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1 a) i) A is immiscible with water. This suggests that part or all of the molecule is non-polar. [1]

ii) The cream precipitate is silver bromide [1]; so, A contains bromine. [1]

A might be a bromoalkane which has reacted with OH^- ions in NaOH(aq) to form an alcohol and Br^- ions. [1] (*Maximum 2 marks*)

b) i) Charring is the formation of carbon [1]; the vapour produced on heating is water [1]; this suggests that B may be hydrated/contain water of crystallisation. [1] (*Maximum 2 marks*)

ii) B is acidic. [1]

iii) B is sufficiently acidic to produce CO_2 [1] from Na_2CO_3(aq). So the acid group present is not a phenol. [1]

iv) The sweet-smelling product is probably an ester [1], which has been formed by reaction of a carboxylic acid [1] with ethanol plus concentrated H_2SO_4 as catalyst.

c) i) The very smoky flame suggests C has an aryl group/high C : H ratio. [1]

ii) C is not acidic/a carboxylic acid. [1]

iii) C contains an –OH group [1]; which reacts with sodium to produce hydrogen. [1]

2 a) The diagram for refluxing should show:

- liquids heated in a round-bottomed or pear-shaped flask [1]
- Liebig (water) condenser arranged vertically [1]
- water in at the bottom, out at the top. [1]

Subtract [1] if condenser is closed at the top.

b) A Refluxing for 45 minutes as the reaction is slow [1]; the reflux condenser prevents escape of volatile reagents such as ethanol. [1] Conc. H_2SO_4 is the catalyst. [1]

B Collecting all the distillate below 84 °C ensures that all the ethyl ethanoate is collected. [1]

C Sodium carbonate neutralises any acid impurity in the distillate. [1]

D Anhydrous sodium sulfate or anhydrous calcium chloride are added to remove water [1] from the organic product.

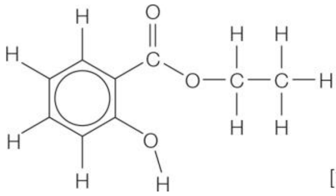
E Collecting liquid that boils between 75 and 79 °C ensures that most of the ethyl ethanoate is collected [1], but other impurities with boiling temperatures above or below this range are not collected. [1]

(*Total 8 marks*)

3 a) Phenol [1]; carboxylic acid [1]

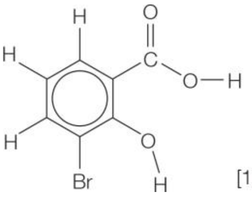
b) $C_7H_6O_3$ [1]

c) i)



[1]

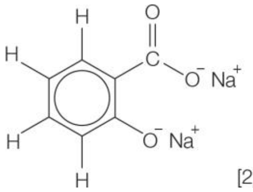
ii)



[1]

(Allow one or two Br atoms at any positions on the ring.)

iii)



[2]

4 a) To spread the heat from the Bunsen over the bottom of the flask. [1]

b) So that a larger surface area of the rind is exposed to hot water and steam. [1]

c) Steam distillation [1] Use a dropping pipette to remove the upper oily layer or use a separating funnel [1]

d) Leave the limonene in a specimen tube with a suitable drying agent such as anhydrous calcium chloride, anhydrous sodium sulfate, anhydrous magnesium sulfate or silica gel. [1]

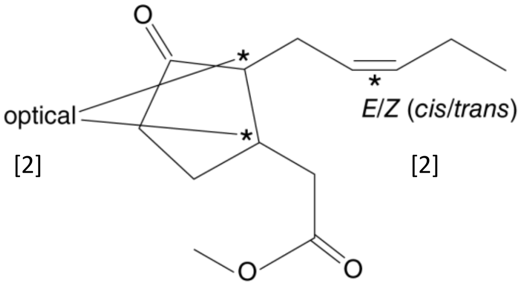
e) Because the temperature required to vaporise the limonene would char the peel and decompose the limonene. [1]

f) The alkene group. [1] Show that the limonene will decolourise yellow/orange bromine water [1] and will also decolourise dilute acidified purple potassium manganate(VII). [1]

5 a) $C_{13}H_{20}O_3$ [1]

b) Alkene [1]; carbonyl [1]; ester [1]

c) i) and **ii)**



[2] [2]

iii) The stereoisomers with the skeletal formula shown will all be *Z* isomers. [1] There will be (+) and (–) isomers at both the chiral centres [1]; therefore four stereoisomers [1]; with the skeletal formula shown.

6 **a)** F is $CH_3CH_2CH_2OH$ [1]; propan-1-ol. [1]

G is $CH_3CHOHCH_3$ [1]; propan-2-ol. [1]

H is CH_3CH_2CHO [1]; propanal [1]

J is CH_3COCH_3 [1]; propanone [1]

b) **i)** The orange [1]; mixture turns green. [1]

The products are propanoic acid [1]

and chromium(III) ions Cr^{3+}/chromium(III) sulfate. [1]

ii) Reduction half-equation:

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$ [1]

Oxidation half-equation:

$CH_3CH_2CHO(aq) + H_2O(l) \rightarrow CH_3CH_2COOH(aq) + 2H^+(aq) + 2e^-$ [1]

Overall ionic equation:

$Cr_2O_7^{2-}(aq) + 8H^+(aq) + 3CH_3CH_2CHO(aq) \rightarrow 2Cr^{3+}(aq) + 3CH_3CH_2COOH(aq) + 4H_2O(l)$ [1]

(Accept $CH_3CH_2CHO + [O] \rightarrow CH_3CH_2COOH$ for [1])

7 **a)** Mass of C in 0.36 g of the compound = $0.88 \times \frac{12.0}{44.0}$ g = 0.24 g [1]

Mass of H in 0.36 g of the compound = $0.36 \times \frac{2.0}{18.0}$ g = 0.04 g [1]

Mass of O in 0.36 g of the compound = (0.36 – 0.28) g = 0.08 g

Ratio of moles of C : H : O $= \frac{0.24}{12.0} : \frac{0.04}{1.0} : \frac{0.08}{16.0}$ [1]

$= 4 : 8 : 1$

Empirical formula of X = C_4H_8O [1]

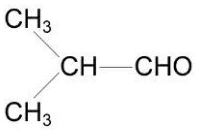
Relative molecular mass of X ≈ 70

Relative molecular mass of empirical formula = 72

∴ Molecular formula of X = C_4H_8O [1]

b) X contains a carbonyl group. [1]

c) $CH_3CH_2CH_2CHO$ butanal [1]



2 methylpropanal [1]

$CH_3CH_2COCH_3$ butanone [1]

d) Butanal and butanone have four different types of carbon so either could be X. [1]

Take the melting temperature of X [1] and compare with values on the data sheet of melting temperatures of 2,4-dinitrophenylhydrazine derivatives of carbonyl compounds. [1]

8 **a)** Warm (reflux) with aqueous NaOH. [1] Acidify with HNO_3(aq) and then add $AgNO_3$(aq). [1]

Cl → white precipitate [1], I → yellow precipitate. [1]

b) Iodine and aqueous sodium hydroxide. [1] Pentan-2-one will give a pale yellow precipitate of CHI_3. [1] There will be no precipitate with pentan-3-one. [1]

c) Add 2,4-dinitrophenylhydrazine at room temperature. [1]

Ketone → phenylhydrazone, yellow solid [1]

Ester → no reaction [1]

d) Acidified potassium dichromate(VI). [1]

Phenol – no reaction. [1]

Primary alcohol – solution turns from orange to green. [1]

e) Dip a glass rod into concentrated hydrochloric acid and hold over open bottles of the compounds. [1]

Amide – no effect. [1]

Amine – clouds of white smoke formed as $CH_3CH_2CH_2CH_2NH_3^+Cl^-$(s) forms. [1]

9 **a)** Mass of carbon = $7.92 \times \dfrac{12.0}{44.0} = 2.16$ g [1]

Mass of oxygen = $1.44 \times \dfrac{2.0}{18.0} = 0.16$ g [1]

Mass of oxygen in Y = (2.64 – 2.16 – 0.16) g = 0.32 g [1]

∴ In Y, ratio of masses C : H : O = 2.16 : 0.16 : 0.32

$$\begin{aligned}\text{Ratio of moles C : H : O} &= \frac{2.16}{12.0} : \frac{0.16}{1.0} : \frac{0.32}{16.0} \quad [1]\\ &= 0.18 : 0.16 : 0.02\\ &= 9 : 8 : 1\end{aligned}$$

Empirical formula of Y = C_9H_8O [1]

Relative molecular mass of Y = 132

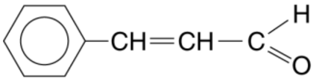
Relative molecular mass of C_9H_8O = 132

∴ Molecular formula of Y = C_9H_8O [1]

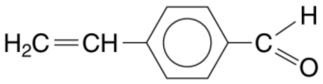
b)

Observations	**Inferences**
Burns with a smoky flame	Y is probably aromatic and contains a benzene ring [1]
The yellow/orange colour of bromine water is decolourised	Y is probably an alkene [1]
A yellow/orange precipitate is produced	Y probably contains a carbonyl group [1]
A silver mirror or dirty grey solid appears	Y is probably an aldehyde [1]

c) Possible structures for Y would be



or



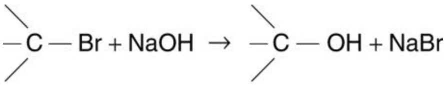
or 1,2 or 1,3 isomers [1]

10 a) Assess the quality of the answers taking into account both the key points made (*up to 4 marks*) and the logic and coherence of the discussion (*up to 2 marks*).

Key points to make in an answer:

- Weigh a sample of D.
- Heat (reflux) with NaOH(aq).
- Cool and add HNO_3 to neutralise excess NaOH.
- Add an excess of $AgNO_3$(aq).
- Filter the cream precipitate of AgBr.
- Wash, dry and weigh.

b) Reaction with NaOH(aq) converts the halogenoalkane to an alcohol + sodium bromide. [1]



[1]

HNO_3 neutralises excess NaOH and the $AgNO_3$ precipitates Br^-(aq) ions in the aqueous solution as cream-coloured AgBr(s). [1]

$$\text{Mass of Br in D} = \text{mass of AgBr} \times \frac{A_r[\text{Br}]}{A_r[\text{AgBr}]}$$ [1]

$$\%\text{ of Br in D} = \frac{\text{mass of Br in D}}{\text{mass of D}} \times 100\%$$ [1]

11 a) *Step 1* $CH_3CH_2CH_2Br$ with KCN in ethanol [1] forms $CH_3CH_2CH_2CN$. [1]

Step 2 $CH_3CH_2CH_2CN$ with Ni/H_2 [1] forms $CH_3CH_2CH_2CH_2NH_2$. [1]

Step 3 $CH_3CH_2CH_2CH_2NH_2$ with CH_3COCl [1] forms $CH_3CONHCH_2CH_2CH_2CH_3$. [1]

b) *Step 1* C_2H_4 with HBr [1] forms CH_3CH_2Br. [1]

Step 2 CH_3CH_2Br with NaOH(aq) [1] forms CH_3CH_2OH. [1]

Step 3 CH_3CH_2OH with acidified $K_2Cr_2O_7$ [1] and distil off the product CH_3CHO immediately it forms. [1]

Step 4 CH_3CH_2Br with Mg in ethoxyethane [1] forms CH_3CH_2MgBr. [1]

Step 5 CH_3CH_2MgBr with CH_3CHO [1] then hydrolysis [1] forms $CH_3CH_2CH(OH)CH_3$. [1]

Step 6 $CH_3CH_2CH(OH)CH_3$ with conc. H_2SO_4 [1] forms $CH_3CH{=}CHCH_3$. [1]

12 a) Ratio of masses C : H : Al = 50 : 12.5 : 37.5

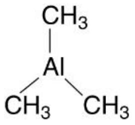
Ratio of moles C : H : Al $= \dfrac{50}{12.0} : \dfrac{12.5}{1.0} : \dfrac{37.5}{27.0}$ [1]

= 4.17 : 12.5 : 1.39

= 3 : 9 : 1

Empirical formula of A = C_3H_9Al [1]

b)



[1]

c) 0.24 dm^3 of B has a mass of 0.16 g

$\therefore$ 24 dm^3 of B has a mass of 16 g

$\therefore$ Molecular mass of B = 16 g mol^{-1} [1]

d) B is methane, CH_4. [1] C is aluminium hydroxide, $Al(OH)_3$. [1]

e) i) $3CH_3Cl(g) + Al/3Na(s) \rightarrow Al(CH_3)_3(l) + 3NaCl(s)$ [1]

ii) 0.24 g of A produce 0.24 dm^3 of B (CH_4)

$\therefore$ 24 g of A produce 24 dm^3 of B (CH_4), i.e. 1 mole of CH_4 [1]

1 mole of C_3H_9Al (72.0 g) produces 3 moles of CH_4. [1]

$Al(CH_3)_3(l) + 3H_2O(l) \rightarrow Al(OH)_3(s) + 3CH_4(g)$ [1]

iii) $Al(OH)_3(s) + 3HCl(aq) \rightarrow AlCl_3(aq) + 3H_2O(l)$ [1]

iv) $Al(OH)_3(s) + NaOH(aq) \rightarrow NaAl(OH)_4(aq)$

or

$Al(OH)_3(s) + OH^-(aq) \rightarrow Al(OH)_4^-(aq)$ [1]