YEAR 12 *Trial Exam Paper*

2020

CHEMISTRY

Written examination

Worked solutions

This book includes:

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

SECTION A – Multiple-choice questions

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

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

Question 1

Answer: B

Explanatory notes

Option B is correct. $n(\text{methane}) = \frac{V}{V_m} = \frac{99.2}{24.8} = 4 \text{ mol}$, which is the highest number of mole; therefore, the energy released will be the highest.

Option A is incorrect, as 50 g of methane is less than 4 mol.

Option C is incorrect, as the number of mole of methane is less than option B.

Option D is incorrect. The pressure is less than option B, so the number of mole of methane is less.

Tip

- *To best manage your time during a Chemistry exam, look for any chance to eliminate unlikely options in multiple-choice questions. In this question, there is no need to calculate the number of mole in option D, as it will definitely be lower than option B.*

Question 2

Answer: A

Explanatory notes

Option A is correct. Australia is a dry continent so the large-scale production of canola crops would place heavy demands on water, fertiliser and arable land. The farming equipment required will produce emissions and use significant amounts of energy.

Option B is incorrect. The oil for the biodiesel comes from the seeds of the crop only.

Option C is incorrect as the triglyceride in oil undergoes hydrolysis, then esterification, or transesterification, rather than condensation.

Option D is incorrect. Each molecule of triglyceride produces three molecules of biodiesel.

Question 3

Answer: B

Explanatory notes

Option B is correct. Propan-1-ol will be relatively soluble due to the presence of an –OH group on a small molecule. The heat of combustion of propan-1-ol is consistent with the trend in heats of combustion of alcohol molecules listed in the data book.

Option A is incorrect. Pentane is insoluble in water. It also has a higher value of heat of combustion.

Option C is incorrect, as cyclohexane is insoluble in water.

Option D is incorrect. Stearic acid is insoluble due to the long non-polar hydrocarbon chain.

Question 4

Answer: C

Explanatory notes

Option C is correct. The reaction is exothermic but the value of ΔH is much lower than typical fuels, such as methane.

Option A is incorrect because the value of ΔH for substance B is low and the high activation energy would also be a problem.

Option B is incorrect because the high activation energy of substance B means it is unlikely to be unstable.

Option D is incorrect because the combustion of substance B is exothermic.

Question 5

Answer: C

Explanatory notes

Option C is correct. The anaerobic digestor will produce biogas and the yeast tank will allow fermentation to produce bioethanol.

Option A is incorrect. Yeast will not produce biogas.

Option B is incorrect, as the digestor will not produce bioethanol.

Option D is incorrect because each tank has a different product.

Question 6

Answer: C

Explanatory notes

Option C is correct. The initial rate of reaction A is higher, which is consistent with an increase in the concentration of the HCl, leading to a greater number of successful collisions.

Option A is incorrect. A lower temperature would cause the initial rate of reaction A to be lower than that of reaction B.

Option B is incorrect because an increase in mass of $CaCO_3$ would lead to a greater final volume of gas.

Option D is incorrect. The shape of the beaker will not alter any rate-impacting parameters, such as temperature, concentration or surface area.

Question 7

Answer: B

Explanatory notes

Option B is correct. The greater mass of $CaCO_3$ is consistent with the higher volume of CO_2 produced. The initial rate is also lower due to the large chip being used. A larger chip will have a lower surface area.

Option A is incorrect as a catalyst would lead to an increase in the reaction rate.

Option C is incorrect. It does not explain the higher volume of CO_2 released.

Option D is incorrect. It does not explain the higher volume of CO_2 released.

Question 8

Answer: D

Explanatory notes

Option D is correct. Each S atom in S_8 gains two electrons to form S^{2-} ions.

Option A is incorrect. The sulfur exists as S_8 as a reactant, and the electrons are on the wrong side of the half-equation.

Option B is incorrect because 16 electrons are required for each S_8 molecule reacting.

Option C is incorrect because 16 electrons are required, and the electrons are on the wrong side of the half-equation.

Tip

- *It is common for the exam to use a new type of galvanic cell and expect you to be able to apply principles of redox chemistry to an unfamiliar context. Be aware that one or both half-equations for the cell might be found on the electrochemical series in your data book.*

Question 9

Answer: D

Explanatory notes

Option D is correct. $n(\text{Li}) = \dfrac{0.69}{6.9} = 0.1$ mol

$$n(S_8) = n(\text{Li})/16 = \frac{0.1}{16} = 0.00625 \text{ mol}$$

Mass sulfur = $n \times M = 0.00625 \times 32 \times 8 = 1.6$ g

Option A is incorrect. The sulfur is present as S_8 not S.

Option B is incorrect because an incorrect mole ratio was used.

Option C is incorrect because the mole ratio is 1:16, not 1:8.

Question 10

Answer: A

Explanatory notes

Option A is correct. The reaction at the cathode needs to be a reduction reaction. It is the oxygen gas that is reduced and the formation of OH^- is consistent with an alkaline environment.

Option B is incorrect because it shows oxygen reacting in an acidic environment.

Option C is incorrect because it shows an oxidation reaction.

Option D is incorrect because it shows an oxidation reaction and would require an acidic environment.

Question 11

Answer: C

Worked solution

Option C is correct. Expression for units for $K_c = \dfrac{[M]^4[M]^6}{[M]^4[M]^5} = M$.

Option A is incorrect.

Option B is incorrect. This response indicates that the equilibrium expression has been applied incorrectly, with the reactants above the products.

Option D is incorrect.

Question 12

Answer: A

Explanatory notes

Option A is correct. When the volume is halved, the concentrations all double. The back reaction is favoured as the system shifts to reduce the number of particles, but the concentration of NO will not drop as far as its original value at t_1.

Option B is incorrect. The amount of NO is lowered due to the back reaction being favoured.

Option C is incorrect. The amount of NO does change.

Option D is incorrect. The only variable that will change the value of K_c is temperature.

Tip

- *When applying Le Chatelier's principle, be sure to check exactly what quantity is being asked for; it could be*
  - *the position of equilibrium*
  - *the impact on the yield*
  - *the impact on K_c*
  - *the impact on the amount of a substance*
  - *the impact on the concentration of a substance.*

Question 13

Answer: D

Explanatory notes

Option D is correct. The addition of water decreases the number of collisions because the particles are farther apart. The reverse reaction is favoured because the ratio of reactants to products is 2:1. The intensity of red decreases and the amount of SCN^- ions increases. The concentration of SCN^- is lower because the volume of the solution has increased.

Option A is incorrect. The temperature has not changed, so the value of K_c will not change.

Option B is incorrect because the addition of water lowers the concentration of the SCN^- ions.

Option C is incorrect because the addition of water lowers the concentration of the SCN^- ions.

Question 14

Answer: C

Explanatory notes

Option C is correct. $Q = It = 9650 \times 90 = 869\,000$ C

$$n(\text{Ag obtained}) = \frac{869\,000}{96\,500} = 9 \text{ mol}$$

This is a higher number of mole than any other option.

Option A is incorrect. No metal is produced from electrolysis of an aqueous aluminium ion solution.

Option B is incorrect. The time would need to be 180 seconds for the amount of copper to match the amount of silver produced in option C.

Option D is incorrect. The amount of charge is the same as option B but the +3 oxidation state of aluminium ions means less metal is obtained.

Tip

- *It is common for electrolysis questions to include aqueous solutions of reactive metals (e.g. option A refers to $AlCl_3(aq)$). These solutions will not produce any metal because water is reduced instead of the metal ion. Watch for reactive metals that have a voltage lower than water (–0.83 V) on the electrochemical series.*

Question 15

Answer: A

Explanatory notes

Option A is correct. Reduction occurs at the cathode. In the electrolysis of molten $MgCl_2$, the reduction reaction is of magnesium ions to magnesium metal.

Option B is incorrect. It is not a balanced half-equation.

Option C is incorrect because it is an oxidation reaction.

Option D is incorrect. The electrolyte is not an aqueous one and the half-equation is not a reduction reaction.

Question 16

Answer: B

Explanatory notes

Option B is correct. $Q = It = 12\,600 \times 60 \times 60 = 4.54 \times 10^7$ C

$$n(\mathrm{e}) = \frac{4.54 \times 10^7}{96\,500} = 470 \text{ mol}$$

$n(Cl_2) = n(\mathrm{e})/2 = 235$ mol

Volume of Cl_2 at SLC = $n \times 24.8 = 5800 = 5.8 \times 10^3$ L

Option A is incorrect. It would be correct if the gas produced was oxygen.

Option C is incorrect because the number of mole of chlorine produced is half the number of mole of electrons.

Option D is incorrect.

Question 17

Answer: D

Explanatory notes

Option D is correct. The ester is ethyl ethanoate and this is formed from the reaction between ethanol and ethanoic acid.

Option A is incorrect. Methanoic acid would produce a different ester.

Option B is incorrect because the alcohol needs to be ethanol.

Option C is incorrect because propan-1-ol contains too many carbon atoms for this ester.

Tip

- *Be careful with the semi-structural formulas of esters. The way the ester group is represented depends upon whether the alcohol or the carboxylic acid is drawn first. For example, if the ethanoic acid was drawn first in the ester in this question, then the semi-structural formula would be* $CH_3COOCH_2CH_3$.

Question 18

Answer: B

Explanatory notes

Option B is correct. The molecular formula of butanoic acid is $C_4H_8O_2$. Option B is the only molecule with this molecular formula.

Option A is incorrect because the molecular formula of C_4H_8O is not correct.

Option C is incorrect because the molecular formula of C_4H_8O is not correct.

Option D is incorrect because the molecular formula of $C_4H_{10}O_2$ is not correct.

Question 19

Answer: B

Explanatory notes

Option B is correct. The flashpoint is the lowest temperature at which the fuel forms a vapour and ignites when a flame is present. The smaller the alkane, the lower the flashpoint.

Option A is incorrect. Alcohols do not have as low a flashpoint as the smaller alkanes.

Option C is incorrect because hexane will have a higher flashpoint than butane. Hexane is a longer alkane molecule than butane.

Option D is incorrect because diesel contains relatively long alkane molecules.

Question 20

Answer: B

Explanatory notes

Option B is correct. As the number of hydroxyl groups increases, the polarity of the molecule will increase. This highly polar molecule will adsorb strongly to the stationary phase, leading to a high retention time.

Option A is incorrect. A highly polar molecule will have a relatively long retention time in a polar stationary phase.

Option C is incorrect because the increase in polarity will be more significant than the increase in relative molecular mass.

Option D is incorrect. A polar molecule will not be highly soluble in a non-polar solvent such as hexane.

Tip

- *Students' performance on questions involving High Performance Liquid Chromatography (HPLC) has not been strong over the past few years. Make sure you understand the significance of the choices of stationary phases and mobile phases, and the types of bonding involved.*

Question 21

Answer: D

Explanatory notes

Option D is correct. When comparing the two chromatograms, run 2 has two peaks with the same retention times as run 1, but the concentrations are different because the peak areas have changed. It is likely that two of the alcohols are the same but the concentrations differ.

Option A is incorrect. If the temperature was the only change, then the chromatogram should still have three peaks.

Option B is incorrect. A change in solvent is likely to produce a completely different chromatogram.

Option C is incorrect. A change in stationary phase is likely to produce a completely different chromatogram.

Question 22

Answer: D

Explanatory notes

Option D is correct. Cyclohexane is the only option that has only one carbon environment (all $-CH_2-$ groups within the ring are equivalent). The shift will be a low one, matching the spectrum shown because cyclohexane does not contain highly electronegative atoms.

Option A is incorrect. Propane has two carbon environments.

Option B is incorrect. Butane has two carbon environments.

Option C is incorrect. Cyclohexene has three carbon environments.

Tip

- *Cyclohexane and benzene are specified in the Study Design. Be aware of their structures and properties.*

Question 23

Answer: A

Explanatory notes

Option A is correct. $n(MnO_4^-) = c \times V = 0.26 \times 0.02 = 0.0052$ mol

$n(Fe^{2+}) = 5 \times 0.0052 = 0.026$ mol

$c(Fe^{2+}) = \frac{n}{V} = \frac{0.026}{0.025} = 1.04$ M

Option B is incorrect. A mole ratio of 2:1 is not correct.

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

Option D is incorrect. The mole ratio has been applied in reverse.

Question 24

Answer: A

Explanatory notes

Option A is correct. A protein such as collagen is the only alternative that will have a significant number of nitrogen atoms.

Option B is incorrect. A triglyceride will not contain as many oxygen or nitrogen atoms.

Option C is incorrect because polysaccharides are unlikely to have several nitrogen atoms.

Option D is incorrect because polysaccharides are unlikely to have several nitrogen atoms.

Question 25

Answer: D

Explanatory notes

Option D is correct. Sucrose hydrolyses to glucose and fructose, whereas lactose hydrolyses to glucose and galactose.

Option A is incorrect. Sucrose is sweeter than lactose.

Option B is incorrect because a different enzyme is required for each reaction.

Option C is incorrect. Sucrose and lactose are isomers of each other that will have the same molar mass.

Question 26

Answer: C

Explanatory notes

Option C is correct. If the empirical formula is $C_9H_{16}O$, then the molecular formula will be $C_{18}H_{32}O_2$. This has two carbon-to-carbon double bonds. A saturated fatty acid will have a general formula of $C_nH_{2n}O_2$. The fatty acid in this question is four hydrogen atoms short of this formula, meaning two double bonds.

Option A is incorrect. This is not a saturated molecule.

Option B is incorrect because the question lists an empirical formula. Once this formula is doubled to give the molecular formula, the correct number of carbon-to-carbon double bonds can be determined.

Option D is incorrect. This molecule has two carbon-to-carbon double bonds.

Tip

- *You need to have a quick way of determining the number of carbon-to-carbon double bonds in a fatty acid. The general formula of a saturated fatty acid is $C_nH_{2n+1}COOH$ or $C_nH_{2n}O_2$. Each carbon-to-carbon double bond causes the number of hydrogen atoms present to drop by 2.*

Question 27

Answer: B

Explanatory notes

Option B is correct. The optimum temperature for many enzymes is around 40 °C. The rate of reaction peaks at this temperature. If the rate of reaction is high, then the time for the reaction is a minimum. The graph is consistent with the time needed for the reaction dropping as the temperature approaches the optimum.

Option A is incorrect. The graph would need to peak at around 40 °C if the number of collisions was plotted on the vertical axis.

Option C is incorrect. The graph would need to peak at around 40 °C if the rate of the reaction was plotted on the vertical axis.

Option D is incorrect.

Question 28

Answer: B

Explanatory notes

Option B is correct. 1.00 g of starch releases 16 kJ of energy.

The mass of triglyceride required to provide the same amount of energy is $\frac{1\times16}{37} = 0.432$ g

Option A is incorrect.

Option C is incorrect because triglyceride produces more energy per gram than carbohydrates.

Option D is incorrect.

Question 29

Answer: B

Explanatory notes

Option B is correct. If 100 g produces 1590 kJ, then 1 g produces 15.9 kJ = 15 900 J.

$15\,900 = 4.18 \times 500 \times \Delta T$

$$\Delta T = \frac{15\,900}{4.18\times500} = 7.6\ °C$$

Option A is incorrect. The calculation should start with 1590 kJ rather than 555 kJ.

Option C is incorrect because it is double the correct answer.

Option D is incorrect. This calculation incorrectly uses 100 g of water rather than 500 g.

Question 30

Answer: A

Explanatory notes

Option A is correct. Repeated trials serve to negate the impact of random errors.

Option B is incorrect. A poor choice of indicator is a mistake rather than a random error.

Option C is incorrect because it is more likely to lead to a systematic error.

Option D is incorrect. Repeating the experiment will not solve the issues caused by a systematic error.

Tip

- *Know your error categories and learn examples from each category. This is a common theme in questions, either in multiple-choice format or in descriptive questions involving experiment design.*

SECTION B

Question 1

Worked solution

Chemical	State
glucose in fermentation	(aq)
sulfuric acid as an esterification catalyst	(l) / (aq)
H_2O reacting with ethene to form ethanol	(g)
biodiesel in combustion	(l)
potassium metal produced in electrolysis	(l)

Explanatory notes

Fermentation to form alcohol occurs in an aqueous evironment. Yeast is a living organism that cannot survive when the alcohol concentration is too high.

Esterification requires that the carboxylic acid, the alcohol and the sulfuric acid are all in the liquid state and not aqueous.

The reaction of ethene and water requires high temperatures, where the water will be present as steam.

Water inhibits the combustion of fuels, especially non-polar fuels such as biodiesel.

Potassium metal is obtained by electrolysis of molten potassium salts. The metal is produced as a liquid.

Mark allocation: 5 marks

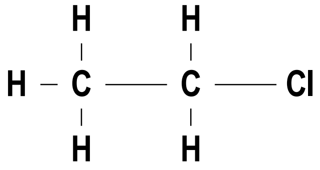
- 1 mark for each correct response (up to 5 marks)

Tip

- *It is an expectation that students include the correct states when writing balanced equations. The five examples included in this question have all appeared on recent VCAA Chemistry exams.*

Question 2a.i.

Worked solution



Explanatory notes

Alcohols can be formed by reaction of chloroalkanes with KOH or NaOH. The hydroxyl group is substituted for the chlorine atom. A salt is also formed.

Chloroethane is the obvious example, but other halogens could be used in place of chlorine.

Mark allocation: 1 mark

- 1 mark for drawing chloroethane or similar haloalkane

Tip

- *Organic flow chart questions are very common. You should rote learn the reagents or catalysts required for each step. Read the question carefully to see whether structural, skeletal or semi-structural responses are required.*

Question 2a.ii.

Worked solution

$C_2H_5Cl(g) + KOH(aq) \rightarrow C_2H_5OH(aq) + KCl(aq)$

Explanatory notes

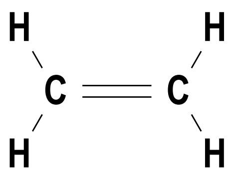
The hydroxyl group is substituted for the chlorine atom. The salt formed is KCl. NaOH could be substituted for KOH or OH^- without the spectator ion.

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation; states are not required

Question 2.b.i.

Worked solution



Explanatory notes

Ethene can be used to produce ethanol in an addition reaction.

Mark allocation: 1 mark

- 1 mark for drawing ethene

Question 2b.ii.

Worked solution

$C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$

Explanatory notes

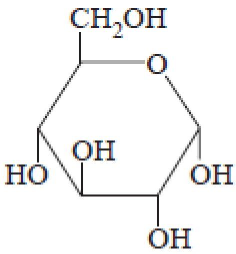
There is only one product, ethanol, in this reaction. The carbon-to-carbon double bond breaks when hydrogen atoms and hydroxyl groups bond to the molecule.

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation; states are not required

Question 2c.i.

Worked solution



Explanatory notes

Glucose can be converted by yeast to ethanol in fermentation reactions.

Mark allocation: 1 mark

- 1 mark for a sketch of glucose

Note: The sketch could match the one provided in the data book or it could show all bonds.

Question 2c.ii.

Worked solution

$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$

Explanatory notes

Glucose reacts in anerobic conditions to form ethanol and CO_2.

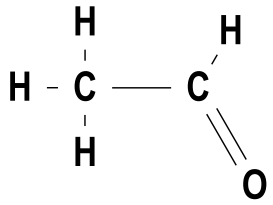
Mark allocation: 1 mark

- 1 mark for a correctly balanced equation

Note: States are not required, but mark is forfeited if ethanol is shown as a liquid.

Question 2d.i.

Worked solution



Explanatory notes

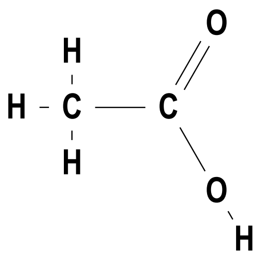
The first stage in the oxidation of a primary alcohol is the formation of an aldehyde.

Mark allocation: 1 mark

- 1 mark for drawing ethanal

Question 2d.ii.

Worked solution



Explanatory notes

Aldehydes will oxidise further to form carboxylic acids.

Mark allocation: 1 mark

- 1 mark for drawing ethanoic acid

Question 3a.i.

Worked solution

	Half-equation	Polarity
Anode	$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$	–ve
Cathode	$Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$	+ve

Explanatory notes

Both half-equations are provided in the electrochemical series in the data book. When the cell discharges, the reaction is between bromine liquid and zinc metal. The reaction of bromine is a reduction reaction, which will occur at the cathode. The cathode in a galvanic cell is positive.

Mark allocation: 3 marks

- 1 mark for each correct half-equation; states are not required (up to 2 marks)
- 1 mark for correct polarity

Question 3a.ii.

Worked solution

$Zn(s) + Br_2(l) \rightarrow 2Br^-(aq) + Zn^{2+}(aq)$

Explanatory notes

The overall reaction is between zinc metal and bromine liquid to form zinc ions and bromide ions.

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation with states

Question 3a.iii.

Worked solution

	Equation	Polarity
Anode	$2Br^-(aq) \rightarrow Br_2(l) + 2e^-$	+ve
Cathode	$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–ve

Explanatory notes

To recharge the cell, electrolysis is used to re-form the zinc and bromine. The reaction of bromide ions is an oxidation one that will occur at the anode. The anode in an electrolytic cell is positive.

Mark allocation: 3 marks

- 1 mark for each correct half-equation; states are not required (up to 2 marks)
- 1 mark for correct polarity

Question 3b.i.

Worked solution

Predicted voltage = 1.09 – (–0.76) = 1.85 V

Explanatory notes

The predicted voltage will be equal to the difference between the voltages of each half-equation given on the electrochemical series. The difference between the bromine and zinc half-equations is 1.85 V.

Mark allocation: 1 mark

- 1 mark for the correct voltage

Question 3b.ii.

Worked solution

The values on the electrochemical series assume standard conditions. This cell might not be operating at standard conditions.

Explanatory notes

The actual voltage obtained by a cell is often less than the predicted value because conditions are unlikely to be standard and cells have internal resistance.

Mark allocation: 1 mark

- 1 mark for a valid reason, such as non-standard conditions or internal resistance in the cell

Question 3c.

Worked solution

$n(\text{Zn}) = \dfrac{520}{65.4} = 7.95 \text{ mol}$

$n(\text{e}) = 2n(\text{Zn}) = 2 \times 7.95 = 15.9 \text{ mol}$

$Q = n(\text{e}) \times 96\,500 = 15.9 \times 96\,500 = 1.53 \times 10^6 \text{ C}$

$t = \dfrac{Q}{i} = \dfrac{1.53\times10^6}{4.8} = 3.2 \times 10^5 \text{ s}$

Explanatory notes

Zinc metal is oxidised in this cell. If all the zinc reacts, the number of mole reacting is 7.95. Every atom of zinc oxidised releases two electrons, allowing the amount of charge to be calculated and the time it takes for this reaction to occur.

Mark allocation: 3 marks

- 1 mark for calculation of number of mole of electrons
- 1 mark for calculation of charge
- 1 mark for calculation of time; answer must be to two significant figures

Tip

- *If your answer to this question used more than two significant figures, you are likely to lose the final mark. The value of 4.8 A given in the question has only two significant figures, so the answer should match. The number of significant figures of the answer are dictated by the item of data that has the least number of significant figures.*

Question 4a.i.

Worked solution

The relative molecular mass of the molecule is 88, which is double the relative mass of 44 of the empirical formula C_2H_4O. Therefore, the molecular formula must be $C_4H_8O_2$.

Explanatory notes

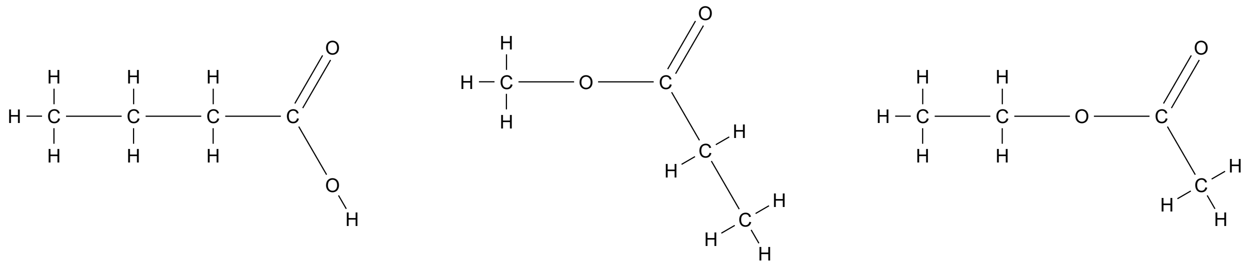
The empirical formula is C_2H_4O. The relative mass is ($12 \times 2 + 4 \times 1 + 16 = 44$). If you double 44, you get the relative molecular mass, so the empirical formula needs to be doubled to $C_4H_8O_2$.

Mark allocation: 2 marks

- 1 mark for correct molecular formula
- 1 mark for using the ratio between the relative molecular mass and the empirical formula mass

Question 4a.ii.

Worked solution



Explanatory notes

The molecular formula matches that of a carboxylic acid or an ester.

Mark allocation: 3 marks

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

Note: There are more than three possible structures.

Question 4a.iii.

Worked solution

If the pH is less than 4, the solution is acidic, suggesting that the molecule is more likely to be a carboxylic acid than an ester. If the pH is greater than 4, the solution might be an ester.

Explanatory notes

The molecular formula is consistent with the molecule in question being either a carboxylic acid or an ester. A pH reading will be low if the solution is acidic and it will be close to 7 if the molecule is an ester.

Mark allocation: 1 mark

- 1 mark for an explanation that suggests a pH reading will distinguish an acid from an ester

Question 4b.

Worked solution

The molecule is likely to be butanoic acid because it will have absorptions at 3000 cm^{-1} and 1700 cm^{-1}, suggesting a –OH (acid) and a C=O bond.

Explanatory notes

The infra-red (IR) spectrum has a broad absorption around 3000 cm^{-1}, which suggests a –OH (acid) functional group, and the absorption around 1700 cm^{-1} is consistent with that of a C=O carbonyl group. Butanoic acid has both of these absorptions, but an ester will not have the broad absorption around 3000 cm^{-1}.

Mark allocation: 2 marks

- 1 mark for suggesting butanoic acid
- 1 mark for using valid absorptions for justification

Question 4c.

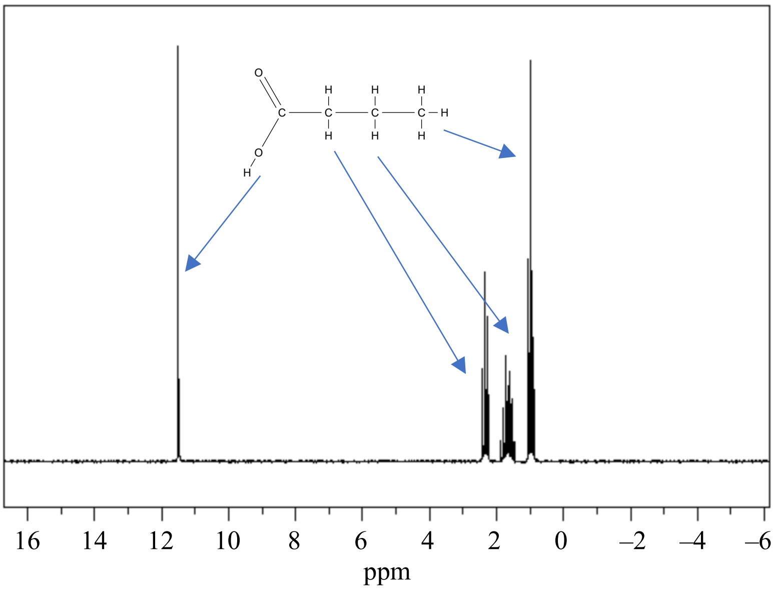
Worked solution

Butanoic acid has four different hydrogen environments. The diagram below shows which part of the molecule causes each set of peaks.

From left to right, the

- –OH has no neighbouring hydrogen atoms → singlet
- first CH_2 has two hydrogen neighbours → triplet
- second CH_2 has five hydrogen neighbours → sextet
- –CH_3 has two hydrogen neighbours → triplet

This is INCORRECT. The 5 hydrogen atoms on adjacent carbon atoms are NOT all equivalent. The second CH_2 will NOT be split into a sextet; it has a complex multiplet splitting pattern.



Mark allocation: 4 marks

- 1 mark for each slitting pattern identified and explained (up to 4 marks)

Note: An explanation that refers to the shift values of each environment could also achieve full marks.

Tip

- *Students often pick the correct structure in instrumentation questions but can find it difficult to explain how they know their answer is correct. The use of an annotated sketch of the molecule can be an effective way to demonstrate this understanding.*

Question 5a.i.

Worked solution

octanoic acid

Explanatory notes

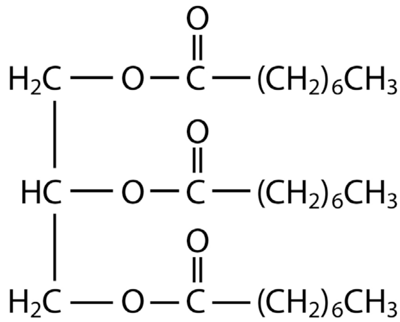
The ester is formed from a carboxylic acid and an alcohol. The carboxylic acid will be octanoic acid because it contains eight carbon atoms.

Mark allocation: 1 mark

- 1 mark for octanoic acid

Question 5a.ii.

Worked solution



Explanatory notes

The triglyceride formed will contain three ester bonds. Each ester bond forms when a molecule of caprylic acid reacts with a hydroxyl group on glycerol.

Marking allocations: 2 marks

- 1 mark for ester bonds drawn correctly
- 1 mark for overall triglyceride structure

Tip

- *It can be easy to struggle drawing biodiesel and triglyceride structures, particularly with ester bonds and distinguishing between the fatty acid and the triglyceride. You must be able to correctly draw an ester or triglyceride from the structures provided in the data book.*

Question 5b.

Worked solution

Methanol is the alcohol usually used to make biodiesel. The choice of ethanol in biodiesel a offers a more sustainable pathway. Ethanol can be produced on a large scale from petroleum or from waste organic matter. If the ethanol is sourced from byproducts of the wheat industry, for example, the production of this form of biodiesel could be sustainable and considered fully renewable. The detrimental impact on the environment would be less than the damaging impact from using the non-renewable alternative, petrodiesel.

Explanatory notes

Biodiesel is made from the reaction of a triglyceride with an alcohol. If the triglyceride and the alcohol are both sourced from organic waste matter, then the production will be a sustainable one. Methanol is often the alcohol used to produce biodiesel, and it is often sourced from petroleum. The shift to ethanol would be a positive move for the environment because all raw materials could be produced sustainably.

Mark allocation: 2 marks

- 1 mark for reference to the production of bioethanol
- 1 mark for a favourable comparison with petrodiesel

Question 5c.

Worked solution

$C_{10}H_{20}O_2(l) + 14O_2(g) \rightarrow 10CO_2(g) + 10H_2O(l)$

Explanatory notes

Complete combustion will form CO_2 and H_2O. The biodiesel must be a liquid because it does not form aqueous solutions.

Mark allocation: 2 marks

- 1 mark for the correct products
- 1 mark for the correct coefficients and states

Question 5d.

Worked solution

M(biodiesel) = 10 × 12 + 20 × 1 + 16 × 2 = 172 g mol^{-1}

n(biodiesel) = $\frac{1000}{172} = 5.81$ mol

$n(CO_2)$ = 10 × n(biodiesel) = 58.1 mol

$V = \frac{nRT}{P} = \frac{58.1 \times 8.31 \times 628}{160}$ = 1895 L = 1900 = 1.90 × 10^3 L

Explanatory notes

This calculation involves several sequential steps:

1. Find the number of mol of biodiesel.
2. Use the mole ratio of biodiesel to CO_2 to find the number of mole of CO_2.
3. Use $PV = nRT$ to determine the volume of the CO_2 produced.

Mark allocation: 4 marks

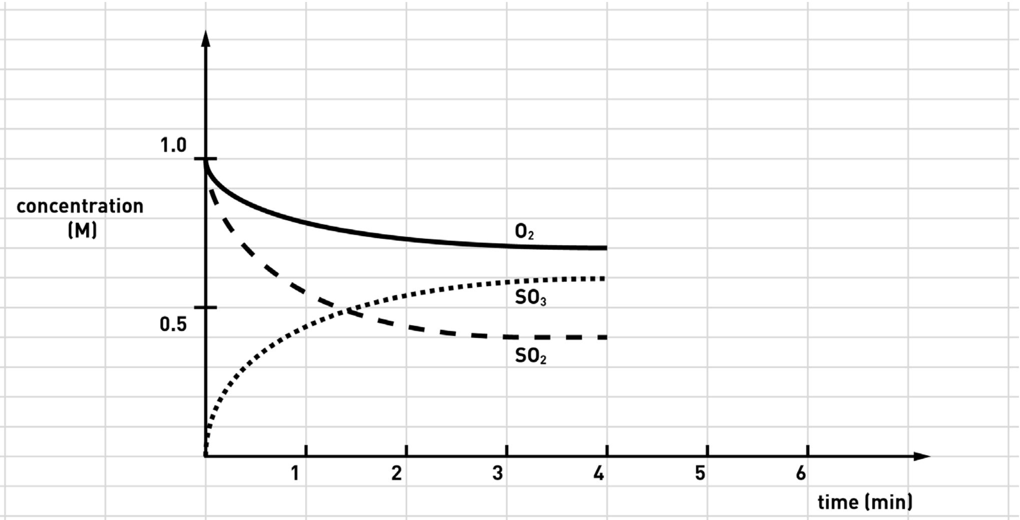
- 1 mark for biodiesel molar mass
- 1 mark for number of mole of biodiesel
- 1 mark for number of mole of CO_2
- 1 mark for correct use of ideal gas equation

Tip

- *It is an expectation that you can complete numerical calculations correctly. The assessors do not have many topics they can use to assess these numerical skills. Therefore, expect that either the volume of exhaust gas will need to be calculated or the concentration of an organic acid or base will need to be determined from titration data.*

Question 6a.i.

Worked solution



Explanatory notes

The concentration of oxygen drops by 0.3. Given the stoichiometry of the reaction, the SO_2 must drop by 0.6 and the concentration of the SO_3 increase by 0.6. Since the starting amounts of SO_2 and O_2 are equal, the graph for SO_2 should also start at 1.0.

Mark allocation: 2 marks

- 1 mark for each consistent graph (up to 2 marks)

Question 6a.ii.

Worked solution

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(0.6)^2}{(0.4)^2(0.7)} = 3\ M^{-1}$$

Explanatory notes

The equilibrium concentrations of all three species need to be read from the graph and substituted into the expression for K_c. The graphs drawn need to be consistent with the stoichiometry of the equation for you to obtain a correct answer.

Marking allocation: 2 marks

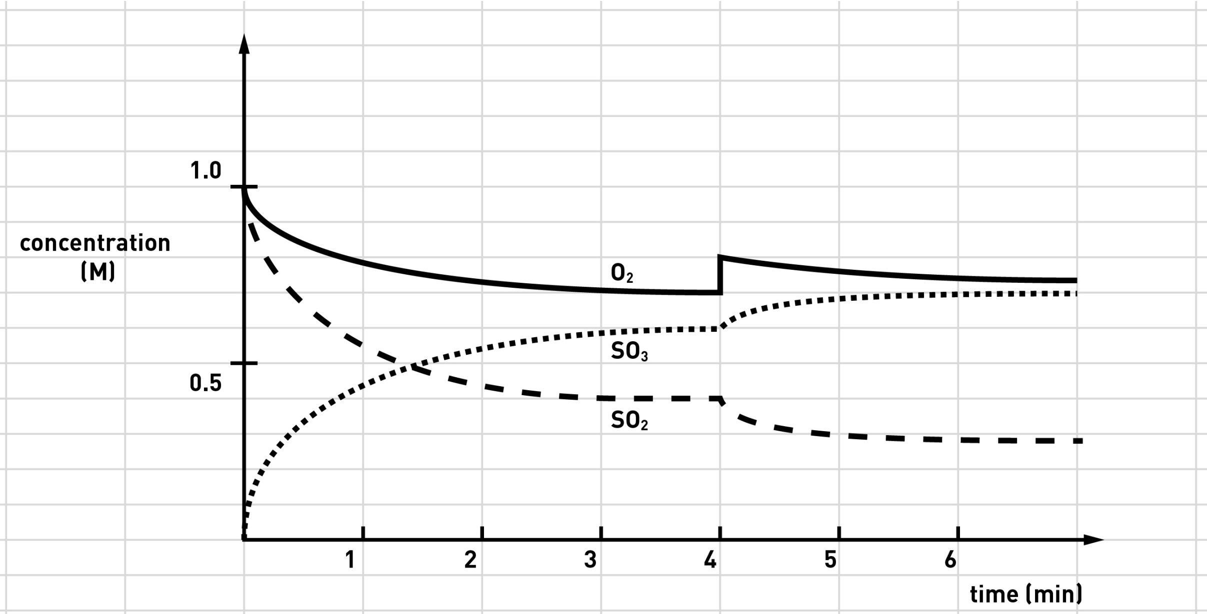
- 1 mark for substituting concentrations into an expression for K_c
- 1 mark for correct answer and units; answer must include one significant figure

Tips

- *Make sure you include a ruler in the stationery you bring into the exam. It can be useful to help read graph values correctly or to draw graphs accurately.*
- *It is expected that you can determine the correct units for each equilibrium constant calculation.*

Question 6b.

Worked solution



Explanatory notes

The O_2 concentration increases immediately from 0.7 M to 0.8 M. The system opposes this increase by favouring the forward reaction. The concentration of the O_2 will drop but it will not drop to, or below, 0.7 M.

The concentration of SO_2 will drop by twice as much as you have shown the O_2 concentration dropping.

The concentration of SO_3 will increase by the same amount as the SO_2 concentration has dropped.

Mark allocation: 3 marks

- 1 mark for each graph that is consistent with Le Chatelier's principle and the stoichiometry of the equation (up to 3 marks)

Question 6c.i.

Worked solution

The value of K_c will decrease.

Explanation

This is an exothermic reaction. The value of K_c will drop when the temperature is increased.

Mark allocation: 1 mark

- 1 mark for stating 'decrease'

Question 6c.ii.

Worked solution

The amount of SO_3 gas will decrease.

Explanatory notes

If the value of K_c drops, the back reaction is favoured, lowering the amount of SO_3.

Mark allocation: 1 mark

- 1 mark for stating 'decrease'

Question 6c.iii.

Worked solution

The total amount of gas will increase.

Explanatory notes

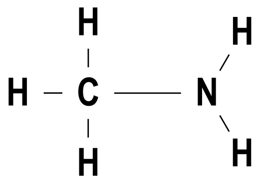
If the back reaction is favoured, the amount of reactant increases at the expense of product. The stoichiometry shows that the total amount of gas will increase if the reverse reaction is favoured.

Mark allocation: 1 mark

- 1 mark for stating 'increase'

Question 7a.i.

Worked solution



Explanatory notes

Amines contain $–NH_2$, and meth- indicates one carbon, and -an indicates only carbon-to-carbon single bonds are present.

Mark allocation: 1 mark

- 1 mark for the correct structure

Question 7a.ii.

Worked solution

$HCl(aq) + CH_3NH_2(aq) \rightarrow CH_3NH_3^+(aq) + Cl^-(aq)$

Explanatory notes

HCl acts as an acid by donating a proton. The proton bonds with methanamine to form $CH_3NH_3^+(aq)$. The amino group on the methanamine accepts the proton, acting as a base.

Mark allocation: 1 mark

- 1 mark for a correct equation with states

Question 7b.i.

Worked solution

$n(HCl) = c \times V = 0.36 \times 0.0122 = 0.004392$ mol

$n(CH_3NH_2) = n(HCl) = 0.004392$ mol

$c(CH_3NH_2) = \frac{n}{V} = \frac{0.004392}{0.02} = 0.2196 = 0.220$ M

Mark allocation: 2 marks

- 1 mark for the correct number of mole of HCl
- 1 mark for the correct concentration of methanamine

Question 7b.ii.

Worked solution

c(original solution) = $\frac{0.220}{1} \times \frac{250}{20} = 2.7 \text{ M}$

Explanatory notes

20 mL of the original solution was diluted to 250 mL. This is a dilution factor of 12.5. The original solution is 12.5 times more concentrated than that of the diluted solution.
$C_1V_1 = C_2V_2$ could also be used to arrive at the same answer.

Mark allocation: 1 mark

- 1 mark for applying a factor of 12.5 to the diluted concentration

Question 7c.i.

Worked solution

The HCl will be diluted slightly by the water present. The titre will be higher than it should be.

Explanatory notes

The water left in the burette will dilute the HCl. More HCl is required than expected as it will be more dilute than it should be.

Mark allocation: 1 mark

- 1 mark for stating the titre will be higher than it should be

Question 7c.ii.

Worked solution

The concentration obtained will be higher than it should be.

Explanatory notes

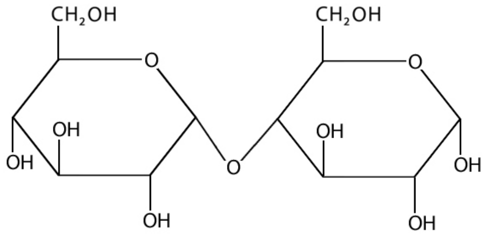
The higher titre value will lead to a high value for the calculated mole of HCl. The subsequent value for the concentration of the methanamine will also be high.

Mark allocation: 1 mark

- 1 mark for stating the concentration will be higher than it should be

Question 8a.i.

Worked solution



Explanatory notes

Starch is a polymer of glucose. The action of amylase and maltase will hydrolyse the starch to glucose. When two glucose molecules join, maltose is formed.

Mark allocation: 1 mark

- 1 mark for drawing maltose (the name maltose is not required, only the structure)

Question 8a.ii.

Worked solution

–OH hydroxyl group

Explanatory notes

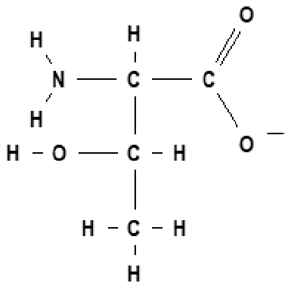
A disaccharide will have up to eight hydroxl groups on it. It will have a glycosidic (ether) linkage, but only one of these. Sucrose (drawn in your data book) can be referenced as a similar example.

Mark allocation: 1 mark

- 1 mark for an answer of hydroxyl, or for drawing –OH

Question 8b.i.

Worked solution



Explanatory notes

The structure of threonine is provided in the data book. The significance of the alkaline conditions is that the amino acid will donate a proton from its structure, leaving it as a negative ion.

Mark allocation: 1 mark

- 1 mark for the correct structure

Question 8b.ii.

Worked solution

The ion in acidic conditions will be two units / g mol^{-1} heavier than the ion in alkaline conditions.

Explanatory notes

In acidic conditions there are excess H^+ ions present. One hydrogen ion will attach to the nitrogen of the amine group and another hydrogen ion will attach to the carboxyl ion. This makes the molecular mass two units heavier than the ion drawn in **part b.i.**

Mark allocation: 1 mark

- 1 mark for stating that the ion at low pH will be 2 units / g mol^{-1} heavier than the ion at high pH

Question 8c.i.

Worked solution

Test 1 is denaturation. This can be concluded because the enzyme is no longer functioning as an enzyme, but its primary structure is still in place.

Explanatory notes

Enzymes can denature when heated or exposed to acidic conditions. The enzyme loses its functioning because it loses its shape. It is still a protein because the primary structure is intact.

Mark allocation: 2 marks

- 1 mark for correctly identifying this process as denaturation
- 1 mark for explaining that the tertiary structure is disrupted

Question 8c.ii.

Worked solution

Test 2 is hydrolysis. Strong acid can break the peptide links that hold the protein together, leading to the reforming of the original amino acids.

Explanatory notes

Heat and strong acid are used for this test. The primary structure of the protein breaks as the covalent peptide (amide) bonds break. Amino acids are formed in this process.

Mark allocation: 2 marks

- 1 mark for identifying this process as hydrolysis
- 1 mark for explaining that the primary structure of the protein has been broken and that the original amino acids have reformed

Tip

- *Read the Study Design carefully to make note of what concepts are referred to directly; for example, the distinction between hydrolysis and denaturation is specifically mentioned.*

Question 8d.

Worked solution

Energy released = 0.60 × 37 = 22.2 kJ

Energy = 4.18 × 200 × Δ*T* = 22 200

$$\Delta T = \frac{22\,000}{4.18 \times 200} = 26.6\ °\text{C}$$

Final temperature = 22.6 + 26.6 = 49.2 °C = 49 °C (to two sig. figures)

Explanatory notes

Stearic acid is a triglyceride. The data book provides a value of 37 kJ per gram of fat combusted.

The energy released by 0.6 g of triglyceride is 22 200 J. This energy is used to heat 200 g of water, so the temperature change can be calculated.

Mark allocation: 2 marks

- 1 mark for calculating the energy released
- 1 mark for the resulting temperature change

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Question 9a.i.

Worked solution

independent variable: volume of water added or concentration of copper solution

Explanatory notes

Extra increments of water are added to the copper half-cell prior to each reading.

Mark allocation: 1 mark

- 1 mark for identifying the water volume or concentration of copper solution

Question 9a.ii.

Worked solution

dependent variable: current

Explanatory notes

The current produced in the cell varies due to the concentration of the solution. The current depends upon the volume of water added.

Mark allocation: 1 mark

- 1 mark for identifying the cell current

Question 9a.iii.

Worked solution

controlled variable: same salt bridge retained

Explanatory notes

There are several controlled variables: the same zinc half-cell (and zinc ion concentration) is used the whole time, the same salt bridge, the same electrodes, and the temperature is probably constant.

Mark allocation: 1 mark

- 1 mark for a valid response

Tip

- *This experiment-design style of question is now an accepted part of each Chemistry exam. Practice is required to anticipate the type of responses expected.*

Question 9b.

Worked solution

The data suggests the opposite conclusion to that made by the student (i.e. that the current is increasing as the concentration decreases). The student has not realised that the addition of water is actually lowering the concentration of the copper half-cell.

Explanatory notes

Each water increment is reducing the copper ion concentration. The data shows that the current is increasing as the concentration drops.

Mark allocation: 2 marks

- 1 mark for stating the student's conclusion is inconsistent with the data
- 1 mark for outlining why the student's conclusion is inconsistent

Question 9c.

Worked solution

As the student adds water, they are inadvertently introducing another variable: the surface area of the electrode in the solution. Each increment means more of the electrode is covered by solution and, perhaps, it is this increase that is leading to the increase in current.

The student should control the volume of the copper solution by preparing solutions of a range of concentrations and adding the same volume of each solution each time a reading is to be taken.

Explanatory notes

The student should ensure the volume used for each copper solution is constant, so that concentration is the only variable being investigated. The preparation of a series of standard solutions of a set volume would allow this.

Marking allocation: 3 marks

- 1 mark for identifying a flaw with the experimental design
- 2 marks for offering a changed design to address this problem

Note: There could be other valid responses to this question such as need for constant stirring of the solution or preference to use a new zinc half-cell for each experiment.

Question 10a.

Worked solution

<u>Carbohydrates present:</u>

Cellulose: The dietary fibre will be mainly cellulose. It is a polymer formed from a β-glucose monomer.

Starch: There is a significant amount of carbohydrate that is not cellulose and not a sugar. This is likely to be starch. Starch is a polymer formed from α-glucose.

Lactose: The milk will contain lactose, which is a disaccharide.

It is not possible to determine the composition of the other sugars that are present.

<u>Metabolism:</u>

Humans cannot digest most cellulose, so it is labelled as fibre. We do not produce cellulase nor do we have a significant microbial sac. (Koalas and elephants are examples of animals with sacs in their intestine that have high concentrations of microorganisms that can break down cellulose.)

Starch will be hydrolysed to glucose. The glucose will then pass into the bloodstream to be used elsewhere.

Most humans can digest lactose, as they produce lactase to hydrolyse the lactose to glucose and galactose. Some humans are lactose intolerant because they do not produce lactase.

Mark allocation: 5 marks

Note: More humans are lactose intolerant than tolerant.

- This question is marked depending on the clarity with which the student addresses the dot points in the question. A good response must:
  - identify the carbohydrates that are likely to be present
  - provide a description of the composition of each carbohydrate
  - explain the likely metabolism of each carbohydrate.

Tip

- *This is another style of question that has evolved in the past few years of the Chemistry exam, which requires students to discuss a concept or theme. Make sure you take note of the mark allocation; you cannot score five marks if you make only three points. Also check that you are addressing any specific dot points given as part of the question.*

Question 10b.i.

Worked solution

C18.2 will correspond to linoleic acid because it has 18 carbon atoms and two carbon-to-carbon double bonds.

Explanatory notes

The data book lists linoleic acid as $C_{17}H_{31}COOH$. This formula has 18 carbon atoms and two carbon-to-carbon double bonds, matching the fatty acid in the question.

Marking allocation: 1 mark

- 1 mark for identifying linoleic acid

Question 10b.ii.

Worked solution

The unsaturated fatty acids are C18.2, C18.1 and C18.3.

The total percentage = 44.8 + 36.2 + 1.2 = 82.2%

Explanatory notes

Unsaturated fats have carbon-to-carbon double bonds. The percentage will be the total of the fatty acids where the final number is not zero (e.g. C18.2 will have two carbon-to-carbon double bonds).

Mark allocation: 1 mark

- 1 mark for the correct percentage

END OF WORKED SOLUTIONS