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$_3$CHOH

OR CH$_2$CH$_2$OH OR C$_2$H$_5$O ✓

**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$_3$COCH$_3$ OR propanone ✓

E is CH$_3$CHOHCH$_3$ OR propan-2-ol ✓

CH$_3$CHOHCH$_3$ + [O] → CH$_3$COCH$_3$ + H$_2$O ✓

If F has been incorrectly identified as propanal, mark identification and equation as ECF, so max = 2

ALLOW E is CH$_3$CH$_2$CH$_2$OH ✓

ALLOW: CH$_3$CH$_2$CH$_2$OH + [O] → CH$_3$CH$_2$CHO + H$_2$O ✓

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$_3$CHOH

OR CH$_2$CH$_2$OH OR C$_2$H$_5$O ✓
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$_3$CH$_2$COOH OR propanoic acid ✓
E is CH$_3$CH$_2$CH$_2$OH OR propan-1-ol ✓
CH$_3$CH$_2$CH$_2$OH + 2[O] $\rightarrow$ CH$_3$CH$_2$COOH + H$_2$O ✓

Extra guidance for marking of question
If E has not been identified OR if F has been identified as a ketone 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. \( \text{C}_3\text{H}_7\text{OH} + [\text{O}] \rightarrow \text{C}_2\text{H}_5\text{CHO} + \text{H}_2\text{O} \) ✓ ; \( \text{C}_3\text{H}_8\text{O} + [\text{O}] \rightarrow \text{C}_3\text{H}_6\text{O} + \text{H}_2\text{O} \) ✓ ;

\( \text{C}_3\text{H}_7\text{OH} + [\text{O}] \rightarrow \text{C}_2\text{H}_5\text{COH} + \text{H}_2\text{O} \) ✓  

2. (a) **method 1:**

fermentation of sugars or carbohydrates **OR** reaction with yeast with sugar or carbohydrates ✓

\( \text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 \) ✓

**method 2:**

hydration of ethene **OR** reaction of ethene with water **OR**

reaction of steam with ethene ✓

\( \text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH} \) ✓

**ALLOW** sugar from equation

**ALLOW** \( \text{C}_2\text{H}_5\text{O} \) in equation

**ALLOW** correct multiples

**IGNORE** state symbols

**ALLOW** ethene from the equation

**IGNORE** mention of any catalyst

**ALLOW** \( \text{C}_2\text{H}_6\text{O} \) in equation **OR** \( \text{H}_2\text{O} \) over the arrow

**ALLOW** correct multiples

**IGNORE** state symbols

(b) (i) \( \text{(CH}_3\text{)_2CO} \) **OR**

\[\begin{array}{c}
\text{H}_2\text{C} \\
\text{C} = \text{O} \\
\text{H}_2\text{C}
\end{array}\] ✓

\( \text{(CH}_3\text{)_2CHOH} + [\text{O}] \rightarrow \text{(CH}_3\text{)_2CO} + \text{H}_2\text{O} \) ✓

If name and formula given both need to be correct

**ALLOW** propanone **OR** acetone

**IGNORE** propone

**NOT** incorrect named compound

**ALLOW** \( \text{C}_3\text{H}_6\text{O} + [\text{O}] \rightarrow \text{C}_3\text{H}_6\text{O} + \text{H}_2\text{O} \)

**ALLOW** \( \text{O} \) instead of \([\text{O}]\)

**ALLOW** correct multiples

**IGNORE** state symbols
(ii) **CH\textsubscript{3}CH\textsubscript{2}COOH 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*

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(c) (i) 2-methylpropan-2-ol ✓

*ALLOW methylpropan-2-ol OR tertiarybutanol*

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(ii) ester ✓

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(iii) CH\textsubscript{3}CO\textsubscript{2}C(CH\textsubscript{3})\textsubscript{3} OR CH\textsubscript{3}COOC(CH\textsubscript{3})\textsubscript{3}

[Diagram of ester structure]

ester group shown ✓
rest of molecule ✓

*ALLOW skeletal formula OR displayed formula*

*ALLOW ester linkage even if rest of structure is wrong*
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 S_N_1 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 ✔

(ii) Nucleophilic substitution ✔
(b) C—I bonds broken more easily ✓
C—I bonds are weaker OR have less bond enthalpy OR C—I bonds are longer ✓
ALLOW or e.g. C—Br bonds are stronger OR broken less easily

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 = C₆H₁₄O ✓
(from mass spectrum), Mᵣ = 102 ✓
evidence that it has been shown that the empirical formula is the molecular formulae e.g. Mᵣ of C₆H₁₄O = 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 C₆H₁₃OH whether branched or unbranched as a catch mark if no other mark has been awarded for the structures

If more than three isomers of C₆H₁₃OH 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

5. (i) Any two realistic fragments,
   e.g. CH₃⁺: 15; C₂H₅⁺: 29; C₃H₇⁺: 43; C₄H₉⁺: 57; OH⁺: 17, etc. (1) (1)
   Do not penalise missing charge. 2
   (ii) breathalysers/monitoring of air pollution, MOT emission testing, etc. (1) 1

6. mole ratio = 88.89/12 : 11.1/1 = 7.41 : 11.1 (1)
   empirical formula = C₂H₃ (1)
   relative mass of C₂H₃ = 27.
   \( M_r = 2 \times 29 \) so molecular formula = C₄H₆ (1)
   X reacts with 2 mol H₂ so there are 2 double bonds (1)
   Possible structure = 1,3-butadiene /
   \[
   \begin{array}{c}
   \hline
   \text{(1)}
   \end{array}
   \]
   \[ \text{[5]} \]

7. (a) (i) \( H^+ \) 1
   \( \text{Cr}_2\text{O}_7^{2-} \) 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

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

8. (i) $\text{H}^+ \checkmark \text{Cr}_2\text{O}_7^{2-}$

(ii) [Diagram of chemical reactions showing compounds E and F, reaction with 2O, and products H$_2$O and COOH]

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

9. (a) (i) (volatile components) can escape/distil out ethanal is most volatile/b pt less than 60°C/partial oxidation

(ii) (volatile components) cannot escape/ refluxed complete oxidation will be achieved/oxidised to the acid

(b) $\text{C}_2\text{H}_5\text{OH} + 2[\text{O}] \rightarrow \text{CH}_3\text{COOH} + \text{H}_2\text{O}$

(CH$_3$COOH + H$_2$O $\checkmark$)

(c) spectrum C spectrum C only shows absorption at 1700 cm$^{-1}$ for the C=O the other two spectra contain the OH group absorption at approx 3000 cm$^{-1}$

10. acrylic acid approx 1700 cm$^{-1}$ (range 1650 – 1750) indicates C=O
approx 3000 cm\(^{-1}\) (range 2500-3300) indicates O-H

**not** 3230 – 3550 cm\(^{-1}\)

11. (a) (i) alkene ✓
    alcohol/hydroxy/hydroxyl ✓

(b) (i) I = alkene & II = alcohol... both are needed ✓
    (ii) decolourised / colourless ✓
    (iii) ✓

    ![Compound Image]

    (iv) X as shown below ✓

12. (a) (i) Alkene/C=C ✓
    Alcohol/ROH/hydroxy/hydroxyl/OH (not OH\(^-\) or hydroxide) ✓
    (ii) One of the C in both C=C is joined to two atoms or groups that are the same ✓
(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\(_3\)COOH  ✓  1
                          catalyst  H\(_2\)SO\(_4\)/H\(^+\)/HCl (aq) or dilute loses the mark ✓  1

(d) (i) C\(_{10}\)H\(_{18}\)O + 2[O] → C\(_{10}\)H\(_{16}\)O\(_2\) + H\(_2\)O ✓✓  2
                          1 mark for H\(_2\)O 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]