1. Crude oil is a mixture of hydrocarbons which are separated by fractional distillation. One of the components obtained contains an alkane A, with eleven carbon atoms.

(a) Write the molecular formula of A. (1 mark)

$C_{11}H_{24}$ ✓1

Accept open structural formula.

Acc $CH_3(CH_2)_9CH_3$

(b) Pentane can be obtained from compound A as shown.

A → Pentane + B

(i) Give the name of this conversion process. (1 mark)

Cracking ✓1

Acc Catalytic / Thermal Cracking.

(ii) State the conditions used in this process. (1 mark)

High temperatures ✓½ // Acc 400-700°C // Heat

High Pressure ✓½ Acc 70 atmospheres. // ~~High~~ pressures. also

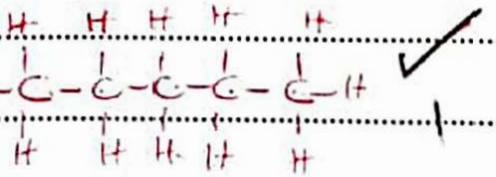
Catalyst ✓½ Acc zeolite catalyst // Silica catalyst // Alumina catalyst

(iii) Give the name of compound B. (1 mark)

Hexene ✓1 Acc C_6H_{12}

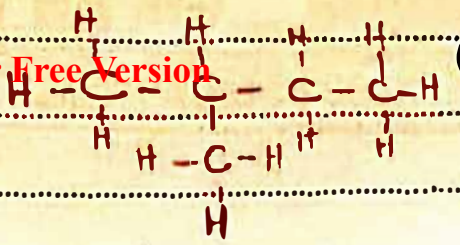
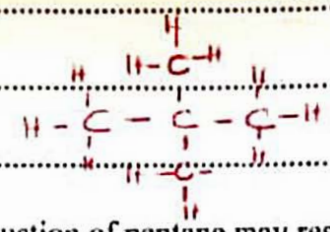
Acc Hex-1-ene // Hex-2-ene // Hex-3-ene.

(c) Draw and name two isomers of pentane. (4 marks)

Isomer 1	Structure	Name
$CH_3CH_2CH_2CH_2CH_3$ // $CH_3(CH_2)_3CH_3$	 ✓1	Pentane ✓1

rej C_5H_{12} molecular formula

* Name correct, wrong structure = 0

Isomer 2	Structure	Name
		2-methylbutane.
		2, 2-dimethylpropane

Acc condensed // open structure

Any 2.

(d) Incomplete combustion of pentane may result in air pollution. Write an equation to illustrate this combustion. (1 mark)

Either 1 Isomer either

$C_5H_{12(g)} + 3O_{2(g)} \longrightarrow 5C_{(s)} + 6H_2O_{(l)}$

OR.

OR

$2C_5H_{12(g)} + 11O_{2(g)} \longrightarrow 10CO_{(g)} + 12H_2O_{(l)}$.

(e) The main component in natural gas is methane. Describe how methane in natural gas is formed. (2 marks)

Decomposition / breakdown / decay of organic matter in the Absence of oxygen

(f) In the laboratory, methane can be prepared from salts of alkanoic acids. Describe how methane is prepared from sodium ethanoate. (2 marks)

Heat a mixture of sodium ethanoate & sodalime

Collect the gas over water // use syringe // upward delivery // downward displacement of air.

Caution of heat must

Accept correct diagram.

Mixture of Sodalime & Ethanoate

Arrow for heat.

method of collection.

Accept eqn.

Sodium ethanoate + Sodalime $\xrightarrow[\text{Heat}]{CaO}$ methane + Na_2CO_3

Then mention method of collection.

Conditions

2. (a) (i) State what is meant by the term 'dynamic equilibrium'.

State of rxn where the Rate of forward and backward Reaction are the Same, but in opposite direction.

(ii) Dichromate(VI) ions are orange in colour while chromate(VI) ions are yellow. Consider the following equilibrium.

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

State and explain the observation that will be made if sulphuric(VI) acid is added to the mixture. (2 marks)

Accept Concn of OH^- reduces

Intensity of Orange colour increases. Addition of H^+ removes OH^- hence reverse / backward rxn is favoured. // equilibrium shifts to the right.

(b) One of the reactions in the manufacture of nitric(V) acid involves catalytic oxidation of ammonia as shown in the equation.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \; ; \; \Delta H = -909 \text{ kJmol}^{-1}$$

The reaction is carried out at a pressure of 10 atmospheres and a temperature of 900 °C

(i) Other than nitric(V) acid, name another product that is formed. (1 mark)

Nitrous acid / HNO_2

Nitric (III) Acid

(ii) State and explain the effect on the position of equilibrium if the reaction is carried out:

I. at 10 atmospheres pressure and 450 °C; (2 marks)

Equilibrium shifts to the ~~left~~ right, forward reaction is favoured since it is exothermic.

II. at 900 °C and 20 atmospheres pressure; (2 marks)

Equilibrium shifts to the left / Backward reaction is favoured / favours the direction with fewer molecules / due decrease in number of moles / molecules.

III. in the absence of a catalyst. (1 mark)

No effect.

(c) State and explain the effect on the rate of the reaction if the reaction is carried out at 10 atmospheres and 450 °C. (2 marks)

Rate of reaction decreases / slowes, decrease in temperature leads to reduction / decrease in kinetic energy of the molecules hence less effective collisions

(d) A factory uses 100 kg of ammonia each day to produce 160 kg of nitrogen(II) oxide. Calculate the percentage yield of nitrogen(II) oxide. (3 marks)

Molar mass NH_3 (17) ✓½

Molar mass NO (30) ✓½

Moles of NH_3 = $\frac{100,000}{17}$ ✓½ = 5882.35

Moles of NO = mole ratio 1:1 ✓½

Mass of NO = 5882.35 × 30 = 176470.58

% yield of NO = $\frac{160,000}{176470} \times 100$ = ✓½ $\left(\frac{160 \times 17}{30 \times 100}\right) \times 100$ All units used

= 90.667% ✓½ = 90.67%

3. (a) One of the ores of iron is haematite, Fe_2O_3. Give the name and formula of two other ores of iron. (2 marks)

	Name	Formula
(i)	siderite ✓½	$FeCO_3$ ✓½
(ii)	Magnetite ✓½	Fe_3O_4 ✓½
	Iron pyrite ✓½	FeS_2 ✓½

(b) In a certain factory, iron is extracted from the haematite ore using the blast furnace as shown in Figure 1. The other raw materials are coke, limestone and air. The melting and boiling points of iron are 1535 °C and 3000 °C, respectively.

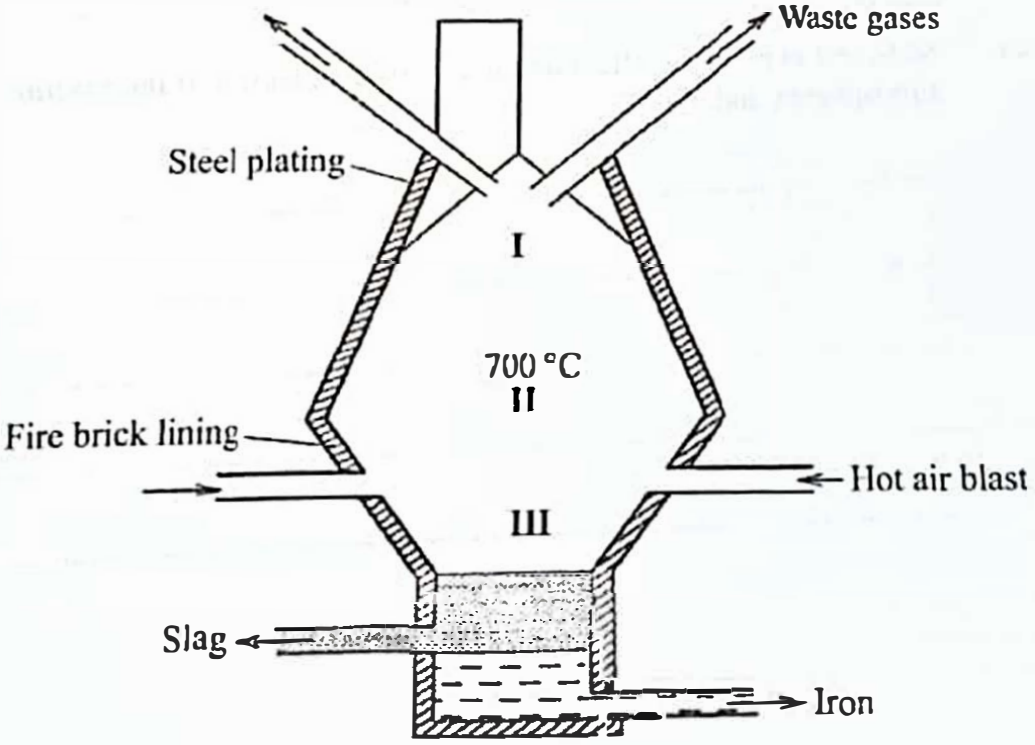


Figure 1

(i) State how the temperature in region I compares with that in region II. Give a reason. (1 mark)

Temp. in region I is lower than that in II ✓½

Raw mtrls are not pre-heated. ✓½ //

Region II is nearer to hot air blast that pre-heats //

Hot air rises in the furnace it becomes cooler //

(ii) The main reducing agent in the furnace is carbon(II) oxide formed by the reaction:

$CO_2(g) + C(s) \rightarrow 2CO(g)$

Write two equations to show how carbon(IV) oxide is formed in the furnace. (2 marks)

I. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ ✓1

II. $CaCO_{3(s)} \xrightarrow[\text{(Limestone)}]{\text{Heat}} CaO_{(s)} + CO_{2(g)}$ ✓1

$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(l)} + 3CO_{2(g)}$

(iii) Suggest a value for the temperature in region III. Give a reason. (2 marks)

Any Value 1535°C — 3000°C. ✓1

Helps maintain Iron in Molten state ✓1

(iv) Name the main component in the slag. ✓1 (1 mark)

Calcium silicate // $CaSiO_3$.

(v) State one role that slag plays in the blast furnace. (1 mark)

Prevents oxidation of Iron by hot air ✓1

(vi) The iron produced in the blast furnace is brittle due to presence of impurities.

I. Name the main impurity in this iron. (1 mark)

Carbon.

II. State one use of this iron. (1 mark)

Making manhole covers | Electric poles | Manufacture of pipes
Making scissors | Fire grills | Manufacture of iron beams | Manufacture of building blocks
Bunsen burner bases | Manufacture of steel | Electric furnace arch
Making sluice gate
Making iron pipes

(vii) Recycling is one method used to reduce production costs. State and explain the by products that can be recycled in this factory. (2 marks)

Waste gases – used to preheat the air blasts.

$CO_{2(g)}$ – CO_2 is combustion CO_2 / Oxides and burning of – used to preheat the air blasts

$CO_{(g)}$ – used as a reducing agent
– used to preheat air blasts.
– ~~[illegible]~~

4. Table 1 shows the elements in period 3 of the periodic table. Study it and answer the questions that follow.

Table 1

Element	Na	Mg	Al	Si	P	S	Cl	Ar

(a) Write the formulae of two oxides, for each of the following:

(i) sodium: Oxide I Na_2O Oxide II Na_2O_2 (1 mark)

(ii) chlorine Oxide I Cl_2O Oxide II Cl_2O_7 (1 mark)

ClO, ClO_2, Cl_2O_3, Cl_2O_5, Cl_2O_6, Cl_2O_3, ClO_3,

(b) The products of the reaction between phosphorus and chlorine depend on the conditions used. Write the equation for the reaction when chlorine reacts with excess phosphorus. (1 mark)

$2P_{(s)} + 3Cl_{2(g)} \rightarrow 2PCl_{3(l)}$ or (g)

$P_{4(s)} + 6Cl_{2(g)} \rightarrow 4PCl_{3(g)}$ or (l)

$P_{10(s)} + 15Cl_{2(g)} \rightarrow 10PCl_{3(g)}$ or (l)

(c) Identify the element with the highest electrical conductivity. Give a reason. (2 marks)

Al (as Al^{3+}) Highest number of delocalised electrons per atom / highest number of valence electrons / Has 3 delocalised electrons per atom.

(d) Describe an experiment that can be used to illustrate the variations in reaction of sodium, magnesium and aluminium with water. (3 marks)

Description is not a marking point

Sodium reacts vigorously with water / hissing sound produced (1)

Magnesium reacts slowly with water / produces few bubbles on the surface (1)

Aluminium does not react with water / produces no bubbles. (1)

(e) State and explain the differences in the melting points of:

(i) chlorine and argon. (2 marks)

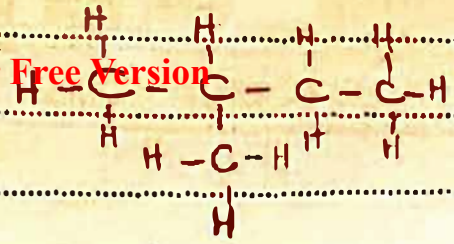
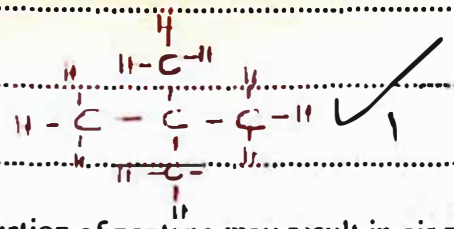
Melting point chlorine greater / higher than that of argon. (1)

$Cl_2(g)$ is diatomic while $Ar(g)$ is monoatomic (1/2)

hence $Cl_2(g)$ has ~~weaker~~ stronger van der waals forces of attraction / molecules of $Cl_2(g)$ are larger / bigger than $Ar(g)$ molecules, hence intermolecular forces in Cl_2 are stronger than Ar (1/2)

(ii) magnesium oxide and silicon(IV) oxide. (2 marks)

Magnesium has a higher melting than oxide silicon(IV) oxide (2)

Isomer 2	Structure	Name
structure	 ✓1	2-methylbutane. ✓1
Any 2	 ✓1	2, 2-dimethylpropane ✓1

Acc condensed || Opt

(d) Incomplete combustion of pentane may result in air pollution. Write an equation to illustrate this combustion. (1 mark)

Either / Ignore state

$C_5H_{12(g)} + 3O_{2(g)} \longrightarrow 5C_{(s)} + 6H_2O_{(l)}$ ✓1

OR

OR

$2C_5H_{12(g)} + 11O_{2(g)} \longrightarrow 10CO_{(g)} + 12H_2O_{(l)}$

(e) The main component in natural gas is methane. Describe how methane in natural gas is formed. (2 marks)

Decomposition / breakdown / decay of organic matter ✓1 in the absence of oxygen ✓1

(f) In the laboratory, methane can be prepared from salts of alkanoic acids. Describe how methane is prepared from sodium ethanoate. (2 marks)

Caution of heat Must

Heat ✓½ a mixture of sodium ✓½ ethanoate & sodalime ✓1 (Ignore state) Collect the gas over water ✓½ / use syringe / upward delivery / downward displacement of air.

Accept correct diagram.

Mixture of Sodalime ✓1 & Ethanoate

Arrow for heat ✓½

method of collection ✓½

Accept eqn:

Sodium ethanoate + Sodalime $\xrightarrow[\text{Heat}]{CaO}$ methane + Na_2CO_3 ✓ (2 mks)

Conditions

then mention method of collection.

5. Table 2 gives standard reduction potentials for some half cells.

Table 2

Half cell	Half cell equation	E^{θ} / V
I	$Fe^{3+}(aq) + e \rightarrow Fe^{2+}(aq)$	+ 0.77
II	$K^{+}(aq) + e \rightarrow K(s)$	– 2.92
III	$Ag^{+}(aq) + e \rightarrow Ag(s)$	+ 0.80
IV	$Pb^{2+}(aq) + 2e \rightarrow Pb(s)$	– 0.13
V	$I_2(aq) + 2e \rightarrow 2I^{-}(aq)$	+ 0.54

(a) State the standard conditions of an electrochemical cell. (2 marks)

1M solution
1atmospheric pressure.
Temperature of 25°C → 298K

3 correct 2 marks
2 correct 1 mark
1 correct ½ mark

(b) An electrochemical cell was constructed using half-cells III and IV.

(i) Complete Figure 2 by labelling the parts of the cells indicated as $A_1 - A_4$. (2 marks)

check if labelled

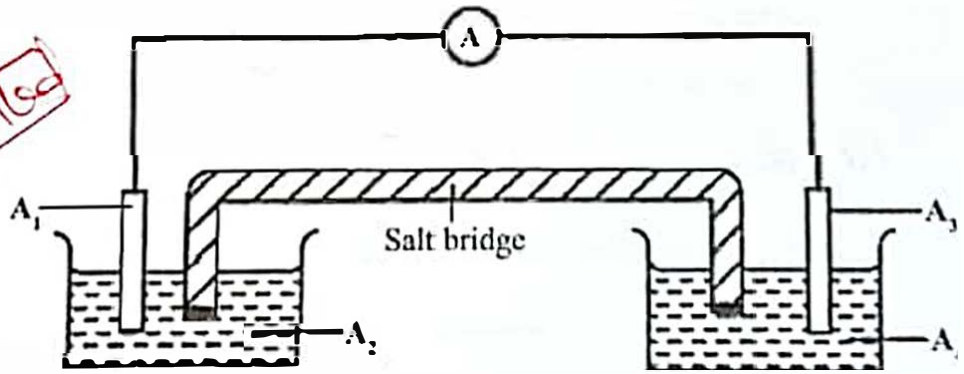


Figure 2

A_1 Pb // Lead electrode. ½

Soluble salt of Pb. A_2 Pb^{2+} // Lead (II) nitrate soln. // 1M Pb^{2+}. ½

A_3 Ag // Silver electrode. ½

Soluble salt of Ag. A_4 Ag^+ // Silver nitrate // 1M Ag^+. ½

(ii) Write an equation for the cell reaction and calculate the e.m.f. of the cell.

Equation (1 mark)

$Pb_{(s)} + 2Ag^+_{(aq)} \rightarrow Pb^{2+}_{(aq)} + 2Ag_{(s)}$ ✓1

e.m.f. (1 mark)

+0.8 − −0.13 ½

+0.93V ½

(iii) The salt bridge helps in completing the circuit. Explain why a saturated solution of potassium chloride is not suitable for use in the salt bridge in this electrochemical cell.

(1 mark)

Formation of insoluble $PbCl_2$ ✓1

That reduces concentration of ions in electrolyte

OR Formation of AgCl that reduces the effectiveness of cell.

(c) State why it is not possible to construct a similar electrochemical cell using half-cells II and III.

(1 mark)

K reacts explosively with water. ✓1

acc E.m.f of cell is very high which can explode the cell.

(d) State and explain the observations made when aqueous potassium iodide is added to aqueous iron(III) sulphate. (2 marks)

Brown (yellow) solution turns green. Fe^{3+} ions are reduced to Fe^{2+}.

Grey/black precipitate is formed. Iodide ions are oxidized to iodine.

Ionic equation

$Fe^{3+}_{(aq)} + 2I^-_{(aq)} \rightarrow Fe^{2+}_{(aq)} + I_{2(s)}$ +0.23V

Must balance

Brown/yellow Green Grey/black Explosion

(e) Acidified potassium dichromate(VI) and acidified potassium manganate(VII) may be used in determining concentration of Fe^{2+} ions in a sample. If acidified potassium dichromate(VI) is used, an indicator is added to determine the end point but for acidified potassium manganate(VII), no indicator is added.

(i) Explain why it is not necessary to use an indicator when acidified potassium manganate(VII) is used. (1 mark)

$H^+/KMnO_4$ acts as its own indicator changing from purple to colourless (decolourised)

(ii) An alloy containing iron was dissolved in an acid and the total volume made up to 250 cm³. 25.0 cm³ of this solution required 18.0 cm³ of 0.15 M acidified potassium dichromate(VI) to react completely. The equation for the reaction is:

$$Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 7H_2O(l)$$

Calculate the mass of iron in the alloy (Fe = 56.0). (3 marks)

Moles of $Cr_2O_7^{2-} = \frac{18 \times 0.15}{1000} = 0.0027$

Moles of Fe^{2+} in 25.0 cm³ $= 6 \times 0.0027 = 0.0162$

Moles of Fe^{2+} in 250 cm³ $= 0.0162 \times 10 \left(\frac{250}{25}\right) = 0.162$

Mass of iron $= 0.162 \times 56$

$= 9.072$ g

Condensed working

$\frac{18 \times 0.15 \times 6 \times 250 \times 56}{1000 \times 25}$

$= 9.072$ g

All marks awarded

$M = \frac{0.0162 \times 1000}{25}$

$= 0.648$ M

6. (a) Water containing hydrogen carbonate, HCO_3^-, and calcium Ca^{2+} ions, is said to be hard water.

(i) Describe one way in which HCO_3^- ions get into river water. (1 mark)

CO_2 dissolves in rain water to form Carbonic acid ½
Carbonic acid react with carbonate rock // Ca & Mg forming Hydrogen carbonates of Ca & Mg that get into rivers ½

(ii) Explain the disadvantage of using this type of water in boilers. (2 marks)

The $Ca(HCO_3)_2$ & $Mg(HCO_3)_2$ decomposes forming $CaCO_3$ / Scales / fur // lining the boilers and causing poor thermal conductivity // reducing efficiency. 1

(b) Analysis of a river water sample showed the presence of the following ions: Ca^{2+}, Na^+, Cl^-, NO_3^-.

(i) Name the type of water hardness present in the sample. (1 mark)

Permanent 1

(ii) Describe one precipitation method that can be used to soften the water. (2 marks)

Addition of washing soda // Na_2CO_3 1
Ca^{2+} and Mg^{2+} precipitates as carbonates which can be filtered off 1

(0.0162 X 250 X 25)

(iii) The water sample was passed through a resin as shown in Figure 3.

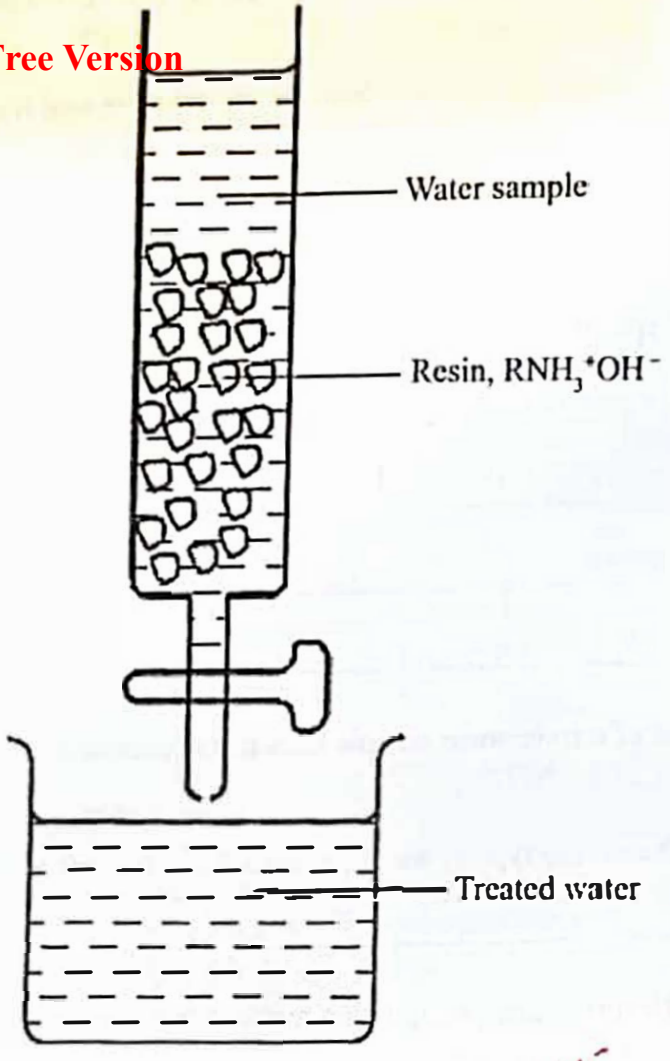


Figure 3

OR Cl^-

Cl^- if ammonium used

*Show charges and balance
*Ignore states

I. Write an equation for a reaction that took place in the column. (1 mark)

$\underbrace{RNH_3^+ OH^-_{(s)}}_{Resin} + NO_3^-_{(aq)} \rightarrow RNH_3^+ NO^-_{(s)} + OH^-_{(aq)}$

II. Complete treatment of the water sample required passing it through another resin. Give the formula of this resin. (1 mark)

$RSO_3^- H^+$

OR

$RCOO^- H^+$

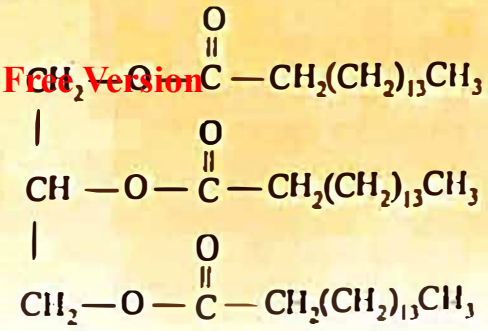
Ignore charges.

III. Explain why a river water sample that has been treated using resins may still require boiling to make it safe for drinking. (2 marks)

Resin does not kill bacteria / pathogens / germs

Boiling kills

(c) Compound **C** was used to prepare a potassium soap.



Compound **C**

(i) Give the formula of the potassium soap obtained. (1 mark)

$C_{15}H_{31}COOK$ / $CH_3(CH_2)_{14}COOK$ / $CH_3(CH_2)_{13}CH_2COOK$

(ii) State one difference in the properties of potassium and sodium soaps. (1 mark)

Potassium soaps lather more readily than Na soaps in water / Potassium soaps have lower/less melting points / Potassium salts are more soluble in water / Potassium soaps are soft/mild while sodium soaps are hard

Good Point ✓ 1

(d) A soapless detergent has the formula
$CH_3(CH_2)_{10}CH_2OSO_3Na$

With reference to this formula, identify the hydrophobic and the hydrophilic parts of the detergent.

Hydrophobic (1 mark)

$CH_3(CH_2)_{10}CH_2^-$ ✓ 1 Reject $CH_3(CH_2)_{10}$

or $(CH_3)_3(CH_2)_{14}^-$

Hydrophilic (1 mark)

$-OSO_3^-Na^+$ ✓ 1 Reject $-CH_2OSO_3^-Na^+$

or

$-OSO_3Na$

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