1. From the evidence, candidates may have identified compound **F** as propanone, propanal or propanoic acid

If **F** is propanone or propanoic acid, then maximum score = 7; **but** if **F** is propanal then maximum score = 6

The mark scheme for **F** = propanone and propanal is shown below.

mass spec of E– Remember to check the spectrum
Quality of Written Communication – mass spec gives M^+ or molecular ion of 60 **OR** mass spec gives parent ion of 60 **OR** highest *m*/*z* (**ALLOW** *m*/*e*) value is 60 ✓

m/*z* = 45 indicates loss of CH_3
OR *m*/*z* = 45 indicates presence of CH_3CHOH
OR CH_2CH_2OH **OR** C_2H_5O ✓

IR of F – Remember to check the spectrum
IR shows no broad absorption between 2500 to 3300 cm^{-1} so no O—H bond
OR no broad absorption between 2500 to 3300 cm^{-1} so not a carboxylic acid ✓

IR shows absorption at 1700 cm^{-1} due to a C=O bond
OR absorption at 1700 cm^{-1} indicates a ketone **OR** aldehyde present

Identification and equation
F is CH_3COCH_3 **OR** propanone ✓

E is $CH_3CHOHCH_3$ **OR** propan-2-ol ✓

$CH_3CHOHCH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$ ✓

If **F** has been incorrectly identified as propanal, mark identification and equation as ECF, so max = 2
ALLOW E is $CH_3CH_2CH_2OH$ ✓

ALLOW: $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓

The mark scheme for **F** = propanoic acid is shown below.

mass spec of E– Remember to check the spectrum
QWC – mass spec gives M^+ or molecular ion of 60
OR mass spec gives parent ion of 60
OR highest *m*/*z* (**OR** *m*/*e*) value is 60 ✓

m/*z* = 45 indicates loss of CH_3
OR *m*/*z* = 45 indicates presence of CH_3CHOH
OR CH_2CH_2OH **OR** C_2H_5O ✓

IR of F– Remember to check the spectrum

IR shows (broad) absorption somewhere between 3500 and 2500 cm^{-1} suggests carboxylic acid **OR** O–H bond ✓

IR shows absorption at 1700 cm^{-1} due to C=O
OR absorption at 1700 cm^{-1} indicates a carboxylic acid ✓

Identification and equation

F is CH_3CH_2COOH **OR** propanoic acid ✓

E is $CH_3CH_2CH_2OH$ **OR** propan-1-ol ✓

$CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓

Extra guidance for marking of question

If **E** has **not** been identified **OR** if **F** has been identified as a **keton**e **or aldehyde**, use the **first** mark scheme

If **F** has been identified as a **carboxylic acid**, use the **second** mark scheme

Mass spec

These two marking points stand as **independent** marks whichever compounds have been identified.

The positive sign for fragment ions is not required. **IGNORE** negative charge.
The mass spec may well be on the actual spectrum.

IR mark

These stand as **independent** marks whichever compounds have been identified.
The IR analysis may well be on the actual spectrum.

Identification marks

If both structure and name are given they must **both** be correct but allow 'propanol' drawn with the correct structure because the position number of the –OH has been clearly identified

ALLOW ECF for identification of **F** e.g. if **E** is pentan-2-ol ✗ then an answer of pentan-2-one for **F** will be given a mark ✓ as ECF

ALLOW identification marks for **E** and **F** from equation

Equation mark

ALLOW ECF for any correct equation showing the oxidation of **any** alcohol to the appropriate product.
ALLOW molecular formulae in equations,

i.e. $C_3H_7OH + [O] \longrightarrow C_2H_5CHO + H_2O$ ✓ ; $C_3H_8O + [O] \longrightarrow C_3H_6O + H_2O$ ✓ ;

$C_3H_7OH + [O] \longrightarrow C_2H_5COH + H_2O$ ✓

[7]

2. (a) **method 1:**
fermentation of sugars or carbohydrates **OR** reaction with yeast with sugar or carbohydrates ✓
$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓

method 2:
hydration of ethene **OR** reaction of ethene with water **OR** reaction of steam with ethene ✓

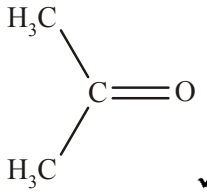
$C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓

ALLOW *sugar from equation*
ALLOW *C_2H_6O in equation*
ALLOW *correct multiples*
IGNORE *state symbols*

ALLOW *ethene from the equation*
IGNORE *mention of any catalyst*
ALLOW *C_2H_6O in equation* ***OR*** *H_2O over the arrow*
ALLOW *correct multiples*
IGNORE *state symbols*

4

(b) (i) $(CH_3)_2CO$ **OR**



✓

$(CH_3)_2CHOH + [O] \rightarrow (CH_3)_2CO + H_2O$ ✓

If name and formula given both need to be correct
ALLOW *propanone* ***OR*** *acetone*
IGNORE *propone*
NOT *incorrect named compound*

ALLOW *$C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$*
ALLOW *O instead of [O]*
ALLOW *correct multiples*
IGNORE *state symbols*

2

(ii) CH_3CH_2COOH **OR** propanoic acid ✓

Any number or range of numbers between 1750–1640 (cm^{-1})
for C=O ✓

Any number or range of numbers between 2500–3300 (cm^{-1})
for O–H ✓

ALLOW *C=O and O—H marks independent of compound identified* ***i.e. stand alone marks***
ALLOW *correct bonds shown by the appropriate absorption on the IR spectrum*
IGNORE *reference to C—O bond*

3

(c) (i) 2-methylpropan-2-ol ✓

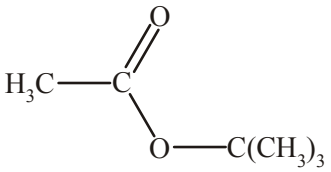
ALLOW *methylpropan-2-ol* ***OR*** *tertiarybutanol*

1

(ii) ester ✓

1

(iii) $CH_3CO_2C(CH_3)_3$ **OR** $CH_3COOC(CH_3)_3$
OR



ester group shown ✓

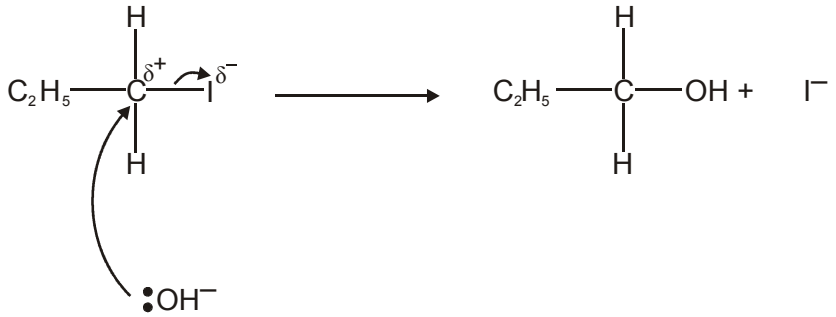
rest of molecule ✓

ALLOW *skeletal formula* ***OR*** *displayed formula*
ALLOW *ester linkage even if rest of structure is wrong*

2

[13]

3. (a) (i)



C–I curly arrow from the bond not from carbon atom ✓

curly arrow from the OH^- ✓

correct partial charges on C—I ✓

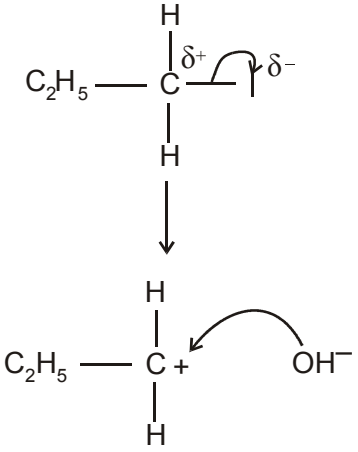
no need to show any lone pairs on oxygen but must have a clear negative sign rather than partial negative charge
IGNORE *lone pairs*
IGNORE *products of this reaction*

ALLOW *curly arrow from a negative charge or from any part of hydroxide ion*

If SN1 mechanism is given then use the mark scheme below
correct partial charges on C—I ✓

C–I curly arrow from the bond not from carbon atom ✓

curly arrow from the OH^- to the ***correct*** *carbocation* ✓



3

(ii) nucleophilic substitution ✓

1

(b) C–I bonds broken more easily ✓
C–I bonds are weaker **OR** have less bond enthalpy **OR** C–I bonds are longer ✓

ALLOW *ora e.g. C—Br bonds are stronger* ***OR*** *broken less easily*

2

[6]

4. from IR absorption, **J** contains O–H **OR** from IR **J** is an alcohol✓

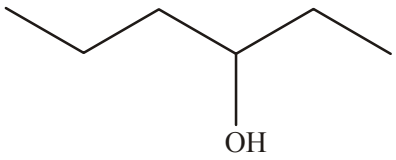
$C : H : O = \frac{70.59}{12.0} : \frac{13.72}{1.0} : \frac{15.69}{16.0}$

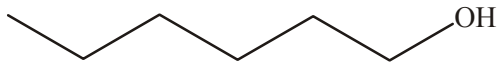
OR 5.8825 : 13.72 : 0.9806 ✓

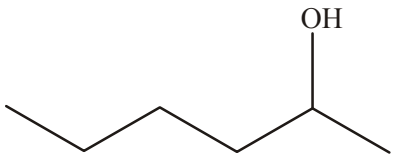
empirical formula = $C_6H_{14}O$ ✓

(from mass spectrum), $M_r = 102$ ✓

evidence that it has been shown that the empirical formula is the molecular formulae e.g. *M*r of $C_6H_{14}O = 102$ so empirical formula is molecular formula ✓







One mark for each correct structure ✓ ✓ ✓

This is a QWC mark

***ALLOW two** marks for correct empirical formula with no working out*

This is a QWC mark

***ALLOW** structural or displayed formulae*
***IGNORE** incorrect names*

***ALLOW** one minor slip in drawing structures e.g. one missing hydrogen but **ALLOW** ecf for bigger slips such as showing just sticks and no hydrogen atoms*
***ALLOW** bond to H in OH*

***ALLOW one** mark for three isomers of $C_6H_{13}OH$ whether branched or unbranched as a catch mark if no other mark has been awarded for the structures*

If more than three isomers of $C_6H_{13}OH$ drawn

- *1 branched and 3 unbranched award **two** marks*
- *any other combination award **one** mark*

***ALLOW** one mark for hexan-1-ol, hexan-2-ol and hexan-3-ol if structures not drawn*

[8]

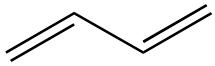
5. (i) Any two realistic fragments,
e.g. CH_3^+: 15; $C_2H_5^+$: 29; $C_3H_7^+$: 43; $C_4H_9^+$: 57; OH^+: 17, *etc*. **(1) (1)**
Do not penalise missing charge. 2

(ii) breathalysers/monitoring of air pollution, MOT emission testing, *etc*. **(1)** 1

[3]

6. mole ratio = 88.89/12 : 11.1/1 = 7.41 : 11.1 **(1)**
empirical formula = C_2H_3 **(1)**
relative mass of C_2H_3 = 27.
$M_r = 2 \times 29$ so molecular formula = C4H6 **(1)**
X reacts with 2 mol H_2 so there are 2 double bonds **(1)**

Possible structure = 1,3-butadiene /



(1)

[5]

7. (a) (i) H^+ 1
$Cr_2O_7^{2-}$ 1

(ii) Orange to green/black/blue 1

(b) (i) contains a C=O/aldehyde, ketone, carboxylic acid and ester/ 1

carbonyl/carbonyl in an aldehyde

(ii) does **not** contain a O–H/ (hydrogen bonded in a) carboxylic acid 1

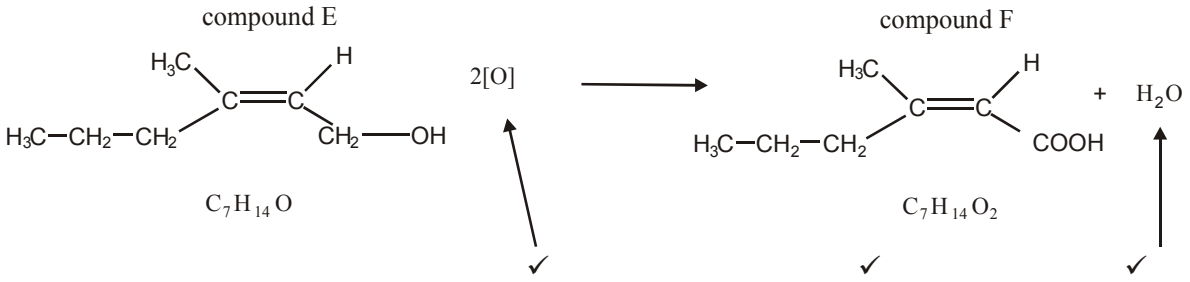
(iii) distillation (no mark) **because** distillation allows loss of volatile components /removes butanal from oxidising mixture 1

prevents formation of RCOOH/ partial oxidation would be achieved or reverse argument for reflux not being used in that reflux prevents loss of volatile components hence complete oxidation would be achieved/RCOOH would be formed ✓ 1

[7]

8. (i) H^+ ✓ $Cr_2O_7^{2-}$ 2

(ii)



3

(iii) carboxylic acid would have an absorption between 1680 – 1750 cm^{-1} /1700 cm^{-1} or 2500 – 3300 cm^{-1}. 1

[6]

9. (a) (i) (volatile components) can escape/distil out 1

ethanal is most volatile/b pt less than 60°C/partial oxidation 1

(ii) (volatile components) cannot escape/ refluxed 1

complete oxidation will be achieved/oxidised to the acid 1

(b) $C_2H_5OH + 2[O] \rightarrow CH_3COOH + H_2O$

($CH_3COOH + H_2O$ ✓) 2

(c) spectrum C 1

spectrum C only shows absorption at 1700 cm^{-1} for the C=O 1

the other two spectra contain the OH group absorption at approx 3000 cm^{-1} 1

[9]

10. acrylic acid 1

approx 1700 cm^{-1} (range 1650 – 1750) indicates C=O 1

approx 3000 cm^{-1} (range 2500- 3300) indicates O-H 1

not 3230 – 3550 cm^{-1}

[3]

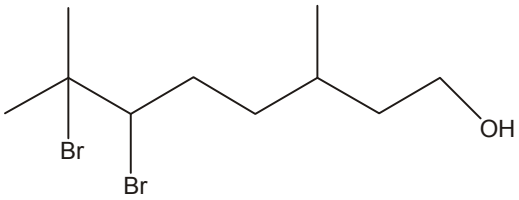
11. (a) (i) alkene ✓ 1

alcohol/hydroxy/hydroxyl ✓ 1

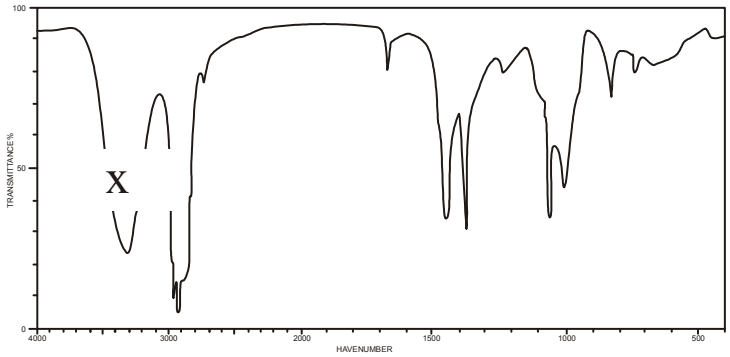
(b) (i) I = alkene & II = alcohol… both are needed ✓ 1

(ii) decolourised / colourless ✓ 1

(iii) ✓ 1



(iv) **X** as shown below ✓ 1



(c) (i) Ni/Pt/Rh/Pd ✓ 1

(ii) compound **B** is $C_{10}H_{22}O$ ✓ 1

(iii) $C_{10}H_{20}O + H_2 \rightarrow C_{10}H_{22}O$ ✓ 1

[9]

12. (a) (i) Alkene/C=C ✓ 1

Alcohol/ROH/hydroxy/hydroxyl/OH (not OH^- or hydroxide) ✓ 1

(ii) One of the C in both C=C is joined to two atoms or groups that are the same ✓ 1

(b) Observation — decolourisation (of Br_2) ✓ — 1

Molecular formula — $C_{10}H_{18}OBr_4$ ✓✓ — 2

$C_{10}H_{18}OBr_2$ gets 1 mark

(c) reagent — CH_3COOH ✓ — 1

catalyst — $H_2SO_4/H^+/HCl$ (aq) *or dilute loses the mark* ✓ — 1

(d) (i) $C_{10}H_{18}O + 2[O] \rightarrow C_{10}H_{16}O_2 + H_2O$ ✓✓ — 2

1 mark for H_2O and 1 mark for 2[O]

(ii) The infra-red spectrum was of compound **Y**

because absorption between 1680 – 1750 cm^{-1} indicates a C=O ✓ — 1

and the absence of a peak between 2500 – 3300 cm^{-1} shows the absence of the OH hydrogen bonded in a carboxylic acid ✓ — 1

[12]