2024 VCE Chemistry (NHT) external assessment report

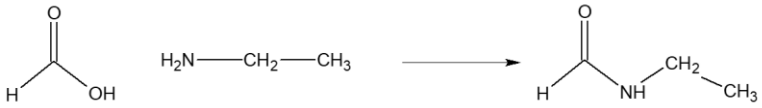
Specific information

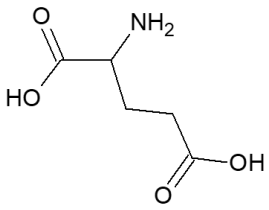
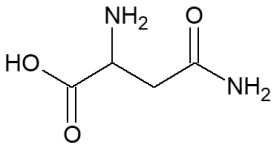
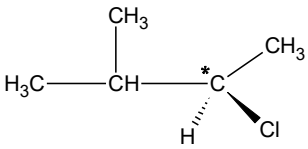
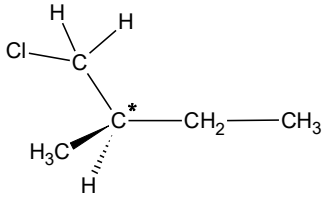
This report provides sample answers, or an indication of what answers may have included. Unless otherwise stated, these are not intended to be exemplary or complete responses.

Section A

Question	Correct answer	Comments
1	A	Galvanic cells convert chemical energy to electrical energy and commonly use up their stored reactants over time. Fuel cells convert chemical energy to electrical energy; these cells do not have stored reactants but rely on a continuous supply.
2	D	Calorimeters are designed to allow the determination of the enthalpy change that occurs during a reaction. Chemical reactions do not have calibration factors; only a calorimeter has a calibration factor associated with it.
3	A	Discussions are where experimental methods and data are evaluated and compared with theoretical expectations. • The introduction should explain background chemical concepts. • The conclusion should summarise the outcome of the analysed results and link these back to the aim. • The results section is used to record data that is being collected.
4	C	Catalysts lower the activation energy of reaction by providing an alternative reaction pathway and do so equally for both forward and backward reactions in equilibrium systems.
5	C	Collision theory accounts for the relationship link between the energy of the collision and the successful reaction occurring. For any given reaction, the likelihood of successful collision orientation between reactants is a fixed value and is not a temperature-dependant variable.
6	D	As the test tube got colder, the reaction must have been endothermic, and in chemical reactions, mass is conserved.
7	C	Since p = $\frac{nRT}{V} = \frac{3.0\ x\ 8.314\ x\ 400}{60} = 166$ kPa
8	A	To test the first law, one variable linked to $Q = It$ needs to be measured.

Question	Correct answer	Comments
		So current can be this variable and keep time constant, or measure the time and keep the current fixed.
9	C	n(ethanol) = $\frac{5.0}{46}$ = 0.1087 mol $n(CO_2)$ = 2 × n(ethanol) = 0.21739 mol $m(CO_2)$ = 0.21739 × 44.0 = 9.56 g
10	A	Statement 1 is correct. Statement 2 is incorrect as exothermic reactions often have a lower activation energy than many endothermic reactions. Students needed to identify which statement(s) are **always** true.
11	B	These two chemicals react in a 1:1 ratio. n(HCl) = c × V = 0.200 × 0.05 = 0.010 mol V(methanamine) = $\frac{n}{c} = \frac{0.010}{0.125}$ –0.080 L
12	A	It is possible for electrolytes to be solids; this is typically seen in solid-oxide fuel cells. Porous electrodes increase the contact area. Membranes are not often used in fuel cells as they cannot typically conduct electricity and if they were present in the electrolyte, they would be selectively allowing ions to pass through. The voltage generated by fuel cells is not affected as they use their reactants, which are in constant supply.
13	C	Flashpoints are determined by the number and relative strength of the intermolecular forces of attraction and will increase as the intermolecular forces of attraction increase. Viscosity increases as the number and relative strength of the intermolecular forces of attraction increase. Boiling point increases as the number and relative strength of the intermolecular forces of attraction increase.
14	D	In both galvanic and electrolytic cells, the anode is where oxidation occurs and so electrons are released from the anode and travel to the cathode. The anode is positive in electrolytic cells. Electrolytic cells do not need to have reactants separated. The overall chemical reaction that occurs in an electrolytic cell is usually an endothermic process (products have higher stored chemical energy than the reactants).
15	B	$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$ Therefore, $\frac{10}{298} = \frac{V_2}{323}$ Final volume = 10.8 L
16	B	Fat molecules are triglycerides. As these are hydrolysed, water is used in the reaction and the triglycerides form a single glycerol molecule and three fatty acids which contain carboxyl groups. A significant number of students chose option D. The presence of the word 'three' in the stem of the question means that it is an incorrect choice, as a single fat molecule does not form three glycerol molecules when it is hydrolysed.

Question	Correct answer	Comments
17	C	CF = $\frac{VIt}{t}$ = $\frac{4.50\ x\ 2.00\ x\ 2.00\ x\ 60}{1.5}$ = 720 J °C^{-1}
18	D	With a polar stationary phase and non-polar mobile phase: • non-polar materials will have a low affinity for the stationary phase and therefore elute with the shortest retention time • polar materials will have a high affinity for the stationary phase and have the longest retention time. Therefore, the expected order of elution from shortest to longest will be based on least polar to most polar, i.e. methyl ethanoate < butan-1-ol < propanoic acid.
19	C	HPLC must have the solvent pumped through the system under pressure, as the liquid needs to be forced through the stationary phase, which is packed inside the column. Samples must be dissolved in the liquid mobile phase; no vaporisation is required. Calibration curves are only utilised to quantify a component. The higher the retention time, the greater the affinity the compound has to the stationary phase.
20	A	The hydroxy(l) group is attached to a carbon with two other carbons attached, so this makes it a secondary alcohol. The numbering of the chain requires the methyl group to be located in as low a number as possible, which means it must be located on carbon number 2 of the chain.
21	D	The reaction between methanoic acid and ethanamine produces the following compound:  This compound matches the skeletal diagram shown in option D.
22	C	Collision theory states that as temperature is increased, the rates of reaction increase. Therefore, increasing the temperature of an equilibrium process causes an instantaneous increase in the rate of both forward and backward reactions. This means only Options C and D are viable representations of this system change. Le Chatelier's principle states that if the temperature of an exothermic reaction is increased, the reaction will shift backwards as it attempts to partially decrease the temperature. To shift backwards, the rate of the backward reaction will be greater than the rate of the forward reaction. As the reactants start to increase in concentration as a result of this, the rate of the forward reaction will slowly start to increase. Only Option C shows this pattern.
23	B	Statement 1 is incorrect as when trehalose is digested it will form glucose, but this glucose needs to undergo a condensation reaction in order to form glycogen. Statement 2 is correct because the digestion of trehalose will form glucose, which will be absorbed and increase the blood glucose levels. Statement 3 is incorrect because as trehalose is digested it produces two glucose molecules, each with a molar mass of 180 g mol^{-1}, and hence the total molar mass will be 360 g mol^{-1}.

Question	Correct answer	Comments
24	B	The energy profile diagram is not affected by the quantity of reactants or products, only by the energy of these molecules as represented in the chemical equation. The horizontal component of this diagram is not 'time', but 'reaction progress'. (Energy profile diagrams are diagrams, not graphs, and they do not have an independent variable.) The average chemical energy of a reaction mixture will be dependent on the quantities of reactants present at the start of the reaction. The bomb calorimeter cannot ascertain the value for the activation energy, therefore can only be used to determine the relative positions of the reactants and products.
25	C	When hydrolysed, the amino acids that form are:   These match glutamic acid and asparagine.
26	C	The following two optically active compounds could have been formed:  
27	D	The current flowing through any cell is determined by the number of reactions occurring per second. Therefore, by changing the surface area of an electrode, the frequency of successful collisions will change and hence current will change. The relative positions of reductant and oxidant do not reflect the rate of a chemical reaction, or the extent of a chemical reaction.
28	A	The Maxwell-Boltzmann distribution curve is a representation of the relationship between the number of particles present in a system and their relative energy levels. The area under this curve is therefore an accurate indication of the total number of particles present.
29	B	At the anode (negative electrode), the same half-equation is occurring in both of these reactions and therefore the same amount of carbon dioxide is being produced. $CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$ At the cathode (positive electrode), the reactions occurring are $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$ and $HCrO_4 + 7H^+ + 4e^- \rightarrow Cr^{3+} + 4H_2O$ In both reactions the identical number of electrons is being used, but in the experimental cell a higher number of moles of water is being produced.

Question	Correct answer	Comments
30	B	Both proline and glutamic acid have five carbon environments, whereas valine and aspartic acid only have four carbon environments. Proline has a single carboxyl group, therefore it will produce a single peak in the region of 180 ppm. Glutamic acid has two carboxyl groups and therefore it will produce two peaks in the region of 180 ppm.

Section B

Question 1a.

An essential amino acid cannot be produced/synthesised by the human body.

Simply stating that an essential amino acid must be part of the diet was not sufficient for the mark.

Question 1b.

The first two marks were awarded for the two following points:

- The blocking protein is denatured.
- Bonds/intermolecular forces between the side chains in the blocking protein are broken/altered.

The final mark was awarded for **one** of the following:

- Mention of the secondary or tertiary structure being altered
- Mention of the shape of the blocking protein being altered.

If students did not specifically mention that they were discussing the blocker protein, it was very unlikely that they could be awarded full marks.

Question 1c.

The first mark was awarded for acknowledging that the Vitamin C content of the soybeans decreases.

The second mark was awarded for identifying that Vitamin C contains hydroxy(l) or highly polar groups that allow it to dissolve in water due to the formation of hydrogen bonds.

Question 2a.

The first mark was awarded for determining the energy content per 100g:

- Energy per 100 g = [22.8 × 16] + [1.1 × 17] + [0.3 × 37] = 394.6 kJ

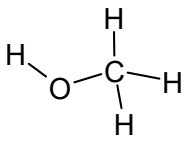
The second mark was awarded for determining the energy content per gram:

- Energy per gram = $\frac{394.6}{100} = 3.9\ kJ/g$

Question 2b.

$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

Question 2ci.



Question 2cii.

The first two marks were awarded for the two following points:

- The energy content is approximately the same for sucrose and aspartame.
- The glycaemic index of sucrose is higher than that of aspartame.

The final mark was awarded for **one** of the following:

- Mention that the hydrolysis of sucrose produces glucose and hence will cause a significant rise in the glycaemic index.
- Mention that the hydrolysis of aspartame does not produce any glucose and hence will not cause a rise in the glycaemic index.

Question 2di.

Each of the following three points was awarded a mark:

- Linolenic acid would most readily undergo oxidation rancidity.
- Linolenic acid has three C=C bonds compared with linoleic acid which has two C=C and lauric acid which has no C=C.
- The C=C bonds are the sites where oxygen reacts, hence why linolenic acid is most likely to undergo oxidative rancidity.

Question 2dii.

$C_{39}H_{74}O_6$

Question 2e.

Each of the following points was awarded a mark:

- Coenzymes bind to the active site, thereby changing the three-dimensional shape and allowing the substrate to bind more effectively.
- Coenzymes can act as electron transport systems for the enzymes.

Question 3a.

Addition reaction

Question 3bi.

Either of the following equations (either molecular or semi-structural representations are acceptable) was awarded two marks:

- $C_3H_7Cl + NH_3 \rightarrow C_3H_9N + HCl$
- $CH_3CH_2CH_2Cl + 2NH_3 \rightarrow CH_3CH_2CH_2NH_2 + NH_4Cl$

The first mark was awarded for recognising the correct reactants.

The second mark was awarded for recognising the correct products.

Question 3bii.

1-propanamine or propan-1-amine

Question 3biii.

- If the student used the equation $C_3H_7Cl + NH_3 \rightarrow C_3H_9N + HCl$

  % atom economy = $\frac{M(desired\ product)}{M(reactants)} x\ 100 = \frac{59.0}{95.5} x\ 100 = 61.8\%$

- If the student used the equation $CH_3CH_2CH_2Cl + 2NH_3 \rightarrow CH_3CH_2CH_2NH_2 + NH_4Cl$

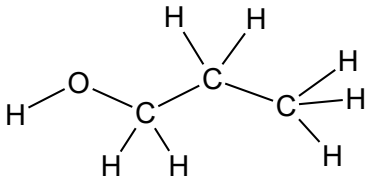
  % atom economy = $\frac{M(desired\ product)}{M(reactants)} x\ 100 = \frac{59.0}{112.5} x\ 100 = 52.4\%$

The first mark was awarded for recognising the correct mathematical relationship for % atom economy.

The second mark was awarded for using the correct molar masses.

The third mark was awarded for correctly determining the % atom economy.

Question 3c.

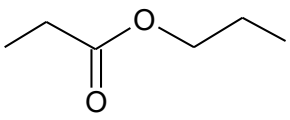


Question 3d.

The mark was awarded for any of the following combinations of reagents:

- $Cr_2O_7^{2-}$ / H^+ (K_2CrO_7 / H^+)
- MnO_4^- / H^+ ($KMnO_4$ / H^+)
- O_2 / catalyst

Question 3ei.



Question 3eii.

Water / H_2O

Question 4a.

The first mark was awarded for identifying the oxidising agent as NiOOH.

The second mark required specific identification of the

- oxidation number of Ni in NiOOH as +3
- oxidation number of Ni in $Ni(OH)_2$ as +2

The oxidising agent must show a decrease in oxidation number.

Question 4b.

Either of the following two points was sufficient to be awarded the mark:

- Students could have identified the properties of the electrode, for example, porous/non-reactive/conductive, etc.
- Students could have identified an actual example of the electrode, for example, graphite, Pt, Au or any metal with an E^0 value greater than −0.83 V.

Question 4c.

Full marks were awarded for the correctly balanced equation:

$2Ni(OH)_2(s) \rightarrow 2NiOOH(s) + H_2(g)$

If students provided the reverse equation, $2NiOOH(s) + H_2(g) \rightarrow 2Ni(OH)_2(s)$, only one mark was awarded.

Question 4d.

'Greater than +1.35 V' or ' > +1.35V'

The recognition of 'greater than' was essential for this mark.

Question 4e.

Any of the following types of responses were acceptable:

- The cell will not be able to be fully recharged.
- The battery does not last as long between recharges.

Simply stating that the cell has a lower efficiency was not acceptable.

Question 4f.

The first mark was awarded for stating that the system was recharging when oxygen was being produced.

$4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$

The second mark was awarded for the correct half-equation at the anode in alkaline conditions.

Question 4g.

The following two points were required to gain the two marks:

- Any oxygen produced in the recharging process will have almost the same E^0 value as that of the expected NiOOH.
- This oxygen, if produced, can react with hydrogen in the discharge reaction to produce water and the cell will continue to operate with a very similar output.

Question 5a.

$$K_c = \frac{[N_2O_4]}{[NO_2]^2}$$

Question 5b.

$[NO_2]_{initial}$ = n/V = 0.25/4.0 = 0.625 M

$[N_2O_4]_{eqm}$ = n/V = 0.0149/4.0 = 0.0.00373 M

	$[NO_2]$	$[N_2O_4]$
I	0.0625	0
C	−0.00745	+0.00373
E	0.05505	0.00373

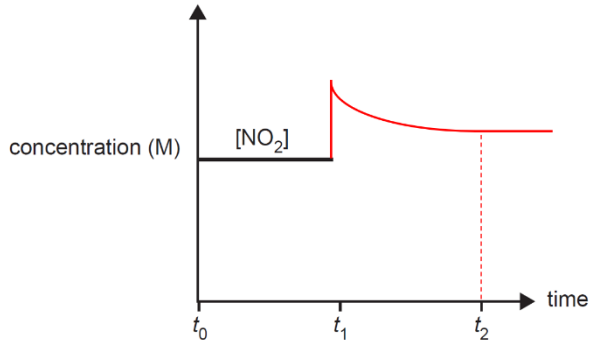
$K = 0.00373 \div (0.05505)^2 = 1.2\ M^{-1}$

The first mark was awarded for equilibrium values for the two chemicals.

A second mark was awarded for the correct calculation of *K*.

A third mark was awarded for correct units being shown.

Question 5c.



The first mark was awarded for the correct system change being shown.

A second mark was awarded for the correct response to the system change being shown.

A third mark was awarded if both of the following were shown:

- Equilibrium was reached at exactly t_2.
- At t_2 the line was horizontal and above the position where it was prior to the system change being made.

Question 6a.

The first mark was awarded for the identification of the O-H (alcohol) or the hydroxy(l) functional group.

The second mark was awarded for the use of 3200–3600 cm^{-1} to support its identification.

Question 6bi.

Base peak is at m/z = 45

Question 6bii.

The first mark was awarded for the understanding that the peaks at m/z = 94 and m/z = 96 are both parent/molecular ions.

The second mark was awarded for the understanding that these arise because of the presence of the two isotopes of chlorine, ^{35}Cl and ^{37}Cl.

Question 6c.

Students needed to identify one piece of information from the table to obtain the first mark and to receive the second mark they needed to relate this information to the structure of the compound.

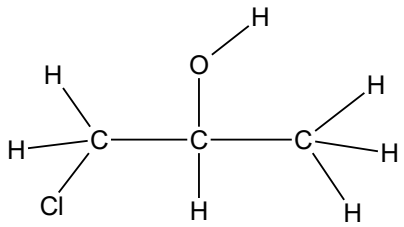
Typical acceptable responses are outlined below:

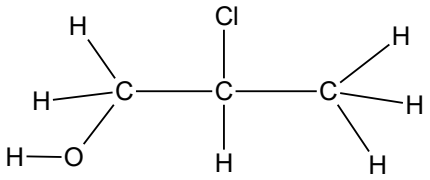
- The sum of the relative peak areas totals 7, therefore the total number of hydrogens present in the compound must be a multiple of 7.
- There are four different chemical shifts, so there must be four different ^{1}H environments in the compound.
- The relative peak areas are 3:1:2:1, therefore the compound must have ^{1}H environments that contain 3 hydrogens, 1 hydrogen, 2 hydrogens and 1 hydrogen (or multiple of these).
- The chemical shift at 1.3 ppm with a relative peak area of 3 suggests the compound has a R-C$\mathbf{H}_3$ group.

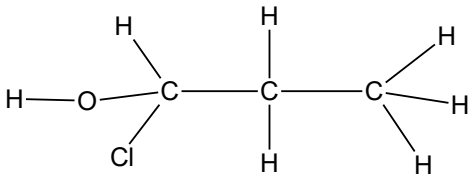
Students need to be reminded that the first answer given on an examination is the only answer that is assessed. Multiple answers were frequently supplied for this question.

Question 6d.

Any of the following structures was accepted for the mark.







Question 6e.

To be awarded the marks for this question, students could not use the data from Question 6a. Any reference to the chloro group or the hydroxy(l) group could not be used.

Any two of the following are typical examples of where marks could have been awarded if they did not conflict with the student's response to Question 6c.

- There are four distinct hydrogen environments listed in ^{1}H-NMR data and the compound provided in Question 6d shows four distinct hydrogen environments.
- There is a 3H environment listed in the ^{1}H-NMR data and there is a -CH_3 group shown in the compound provided in Question 6d.
- There is a 3:1:2:1 ratio of hydrogens shown in the ^{1}H-NMR data and there are the same number of hydrogens shown in each environment of the compound provided in Question 6d.
- The base peak at m/z = 45 suggests the loss of a -CH_2Cl group and the compound shown in Question 6d has a -CH_2Cl group.
- The structure in Question 6d has a molar mass of 94.5 g/mol, which is consistent with the two molecular ion peaks m/z = 94 and m/z = 96.

It was important that students recognised they needed to provide two key pieces of information from the spectral information and then clearly reference these back to the structure they had drawn.

Question 7a.

Negative, (−)

Question 7b.

The mark was awarded for any one of the following:

- The membrane allows for the movement of (small) positive ions such as Li^+ to move through it.
- The membrane does not allow the large anions such as Cl^-/^-OH to pass through.
- The membrane allows for the separation/isolation of the desired product, LiOH.

Question 7c.

Hydrogen gas, $H_2(g)$

Question 7d.

The first mark was awarded for the recognition that zinc would react at the anode.

The second mark was awarded when understanding was shown that this occurs because Zn is a stronger reductant/reducing agent than the Cl^- ion and therefore Zn^{2+} ions would be produced and possibly contaminate the LiOH being formed.

The third mark was awarded for the equation $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

Question 7e.

$n(Cl_2) = \frac{0.5}{71} = 0.00704 \text{ mole}$

$n(e^-) = 2n(Cl_2) = 2 \times 0.00704 = 0.01408 \text{ mole}$

$Q = n(e^-) \times F = I \times t$

$t = \frac{n(e^-) \times F}{I} = \frac{0.01408 \text{ mole} \times 96500}{0.895} = 1518 \text{ seconds} = 1.52 \times 10^3 \text{ s}$

The first mark was awarded for the correct calculation of $n(Cl_2)$.

The second mark was awarded for the correct $n(e^-)$.

The third mark was awarded for the correct value, in seconds, and stated to three significant figures.

Question 8a.

Type or structure of alcohol

Question 8b.

The mark was awarded for any one of the following concepts:

- length of the carbon backbone of the fuel
- number of carbons present in the fuel
- change in the molar mass of the fuel.

Question 8c.

Energy absorbed by the water $q = mc\Delta T$

$= 100 \times 0.997 \times 4.18 \times (38.20 - 23.20)$

$= 6.25$ kJ

Heat of combustion $= q/m$

$= 6.25 / (218.556 - 218.173)$

$= 16.3$ kJ g^{-1}

The first mark was awarded for correctly identifying and using the density of water as 0.997 g/mL.

The second mark was awarded for determining the value for q.

The third mark was awarded for determining and using the correct mass of fuel.

The fourth mark was awarded for the correct determination of the heat of combustion in kJ g^{-1}.

Question 8di.

$C_4H_9OH(l) + 4O_2(g) \rightarrow 4CO(g) + 5H_2O(l/g)$

The first mark was awarded for a correctly balanced incomplete combustion equation.

The second mark was awarded for the correct use of states.

Either state for water was accepted because no conditions were stated in the stem of the question.

Question 8dii.

The first mark was awarded for the understanding that haemoglobin binds more strongly with carbon monoxide than oxygen gas (i.e. higher K value).

The second mark was awarded when the student linked this to the concept that carbon monoxide therefore causes cells or the body to be starved of oxygen.

Question 8diii.

The mark was awarded for any one of the following concepts:

- Conduct the experiment in a well-ventilated area.
- Conduct the experiment in a fume hood.
- Any other valid safety precaution.

Question 8ei.

The mark was awarded for any one of the following concepts:

- incomplete combustion of the fuel
- loss of water due to evaporation
- any part of the equipment absorbing the heat energy (other than the water).

Incorrectly calibrated balances and thermometers were not accepted because these pieces of equipment were being used to measure changes in values, not discrete values.

Question 8eii.

The first mark was awarded for stating that the accuracy will decrease.

The second mark was awarded when the student linked their experimental error to specifically stating how this would have affected the accuracy.

Typical responses are shown below:

- Incomplete combustion of the fuel – the incomplete oxidation would have resulted in less heat energy being produced and this would have caused a lower heat of combustion to be calculated compared to the true value.
- Loss of water due to evaporation – with less water, this would have caused the temperature of the water to increase and this would have resulted in a higher heat of combustion to be calculated compared to the true value.
- Any part of the equipment absorbing the heat energy (other than the water) – this would have resulted in a lower temperature change of the water, which would have caused a lower heat of combustion to be calculated compared to the true value.

Question 8f.

The mark was awarded for any identification that links results back to the structure of the fuel.

Acceptable responses included:

- A longer carbon chain in the fuel resulted in a higher the molar heat of combustion.
- A larger molar mass of the fuel resulted in a higher molar heat of combustion.
- More carbon atoms present in the fuel resulted in a higher molar heat of combustion.

Question 9a.

The allocation of marks for this question was based on students' interpretation of the relative benefits associated. They could provide any of the following:

- three pro arguments, one counter-argument and an evaluation statement
- two pro arguments, two counter-arguments and an evaluation statement
- one pro argument, three counter-arguments and an evaluation statement.

A typical example could look like the following:

- The first mark for recognition that the use of fossil fuels results in a net increase in carbon dioxide being released into the atmosphere.
- The second mark for recognition that the use of biofuels results in no significant increase in carbon dioxide being released into the atmosphere.
- The third mark for recognition that the clearing of land to be able to produce biofuels may cause less carbon dioxide to be taken up by the plants compared to existing forests.
- The fourth mark for recognition that the production and transportation of materials in the manufacture of biofuels may release extra carbon dioxide into the atmosphere.
- The fifth mark was awarded for an overall evaluation statement about these points.

Question 9b.

The first mark was awarded for recognition that petrodiesel is a hydrocarbon, whereas biofuels are esters.

Any two of the following points could have been used to gain the remaining two marks:

- Biodiesel is already partially oxidised and so will produce a lower heat of combustion, therefore more fuel will need to be carried to match the performance of petrodiesel.
- Biodiesel (due to its ester group) will have a greater viscosity compared to petrodiesel and hence this may reduce its suitability because of reduced flow rates.
- Biodiesel (due to its ester group) will have a lower cloud point compared to petrodiesel and hence this may reduce its suitability in cold climates because solid fuels cannot flow.
- Biodiesel (due to its ester group) will have a higher flash point compared to petrodiesel and hence this may make starting the engines more difficult.