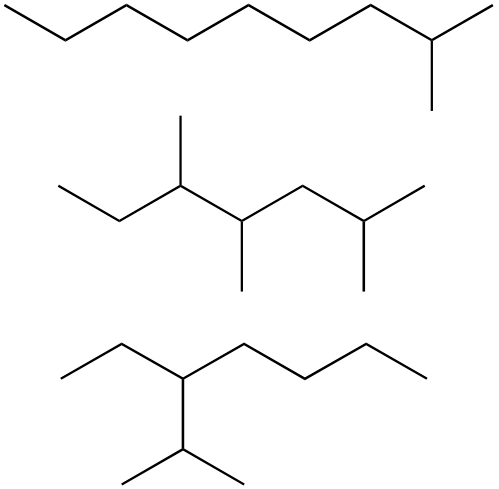
# F322 Chains, Energy and Resources

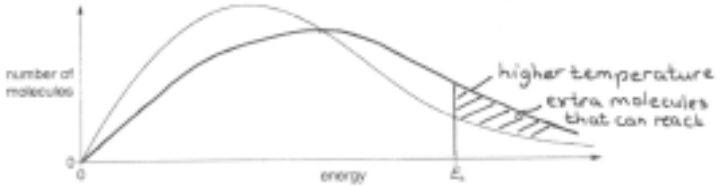
| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| 1 | (a) | | Fractional distillation ✓<br><br>Because fractions have different boiling points ✓ | 2 | **DO NOT ALLOW** just 'distillation'<br><br>For fractions, **ALLOW** components **OR** hydrocarbons **OR** compounds<br>**ALLOW** condense at different temperatures<br>**ALLOW** because van der Waals' forces differ between molecules<br>**IGNORE** reference to melting points<br>**IGNORE '**crude oil' **OR** 'mixture' has different boiling points'<br>…… **but ALLOW** 'separates crude oil by boiling points |
| | (b) | (i) | Decane ✓ | 1 | **DO NOT ALLOW** deceane |
| | | (ii) | Skeletal formula of branched $C_{10}H_{22}$ ✓ | 1 | Formula **must** be skeletal<br>**AND** must not include any symbol, e.g. $CH_3$<br><br>Any possible skeletal formulae e.g. |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| | | | | |  |
| | | (iii) | Decane has more surface contact **OR** branched chains have less surface contact ✓<br><br>Decane has more van der Waals' forces **OR** branched chains have fewer van der Waals' forces ✓ | 2 | **Both answers need to be comparisons**<br>Assume 'it' refers to decane<br>**IGNORE** surface area<br>**ALLOW** straight chains can get closer together **OR** branched chains cannot get as close to one another<br>**IGNORE** branched chain are more compact<br><br>**ALLOW** Decane has stronger van der Waals' forces **OR** branched chains have weaker van der Waals' forces<br><br>More intermolecular forces is **not** sufficient |
| | | (iv) | Branched chains have more efficient combustion **OR** decane has less efficient combustion ✓ | 1 | **ALLOW** branched chains are easier to burn **OR** easier to combust **OR** burn better **OR** more efficient fuel **OR** less likely to produce pre-ignition or knocking **OR** increases octane rating<br><br>**ALLOW** ORA for decane |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| | | | | | Better fuel is **NOT** sufficient<br>Burns more cleanly is **NOT** sufficient |
| | **(c)** | **(i)** | $C_{10}H_{22} + 15½O_2 \longrightarrow 10CO_2 + 11H_2O$<br><br>All **four** species correct ✓<br><br>balancing of four correct species ✓ | **2** | **ALLOW** any correct multiple<br>**IGNORE** state symbols |
| | | **(ii)** | $N_2 + O_2 \longrightarrow 2NO$ ✓ | **1** | **ALLOW** any correct multiple including fractions<br>**IGNORE** state symbols<br><br>The mark is for the equation<br>**IGNORE** writing |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| | (d) | (i) | Species with an unpaired electron ✓ | 1 | **ALLOW** atom, molecule or particle with an unpaired electron<br>**ALLOW** 'has an unpaired electron'<br>**ALLOW** particle formed by homolytic fission<br><br>**DO NOT ALLOW** particle with a single electron<br>**OR** particle with a free electron |
| | | (ii) | catalyst ✓ | 1 | |
| | | (iii) | $O + O_2 \longrightarrow O_3$<br>**OR** O reacts with $O_2$ to make ozone<br>**OR** the reaction is reversible ✓<br><br>Rate of formation of ozone is the same as rate of decomposition ✓ | 2 | **ALLOW** $O_2 + O \rightleftharpoons O_3$ **OR** $O_3 \rightleftharpoons O_2 + O$ ✓✓<br><br>**ALLOW** is in equilibrium<br>**OR** $\rightleftharpoons$ in **correct** equation<br>**OR** has steady state condition ✓<br><br>**IGNORE** other equations involving ozone |
| | | (iv) | absorbs (harmful) UV ✓ | 1 | **ALLOW** 'keeps out UV' **OR** 'filters UV'<br><br>**ALLOW** increased UV could cause skin cancer<br>**OR** increased UV could cause cataracts<br>**OR** increased UV could cause mutation of crops ✓<br><br>**IGNORE** gamma |
| | | | **Total** | 15 | |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| 2 | (a) | (i) | $2H_2O_2 \longrightarrow 2H_2O + O_2$ ✓ | 1 | **ALLOW** any correct multiple including fractions<br>**IGNORE** state symbols |
| | | (ii) | More crowded particles<br>**OR** more particles per (unit) volume ✓<br><br>more collisions per second<br>**OR** more frequent collisions ✓ | 2 | **ALLOW** particles are closer together<br>**DO NOT ALLOW** 'area' instead of 'volume'<br>**IGNORE** 'more concentrated particles'<br><br>**ALLOW** collisions more often<br>**OR** increased rate of collision<br>**OR** collisions are more likely<br>**OR** there is a greater chance of collisions<br><br>'More collisions' is **not** sufficient |
| | | (iii) | **Any two from the following:**<br><br>Reaction takes alternative route ✓<br><br>Activation energy is lowered ✓<br><br>More molecules have energy above activation energy<br>**OR** more molecules have enough energy to react ✓ | 2 | <br><br>**ALLOW** catalyst changes reaction mechanism<br><br><br>**ALLOW** an alternative approach using adsorption<br><br>particles **adsorbed** onto surface ✓<br><br>so bonds weakened as a result of the adsorption ✓ |

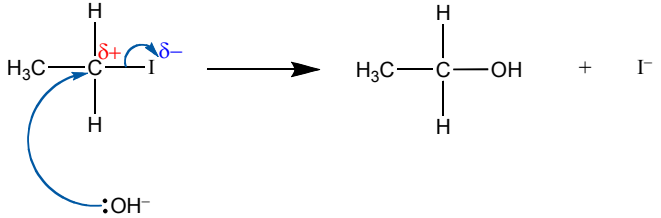
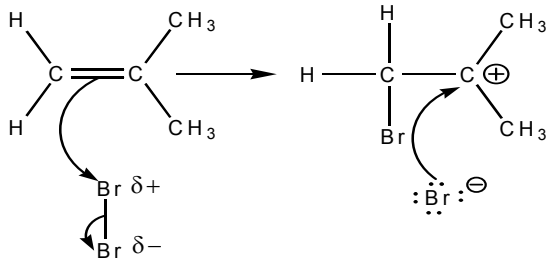
| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| | | (iv) | Correct curve for higher temperature ✓<br><br>Activation energy does not change<br>**OR** clearly labelled on diagram, e.g. $E_a$ **OR** $E$ ✓<br><br>More molecules have energy above activation energy<br>**OR** more molecules have enough energy to react ✓ | **3** | maximum of curve to right<br>**AND** lower than maximum of original curve<br>**AND** above dotted line at higher energy as shown in diagram below<br><br>**IGNORE** minor point of inflexion of curve<br><br><br><br><br>Note that the diagram above would score all 3 marks<br><br>More successful collisions is **not** sufficient |
| | (b) | (i) | $\frac{34.0}{}$ × 100<br>**267.4** ✓<br><br>12.7% ✓ | **2** | First mark for 267.4 **OR** (34.0 + 233.4) **OR** (169.3 + 98.1) at **bottom** of fraction with or without × 100<br><br>**ALLOW** from 2 sig figs up to calculator value<br>**ALLOW** full marks for 13 **OR** 12.7 **OR** 12.72 **OR** 12.715 up to calculator value with no working out<br>12.71 scores one mark only<br>**NO ECF** for this part from incorrect numbers in first expression |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| | | (ii) | **Any three from the following**:<br><br>Oxygen comes from air ✓<br><br>No poisonous materials formed<br>**OR** no poisonous materials involved ✓<br><br>No waste products formed **OR** atom economy is 100% ✓<br><br>Anthraquinone is regenerated **OR** recycled **OR** used again<br>**OR** Anthraquinone acts as a catalyst ✓ | 3 | <br><br>**IGNORE** hydrogen comes from the air<br><br>**IGNORE** harmful<br><br>**ALLOW** higher atom economy |
| | (c) | | Bond breaking absorbs energy<br>**AND** bond making releases energy ✓<br><br>More energy released than absorbed ✓ | 2 | **ALLOW** bond breaking is endothermic<br>**AND** bond making is exothermic<br><br>**ALLOW** exothermic change transfers more energy than endothermic change<br>**OR** bond making transfers more energy than bond breaking<br>**OR** '(the sum of the) bond enthalpies in the products is greater than the (sum of the) bond enthalpies in the reactants'<br>**OR** '(the sum of the) bond enthalpies of the bonds made is greater than (the sum of) the bond enthalpies of the bonds broken'<br><br>**IGNORE** reference to strong and weak bonds<br><br>**IGNORE** enthalpy of products is less than enthalpy of reactants |
| | | | **Total** | 15 | |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| 3 | (a) | | Respiration ✓ | 1 | **IGNORE** anaerobic |
| | (b) | (i) | 100 × 4.18 × 17.3 ✓<br><br>7.23 (kJ) ✓ | 2 | **ALLOW** 7231 J ✓<br><br>**ALLOW** 7.23 with no working out<br>**ALLOW** from 7.2 up to calculator value of 7.2314<br><br>**ALLOW** from 0.060 up to calculator value for 1 mark<br>(i.e. ECF from use of $m$ = 0.831 in first stage)<br><br>**IGNORE** sign |
| | | (ii) | $M_r$ = 180 ✓<br><br>amount = 4.62 × $10^{-3}$ (mol) ✓ | 2 | <br><br>**ALLOW** 4.6 × $10^{-3}$ **OR** 4.62 × $10^{-3}$<br>**OR** 4.617 × $10^{-3}$ up to calculator value<br>**DO NOT ALLOW** 0.005<br>**ALLOW** ECF from wrong $M_r$ |
| | | (iii) | $\Delta H_c$ = 1560 (kJ) **OR** 1570 (kJ)<br>but answer must be to 3 sig fig ✓<br><br>minus sign ✓ | 2 | **ALLOW** ECF from 'answer to **(i)** ÷ answer to **(ii)**'<br>but answer must be to 3 sig fig<br><br>minus mark is an independent mark |

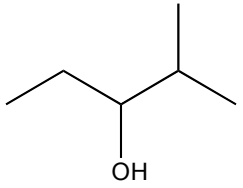
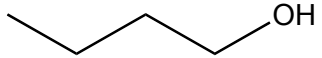
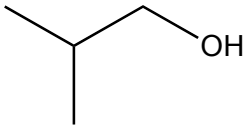
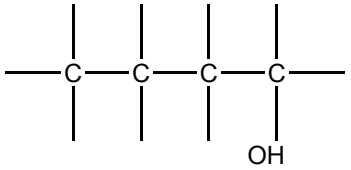
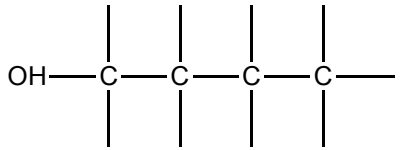
| Question | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|
| (c) | +1250 ✓<br><br>+(−394 × 6) + (−286 × 6) **OR** –4080 ✓<br><br>−2830 ✓ | 3 | **ALLOW** full marks for −2830 with no working out ✓✓✓<br><br>**ALLOW for 2 marks:**<br>+2830 cycle wrong way around<br><br>**OR** 1400 **OR** 860 one value not × 6<br><br>**OR** –5330 **OR** +5330 wrong sign for 1250 or 4080<br><br>**OR** +570 ✓✓ correct cycle but not × 6<br><br>**ALLOW for 1 mark:**<br>–1400 **OR** –860 cycle wrong way around and one value not × 6<br><br>**OR** –570 cycle wrong way around and not × 6<br><br>**OR** –1930 **OR** +1930 ✓ wrong sign and not × 6<br><br>**Note:** There may be other possibilities. |
| (d) | **Any two from the following:**<br><br>Heat released to the surroundings ✓<br><br>Incomplete combustion **OR** incomplete reaction **OR** not everything burns ✓<br><br>Non-standard conditions ✓ | 2 | <br><br>**ALLOW** heat loss<br><br>**IGNORE** reference to evaporation |
| | **Total** | 12 | |

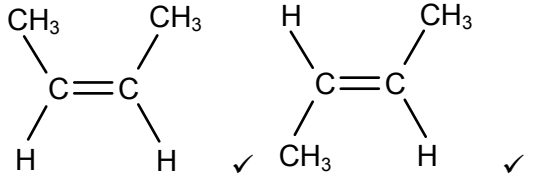
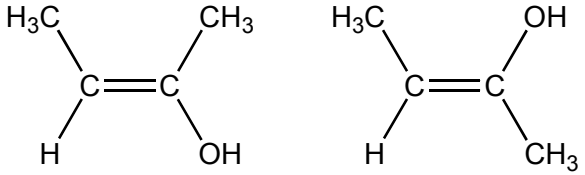
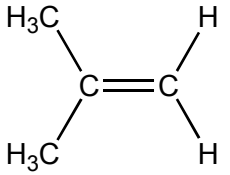
| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| 4 | (a) | (i) | $CH_4 + Br_2 \longrightarrow CH_3Br + HBr$ ✓ | 1 | **ALLOW** any correct multiple<br>**IGNORE** state symbols |
| | | (ii) | Dibromomethane<br>**OR** tribromomethane<br>**OR** tetrabromomethane ✓ | 1 | **ALLOW** 1,1-dibromomethane<br>**OR** 1,1,1-tribromomethane etc<br><br>**ALLOW** 1-dibromomethane<br><br>**DO NOT ALLOW** 2,2-dibromomethane etc<br><br>**ALLOW** correct formulae e.g. $CH_2Br_2$ |
| | | (iii) | $Br_2 \longrightarrow 2Br$<br>**OR** homolytic fission of bromine ✓<br><br>$Br + CH_4 \longrightarrow HBr + CH_3$ ✓<br>$CH_3 + Br_2 \longrightarrow CH_3Br + Br$ ✓<br><br>$Br + CH_3 \longrightarrow CH_3Br$<br>**OR** $Br + Br \longrightarrow Br_2$ ✓<br><br>Ethane made when two methyl radicals react<br>**OR** $CH_3 + CH_3 \longrightarrow C_2H_6$ ✓<br><br>**Quality of Written Communication** – Consists of initiation step linked to correct equation<br>propagation step linked to one equation in which there is a radical on the left and a radical on the right<br>termination step linked to correct equation:<br><br>2 names of steps linked to correct equations ✓<br>**BUT**<br>3 names of steps linked to correct equations ✓✓ | 7 | **All equations can be described in words**<br><br>Radicals do **NOT** need a single dot<br><br>**IGNORE** any state symbols<br><br>**ALLOW** any other suitable termination<br><br>If no equations are given to link the names of the step then award one mark for mention of all three steps |

| Question | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|
| (b) | **EITHER**<br>Nucleophilic substitution ✓<br>Example of nucleophilic substitution ✓<br>Heterolytic fission ✓<br>C–I curly arrow ✓<br>Correct dipole on C— I bond ✓<br>$OH^-$ curly arrow from one lone pair on O of $OH^-$ ion<br>**OR** from minus sign on $OH^-$ ion ✓ | 6 | The example mark can be awarded as an example of the name of the mechanism given or if the name is wrong can be given as an example of a reasonably correct drawn mechanism<br><br>*If **curly half arrows** drawn do not give a mark the first time used and then apply ECF*<br><br><br>**ALLOW** mechanisms for other halogenoalkaes<br><br><br>**ALLOW** mechanisms for other halogens and hydrogen halides |
| | **OR**<br>Electrophilic addition ✓<br>Example of electrophilic addition ✓<br>Heterolytic fission ✓<br>Curly arrow from C=C bond to Br—Br bond and Dipole and curly arrow associated with $Br_2$ ✓<br>Correct carbocation ion ✓<br>Curly arrow from one lone pair on $Br^-$ ion<br>**OR** from minus sign on $Br^-$ ion ✓ | | |
| | **ALLOW**<br>Electrophilic substitution ✓<br>Example of electrophilic substitution ✓<br>Heterolytic fission ✓<br>Curly arrow from benzene ring to the electrophile (i.e. $NO_2^+$ OR $Br^+$) ✓<br>Correct intermediate ✓<br>Curly arrow to show loss of hydrogen ion ✓ | | **ALLOW**<br>Nucleophilic addition ✓<br>Example of nucleophilic addition ✓<br>Heterolytic fission ✓<br>Correct dipole on carbonyl group ✓<br>Curly arrow from lone pair on $H^-$ ion<br>**OR** from minus sign on $H^-$ to C=O carbon and breaking of C=O bond ✓<br>Curly arrow from carbonyl oxygen to either $H^+$ or $H_2O$ ✓ |
| | **Total** | **15** | |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| 5 | (a) | | Cracking ✓ | 1 | **ALLOW** catalytic or thermal cracking ✓ |
| | (b) | (i) | Acid ✓ | 1 | **ALLOW** correct formula if no name given:<br>e.g. $H_3PO_4$ **OR** $H_2SO_4$ **OR** $H^+$ ✓<br><br>**ALLOW** correct name of acid even if an incorrect formula is used<br><br>**IGNORE** heterogeneous **OR** homogeneous |
| | | (ii) | The position of equilibrium will shift so as to minimise the effect of any change in conditions ✓ | 1 | **DO NOT ALLOW** 'reaction shifts'<br>The idea of a shift in equilibrium is essential |
| | | (iii) | Low temperature **AND** high pressure ✓<br><br>Low temperature because the (forward) reaction is exothermic ✓<br><br>High pressure because there are fewer moles (of gas) on the right hand side ✓ | 3 | One mark for conditions.<br>This mark is independent of the reasons for conditions<br><br>One mark for reason for the chosen temperature<br><br>One mark for reason for the chosen pressure<br>**ALLOW** fewer moles of products |
| | | (iv) | (60 atmosphere pressure is a) high pressure may be too expensive **OR** may cause safety problems ✓<br><br>(300 ºC is sufficiently high) to give a fast rate of reaction ✓<br><br>without shifting equilibrium to the left<br>**OR** compromising equilibrium yield ✓ | 3 | |
| | (c) | | Propene ✓ | 1 | **ALLOW** prop-1-ene ✓<br>**DO NOT ALLOW** prop-2-ene |
| | (d) | (i) | —$CH_2CHCl$— + $2\frac{1}{2}O_2 \longrightarrow 2CO_2 + H_2O + HCl$ ✓ | 1 | |
| | | (ii) | Alkali **OR** base **OR** carbonate ✓ | 1 | **ALLOW** correct formula of or named carbonate **OR** alkali **OR** base<br>Correct name and wrong formula does **not** score |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| | (e) | | **Any two marks from the following**:<br><br>Develop photodegradable polymers ✓<br><br>Develop biodegradable polymers<br>**OR** develop compostable polymers ✓<br><br>Develop techniques for cracking polymers<br>**OR** develop use as a chemical feedstock ✓<br><br>Develop ways of making polymers from plant-based substances<br>**OR** reduce the need to use finite raw materials such as crude oil ✓<br><br>Designing processes with high atom economy<br>**OR** reduce waste products during manufacture ✓<br><br>Develop ways of sorting **AND** recycling polymers ✓ | **2** | |
| | | | **Total** | **14** | |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| 6 | (a) | (i) | 2-Methylpropan-2-ol ✓ | 1 | **ALLOW** methylpropan-2-ol |
| | (b) | |   ✓ | 1 | Formula **must** be skeletal **AND** not include any symbol except for OH |
| | (c) | (i) | Same **molecular** formula but different structural formulae ✓ | 1 | **ALLOW** Same molecular formula but different arrangement of atoms<br>**OR** Same molecular formula but different structures<br>**OR** Same molecular formula but different displayed formulae<br><br>**DO NOT ALLOW** Same molecular formula but different spatial arrangement of atoms |
| | | (ii) | $CH_3CH_2CH_2CH_2OH$ **OR** $(CH_3)_2CHCH_2OH$ ✓<br><br>**ALLOW**<br>  **OR**   | 1 | **ALLOW** displayed formula<br><br>**ALLOW** sticks (i.e. no H shown bonded to C)<br><br>**ALLOW**<br> <br>*sticks OK and –OH is OK*<br><br>**DO NOT ALLOW** OH shown as below<br> <br>*sticks OK but OH– is not OK*<br><br>**ALLOW** correct ethers |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| | **(d)** | | Has O–H (bonds)<br>**OR** has hydroxyl (groups) **OR** has hydroxy (groups) ✓<br><br>Forms hydrogen bonds with water (molecules) ✓ | **2** | **ALLOW** marks from a diagram of hydrogen bonding<br>**IGNORE** reference to alcohol functional group<br><br>**DO NOT ALLOW** 'forms hydrogen bonds' |
| | **(e)** | | $CH_3COOCH_2CH_2OOCCH_3$<br><br>1 mark for each ester end of molecule ✓✓ | **2** | **ALLOW** displayed formula **OR** skeletal formula<br>**ALLOW** sticks<br><br>$CH_3COOCH_2CH_2OH$ shows one of the two ester groups and scores one mark |
| | **(f)** | **(i)** |  ✓ ✓ | **2** | **DO NOT ALLOW**<br><br>i.e. no ECF |
| | | **(ii)** | *E/Z* ✓ | **1** | **ALLOW** *cis-trans*<br>**IGNORE** geometric |
| | | **(iii)** | $CH_3CH_2CH{=}CH_2$ **OR** but-1-ene ✓ | **1** | If but-1-ene given in part **(i)**,<br>**ALLOW** but-2-ene **OR** $CH_3CH{=}CHCH_3$<br>i.e. ECF from **f(i)**<br><br>**DO NOT ALLOW** methylpropene:<br> |

| Question | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|
| From the evidence, candidates may have identified compound **F** as propanone, propanal or propanoic acid<br>• The mark scheme for **F** = propanone and propanal is shown in the 'Expected Answers' column.<br>• The mark scheme for **F** = propanoic acid is shown in the 'Additional Guidance' column.<br>If **F** is propanone or propanoic acid, then maximum score = 7; **but** if **F** is propanal then maximum score = 6 | | | |
| **(g)** | **Mark scheme for F = propanone and propanal** | **7** | **Mark scheme for F = propanoic acid** |
| | **mass spec of E– Remember to check the spectrum**<br>**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 ✓<br><br>*m*/*z* = 45 indicates loss of $CH_3$<br>**OR** *m*/*z* = 45 indicates presence of $CH_3CHOH$<br>**OR** $CH_2CH_2OH$ **OR** $C_2H_5O$ ✓ | | **mass spec of E– Remember to check the spectrum**<br>**QWC –** mass spec gives $M^+$ or molecular ion of 60<br>**OR** mass spec gives parent ion of 60<br>**OR** highest *m*/*z* (**OR** *m*/*e*) value is 60 ✓<br><br>*m*/*z* = 45 indicates loss of $CH_3$<br>**OR** *m*/*z* = 45 indicates presence of $CH_3CHOH$<br>**OR** $CH_2CH_2OH$ **OR** $C_2H_5O$ ✓ |
| | **IR of F – Remember to check the spectrum**<br>IR shows no broad absorption between 2500 to 3300 $cm^{-1}$ so no O—H bond<br>**OR** no broad absorption between 2500 to 3300 $cm^{-1}$ so not a carboxylic acid ✓<br><br>IR shows absorption at 1700 $cm^{-1}$ due to a C=O bond<br>**OR** absorption at 1700 $cm^{-1}$ indicates a ketone **OR** aldehyde present ✓ | | **IR of F– Remember to check the spectrum**<br>IR shows (broad) absorption somewhere between 3500 and 2500 $cm^{-1}$ suggests carboxylic acid **OR** O–H bond ✓<br><br>IR shows absorption at 1700 $cm^{-1}$ due to C=O<br>**OR** absorption at 1700 $cm^{-1}$ indicates a carboxylic acid ✓ |
| | **Identification and equation**<br>**F** is $CH_3COCH_3$ **OR** propanone ✓<br><br>**E** is $CH_3CHOHCH_3$ **OR** propan-2-ol ✓<br><br>$CH_3CHOHCH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$ ✓ | | **Identification and equation**<br>**F** is $CH_3CH_2COOH$ **OR** propanoic acid ✓<br><br>**E** is $CH_3CH_2CH_2OH$ **OR** propan-1-ol ✓<br><br>$CH_3CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2COOH + H_2O$ ✓ |
| | If **F** has been incorrectly identified as propanal, mark identification and equation as ECF, so max = 2<br>**ALLOW E** is $CH_3CH_2CH_2OH$ ✓<br><br>**ALLOW**: $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓ | | |
| | **Total** | **19** | |

**Extra guidance for marking of Q6(g)**

If **E** has **not** been identified **OR** if **F** has been identified as a **ketone or aldehyde**,
use the **left-hand** mark scheme

If **F** has been identified as a **carboxylic acid**,
use the **right-hand** 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. $C_3H_7OH + [O] \rightarrow C_2H_5CHO + H_2O$ ✓ ; $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$ ✓ ; $C_3H_7OH + [O] \rightarrow C_2H_5COH + H_2O$ ✓

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| 7 | (a) | (i) | Infrared (radiation absorbed) ✓<br><br>by (C–H) bond vibration ✓ | 2 | **ALLOW** bond stretching **OR** bond bending<br><br>**DO NOT ALLOW** molecules vibrating |
| | | (ii) | Greater concentration of carbon dioxide<br>**OR** more carbon dioxide is being made ✓ | 1 | **ALLOW** carbon dioxide is the main contributor to global warming<br><br>**DO NOT ALLOW** any response that states that $CO_2$ causes ozone depletion<br><br>**ALLOW** C=O bonds absorb IR more readily than C–H bonds<br><br>**ALLOW** carbon dioxide has a greater greenhouse effect |

| Question | | | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|---|---|
| 7 | (b) | | **Any five from the following:**<br>Developing carbon capture **AND** storage ✓<br><br>One example of CCS ✓<br><br>Second example of CCS ✓<br><br><br><br><br><br><br>Provide evidence to governments **OR** international conferences (e.g. Kyoto) **OR** reports to United Nations etc ✓<br><br>Educating society **OR** writing in journals **OR** producing documentaries **OR** writing books **OR** making posters ✓<br><br>Monitoring atmospheric changes ✓<br><br>Develop alternative energy sources ✓<br>One example of an alternative energy source e.g. develop fuel cells **OR** developing solar power **OR** fuels that do not produce $CO_2$ ✓<br><br>(Develop) more efficient engines for transport **OR** lean burn engines **OR** hybrid engines **OR** electric cars ✓<br><br>Find uses for carbon dioxide<br>**OR** named use:<br>e.g. dry cleaning **OR** making decaffeinated coffee **OR** blowing agent **OR** fizzy drinks, etc ✓ | **5** | carbon, capture **AND** storage required<br>**ALLOW** CCS<br><br>**Examples of CCS**<br><br>**deep** in the oceans **OR** on the **sea-bed** ✓<br>**DO NOT ALLOW** dissolve $CO_2$ in the sea<br>**OR** stored in ocean<br><br>storage in geological formations<br>**OR** piped into disused or partially filled oil wells or porous rocks **OR** under the sea-bed ✓<br><br>by reaction with metal oxides<br>**OR** reaction to form (solid) carbonates<br>**OR** stored as a carbonate<br>**OR** equation to show formation of metal carbonate ✓<br>**IGNORE** mineral storage<br><br><br><br><br><br>**ALLOW** idea of biofuels only if linked to carbon-neutrality<br><br><br><br>**IGNORE** reforestation<br>**IGNORE** reference to CFCs<br><br>**DO NOT ALLOW** use less carbon dioxide |

| Question | Expected Answers | Marks | Additional Guidance |
|---|---|---|---|
| (c) | **Any two from the following:**<br><br>There are times when $CO_2$ has a **high** concentration and the temperature is also **high**<br>**OR**<br>There are times when $CO_2$ has a **low** concentration and the temperature is **low** ✓<br><br>It is impossible to measure with certainty the average temperature years ago ✓<br><br>There are other gases that may cause a greenhouse effect<br>**OR**<br>There are other factors that may cause a greenhouse effect ✓<br><br>There are very few anomalous results ✓ | **2** | **ALLOW** a (positive) correlation between temperature and carbon dioxide concentration<br>but **DO NOT ALLOW** just 'a correlation'<br><br>**IGNORE** 'graphs are the same shape'<br>**IGNORE** 'graphs are similar' |
| | **Total** | **10** | |