reveals the abundances of these isotopes, which can be used to calculate the relative atomic mass of the element.

The mass spectrum of a sample of magnesium, with the percentage of abundance of each isotope is shown below.



Calculate the relative atomic mass, *Ar*, of magnesium in the sample.
Express your answer to **two** decimal places.

[1]

(c) Successive ionisation energies for the element Magnesium are given in the table.

Element	1st ionisation energy / kJ mol^{-1}	2nd ionisation energy / kJ mol^{-1}	3rd ionisation energy / kJ mol^{-1}
Mg	736	1450	7740
Al	577	1820	2740

(i) Complete the electronic configuration of the following particles:

Mg $1s^2$ _____

Al $1s^2$ _____

[2]

(ii) Explain why the 1st ionisation energy of aluminium is lower than that of magnesium.

.....

.....

.....

.....

[2]

(iii) Explain why there is a large increase between the 2nd and 3rd ionisation energies of magnesium.

.....

.....

.....

.....

[2]

[Total: 11]

2 The main ore of manganese, pyrolysite, is mainly MnO_2. A solution of $SnCl_2$ can be used to estimate the percentage of MnO_2 in a sample of pryolusite, using the following method.

- A known mass of pyrolysite is warmed with an acidified solution containing a known amount of $SnCl_2$.
- The excess $Sn^{2+}(aq)$ ions are titrated with a standard solution of $KMnO_4$.

In one such experiment, 0.110 g of pyrolysite was warmed with an acidified solution containing 2.00×10^{-3} mol Sn^{2+}. After the reaction was complete, the mixture was titrated with 0.0200 mol dm^{-3} $KMnO_4$, and required 18.1 cm^3 of this solution to reach the end point.

The equation for the reaction between Sn^{2+} and MnO_2 is as follows:

$$MnO_2 + 4H^+ + Sn^{2+} \longrightarrow Mn^{2+} + 2H_2O + Sn^{4+}$$

Acidified $KMnO_4$ oxidises Sn^{2+}. The reduction and oxidation half equations are as follow:

$$MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$$

$$Sn^{2+} \longrightarrow Sn^{4+} + 2e$$

(a) Write the equation for the reaction between MnO_4^- and Sn^{2+} in acidic medium.

.....

[1]

[Turn over

(b) (i) Calculate the number of moles of MnO_4^- used in the titration.

[1]

(ii) Calculate the number of moles of Sn^{2+} that reacted with 0.110 g sample of pyrolysite.

[2]

(iii) Calculate the mass of MnO_2 in 0.110 g of pyrolysite.

[1]

(iv) Calculate the percentage of MnO_2 in pyrolysite.

[1]

(c) In the experiment, the student did not ensure complete reaction between Sn^{2+} and pyrolysite and continued with the titration with $KMnO_4$.

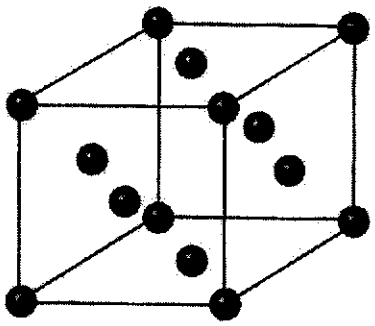
Explain the effect, if any, that the error will have on the amount of, in moles, of MnO_4^- calculated in **(b)(i)** and thus the percentage of MnO_2 calculated in **(b)(iv)**.

.....

.....

[1]
[Total: 7]

3 Structure and bonding can be used to explain many of the properties of substances. Copper and iodine are both solids with the same face-centered crystal structure which is shown below.



The particles present in such a crystal may be atoms, molecules, electrons, anions or cations. In the diagram above, the particles present are represented by ●.

(a) Copper, silicon(IV) oxide, sodium chloride and iodine are all examples of crystalline solids, though the crystalline solid may be a different structure.

Complete the table with:

- the type of particles present in each crystalline solid
- the name of a type of lattice structure found in each crystalline solid

crystalline solid	particles	type of lattice structure
copper		
silicon(IV) oxide		
iodine		

[2]

(b) When separate samples of silicon(IV) oxide or iodine are heated to 100°C, the silicon(IV) oxide remains as a solid while the iodine turns into a vapour. Explain, in terms of the bonding present in the solid structure, why silicon(IV) oxide remains a solid at 100°C.

.....

.....

[1]

(c) The acid and base behaviour of oxides, magnesium oxide, aluminium oxide and silicon(IV) oxide, show periodic trends.

(i) Aluminium oxide is said to be *amphoteric*. Write equations to illustrate this fact.

.....

.....

[2]

[Turn over

(ii) Write balanced equations, if any, to illustrate how magnesium oxide and silicon(IV) oxide differ in their behaviour when reacted with

I acids and bases
II water

.....

.....

.....

.....

[3]

(d) The elements in Group 17, the halogens, and their compounds, show many similarities and trends in their properties. Some data are given for the elements fluorine to iodine.

	HF	HCl	HBr	HI
boiling point / °C	+20	−85	−67	−35
bond energy / kJ mol^{-1}	562	431	366	299

(i) Explain the trend in the boiling points of the hydrogen halides, HCl, HBr and HI.

.....

.....

.....

.....

.....

[2]

(ii) Suggest why the hydrogen halide HF does not follow the trend in boiling points shown by HCl, HBr and HI.

.....

.....

[1]

[Total: 11]

4 About 3,000 tonnes of ammonium nitrate, $NH_4NO_3(s)$ detonated and resulted in an explosion in Beirut, Lebanon on 5 August 2020, that killed at least 80 people and injured thousands more. It was reported that the ammonium nitrate was stored in a warehouse without proper safety controls.

[1 tonne = 1000 kg]

(a) Ammonium nitrate primarily breaks down into a number of gases: nitrogen, water vapour and oxygen. Construct an equation for the decomposition of ammonium nitrate.

.....

[1]

(b) Calculate the total volume of gas evolved at room temperature pressure when 3,000 tonnes of ammonium nitrate is detonated.

[2]

(c) Ammonium nitrate can be formed by the reaction of ammonia with concentrated nitric acid.

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

Suggest the type of reaction and the role of NH_3 in the above reaction.

type of reaction .....

role of NH_3 .....

[2]

(d) Draw the structure and suggest the shape of ammonium ion.

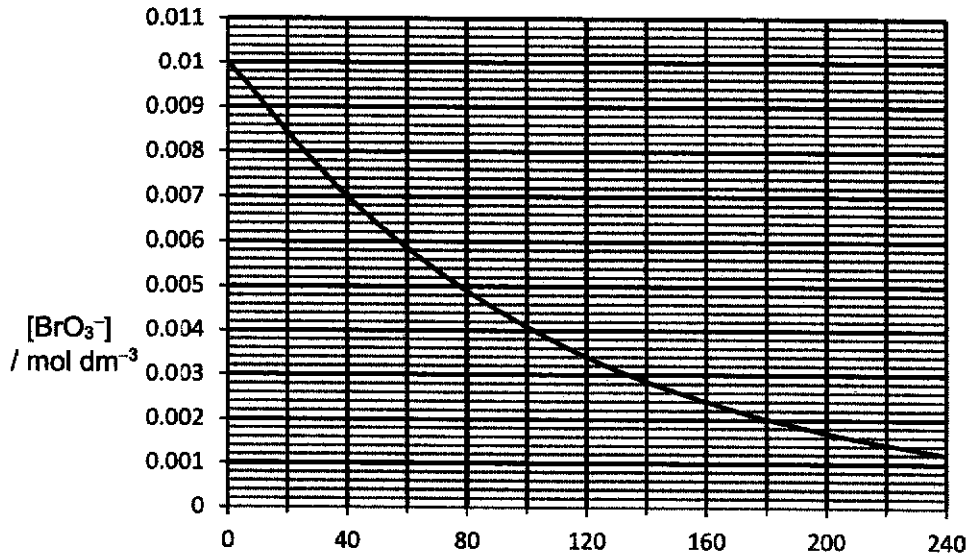
[2]

[Total: 7]

5 The oxidation of bromide ions by bromate(V) ions, BrO_3^-, in acidic solution is represented by the equation below.

$$5Br^- + BrO_3^- + 6H^+ \longrightarrow 3Br_2 + 3H_2O$$

Experiments are conducted to investigate how the rate of reaction depends on the concentration of each of the three reactants. The following graph shows the result of an experiment measuring $[BrO_3^-]$ over time, while the concentrations of two reactants were in excess and kept constant.



The concentration was determined at regular time intervals as the reaction progressed.

(a) Showing all working, and clearly any construction lines on the graph. Use the graph to determine:

(i) the order of reaction with respect to BrO_3^-,

[2]

(ii) the initial rate, in mol dm^{-3} s^{-1}.

[1]

(b) **(i)** The order of reaction with respect to $[H^+]$ and $[Br^-]$ is one and zero respectively.

Using your answer in **(a)(i)** and the info provided, write the rate equation for this reaction.

_____ [1]

(ii) State and explain the effect on the rate of this reaction when only $[Br^-]$ is increased by 2 times.

_____

_____ [1]

(c) The rate of reaction was measured as 8.20×10^{-6} mol dm^{-3} s^{-1} when $[Br^-] = 0.10$ mol dm^{-3}, $[BrO_3^-] = 0.10$ mol dm^{-3} and $[H^+] = 0.40$ mol dm^{-3}.

Determine the rate constant for this reaction and state its units.

[2]

[Total: 7]

6 Crotonaldehyde is an aldehyde that has a molecular formula of C_4OH_6. The main use of it is to prepare sorbic acid which is used as food preservative.

(a) **(i)** Crotonaldehyde is able to exhibit cis-trans isomerism.

Draw the formula of the cis-trans isomers of Crotonaldehyde in the boxes provided.

cis-isomer	trans-isomer

[2]

(ii) Crotonaldehyde reacts with aqueous bromine. Name the functional group in crotonaldehyde that reacts with bromine and write down the observations of the reaction.

reagent	functional group present	observation
aqueous bromine		

[1]

(b) Fig 6.1 shows a possible reaction sequence with crotonaldehyde as an intermediate product.

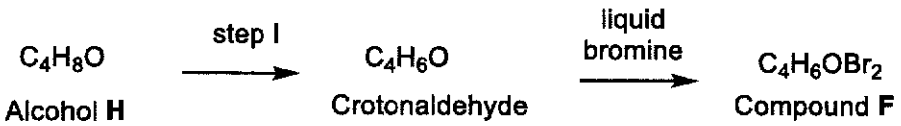


Fig. 6.1

(i) Suggest the reagents and conditions for the step I.

reagent(s) .....

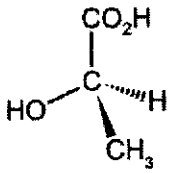
condition(s) .....

[2]

(ii) Draw the skeletal structure of compound **F**.

[1]

(c) In recent developments, there is increasing awareness of diminishing supply of crude oil has placed much attention on PLA (polylactic acid) as it is biodegradable. Lactic acid is produced from corn starch and has the structure shown below.



The glass transition temperature of PLA is between 60°C – 70°C and a melting point of 175°C. The Glass Transition Temperature is the temperature at which the polymer structure turns from hard to viscous liquid or rubbery structure when heated.

(i) Draw the section of the PLA polymer showing 2 repeat units.

[1]

(ii) Explain why PLA would not be a suitable packaging material for foods pickled in vinegar.

.....

.....

[1]

(iii) PLAs containers are not used for hot drinks. Suggest why.

.....

.....

[1]

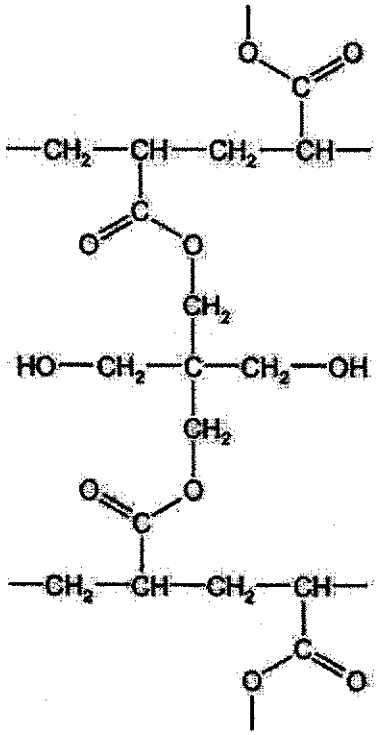
(iv) Suggest a reason why PLA is popular packaging material, other than it is biodegradable.

.....

.....

[1]

(d) Another useful development is a range of polymers known as hydrogels, which are hydrophilic and can absorb large quantities of water. The presence of side chains in the polymers can react to form cross-linked. The hydrogel formed below, is formed from chains of one polymer which are cross-linked using another molecule.



The monomer of this polymer chain is $CH_2CHCOOH$.

(i) State the type of polymerisation used to form these chains.

.....

[1]

(ii) Draw the structure of the molecule used to cross-link the polymer chains.

[1]

(iii) Predict if these polymers can be recycled. Explain your answer.

.....

.....

.....

[2]

(iv) Not every available side chain in the polymer is cross-linked, and the amount of cross-linking affects the properties of the hydrogel.

I Once the hydrogel has absorbed water, it can be dried and re-used a number of times. Suggest why the amount of cross linking has little effect on the ability of hydrogel to absorb water.

.....

.....

[1]

II Suggest one property of hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.

.....

.....

.....

[2]

[Total: 17]

Section B

Answer **one** question from this section, in the spaces provided.

7 **(a)** A hydride of nitrogen, **Q**, contains 12.5% of hydrogen by mass.

(i) Calculate the empirical formula of **Q**.

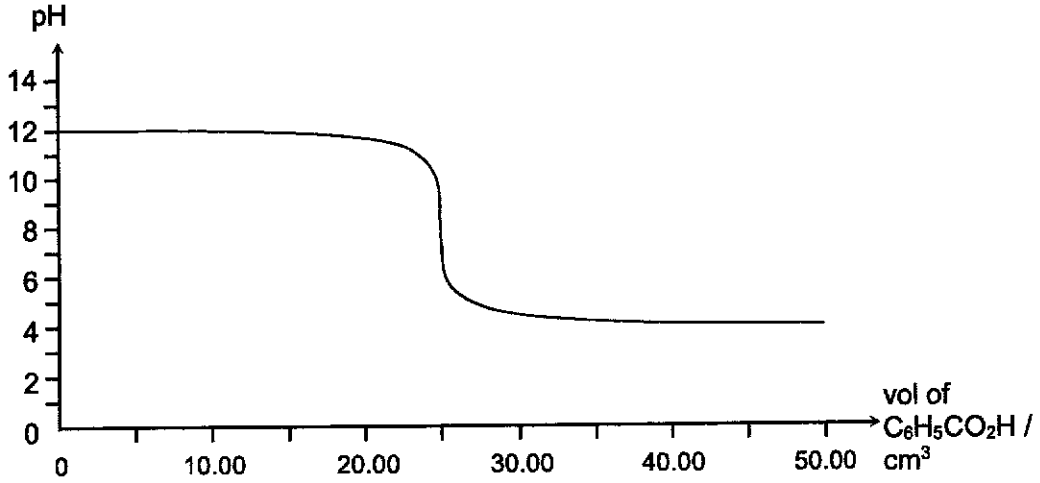
[1]

(ii) When **Q** was heated strongly, it decomposes into its elements. 10 cm^3 of **Q** gave 30 cm^3 of products (volumes are measured under the same conditions).

What is the molecular formula of **Q**?

[2]

(b) A solution of benzoic acid, $C_7H_6O_2$ is added to 20.00 cm^3 of aqueous sodium hydroxide. The change in pH was measured and the following titration curve was obtained.



(i) Using the titration curve, calculate the concentration of OH^- at the beginning of the reaction.

[1]

(ii) Suggest why phenolphthalein is a suitable indicator for the above reaction and state the expected colour change.

.....

.....

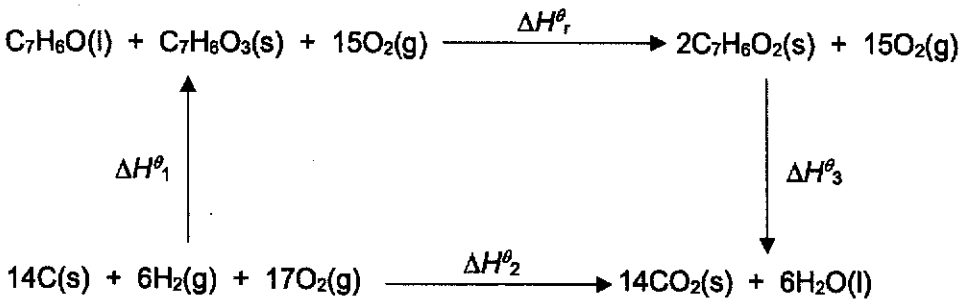
.....

[2]

(iii) Using the answer in **(b)(i)**, calculate the concentration of the solution of benzoic acid.

[2]

(c) The diagram below shows the energy cycle involving reactions of C_7H_6O, $C_7H_6O_3$ and $C_7H_6O_2$.



ΔH^θ_c carbon	=	–393.5 kJ mol^{-1}
ΔH^θ_c hydrogen	=	–285.8 kJ mol^{-1}
ΔH^θ_f $C_7H_6O(l)$	=	–87.0 kJ mol^{-1}
ΔH^θ_f $C_7H_6O_3(s)$	=	–367.0 kJ mol^{-1}
ΔH^θ_c $C_7H_6O_2(s)$	=	–3228 kJ mol^{-1}

(i) Use the energy cycle and data above to calculate the value for ΔH^θ_1, ΔH^θ_2 and ΔH^θ_3.

[3]

(ii) Write an equation that links ΔH^θ_r, ΔH^θ_1, ΔH^θ_2 and ΔH^θ_3.

.....

[1]

(iii) Hence or otherwise, calculate the standard enthalpy change of reaction, ΔH^θ_r.

[1]

[Turn over

(d) Caprylic acid dissociates as shown below.

$$CH_3(CH_2)_6COOH \rightleftharpoons CH_3(CH_2)_6COO^- + H^+$$

(i) Write an equilibrium expression, K_c, for this reaction.

[1]

(ii) The reaction mixture is allowed to reach equilibrium. The equilibrium concentrations of H^+ and $CH_3(CH_2)_6COO^-$ are found to be 6.31×10^{-5} mol dm^{-3}.

Given that the K_c value for the equilibrium is 3.08×10^{-5}, calculate the initial concentration of caprylic acid.

[2]

(e) Aqueous sodium chromate(VI) contains yellow CrO_4^{2-} ions. These chromate(VI) ions exist in equilibrium with dichromate(VI) ions as shown by the equilibrium below.

$$\underset{\text{yellow}}{2CrO_4^{2-}(aq)} + 2H^+(aq) \rightleftharpoons \underset{\text{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l)$$

(i) Describe and explain what you would observe if dilute acid was added to a portion of the equilibrium mixture shown above.

.....

.....

.....

[2]

(ii) When the equilibrium mixture is cooled, the solution becomes more orange.

Is the forward reaction endothermic or exothermic? Explain your answer.

.....

.....

.....

.....

[2]

[Total: 20]

8 (a) (i) A gaseous aromatic hydrocarbon, **X**, was subjected to combustion analysis. **X** on complete combustion gave 0.814 g of carbon dioxide and 0.208 g of water. What is the empirical formula of **X**?

[2]

(ii) A 0.245 g sample of **X** has a volume of 51.8 cm^3 at standard temperature and pressure. Determine the molecular formula of **X**.

[2]

(b) Ethanoic acid is a weak acid with a sharp smell.

(i) Explain what is meant by a *weak acid*?

.....

.....

[1]

(ii) A 0.150 mol dm^{-3} of ethanoic acid has a pH of 3.1. Given that sulfuric acid is a strong acid, calculate the pH of sulfuric acid of the same concentration.

[2]

(c) In humans it is important for blood to be maintained at a pH between 7.35 and 7.45. One of the ways it does this is by using a buffer of $CO_2(aq)$ and $HCO_3^-(aq)$.

During vigorous exercise the muscle produce lactic acid. Lactic acid is transported by the blood to the liver to be broken down.

Write equation(s) to explain how the $CO_2(aq)/HCO_3^-(aq)$ buffer system helps to maintain the pH of blood between 7.35 and 7.45 during exercise.

.....

.....

.....

.....

.....

[2]

(d) Aqueous iron(III), Fe^{3+} exists as $[Fe(H_2O)_6]^{3+}$, which is a yellow solution. The complex, $[Fe(H_2O)_5(SCN)]^{2+}$, is formed when a solution of SCN^- is added as shown in the following equation.

$$\underset{\text{yellow}}{[Fe(H_2O)_6]^{3+}(aq)} + \underset{\text{colourless}}{SCN^-(aq)} \rightleftharpoons \underset{\text{blood-red}}{[Fe(H_2O)_5(SCN)]^{2+}(aq)} + H_2O(l)$$

(i) Write an equilibrium expression, K_c, for this reaction.

[1]

50.0 cm^3 of aqueous iron(III) is mixed with 25.0 cm^3 of 0.05 mol dm^{-3} SCN^- solution.

At equilibrium, the concentrations of SCN^- and the complex, $[Fe(H_2O)_5(SCN)]^{2+}$ is 5.45×10^{-3} mol dm^{-3} and 3.36×10^{-5} mol dm^{-3} respectively.

The numerical value of the equilibrium constant, K_c, for the reaction is 0.302.

(ii) Calculate the concentration of Fe^{3+} at equilibrium.

[1]

(iii) Calculate the initial concentration of Fe^{3+} in the mixture.

[2]

(iv) Hence calculate the amount of Fe^{3+} in 50 cm^3 of the stock solution.

[1]

(v) The reaction mixture is allowed to reach equilibrium. $NaHPO_4$, which reacts with iron(III), is then added to the equilibrium mixture.

Describe and explain what you would observe after $NaHPO_4$ was added.

.....

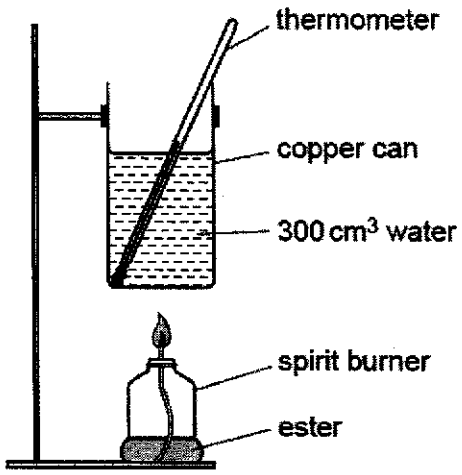
.....

.....

.....

[2]

(e) A student used the apparatus shown to carry out experiments to determine the standard enthalpy change of combustion of methyl ethanoate, CH_3COOCH_3.



Mass of copper can = 250 g

An initial experiment was carried out using methyl ethanoate. This ester was burnt in a spirit burner underneath a copper can so that the flame from the burner heated 300 cm^3 of water in the can. It was found that 0.980 g of ester was required to raise the temperature of the water in the can by 10.0 °C.

(i) Calculate the heat gain by the water given that the specific heat capacity of water is 4.18 $J\,g^{-1}\,K^{-1}$. Take the density of water to be 1.00 $g\,cm^{-3}$.

[1]

(ii) Given that the **total** heat energy gain is 13.5 kJ, calculate the heat capacity of the copper can used in this experiment.

[1]

(iii) Given that the ΔH^{θ}_{c} of methyl ethanoate is 1592.1 kJ mol^{-1}, calculate the **total** theoretical heat energy **in kJ** released by the mass of methyl ethanoate burnt in this experiment.

[1]

(iv) Calculate the percentage efficiency of heat transfer in this experiment.

[1]

[Total: 20]

H1 Paper 1

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

How many molecules are present in 1 cm^3 of oxygen gas under room conditions?

A $\frac{2 \times 6.02 \times 10^{23}}{24000}$

B $\frac{1 \times 24000}{6.02 \times 10^{23}}$

C $\frac{1 \times 6.02 \times 10^{23}}{24000}$

D $\frac{6.02 \times 10^{23} \times 24000}{1 \times 1000}$

[redacted]

2 The proton and an electron moved at the same speed perpendicular to a uniform electric field.

What deflection is observed?

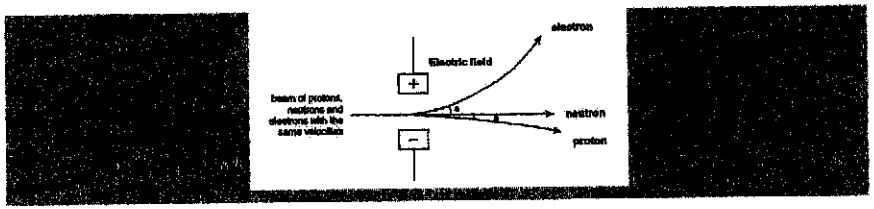
A They are deflected in opposite directions. The proton is deflected most.

B They are deflected in the opposite directions. The electron is deflected most.

C They are deflected in the same direction. The proton is deflected most.

D They are deflected in the same direction. The electron is deflected most.

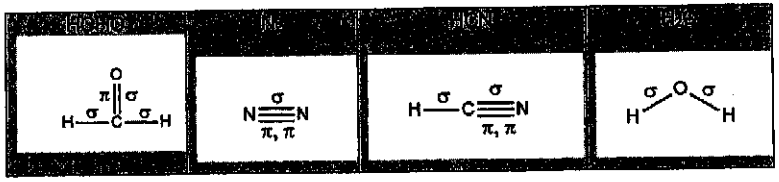
[redacted]



3 Which molecule contains the same numbers of bonds sigma and pi bonds?

A HCHO **B** N_2 **C** HCN **D** H_2O

Answer: C



4 U_3O_8 is a catalyst, prepared by heating a uranium nitrate salt, $UO_2(NO_3)_2$. This salt decomposes quantitatively to give U_3O_8, NO_2 and O_2 only.

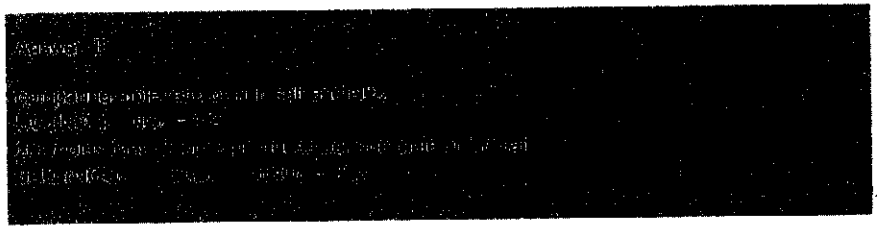
How many moles of NO_2 are produced from one mole of the salt?

A $^1/_3$

B $^1/_2$

C $^2/_3$

D 2

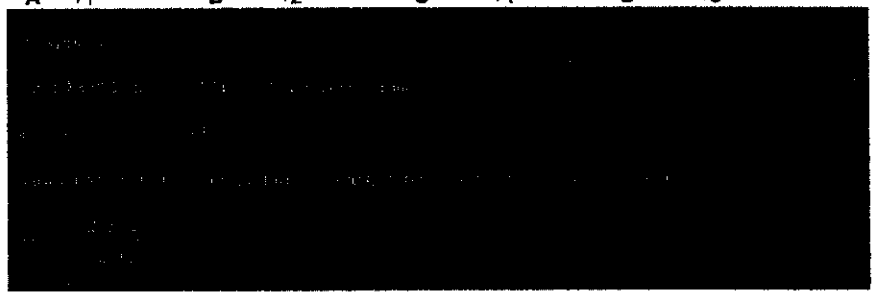


5 5×10^{-3} mol of solution of a metallic salt was found to react exactly with 2.5×10^{-3} mol of aqueous sodium sulfite. In this reaction, the sulfite ion is oxidised as follows:

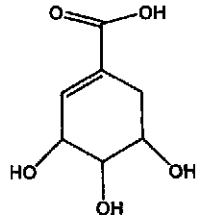
$$SO_3^{2-}(aq) + H_2O(l) \longrightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e$$

What is the new oxidation number of the metal in the salt if its original oxidation number was +3?

A +1 **B** +2 **C** +4 **D** +5



6 Shikimic acid is a naturally occurring compound found in the spice plant star anise, also known as Japanese flower shikimi.



Shikimic acid

What is the percentage composition by mass of carbon in shikimic acid?

A 48.3% **B** 48.8% **C** 49.7% **D** 50%

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

Which of the following ions contains an unpaired electron?

A Ca^{2+}

B Cu^{2+}

C K^{+}

D Ti^{2+}

[redacted]

8 Which of the following pairs of compounds shows the same shape and similar bond angles?

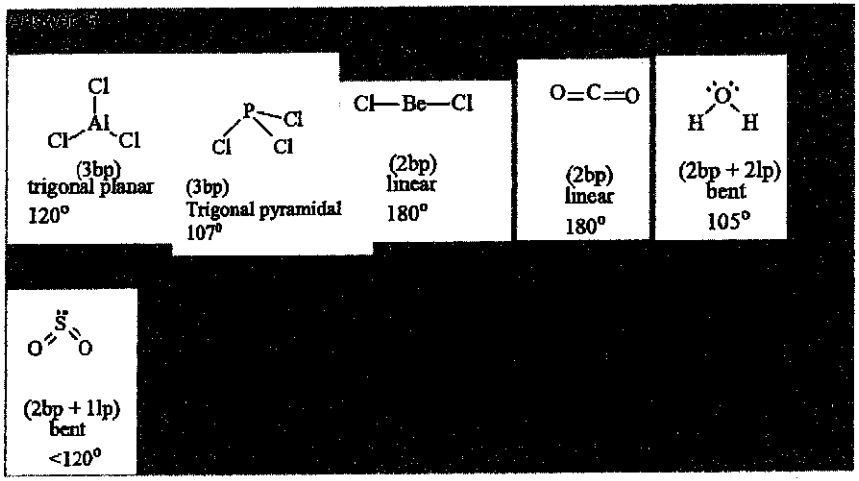
A $AlCl_3$ and PCl_3

B $BeCl_2$ and CO_2

C SO_2 and CO_2

D $BeCl_2$ and H_2O

[redacted]



9 Which of the following can form hydrogen bonding?

1 NH_4Cl (s)

2 NH_3 (*l*)

3 $CH_3CH_2CH_2OH$ (*l*)

A 1 and 2 only

B 2 and 3 only

C 3 only

D All the above

[redacted]

10 Which of the following shows the sequence of the magnitude of lattice energies of the following compounds in ascending order?

I NaCl
II RbCl
III MgS
IV BaS

A I, II, III, IV

B II, I, IV, III

C III, IV, I, II

D IV, III, II, I

[redacted]

11 Which equation correctly describes the reaction whose ΔH_f is the standard enthalpy change of formation of cabon monoxide at 298K?

A $C(g) + O(g) \rightarrow CO(g)$

B $C(g) + \frac{1}{2} O_2(g) \rightarrow CO(g)$

C $C(s) + \frac{1}{2} O_2(g) \rightarrow CO(g)$

D $2C(s) + O_2(g) \rightarrow 2CO(g)$

[redacted]

12 A chemical plant illegally dumped two radioactive isotopes **P** and **Q** in a landfill. The amount of **P** is 4 times the amount of **Q**. The radioactive decay of isotopes follows first-order kinetics. The half-life of **P** is 2 days whereas that of **Q** is 8 days. By the time the authorities found out about this illegal dumping and analysed a sample of the waste, the ratio of **P** to **Q** was found to be 1:2.

How long was the waste in the landfill before the authorities arrived?

A 8 days

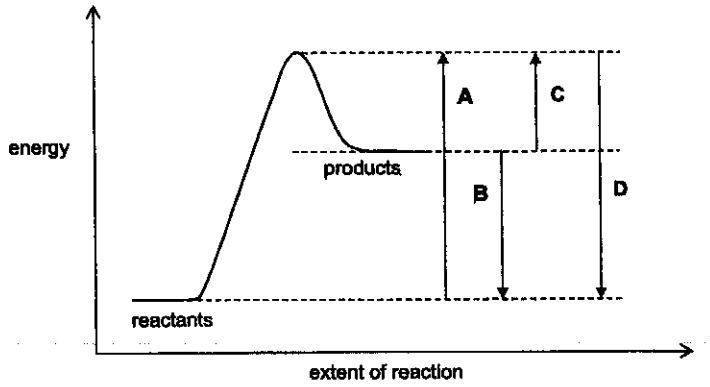
B 16 days

C 32 days

D 64 days

[redacted]

13 Which arrow on the reaction pathway diagram shows the enthalpy change of reaction for the reverse reaction?



[redacted]

14 Hydrogen and nitrogen monoxide can react to form nitrogen and steam.

$$2H_2(g) + 2NO(g) \rightarrow N_2(g) + 2H_2O$$

The rate of this reaction is first order with respect to hydrogen and second order with respect to nitrogen monoxide.

Which of the following conclusions can be drawn from this information?

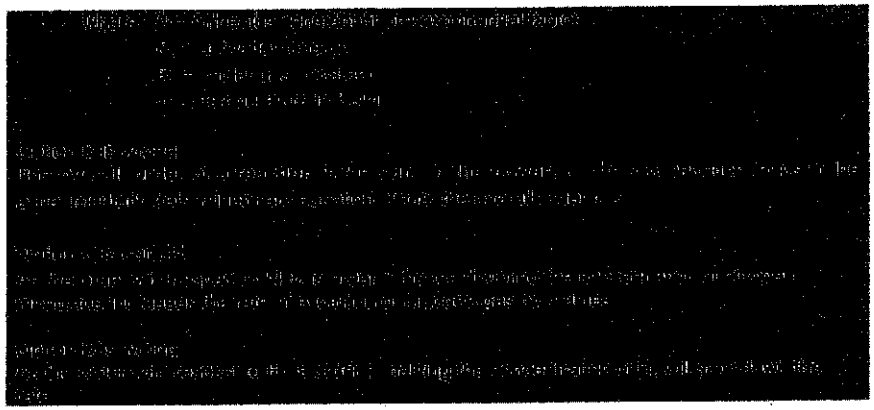
A The value of rate constant depends on the concentrations of hydrogen and nitrogen monoxide.

B The overall order of reaction is two.

C Doubling the concentration of nitrogen monoxide increases the rate of evolution of nitrogen gas by 4 times.

D Halving the concentration of hydrogen will not change the rate of reaction.

[redacted]



15 The following equilibrium exists in a mixture of concentrated nitric acid and concentrated sulfuric acid.

$$HNO_3 + H_2SO_4 \rightleftharpoons H_2NO_3^+ + HSO_4^-$$

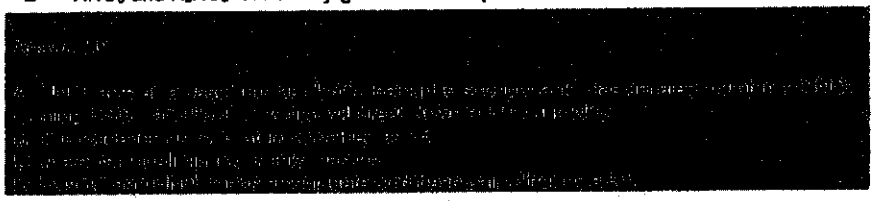
Which of the statements is correct?

A HNO_3 is a stronger acid than H_2SO_4.

B The nitric acid acts as an oxidising agent.

C The sulfuric acid acts as a dehydrating agent.

D HNO_3 and $H_2NO_3^+$ are a conjugate acid–base pair.



16 A mixture was made by adding 10 cm^3 of a solution of pH 1 to 30 cm^3 of another solution of pH 5. What is the final pH of the mixture?

A 1.6

B 2.5

C 3.0

D 4.0

17 The gallium hydrate hydrolyses as shown below.

$$[Ga(H_2O)_6]^{3+}\ (aq) \rightleftharpoons [Ga(H_2O)_5OH]^{2+}\ (aq) + H_3O^+\ (aq) \qquad \Delta H = \text{positive}$$

Which of the following statements about the equilibrium are <u>true</u>?

1 $[Ga(H_2O)_6]^{3+}$ is more stable at low pH values.

2 Increasing the temperature will favour the formation of $[Ga(H_2O)_5OH]^{2+}$

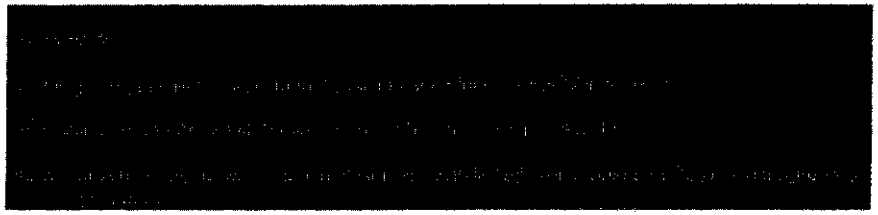
3 Increasing the concentration of $[Ga(H_2O)_6]^{3+}$ will increase K_c as the forward reaction is favoured.

A 1 only

B 1 and 2 only

C 2 and 3 only

D All the above



18 When pressure is increased for a homogeneous gaseous system at equilibrium, the position of equilibrium shifted to the right.

Which of the following could be the units of the equilibrium constant, K_c, for this system?

A $mol^{-1}\,dm^3$

B $mol\,dm^{-3}$

C $mol^2\,dm^{-6}$

D no units

[redacted]

19 Which property decreases from Na_2O to P_4O_{10} for the oxides of period 3 elements?

A melting point

B covalent character

C solubility in aqueous alkali

D pH when mixed with water

[redacted]

20 The proton number of the element **P** is less than 20.

The chloride of element **P** has a simple molecular structure, and is readily hydrolysed in water to give an acidic solution.

The oxide of **P** is insoluble in water.

In which Group of the Periodic Table is **P** likely to be found?

A Group 1

B Group 2

C Group 14

D Group 15

[redacted]

21 Which of the following series does not have a decreasing trend?

A atomic radius of P, S and Cl

B melting point of Si, P and S

C ionic radius of Na^+, Mg^{2+} and Al^{3+}

D electrical conductivity of Al, Si and P

[redacted]

22 Which of the following statements are true about the elements in Group 1 of the Periodic Table?

1 The ionic radius increases down the group.

2 The reducing power increases down the group.

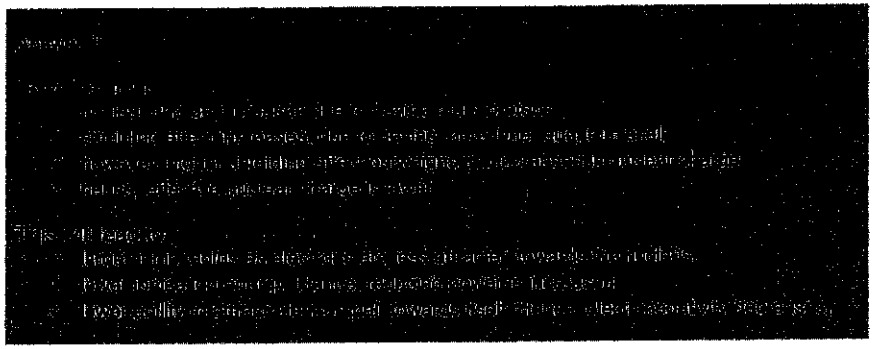
3 The electronegativities decrease down the group.

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

D All the above

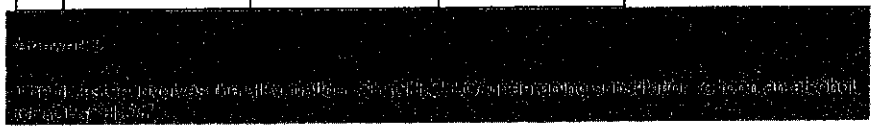


23 Sodium hydroxide reacts with chloropropane in a series of steps to produce propanoic acid.

$$CH_3CH_2CH_2Cl \xrightarrow{\text{step 1}} Q \xrightarrow{\text{step 2}} CH_3CH_2COOH$$

What are the identities of the reagents for step 1 and step 2, and the organic intermediate Q?

	step 1	Q	step 2
A	$Cr_2O_7^{2-}$/ H^+	$CH_3CH_2CH_2OH$	$KMnO_4$ / H^+
B	NaOH/ethanol	$CH_3CH_2CH_2$	H_2SO_4(aq)
C	NaOH(aq)	$CH_3CH_2CH_2OH$	$Cr_2O_7^{2-}$/ H^+
D	$NaBH_4$	$CH_3CH_2CH_2CH_3$	$KMnO_4$ / H^+



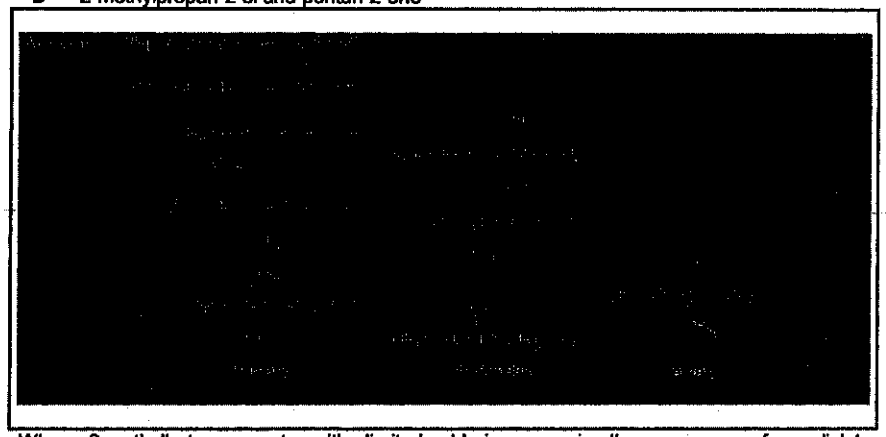
24 Which of the following pairs of compounds can be distinguished by using acidified potassium manganate(VII) solution?

A pentan-2-one and pentan-3-one

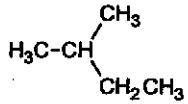
B pentan-2-one and pentanal

C propan-1-ol and propan-2-ol

D 2-methylpropan-2-ol and pentan-2-one



25 When 2-methylbutane reacts with limited chlorine gas in the presence of uv light, monochlorinated compounds are formed.



2-methylbutane

Which of the following statements is not correct?

1 H_2 molecule is a by-product of the reaction.

2 Four different monochlorinated isomers may be formed.

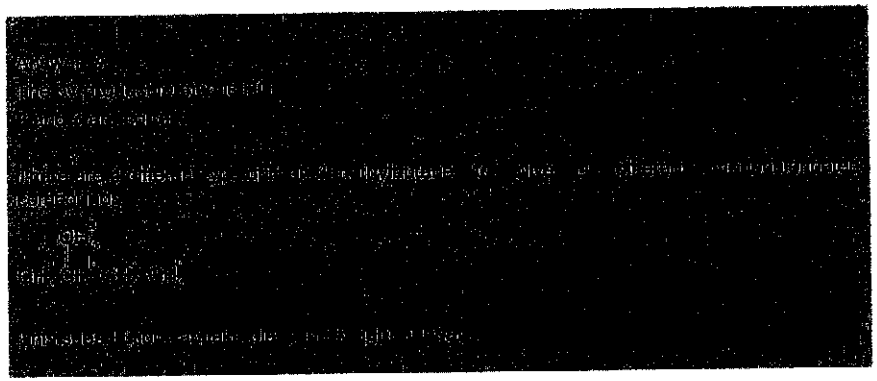
3 The reaction can take place if heat is used instead of uv light.

A 1 only

B 2 only

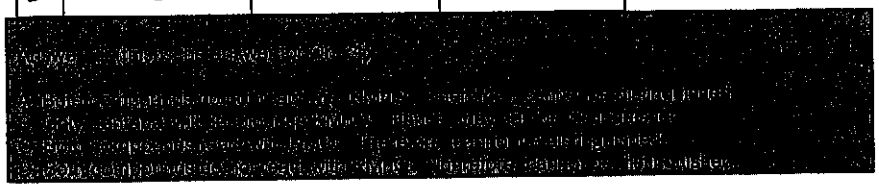
C 1 and 2 only

D All the above



26 Alcohols can be classified into primary, secondary and tertiary alcohols. How many structural isomers are there for each type with the formula $C_5H_{12}O$?

	primary	secondary	tertiary
A	3	3	2
B	4	2	2
C	4	3	1
D	5	2	1



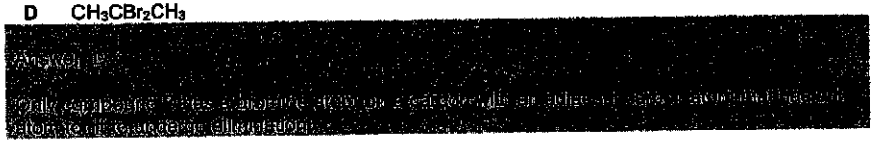
27 Which compound can undergo a reaction when treated with hot ethanolic potassium hydroxide?

A CH_2Br_2

B CBr_3CBr_3

C $(CH_3)_2CCBr_2$

D $CH_3CBr_2CH_3$



28 Butanoic acid was heated under reflux with a mixture of ethanol and propanol in the presence of concentrated sulfuric acid. Which of the following is a possible product of this reaction?

A ethyl propanoate

B propyl butanoate

C butyl butanoate

D propyl ethanoate

29 Poly(ethane) cup is attached to the pelvic girdle by bone cement in an artificial hip joint. The formation of the cement is highly exothermic and involves polymerisation of the monomer methyl-2-methylpropenoate, $CH_2=C(CH_3)COOCH_3$.

Which statements about this polymerisation are correct?

1 More energy is released in making two C–C bonds than in breaking a C=C bond.

2 The formation of the cement occurs by condensation polymerisation.

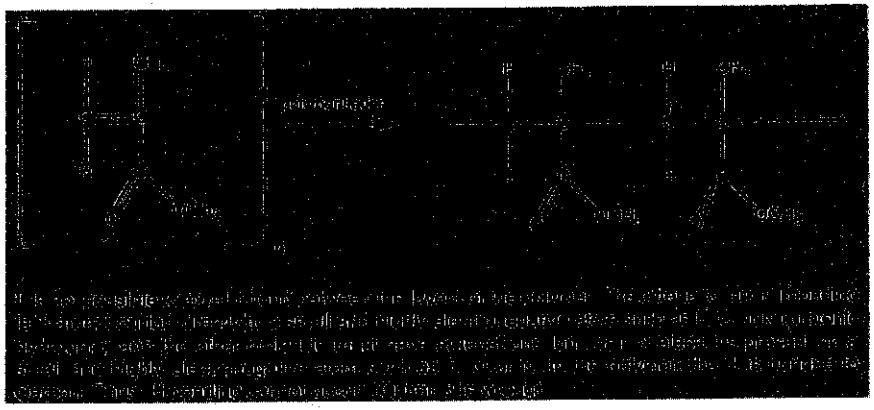
3 The polymer can form strong hydrogen bonds between layers.

A 1 only

B 1 and 2 only

C 2 and 3 only

D All the above



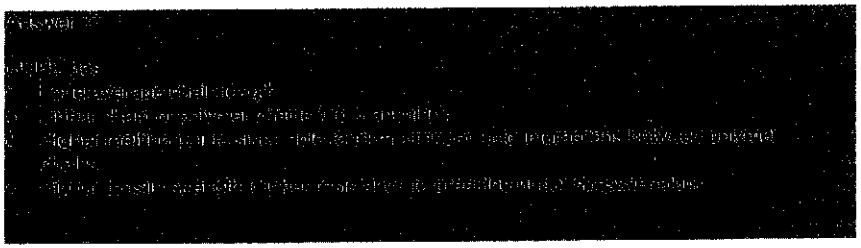
30 Which of the following statement regarding the properties of high density polyethene (HDPE) and low density polyethene (LDPE) is least likely to be correct?

A HDPE is harder than LDPE.

B HDPE has a higher melting point than LDPE.

C HDPE has more branching than LDPE.

D HDPE is less flexible than LDPE.



YISHUN INNOVA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME

CG | INDEX NO | H1 GROUP

CHEMISTRY 8873/02

Paper 2 Structured Questions **1 September 2020**

Candidates answer on the Question Paper. **2 hours**

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, index number and CG 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, highlighters, and glue or correction fluid/tape.

Section A
Answer all questions.

Section B
Answer **one** question.

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

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

For Examiner's Use	
	/30
1	/11
2	/7
3	/11
4	/7
5	/6
6	/17
7 or 8	/20
Penalty	
	/80
	/110

This document consists of **24** printed pages and **0** blank page.

Section A

Answer **all** the questions in this section, in the spaces provided.

1 The element magnesium, Mg, is a metal which is used in many alloys which are strong and light. Magnesium can exist as a number of different isotopes.

(a) What is meant by the term *isotope*?
Atoms of the same element with same number of proton/proton number,

different number of neutrons / nucleon number

[2]

(b) (i) Complete the table below for two of the isotopes of magnesium.

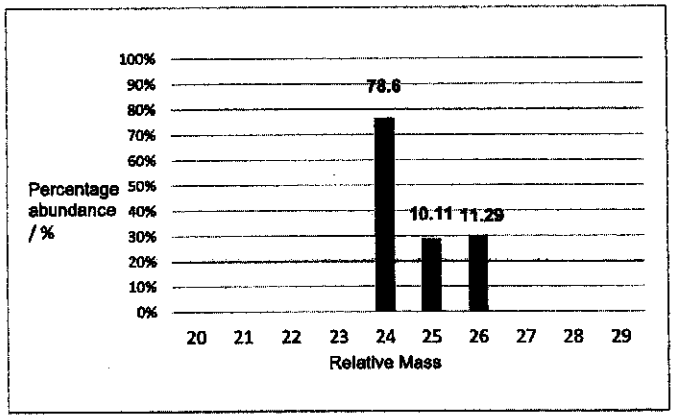
isotopic species	number of proton	number of neutrons	number of electrons
$^{24}_{12}Mg$			
		14	11

Isotopic species	number of proton	number of neutrons	number of electrons
$^{24}_{12}Mg$	12	12	12
$^{26}_{12}Mg^{+}$	12	14	11

[2]

(ii) The relative atomic mass of an element can be determined using data from its mass spectrum. The mass spectrum of an element reveals the abundances of these isotopes, which can be used to calculate the relative atomic mass of the element.

The mass spectrum of a sample of magnesium, with the percentage of abundance of each isotope is shown below.



Calculate the relative atomic mass, *Ar*, of magnesium in the sample.
Express your answer to two decimal places.

Ar = [(24x78.6) + (25x10.11) + (26x11.29)] / 100
= 24.33 (2 decimal places)

[1]

(c) Successive ionisation energies for the element Magnesium are given in the table.

Element	1st Ionisation energy / kJ mol^{-1}	2nd Ionisation energy / kJ mol^{-1}	3rd Ionisation energy / kJ mol^{-1}
Mg	736	1450	7740
Al	577	1820	2740

(i) Complete the electronic configuration of the following particles:

Mg $1s^2$ $2s^22p^63s^2$

Al $1s^2$ $2s^22p^63s^23p^1$

(ii) Explain why the 1st ionisation energy of aluminium is lower than that of magnesium.

The outermost electron in Mg is in the 3s subshell, while the outermost electron in Al is in the 3p subshell. As the average distance from the nucleus of a 3p orbital is slightly larger than that of a 3s orbital, less energy is required to remove the 3p electron in Al.

[2]

(iii) Explain why there is a large increase between the 2nd and 3rd ionisation energies of magnesium.

The large increase in the ionisation energies is due to the 3rd electron being removed from the inner quantum shell.
As there is less shielding effect on the outermost electron and same nuclear charge, there is a net increase in effective nuclear charge, thus more energy is required to remove the 3rd electron.

[2]

[Total: 11]

2 The main ore of manganese, pyrolysite, is mainly MnO_2. A solution of $SnCl_2$ can be used to estimate the percentage of MnO_2 in a sample of pryolusite, using the following method.

- A known mass of pyrolysite is warmed with an acidified solution containing a known amount of $SnCl_2$.
- The excess $Sn^{2+}(aq)$ ions are titrated with a standard solution of $KMnO_4$.

In one such experiment, 0.110 g of pyrolysite was warmed with an acidified solution containing 2.00×10^{-3} mol Sn^{2+}. After the reaction was complete, the mixture was titrated with 0.0200 mol dm^{-3} $KMnO_4$, and required 18.1 cm^3 of this solution to reach the end point.

The equation for the reaction between Sn^{2+} and MnO_2 is as follows:

$$MnO_2 + 4H^+ + Sn^{2+} \longrightarrow Mn^{2+} + 2H_2O + Sn^{4+}$$

Acidified $KMnO_4$ oxidises Sn^{2+}. The reduction and oxidation half equations are as follow:

$$MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$$
$$Sn^{2+} \longrightarrow Sn^{4+} + 2e$$

(a) Write the equation for the reaction between MnO_4^- and Sn^{2+} in acidic medium.

$2MnO_4^- + 5Sn^{2+} + 16H^+ \rightarrow 2Mn^{2+} + 5Sn^{4+} + 8H_2O$

[1]

(b) (i) Calculate the number of moles of MnO_4^- used in the titration.

no. of moles of MnO_4^- used in titration= $0.02 \times 18.1/1000$
$= 3.62 \times 10^{-4}$ mol

[1]

[Turn over

(ii) Calculate the number of moles of Sn^{2+} that reacted with 0.110 g sample of pyrolysite.

no. of moles of Sn^{2+} reacted with MnO_4^- = $3.62 \times 10^{-4} \times 5/2 = 9.05 \times 10^{-4}$
[1]

no. of moles of Sn^{2+} reacted with MnO_2 (in Pyrolysite)
$= 2.00 \times 10^{-3} - 9.05 \times 10^{-4}$
$= 1.095 \times 10^{-3}$ mol

[2]

(iii) Calculate the mass of MnO_2 in 0.110 g of pyrolysite.

mass of MnO_2 (in Pyrolysite)
= 1.095×10^{-3} mol **(ans in (ii))** x (54.9 + 16.0+16.0)
= 0.0952g

[1]

(iv) Calculate the percentage of MnO_2 in pyrolysite.

Percentage of MnO_2 in pyrolysite = 0.0952 / 0.110 x 100% = **86.5%**

[1]

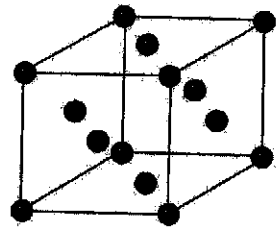
(c) In the experiment, the student did not ensure complete reaction between Sn^{2+} and pyrolysite and continued with the titration with $KMnO_4$.

Explain the effect, if any, that the error will have on the amount of, in moles, of MnO_4^- calculated in **(b)(i)** and thus the percentage of MnO_2 calculated in **(b)(iv)**.

The amount of MnO_4^- calculated in **(b)(i)** will be higher and the percentage of MnO_2 calculated in **(b)(iv)** will be lower.

[1]
[Total: 7]

3 Structure and bonding can be used to explain many of the properties of substances. Copper and iodine are both solids with the same face-centered crystal structure which is shown below.



The particles present in such a crystal may be atoms, molecules, electrons, anions or cations. In the diagram above, the particles present are represented by ●.

(a) Copper, silicon(IV) oxide, sodium chloride and iodine are all examples of crystalline solids, though the crystalline solid may be a different structure.

Complete the table with:

- the type of particles present in each crystalline solid

[Turn over

- the name of a type of lattice structure found in each crystalline solid

crystalline solid	particles	type of lattice structure
copper		
silicon(IV) oxide		
iodine		

Crystalline solid	particles	type of lattice structure
Copper	cations and electrons	Giant metallic
Silicon(IV) oxide	atoms	Giant molecular / macromolecular
Iodine	molecules	Simple molecular

[2]

(b) When separate samples of silicon(IV) oxide or iodine are heated to 100°C, the silicon(IV) oxide remains as a solid while the iodine turns into a vapour. Explain, in terms of the bonding present in the solid structure, why silicon(IV) oxide remains a solid at 100°C.

Large amount of energy is required to break these **strong Si-O bonds between the atoms**, thus the melting point of SiO_2 is high, it remains as a solid at 100°C.

[1]

(c) The acid and base behaviour of oxides, magnesium oxide, aluminium oxide and silicon(IV) oxide, show periodic trends.

(i) Aluminium oxide is said to be *amphoteric*. Write equations to illustrate this fact.

$Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$

$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$

[2]

(ii) Write balanced equations, if any, to illustrate how magnesium oxide and silicon(IV) oxide differ in their behaviour when reacted with

I acids and bases

$MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$

$SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$

II water

$MgO + H_2O \rightarrow Mg(OH)_2$

SiO_2 is insoluble in water [not needed; no marks awarded]

[3]

(d) The elements in Group 17, the halogens, and their compounds, show many similarities and trends in their properties. Some data are given for the elements fluorine to iodine.

	HF	HCl	HBr	HI
boiling point / °C	+20	−85	−67	−35
bond energy / kJ mol^{-1}	562	431	366	299

(i) Explain the trend in the boiling points of the hydrogen halides, HCl, HBr and HI.

- HCl, HBr and HI has simple molecular structures and are polar.
- permanent dipole – permanent dipole forces of attractions
- as well as instantaneous dipole – induced dipole interactions(id-id) exist between their molecules.
- From HCl, HBr and HI, the number of electrons increases, resulting in a larger electron cloud size / larger more polarisable electron cloud.

Hence, more energy is required to overcome the stronger id - id between simple molecules interactions during boiling.

[2]

(ii) Suggest why the hydrogen halide HF does not follow the trend in boiling points shown by HCl, HBr and HI.

HF has strong hydrogen bonds between the HF molecules. Thus, while the electron cloud size is smaller, it has a much higher boiling point than those of the others because much more energy is required to overcome the strong hydrogen bonds between the HF molecules.

[Total: 11]

4 About 3,000 tonnes of ammonium nitrate, $NH_4NO_3(s)$ detonated and resulted in an explosion in Beirut, Lebanon on 5 August 2020, that killed at least 80 people and injured thousands more. It was reported that the ammonium nitrate was stored in a warehouse without proper safety controls.

[1 tonne = 1000 kg]

(a) Ammonium nitrate primarily breaks down into a number of gases: nitrogen, water vapour and oxygen. Construct an equation for the decomposition of ammonium nitrate.

$2NH_4NO_3(s) \rightarrow 2N_2(g) + 4H_2O(g) + O_2(g)$

[1]

(b) Calculate the total volume of gas evolved at room temperature pressure when 3,000 tonnes of ammonium nitrate is detonated.

No. of moles of NH_4NO_3 = 3000x1000x1000 / 80.0 = 3.75×10^7 moles

at room temp, H_2O is liquid.
Thus, mole ratio of ammonium nitrate : gases = 2:3
Total no. of moles of gas evolved = $3.75 \times 10^7 / 2 \times 3 = 5.625 \times 10^7$ moles

Total volume of gas = $5.625 \times 10^7 \times 24\ dm^3 = 1.35 \times 10^9\ dm^3$

[2]

(c) Ammonium nitrate can be formed by the reaction of ammonia with concentrated nitric acid.

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

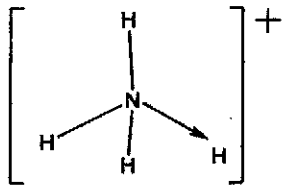
Suggest the type of reaction and the role of NH_3 in the above reaction.

type of reaction: Acid-base reaction

role of NH_3: Bronsted Lowry base (proton acceptor)

[2]

(d) Draw the structure and suggest the shape of ammonium ion.



Tetrahedral

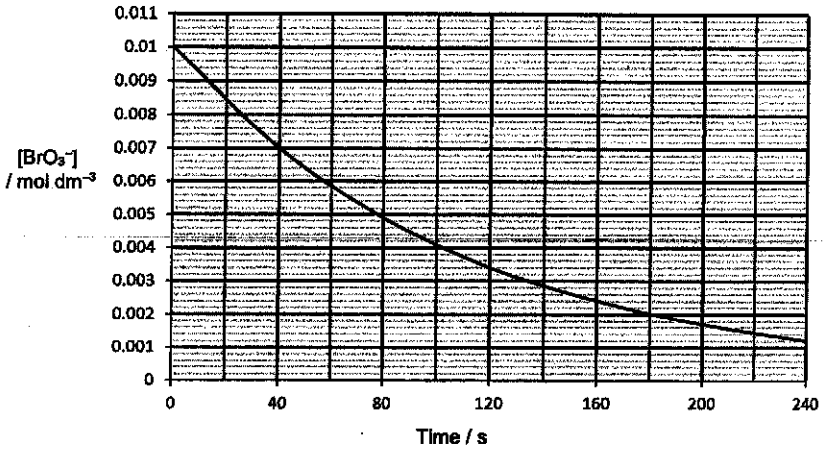
[2]

[Total: 7]

5 The oxidation of bromide ions by bromate(V) ions, BrO_3^-, in acidic solution is represented by the equation below.

$$5Br^- + BrO_3^- + 6H^+ \longrightarrow 3Br_2 + 3H_2O$$

To investigate how the rate of reaction depends on the concentration of each of the three reactants. The following graph shows the result of an experiment measuring $[BrO_3^-]$ over time, while the concentrations of two reactants were in excess and kept constant.



The concentration was determined at regular time intervals as the reaction progressed.

(a) Showing all working, and clearly any construction lines on the graph. Use the graph to determine:

(i) the order of reaction with respect to BrO_3^-,

show construction lines for $(t_{1/2})_1$ and $(t_{1/2})_2$

T1/2 is approximately constant ≈ 80s
Thus, it is first order w.r.t. BrO_3^-

[2]

(ii) the initial rate, in mol $dm^{-3}\ s^{-1}$.

accept initial rate with appropriate tangent lines drawn at t=0.

(b) (I) The order of reaction with respect to $[H^+]$ and $[Br^-]$ is one and zero respectively.

Using your answer in (a)(i) and the info provided, write the rate equation for this reaction.
Rate = $k[Br^-]^0[BrO_3^-][H^+]$

Rate = $k[BrO_3^-][H^+]$

[1]

(II) State and explain the effect on the rate of this reaction when only $[Br^-]$ is increased by 2 times.

Rate remains unchanged as rate is independent of $[Br^-]$.

[1]

(c) The rate of reaction was measured as 8.20×10^{-6} mol dm^{-3} s^{-1} when $[Br^-] = 0.10$ mol dm^{-3}, $[BrO_3^-] = 0.10$ mol dm^{-3} and $[H^+] = 0.40$ mol dm^{-3}.

Determine the rate constant for this reaction and state its units.
Rate = $k[BrO_3^-][H^+]$

$8.20 \times 10^{-6} = k \times 0.10 \times 0.40$
$k = 2.05 \times 10^{-4}$

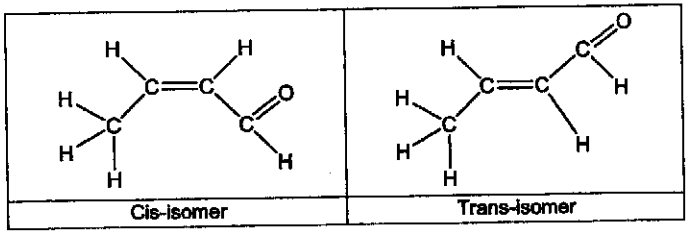
units of rate constant= $mol^{-1}dm^3s^{-1}$

[2]
[Total: 6]

6 Crotonaldehyde has a molecular formula of C_4OH_6. The main use of it is to prepare sorbic acid which is used as food preservative.

(a) (I) Crotonaldehyde is able to exhibit cis-trans isomerism.

Draw the formula of the cis-trans isomers of Crotonaldehyde in the boxes provided.



[2]

(II) Crotonaldehyde reacts with aqueous bromine. Name the functional group in crotonaldehyde that reacts with bromine and write down the observations of the reaction.

Reagent	Functional group present	Observation
Aqueous bromine	alkene	decolourisation of orange solution

[1]

(b) Fig 6.1 shows a possible reaction sequence with crotonaldehyde as an intermediate product.

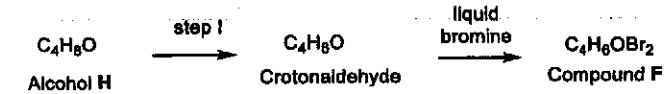


Fig. 6.1

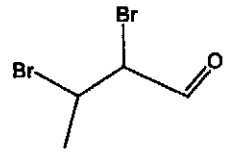
(I) Suggest the reagents and conditions for the step I.

reagent(s) $K_2Cr_2O_7$, dilute H_2SO_4,

condition(s) heat with immediate distillation

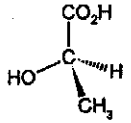
[2]

(II) Draw the skeletal structure of compound F.



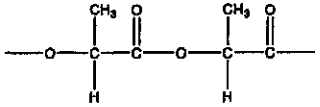
[1]

(c) In recent developments, there is increasing awareness of diminishing supply of crude oil has placed much attention on PLA (polylactic acid) as it is biodegradable. Lactic acid is produced from corn starch and has the structure shown below.



The glass transition temperature of PLA is between 60°C – 70°C and a melting point of 175°C. The Glass Transition Temperature is the temperature at which the polymer structure turns from hard to viscous liquid or rubbery structure when heated.

(i) Draw the section of the polymer showing 2 repeat units.



[1]

(ii) Explain why PLA would not be a suitable packaging material for foods pickled in vinegar.

The container will react or dissolve due **to ester hydrolysis** with the acid in the vinegar.

[1]

(iii) PLAs containers are not used for hot drinks. Suggest why.

The container will **soft** above 60°C, will not be hard enough to hold the drinks.

[1]

(iv) Suggest a reason why PLA is popular packaging material, other than it is biodegradable.

Any of the following

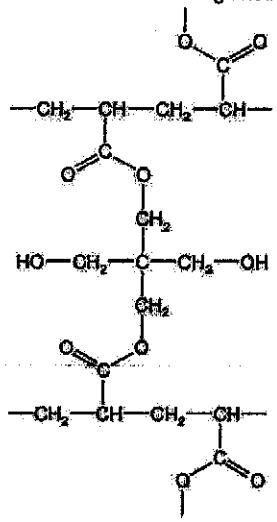
- it (is a thermoplastic), can be recycled
- It is made from renewable resource (corn starch)

accept other possible answers

[1]

[Turn over

(d) Another useful development is a range of polymers known as hydrogels, which are hydrophilic and can absorb large quantities of water. The presence of side chains in the polymers can react to form cross-linked. The hydrogel formed below, is formed from chains of one polymer which are cross-linked using another molecule.



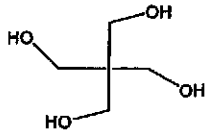
The monomer of this polymer chain is $CH_2CHCOOH$.

(i) State the type of polymerisation used to form these chains.

Addition polymerisation

[1]

(ii) Draw the structure of the molecule used to cross-link the polymer chains.



[1]

(iii) Predict if these polymers can be recycled. Explain your answer.

Due to the crosslinks, there are **strong covalent bonds that hold the layers together** is not broken due to heating.

It doesn't melt / will char or decompose and cannot be recycled.

[2]

[Turn over

(iv) Not every available side chain in the polymer is cross-linked, and the amount of cross-linking affects the properties of the hydrogel.

I Once the hydrogel has absorbed water, it can be dried and re-used a number of times. Suggest why the amount of cross linking has little effect on the ability of hydrogel to absorb water.

The number of available sites (presence of –OH group) to form hydrogen bonds with water remains the same.

[1]

II Suggest one property of hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.
With more cross-linking, the hydrogel will become harder/more rigid/brittle. The cross links are strong covalent bonds which holds the layers together, and will not break easily.

Or more compact/higher density due to more extensive bonds between layers.

[Total: 17]

Section B

Answer **one** question from this section, in the spaces provided.

7 (a) A hydride of nitrogen, **Q**, contains 12.5% of hydrogen by mass.

(i) Calculate the empirical formula of **Q**.

	N	H
Mass in 100g/g	87.5	12.5
Amount / mol	6.25	12.5
Simplest ratio	1	2

Empirical formula: NH_2

[1]

(ii) When **Q** was heated strongly, it decomposes into its elements. 10 cm^3 of **Q** gave 30 cm^3 of products (volumes are measured under the same conditions).

What is the molecular formula of **Q**?

Let the molecular formula be $(NH_2)n$

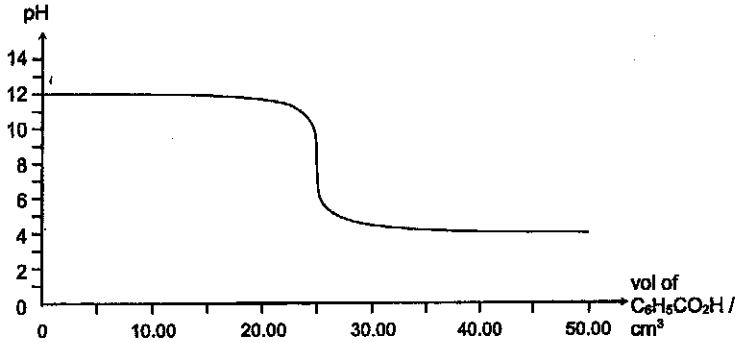
$(NH_2)n \rightarrow n/2\ N_2 + n\ H_2$
10 cm^3 30 cm^3
1mol 3mol

Mole ratio of reactant : product = 1 : 3
n : 1.5 n = 1 : 3
n = 2

Molecular formula : N_2H_4

[2]

(b) A solution of benzoic acid, $C_7H_6O_2$ is added to 20.00 cm^3 of aqueous sodium hydroxide. The change in pH was measured and the following titration curve was obtained.



(i) Using the titration curve, calculate the concentration of OH^- at the beginning of the reaction.

Since pH = 12, pOH = 14 – 2 = 2

$[OH^-] = 10^{-2} = 0.0100$ mol dm^{-3}

[1]

(ii) Suggest why phenolphthalein is a suitable indicator for the above reaction and state the expected colour change.

The pH range for colour change that lies within the pH range of rapid change of the titration.

pink to colourless

[2]

(iii) Using the answer in **(b)(i)**, calculate the concentration of the solution of benzoic acid.

Amt of NaOH used = $0.01 \times \frac{20.00}{1000} = 0.000200$ mol

Thus amt of benzoic acid reacted = 0.000200 mol

[benzoic acid] = $\frac{0.002}{25} \times 1000 = 0.00800$ mol dm^{-3}

[2]

(c) **(i)** Use the energy cycle below and the following data to calculate the value for $\Delta H^{\ominus}_1$, $\Delta H^{\ominus}_2$ and $\Delta H^{\ominus}_3$.

$C_7H_8O(l) + C_7H_8O_3(s) + 15O_2(g) \xrightarrow{\Delta H^{\ominus}_r} 2C_7H_6O_2(s) + 15O_2(g)$

$\Delta H^{\ominus}_1$ ↑ ; ↓ $\Delta H^{\ominus}_3$

$14C(s) + 6H_2(g) + 17O_2(g) \xrightarrow{\Delta H^{\ominus}_2} 14CO_2(s) + 6H_2O(l)$

$\Delta H^{\ominus}_c$ carbon	=	–393.5 kJ mol^{-1}
$\Delta H^{\ominus}_c$ hydrogen	=	–285.8 kJ mol^{-1}
$\Delta H^{\ominus}_f$ $C_7H_8O(l)$	=	–87.0 kJ mol^{-1}
$\Delta H^{\ominus}_f$ $C_7H_8O_3(s)$	=	–367.0 kJ mol^{-1}
$\Delta H^{\ominus}_c$ $C_7H_6O_2(s)$	=	–3228 kJ mol^{-1}

$\Delta H^{\ominus}_1 = \Delta H^{\ominus}_f\ C_7H_8O(l) + \Delta H^{\ominus}_f\ C_7H_8O_3(s)$
$= (-87) + (-367)$
$= \underline{-454\ kJ\ mol^{-1}}$

$\Delta H^{\ominus}_2 = 14\Delta H^{\ominus}_c$ carbon $+ 6\Delta H^{\ominus}_c$ hydrogen
$= 14\ (-393.5) + 6(-285.8)$
$= \underline{-7223.8\ kJ\ mol^{-1}}$

$\Delta H^{\ominus}_3 = 2\Delta H^{\ominus}_c\ C_7H_6O_2(s)$
$= 2(-3228)$
$= \underline{-6456\ kJ\ mol^{-1}}$

[3]

(ii) Hence, calculate the standard enthalpy change of reaction, $\Delta H^{\ominus}_r$.

By Hess' Law,
$\Delta H^{\ominus}_r = -\Delta H^{\ominus}_1 + \Delta H^{\ominus}_2 - \Delta H^{\ominus}_3$
$= -(-454) + (-7223.8) - (-6456)$
$= \underline{-314\ kJ\ mol^{-1}}$

[2]

(d) Caprylic acid dissociates as shown below.

$$CH_3(CH_2)_6COOH \rightleftharpoons CH_3(CH_2)_6COO^- + H^+$$

(i) Write an equilibrium expression, K_c, for this reaction.

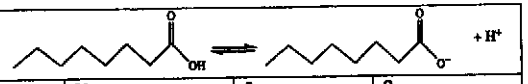
$$K_c = \frac{[CH_3(CH_2)_6COO^-][H^+]}{[CH_3(CH_2)_6COOH]}$$

[1]

(ii) The reaction mixture is allowed to reach equilibrium. The equilibrium concentrations of H^+ and $CH_3(CH_2)_6COO^-$ are found to be 6.31×10^{-5} mol dm^{-3}.

Given that the K_c value for the equilibrium is 3.08×10^{-5}, calculate the initial concentration of caprylic acid.

Let the initial concentration of caprylic acid be X mol dm^{-3}.



mol dm^{-3}			
Initial	X	0	0
Change	-6.31×10^{-5}	$+6.31 \times 10^{-5}$	$+6.31 \times 10^{-5}$
Equilibrium	$X - 6.31 \times 10^{-5}$	6.31×10^{-5}	6.31×10^{-5}

$$3.08 \times 10^{-6} = \frac{(6.31 \times 10^{-5})^2}{X - 6.31 \times 10^{-5}}$$

$X = 0.000192$ mol dm^{-3}

[2]

(e) Aqueous sodium chromate(VI) contains yellow CrO_4^{2-} ions. These chromate(VI) ions exist in equilibrium with dichromate(VI) ions as shown by the equilibrium below.

$$\underset{\text{yellow}}{2CrO_4^{2-}(aq)} + 2H^+(aq) \rightleftharpoons \underset{\text{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l)$$

(i) Describe and explain what you would observe if dilute acid was added to a portion of the equilibrium mixture shown above.

When dilute acid is added, the equilibrium will shift right to remove excess acid. Hence, an orange solution is observed.

[2]

(ii) When the equilibrium mixture is cooled, the solution becomes more orange.

Is the forward reaction endothermic or exothermic? Explain your answer.

When the solution is cooled, the equilibrium will favour the exothermic reaction to produce more heat. When the solution becomes more orange and less yellow, the equilibrium has shifted right.

Hence, the equilibrium is exothermic.

[2]

[Total: 20]

8 (a) (i) A gaseous aromatic hydrocarbon, **X**, was subjected to combustion analysis. **X** on complete combustion gave 0.814 g of carbon dioxide and 0.208 g of water. What is the empirical formula of **X**?

$C_xH_y + (x+y/4)\ O_2 \rightarrow xCO_2 + y/2\ H_2O$

$n(C) = n(CO_2) = 0.814/44 = 0.0185$ mol

$n(H) = 2 \times n(H_2O) = 2 \times 0.208/18 = 0.02311$ mol

	C	H
Amount / mol	0.0185	0.02311
Mole ratio	0.0185/0.0185 = 1	0.02311/0.0185 = 1.25
Simplest ratio	4	5

Empirical formula of X = C_4H_5

[2]

(ii) A 0.245 g sample of **X** has a volume of 51.8 cm^3 at standard temperature and pressure. Determine the molecular formula of **X**.

$n(X) = 51.8/1000 \div 22.7 = 0.002282$ mol

$M_r(X) = 0.245 \div 0.002282 = 107.4$

Let the molecular formula of X be $(C_4H_5)_n$

$48n + 5n = 107.4$

$53n = 107.4$

$n = 2$

Therefore the molecular formula of X = C_8H_{10}.

[2]

(b) Ethanoic acid is a weak acid with a sharp smell.

(i) Explain what is meant by a *weak acid*?

A weak acid is a proton donor that dissociates partially / A weak acid dissociates partially to product $H^+(aq)$

[1]

(ii) Given that a 0.150 mol dm^{-3} of ethanoic acid has a pH of 3.1.

Calculate the pH of sulfuric acid of the same concentration.

$[H^+] = 2 \times$ [sulfuric acid] $= 2 \times 0.150 = 0.30$ mol dm^{-3}

$pH = -\log(0.30) = 0.523$

[2]

(c) In humans it is important for blood to be maintained at a pH between 7.35 and 7.45. One of the ways it does this is by using a buffer of $CO_2(aq)$ and $HCO_3^-(aq)$.

During vigorous exercise the muscle produce lactic acid. Lactic acid is transported by the blood to the liver to be broken down.

Write equation(s) to explain how the $CO_2(aq)/HCO_3^-(aq)$ buffer system helps to maintain the pH of blood between 7.35 and 7.45 during exercise.

$H^+ + HCO_3^- \rightarrow CO_2 + H_2O$

During exercise, the **additional H^+ ions due to lactic acid is removed by the large reservoir of HCO_3^-** in blood. Hence, the **pH remains relatively unchanged** at between 7.35 – 7.45.

[2]

(d) Aqueous iron(III) exists as $[Fe(H_2O)_6]^{3+}$, which is a yellow solution. The complex, $[Fe(H_2O)_5(SCN)]^{2+}$, is formed when a solution of SCN^- is added as shown in the following equation.

$$[Fe(H_2O)_6]^{3+}(aq) + SCN^-(aq) \rightleftharpoons [Fe(H_2O)_5(SCN)]^{2+}(aq) + H_2O(l)$$

yellow colourless blood-red

(i) Write an equilibrium expression, K_c, for this reaction.

$$K_C = \frac{[[Fe(H_2O)_5(SCN)]^{2+}]}{[[Fe(H_2O)_6]^{3+}][SCN^-]}$$

[1]

50.0 cm^3 of aqueous iron(III) is mixed with 25.0 cm^3 of 0.05 mol dm^{-3} SCN^- solution.

At equilibrium, the concentrations of SCN^- and the complex is 5.45×10^{-3} mol dm^{-3} and 3.36×10^{-5} mol dm^{-3} respectively.

The numerical value of the equilibrium constant, K_c, for the reaction is 0.302.

(ii) Calculate the concentration of Fe^{3+} at equilibrium.
Let the $[Fe^{3+}]$ at equilibrium be x

$$0.302 = \frac{[[Fe(H_2O)_5(SCN)]^{2+}]}{[[Fe(H_2O)_6]^{3+}][SCN^-]}$$

$[Fe^{3+}] = (3.36 \times 10^{-5}) \div (0.302 \times 5.45 \times 10^{-3})$
$= 0.0204$ mol dm^{-3}

[1]

(iii) Calculate the initial concentration of Fe^{3+} in the mixture.
Amount of SCN^- = $0.05 \times 0.025 = 1.25 \times 10^{-3}$ (in 75 cm^3)
Initial $[SCN^-]$ in the mixture = $(1.25 \times 10^{-3} \div 75) \times 1000 = 0.01667$ mol dm^{-3}

Change in [SCN-] = $0.01667 - 5.45 \times 10^{-3}$
$= 0.01122$ mol dm^{-3}

Initial $[Fe^{3+}] = 0.01122 + 0.0204$
$= 0.03162$
$= 0.0316$ mol dm^{-3}

[2]

[Turn over

(iv) Hence calculate the amount of Fe^{3+} in 50 cm^3 of the stock solution.
Amount of Fe^{3+} in 50 cm^3 stock solution = Amount of Fe^{3+} in 75 cm^3 mixture
$= 0.03162 \times 75/1000$
$= 0.0023715$
$= 0.00237$ mol

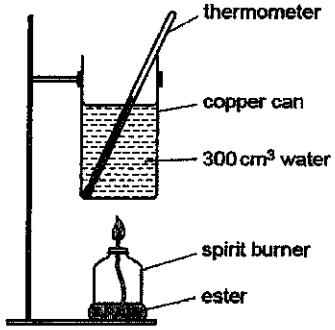
[1]

(v) The reaction mixture is allowed to reach equilibrium. $NaHPO_4$, which reacts with iron(III), is then added to the equilibrium mixture.

Describe and explain what you would observe after $NaHPO_4$ was added.
$NaHPO_4$ will react with Fe^{3+} (aq); hence $[Fe^{3+}]$ will decrease. Position of equilibrium will shift to the left to produce more Fe^{3+} that has reacted with $NaHPO_4$. The colour of the solution becomes lighter.

[2]

(e) A student used the apparatus shown to carry out experiments to determine the standard enthalpy change of combustion of methyl ethanoate, CH_3COOCH_3.



Mass of copper can = 250 g

An initial experiment was carried out using methyl ethanoate. This ester was burnt in a spirit burner underneath a copper can so that the flame from the burner heated 300 cm^3 of water in the can. It was found that 0.980 g of ester was required to raise the temperature of the water in the can by 10.0 °C.

(i) Calculate the heat gain by the water given that the specific heat capacity of water is 4.18 $J\,g^{-1}\,K^{-1}$. Take the density of water to be 1.00 g cm^{-3}.
Heat energy gained by water = (300)(4.18)(10)
= **12540 J**

[1]

[Turn over

(II) Given that the **total** heat energy gain is 13.5 kJ, calculate the heat capacity of the copper can used in this experiment.

Heat energy gained by copper can = 13500- 12540
= **960 J**

Heat capacity of copper can= $\frac{960}{(10)}$ = **96 J K^{-1}**

[1]

(III) Given that the ΔH^{θ}_{c} of methyl ethanoate is 1592.1 kJ mol^{-1}, calculate the **total** theoretical heat energy **in kJ** released by the mass of methyl ethanoate burnt in this experiment.

Heat energy released = $\frac{0.98}{74.0}$ x 1592.1 = 21.1 kJ

[1]

(Iv) Calculate the percentage efficiency of heat transfer in this experiment.

Percentage efficiency of heat transfer = $\frac{13500}{21100}$ x 100 % = 64.0 %

[1]

[Total: 20]