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YEAR 12 *Trial Exam Paper*

2021
CHEMISTRY

Written examination

Worked solutions

This book presents:

- correct solutions, with full working
- explanatory notes
- mark allocations
- tips.

SECTION A – Multiple-choice questions

Question	Answer
1	*D*
2	*C*
3	*A*
4	*B*
5	*D*
6	*C*
7	*D*
8	*B*
9	*A*
10	*B*
11	*A*
12	*C*
13	*D*
14	*C*
15	*B*

Question	Answer
16	*C*
17	*C*
18	*B*
19	*D*
20	*C*
21	*D*
22	*A*
23	*C*
24	*C*
25	*D*
26	*B*
27	*D*
28	*C*
29	*B*
30	*D*

Question 1

Answer: D

Explanatory notes

Option D is correct. Methyl stearate is an example of biodiesel. The viscosity of biodiesel is higher than the other fuels, which have shorter molecules. Biodiesel has dipole-dipole bonding as well as dispersion forces.

Option A is incorrect. Bioethanol has hydrogen bonding but small molecules will not be highly viscous.

Option B is incorrect. Petrodiesel molecules will have shorter molecules than biodiesel and petrodiesel does not have oxygen atoms. The intermolecular forces of petrodiesel are weaker.

Option C is incorrect. Petrol molecules are significantly shorter than biodiesel molecules.

Question 2

Answer: C

Explanatory notes

Option C is correct.

n(gas) at standard laboratory conditions (SLC) = $\frac{49.6}{24.8}$ = 2.0 mol

2.0 mol of methane would produce 2.0 × 890 kJ = 1780 kJ.

% methane = $\frac{1300 \times 100}{1780}$ = 73%

There are alternative methods that you could use to arrive at the correct answer.

Options A, B and D are incorrect.

Question 3

Answer: A

Explanatory notes

Option A is correct. A fuel needs to be a liquid (above the melting point) to either auto-ignite or burn.

Option B is incorrect because fuels are normally liquids or vapours when they ignite.

Option C is incorrect because the fuel needs to be a liquid for it to form enough vapour to ignite.

Option D is incorrect because the boiling point of a substance is always higher than the melting point.

Question 4

Answer: B

Explanatory notes

Option B is correct. The question refers to the reverse reaction, which is exothermic. A catalyst does not affect the enthalpy change of 90 kJ mol^{-1} but it will lower the activation energy to a value less than 40 kJ mol^{-1}. Option B is the only option with an unchanged enthalpy but with a lower activation energy.

Option A is incorrect because the reverse reaction is exothermic. The ΔH value cannot be positive. The activation energy will always be a positive value, and its magnitude is less than 40 kJ mol^{-1}.

Option C is incorrect because the catalyst will lead to a lower activation energy.

Option D is incorrect. The enthalpy value is incorrect.

Tip

- *Be wary of the use of the word 'reverse' in energy profile questions and 'discharge/recharge' in redox questions. It is common for VCAA questions to use these terms to catch out those students who are not reading the question carefully.*

Question 5

Answer: D

Explanatory notes

Option D is correct.

Energy released = mass × heat of combustion = 3.00 × 51.9 = 156 kJ

$n(\text{ethane}) = \frac{3.00}{30} = 0.100 \text{ mol} \Rightarrow n(CO_2) = 2n(\text{ethane}) = 2 \times 0.100 = 0.200 \text{ mol}$

$\text{mass}(CO_2) = n \times M = 0.200 \times 44 = 8.80 \text{ g}$

Option A is incorrect because the mass of CO_2 has not been determined.

Option B is incorrect because the mass of CO_2 is not double the mass of ethane.

Option C is incorrect. The heat of combustion needs to be determined for 3.00 g.

Question 6

Answer: C

Explanatory notes

Option C is correct. The combination of higher surface area, higher concentration and higher temperature will lead to the fastest initial reaction rate. Note that the question refers only to the initial rate.

Option A is incorrect. The concentration and temperature are both lower than those in option C.

Option B is incorrect as the concentration, surface area and temperature are all lower than those in option C. The extra volume of solution might have an impact in the long run but not initially.

Option D is incorrect as the marble chips are not ground and the concentration is lower than that in option C.

Question 7

Answer: D

Explanatory notes

Option D is correct. As the reaction proceeds, the concentration of H^+ ions decreases. This will lead to a corresponding increase in the pH of the solution.

Option A is incorrect. The solution gradually loses its purple colour so a cross is not going to become obscured.

Option B is incorrect because no precipitate forms.

Option C is incorrect. The concentration of H^+ ions drops during the reaction but no OH^- ions are produced, so the pH is going to stay under 7 the whole time. If phenolphthalein was added, it would not change colour. It would also be difficult to distinguish whether phenolphthalein or the MnO_4^- ions are producing the colour.

Question 8

Answer: B

Explanatory notes

Option B is correct. Manganese is reduced from +7 to +2 and the carbon is oxidised from +3 to +4.

Option A is incorrect because the oxidation number of the oxygen is unchanged.

Option C is incorrect. Manganese is not oxidised.

Option D is incorrect because manganese is reduced rather than hydrogen.

Question 9

Answer: A

Explanatory notes

Option A is correct.

n(oxalic acid) = 0.015 × 0.020 = 0.00030 mol

$n(KMnO_4) = \frac{2}{5} \times 0.00030 = 1.2 \times 10^{-4}$ mol

$c(KMnO_4) = \frac{0.00012}{0.018} = 0.0067$ M

Option B is incorrect. An incorrect mole ratio was used.

Option C is incorrect because the mole ratio is not 1:1.

Option D is incorrect. The mole ratio has been used the wrong way around (5:2 rather than 2:5).

Question 10

Answer: B

Explanatory notes

Option B is correct. In this cell, zinc atoms will form zinc ions and gold ions will form gold atoms. The reaction of the gold ions is reduction, which will occur at the cathode. Since the charge on the gold ions is +1, two gold ions will need to react for each zinc atom reacting. (The ionic equation for the reaction is $Zn(s) + 2Au^{+}(aq) \rightarrow Zn^{2+}(aq) + 2Au(s)$.)

Option A is incorrect because gold atoms will not be forming gold ions.

Option C is incorrect because the ratio of zinc to gold is the wrong way around.

Option D is incorrect. The ratio of zinc to gold is not 1:1.

Tip

- *It is assumed that you can construct and analyse a cell from any combination of half-equations. You need to have a set of rules for determining the polarity and direction of electron flow. Relevant half-equations can be found in the data book.*

Question 11

Answer: A

Explanatory notes

Option A is correct. Gold is forming at the positive electrode and the amount (number of mole) will be double the amount of zinc reacting at the negative electrode.

Option B is incorrect. The different relative atomic masses of each metal rules out a 1:1 mass change ratio.

Option C is incorrect. The ratio in option C would be correct for a mole ratio but not a mass ratio.

Option D is incorrect because the balanced equation shows a 2:1 ratio.

Question 12

Answer: C

Explanatory notes

Option C is correct. Option C is the reverse of the equation given. This leads to the K_c value being the reciprocal of the original value. The reciprocal of 4.0 is 0.25.

Option A is incorrect. The K_c value of this equation would be 2.0.

Option B is incorrect because it would lead to the value of K_c being 16.

Option D is incorrect because the value of K_c will be $\sqrt{0.25}$.

Question 13

Answer: D

Explanatory notes

Option D is correct. Even if the concentration of CO is quite low, the high K_c value for Reaction 2 means that the reaction proceeds easily, using up important supplies of Hb_4.

Option A is incorrect. It is the value of K_c that causes the problems, not the energy changes in the reaction.

Option B is incorrect because the double arrow in the equation for Reaction 2 indicates that the reaction is reversible.

Option C is incorrect. The discussion has the relative values of K_c the wrong way around.

Tip

- *Be aware that the mechanism of carbon monoxide poisoning is specified in the Study Design. It has not been referred to on recent exams, but you should cover all contingencies.*

Question 14

Answer: C

Explanatory notes

Option C is correct. The half-equation for the reduction of aluminium ions is $Al^{3+}(l) + 3e^{-} \rightarrow Al(l)$. When combined with the half-equation provided, the overall equation is $4Al^{3+}(l) + 6O^{2-}(l) + 3C(s) \rightarrow 4Al(l) + 3CO_2(g)$.

Option A is incorrect, as shown by the balanced equation.

Option B is incorrect, as shown by the balanced equation.

Option D is incorrect. The mole ratio is the wrong way around.

Tip

- *This question is an example of the degree of logic that is expected on recent exams. The amount of rote learning required for the exam has dropped; instead, you are expected to be able to apply knowledge in unusual contexts. For this question, the formula Al_2O_3 can be used to confirm that aluminium will start as Al^{3+}. Therefore, the ratio between aluminium and CO_2 can be determined by inspection of both half-equations.*

Question 15

Answer: B

Explanatory notes

Option B is correct. $Q = It = 180\,000 \times 60 \times 60 = 6.48 \times 10^{8}$ C

$$n(\text{e}) = \frac{Q}{F} = \frac{6.48\times10^{8}}{96\,500} = 6.72 \times 10^{3} \text{ mol}$$

$$n(\text{Al}) = \frac{n(\text{e})}{3} = 2.24 \times 10^{3} \text{ mol}$$

mass(Al) = $2.24 \times 10^{3} \times 27 = 6.04 \times 10^{4}$ g = 60.4 kg

Option A is incorrect. The correct answer is 60 kg.

Option C is incorrect. It has assumed $n(\text{Al}) = \frac{1}{2}n(\text{e})$.

Option D is incorrect. It has assumed $n(\text{Al}) = n(\text{e})$.

Question 16

Answer: C

Explanatory notes

Option C is correct. Cu^{2+} ions are a stronger oxidant than water and Br^- ions are a stronger reductant than water, so the reaction will be the same for molten $CuBr_2$ as for aqueous $CuBr_2$.

Option A is incorrect because aqueous KF will produce hydrogen and oxygen gases, as water is both the strongest oxidant and strongest reductant present.

Option B is incorrect because concentrated NaCl will produce Cl_2 gas at the anode rather than oxygen, owing to the non-standard conditions.

Option D is incorrect. Aqueous $MgBr_2$ will produce hydrogen gas at the cathode rather than magnesium metal because water is a stronger oxidant than Mg^{2+} ions.

Question 17

Answer: C

Explanatory notes

Option C is correct.

Option A is incorrect. A tertiary alcohol will contain more than three carbon atoms.

Option B is incorrect. Tertiary alcohols cannot be oxidised.

Option D is incorrect. The term tertiary refers to the carbon atom that has the hydroxyl group.

Question 18

Answer: B

Explanatory notes

Option B is correct. To determine if an alkene can form geometric isomers, inspect both carbon atoms on the double bond. If either of the carbon atoms has the same groups attached to it, it will not form a geometric isomer. In option B, the final carbon atom has two hydrogen atoms attached to it.

Options A, C and D are incorrect because they can form geometric isomers.

Question 19

Answer: D

Explanatory notes

Option D is correct. Propanal is CH_3CH_2CHO.

Option A is incorrect because propan-1-ol has the molecular formula C_3H_8O.

Option B is incorrect because a carboxylic acid will contain at least two oxygen atoms.

Option C is incorrect. Methyl ethanoate ester will contain two oxygen atoms.

Question 20

Answer: C

Explanatory notes

Option C is correct. Butan-2-ol has an –OH (alcohol) functional group that will produce a broad absorption around 3300 cm^{-1}. When the butan-2-ol has all reacted, this peak will no longer be visible.

Option A is incorrect. The presence of some ketone does not imply that all the butan-2-ol has reacted.

Option B is incorrect. The absorption at 1750 cm^{-1} is due to the formation of the carbonyl (C=O) group.

Option D is incorrect. The absorption around 3300 cm^{-1} will not move to 3000 cm^{-1}. The –OH functional group disappears completely.

Question 21

Answer: D

Explanatory notes

Option D is correct. A solution of pH 12 will have a significant hydroxide ion, OH^-, concentration. The hydroxide ions will react with the protons from both carboxyl groups to form water.

Option A is incorrect because the amine groups would accept a proton in water.

Option B is incorrect because a zwitterion has no net charge.

Option C is incorrect because the carboxyl groups would retain their protons in an acidic environment.

Tip

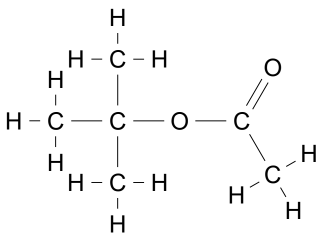
- *Examiners have increased their expectation that you know the forms that each amino acid takes at various pH levels. You must learn that zwitterions have no net charge and may be different from the forms of the amino acids in acidic or alkaline conditions.*

Question 22

Answer: A

Explanatory notes

Option A is correct. Inspection of the diagram shows that the molecule has only two hydrogen environments.



Options B, C and D are incorrect. The molecule has only two hydrogen environments.

Question 23

Answer: C

Explanatory notes

Option C is correct. The peak heights are the same and retention times are shorter but in the same ratios. This would be the result of a higher solvent flow rate.

Option A is incorrect. A change of solvent is likely to produce a different peak pattern.

Option B is incorrect. If the concentrations were increased, the retention times would be unchanged but the peak areas would be greater.

Option D is incorrect. It is possible to have another four fatty acids with retention times in the same ratio as the first set but option C is more likely.

Question 24

Answer: C

Explanatory notes

Option C is correct. The fatty acid contains 18 carbon atoms and three carbon-to-carbon double bonds (C=C). Therefore, the number of hydrogen atoms will be 30 (i.e. $2n – 6$, where n is the number of carbon atoms).

Options A and B are incorrect because the molecule contains 18 carbon atoms.

Option D is incorrect. It contains one too many hydrogen atoms.

Tip

- *It saves time knowing that the general molecular formula for a saturated fatty acid is $C_nH_{2n}O_2$. This molecule has 18 carbon atoms, so the number of hydrogen atoms when saturated will be 36. The presence of three C=C double bonds will lead to six fewer hydrogen atoms.*

Question 25

Answer: D

Explanatory notes

Option D is correct. The melting point of stearic acid will be higher than that of the other fatty acid, because the C=C double bonds prevent close-packing and thus the dispersion forces are weaker in the unsaturated molecule (the other fatty acid). This means that the stearic acid melting point will be higher. Stearic acid has the same molecular length as the fatty acid shown but stearic acid is saturated. For molecules of the same length, the lower the degree of saturation, the lower the melting point and the lower the viscosity. The presence of C=C double bonds increases the susceptibility to rancidity.

Option A is incorrect because stearic acid will have a higher melting point and viscosity. The C=C double bonds in the molecule shown will introduce kinks to the hydrocarbon chain, lowering the dispersion forces between molecules.

Option B is incorrect because stearic acid is less prone to rancidity as it is saturated.

Option C is incorrect. The viscosity of stearic acid will be higher than that of the other fatty acid because its molecules will pack more tightly. This is because the other fatty acid C=C double bonds prevent close-packing.

Question 26

Answer: B

Explanatory notes

Option B is correct. The heat of combustion of a carbohydrate is supplied in the data book as 16 kJ g^{-1}. The energy released from 0.50 g will be 8 kJ or 8000 J.

ΔT will be obtained from $q = 4.18 \times m \times \Delta T = 8000$ J.

$$\Rightarrow \Delta T = \frac{8000}{(4.18 \times 100)} = 19\ ^\circ\text{C}$$

Option A is incorrect. The value is too low.

Option C is incorrect. The value is too high.

Option D is incorrect. Only 0.50 g of sucrose was used, not 1.0 g.

Question 27

Answer: D

Explanatory notes

Option D is correct. Pantothenic acid has several polar functional groups. This will lead to the compound being polar and water soluble. If water soluble, it will need to be consumed frequently because the human body will not store it.

Option A is incorrect. All vitamins, except vitamin D, are considered essential.

Option B is incorrect because this vitamin will be water soluble.

Option C is incorrect because it is a relatively polar molecule.

Question 28

Answer: C

Explanatory notes

Option C is correct.

Options A and D are incorrect Ascorbic acid is not a protein.

Option B is incorrect. Ascorbic acid is soluble in water.

Question 29

Answer: B

Explanatory notes

Option B is correct. The mass of water is greater than it should be, so the amount of energy required to raise the temperature by 1 °C (the calibration factor) will be greater than it should be.

Option A is incorrect because the extra mass will lead to a smaller change of temperature.

Option C is incorrect. A low ΔT will lead to a high calibration constant.

Option D is incorrect because ΔT will be smaller than expected.

Tip

- *Recent exams feature questions referring to experiment design. As you do experiments during the year, focus on the design of the experiment, not just the outcomes.*

Question 30

Answer: D

Explanatory notes

Option D is correct. This is a systematic error but the value of ΔT is still correct if the initial and final readings are both out by 2 °C.

Option A is incorrect because it is a systematic error.

Option B and C are incorrect as the value of ΔT will still be accurate.

SECTION B

Question 1a.

Worked solution

Octane volume: 90% of 1.00 L = 0.90 L = 900 mL

Octane mass: $d \times V = 0.700 \times 900 = 630$ g

Ethanol volume: 10% of 1.00 L = 0.10 L = 100 mL

Ethanol mass: $d \times V = 0.790 \times 100 = 79$ g

Explanatory notes

The volume of ethanol and octane in the 1.00 L sample needs to be determined. This is an easy percentage calculation because the concentration of each fuel is given in percentage volume/volume (% v/v).

The mass of each component is then calculated using the formula $m = d \times V$. The volume units should be mL to match the density units supplied.

Mark allocation: 2 marks

- 1 mark for octane calculations
- 1 mark for ethanol calculations

Tip

- *The formula* $d = \frac{m}{V}$ *is a general science equation and its use is common in VCE Chemistry exams. Make sure that you are familiar with using it and adapting it to the different possible units for density.*

Question 1b.

Worked solution

Energy released by ethanol = 29.6 × 79 = 2338.4 kJ

Energy released by octane = 47.9 × 630 = 30 177 kJ

Total energy released = 2338.4 + 30 177 = 32 515.4 kJ = 3.25×10^4 kJ (to 3 sig. figures)

Explanatory notes

The amount of energy for each fuel is the mass of fuel multiplied by the amount of energy per gram of the fuel. The heat of combustion values are supplied in the data book.

Mark allocation: 2 marks

- 1 mark for the energy released from each fuel
- 1 mark for total energy provided

Tip

- *This question requires you to use the Chemistry data book. It is expected that you will know to do this even though the question does not direct you to the data book. You need to be familiar with the wealth of chemical information that can be found in this book.*

Question 1c.

Worked solution

$C_8H_{18}(l) + 12.5O_2(g) \rightarrow 8CO_2(g) + 9H_2O(l)$

Explanatory notes

The complete combustion will produce CO_2 and H_2O. Octane fuel is a liquid. The water can be shown as either a liquid or gas.

Mark allocation: 1 mark

- 1 mark for a balanced equation with states

  Note: H_2O can be shown as (l) or (g) and the equation could be doubled to remove the fraction. C_8H_{18} must never be shown as (aq).

Question 1d.

Worked solution

$n(\text{octane}) = \frac{m}{M} = \frac{630}{114} = 5.53 \text{ mol}$ $n(\text{ethanol}) = \frac{m}{M} = \frac{79}{46} = 1.72 \text{ mol}$

$n(CO_2)$ from octane = $8n(\text{octane}) = 8 \times 5.53 = 44.2$ mol

$n(CO_2)$ from ethanol = $2n(\text{ethanol}) = 2 \times 1.72 = 3.44$ mol

Total $n(CO_2) = 44.2 + 3.44 = 47.6$ mol

$$V = \frac{nRT}{P} = \frac{47.6 \times 8.31 \times 673}{100} = 2660 \text{ L}$$

Explanatory notes

Ethanol molecules contain two carbon atoms, so each mole of ethanol will produce two mole of CO_2.

Octane molecules contain eight carbon atoms, so each mole of octane will produce eight mole of CO_2.

The ideal gas equation can then be used to calculate the volume of a given amount of CO_2 gas.

Mark allocation: 3 marks

- 1 mark for the number of mole of CO_2 from octane
- 1 mark for the number of mole of CO_2 from ethanol
- 1 mark for the correct volume, in L

Question 1e.i.

Worked solution

$C_2H_4 + H_2O \rightarrow C_2H_6O$

Explanatory notes

This is a standard addition reaction. Ethene is the obvious starting alkene to provide the two carbon atoms required.

Mark allocation: 1 mark

- 1 mark for a balanced equation

Question 1e.ii.

Worked solution

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_6O(aq) + 2CO_2(g)$

Explanatory notes

This is a fermentation reaction conducted in the absence of air or oxygen.

Mark allocation: 1 mark

- 1 mark for a balanced equation with states

Tip

- *It is expected that you can write the equation for the fermentation of glucose; learn it off-by-heart.*

Question 2a.i.

Worked solution

M^{-1}

Explanatory notes

Inspection of the expression for K_c shows the concentrations $\frac{[M]^2}{[M]^2[M]}$, giving units of M^{-1}.

Mark allocation: 1 mark

- 1 mark for correct unit

Question 2a.ii.

Worked solution

The oxidation number of nitrogen in NO is +2 and is +4 in NO_2.

Explanatory notes

Assume that oxygen will have an oxidation number of –2 to work out the oxidation number of the nitrogen.

Mark allocation: 1 mark

- 1 mark for correct change of +2 to +4

Question 2a.iii.

Worked solution

Exothermic. The data in the table shows that the value of K_c decreases with temperature. This is consistent with an exothermic reaction.

Explanatory notes

Look at the trend in K_c as the temperature changes.

If K_c increases with temperature, the reaction is endothermic.

If K_c decreases with temperature, the reaction is exothermic.

Mark allocation: 2 marks

- 1 mark for exothermic
- 1 mark for an explanation referring to the value of K_c and by comparing it with temperature

Question 2b.

Worked solution

Strategy 1: decrease temperature

The reaction is exothermic. The value of K_c increases when the temperature is decreased, leading to an improved yield.

Strategy 2: increase pressure

An increase in pressure will favour the side of the reaction with the least number of particles, which in this case is the products.

Explanatory notes

To change the yield, reaction conditions must be changed. The reaction is exothermic; therefore, when the temperature is decreased, the value of K_c will increase. This leads to a shift in the forward direction and a higher yield.

When the pressure is increased, the system will oppose this change by moving in the direction of fewer particles. For this process the ratio of reactants to products is 3:2. The forward reaction is favoured, increasing the yield. An understanding of Le Chatelier's principle is necessary for this question.

Mark allocation: 4 marks

- 1 mark for each correct strategy (up to 2 marks)
- 1 mark for each supporting explanation (up to 2 marks)

Note: Other acceptable responses include an increase in oxygen/air concentration or the removal of product.

Question 2c.

Worked solution

Let $x = [O_2]$ at equilibrium.

[NO] will be $2x$.

$$\frac{[NO_2]^2}{[NO]^2[O_2]} = 4.4$$

$$\frac{(0.42)^2}{(2x)^2(x)} = 4.4$$

$$17.6x^3 = 0.1764$$

$$x = \sqrt[3]{0.010022}$$

$$= 0.216 \text{ M}$$

$$= 0.22 \text{ M (to 2 sig. figures)}$$

Explanatory notes

Write the expression for K_c. The value of K_c is known, as is the concentration of NO_2.

Since NO_2 was added to an empty reactor, the balanced equation shows that the amount of NO formed will be twice that of O_2. This leads to an expression to solve that has only one unknown.

If $[O_2] = x$, then [NO] will be $2x$.

Mark allocation: 3 marks

- 1 mark for the correct expression for K_c
- 1 mark for the correct substitution into the expression
- 1 mark for the correct answer

Tip

- *This question requires you to be able to use your calculator to find the cube root. Check that you are able to use the calculator that you will take into the exam to handle standard notation and other common maths functions.*

Question 3a.i.

Worked solution

$C_2H_3^+$

Explanatory notes

$C_2H_3^+$ is the only plausible possibility to give a relative mass of 27. The fragment needs to include a positive sign, as all peaks are due to ions.

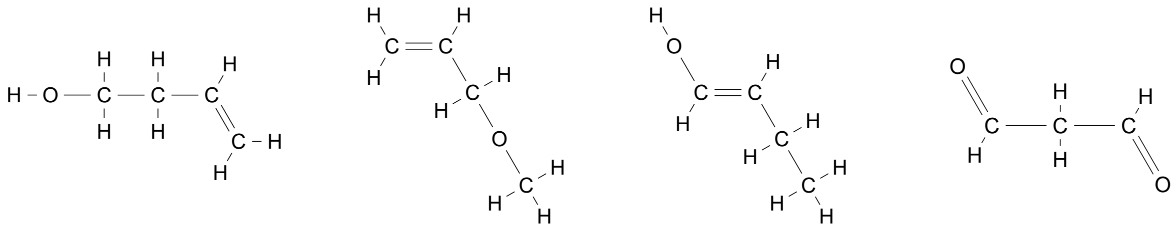
Mark allocation: 1 mark

- 1 mark for $C_2H_3^+$

Question 3a.ii.

Worked solution

Any three of the following molecules:



Explanatory notes

The mass of the parent molecular ion indicates that the relative molecular mass of the compound is 72. The molecule must contain carbon, hydrogen and oxygen.

The molecular formula could be $C_3H_4O_2$ or C_4H_8O.

The structures shown above meet these criteria.

Mark allocation: 3 marks

- 1 mark for each valid structure (up to 3 marks)

Tips

- *Past exams provide many examples of 'mystery molecules' on which you can practise and learn to understand that there are standard things to look for on the spectra provided. Be aware that you can often obtain full marks without deducing the final structure of the compound.*
- *It may help to read every part of the question before drawing the molecules, as you may be able to get hints and save yourself some time.*

Question 3b.

Worked solution

Conclusion 1: The compound contains an –OH (alcohol) functional group.

There is a broad absorption around 3300 cm^{-1}.

Conclusion 2: The compound contains a C=C double bond.

The sharp absorbance is at 1680 cm^{-1}.

Explanatory notes

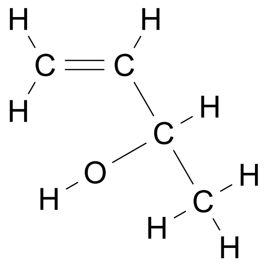
The substance contains oxygen, so an absorption around 3300 cm^{-1} will confirm it is an –OH functional group that is present as an alcohol rather than a carboxylic acid. The absorption around 1680 cm^{-1} is a little closer in wavelength to a C=C double bond rather than a C=O bond.

Mark allocation: 2 marks

- 1 mark for –OH (alcohol) identified (must be –OH (alcohol) and not –OH (acid))
- 1 mark for the C=C bond identified (or for identifying the lack of a C=O bond)

Question 3c.

Worked solution



Name: but-3-en-2-ol

Justification: The ^{13}C-NMR shows four carbon environments; therefore, any C_3 options are ruled out.

The molecular formula must be C_4H_8O in order for there to be four carbon environments and a relative molecular mass of 72.

The infra-red spectrum suggests a C=C double bond and an –OH functional group.

The molecule drawn has five hydrogen environments.

The ^{13}C-NMR shifts match the molecule drawn.

Explanatory notes

Logic can be used to narrow down the options in this question.

The relative molecular mass is 72 and the ^{13}C-NMR shows that four carbon atoms are present. This makes the molecular formula C_4H_8O.

The infra-red spectrum shows that the molecule contains an –OH bond, so it cannot also contain a C=O group.

The infra-red absorbance at 1680 cm^{-1} must therefore be a C=C double bond.

The molecule has to be a form of butenol.

The exact structure can be deduced by careful comparison of the ^{13}C-NMR shifts.

Mark allocation: 4 marks

- 1 mark for a structure with the molecular formula C_4H_8O
- 1 mark for a C=C and an –OH bond
- 1 mark for five hydrogen environments and four carbon environments
- 1 mark for a reference to shifts on ^{13}C-NMR

Note: Full marks can be given to any response that leads to an isomer of butenol if the response is explained clearly.

Question 4a.i.

Worked solution

$C_6H_5COOH(aq) + NaOH(aq) \rightarrow C_6H_5COONa(aq) + H_2O(l)$

Note: $NaC_6H_5COO(aq)$ is also acceptable in place of $C_6H_5COONa(aq)$.

Explanatory notes

Benzoic acid acts like any carboxylic acid, donating a proton from the –COOH functional group. An acid and a base form a salt (sodium benzoate) and water.

Mark allocation: 1 mark

- 1 mark for a correct equation

Question 4a.ii.

Worked solution

Assumption: Benzoic acid, like most carboxylic acids, is a weak acid.

Phenolphthalein is a suitable indicator.

Explanatory notes

Carboxylic acids are weak acids. The titration is between a weak acid and a strong base so the equivalence point will be around pH 8–10, matching the transition of phenolphthalein.

Mark allocation: 2 marks

- 1 mark for the assumption of a weak acid
- 1 mark for an indicator changing colour at a pH over 7

Question 4b.i.

Worked solution

n(NaOH) = $c \times V$ = 0.150 × 0.0200 = 0.00300 mol

n(benzoic acid in titre) = n(NaOH) = 0.00300 mol

n(benzoic acid in flask) = $\frac{0.003 \times 250}{17.8} = 0.0421$ mol

mass(benzoic acid) = $n \times M$ = 0.0421 × 122 = 5.14 g

Explanatory notes

The number of mole of NaOH can be determined first.

The number of mole of benzoic acid in the titration will be the same as the number of mole of NaOH (1:1 mole ratio in the balanced equation).

The mean titre used is 0.0178 L. The first titre is ignored because it is not concordant.

The number of mole of benzoic acid in the whole flask can be calculated.

The mass of the sample that is benzoic acid can be calculated from the mole.

Mark allocation: 3 marks

- 1 mark for n(NaOH)
- 1 mark for n(benzoic acid in flask)
- 1 mark for the mass of the benzoic acid

Question 4b.ii.

Worked solution

percentage mass/mass (% m/m) benzoic acid = $\frac{5.14 \times 100}{6.00} = 85.7\%$ (m/m)

Explanatory notes

The mass of solid that is actually benzoic acid is 5.14 g. The mass of the sample is 6.00 g. The % (m/m) can be calculated from these two figures.

Mark allocation: 1 mark

- 1 mark for percentage calculation

Question 4c.

Worked solution

This would be an example of poor technique and a waste of money because the burette should be rinsed with the solution that is going into it.

Explanatory notes

If the burette is rinsed with water, any remaining water will dilute the solution going into the burette.

Mark allocation: 1 mark

- 1 mark for stating that this is not good practice

Question 5a.

Worked solution

Overall equation: $2CO_2 \rightarrow 2CO + O_2$

Oxidation half-equation: $2O^{2-} \rightarrow O_2 + 4e^-$ Polarity: +ve

Reduction half equation: $CO_2 + 2e^- \rightarrow CO + O^{2-}$ Polarity: –ve

Explanatory notes

The cell diagram shows CO_2 as the reactant and CO as the product. It also indicates the presence of O^{2-} ions and the production of O_2. This is enough information to predict the half-equation for CO_2 to CO and predict the half-equation for O^{2-} to O_2.

Mark allocation: 3 marks

- 1 mark for the overall equation
- 1 mark for each half-equation with the correct polarity (up to 2 marks)

Tip

- *Expect the exam to feature cells that you have not seen before. Although the cell is unfamiliar, enough detail is provided for you to deduce the reactions that will occur. In this question, the diagram provided gave several clues to the reactants and products.*

Question 5b.

Worked solution

Ion: O^{2-}

Direction of movement: left to right (cathode to anode)

Explanatory notes

The O^{2-} ions are evident in the diagram provided or from the half-equations in **part a.** Being negatively charged, they will be attracted to the positive electrode; that is, the anode.

Mark allocation: 2 marks

- 1 mark for identifying O^{2-}
- 1 mark for stating the correct ion movement direction

Question 5c.

Worked solution

If methane is produced as biogas from the waste of inhabitants, the oxygen could be used to produce energy.

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

Note: The combustion of petrol, ethanol, diesel or biodiesel would also be possible answers.

Explanatory notes

Fuel is likely to be scarce on Mars. The waste of the inhabitants could be collected and used to produce biogas. The combustion of the biogas could generate thermal or electrical energy.

Mark allocation: 2 marks

- 1 mark for a practical combustion example
- 1 mark for a balanced equation

Question 5d.i.

Worked solution

Like a fuel cell, MOXIE uses a continuous supply of reactant. However, it requires electrical energy to function, whereas a fuel cell generates electricity.

Explanatory notes

A characteristic of a fuel cell is that it requires a continuous supply of reactants. A MOXIE unit has the same feature, but it requires electrical energy rather than producing it like a fuel cell does.

Mark allocation: 1 mark

- 1 mark for stating that a continuous supply of reactant is being used in an electrolytic cell, which requires electricity

Question 5d.ii.

Worked solution

MOXIE is an electrolytic cell; therefore, electrical energy will need to be sourced for it to function.

Explanatory notes

The availability of electrical energy on Mars is not a given. MOXIE would need access to electrical energy for it to operate to undergo electrolysis.

Mark allocation: 1 mark

- 1 mark for identifying electrical energy as the required input

Question 6a.

Worked solution

The sodium electrode is negative and the oxygen (porous) electrode is positive.

Explanatory notes

Sodium metal is oxidised to sodium ions at the left electrode. This is an oxidation reaction. Oxidation occurs at the anode and the anode is negative for a galvanic cell.

Mark allocation: 1 mark

- 1 mark for indicating the sodium electrode is negative and the oxygen electrode is positive

Question 6b.

Worked solution

Anode: $Na \rightarrow Na^{+} + e^{-}$

Cathode: $O_2 + 2H_2O + 4e^{-} \rightarrow 4OH^{-}$

Overall equation: $4Na + O_2 + 2H_2O \rightarrow 4Na^{+} + 4OH^{-}$

Explanatory notes

The reaction of sodium metal forms sodium ions. The oxygen gas reacts with water to form OH^{-} ions. The choice of an alkaline electrolyte indicates the formation of OH^{-} ions.

The sodium half-equation produces one electron only, so the balanced equation will require four sodium atoms for each oxygen molecule reacting.

Mark allocation: 3 marks

- 1 mark for each half-cell equation (up to 2 marks)
- 1 mark for the overall equation

Note: It would be acceptable to write the products as 4NaOH.

Question 6c.

Worked solution

+0.40 – –2.71 = 3.11 V

Explanatory notes

The standard cell voltage is the difference between the individual cell voltages of 0.40 and –2.71 V.

Mark allocation: 1 mark

- 1 mark for a correct voltage of 3.11 V

Question 6d.

Worked solution

The oxygen cell electrode needs to be porous and it needs to be inert in an alkaline environment that contains NaOH, otherwise known as caustic soda.

Explanatory notes

Oxygen from the air will need to be able to migrate through the electrode but the alkaline electrolyte needs to be contained by the electrode. The porous nature of the electrode needs to be carefully engineered to allow gases through but not liquids. The electrode will need to be made of inert material that will not react with the highly alkaline electrolyte.

Mark allocation: 2 marks

- 1 mark for each valid reason provided (up to 2 marks)

Question 7a.i.

Worked solution

$C_3H_7Cl + NH_3 \rightarrow C_3H_9N + HCl$

Explanatory notes

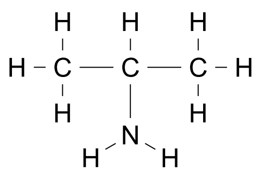
The reaction of chloroalkanes with ammonia is a standard pathway for the formation of an amine. This is a substitution reaction, with HCl as the other product.

Mark allocation: 1 mark

- 1 mark for a balanced equation (no states required)

Question 7a.ii.

Worked solution



propan-2-amine

Explanatory notes

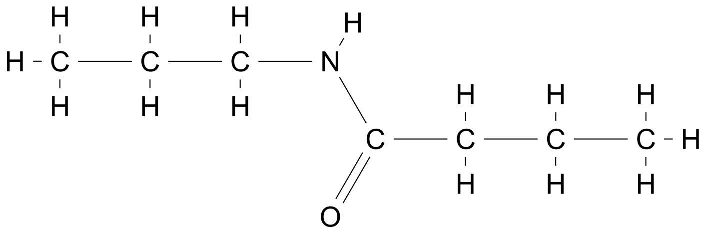
The amine group can be positioned on the second carbon to form a structural isomer.
The molecule is propan-2-amine.

Mark allocation: 1 mark

- 1 mark for the correct structure and name

Question 7b.i.

Worked solution



Explanatory notes

The reaction of an amine and a carboxylic acid is a condensation reaction that produces an amide.

Mark allocation: 1 mark

- 1 mark for a diagram of the amide structure

Note: An incorrect structure for Compound A could lead to a consequential mark.

Question 7b.ii.

Worked solution

amide

Explanatory notes

The reaction of an amine and a carboxylic acid is a condensation reaction that produces an amide.

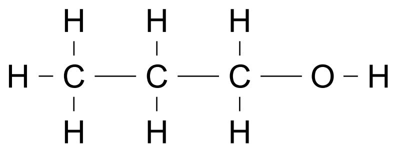
Mark allocation: 1 mark

- 1 mark for amide

Note: If Compound A is incorrect, a consequential mark would be accepted

Question 7c.

Worked solution



Explanatory notes

Chloroalkanes can be converted to alcohols when they are reacted with potassium hydroxide. A hydroxyl group, –OH, is substituted for the Cl atom.

Mark allocation: 1 mark

- 1 mark for drawing propan-1-ol

Question 7d.i.

Worked solution

$CH_3CH_2CH_2OCOCH_2CH_2CH_3$

OR

$CH_3CH_2CH_2COOCH_2CH_2CH_3$

Explanatory notes

The reaction of a carboxylic acid and an alcohol produces an ester and water.

Mark allocation: 1 mark

- 1 mark for the correct semi-structural formula

Question 7d.ii.

Worked solution

propyl butanoate

Explanatory notes

The alcohol is named first, then the carboxylic acid.

Mark allocation: 1 mark

- 1 mark for the correct name

Note: 1-propyl butanoate is also acceptable

Tips

- *Organic compounds must be spelled correctly to obtain the marks allocated in a question such as this. Make sure that you can spell terms like 'glycosidic' and 'propanoate' correctly.*
- *This is a common style of question on VCE Chemistry exams. Be sure to read exactly what each part of the question asks for because sometimes it is a structural formula, sometimes semi-structural formula and even, at times, a skeletal structure.*

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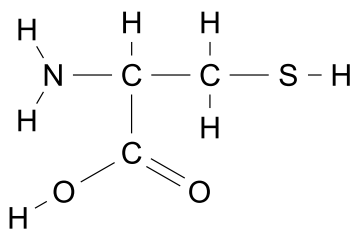
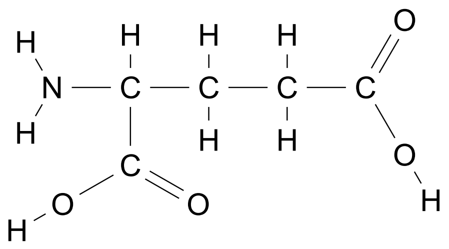
Question 8a.i.

Worked solution

cysteine and glutamic acid

Explanatory notes





Glycine has reacted with cysteine and glutamic acid, both of which are shown above.

Mark allocation: 2 marks

- 1 mark for each correct amino acid (up to 2 marks)

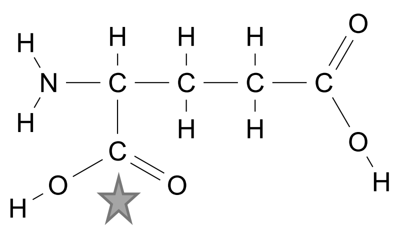
Question 8a.ii.

Worked solution

Glutamic acid has not reacted with cysteine in the correct fashion for a protein. Glutamic acid contains two carboxyl groups. For a protein to be able to be formed, the amide bond would need to have formed with the other carboxyl group. The carboxylic acid group reacting is not the usual one for a protein structure to form.

Explanatory notes

Glutamic acid has not reacted with cysteine in the correct fashion for a protein.



For a tripeptide to form that might result in a protein, the carboxyl group that is marked needs to form the amide bond.

Mark allocation: 1 mark

- 1 mark for identifying the need for the amide bond to be with the other carboxyl group

Question 8a.iii.

Worked solution

molar mass of glycine is 75 g mol^{-1}

molar mass of the tripeptide = 75 + 121 + 147 – (2 × 18) = 307 g mol^{-1}

Explanatory notes

The mass of the triglyceride is the mass of the individual amino acids minus the mass of two water molecules formed when the two amide bonds formed.

Mark allocation: 2 marks

- 1 mark for the molar mass of glycine or similar valid working
- 1 mark for the tripeptide molar mass

Question 8b.

Worked solution

Molecule B will be the antioxidant. The presence of two hydroxyl groups allows it to function as an antioxidant.

Explanatory notes

A characteristic of many antioxidants is the presence of hydroxyl groups. The hydroxyl groups act by reacting with oxygen present near a food. This limits the amount of oxygen available to cause deterioration of the biomolecules in the food itself.

Mark allocation: 2 marks

- 1 mark for selecting Molecule B
- 1 mark for recognising the impact of –OH groups

Question 9a.i.

Worked solution

temperature

Explanatory notes

The experiment is designed to vary the temperature in a systematic way. This makes temperature the independent variable.

Mark allocation: 1 mark

- 1 mark for temperature

Question 9a.ii.

Worked solution

time for a reaction to occur

Explanatory notes

As the temperature is varied, the time taken for the colour change to occur also changes. This makes the time for the colour change to occur the dependent variable.

Mark allocation: 1 mark

- 1 mark for stating time for a reaction to occur or time for a colour change to occur

  Note: Stating only 'time' is not enough information. 'Rate of reaction' would also be an acceptable answer.

Question 9b.i.

Worked solution

$$\text{sucrose} \xrightarrow{\text{invertase}} \text{glucose} + \text{fructose}$$

Explanatory notes

The enzyme is catalysing the hydrolysis of sucrose to the two monosaccharides it is made from; that is, glucose and fructose.

Mark allocation: 1 mark

- 1 mark for the equation for hydrolysis of sucrose

Question 9b.ii.

Worked solution

Benedict's solution reacts with glucose. Once a significant level of glucose forms, the reagent will turn noticeably orange. The faster the glucose forms, the shorter the time taken for the colour change to occur. (The rate of the reaction is the reciprocal of the time taken.)

Explanatory notes

Benedict's solution contains blue Cu^{2+} ions. When they react with a reducing sugar, the ions are reduced to Cu^{+}, which is orange in colour. The faster the glucose forms, the shorter the time for the orange colour to become evident.

Mark allocation: 1 mark

- 1 mark for linking the colour change to the formation of glucose

Question 9b.iii.

Worked solution

It will not as enzymes are usually specific to one reaction only.

Explanatory notes

The structure of sucrose can be seen by reacting one glucose and one fructose together (seen in the data book) and this is different to lactose (also seen in the data book). As enzymes are specific to one reaction, the different structures would mean that invertase would not work on sucrose

Mark allocation: 1 mark

- 1 mark for the correct response

Question 9c.

Worked solution

Enzyme activity varies with pH. The addition of the same buffer to each solution allows the student to control pH so that it is not influencing the reaction.

Explanatory notes

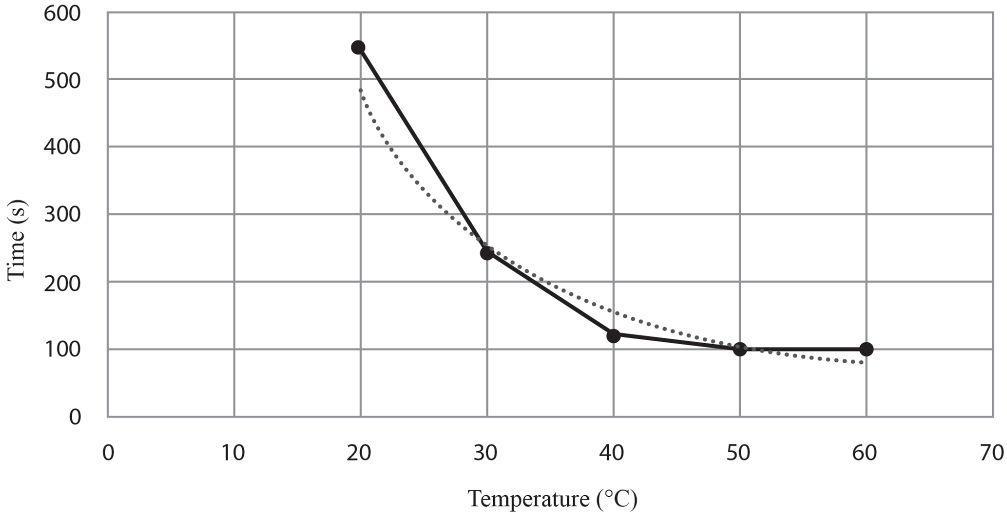
Adding a buffer of pH 5 will ensure that the pH in every test tube is the same. The pH will therefore not impact upon the aim of the experiment.

Mark allocation: 2 marks

- 1 mark for stating that pH can impact enzyme activity
- 1 mark for stating that the buffer will act to control pH in the experiment

Question 9d.i.

Worked solution



Explanatory notes

The dotted line is a line of best fit, which is a preferred option when graphing experimental data.

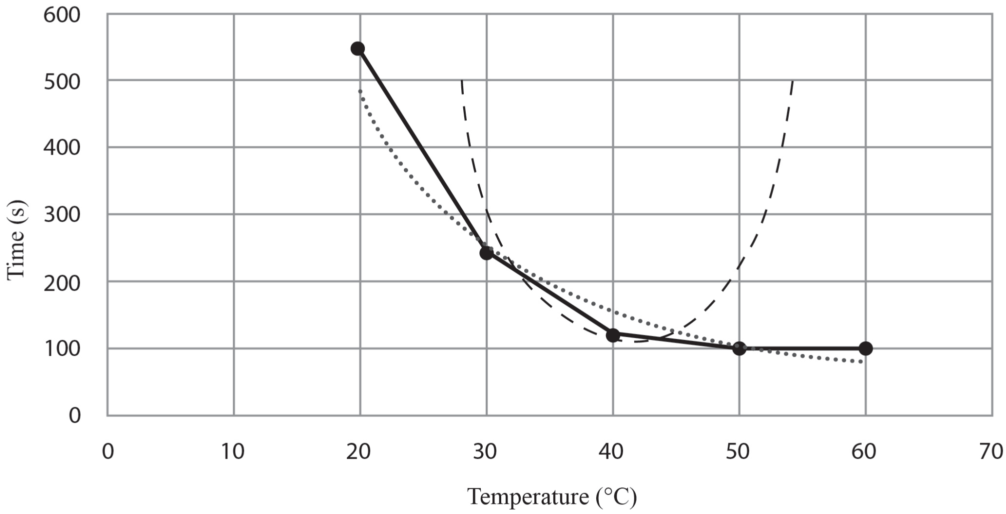
Mark allocation: 1 mark

- 1 mark for a graph with the points plotted correctly

Question 9d.ii.

Worked solution

The theoretical curve should look like the dashed line.



Explanatory notes

Most enzymes have an optimum operating temperature, which is often around 40 °C. We would expect the fastest rate to be at this temperature, meaning the colour change happens in the shortest time period. As the solutions are actually starting at room temperature instead of the desired temperature, the solution labelled at 60 °C is probably actually getting to 40 °C faster than the other solutions.

Mark allocation: 1 mark

- 1 mark for a parabola-shaped graph with the minimum time at around 40 °C

Question 9d.iii.

Worked solution

The test tubes are all starting at room temperature and are then placed in the water bath. This is flawed because it might take several minutes for the contents to reach the temperature at which they are meant to be. Most of the reaction is not occurring at the planned temperature.

A modification to address this issue would be to sit each test tube with buffer and sucrose solution in the water bath until the contents reach the desired temperature, and then add the invertase.

Explanatory notes

To test solutions at different temperatures, the solutions should be at the required temperature when timing starts. This experiment design needs to be modified to sit the solutions in the water bath from the start to ensure that the student is actually operating at the temperature they think they are.

Mark allocation: 2 marks

- 1 mark for identifying a valid issue, such as initial temperature
- 1 mark for suggesting a modification to the design

Tip

- *Each exam for the past eight years has included a question relating to experiment design. These questions require an understanding of variables and they also require you to be clear on the different types of possible errors.*

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Question 10a.

Worked solution

Steam–methane reforming: This process uses methane as a raw material. Methane is a fossil fuel that is non-renewable, so the widespread use of methane would use large quantities of a non-renewable fuel. The methane has to be 'mined', creating potential hazards such as leaks or explosions. The process produces CO as a by-product. This is a dangerous gas. The CO and hydrogen gases must be separated. The high temperatures required for this steam–methane reforming process add to the potential risks of this industry.

Electrolysis of water: This is a simpler process and water is readily available. Although the hydrogen must be handled carefully, it does not need to be separated from the oxygen gas that is also produced. The water used for this process does not have to be of drinking quality, so it is in ready supply and this makes the process sustainable. The environmental impact depends upon how the electrical energy required is sourced. If it is produced from coal-fired power stations, then fossil fuels are being consumed. If the electricity is produced by renewable means such as wind turbines, the process is low impact.

Explanatory notes

Steam–methane reforming: This process has all the problems associated with the uses and the mining of methane, which include the damage and hazards of drilling processes and the use of a non-renewable fuel. The CO produced is a toxic gas that needs to be stored safely and disposed of or, better still, recycled. It can be converted to CO_2, which is a less toxic greenhouse gas.

Electrolysis of water: This process requires electricity. If the electricity is produced from non-renewable means, then most of the advantages of this process are lost. If the energy is from renewable means, then there are significant potential environmental savings. The hydrogen could be produced without any impact on fuel reserves and without creating any emissions.

With either process, the hydrogen must be stored securely and handled carefully.

Mark allocation: 5 marks

- 1 mark for discussing the issues of sourcing methane
- 1 mark for mentioning the hazards associated with hydrogen gas
- 1 mark for discussing the problems associated with CO production
- 2 marks for discussing the significance of how the electricity for electrolysis is sourced

Note: A table would be an efficient way to answer this question.

Question 10b.

Worked solution

Production of ammonia: Le Chatelier's principle suggests that

- the temperature should be relatively low because the reaction is exothermic
- high pressure should favour the forward reaction
- a catalyst and an excess of air (N_2) will help favour the forward reaction
- the removal of product will favour the forward reaction.

In the form of ammonia, the hydrogen is now safer to transport because ammonia is not explosive. As a liquid, ammonia is easier to handle and it occupies a lower volume than gaseous hydrogen.

Reforming hydrogen: The conditions need to be the reverse of the conditions used to produce ammonia, so

- a high temperature should be used
- low pressure should be used
- the removal of hydrogen will favour the production of further hydrogen.

Explanatory notes

Le Chatelier's principle can be applied to ensure that the yield of each reaction is maximised.

Production of ammonia: low temperature, high pressure, removal of product, catalyst (in reference to rate not yield), and excess nitrogen because nitrogen is cheap.

Production of hydrogen: high temperature, low pressure and removal of hydrogen or nitrogen.

Mark allocation: 5 marks

- 2 marks for stating the conditions for forming ammonia
- 1 mark for stating the advantages of using ammonia as a means to transport hydrogen fuel
- 2 marks for stating the conditions for reforming hydrogen