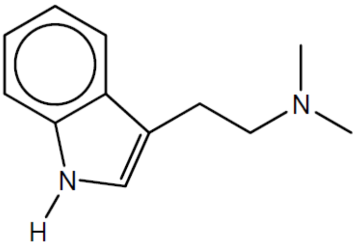
1 **(a)** N,N-dimethyltryptamine is a psychoactive drug whose primary action is to alter cognition and perception. Depending on the dose and method of administration, its subjective effects can range from short-lived milder psychedelic states to powerful immersive experiences.



N,N-dimethyltryptamine

(i) Suggest a reason why N,N-dimethyltryptamine is soluble in acidic solutions.

It will react with acid to form a salt / cation which is able to form ion-dipole interactions with water molecules.

(ii) Would you expect N,N-dimethyltryptamine to have a high or low melting point? Explain your answer in terms of structure and bonding.

It is expected to have a low melting point. It has a simple molecular structure with weak van der Waals' forces between molecules. Thus less energy is required to break the weak forces.

[4]

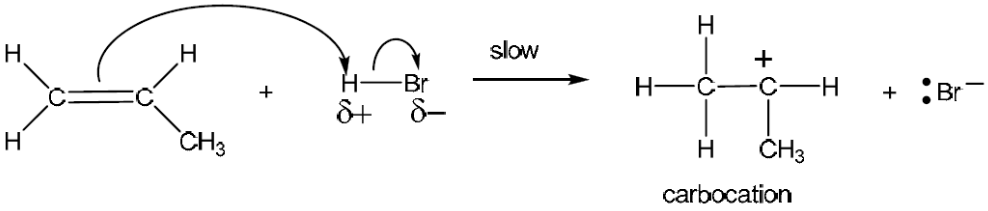
(b) Propene is an important starting product in the petrochemical industry and is often used as the raw material for a wide variety of products.

(i) Name and describe the mechanism of the reaction between propene and hydrogen bromide.

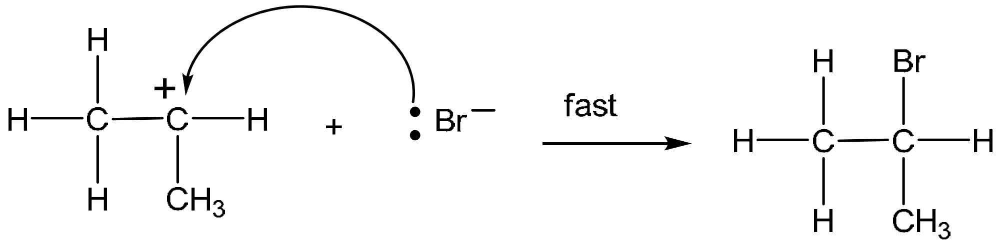
[3]

Electrophilic Addition

Step 1



Step 2



(ii) The bromine atom in the product from **b(i)** is very reactive towards nucleophilic reagents. The bromine atom in 1–bromopropene is unreactive towards nucleophilic reagents. Suggest an explanation for the unreactivity of the bromine atom in 1–bromopropene.

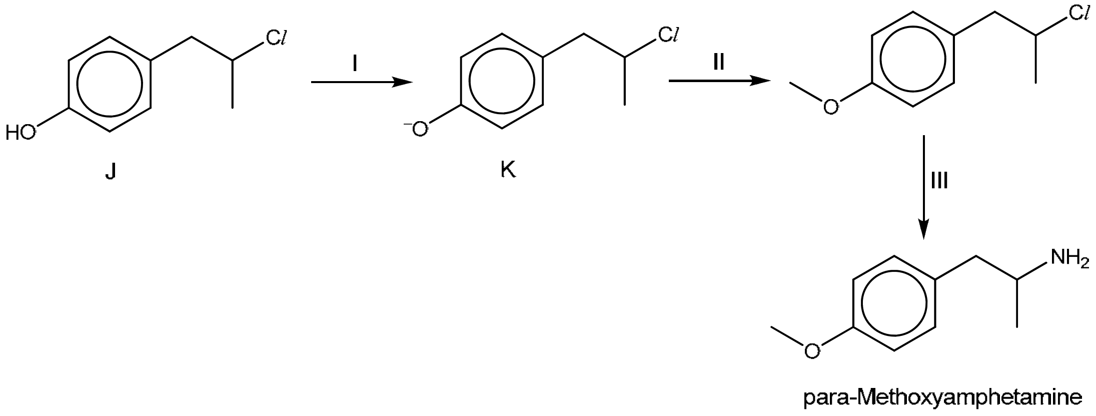
[2]

In 1-bromopropene, the p orbital of Br overlaps with the π orbital of adjacent C atom, strengthening the C – Br bond. Thus, the C – Br bond is too strong to be broken and hence unreactive towards nucleophilic reagents.

OR

In 1-bromopropene, the C atom is adjacent to the double bond and hence less electron deficient and thus less susceptible to nucleophilic attacks.

(c) *para*-Methoxyamphetamine first came into circulation in the early 1970s and went by the street names of "Chicken Powder" and "Chicken Yellow" and was found to be the cause of a number of drug overdose deaths in the United States and Canada at that time. It can be synthesised by the following route.



(i) Suggest reagents and conditions for steps II and III.

II: CH_3Br / CH_3I/ CH_3Cl, heat with reflux

III: NH_3 in ethanol, heat in a sealed tube

(ii) What type of reaction is step II?

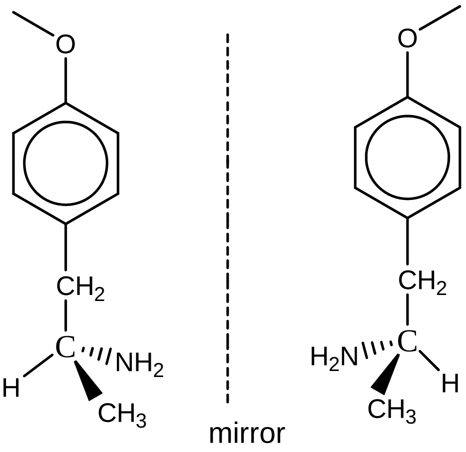
Nucleophilic substitution

(iii) Suggest why compound **J** is converted into **K** before step **II** is carried out.

To generate a stronger nucleophile, phenoxide ion.

(iv) What type of stereoisomerism does *para*-methoxyamphetamine exhibits? Draw the structures of the stereoisomers of *para*-methoxyamphetamine.

Optical isomerism



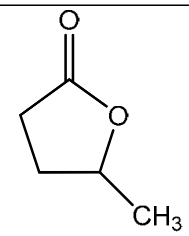
[6]

(d) Compound **P** is a neutral, sweet-smelling liquid with molecular formula $C_5H_8O_2$. It reacts with hot sulfuric acid to give a single compound **Q**, $C_5H_{10}O_3$. **Q** has two stereoisomers and gives a pale yellow precipitate with alkaline iodine and compound **R**. Deduce the structures of **P**, **Q** and **R**.

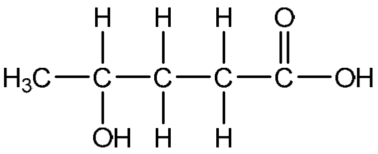
P undergoes acidic hydrolysis with hot sulfuric acid to give Q. P is an ester.

Q contains $CH_3CH(OH)$ since it undergoes mild oxidation with alkaline iodine.

Q only contains 1 chiral carbon since it has two stereoisomers.

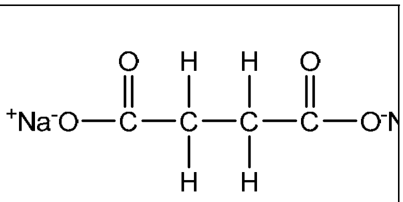


P



$H_3C-CH(OH)-CH_2-CH_2-C(=O)-OH$

Q



$^{+}Na\,^{-}O-C(=O)-CH_2-CH_2-C(=O)-O^{-}$

R

[5]

[Total:20]

2 **(a)** When a precipitate is formed, ΔG^{θ}_{ppt}, in kJ mol^{-1}, is given by the following expression.

$$\Delta G^{\theta}_{ppt} = \frac{2.303RT\ \log K_{sp}}{1000}$$

(i) Given that the K_{sp} value of BaF_2 is 1.70x10^{-6} at 298K, calculate ΔG^{θ}_{ppt}, in kJ mol^{-1}, for BaF_2.

ΔG^{θ}_{ppt} = [2.303 x 8.31 x 298 x log (1.70x 10^{-6})] ÷ 1000 = -32.9 kJ mol^{-1}

(ii) The standard enthalpy change of formation of BaF_2 is −858 kJ mol^{-1}. Use your answer in **(a)(i)** to calculate ΔS^{θ}_{ppt}, in J mol^{-1} K^{-1} for the formation of the precipitate at 298K.

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

$-32.9 = -858 - (298)\ \Delta S$

ΔS = -2.77 kJ mol^{-1}K^{-1}

= -2770 J mol^{-1}K^{-1}

(iii) Explain the significance of the sign of your answer in **(ii)**.

The sign is negative which means that entropy decreases as the system is **more ordered/less disordered** when there is **a phase change from aqueous to solid state.**

(iv) Predict and explain whether the precipitation will be feasible at high or low temperature.

Since ΔS is negative, (-T ΔS) is always positive. At high temperature, the magnitude of (-T ΔS) would be greater than ΔH. Hence ΔG would be positive and the reaction would not be feasible. Therefore the reaction is feasible at **low temperature.**

(v) Suggest how the magnitude of the lattice energy of BaF_2 might compare to that of $BaCl_2$. Explain your answer.

- Although fluoride ion and chloride ion have the same charge,
- fluoride ion is smaller than chloride ion.
- |L.E| α $\left|\frac{q_+q_-}{r_+ + r_-}\right|$ or Since lattice energy is inversely proportional to the

ionic radius

- Therefore the magnitude of the lattice energy of BaF_2 would be greater than that of $BaCl_2$.

[7]

(b) In the past, chemical analysis was carried out by chemists using traditional laboratory apparatus. Many qualitative tests used depended on an application of the principles of solubility product.

(i) Write an expression for the K_{sp} of barium fluoride.

$K_{sp} = [Ba^{2+}][F^-]^2$

(ii) Predict whether precipitation occurs if 50.0 cm^3 of 0.150 mol dm^{-3} of $Ba(OH)_2$ solution is mixed with 50.0 cm^3 of 0.100 mol dm^{-3} of KF solution in the laboratory.

The K_{sp} of BaF_2 is 1.70×10^{-6} $mol^3\ dm^{-9}$.

$$[Ba^{2+}]_{new} = \frac{0.150}{2} = 0.075 \text{ mol dm}^{-3}$$

$$[F^-]_{new} = \frac{0.100}{2} = 0.05 \text{ mol dm}^{-3}$$

$IP = [Ba^{2+}][F^-]^2 = 0.075 \times (0.05)^2 = 1.875 \times 10^{-4}\ mol^3\ dm^{-9}$

$1.875 \times 10^{-4}\ mol^3\ dm^{-9} > K_{sp}$ Precipitation occurs.

[3]

(c) Myrcene is a naturally occurring compound found in the leaves of bay trees. It is known to be a polyunsaturated hydrocarbon. It can react with hydrogen to produce a saturated hydrocarbon.
In a laboratory investigation, a 1.00 g sample of pure myrcene fully reacted with exactly 510 cm^3 of hydrogen gas measured at 20.0°C and 105.0 kPa. In this reaction, myrcene was converted to a saturated alkane with a molecular formula $C_{10}H_{22}$.

(i) What type of reaction has occurred between the myrcene and hydrogen?

Addition of hydrogen /hydrogenation/redox/ reduction

(ii) Calculate the amount, in moles, of hydrogen reacting.

no of moles of $H_2 = pV / RT$
$= 105 \times 10^3 \times 510 \times 10^{-6} / (8.31 \times [20.0 + 273])$
= **0.0220** mol

(iii) Calculate the mass of $C_{10}H_{22}$ produced in the reaction.

mass of $C_{10}H_{22}$ = mass of myrcene + mass of H_2

mass of H_2 = 0.0220 x 2.0 = 0.044 g
mass of $C_{10}H_{22}$ = 1.00 + 0.0440 = 1.04 g

(iv) Determine the number of double bonds in each molecule of myrcene.

no of moles of $C_{10}H_{22}$ = 1.044 / 142 = $7.35\text{x}10^{-3}$ mol = n(myrcene)
equation for reaction is myrcene + $xH_2 \rightarrow C_{10}H_{22}$
$n(H_2)$ / n(myrcene) = x / 1
0.0220 / $7.35\text{x}10^{-3}$ = x
3 = x
3 molecules of H_2 added to each myrcene molecule. Hence there are 3 C=C double bonds.

The following is an alternate approach.
no of moles of $C_{10}H_{22}$ = $7.35\text{x}10^{-3}$ mol
no of moles of myrcene = $7.35\text{x}10^{-3}$
Molar mass of myrcene = 1.0 / $7.35\text{x}10^{-3}$= 136 g mol^{-1}
molar mass of myrcene is 6 less than molar mass $C_{10}H_{22}$.
→ 3 H_2 molecules added to each myrcene molecule
→ 3 C=C double bonds.
One mark was awarded if 3 double bonds was stated, but to obtain the second mark a logical explanation of how the number of double bonds was determined was required.

[6]

(d) In September 2009, the wholesale of weedkiller containing chlorate(V) ions was banned in various European countries.

Chlorate(V) ions can act as a strong oxidising agent in acid solution according to the following half equation:

$$ClO_3^-\ (aq) + 6H^+\ (aq) + 6e \rightarrow Cl^-\ (aq) + 3H_2O(l)$$

In an experiment, 25.0 cm^3 of a sample of sodium chlorate(V) solution reacted with an excess of sodium iodide, NaI. The iodine produced required 25.00 cm^3 of 1 mol dm^{-3} of sodium thiosulfate, $Na_2S_2O_3$, for complete reaction.

(i) Write a balanced equation between chlorate(V) ions and iodide ions in acidic medium.

[R] $ClO_3^- + 6H^+ + 6e \rightarrow Cl^- + 3H_2O$
[O] $2I^- \rightarrow I_2 + 2e$

Overall: $ClO_3^- + 6H^+ + 6I^- \rightarrow Cl^- + 3H_2O + 3I_2$

(ii) Calculate the number of moles of iodine liberated by the chlorate(V) solution.

[R] : $I_2 + 2e \longrightarrow 2I^-$

[O] : $2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2e$

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

No of moles of thiosulfate = $\frac{25}{1000}$ x 1 = 0.025 mol

No of moles of iodine = 0.025 ÷ 2 = 0.0125 mol

(iii) Calculate the concentration of sodium chlorate(V) in the solution.

Mole Ratio
$ClO^- : I_2$

1:3

No of moles of chlorate = 0.0125 ÷3 = 4.167 x 10^{-3} mol

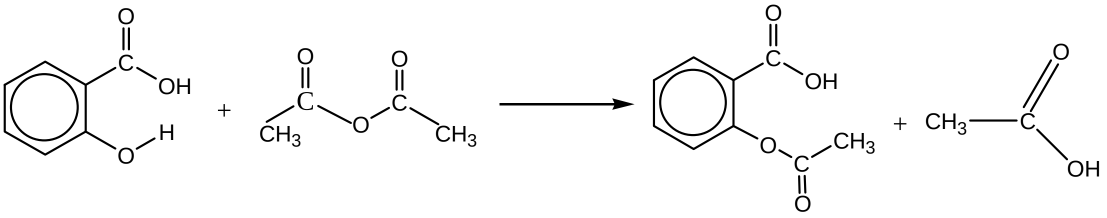
Concentration of sodium chlorate(V) = $\frac{4.167 x 10^{-3}}{\frac{25}{1000}}$ = 0.167 mol dm^{-3}

[4]

[Total: 20]

3 **(a)** A sample of aspirin was prepared by reacting 2.20 g of salicylic acid with 4.20 cm^3 of ethanoic anhydride in a conical flask. After heating for 20 minutes the reaction mixture was cooled and white crystals precipitated. The crystals were then collected, dried to constant mass and weighed.

The equation for the reaction is:



salicyclic acid(s) ethanoic anhydride(l) aspirin(s)

The following results were obtained.

mass of salicylic acid	2.20 g
volume ethanoic anhydride	4.20 cm^3
mass of product	2.25 g

Use the following data to answer the questions below.

	molar mass (g mol^{-1})	**density (gcm^{-3})**
aspirin	180	–
ethanoic anhydride	102	1.08
salicyclic acid	138	–

(i) Calculate the initial amount, in moles, of salicylic acid used in this preparation.

no of moles of salicylic acid = $\frac{2.20}{138}$ = **0.0159** mol

(ii) What initial amount, in moles, of ethanoic anhydride was used?

mass of ethanoic anhydride = Volume x Density
= 4.20 x 1.08 g

no of moles of ethanoic anhydride = 4.20 x $\frac{1.08}{102}$ = **0.0445** mol

(iii) What is the maximum mass of aspirin that can theoretically be produced from these reagents?

Salicylic acid is the limiting reagent
no of moles of aspirin = no of moles of salicylic acid = 0.0159 mol
mass of aspirin = 0.0159 x 180 = **2.86 g**

(iv) Determine the percentage yield in this preparation.

% yield = [mass of aspirin collected/mass of aspirin theoretical] x 100

$= \frac{2.25}{2.86} \times 100$

= **78.4** %

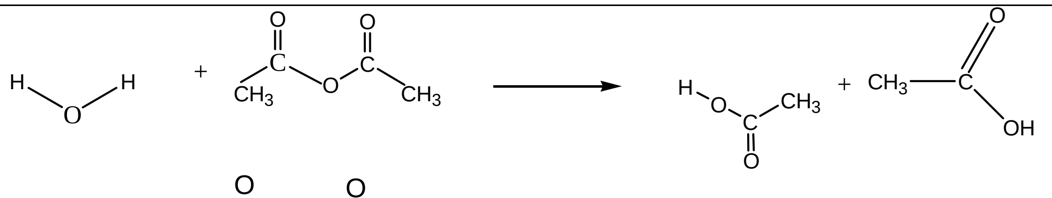
(v) To check whether the aspirin obtained is contaminated with salicyclic acid, a simple chemical test can be carried out. Suggest what reagent can be used and state the observation.

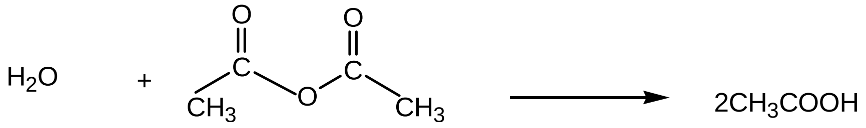
Neutral $FeCl_3$ (aq)(reacts with phenol), forming purple coloration

OR

Br_2(aq), orange decolourise & white ppt formed.

(vi) In carrying out the above preparation, the acid anhydride used must not contain moisture. Write an equation for the reaction between ethanoic anhydride with water.





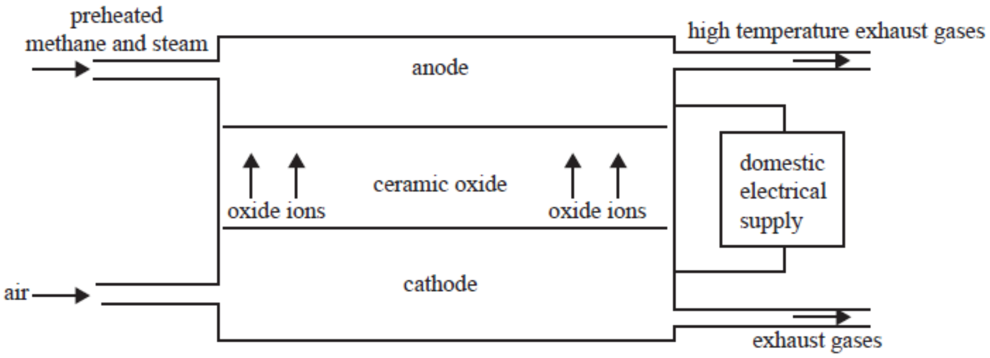
(vii) Acid chlorides closely resemble the acid anhydrides in chemical reactions. They also react with nucleophilic reagents but at a faster rate and therefore more difficult to handle.

Suggest another reason why ethanoyl chloride is **not** used in the above preparation of aspirin.

HC*l* fumes will be produced which is a toxic gas

[7]

(b) A company wish to manufacture solid oxide fuel cell for use in the home. These fuel cells uses natural gas to produce electricity through an electrochemical process summarised in the diagram below.



(i) Write an equation for the reaction at the cathode where atmospheric oxygen is converted to oxide ions.

$O_2(g) + 4e \longrightarrow 2O^{2-}(g)$

Or $\frac{1}{2}O_2(g) + 2e \longrightarrow O^{2-}(g)$

(ii) A complex series of reactions takes place at the anode. These may be summarised by the half-equation

$4O^{2-}(g) + CH_4(g) \longrightarrow CO_2(g) + 2H_2O(g) + 8e$

Write an equation that represents the overall reaction that takes place in this fuel cell.

$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$

(iii) Suggest one way in which a fuel cell differs from other galvanic cells.

fuel cells require a continuous supply of reactants, whereas in a galvanic cell they are stored in the cell

or

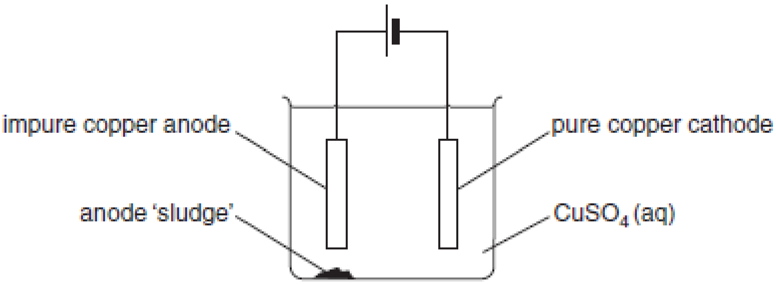
some products are removed from fuel cells

or

fuel cell electrodes are porous.

[3]

(c) The electrolytic purification of copper can be carried out in an apparatus similar to the one shown below.



Most of the current passed through the cell is used to dissolve the copper at the anode and precipitate pure copper onto the cathode. However, a small proportion of it is 'wasted' in dissolving the impurities at the anode which then remain in solution. When a current of 20.0 A was passed through the cell for 10.0 hours, it was found that 225 g of pure copper was deposited on the cathode.

Calculate the following, using appropriate data from the *Data Booklet*.

(i) number of moles of copper produced at the cathode

amount of copper = $\frac{225}{63.5}$ = 3.54 mol

(ii) number of moles of electrons needed to produce this copper

amount of electrons needed = 2 × 3.54 = 7.08/9 (7.087) mol

(iii) number of moles of electrons that passed through the cell

no. of coulombs = 20 × 10 × 60 × 60 = 7.2×10^5 C

no. of moles of electrons = $\dfrac{7.2 \times 10^5}{96500}$ = 7.46 mol

(iv) Hence calculate the percentage of the current through the cell that has been ‘wasted’ in dissolving the impurities at the anode.

[4]

percentage “wasted” = 100 × $\dfrac{(7.461 - 7.087)}{7.461}$ = 5.01 (5.0)%

[4]

(d) **(i)** State what is meant by an *acidic buffer solution*.

Acidic buffer solution is a mixture of **a weak acid and its soluble salt and resist pH changes when little amount of acid or alkali is added**.

(ii) Explain, using relevant equations, how a mixture of HC*l*O and NaC*l*O can regulate pH when relatively small amount of acid or base is added to the solution.

Small additional H^+ ions are removed by the large reservoir of NaC*l*O

$$NaClO + H^+ \rightarrow HClO + Na^+$$

Small additional OH^- ions are removed by large reservoir of HC*l*O

$$HClO + OH^- \rightarrow ClO^- + H_2O$$

(iii) Explain why NaC*l*O exists as a solid whereas HC*l*O exists as a liquid under standard condition.

NaClO has giant ionic structure which consists of strong electrostatic forces of attraction between oppositely charged ionswhereas HClO has simple molecular structure which consists of weak van der Waals’ forces between molecules.

Less energy is needed to break the weak VDW. Hence NaC*l*O exists as a solid whereas HC*l*O exists as a liquid.

2 correct structures stated-

[6]

[Total: 20]

4 **(a)** By considering the likely mechanism of each reaction, suggest reasons why reaction **I** below must be heated for some time for it to occur, whereas reaction **II** takes place almost instantaneously at room temperature.

$$CH_3CH_2CH_2Br(l) + NaOH(aq) \rightarrow CH_3CH_2CH_2OH(aq) + NaBr(aq) \qquad \textbf{I}$$

$$HBr(aq) + NaOH(aq) \rightarrow H_2O + NaBr(aq) \qquad \textbf{II}$$

[2]

Reaction I involves **breaking of strong covalent bonds**, thus heat is required.

Reaction II involves **reaction of opposite charge ions attracting one another**, thus the reaction occurs instantaneously.

(b) How would the rate of reaction between $CH_3CH_2CH_2Cl(l)$ and NaOH(aq) compare to that of reaction **I**? Use appropriate data from the Data Booklet to explain your answer.

[2]

This hydrolysis reaction involves breaking of C-X bond. Since **C-Cl bond (BE of 340 kJ mol^{-1}) is stronger] than that of C-Br bond (BE of 280 kJ mol^{-1})**, the **rate** of hydrolysis to break C-Cl bond in $CH_3CH_2CH_2Cl(l)$ is **slower**.

(c) In the presence of ethanolic potassium hydroxide, there is a competition between substitution and elimination of the bromoalkane. The data below shows some examples.

Formula of bromoalkane	Type of bromoalkane	Conditions	$\frac{\text{elimination}}{\text{substitution}}$ ratio
$(CH_3)_2CHBr$	Secondary	2 mol dm^{-3} OH^- in 60 % ethanol*	1.5
$(CH_3)_2CHBr$	Secondary	2 mol dm^{-3} OH^- in 80 % ethanol*	2.2
$(CH_3)_3CBr$	Tertiary	2 mol dm^{-3} OH^- in 100 % ethanol	13.0

* the remainder is water

Using the data given above, draw the structural formula of the major product of each of the following reactions:

[3]

(i) Heating $(CH_3)_2CHCH_2Br$ with NaOH(aq)

$(CH_3)_2CHCH_2OH$

(ii) Heating $CH_3CH_2CHBrCH_2CH_3$ with NaOH in 100 % ethanol

$CH_3CH_2CH=CHCH_3$

(iii) Heating $(CH_3)_3CBr$ with NaOH in 100 % ethanol

$(CH_3)_2C=CH_2$

(d) The rate constant for the reaction of $CH_3CH_2CHBrCH_3$ and KCN was measured at various temperatures and the results are shown below.

T/K	300	310	320	330
***k*/s^{-1}**	3.7×10^{-5}	9.4×10^{-5}	5.5×10^{-4}	2.0×10^{-3}

(i) Deduce the overall order of this reaction.

[1]

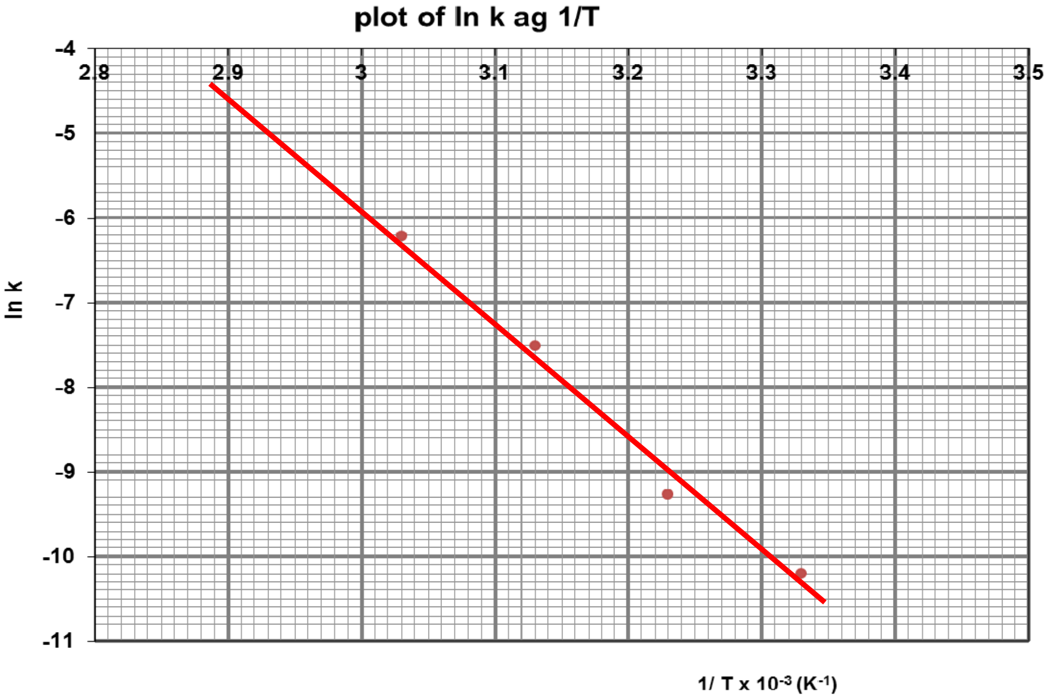
1st order because the unit of rate constant is s^{-1}.

(ii) From the plotted graph given and by using the modified Arrhenius equation,

$$\ln k = \text{constant} - E_a / RT$$

determine the activation energy, E_a, of the reaction.

[2]



The slope of the line is found to be – E_a /R

Thus, slope = $\dfrac{-10-(-4.6)}{(3.3-2.9)\times 10^{-3}}$ = -13500 = – E_a /R

E_a = **112.2 kJ mol^{-1}**

(ii) Estimate the rate constant of the reaction at 340 K and hence calculate the half-life of the reaction at the same temperature.

[2]

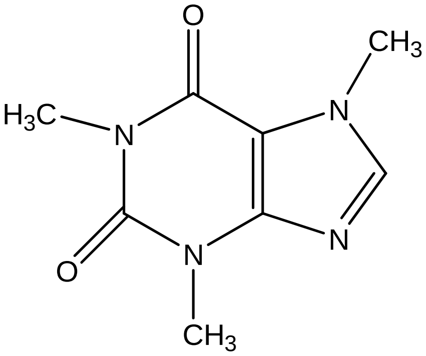
From the graph at 340 K,

ln k = − 5.10

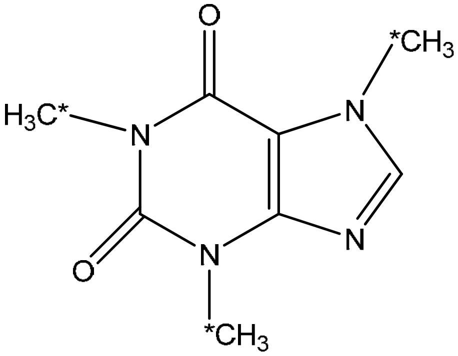
thus, k = **6.10 x 10^{-3} s^{-1}**

since $t_{1/2}$ = ln 2 /k = **114 s**

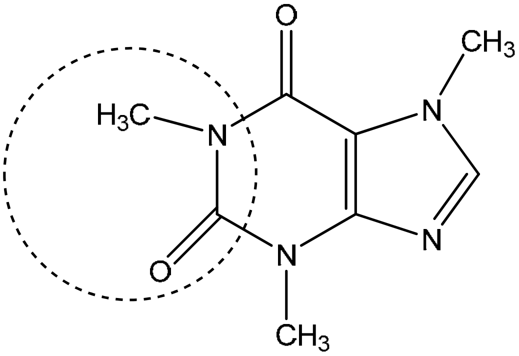
(e) Caffeine is a stimulant found in coffee and tea. It is also added to cola drinks. The structure of caffeine is given below.



(i) Copy the above structure and label (with a *) all the carbon atoms with bond angles of 109 °.



(ii) On the structure that you have drawn, draw a circle round an amide group.



(iii) Decaffeinated coffee and tea are made by extracting the caffeine from solid coffee or tea using a solvent.

Suggest, with two reasons, which of the following industrial solvents would be the most suitable.

- Benzene
- A hydrocarbon, such as cyclohexane
- Liquid carbon dioxide

[5]

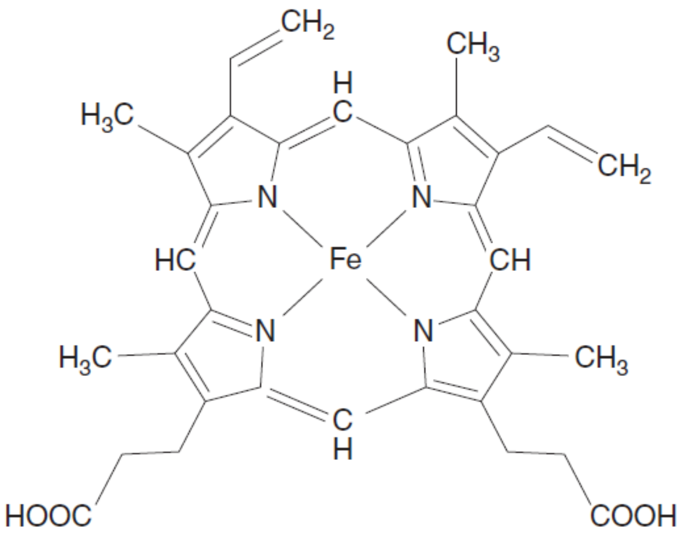
Liquid carbon dioxide is the most suitable solvent

Reason 1: Liquid carbon dioxide is **not toxic**.

Reason 2: Liquid carbon dioxide has low boiling point & **can be easily evaporated off** without leaving any odour.

(f) Iron is an extremely important metal used in haemoglobin to transport oxygen molecules from the lungs to muscle cells and to carry carbon dioxide in the reverse direciton.

One haemoglobin molecule contains four haem groups, each of which contains one iron atom. In the haem group four nitrogen atoms are in the same plane as the iron atom. The oxygen molecule is attached above this plane, and the iron atom is joined to a protein chain below this plane.



haem

(i) How many oxygen **atoms** could one haemoglobin molecule transport?

[1]

8 atoms *(also allow 4 oxygen molecules)*

(ii) By what type of bonding is the oxygen molecule likely to be held to the iron atom in haem?

[1]

Dative bond / co-ordinate bond

(iii) What is the geometry of bonding around the iron atom?

[1]

Octahedral / 6 co-ordinate

[Total:20]

5. **(a)** Bromine containing products, such as sodium bromate is frequently used in hair straightener and conditioning products.

(i) Write a balanced equation for the reaction that can make a solution that contains sodium bromate(I) under suitable condition in laboratory.

$Br_2 + 2\ NaOH \rightarrow NaBr + NaBrO + H_2O$

(ii) Bromine can be obtained from the sodium bromide dissolved in sea water by the following step:

Blowing out the bromine with air and absorbing it in aqueous sodium carbonate.

This step produces a mixture of solution **Z** and sodium bromide in the molar ratio of 1:5. **Z** has the following composition by mass:

Na, 15.2%; Br,52.9%; O,31.8%

I. Calculate the empirical formula of **Z**.

II. Construct an equation for the formation of **Z** in the above step mentioned.

	Na	Br	O
Mass in 100g	15.2	52.9	31.9
Mr	23.0	79.9	16.0
No. of moles	0.66	0.66	1.99
Simplest ratio	1	1	3

Empirical formula of Z : $NaBrO_3$

II:
$3\ Br_2 + 6\ OH^- \rightarrow BrO_3^- + 5\ Br^- + 3\ H_2O$

(iii) An acidified aqueous solution of **Z** reacts with hydrogen sulphide, H_2S, to give a precipitate of sulphur and an orange red solution. On shaking with trichloroethane, the colour is transferred to the organic layer.

I State the role of H_2S and suggest an identity for the orange red solution.

II Construct a balanced equation for the reaction.

I) It is acting as a reducing agent.
Orange red solution is bromine.

II Half equation:

$H_2S \rightleftharpoons S + 2e + 2H^+$

$2BrO_3^- + 12H^+ + 10e \rightleftharpoons Br_2 + 6H_2O$

Overall equation: $5H_2S + 2H+ + 2BrO_3^- \rightarrow 5S + Br_2 + 6H_2O$

(iv) When solid calcium fluoride reacts with concentrated sulfuric acid, gaseous hydrogen fluoride is produced. A similar reaction occurs with solid calcium chloride but with solid calcium bromide, bromine is formed.

I Write an equation for the reaction of solid calcium fluoride with concentrated sulfuric acid.

II Explain why when reacted with concentrated sulfuric acid, solid calcium bromide form bromine whereas solid calcium chloride forms hydrogen chloride? Suggest a possible reaction product of the concentrated sulfuric acid in the reaction.

I. $CaF_2 + 2H_2SO_4 \rightarrow 2HF + Ca(HS0_4)_2$

II. With conc. H_2SO_4, $CaBr_2$ produces HBr which is readily oxidised by conc. H_2SO_4 to Br_2.

$CaCl_2$, however, produces HCl which is not further oxidised by conc. H_2SO_4 .

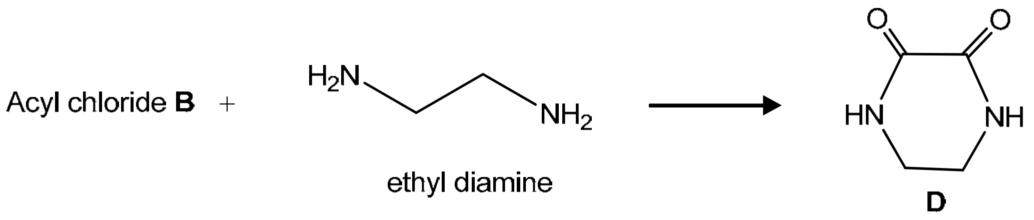
A possible reaction product is SO_2.

$[2HBr + H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_2O]$

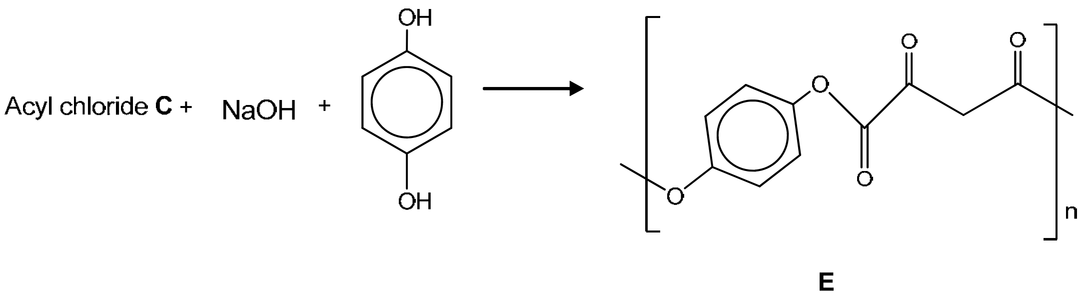
[9]

(b) Acyl chlorides are useful intermediates for making various acid derivatives. The following reaction shows two reactions of acyl chlorides.

Reaction scheme 1

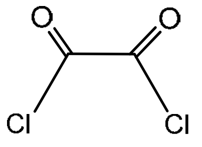


Reaction scheme 2

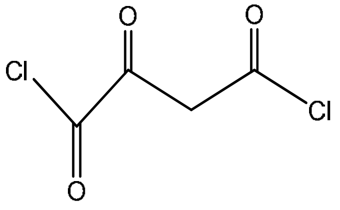


(i) Suggest the structures of acyl chlorides used in reaction scheme 1 and 2. [2]

B:



C:



(ii) Suggest the type of polymer **E**. [1]

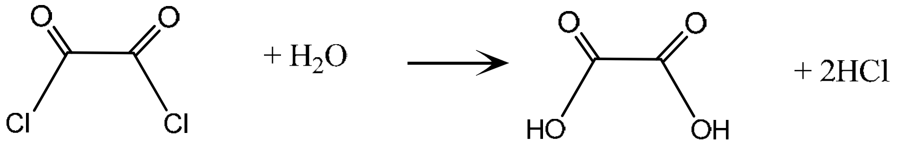
Ester

(iii) Both compound **B** and compound **D** are soluble in water.

I. Write a balanced equation when compound **B** dissolves in water and describe the effect of the resulting solution on Universal Indicator solution.

II. Explain why compound **D** is soluble in water.

I.



1m for equation

The solution turns red.

II. Compound **D** is an amide, it is able to form compatible interactions with water which is **hydrogen bonding between the compound D and water molecules**
Thus, compound **D** is soluble in water.

(iv) Suggest an observation for reaction scheme 2.

Steamy white fumes of HC*l*

[7]

(c) "Ca^{2+} and C*l*$^-$ are isoelectronic but the radii of the ions are different".

(i) Explain the term 'isoelectronic'.

Ions that contain the same number of electrons.

(i) With the aid of the *Data Booklet*, explain the above observation as fully as you can.

- Both Ca^{2+} and C*l*$^-$ are isoelectronic, hence same shielding effect.
- However, Ca^{2+} (20 protons) has higher nuclear charge than Cl^- (17 protons) hence higher effective nuclear charge.
- Hence there is stronger electrostatic attraction between nucleus and valence electrons of Ca^{2+}.
- Thus, valence electrons of Ca^{2+} are pulled closer to the nucleus and Ca^{2+} is smaller.
- Ca^{2+} has smaller ionic radiuWs than C*l*$^-$.

(iii) State **two** ways in which the behaviour of Ca^{2+} ions in an electric field differs from that of Cl^- ions.

- Ca^{2+} are deflected towards the **negative** potential**.** Cl^- ionsare deflected towards the **positive** potential**.**
- Ca^{2+} will be deflected to a greater extend as it has higher charge/mass ratio compared to Cl^-.

[4]

[Total:20]