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YEAR 12 *Trial Exam Paper*

2022
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	*D*
2	*C*
3	*C*
4	*A*
5	*A*
6	*C*
7	*B*
8	*C*
9	*D*
10	*C*
11	*B*
12	*A*
13	*B*
14	*C*
15	*D*

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

Question 1

Answer: D

Explanatory notes

Option D is correct. This is the process occurring when biogas forms. Biogas typically has a methane content of around 70%.

Option A is incorrect. Biodiesel is formed from this reaction.

Option B is incorrect because fermentation will produce ethanol.

Option C is incorrect because the components left at the bottom of a fractionating column will be long alkane molecules.

Question 2

Answer: C

Explanatory notes

Option C is correct. The molar mass will equal the molar mass of
lauric acid + methanol – water = 200 + 32 – 18 = 214 g mol^{-1}.

Option A is incorrect because that is the molar mass of only lauric acid.

Option B is incorrect. The answer is 214 g mol^{-1}.

Option D is incorrect. The mass of water has not been subtracted.

Tip

- *To answer this question, you must know the structure of lauric acid. This is provided in the table of fatty acids in your data book. It is good practice to flip through the data book the day before the exam to ensure that you can locate each table or structure efficiently during the exam.*

Question 3

Answer: C

Explanatory notes

Option C is correct. The balanced equation for the reaction between butane and oxygen has the required mole ratio of 2:13 between the fuel and oxygen.

$2C_4H_{10}(l) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$

Option A is incorrect because 2 mole of ethane reacts with 7 mole of oxygen gas.

Option B is incorrect because 2 mole of propane reacts with 10 mole of oxygen gas.

Option D is incorrect because 2 mole of pentane reacts with 16 mole of oxygen gas.

Question 4

Answer: A

Explanatory notes

Option A is correct. Hydrogen gas has a greater energy density than the other fuels listed. 100 g of hydrogen would release 100 × 141 = 1.41×10^4 kJ.

Option B is incorrect. 200 g of methane releases 200 × 55.6 = 1.11×10^4 kJ.

Option C is incorrect. 220 g of ethane releases 220 × 51.9 = 1.14×10^4 kJ.

Option D is incorrect. 225 g of propane releases 225 × 50.5 = 1.14×10^4 kJ.

Tip

- *For this question, there is no need to convert the masses to mole. The heats of combustion are supplied in the data book in both mass and mole formats. Use the unit that matches the unit used in the question.*

Question 5

Answer: A

Explanatory notes

Option A is correct. Energy is always required to break the bonds in a reactant, therefore the activation energy is always positive.

Option B is incorrect because the mechanism of a catalyst is lowering the activation energy.

Option C is incorrect. The forward and back reactions will have different activation energies because different bonds are breaking.

Option D is incorrect. The value of ΔH needs to be high but the activation energy does not necessarily need to be high.

Question 6

Answer: C

Explanatory notes

Option C is correct. The value of ΔH for this reaction is –700 – 1520 = –2220 kJ mol^{-1}. From the data book, this corresponds to propane.

Options A, B and D are incorrect because the value of ΔH is not –2220 kJ mol^{-1}.

Question 7

Answer: B

Explanatory notes

Option B is correct. When reversing an equation, the sign of ΔH is changed; that is, –92 kJ mol^{-1}, and K_c is the reciprocal of that of the forward reaction; that is, $\frac{1}{0.8} = 1.25$.

Option A is incorrect because the K_c of the reverse equation must be the reciprocal of the value of the forward reaction.

Option C is incorrect. ΔH of the reverse equation is not the reciprocal of the forward reaction.

Option D is incorrect. ΔH of the reverse equation is not the reciprocal of the forward reaction and it must be a negative value.

Tip

- *For questions of this nature, there are standard changes made to equations. For example, reversing the equation will change the sign of ΔH but it makes the K_c the reciprocal. Learn the effect of each change.*

Question 8

Answer: C

Explanatory notes

Option C is correct.

$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$

0.8 – 2x	x	3x
0.8 – 0.4	0.2	3 × 0.2
0.4	0.2	0.6

The amount of H_2 that forms will be three times that of N_2, and the amount of NH_3 reacting will be double the amount of N_2 that formed.

Option A is incorrect because the amount of H_2 formed is incorrect.

Option B is incorrect because the amount of NH_3 must be lower than it was before the reaction.

Option D is incorrect. The amount of NH_3 must be lower than it was before the reaction, and the amount of H_2 is wrong.

Question 9

Answer: D

Explanatory notes

Option D is correct. The increased temperature will lead to an increase in the reaction rate. But the forward reaction is exothermic, so the yield will decrease.

Option A is incorrect because the reaction rate will increase.

Option B is incorrect on both accounts – the reaction rate will be higher and the yield will be lower.

Option C is incorrect. The yield of methanol will be lower.

Question 10

Answer: C

Explanatory notes

Option C is correct. 10 g of Mg = $\frac{10}{24.3}$ = 0.41 mol

In Experiment A, HCl is the limiting reagent.

In Experiment B, Mg is the limiting reagent.

	$Mg(s)$	+	$2HCl(aq) \rightarrow MgCl_2(aq)$	+	$H_2(g)$
Experiment A:	0.41 mol		0.60 mol →		0.3 mol
Experiment B:	0.41 mol		1.2 mol →		0.41 mol

Option A is incorrect. The higher HCl concentration will lead to a higher reaction rate.

Option B is incorrect. Experiment B will produce a greater volume of H_2 than Experiment A.

Option D is incorrect. The volume of H_2 produced is not double that produced in Experiment A.

Question 11

Answer: B

Explanatory notes

Option B is correct. Let us consider each statement.

I Oxidation occurs at the anode. This is true for any type of cell.

II The anode will be negative. This applies to a galvanic cell but not an electrolytic cell.

III Electrons travel from the anode to the cathode. This is true because oxidation releases electrons.

IV The cell produces energy. This is true only for a galvanic cell.

V The strongest oxidant will react with the strongest reductant. This statement applies to both cells.

Option A is incorrect because statement II is not correct.

Options C and D are incorrect because statement IV is not correct.

Question 12

Answer: A

Explanatory notes

Option A is correct. If the cell voltage of the left-hand cell is 1.08 V, the potential of the $Cr^{3+} + 3e^- \rightarrow Cr(s)$ half-cell will be $0.34 - 1.08 = -0.74$ V.

The cell voltage for the right-hand cell will be $-0.25 - -0.74 = 0.49$ V.

Option B is incorrect because chromium will not be the positive electrode.

Option C is incorrect because the cell voltage is not correct.

Option D is incorrect. The cell voltage is not correct nor is the polarity.

Tip

- *The polarity given in the diagram's left cell is very useful. If copper is the positive electrode, this tells you that its half-equation is higher up the electrochemical table than that of chromium. The positive electrode will definitely be the cathode as well. This is a useful procedure to follow in questions like this – look for the positive electrode and then be aware that the reaction there is reduction, and the other half-equation will be lower on the electrochemical series.*

Question 13

Answer: B

Explanatory notes

Option B is correct. The half-equation is $Cr^{3+} + 3e^- \rightarrow Cr(s)$ and the potential is $0.34 - 1.08 = -0.74$ V.

Option A is incorrect. The oxidation state of chromium ions is Cr^{3+}.

Options C and D are incorrect. The cell potential should be –0.74 V.

Question 14

Answer: C

Explanatory notes

Option C is correct. Although the axes do not have numerical values, the same amount of charge is producing less of X than of copper. Therefore, the charge of X ions is probably X^{3+}, which matches aluminium. To obtain aluminium by electrolysis, a molten electrolyte is required.

Option A is incorrect because no metal would be deposited from a solution of LiCl. Also, if it was lithium, the gradient would be double that of copper because the charge of lithium ions is +1.

Option B is incorrect because zinc ions and copper ions have the same charge, so will produce the same number of mole of metal.

Option D is incorrect. No aluminium will be produced from an aqueous aluminium solution.

Tips

- *The lack of numerical values on the axes makes this an example of a high-level question that is typical of a Chemistry exam. The question has a simple solution when you apply your understanding of electrolysis principles.*
- *There is a common trap in this question – if the metal half-equation has a potential lower than that of the water half-equation at –0.83 V, water will react instead of the metal ion.*

Question 15

Answer: D

Explanatory notes

Option D is correct. $n(\text{Cr}) = \frac{3.12}{52} = 0.06 \text{ mol} \Rightarrow n(\text{e}) = 3 \times n(\text{Cr}) = 0.18 \text{ mol}$

$Q = 96\,500 \times 0.18 = 17\,400 \text{ C}$

For option D, $Q = It = 174 \times 100 = 17\,400$ C.

Option A is incorrect because the $n(\text{Cr}) \neq n(\text{e})$.

Option B is incorrect. The chromium:electron ratio is not 1:2.

Option C is incorrect. The amount of charge is not equal to 17 400 C.

Tip

- *You do not have to waste time being careful of significant figures in questions like this. The values of the alternatives are all separated enough that you should be able to select the correct answer even if you have used only two significant figures on your calculator.*

Question 16

Answer: C

Explanatory notes

Option C is correct. Ketones can be formed from oxidation of secondary alcohols.

Option A is incorrect. The reaction of an alcohol and a carboxylic acid produces an ester.

Option B is incorrect. Butanoic acid is not easily oxidised.

Option D is incorrect. The formation of a ketone is from an oxidation reaction, not from a substitution reaction.

Question 17

Answer: B

Explanatory notes

Option B is correct. There are five carbon atoms in the chain and no carbon-to-carbon double bonds, so it is a pentane derivative. Alcohol groups have precedence over amine groups, so number from the right-hand side.

Option A is incorrect because it gives a higher priority to an amine group rather than an alcohol group.

Options C and D are incorrect. The alcohol component should be shown using the suffix -ol. It is also not a butane derivative.

Tip

- *The IUPAC naming system gives functional groups an order of priority, starting with carboxylic acids. Make sure you learn this order off by heart.*

Question 18

Answer: C

Explanatory notes

Option C is correct. Propanal will have dispersion forces and the presence of an oxygen atom will add dipole forces. It does not have hydrogen bonds because the oxygen atom is not bonded to a hydrogen atom.

Options A, B and D are incorrect because propanal does not have hydrogen bonds.

Tip

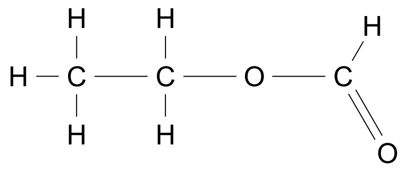
- *A discussion of solubility is different from a discussion of boiling point. Liquid propanal will not form hydrogen bonds but propanal can form hydrogen bonds with water when it dissolves.*

Question 19

Answer: B

Explanatory notes

Option B is correct. Ethyl methanoate has three hydrogen environments.



Option A is incorrect because propanone has one hydrogen environment.

Option C is incorrect. Methyl ethanoate has two hydrogen environments.

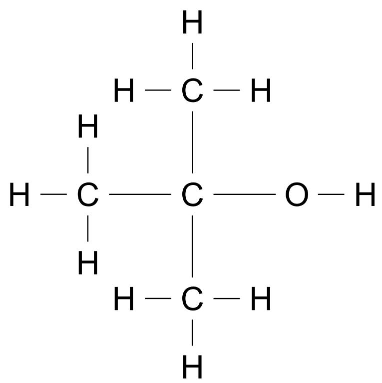
Option D is incorrect. This molecule would have a broad infra-red absorption above 2500 cm^{-1}.

Question 20

Answer: A

Explanatory notes

Option A is correct. The molecule shown is the only option with two hydrogen environments.



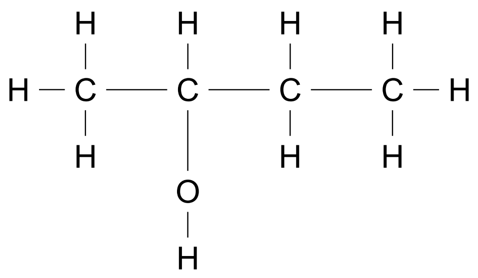
Options B, C and D are incorrect because they will have more than two hydrogen environments.

Question 21

Answer: C

Explanatory notes

Option C is correct. Butan-2-ol is a secondary alcohol. It will form a ketone when it is oxidised by $Cr_2O_7^{2-}$. A ketone will not react with Na_2CO_3.



Option A is incorrect because butan-1-ol will form an acid when oxidised.

Option B is incorrect. This alcohol will not be oxidised because it is a tertiary alcohol.

Option D is incorrect. It would form an acid when oxidised.

Tip

- *There are some standard chemical reactions of organic compounds that you need to know:*
  - *A carboxylic acid will react with carbonate ions.*
  - *A primary alcohol can be oxidised to a carboxylic acid. This is evident by a colour change.*
  - *A secondary alcohol is oxidised to a ketone. This is evident by a colour change.*
  - *A tertiary alcohol does not oxidise.*

Question 22

Answer: B

Explanatory notes

Option B is correct. The titration is between a strong acid (HCl) and a weak base. The transition will occur at a pH around 3 to 5, which matches bromophenol blue.

Options A and C are incorrect because the transition pH is too high.

Option D is incorrect. Phenolphthalein is better suited to a titration between a weak acid and a strong base. Its transition point is too high, being from pH 8 to 10.

Question 23

Answer: B

Explanatory notes

Option B is correct. With a polar solvent, molecules will emerge in order of polarity. Ethanol, being a small molecule, is more polar than heptan-1-ol and both will be more polar than an equivalent chloroalkane. Hexane is non-polar and likely to emerge last.

Options A and C are incorrect. Hexane will have the longest retention time because it is non-polar.

Option D is incorrect. This is the reverse order of the correct answer.

Question 24

Answer: D

Explanatory notes

Option D is correct. The metabolism of starch starts in your mouth, where the amylase in saliva can start the hydrolysis procedure. Other food groups will not start reacting until they reach the stomach or intestines.

Option A is incorrect because the metabolism of fats occurs mainly in the small intestine.

Option B is incorrect. Amylase does not affect protein.

Option C is incorrect. Humans cannot process most fibre.

Question 25

Answer: C

Explanatory notes

Option C is correct. Enzyme reactions cause fruit to go brown. The acidity of lemon juice takes it further from its optimum pH.

Option A is incorrect because lemon juice is unlikely to increase activation energy.

Option B is incorrect. Lemon juice is an aqueous solution that will not form a waterproof barrier.

Option D is incorrect. If the protein in banana was hydrolysed, the taste, texture and colour would be very different.

Tip

- *It is expected that you will be able to connect classroom concepts with the everyday world. Some examples of contexts used in recent VCAA Chemistry exams are in regard to the atmosphere on Mars, poaching eggs and the operation of a submarine.*

Question 26

Answer: A

Explanatory notes

Option A is correct. Foods that are high in amylopectin will hydrolyse to glucose faster than foods that are high in amylose.

Option B is incorrect because the energy density of both forms of starch will be similar.

Option C is incorrect. Neither forms of starch are particularly sweet.

Option D is incorrect. The potatoes should soften faster than legumes because amylopectin is slightly soluble in water.

Question 27

Answer: D

Explanatory notes

Option D is correct. The energy per gram = $0.21 \times 17 + 0.25 \times 16 + 0.54 \times 37 = 27.6$ kJ

Energy from 1.5 g = $1.5 \times 27.6 = 41$ kJ

Option A is incorrect because the factor of 1.5 has not been applied.

Options B and C are incorrect. The answer is 41 kJ.

Question 28

Answer: C

Explanatory notes

Option C is correct. Each molecule of linoleic acid contains two carbon-to-carbon double bonds. The three branches of a triglyceride will include six carbon-to-carbon double bonds.

Option A is incorrect because each linoleic acid chain will have two carbon-to-carbon double bonds.

Option B is incorrect. A triglyceride will contain three fatty acid chains, not one.

Option D is incorrect. This would be correct for linoleic acid.

Question 29

Answer: B

Explanatory notes

Option B is correct. Humans process only a small percentage of dietary fibre, so replacing some of the sugar with fibre will lower the amount of energy we derive from the muesli bar.

Option A is incorrect because aspartame has a similar energy density to sucrose.

Option C is incorrect. Oil will release more energy than sucrose.

Option D is incorrect. Whatever you replace the sweeteners with will likely add a similar amount of energy.

Question 30

Answer: D

Explanatory notes

Option D is correct. A pipette will have less uncertainty than a measuring cylinder. This will lead to increased precision when using the pipette.

Option A is incorrect because the measuring cylinder does not have less uncertainty.

Option B is incorrect. The uncertainty of the measuring cylinder is greater but this does not make the data invalid.

Option C is incorrect. The measuring cylinder does not necessarily have a systematic error, it is just hard to read accurately.

SECTION B

Question 1a.

Worked solution

A fuel cell is more efficient because it converts chemical energy directly to electrical energy and it does not lead to as much wasted thermal energy. The gas-fired power station has many energy transformations and each one leads to some loss of energy.

Explanatory notes

In a fuel cell, chemical energy is converted directly to electrical energy. In a gas-fired power station, a series of energy conversions is required, and energy is lost to the system from each conversion.

Mark allocation: 2 marks

- 1 mark for a valid reason
- 1 mark for an explanation

Question 1b.

Worked solution

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

Explanatory notes

The reaction of methane in a fuel cell will be the same as the complete combustion equation. The products are CO_2 and H_2O.

Mark allocation: 1 mark

- 1 mark for a balanced equation showing correct states

Tips

- *There is a specific dot point in the Study Design that refers to the comparison of fuels in a fuel cell with the combustion of fuels.*
- *It is also safer to show H_2O as a liquid rather than a gas in a combustion reaction. If the question specifically mentions standard laboratory conditions (SLC) or asks for a thermochemical equation, water must be shown as a liquid. In a question such as this, either would be accepted.*

Question 1c.i.

Worked solution

The mass of methane required to produce 1.0 MJ of energy = $\frac{1000}{55.6}$ = 17.98 g.

The process, however, is only 42% efficient, so the mass will be $\frac{17.98 \times 100}{42}$ = 42.8 g = 43 g.

Explanatory notes

Each gram of methane can produce 55.6 kJ of energy (refer to the data book). The mass of methane required to produce 1000 kJ can then be calculated and adjusted for the inefficiency of the process.

Mark allocation: 2 marks

- 1 mark for the mass of methane if the process was 100% efficient
- 1 mark for adjusting the answer for the reduced efficiency

Tip

- *The calculation has two steps. It is acceptable to do the steps in the opposite order, as the same answer is obtained.*

Question 1c.ii.

Worked solution

Mass of methane required is 17.98 g but the cell is only 71% efficient.

Final mass of methane required = $\frac{17.98 \times 100}{71}$ = 25.3 g = 25 g.

Explanatory notes

The amount of energy required has already been calculated in **part i.** The only difference is the higher efficiency of the fuel cell.

Mark allocation: 1 mark

- 1 mark for the correct numerical answer

Question 1c.iii.

Worked solution

Mass of methane required is 43 g.

$n(CH_4) = \frac{43}{16} = 2.7$ mol

$n(CO_2) = n(CH_4) = 2.7$ mol ⇨ mass = 2.7 × 44 = 120 g

Explanatory notes

The balanced equation shows that the number of mole of CO_2 is the same as that of methane. The question is answered by finding the number of mole of methane, then finding the number of mole of CO_2 and converting this to a mass.

Mark allocation: 2 marks

- 1 mark for finding the number of mole of CO_2
- 1 mark for finding the mass of CO_2

Question 1d.

Worked solution

Methane could be produced as biogas.

Explanatory notes

If bacteria act on biomass in anerobic conditions, biogas is produced. Methane is the major component of biogas.

Mark allocation: 1 mark

- 1 mark for biogas or collection from landfill

Question 2a.i.

Worked solution

Anode: $Li \rightarrow Li^+ + e^-$

Cathode: $2SOCl_2 + 4e^- \rightarrow S + SO_2 + 4Cl^-$

Explanatory notes

The two reactants are Li and $SOCl_2$. The half-equation for Li can be found at the bottom of the electrochemical series. The $SOCl_2$ forms both S and SO_2. This can be deduced from the overall equation.

Mark allocations: 2 marks

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

Note: States are not required. If (aq) is shown, then no mark is awarded.

Tip

- *Most VCAA Chemistry papers include a high-technology battery question. You are not expected to be familiar with the cell but you are expected to apply the skills that you have learned on writing half-equations and predicting equations. Sometimes one of the half-equations will be in the electrochemical series in the data book.*

Question 2a.ii.

Worked solution

Lithium is the negative electrode (so a – symbol should be on the diagram).

Explanatory notes

The lithium reaction is oxidation. Oxidation occurs at the anode and the anode is negative.

Mark allocation: 1 mark

- 1 mark for correct polarity

Question 2b.i.

Worked solution

The high volume of the SO_2 gas forming would be a problem if it was not soluble. Significant amounts of gas forming in an enclosed container will lead to high pressure and a potential explosion.

Explanatory notes

SO_2 is a gas. Gases have a low density. It would cause many problems if a gas was forming in the cell as it discharged.

Mark allocation: 1 mark

- 1 mark for a reference to the volume of a gas being a problem

Question 2b.ii.

Worked solution

If water was able to penetrate the casing, it would react dangerously with lithium metal.

Explanatory notes

Lithium reacts vigorously with water, so the casing needs to be waterproof. $SOCl_2$ might also be toxic if released.

Mark allocation: 1 mark

- 1 mark for a valid reason

Note: There is more than one possible answer.

Question 2c.

Worked solution

The Li–$SOCl_2$ is a primary cell and needs to be disposed of once it is discharged. A fuel cell can continue to operate as long as reactants are available.

Explanatory notes

A primary cell cannot be recharged. It might be a problem or significant cost to be continually replacing the cell.

Mark allocation: 1 mark

- 1 mark for demonstrating awareness that the Li cell is a primary one

Question 2d.

Worked solution

$n(\text{Li}) = \frac{3.4}{6.9} = 0.4928 \text{ mol} \Rightarrow n(\text{e}) = 0.4928 \text{ mol}$

$Q = 0.4928 \times 96\,500 = 47\,551 \text{ C}$

$t = \frac{Q}{i} = \frac{47\,550}{4.12} = 11\,541 = 11\,500$ seconds (three significant figures)

Explanatory notes

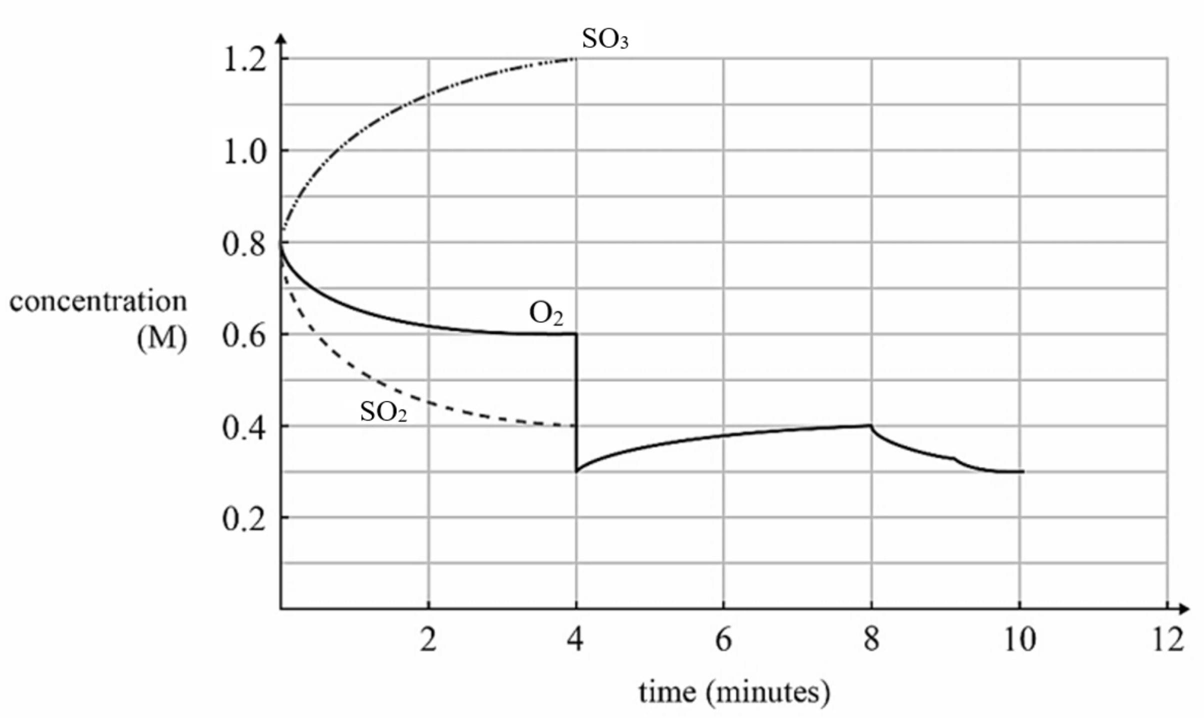
The number of mole of lithium can be calculated from its mass. The number of mole of electrons is the same as the number of mole of lithium as it forms Li^+ ions. The charge is calculated next and then the time.

Mark allocation: 3 marks

- 1 mark for the number of mole of electrons
- 1 mark for the charge
- 1 mark for the time to three significant figures

Question 3a.

Worked solution



Explanatory notes

The initial concentration of each species is 0.8 M. The O_2 graph shows that the forward reaction is favoured. The stoichiometry of the reaction shows that the concentration of SO_2 will drop by twice that of O_2, and that SO_3 will increase at the rate that SO_2 decreases.

Mark allocation: 2 marks

- 1 mark for each accurately graphed concentration (up to 2 marks)

Question 3b.

Worked solution

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(1.2)^2}{(0.4)^2(0.6)} = 15 \text{ M}^{-1}$$

Explanatory notes

The concentrations can be read from the graph and substituted into the expression for K_c.

Mark allocation: 3 marks

- 1 mark for correct expression for K_c
- 1 mark for reading concentrations and substituting them into the expression
- 1 mark for correct answer and units

Question 3c.

Worked solution

After the volume change, the immediate impact is for the [SO_2] to drop to 0.2 M and the [SO_3] to drop to 0.6 M. The [O_2] is then changed by 0.1 M after the volume change, so the [SO_2] increases by 0.2 M to 0.4 M and the [SO_3] drops by 0.2 M to 0.4 M.

Explanatory notes

The impact of doubling the volume is to halve all concentrations. The system then moves to favour the reactants, the side with more particles. SO_2 will increase twice as much as O_2, and SO_3 will drop by the same amount that SO_2 increased.

Mark allocation: 2 marks

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

Note: If a student chooses to answer the question by extending the graph provided, that is also acceptable.

Tip

- *When the volume of an equilibrium system is doubled, the concentrations are halved. But the magnitude of the change in concentration for each species will depend upon its starting value. Be sure not to show the concentration of each species dropping by the same amount, only by the same percentage.*

Question 3d.i.

Worked solution

The temperature was lowered. A decrease in temperature will favour the forward reaction, therefore lowering the [O_2].

Explanatory notes

The temperature was lowered. The [O_2] dropped, which means the forward reaction was favoured. For an exothermic reaction, a decrease in temperature favours the forward reaction.

Mark allocation: 2 marks

- 1 mark for identifying that the temperature dropped
- 1 mark for the explanation

Question 3d.ii.

Worked solution

A catalyst will not change the value of K_c, but it will cause the system to reach equilibrium faster.

Explanatory notes

Catalysts affect the rate of both the forward and back reactions. This system is moving toward equilibrium, so the addition of a catalyst will cause it to reach equilibrium faster but won't impact the position of equilibrium.

Mark allocation: 1 mark

- 1 mark for stating that a catalyst will allow the system to reach equilibrium faster but will not change the value of K_c

Question 4a.i.

Worked solution

$C_3O_2H_4$

Explanatory notes

From the spectrum, the relative molecular mass is 72. With three carbons, it is likely that there are two oxygen atoms, leaving four hydrogen atoms.

Mark allocation: 1 mark

- 1 mark for correct molecular formula

Question 4a.ii.

Worked solution

C_4OH_8

Explanatory notes

The mass of four carbon atoms and one oxygen atom is 64. This leaves eight hydrogen atoms to make up the relative molecular mass of 72.

Mark allocation: 1 mark

- 1 mark for correct molecular formula

Question 4a.iii.

Worked solution

C_4OH_8 offers a range of isomers with a C=C double bond or a C=O carbonyl bond.

Explanatory notes

$C_3O_2H_4$ does offer a few possibilities but there are more structures possible from a molecule containing four carbon atoms. In addition, it could be argued that the large number of peaks on this spectrum is likely to indicate that the carbon chain contains four carbon atoms rather than three. It might also be possible to suggest that the fragment peak at m/z of 57 matches butanal with a methyl group removed.

Mark allocation: 1 mark

- 1 mark for identifying C_4OH_8 as having the greater number of possible isomers, with justification

Question 4b.

Worked solution

The molecule contains a C=O group due to the absorbance around 1750 cm^{-1}.

It is not an alcohol or a carboxylic acid.

Explanatory notes

The absorbance around 1750 cm^{-1} is characteristic of a carbonyl (C=O) group. Given that the molecule contains oxygen, the presence of this group is very possible.

It has no –OH bond or carboxylic acid group because there is no broad absorption around 3300 cm^{-1} or 3000 cm^{-1}.

Mark allocation: 2 marks

- 1 mark for each valid absorption reference

Note: There are other possible answers.

Question 4c.

Worked solution

The molecule has four carbon environments. This rules out any isomers with the molecular formula $C_3O_2H_4$ and makes C_4OH_8 the likely molecular formula.

Explanatory notes

The ^{13}C spectrum has four distinct peaks, hence at least four carbon atoms are present. This rules out any isomers with three carbon atoms.

Note: The spectrum shows four peaks – it is not a case of splitting. The VCE Study Design does not cover splitting in ^{13}C spectra.

The values of the shifts could also be used to provide a valid answer to this question.

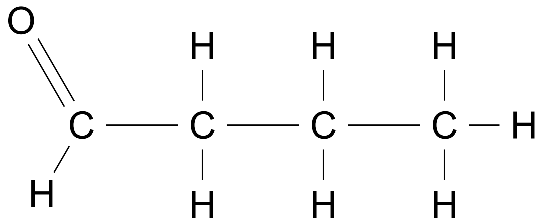
Mark allocation: 2 marks

- 1 mark for the molecular formula with four carbon environments
- 1 mark for ruling out any isomers with three carbon atoms

Question 4d.

Worked solution

The molecule is likely to be butanal.



It has an oxygen atom but it is not an alcohol or carboxylic acid.

The molecular formula is consistent with butanal.

Butanal has four carbon environments and four hydrogen environments, as the spectra show. The shift on the ^{1}H NMR at 9.8 is characteristic of an aldehyde rather than a ketone. The other three shifts coincide with each hydrogen environment as you move from the aldehyde group.

Note: It may be helpful to include a drawing of the molecule in your justification. However, this is not required for full marks.

Explanatory notes

As outlined above, butanal is consistent with the data provided.

Mark allocation: 3 marks

- 1 mark for stating butanal
- 2 marks for providing evidence consistent with this structure

Tip

- *On this occasion, the splitting pattern is not very useful. The value of the shift at 9.8 is more useful because aldehydes are the most likely cause of this. When the hydrogen atoms on neighbouring carbons are themselves different, the splitting pattern will not be a simple one.*

Question 5a.i.

Worked solution

A vitamin is a substance that is essential to the human body but is needed in much smaller quantities than the three major food groups.

Explanatory notes

Each vitamin performs a function of limiting a particular disease in the body. The body needs a low level of each vitamin to be healthy.

Mark allocation: 1 mark

- 1 mark for an acceptable definition

Question 5a.ii.

Worked solution

Vitamin C is essential because it is not made in the human body.

Explanatory notes

The only vitamin that humans can synthesise is vitamin D. We must include amounts of all other vitamins in our diet.

Mark allocation: 1 mark

- 1 mark for an answer of yes with a brief explanation

Question 5b.i.

Worked solution

Vitamin C is water soluble. The four hydroxyl groups it contains ensures that it can form hydrogen bonds with water.

Explanatory notes

The vitamins with multiple –OH groups will be soluble in water. The –OH groups allow the molecule to form a number of hydrogen bonds with water.

Mark allocation: 1 mark

- 1 mark for reference to multiple –OH groups

Tip

- *The Study Design specifically refers to a comparison between vitamin C and vitamin D. There are about 20 other very specific references like this, such as lactose intolerance and aspartame compared to natural sugars. The examiners know they will receive few complaints about the content of the exam when the questions obviously relate to the Study Design. Ensure that you are familiar with the Study Design contexts.*

Question 5b.ii.

Worked solution

The body releases vitamin C easily in urine, so it needs to be replaced regularly.

Explanatory notes

If a vitamin is water soluble, the body disposes of it regularly in urine and faeces. It therefore needs to be replaced regularly. Taking a megadose and expecting that to last for a month will not work.

Mark allocation: 2 marks

- 1 mark for stating the body can release water-soluble vitamins
- 1 mark for explaining that we need to consume the vitamin regularly

Question 5c.i.

Worked solution

An antioxidant is a substance added to foods to limit the negative impact of oxygen on the food.

Explanatory notes

Oxygen can react with the components of many foods to change their taste or their suitability for consumption. An antioxidant limits the impact of oxygen on a food.

Mark allocation: 1 mark

- 1 mark for stating that antioxidants protect foods from deterioration due to oxygen

Question 5c.ii.

Worked solution

Vitamin C reacts with the oxygen itself, so the oxygen is not changing the food.

Explanatory notes

Vitamin C protects foods in two ways. The –OH groups react with oxygen to lower the concentration of oxygen around the food. They can also terminate the propagation reactions of fatty acids.

Mark allocation: 1 mark

- 1 mark for either of the two reasons given in the explanatory notes

Question 5d.

Worked solution

Vitamin C contains two optical isomers due to the presence of a chiral carbon. Due to their different spatial arrangements, one of the isomers is suitable for a particular reaction whereas the other is not.

Explanatory notes

Vitamin C contains a chiral carbon, the carbon below the pentagonal ring. Therefore, it has two optical isomers. One of the optical isomers has the required orientation to lead to a particular reaction, whereas the other does not.

Mark allocation: 2 marks

- 1 mark for stating there is a chiral carbon, resulting in two optical isomers
- 1 mark for explaining that each optical isomer can react differently in the body

Question 5e.

Worked solution

$C_6H_8O_6(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2e^-$

Explanatory notes

Examining the structure of vitamin C shows that its molecular formula is $C_6H_8O_6$. The half-equation can be written by first writing the reactant and product, then balancing the number of hydrogen atoms, then balancing the charge.

$C_6H_8O_6\ (aq) \rightarrow C_6H_6O_6(aq)$

$C_6H_8O_6\ (aq) \rightarrow C_6H_6O_6(aq) + 2H^+$ *balance the number of hydrogens*

$C_6H_8O_6\ (aq) \rightarrow C_6H_6O_6(aq) + 2H^+ + 2e^-$ *balance the charge*

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation. States are required.

Tip

- *Be aware that you are expected to be able to work out the molecular formula in this question from the structural diagram.*

Question 6a.i.

Worked solution

lysine

Explanatory notes

Lysine has two $–NH_2$ basic groups and only one carboxylic acid group, so it will form a basic solution in water. The pH of a basic solution is higher than that of a neutral solution.

Mark allocation: 1 mark

- 1 mark for lysine

Question 6a.ii.

Worked solution

Cysteine can form a disulfide link with another cysteine molecule: –S–S–.

Explanatory notes

Cysteine has a –S–H group as the R group. This can form a covalent bond with another cysteine R group. The bond is referred to as a disulfide link or disulfide bridge: –S–S–.

Mark allocation: 2 marks

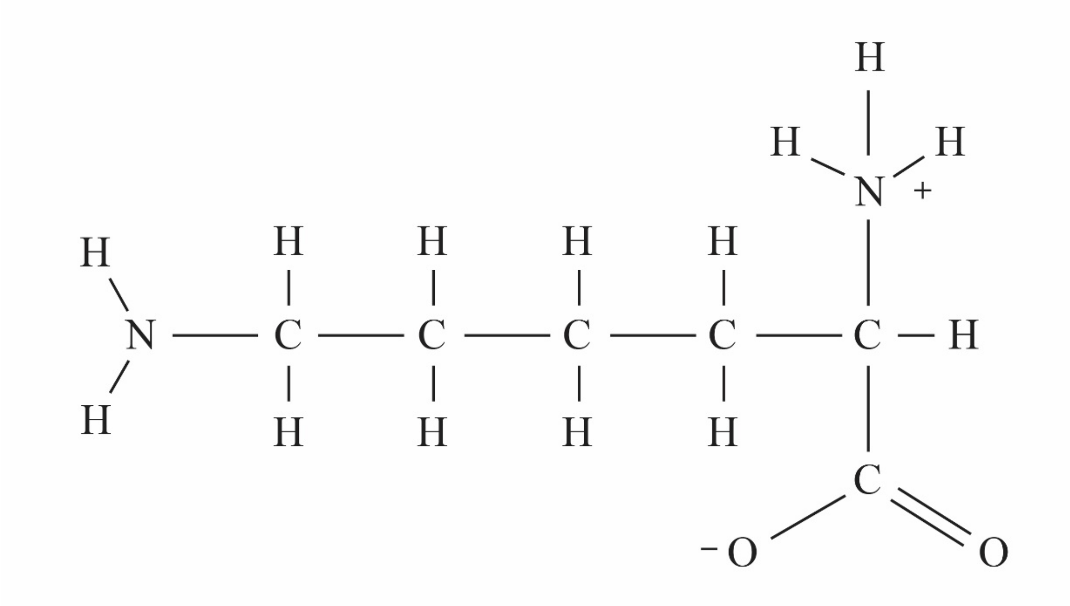
- 1 mark for cysteine
- 1 mark for drawing a disulfide link

Tip

- *There is an expectation that you have a very clear understanding of the types of bonds or forces that are relevant to each level of a protein structure, and that hydrogen bonding is crucial to a secondary structure but a tertiary structure can be due to several types of bonds.*

Question 6b.

Worked solution



Explanatory notes

In a zwitterion, the proton from the carboxyl group moves to the nearby amine group.
A zwitterion must be neutral in charge.

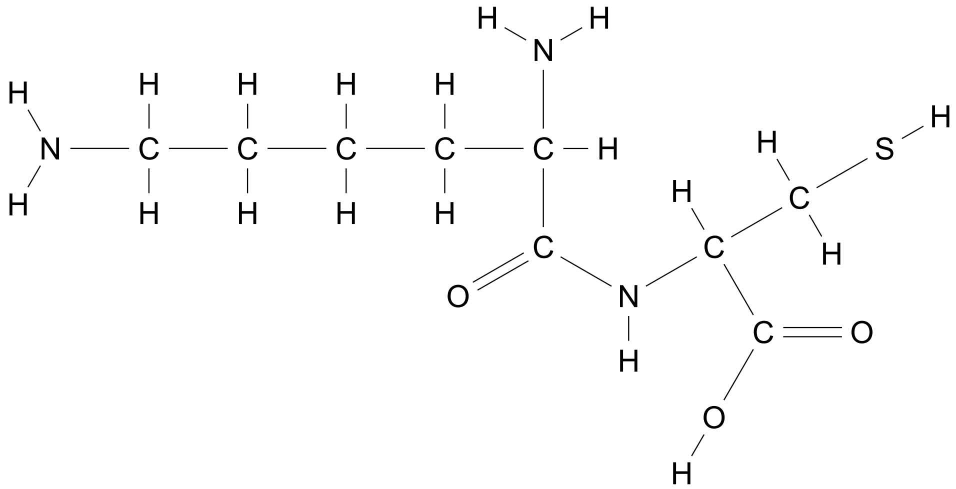
Mark allocation: 1 mark

- 1 mark for a correct diagram

Note: The VCAA expects the positive charge to be shown next to the nitrogen atom and not on the hydrogen atom.

Question 6c.i.

Worked solution



Explanatory notes

A peptide link forms between the two molecules. The order of the amino acids gives the possibility of a second structure.

Mark allocation: 1 mark

- 1 mark for a correct diagram

Question 6c.ii.

Worked solution

The structure of the dipeptide formed depends upon the order in which the amino acids are joined.

Explanatory notes

The dipeptide that is formed when lysine bonds to cysteine is a structural isomer of the dipeptide that is formed when cysteine bonds to lysine. The order of the amino acids makes a difference to the product.

Mark allocation: 1 mark

- 1 mark for explaining that the sequence of the two dipeptides leads to a different product

Question 7a.i.

Worked solution

The boiling points of propene and propane will be similar and relatively low because they have only dispersion forces between molecules. The boiling point of propan-1-ol will be higher than that of propene because it has an oxygen atom that can form hydrogen bonds with water.

Explanatory notes

Propene and propane are both hydrocarbons. The only intermolecular forces present in samples of each are weak dispersion forces. They are both gases at room temperature.

Propan-1-ol has an –OH functional group. The electronegativity of the oxygen atom allows for hydrogen bonding between the molecules and this results in a higher boiling point than propene.

Mark allocation: 2 marks

- 1 mark for comparison between propane and propene
- 1 mark for comparison between propene and propan-1-ol

Question 7a.ii.

Worked solution

The solubility of propene in water will be low. Propene is non-polar and will not dissolve in a polar solvent like water.

Explanatory notes

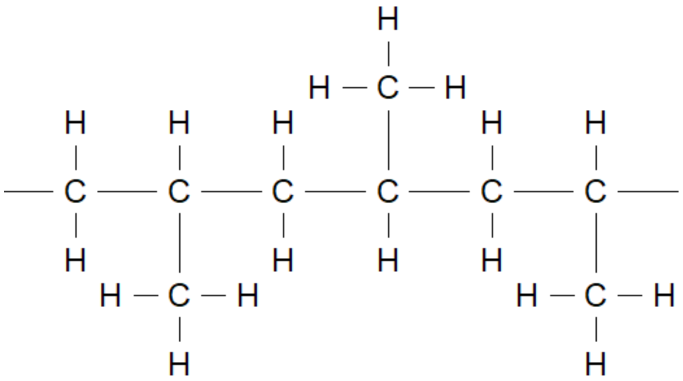
Propene is non-polar. It does not have highly electronegative atoms such as oxygen and nitrogen, so it is not attracted to the dipoles in water.

Mark allocation: 2 marks

- 1 mark for stating low solubility
- 1 mark for discussing the lack of polarity

Question 7b.

Worked solution



Explanatory notes

The carbon-to-carbon double bond in propene breaks, allowing the molecules to join together.

Mark allocation: 1 mark

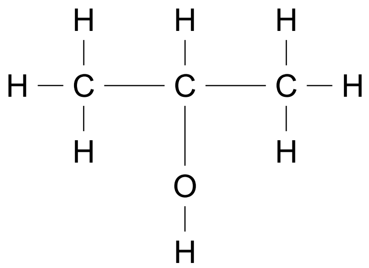
- 1 mark for a correct structure. It needs to have the bonds on each end open and the chain shown should have an even number of carbon atoms.

Tip

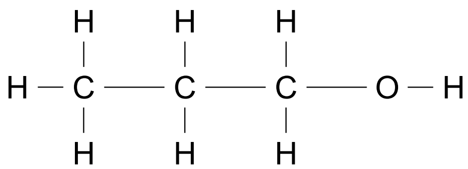
- *Questions on polymer structures are not common but are still possible, as addition reactions of alkenes are in the Study Design.*

Question 7c.

Worked solution



propan-2-ol



propan-1-ol

Explanatory notes

When the carbon-to-carbon double bond breaks, there are two possible positions for the –OH bond to attach. When the question referring to molecules says 'draw', the expectation is that you will draw full structural formulas, including showing the bond between in the –O–H for full marks.

Mark allocation: 2 marks

- 1 mark for each correct structure and name (up to 2 marks)

Question 7d.

Worked solution

Propene does not have geometric isomers because the carbon atom on the end of the double bond does not have two different groups attached to it.

Explanatory notes

For an alkene to have cis and trans isomers, each carbon atom on the double bond must have two different groups attached. In propene, the end carbon has two hydrogen atoms on it.

Mark allocation: 1 mark

- 1 mark for answer ‘no’ with a valid explanation

Question 7e.

Worked solution

$C_3H_6(g) + Br_2(g) \rightarrow C_3H_6Br_2(g)$

Explanatory notes

The molecule shown can be made from an addition reaction between propene and bromine.

Mark allocation: 1 mark

- 1 mark for a balanced equation

  Note: States are not required.

Question 8a.

Worked solution

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

Cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Explanatory notes

When water is electrolysed, oxygen gas is formed at the anode and hydrogen gas is formed at the cathode. The half-equations can be read from the electrochemical series: 1.23 for oxygen formation and –0.83 for hydrogen formation.

Mark allocation: 2 marks

- 1 mark for each correct half-equation (up to 2 marks)

Question 8b.i.

Worked solution

$Q = It = 1.4 \times 10 \times 60 = 840$ C

$n(\text{e}) = \dfrac{840}{96\,500} = 0.00870 \text{ mol} \Rightarrow n(\text{H}_2) = 0.00870 \div 2 = 0.00435 \text{ mol}$

$V = \dfrac{nRT}{P} = \dfrac{0.00435 \times 8.31 \times 294}{120} = 0.089 \text{ L}$

Explanatory notes

The charge is calculated first, using the given current and time values. The number of mole of electrons leads to the number of mole of hydrogen gas, which in turn is used to calculate the volume of the gas.

Mark allocation: 4 marks

- 1 mark for charge
- 1 mark for the number of mole of hydrogen
- 2 marks for the volume calculation and units

Question 8b.ii.

Worked solution

The volume of oxygen gas is half that of hydrogen gas = 0.044 L.

Explanatory notes

The overall equation for electrolysis of water shows that the volume of hydrogen gas produced will be double that of oxygen produced.

Mark allocation: 1 mark

- 1 mark for halving the answer to **part b.i.**

Question 8c.

Worked solution

Hydrogen gas formed might explode.

Explanatory notes

Hydrogen is a very flammable gas. If the apparatus leaks hydrogen, there is potential for an explosion.

A build up of hydrogen if the apparatus runs too long is another acceptable response.

Mark allocation: 1 mark

- 1 mark for a valid reason

Question 9a.i.

Worked solution

electrode separation distance

Explanatory notes

The electrode separation distance is varied in this experiment. It is the independent variable.

Mark allocation: 1 mark

- 1 mark for identifying electrode separation distance

Question 9a.ii.

Worked solution

anode mass loss

Explanatory notes

The anode mass loss is being checked after each change in electrode separation, therefore it is the dependent variable.

Mark allocation: 1 mark

- 1 mark for identifying anode mass loss

Question 9b.

Worked solution

The similarity of the results of the first three trials indicates a high precision.

Explanatory notes

Trials 1, 2 and 3 are all run with the same conditions. The results obtained are very close in value. This would justify the conclusion that the precision of the results is high.

Mark allocation: 1 mark

- 1 mark for concluding that the precision is high, with reference to the data

Question 9c.

Worked solution

The student's conclusion is not justified because the experiment's design is flawed. The actual current was not measured during each trial. It is likely that the current was higher as the separation distance reduced. The student's conclusion assumes that the current is constant because the voltage is constant, but this is unlikely to be the case.

Explanatory notes

As the electrodes are moved closer, it is likely that the resistance of the circuit drops and the current increases. When the current increases, the mass change should increase, which is what happened. The experiment needed to measure current and to adjust the voltage to maintain a constant current.

There are several ways that a student could choose to provide a valid response to this question. The key points are that the mass is changing with separation distance – it is not constant like you might expect. Also, it would be better if the current had been recorded for each trial, as this would place you in a position to judge why the mass is changing.

Mark allocation: 3 marks

- 1 mark for suggesting the conclusion is not valid
- 2 marks for outlining a case that the experiment design might be flawed and the current might not have been constant

Question 9d.

Worked solution

This is not a valid suggestion. The copper ion concentration should not be changing because copper is oxidised at one electrode and copper ions are reduced at the other.

Explanatory notes

This would not be correct because the copper ion concentration should be relatively constant. As copper forms ions at the anode, copper ions are converted to copper atoms at the cathode. This means that the overall concentration is not changing.

Mark allocation: 2 marks

- 1 mark for concluding this is not a valid suggestion
- 1 mark for stating that the copper ion concentration should not be changing

Question 9e.

Worked solution

The charge on a silver ion is Ag^+, whereas that on a copper ion is Cu^{2+}. The number of mole of silver lost at the anode will be double that of copper. Silver also has a greater atomic mass, so the mass loss will be more than double that of copper.

Explanatory notes

$Ag \rightarrow Ag^+ + e^-$ Relative atomic mass of Ag: 107.9

$Cu \rightarrow Cu^{2+} + 2e^-$ Relative atomic mass of Cu: 63.5

The half-equations above can be used to show that the same amount of charge should produce twice the number of mole of silver metal loss. Each silver atom is significantly heavier than each copper atom – this will make the mass loss difference even greater.

Mark allocation: 2 marks

- 1 mark for comparing the charges on silver and copper ions
- 1 mark for demonstrating an awareness that the respective masses must also be taken into account

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Question 10a.

Worked solution

Inject an alcohol sample into a HPLC column. If the mobile phase is polar, the more polar components of the mixture will pass through the column quickly. They will have low retention times. The less polar molecules will have a greater attraction to the stationary phase, so they will have higher retention times.

To detect methanol: Run a sample of pure methanol to find its retention time. Any subsequent alcohol sample with a peak at that retention time contains methanol. Repeat for other samples.

To determine ethanol concentration: As the concentration of a component increases, the area under the peak that it produces increases. Prepare a series of standard ethanol solutions, inject them into the column to find the area under the peak, and make a calibration curve of area versus concentration. Run the alcohol samples through and compare the area under the ethanol peak to the values of the standard solutions.

Explanatory notes

A mixture can be injected into a HPLC column. The mobile phase will carry the components of the mixture through the column but they will travel at different rates. If reverse phase HPLC is used, the more polar molecules will move through the column faster, as they spend little time adsorbed to a non-polar stationary phase. They have short retention times. The less polar molecules will travel more slowly through the column because they adsorb more to the stationary phase. They have longer retention times.

In a mixture of alcohols, methanol should have the lowest retention time, ethanol should have the next lowest and so on. You would identify the alcohol by running a sample of a known alcohol through the column and noting its retention time. If that alcohol is in the drink sample, there will be a peak with the same retention time.

The higher the concentration of the alcohol, the greater the area under the peak will be. If you prepare a set of standard solutions of different concentrations, you can form a calibration curve of concentration versus peak area.

Mark allocation: 6 marks

- 2 marks for an explanation of how components separate in HPLC
- 2 marks for an explanation of how HPLC can be qualitative
- 2 marks for an explanation of how HPLC can be quantitative

Question 10b.

Worked solution

IR spectroscopy is not a good choice. The level of absorption does not vary in a linear fashion with concentration, so it is not used to determine concentration.

IR is useful for detecting particular functional groups, but alcohols all have the same –OH functional group so they will produce a similar broad band at around 3300 cm^{-1}. In a mixture of alcohols, it would be difficult to discern the absorptions of each component.

Explanatory notes

IR spectroscopy would not be a good choice for either aspect of this task: identifying the alcohol present or determining its concentration. IR can identify functional groups but both methanol and ethanol have several bond types in common. An IR spectrum of a pure sample of methanol would be slightly different from that of ethanol, but it would be difficult to identify the components of a mixture of the alcohols. IR spectra do not give a reliable measure of concentration – the intensity of an absorption will increase with concentration but it is not easy to obtain reliable comparisons. It would be valid to bring the fingerprint region of the spectrum into the discussion.

Mark allocation: 3 marks

- 1 mark for suggesting IR is not a suitable technique
- 1 mark for discussing the qualitative aspect
- 1 mark for discussing the quantitative aspect

Tip

- *For the past few years, the final question of the paper has been a discussion question worth several marks. When answering these questions, it is very important to address any specific dot points provided, as the marking scheme will reflect these dot points. It is also worth taking a bit of time to structure your response, putting your most important points down first. Sketches can be a useful way to add clarity to a response.*

END OF WORKED SOLUTIONS