HWA CHONG INSTITUTION
Preliminary Examination
Higher 1

CANDIDATE NAME		**CT GROUP**	**15S**

CHEMISTRY **8872/02**

Paper 2 **30 August 2016**

2 h

Candidates answer **Section A** on the Question Paper.

Additional Materials: Data Booklet
Writing paper; Graph paper

READ THESE INSTRUCTIONS FIRST

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

Section A

Answer **all** questions.

Section B

Answer **two** questions on separate answer paper.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

FOR EXAMINERS' USE ONLY

Paper 1	**Paper 2**				**TOTAL**
Multiple Choice	**Section A (Structured)**		**Section B (Free Response)**		
	Q1	/10	Q4	/ 20	
	Q2	/14	Q5	/ 20	
	Q3	/16	Q6	/ 20	
/ 30	**Subtotal**	**/ 40**	**Subtotal**	**/ 40**	**110**

This question booklet consists of **13** printed pages.

Section A

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

1 (a) An equilibrium exists between aqueous chromate (VI) ions and dichromate (VI) ions as shown by the expression below:

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

Yellow orange

(i) State the meaning of the term *dynamic equilibrium*.

Dynamic equilibrium is achieved in a reversible reaction when rate of forward reaction equals the rate of backward reaction.

....[1]

(ii) Write an expression for the equilibrium constant, K_c, for this reaction.

$Kc = [Cr_2O_7^{2-}] / [CrO_4^{2-}]^2[H^+]^2$

[1]

(iii) The initial concentration of CrO_4^{2-} ions and H^+ ions ae 0.85 mol dm^{-3} and 1.20 mol dm^{-3} respectively. After equilibrium is reached, the concentration of $Cr_2O_7^{2-}$ ions is 0.200 mol dm^{-3}.

Calculate the value of K_c for this equilibrium and state its units.

	$2CrO_4^{2-}(aq)$	$+ 2H^+(aq)$	$\rightleftharpoons Cr_2O_7^{2-}(aq)$	$+ H_2O(l)$
I	0.85	1.20	0	0
C	-0.400	-0.400	+0.200	
E	0.45	0.80	0.200	

$Kc = 0.200/(0.45)^2(0.8)^2 = 1.54\ mol^{-3}\ dm^9$

K_c = ... units = ...

[3]

(b) (i) State Le Chatelier's Principle.

LCP states that when a system in equilibrium is subjected to change in conditions which disturbs the equilibrium the position of equilibrium will shift in a way to reduce that change.

....[1]

(ii) Describe and explain what happens to the colour in the beaker when aqueous sodium hydroxide is added.

The alkali will neutralize the H^+ reducing the $[H^+]$. Hence, by Le Chatelier's Principle, the position of equilibrium will shift left and the colour will more yellow.

……………………………………………………………………………………[2]

(iii) When the beaker containing aqueous chromate (VI) and dichromate (VI) ions in equilibrium is heated, the solution becomes more yellow. Explain whether the equilibrium is exothermic or endothermic.

The forward reaction is exothermic while backward reaction is endothermic. When temperature increase the backward reaction, which reduce temperature is favoured.

……………………………………………………………………………………

……………………………………………………………………………………[2]

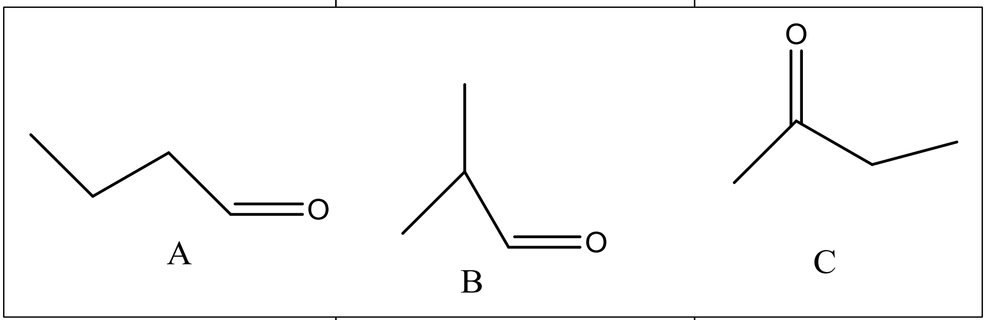
[Total: 10]

2 **A, B, C, D, E** and **F** are all structural isomers with the molecular formula C_4H_8O

(a) **A, B** and **C** all give an orange precipitate when treated with 2,4- DNPH but only **A** and **B** give a brick-red precipitate when warmed with Fehling's solution.

(i) Draw the structural formulae of **A, B** and **C**

A	**B**	**C**



(ii) Name the type of structural isomerism shown by **A** and **B**

Chain isomerism
……………………………………………………………………………………………..

(iii) State what you would see when a sample of **A** is warmed with Tollens' reagent.

…………silver mirror…………………………………………………..

……………………………………………………………………………………………..

…………………………………………………………………………………………….

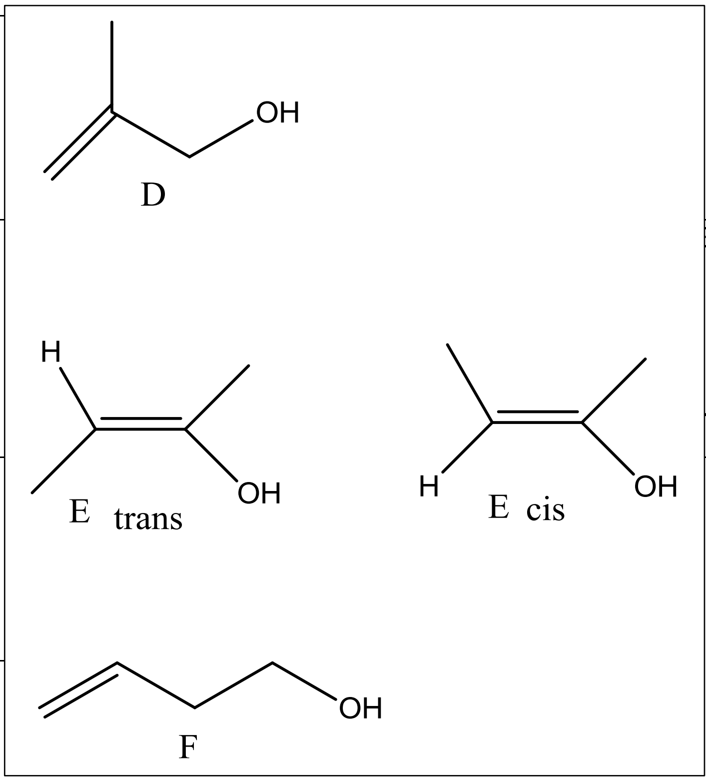
(iv) State the reagents used that give a positive test for **C** but not **A** and **B**.

……………iodine/ NaOH(aq) ………………………

[6]

(b) D, E and F all decolourise bromine and effervescence slowly with sodium metal.
E shows geometrical isomerism.
Only D has branched chain.
None of these isomers contains C=O

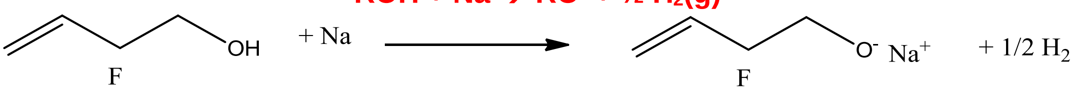
(i) Give the structures of D, E and F. Show the two stereoisomers of E and **label** the stereoisomerism shown.



(ii) Write balanced equation showing how one of these isomers react with sodium metal.

(c)

ROH + Na → RO^- + ½ H_2(g)



[6]

Another compound, **G**, C_3H_6O, gives a silver mirror when Tollen's reagent was added to it.

Give equations for the reactions of **G** with acidified potassium dichromate(VI) and sodium tetrahydridoborate, $NaBH_4$, using [O] or [H] as appropriate.

(i) reaction with acidified potassium dichromate(VI)

C_3H_6O + [O] → $CH_3CH_2CO_2H$……

(ii) reaction with sodium tetrahydridoborate, $NaBH_4$

C_3H_6O + 2[H] → $CH_3CH_2CH_2OH$……

[2]
[Total: 14]

3 'Water gas' is an equimolar mixture of hydrogen and carbon monoxide. It is used as a gaseous fuel in the industry. It is produced when steam is blown through white-hot coke in the following reaction.

$$H_2O(g) + C(s) \rightarrow H_2(g) + CO(g)$$

Another widely-used industrial fuel is natural gas, which consists mainly of methane. $\Delta H^{\ominus}_c$ values are given in the table below.

Substance	Standard enthalpy change of combustion, $\Delta H^{\ominus}_c$/ kJ mol^{-1}
CH_4	-890
H_2	-242
CO	-283
C	-394

(a) (i) Define the term *standard enthalpy change of combustion,* $\Delta H^{\ominus}_c$

The heat evolved when 1 mole compound is completely burn in excess oxygen gas under standard conditions.

……………………………………………………………………………………….[2]

(ii) Using the data given, calculate the volume of methane required to produce 1 MJ of heat energy when burned.

[2]

n_{CH4} required = 1 x 10^6 / 890 x 10^3 = 1.1236 mol

volume of methane = 1.1236 x 22400 = 25200 cm^3

(iii) Calculate the volume of "water gas" required to produce the same amount of heat energy as methane. (1 mole of gas occupies 22400 cm^3 at stp)

[2]

a x 242 + a x 283 = 1000 kJ

a = 1.905 moles of each gas

total = 1.905 x 2 = 3.81 moles of gas

Vol of gas = 3.81 x 22400 = <u>**85344**</u> (85300) cm^3 at stp

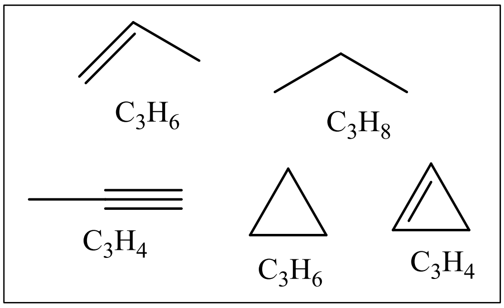
(b) In recent years, there has been worldwide interest in the extraction of 'shale gas' as an important energy source.
One of the problems associated with using shale gas is its variable composition.
Table 1 shows the percentage composition of shale gas from four different sources **J**, **K**, **L** and **M**.

	Percentage composition				
Source of shale gas	CH_4	C_2H_x	C_3H_y	CO_2	N_2
J	80.3	8.1	2.3	1.4	7.9
K	82.1	14.0	3.5	0.1	0.3
L	88.0	0.8	0.7	10.4	0.1
M	77.5	4.0	0.9	3.3	14.3

Table 1

In the formulae above, x and y and variables.

(i) Draw the structures of three possible compounds with the formula C_3H_y.



[2]

(ii) Which source of shale gas **J**, **K**, **L** or **M,** will provide the most energy when burned? Explain your answer.

K 99.6% hydrocarbon (can undergo combustion) 82.1 + 14 + 3.5 %
…………………………………………………………………………[1]

(iii) Suggest **two** methods (physical or chemical) by which carbon dioxide can be removed from shale gas.

1. Reacted with lime / CaO / sodalime/ $Ca(OH)_2$ /KOH/NaOH

2. Liquefied under pressure ≥ more than 5 atm
3. Dissolved in water under pressure.

…………………………………………………………………………………[2]

(c) **Table 2** shows a comparison of the relative amounts of pollutants produced when shale gas, fuel oil and coal are burned to produce **the same amount of energy**.

Air pollutant	**Shale gas**	**Fuel oil**	**Coal**
CO_2	117	164	208
CO	0.040	0.033	0.208
NO_2	0.092	0.548	0.457
SO_2	0.001	1.12	2.59
Particulates	0.007	0.84	2.74

Table 2

(i) Suggest why shale gas produces the smallest amount of CO_2.

Have a shorter carbon chain/ shorter hydrocarbon

....[1]

(ii) Explain which of the three fuels, shale gas, fuel oil or coal, is the **largest** contributor to 'acid rain'.

Coal produces the most SO_2 / largest combined amount of SO_2 and NO_2….

....[1]

(iii) NO_2 is produced by the combustion of nitrogen gas. Suggest a reason why fuel oil and coal produce more NO_2 than shale gas.

They burn at higher temperatures/ releases more heat on burning

....[1]

(iv) State one environmental consequence of raised levels of

CO, gas is toxic/ bond to haemoglobin, Hb, and prevent Hb from carrying O_2

CO_2, contributes to global warming.......................... ......[2]

[Total: 16]

Section B

Answer **two** questions from this section on separate answer paper.

4 (a) Suggest suitable reagents and conditions for the following reactions of propan-1-ol.

$$CH_3CH_2CH_2Br \xleftarrow{\text{(i)}} CH_3CH_2CH_2OH \xrightarrow{\text{(ii)}} CH_3CH_2CO_2H$$

propan-1-ol

(iii) What products would be formed in (i) and (ii) if propan-2-ol is used instead of propan-1-ol?

(iv) Suggest how butanoic acid, $CH_3CH_2CH_2CO_2H$ can be synthesised starting from 1-bromopropane, $CH_3CH_2CH_2Br$. State the reagents, conditions and the intermediate compounds.

[6]

i) PBr_3 ii) $KMnO_4$ (aq) , H_2SO_4(aq) heat

iii)

$$CH_3CHBrCH_3 \xleftarrow{\text{i)}} CH_3CH(OH)CH_3 \xrightarrow{\text{ii)}} CH_3COCH_3$$

iv)

$$CH_3CH_2CH_2Br \xrightarrow[\text{heat}]{\text{ethanolic KCN}} CH_3CH_2CH_2CN \xrightarrow[\text{heat}]{H_2SO_4(aq)} CH_3CH_2CH_2CO_2H$$

(b) Alcohols **A** and **B** are isomers.

$CH_3CH(OH)CH_2CH_3$ **A** $(CH_3)_3COH$ **B**

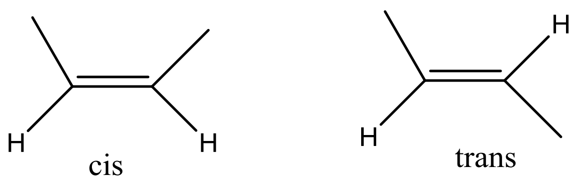
(i) Draw the structural formula of one other alcohol isomeric with **A** and **B**.

$CH_3CH_2CH_2CH_2OH$

(ii) What reagent and condition would you use to dehydrate **A** and **B** to alkenes?

Excess conc H_2SO_4 heat 170 °C

(iii) Draw two geometric isomers resulting from dehydrating **A** and state the reasons why geometric isomerism arise?



cis trans

Geometrical isomerism arises because of restriction of rotation of C=C and each of these C does not have 2 similar groups attached to it.

(iv) Describe how **A** could be distinguished from **B** using a chemical test .

[8]

A undergo oxidation by heating with $KMnO_4$, $H_2SO_4(aq)$ or $K_2Cr_2O_7(aq)$
Purple $KMnO_4$, will turn colorless or orange $K_2Cr_2O_7(aq)$ turn green.
B will not have any observation change; $KMnO_4$ will remain purple or orange $K_2Cr_2O_7(aq)$ remain green

(c) (i) Explain the term *amphoteric.*

Amphoteric compound can react with both acid and bases.

(ii) Write balanced equations to illustrate the amphoteric nature of aluminium oxide, Al_2O_3 .

$Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$
$Al_2O_3 + 2OH^- + 3 H_2O \rightarrow 2[Al(OH)_4]^-$

(iii) How do the oxides of elements either side of aluminium in the third period differ in their acid/base behaviour? Write balanced equations to illustrate your answer.

[6]

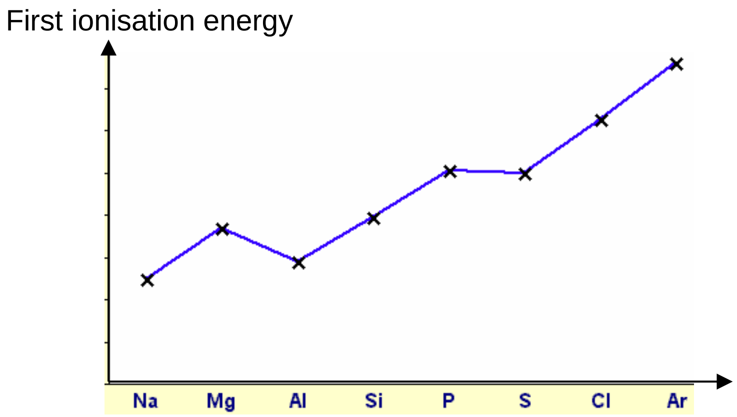
[Total: 20]

MgO is basic $MgO + 2H^+ (H_2SO_4) \rightarrow Mg^{2+} + H_2O$ MgO is sparingly soluble in water

SiO_2 is acidic $SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$ SiO_2 is insoluble in water

Hot conc base required

5 (a) Sketch a graph showing the variation of first ionisation energy across the third period of the Periodic Table, and explain qualitatively its shape. [3]



There is a general increase in first ionisation energy across Period 3. This is because the effective nuclear charge of the atoms increases as the number of protons in the nucleus increases but electrons are added to the same valence shell hence shielding effect is approximately constant.✓

The first ionisation energy of Al is lower than that of Mg because the outermost electron of Al is in a 3p orbital which is on average further away from the nucleus than a 3s orbital. Hence the outermost 3p electron in Al experiences less electrostatic attraction than the outermost 3s electron in Mg.✓

The first ionisation energy of S ($1s^22s^22p^63s^23p^4$) is smaller than that of P ($1s^22s^22p^63s^23p^3$) because the fourth 3p electron experiences inter-electronic repulsion due to pairing. (This repulsion is larger than the extra attraction owing to the additional proton.)✓

(b) Explain the meaning of the following terms.

(i) Order of reaction

(ii) Half-life. [2]

(b) (i) The order of a reaction with respect to a <u>reactant</u> refers to the <u>power</u> to which the <u>concentration</u> of that reactant is raised in the <u>rate equation</u>.

(ii) The half-life of a reactant refers to the time taken for the <u>concentration</u> of that reactant to decrease to half of its original value.

(c) The reaction between hydrogen peroxide and acidified potassium iodide releases iodine.

$$H_2O_2 + 2I^- + 2H^+ \rightarrow 2H_2O + I_2$$

The rate of reaction can be followed by measuring the amount of iodine produced after various times, from which the concentration of H_2O_2 remaining can be calculated. The following reaction mixture was prepared.

Initial $[H^+]$ = 0.200 mol dm^{-3}

Initial $[I^-]$ = 0.200 mol dm^{-3}

Initial $[H_2O_2]$ = 0.0200 mol dm^{-3}

The following table shows $[H_2O_2]$ at various times.

time/ s	$[H_2O_2]$ / mol dm^{-3}
0	0.0200
80	0.0167
183	0.0135
315	0.0103
490	0.0071
760	0.0039

Plot these data on suitable axes and, showing all your working and drawing clearly any construction lines on your graph, use your graph to determine:

(i) the order of reaction with respect to $[H_2O_2]$

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

Further experiments were carried out changing $[H^+]$ and $[I^-]$, but keeping the initial $[H_2O_2]$ the same as before. The following results were obtained.

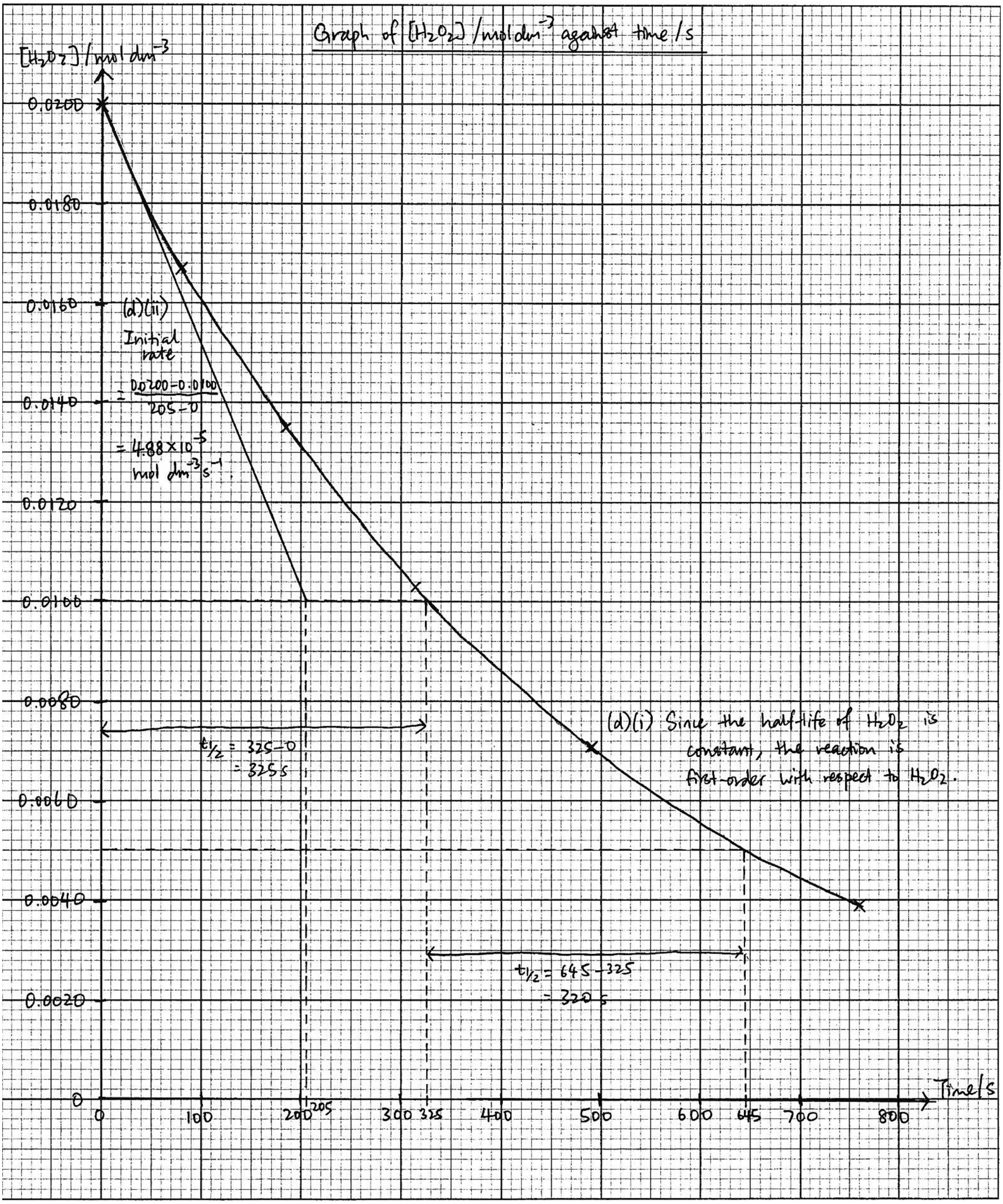
Initial $[H^+]$ / mol dm^{-3}	Initial $[I^-]$ /mol dm^{-3}	initial rate / mol $dm^{-3}s^{-1}$
0.400	0.200	8.4×10^{-5}
0.300	0.200	6.3×10^{-5}
0.200	0.100	2.1×10^{-5}

(iii) Determine the orders with respect to $[H^+]$ and $[I^-]$. Explain your reasoning.

(iv) Hence write the rate equation for the reaction.

[8]

(d) Remarks: A graph of $[H_2O_2]$ against time should be *plotted* on graph paper not ordinary lined paper. Use conveniently-read scales. Draw a smooth curve through the points. Label both axes including units.



(i) Remarks: Draw construction lines and mark out the $t_{1/2}$ values.

Two half-life values are labelled on the graph: 325 s and 320 s and they are close, so half-life is approximately constant, therefore reaction is first order with respect to H_2O_2.

(ii) Remarks: Draw a tangent line at time zero, *draw a good tangent line!* Rate of reaction is always positive.

Initial rate = – gradient of tangent at time zero

$$= \frac{0.02-0.01}{205} = 4.88 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$$

(iii) For the first two sets of data, $[I^-]$ is constant ($[H_2O_2]$ also kept constant). When $[H^+]$ increases by 4/3 times (from 0.3 to 0.4 mol dm^{-3}), initial rate also increases by 4/3 times (from 6.3 to 8.4 mol dm^{-3} s^{-1}). Therefore, rate α $[H^+]$, reaction is first order for H^+.

Let the rate equation be rate = $k\,[H_2O_2]\,[H^+]\,[I^-]^a$

For last two sets of data, $[H_2O_2]$ is the same.

$6.3 \times 10^{-5} = k\,(0.3)(0.2)^a$

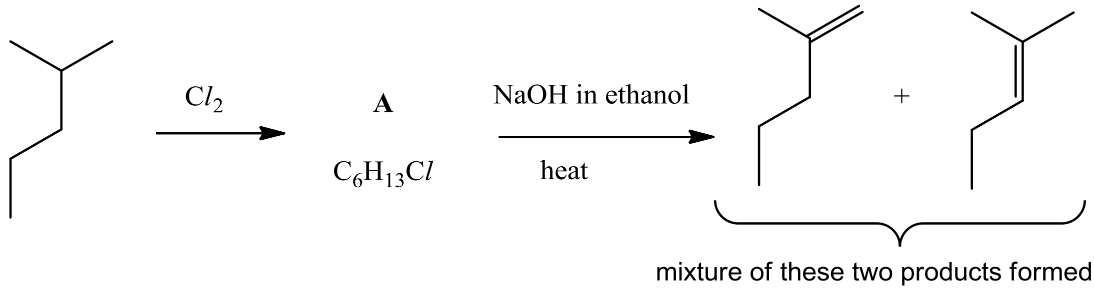
$2.1 \times 10^{-5} = k\,(0.2)(0.1)^a$

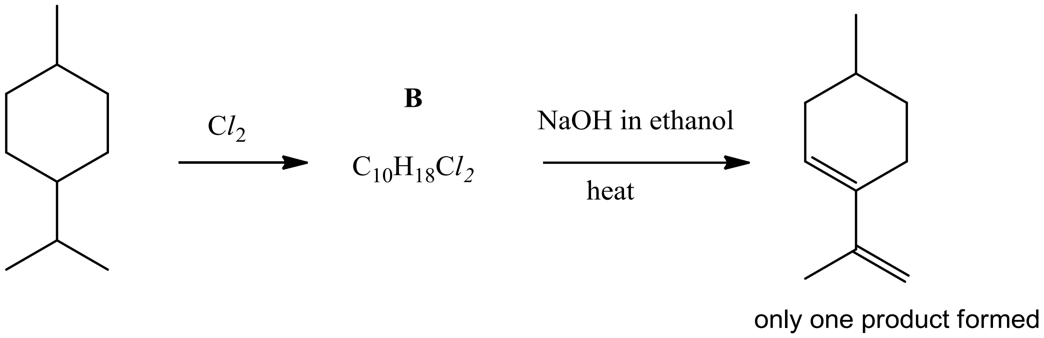
$\Rightarrow a = 1$

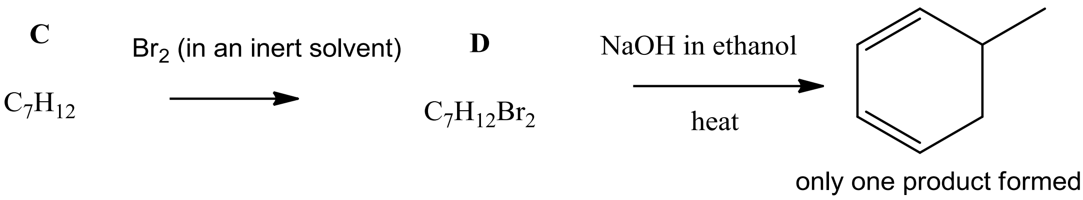
Hence the reaction is first order with respect to I^- as well.

(iv) rate = $k\,[H_2O_2]\,[H^+]\,[I^-]$

(d) Suggest a structural formula for each of the compounds A-D in the following schemes.

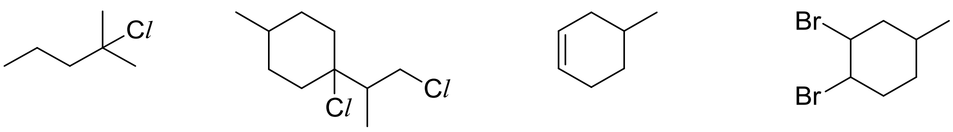






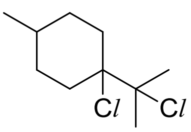
[4]

(d)



A **B** **C** **D**

Note: **B** can also be



(e) Chlorofluoroalkanes, CFCs, were once used as refrigerant fluids and aerosol propellants. In many applications they have now been replaced by alkanes. This is because CFCs contribute to the destruction of the ozone layer.

(i) Suggest one reason why CFCs, were originally used for these purposes.

(ii) Explain how CFCs destroy the ozone layer.

(iii) Suggest one potential hazard of using alkanes instead of CFCs.

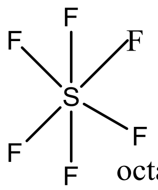
[3]

[Total: 20]

(i)	CFCs are non-toxic and contain C–F bonds that are inert, making them safe to use as refrigerant fluids and aerosol propellants.
(ii)	CFCs can be broken down in the atmosphere by UV light to form chlorine radicals that deplete the concentration of ozone.
(iii)	Alkanes are highly flammable, and poses a fire-hazard if used as a substitute for CFCs.

6 (a) Molecular shapes can be explained using the Valence Shell Electron Pair Repulsion theory.

(i) Predict and explain the shape of sulfur hexafluoride SF_6.



octahedral shape

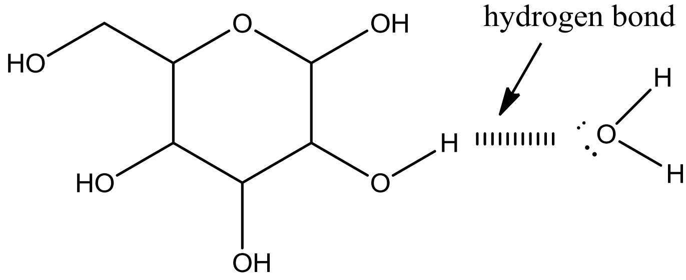
Six bond pairs around Sulphur; to minimize repulsion the six S-F bonds are in octahedral positions

(b) (ii) Caesium fluoride, CsF, has a similar formula mass to sulfur hexafluoride. State and explain two differences you would expect to find in the physical properties of the two compounds.

[4]

Melting point of CsF is higher than SF_6 as CsF has a strong ionic bonds with giant structure. Melting involves the breaking of strong electrostatic forces of attraction between the ions.
SF_6 has a simple molecular structure with dispersion forces between the molecules. Less energy is required to break this forces and thus melting point is low
CsF has electrical conductivity when molten or in aqueous solution but not SF6. The ions Cs^+ and F^- are charge carrier. SF_6 do not have ions.

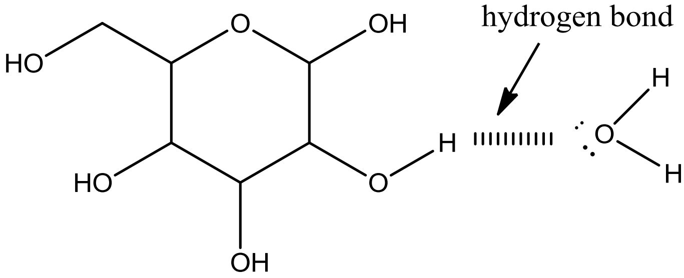
The structure of glucose is given below.



Glucose

(i) What type of intermolecular force is likely to be responsible for the binding of water to glucose? Draw a diagram to illustrate your answer.

[2]



Glucose

(ii) State two requirements for two molecules to form the intermolecular force that you have identified in b(i). [2]

One molecule must contain a proton H bonded to a highly electronegative atom N,O or F

The other molecule must also contain an atom with highly electronegative atom N,O or F which have lone pair/s of electron

(c) HC*l*, HBr and HI are strong acids when dissolved in water, whereas HF is a weak acid, with Ka = 5.6×10^{-4} mol dm^{-3}

(i) Use the Data Booklet to suggest a reason for this difference.

(ii) Calculate the pH of 0.50 mol dm^{-3} solutions of HC*l* **and** HF

[3]

For the HC*l*(aq), [H$^+$] = 0.50 mol dm^{-3}, pH = –lg 0.50 = 0.301

For the HF(aq),

$$K_a = \frac{[H^+][F^-]}{[HF]} = \frac{x^2}{0.50 - x} \approx \frac{x^2}{0.50}$$

$x^2 = 5.6 \times 10^{-4} \times 0.50$

$\therefore x$ = [H$^+$] = 0.0167 mol dm^{-3}, pH = –lg 0.0167 = 1.78

HC*l* is a strong acid ⇒ it dissociates completely in water ⇒ [HC*l*] = [H$^+$]
[H$^+$] in the HF solution needs to be calculated from its K_a.

(d) When methylbenzene is reacted with Cl_2 and $AlCl_3$, a monochloro compound **K** is formed. Treatment of **K** with more Cl_2 in the presence of light produces compound **L**. When **L** is heated with NaCN in ethanol, compound **M**, C_8H_6ClN, is formed. **M** can be converted into an acidic compound **N** by heating under reflux with dilute H_2SO_4. Heating **L** with NaOH(aq) produces compound **P**, C_7H_7ClO. When a mixture of **N** and **P** is heated with a small amount of concentrated H_2SO_4, compound **Q**, $C_{15}H_{12}Cl_2O_2$ is produced.

Identify the six compounds **K-Q**. State the type of **each** reaction described above.

[9]

[Total: 20]