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YEAR 12 *Trial Exam Paper*

2023
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	*D*
5	*B*
6	*B*
7	*A*
8	*C*
9	*B*
10	*A*
11	*D*
12	*D*
13	*C*
14	*B*
15	*A*

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

Question 1

Answer: D

Explanatory notes

Option D is correct. Waste fruit could be added to a digester to form biogas. Alternatively, the sugars in the fruit could be fermented to produce bioethanol.

Option A is incorrect as there are limits to the amount of biomass or crops that can be set aside for fuel production.

Option B is incorrect. Biofuels are replaceable but not instantaneously – it takes time to grow crops and biochemical reactions are often slow reactions.

Option C is incorrect as the combustion of biofuels still produces emissions such as CO_2.

Question 2

Answer: C

Explanatory notes

Option C is correct.

Ethane: $C_2H_6(g) + 3.5O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

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

The balanced equations show the ratio between the amounts of CO_2 produced to be 2:8 or 1:4 and the ratio between the amounts of water to be 3:9 or 1:3.

Options A, B and D are incorrect as the correct ratio is 1:4 (CO_2) and 1:3 (H_2O).

Question 3

Answer: C

Explanatory notes

Option C is correct. The only gaseous product will be CO_2 because the water will be a liquid at SLC. Reactor B produces four times as much CO_2 as Reactor A, so the pressure caused by the product gases will be four times greater in Reactor B than in Reactor A.

Options A, B and D are incorrect because the CO_2 ratio is 1:4. If a student mistakenly tries to include the volume of water, they might arrive incorrectly at one of these other ratios.

Tip

- *Questions 2 and 3 highlight a number of recurring concepts. The reference to the temperature returning to 25 °C after the reaction is deliberate. This makes it clear that the water will be present as a liquid and therefore it will not contribute to the pressure in the reactor. The heat of combustion values in the data book refer to reactions during which the products are returned to 25 °C and the water is in a liquid state. Question 3 also highlights that the pressure of each gas in a mixture can be considered independently from the other components of the mixture.*

Question 4

Answer: D

Explanatory notes

Option D is correct. The data book gives the heat of combustion of ethanol as 29.6 kJ g^{-1}.

The mass of ethanol required to produce 1.00 MJ = $\frac{1000}{29.6}$ = 33.8 g.

However, the process is only 22% efficient, so mass = 33.8 × $\frac{100}{22}$ = 154 g.

Note: The 22% adjustment can also be applied as the first calculation – the same answer will be obtained.

Option A is incorrect. The conversion of units is not correct.

Option B is incorrect. The conversion of units is not correct, nor is the efficiency taken into consideration.

Option C is incorrect. The 22% efficiency is not taken into consideration.

Question 5

Answer: B

Explanatory notes

Option B is correct. The data book provides the values for the second and the last columns; that is, 51.6 kJ g^{-1} and 1560 kJ mol^{-1}.

Therefore, the energy in joules per gram will be 51.9 × 1000 = 5.19 × 10^4.

Converting to MJ per tonne gives 51.9 × $\frac{1\,000\,000}{1000}$ = 5.19 × 10^4.

Options A and C are incorrect as the J g^{-1} will be 1000 times greater than the kJ g^{-1}.

Option D is incorrect. The values in most columns are incorrect.

Question 6

Answer: B

Explanatory notes

Option B is correct. To be a useful fuel, the ΔH value needs to be sizeable. Given that propane can be handled safely, the activation energy must be relatively high. Option B meets both of these requirements.

Option A is incorrect as the activation energy is very low, which is characteristic of a very unstable compound.

Option C is incorrect as the value of ΔH is positive, meaning that the reaction requires energy.

Option D is incorrect as the value of ΔH is too small for the fuel to be useful.

Question 7

Answer: A

Explanatory notes

Option A is correct. $Q = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{(1.6)^2}{(0.8)^2(0.6)} = 6.67\ M^{-1}$

The concentration fraction, Q, is less than the value of K_c: therefore the forward reaction needs to be favoured for Q to reach K_c.

The favouring of the forward reaction causes the concentration of products to increase and the concentration of reactants to decrease. This will cause the value of Q to increase.

Option B is incorrect. The concentration fraction is not equal to K_c.

Option C is incorrect. The system must move in the forward direction.

Option D is incorrect. Perhaps K_c is wrong but the use of the words 'must be wrong' is not justified. Option A is a more correct answer.

Tip

- *Textbooks make few references to the concentration fraction, Q, but it is expected that you are aware of what it refers to. When you use the expression for the equilibrium constant but the system is not at equilibrium, you must work out the concentration fraction.*

Question 8

Answer: C

Explanatory notes

Option C is correct. $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$

The amount of NH_3 increases by 0.12 mol. The reverse reaction is favoured and the amount of N_2 and H_2 will decrease.

Using the mole ratios in the balanced equation, the amount of N_2 must decrease by 0.06 mol (0.72 – 0.06 = 0.66) and the amount of H_2 by 0.18 (0.72 – 0.18 = 0.54).

Since the volume is 1 L, the concentrations will equal the amounts.

Option A is incorrect as it shows the change in mole of each species rather than the equilibrium amounts.

Option B is incorrect as the amounts of N_2 and H_2 must decrease.

Option D is incorrect. The amount of H_2 is wrong.

Note: For students familiar with the use of 'ICE' tables, the amounts of each species could be determined with an ICE table.

Question 9

Answer: B

Explanatory notes

Option B is correct. The change has an immediate effect on both the forward and reverse reactions, and it favours an increase in both. This is consistent with a temperature increase. As the reaction is endothermic, it will favour the forward reaction more.

Option A is incorrect as the addition of a catalyst would not favour the forward reaction over the reverse reaction.

Option C is incorrect as a decrease in temperature would lead to decreases in the reaction rates.

Option D is incorrect. A decrease in volume would lead to a sharp increase in the reverse reaction and a decrease in the forward reaction.

Tip

- *When you are presented with an equilibrium graph, check to see if the vertical axis is labelled 'rate' (as in this question) or 'concentration'. The logic required differs depending on which variable is used. For example, a temperature change has an instant effect on rate (as in this question) but a delayed effect on concentration.*

Question 10

Answer: A

Explanatory notes

Option A is correct. The fact that HCl is the limiting reagent is important here.

$n(CaCO_3)$ in Experiment 1 $= \frac{1}{100.1} = 0.01$ mol

$n(HCl) = 0.01 \times 0.1 = 0.001$ mol

Therefore, the volume of CO_2 evolved in both experiments will be the same because there is not enough HCl to completely react all the $CaCO_3$ in either experiment. The rate in Experiment 1 is faster due to the greater surface area.

Option B is incorrect. The rate of Experiment 1 is greater than that of Experiment 2.

Option C is incorrect. The rate of Experiment 2 is less than that of Experiment 1 and the volumes will be the same.

Option D is incorrect as the final gas volumes will be the same.

Question 11

Answer: D

Explanatory notes

Option D is correct. The overall equation is derived from the combination of

$Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2Ag(s) + 2OH^-(aq)$ and

$Zn(s) + 2OH^-(aq) \rightarrow Zn(OH)_2(s) + 2e^-$

The OH^- ions cancel, as do the electrons.

The voltage of the cell will be 0.34 – (–0.76) = 1.1 V

Option A is incorrect as this would be a recharge reaction.

Option B is incorrect. It is not balanced, nor is the voltage correct.

Option C is incorrect due to the incorrect voltage.

Tip

- *When a question offers you two half-equations, you must check in which format the half-equations are presented. They might be presented as they appear in the electrochemical series, where they are both shown as reduction equations (as in this question) or they might be presented as the actual half-equations of the cell in operation. It might also be that they are listed in alphabetical order rather than in order of voltage, in which case you might need to rewrite them in order, showing the half-equation with the highest voltage at the top.*

Question 12

Answer: D

Explanatory notes

Option D is correct. The relevant half-equations are

Cl_2 $(g) + 2e^- \rightarrow 2Cl^-(aq)$ and

$Cu^{2+}(aq) + 2e^- \rightarrow$ **Cu**(s)

leading to an overall equation of $Cl_2(g) + Cu(s) \rightarrow 2Cl^-(aq) + Cu^{2+}(aq)$, where electrons are flowing from the copper electrode to the chlorine half-cell.

Option A is incorrect as copper ions are not reacting, nor are chloride ions.

Option B is incorrect as the anions will flow into the copper half-cell to balance out the extra copper ions that are forming.

Option C is incorrect as the concentration of copper ions in this half-cell is increasing.

Question 13

Answer: C

Explanatory notes

Option C is correct. The solution to **Question 12** shows that the copper is being oxidised, therefore it is the anode, and the anode in a galvanic cell is negative. The anode in a galvanic cell is the source of electrons. The chlorine half-cell electrode will be positive and the cell potential will be 1.36 – 0.34 = 1.02 V.

Option A is incorrect as the polarities are wrong.

Option B is incorrect as the polarity and voltage are both wrong.

Option D is incorrect. The half-cell potentials have been added rather than subtracted.

Question 14

Answer: B

Explanatory notes

Option B is correct. The half-equations in the electrochemical series that react in 0.1 M KCl are

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow \mathbf{2H_2O}(l)$ *This half-equation will be reversed when running.*

$\mathbf{2H_2O}(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Therefore, water will form O_2 gas and H^+ ions at the anode. The H^+ ions will change methyl orange to red.

Option A is incorrect as 0.1 M KBr will produce bromine at the anode rather than H^+ ions.

Option C is incorrect as 4.0 M NaCl will produce Cl_2 gas at the anode rather than H^+ ions. Cl_2 gas is formed due to the high concentration of Cl^- ions. If the Cl^- concentration is high, the Cl^- ions are more attracted to the anode than the polar water molecules.

Option D is incorrect as Cl_2 would form at the anode.

Question 15

Answer: A

Explanatory notes

Option A is correct. The copper must be oxidised if it is losing mass. Oxidation occurs at the anode and the only anode option is A.

Options B, C and D are incorrect as reduction occurs at the cathode. Reduction of Cu^{2+} ions would lead to a mass increase, not decrease.

Question 16

Answer: C

Explanatory notes

Option C is correct. The mass change is 8.622 – 7.987 = 0.635 g.

$n(\text{Cu}) = \dfrac{0.635}{63.5} = 0.01 \text{ mol}$

n(e) required = 2n(Cu) = 0.01 × 2 = 0.02 mol, as Cu^{2+}

Charge required = n(e) × 96 500 = 0.02 × 96 500 = 1930 C

This matches option C, where $Q = It$ = 1.93 × 1000 = 1930 C.

Option A is incorrect as it incorrectly uses a mole ratio of n(Cu) = 2n(e).

Option B is incorrect as it incorrectly uses a mole ratio of n(Cu) = n(e).

Option D is incorrect as it incorrectly uses a mole ratio of n(e) = 4n(Cu).

Tip

- *In questions like this, you do not have to waste time being careful about significant figures. The alternatives are all separated enough that you should be able to select the correct answer even if you have calculated to two significant figures on your calculator.*

Question 17

Answer: D

Explanatory notes

Option D is correct. Amino groups have priority over halo groups, so numbering starts at the right-hand end of the molecule. This places the chlorine atoms on carbon 3 and carbon 4.

Option A is incorrect as it assumes the halo groups have higher priority than the amino group.

Option B is incorrect as amine should appear in the suffix of the name.

Option C is incorrect. It places the chlorine atoms on the same carbon atom.

Tip

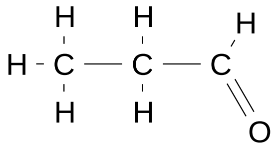
- *The IUPAC naming system gives functional groups an order of priority, starting with carboxylic acids. Make sure you learn this order off by heart.*

Question 18

Answer: C

Explanatory notes

Option C is correct. Propanal does contain an oxygen atom, hence, the significant dipole, but it does not contain a hydrogen bond because the oxygen is not bonded directly to a hydrogen atom. Therefore, it will form dipole-to-dipole bonds as a liquid. As a solution in water, however, a hydrogen bond can form between the water and propanal molecules.



Option A is incorrect as the presence of dipoles will lead to intermolecular bonds that are stronger than the dispersion forces.

Option B is incorrect. Propanal solutions will have hydrogen bonds.

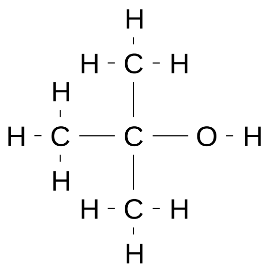
Option D is incorrect. Propanal liquid will not form hydrogen bonds.

Question 19

Answer: B

Explanatory notes

Option B is correct. The two carbon environments and two hydrogen environments are evident on the diagram of the molecule below.



Option A is incorrect as 2-methylpropan-1-ol has four hydrogen environments and three carbon environments.

Options C and D are incorrect. Both have more than two hydrogen and carbon environments.

Tip

- *When the number of carbon or hydrogen environments is less than the number of carbon atoms, there is a good chance that the molecule will be a relatively symmetrical one.*

Question 20

Answer: A

Explanatory notes

Option A is correct. The molecule shown has two parent molecular ions that are characteristic of a chlorine compound. Chlorine has a ^{35}Cl isotope and a ^{37}Cl isotope. The relative molecular mass is a weighted mean of these two peaks.

Option B is incorrect. The mass spectrometer printout is not simplified in any way.

Option C is incorrect. There is no reason to suspect that a contaminated sample has been used.

Option D is incorrect. The isotopes of carbon or hydrogen will form much smaller peaks than the peak at m/z 66.

Tip

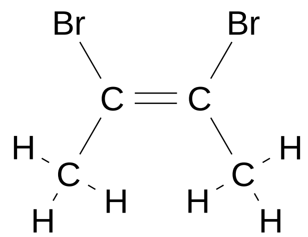
- *The 2022 VCAA Chemistry Exam had a question containing a mass spectrum of a chlorine compound, and it was not handled well by students. This question will serve as a check of whether you understand that the relative molecular mass is a weighted average of the parent molecular ions.*

Question 21

Answer: A

Explanatory notes

Option A is correct. The diagram below shows the *cis* isomer. A *trans* isomer forms if the bromine atoms are on opposite sides.



Options B and C are incorrect because the first carbon on the molecule can have bromine atoms in either position.

Option D is incorrect. An alkane will not have geometric isomers.

Question 22

Answer: D

Explanatory notes

Option D is correct. Propanol will be oxidised to propanoic acid. To balance the half-equation, add one molecule of water to the left-hand side to balance the oxygen atoms. Next, balance the hydrogen atoms ($4H^+$ ions required), then the charge.

Option A is incorrect as the question states complete oxidation. Propanal would be formed only if it was partial oxidation.

Option B is incorrect as it shows a reduction reaction.

Option C is incorrect. The reaction takes place in acid conditions, not alkaline.

Question 23

Answer: C

Explanatory notes

Option C is correct. The addition of acid can denature an enzyme. The added acid can disrupt the salt bridges that have formed between carboxyl groups and amine groups.

Option A is incorrect. Denaturation does not break the primary structure of the protein.

Option B is incorrect. The addition of acid will have little effect on the non-polar groups.

Option D is incorrect. The ionic bonds are disrupted before the covalent bonds.

Question 24

Answer: C

Explanatory notes

Option C is correct. The ester bonds in triglycerides are hydrolysed by lipase to fatty acids and glycerol. The fatty acids are transported in the blood and then reformed into triglycerides in a condensation reaction.

Option A is incorrect as triglycerides are not polymers.

Option B is incorrect. Peptide bonds are relevant to proteins, not triglycerides.

Option D is incorrect. The question refers to the role of triglycerides in energy storage.

Question 25

Answer: C

Explanatory notes

Option C is correct. The heat of combustion value for fats and oils, as given in the data book, is 37 kJ g^{-1}.

Energy released = 37 000 × 0.368 = 13 600 J

$$CF = \frac{energy}{\Delta T} = \frac{13600}{11.3} = 1200 \text{ J °C}^{-1}$$

Option A is incorrect. Inconsistent units have been used in the calculations. The heat of combustion figure from the data book is in kJ and must be converted to J to match the units of the calibration factor.

Option B is incorrect. The correct answer is 1200 J $°C^{-1}$.

Option D is incorrect as it assumes 1 g of oil is burned.

Question 26

Answer: B

Explanatory notes

Option B is correct. Energy released will be 37 000 × 0.288 = 10 700 J.

The calibration factor should be unchanged, so $\Delta T = \frac{energy}{CF} = \frac{10700}{1200} = 8.88$ °C.

Option A is incorrect. The mass of oil reacting is less so the temperature change will be less.

Option C is incorrect. The correct answer must be less in the second experiment.

Option D is incorrect. The formula rearrangement used is not correct.

Question 27

Answer: B

Explanatory notes

Option B is correct. Many coenzymes are derived from vitamins and they do act as carriers of electrons or other groups.

Option A is incorrect as coenzymes are not enzymes with a tertiary structure that denatures above 40 °C.

Options C and D are incorrect. Coenzymes can change during a reaction. They may be reformed after the reaction but they change during it.

Question 28

Answer: D

Explanatory notes

Option D is correct. Each molecule of arachidonic acid contains four carbon-to-carbon bonds. Stearic acid is saturated. The total number of double bonds = 4 + 4 + 0 = 8.

Options A, B and C are incorrect as the answer is 8.

Tip

- *You can determine the number of carbon-to-carbon double bonds using the following formula: Saturated fatty acid = $C_nH_{2n+1}COOH$, where n stands for the number of carbon atoms. For example, when a fatty acid has 19 carbons, it will have 2 × 19 + 1 = 39 hydrogen atoms if it is saturated. Each double bond leads to two fewer hydrogen atoms. Arachidonic acid, $C_{19}H_{31}COOH$, has four carbon-to-carbon double bonds (39 – 31 = 8 fewer hydrogens). If the fatty acid given in the question is one of those in the data book, you can count the number of double bonds by examining its structure.*

Question 29

Answer: A

Explanatory notes

Option A is correct. The mass of aspartame required will be $\frac{14}{188}$ = 0.0745 g.

The energy released will be 0.0745 × 16 = 1.19 = 1.2 kJ.

Options B and D are incorrect as the correct answer is 1.2 kJ.

Option C is incorrect. The units have not been converted correctly.

Question 30

Answer: B

Explanatory notes

Option B is correct. The wick length is likely to cause some variability in the rate of burning but it is unlikely to be predictable in its effect.

Option A is incorrect. It is likely to have some effect.

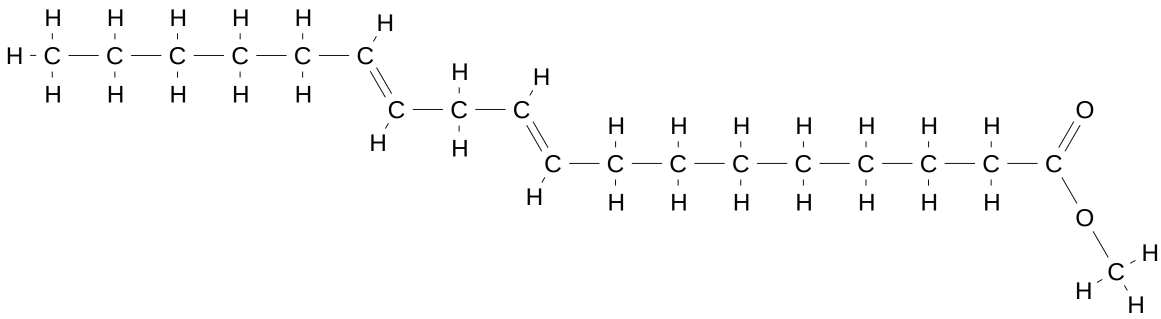
Option C is incorrect. The effect of wick length is unlikely to be the same in each instance.

Option D is incorrect. The precision of the experiment might suffer but the results should still be valid.

SECTION B

Question 1a.i.

Worked solution



Explanatory notes

The structure of linoleic acid is shown in the Data Book. When the methyl ester forms, a -CH_3 group is added to the molecule to form an ester. A water molecule is also formed.

Marking allocation: 2 marks

- 1 mark for the backbone structure with two carbon-to-carbon double bonds. The hydrocarbon chain can be shown in a semi-structural format but the ester bond should be drawn fully.
- 1 mark for the ester bond drawn correctly.

Question 1a.ii.

Worked solution

An omega-6 fatty acid has a carbon-to-carbon double bond on the sixth carbon from the methyl end of the hydrocarbon chain. This required double bond is evident in the diagram above.

Explanatory notes

Fatty acids consist of a hydrocarbon chain and a carboxyl group. The methyl group on the end of the hydrocarbon chain is referred to as the omega end. An omega-6 fatty acid has a carbon-to-carbon double bond on the sixth carbon of the chain from the omega end.

Mark allocation: 1 mark

- 1 mark for an accurate explanation of what an omega-6 fat is

Question 1b.i.

Worked solution

$C_{19}H_{34}O_2$(l) + 26.5O_2(g) → 19CO_2(g) + 17H_2O(l)

Explanatory notes

Complete combustion of an organic fuel will produce CO_2 and H_2O as products. Biodiesel will be a liquid and water will also be a liquid at standard laboratory conditions (SLC).

Mark allocation: 2 marks

- 1 mark for correct formulas for reactants and products
- 1 mark for correct balancing and states

Tip

- *With combustion equations:*
  - *water should be shown as a liquid when it is a thermochemical equation*
  - *the coefficient of oxygen can be shown as ½, if that is necessary*
  - *the fuel will not burn successfully if it is (aq)*

Question 1b.ii.

Worked solution

The heat of combustion is listed as 11 700 kJ mol^{-1} or 11.7 MJ mol^{-1}.

n(methyl linoleate) required to produce 1.00 MJ = $\frac{1.00}{11.7}$ = 0.0855 mol.

Molar mass of methyl linoleate = (19 × 12 + 34 × 1 + 16 × 2) = 294 g mol^{-1}

Mass(methyl linoleate) = $n \times M$ = 0.0855 × 294 = 25.1 g

Explanatory notes

1 mole of methyl linoleate produces 11 700 kJ mol^{-1}. To make this calculation, the units used for heat of combustion and energy must be the same.

Heat of combustion = 11.7 MJ mol^{-1}

The release of 1.00 MJ will require the combustion of $\frac{1.00}{11.7}$ = 0.0855 mol.

The mass of 0.0855 mol can be calculated using $n = m \times M$.

Mark allocation: 2 marks

- 1 mark for calculation of number of mole
- 1 mark for correct calculation of mass and correct unit of g

Question 1b.iii.

Worked solution

$n(CO_2) = 19 \times n(\text{ester}) = 19 \times 0.0855 = 1.62$ mol

$$V = \frac{nRT}{P} = \frac{1.62 \times 8.31 \times 553}{245} = 30.5 \text{ L}$$

Explanatory notes

This is a standard application of the ideal gas equation, using $V = \frac{nRT}{P}$.

The temperature, in K, will be 280 + 273 = 553 K.

The volume calculated will be in L.

Mark allocation: 2 marks

- 1 mark for substitution of correct temperature and pressure
- 1 mark for correct answer and units

Question 1c.i.

Worked solution

Lipase breaks the ester bonds in triglycerides to produce fatty acids and glycerol.

Explanatory notes

Digestion of oils is a hydrolysis reaction, where the ester bonds are broken to form glycerol and fatty acids.

Mark allocation: 1 mark

- 1 mark for stating ester bonds

Question 1c.ii.

Worked solution

Bile acts as an emulsifier. It breaks large blobs of oil into much smaller blobs, increasing the surface area and speeding up the hydrolysis reaction.

Explanatory notes

Bile acts as an emulsifier. It converts large blobs of oil into many smaller blobs. The surface area of the blobs is increased, facilitating the action of lipase enzyme. The reaction rate is increased.

Mark allocation: 2 marks

- 1 mark for explaining that bile is an emulsifier
- 1 mark for explaining the subsequent increase in reaction rate

Question 2a.i.

Worked solution

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

Explanatory notes

Ammonia is one reactant in the cell and oxygen is the other. Given that it is operating in alkaline conditions, the half-equation for the reaction of oxygen will be the one at 0.40 V in the electrochemical series.

Mark allocation: 1 mark

- 1 mark for the correct half-equation

Tips

- *The oxygen half-equation in a fuel cell will be:*

  $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ *if it is acidic conditions*

  $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ *if it is alkaline conditions.*

- *Both half-equations are provided in the electrochemical series.*

Question 2a.ii.

Worked solution

$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(l)$

Explanatory notes

The overall equation is derived by balancing the electrons in the half-equations, then adding the two half-equations.

$(2NH_3(g) + 6OH^-(aq) \rightarrow N_2(g) + 6H_2O(l) + 6e^-) \times 2$

$(O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)) \times 3$

Overall equation is $4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(l)$

Mark allocation: 2 marks

- 1 mark for the correct reactants and products, with states not checked
- 1 mark for the correctly balanced equation

Question 2b.i.

Worked solution

The ammonia reaction is at the anode, which has a negative polarity.

Explanatory notes

The ammonia half-equation is an oxidative one.

Oxidation occurs at the anode and the anode has a negative polarity.

Mark allocation: 1 mark

- 1 mark for indicating negative polarity

Question 2b.ii.

Worked solution

Nitrogen is oxidised from –3 to 0.

Explanatory notes

In NH_3, the oxidation state of hydrogen is +1, so nitrogen will be –3. When elemental nitrogen is formed, the oxidation state will be 0.

Mark allocation: 1 mark

- 1 mark for writing –3 to 0

Tip

- *When writing oxidation states, include the sign first and then the number: for example, –3 rather than 3–.*

Question 2c.

Worked solution

This is a fuel cell. It will not be recharged. It uses a continuous supply of reactants instead. Therefore, it is not a problem that the cell cannot be recharged.

Explanatory notes

The principle of a fuel cell is that it utilises a continuous supply of reactants. It is not an expectation that it will be rechargeable.

Mark allocation: 1 mark

- 1 mark for explaining that the cell needs a continuous supply of reactants

Question 2d.i.

Worked solution

Ammonia is not as explosive as hydrogen; hence, it safer to handle.

Explanatory notes

Ammonia offers two important advantages over hydrogen: it is easy to store as a liquid, so transport is easier, and it is less explosive than hydrogen, making it safer to handle.

Mark allocation: 1 mark

- 1 mark for a valid explanation that includes a comparison with hydrogen

Question 2d.ii.

Worked solution

The electrodes in a fuel cell must catalyse the reaction and they must be porous to allow gas to flow through them. Porosity improves the efficiency of the cell.

Explanatory notes

Fuel cell electrodes have important functions in the cell's operation. They must act as catalysts for the reaction and the reactant gases must be able to move through them.

Mark allocation: 2 marks

- 1 mark for stating that they act as a catalyst
- 1 mark for stating that they must be porous

Question 3a.

Worked solution

Reaction 1: There will be an increase in the rate and an increase in yield. An increase in temperature increases collision frequency and the proportion of successful collisions. This is an endothermic reaction, meaning an increase in temperature will lead to a higher yield

Reaction 2: There will be an increase in the rate and a decrease in yield. An increase in temperature increases collision frequency and the proportion of successful collisions. This is an exothermic reaction, meaning an increase in temperature will lead to a lower yield.

Explanatory notes

For both reactions, an increase in temperature will lead to an increase in the reaction rate, whereby the particles move faster so collide more frequently and a higher proportion of particles have sufficient energy to react.

The effect on yield depends on whether the reaction is exothermic or endothermic. For exothermic reactions, the reverse reaction is favoured. For endothermic reactions the forward reaction is favoured.

Mark allocation: 4 marks

- 1 mark for the effect on each reaction (up to 2 marks)
- 1 mark for the explanation of the effect on each reaction (up to 2 marks)

Question 3b.

Worked solution

Reaction 1: There will be an increase in the rate and a decrease in yield. An increase in pressure leads to more collisions because the particles are closer together. The reverse reaction is favoured to oppose the increase in pressure.

Reaction 2: There will be an increase in rate and no effect on yield. An increase in pressure leads to more collisions because the particles are closer together. There are the same number of reactant and product particles, so the yield will not change.

Explanatory notes

An increase in pressure will mean that the particles are closer together, therefore the frequency of collisions will increase.

The effect on yield depends on the ratio of reactant particles to product particles. The system will favour the side with the least particles to decrease the pressure. In the case of reaction 1 the reverse reaction is favoured but in reaction 2 there are the same number of reactant and product particles, so neither reaction is favoured.

Mark allocation: 4 marks

- 1 mark for the effect on each reaction (up to 2 marks)
- 1 mark for the explanation of the effect on each reaction (up to 2 marks)

Question 3c.

Worked solution

Strategy 1: An excess of steam is used.

Explanation: An increase in reactant concentration will push the reaction in the forward direction, leading to the production of more product.

Strategy 2: The catalyst is laid out in thin layers in tubes.

Explanation: This will ensure that the surface area of the catalyst is maximised, making it more efficient.

Explanatory notes

Excess steam: Steam is a cheap reactant as it is just water as a gas. If you use an excess of steam, the system will try to partially oppose this by moving in the forward direction, resulting in a higher yield. (Le Chatelier's principle could be used as the basis of the explanation.)

Catalyst: The mechanism of a catalyst usually relates to activity occurring at its surface. If the surface area is maximised, then the effectiveness of the catalyst is maximised.

Mark allocation: 2 marks

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

Note: There are other possible valid answers, such as the development of new catalysts or the removal of one of the products.

Question 4a.i.

Worked solution.

$C_3H_8O_2$. The m/z ratio of the parent molecular ion is 76, matching the formula of $C_3H_8O_2$.

Explanatory notes

The m/z ratio of the parent molecular ion is 76. This matches the relative molecular mass of $C_3H_8O_2$. (The molecular formula matches the empirical formula.)

Mark allocation: 1 mark

- 1 mark for the correct molecular formula

Question 4a.ii.

Worked solution

CH_2OH^+

Explanatory notes

An m/z ratio of 31 is common in primary alcohols. Given that the molecule contains oxygen, the presence of this functional group is a possibility.

Mark allocation: 1 mark

- 1 mark for a valid fragment with a relative mass of 31.

  Note: The positive sign must be shown to receive a mark.

Question 4b.

Worked solution

The compound contains an –OH (alcohol) functional group, as evidenced by the broad absorption around 3300 cm^{-1}.

The compound does not contain a C=O group due to the lack of absorption around 1750 cm^{-1}.

Explanatory notes

Given that the molecular formula contains oxygen atoms, it is reasonable to start looking at the 3300 cm^{-1} and 1750 cm^{-1} regions.

The molecule does not contain a C=O group due to the lack of absorption around 1750 cm^{-1}.

It is likely to have a –OH bond as there is a broad absorption around 3300 cm^{-1}.

The molecule could be an alcohol but is unlikely to be a carboxylic acid, an aldehyde or a ketone.

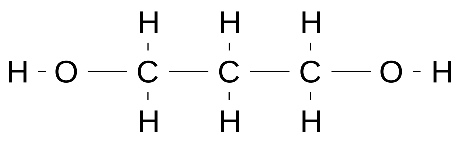
Mark allocation: 2 marks

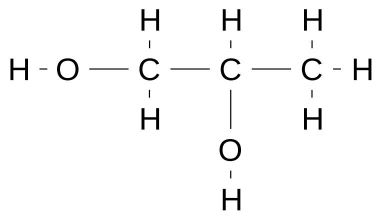
- 1 mark for each valid absorption reference.

  Note: There are other possible answers that might refer to bonds such as the C—C bond or the C – H bond.

Question 4c.

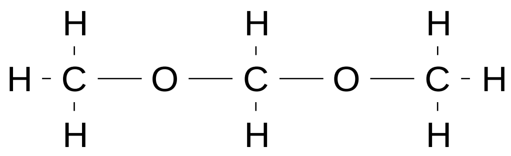
Worked solution





Explanatory notes

Isomers of propanediol are possible answers. At this point, other isomers with the correct molecular formula could be accepted, such as $HOCH_2OCH_2CH_3$ or the one pictured below.



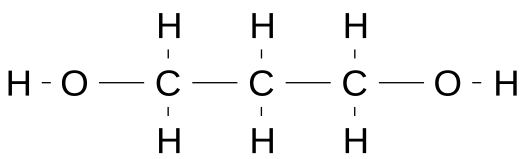
Mark allocation: 2 marks

- 1 mark for each structure with a molecular formula of $C_3H_8O_2$ (up to 2 marks)

Question 4d.i.

Worked solution

Name: propane-1,3-diol.



Explanatory notes

The molecule has two hydroxyl groups and they must be on opposite ends for the NMR spectrum to be accurate.

Mark allocation: 2 marks

- 1 mark for drawing propane-1,3-diol
- 1 mark for providing the correct IUPAC name

Question 4d.ii.

Worked solution

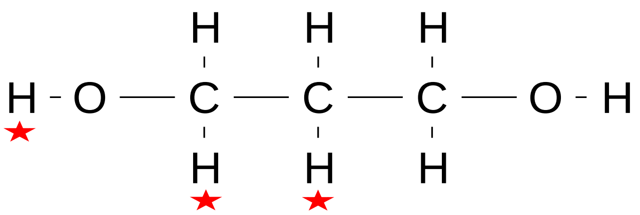
This molecule has three different hydrogen environments, and the splitting patterns match those in the question: the –OH protons are a singlet; the middle hydrogen atoms have four neighbours, leading to the quintet on the spectrum; and the other protons have two neighbours, producing the triplet.

Explanatory notes

The mass spectrum confirms the molecular formula.

The infrared spectrum suggests an alcohol.

The NMR can then be used to confirm the choice of propane-1,3-diol.



The three different hydrogen environments are shown with stars. They are, from left to right, a singlet, a triplet and a quintet.

Mark allocation: 2 marks

- 2 marks for an appropriate justification of propane-1,3-diol

Tip

- *The molecules you are required to identify in these styles of questions are not necessarily ones that you will be familiar with. If you cannot picture the structure immediately, try visualising the atoms like the models you make in class, whereby you randomly try the atoms present in any sequence. In this question, there are two –OH groups. In past VCAA questions, there have been questions about branched chains or ether (C–O–C) functional groups.*

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Question 5a.i.

Worked solution

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

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$

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

Explanatory notes

This is an aqueous solution, so the two water half-equations are included. Copper metal and copper ions are present, so the copper half-equation is present. Iron metal is present, so the iron half-equation is included.

Note: Students might also include the half-equation for gold, $Au^+(aq) + e^- \rightarrow Au(s)$, as it is present as an impurity. This half-equation will not actually occur but could be a possibility. If a student shows this equation, it is an acceptable addition but is not compulsory. This also applies if students write the half-equation for sulfur.

Mark allocation: 2 marks

- 1 mark for both water half-equations
- 1 mark for both metal half-equations

Tip

- *You may have performed an experiment like this in class, where you measured the change in mass of the copper electrodes of an electrolytic cell. Your experiences conducting experiments during the year will likely be beneficial on one or more exam questions.*

Question 5a.ii.

Worked solution

Anode half-equation: $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

Cathode half-equation: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Overall equation: $Cu(s) + Cu^{2+}(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$

Explanatory notes

The species present in this cell are in bold.

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow \mathbf{2H_2O(l)}$

$\mathbf{Cu^{2+}(aq)} + 2e^- \rightarrow \mathbf{Cu(s)}$

$Fe^{2+}(aq) + 2e^- \rightarrow \mathbf{Fe(s)}$ (This cannot react as it is the negative electrode.)

$\mathbf{2H_2O(l)} + 2e^- \rightarrow 2H_2(g) + 2OH^-(aq)$

The species that react out of the possible reactants are the strongest oxidising agent, Cu^{2+} and the strongest reducing agent, Cu(s). The reaction of Cu^{2+} is reduction, which will occur at the cathode. Cu(s) reacts at the anode.

Mark allocation: 3 marks

- 1 mark for each correct equation

Question 5b.

Worked solution

Gold particles will fall to the bottom of the cell under the electrode. The gold could be collected from there.

Explanatory notes

The gold is present as gold metal, which is a very dense metal. As the copper forms Cu^{2+} ions on the anode, the anode crumbles away and the gold particles drop to the bottom of the cell under the electrode. They can be collected from under this electrode.

Mark allocation: 1 mark

- 1 mark for suggesting the gold should drop to the bottom of the cell under the electrode

Question 5c.

Worked solution

1.00 kg of blister copper will be 1000 × 98% copper = 980 g copper.

$$n(\text{Cu}) = \frac{980}{63.5} = 15.43 \text{ mol}$$

$$n_\text{e} = 2n(\text{Cu}) = 2 \times 15.43 = 30.87 \text{ mol}$$

$$Q = n_\text{e} \times 96\,500 = 2.98 \times 10^6 \text{ C}$$

$$t = \frac{Q}{I} = \frac{2.98\times106}{360} = 8274 \text{ s} = 2.30 \text{ h}$$

Explanatory notes

The blister copper is 98% copper, so the first calculation is to establish the exact mass of copper, 980 g.

The number of mole of copper is then calculated.

Each copper atom reacting requires two electrons, so the n_e is double the number of mole of copper.

The charge required is calculated next, then the time. The time in seconds needs to be divided by 3600 to convert it to hours.

Mark allocation: 4 marks

- 1 mark for correctly calculating the mass of copper. (This step does not have to be the first step.)
- 1 mark for the correct number of mole of electrons
- 1 mark for the correct charge
- 1 mark for the correct time in hours

Question 6a.i.

Worked solution

Lysine contains a chiral carbon; therefore, it can form two enantiomers or optical isomers.

Explanatory notes

The carbon atom that attaches to the R group of lysine is a chiral carbon. This leads to lysine having two enantiomers or optical isomers.

Mark allocation: 2 marks

- 1 mark for mentioning a chiral carbon
- 1 mark for subsequently mentioning enantiomers or optical isomers

Question 6a.ii.

Worked solution

It is common for the properties of enantiomers to differ in the body. The different spatial orientations of each isomer can cause them to interact differently with a substrate or enzyme. It is likely that L-lysine matches the active site of the enzyme and therefore is active in the body but D-lysine does not match the active site.

Explanatory notes

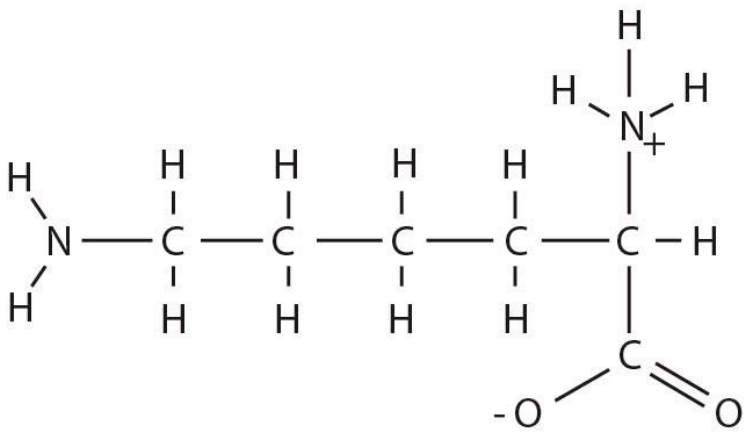
The orientation of functional groups differs in each enantiomer. The different orientation might mean that one enantiomer has the correct orientation for a particular enzyme or substrate but the other does not.

Mark allocation: 1 mark

- 1 mark for explaining that optical isomers can behave differently in biochemical reactions

Question 6b.i.

Worked solution



Explanatory notes

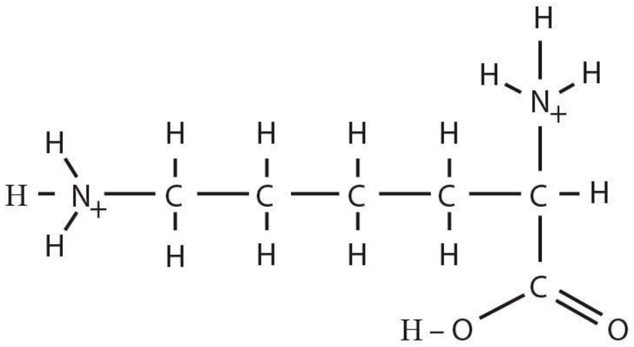
In a zwitterion, the proton from the carboxyl group moves to the nearby amine group.
A zwitterion must be neutral in charge, so the other amine group is unchanged.

Mark allocation: 1 mark

- 1 mark for the correct diagram

Question 6b.ii.

Worked solution



Explanatory notes

In acidic conditions there is an excess of H^+ ions. These ions will attach to the carboxyl group and to the amine group on the R group.

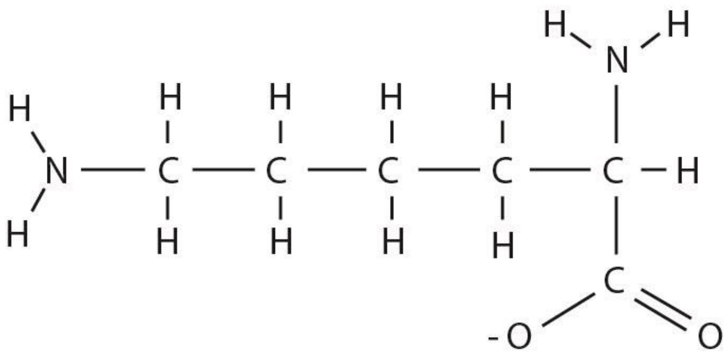
Mark allocation: 1 mark

- 1 mark for a correct diagram.

Note: It must be clear that the + signs are on the N atoms and not the H atoms.

Question 6b.iii.

Worked solution



Explanatory notes

The excess OH^- ions from the base will accept any possible protons from the lysine.

Mark allocation: 1 mark

- 1 mark for a correct diagram

Tip

- *To answer questions like* ***part a****, keep in mind that:*
  - *a zwitterion must be neutral*
  - *at low pH, excess H^+ ions are available*
  - *at high pH, H^+ ions are drawn from the amino acid to react with the base.*

Question 6c.

Worked solution

The amine group on the R group of lysine can act as a base and accept a proton from an acidic R group. When this happens, a relatively strong ionic bond forms between the two R groups.

Explanatory notes

Amino acids with amine R groups can form salt bridges with amino acids with acidic R groups, such as aspartic acid. The amine group accepts a proton from the carboxyl group for the two ions to form. This formation is referred to as a salt bridge. (It is also acceptable to state that the amine group can also form hydrogen bonds with other polar R groups.)

Mark allocation: 2 marks

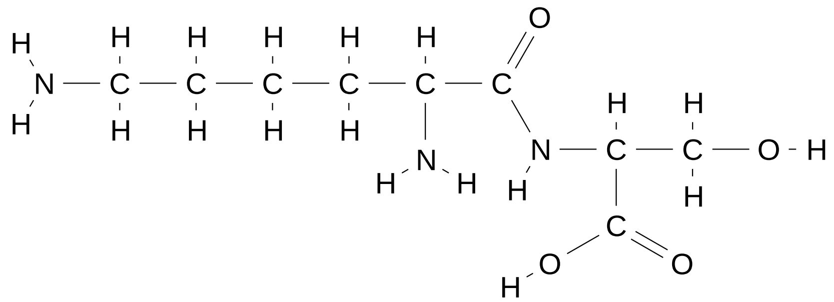
- 1 mark for discussing how the amine group can act as a base
- 1 mark for stating that an ionic bond forms between the R groups. (Alternatively, 1 mark for discussing hydrogen bonding.)

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 6d.

Worked solution



Explanatory notes

When the amino acids react, a peptide bond forms between them and water is released as a small molecule.

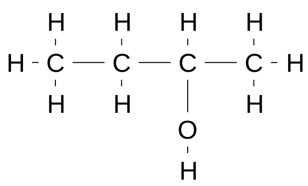
Mark allocation: 2 marks

- 1 mark for the peptide bond drawn correctly
- 1 mark for the remainder of structure being correct

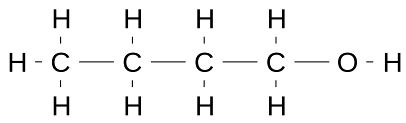
Question 7a.

Worked solution

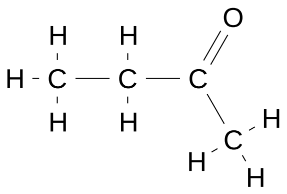
Compound B



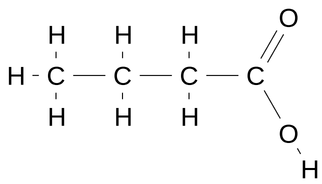
Compound C



Compound D



Compound E



Explanatory notes

When Compound A reacts, an –OH group and a –H atom will be added over the carbon-to-carbon double bond. There are two positions to which the –OH group can attach (see solutions above).

Compound B is a secondary alcohol, so it will form a ketone when oxidised.

Compound C is a primary alcohol, so it will form a carboxylic acid when oxidised.

Mark allocation: 4 marks

- 1 mark for each correct structure (up to 4 marks)

Question 7b.i.

Worked solution

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$

Explanatory notes

This half-equation can be written by balancing the oxygen first, then the hydrogen and finally the charges.

Mark allocation: 1 mark

- 1 mark for a correct half-equation

Tip

- *The reagent used in this question (MnO_4^-) might not be familiar to many students. So how are you supposed to know what its function is? The type of ions that it is acting in a similar way to are the $Cr_2O_7^{2-}$ ions used to convert alcohol molecules to carboxylic acid. You are expected to be able to deduce that MnO_4^- will work in the same way.*

Question 7b.ii.

Worked solution

$C_4H_8 + H_2O \rightarrow C_4H_{10}O$

Explanatory notes

This is an addition reaction where the hydroxyl group is added over the carbon-to-carbon double bond.

Mark allocation: 1 mark

- 1 mark for a valid equation (semistructural formulas can be used)

Note: States are not required.

Question 7c.i.

Worked solution

addition

Explanatory notes

A reaction over a carbon-to-carbon double bond that forms only one product is an addition reaction.

Mark allocation: 1 mark

- 1 mark for specifying addition

Question 7c.ii.

Worked solution

oxidation

Explanatory notes

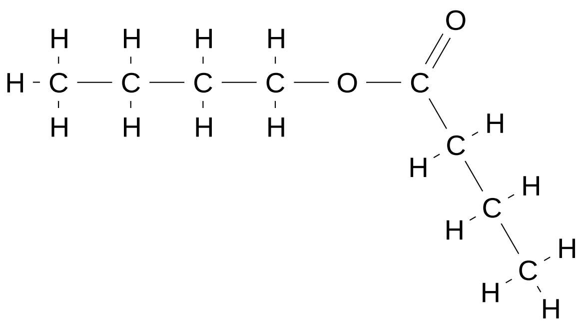
$MnO_4^-(aq)$ is an oxidising agent. It is reduced to Mn^{2+} during the reaction.

Mark allocation: 1 mark

- 1 mark for specifying oxidation

Question 7d.

Worked solution



IUPAC name: butyl butanoate

Explanatory notes

When an alcohol and an acid react with sulfuric acid as a catalyst, an ester is formed. With butanol reacting with butanoic acid, the ester will be butyl butanoate.

Mark allocation: 2 marks

- 1 mark for the correct structure
- 1 mark for the correct name

Question 8a.i.

Worked solution

The independent variable is the type of indicator.

Explanatory notes

The experiment has used three different indicators and the titre obtained will depend on this indicator.

Mark allocation: 1 mark

- 1 mark for specifying the indicator

Question 8a.ii.

Worked solution

The dependent variable is the mean titre.

Explanatory notes

The titre obtained will depend upon the indicator used.

Mark allocation: 1 mark

- 1 mark for specifying mean titre

Question 8b.i.

Worked solution

$CH_3CH_2COOH(aq) + NaOH(aq) \rightarrow NaCH_3CH_2COO(aq) + H_2O(l)$

Explanatory notes

An acid and a base will form a salt and water. The salt will be formed from the sodium and propanoate ions, $NaCH_3CH_2COO$.

Mark allocation: 1 mark

- 1 mark for a correct equation and states.

Note: Propanoic acid could also be shown as $C_3H_6O_2$.

Question 8b.ii.

Worked solution

The fact that propanoic acid is a weak acid will have no effect upon the titre obtained. The reaction between a weak acid and a strong base is not a reversible reaction.

Explanatory notes

The reaction of a weak acid, such as propanoic acid, with water is a reversible reaction. However, the reaction of propanoic acid and sodium hydroxide is not reversible, so the weak acid nature of propanoic acid will not affect the titre obtained.

Mark allocation: 1 mark

- 1 mark for explaining that there would be no impact

Question 8c.

Worked solution

Sodium hydroxide is not a good standard, as it can both absorb water and react with CO_2 when left open. The equation is:

$2NaOH(s) + CO_2(g) \rightarrow Na_2CO_3(aq) + H_2O(l)$

Explanatory notes

A primary standard needs to be both pure and stable. Each time the sodium hydroxide container is opened, it can absorb either water or CO_2. When it does this, it is no longer possible to weigh an accurate mass of sodium hydroxide.

Mark allocation: 2 marks

- 1 mark for an explanation
- 1 mark for a supporting equation

Question 8d.

Worked solution

The student has useful data but it would be better to rephrase the hypothesis as 'An appropriate choice of indicator will maximise the accuracy and precision of results.' The conclusion that could then be drawn is that the hypothesis is true. The titre data for phenolphthalein is precise and concordant, whereas the titre data for the other two indicators is not. Phenolphthalein is a good choice for the titration between a weak acid and a strong base due to its high transition pH.

Explanatory notes

The student has performed a useful experiment but has not phrased their hypothesis appropriately, as the student's understanding of indicators is flawed. The student has assumed any indicator will produce the same mean titre, but this is not the case. The indicator chosen must be one that is suitable for the reaction between a weak acid (propanoic acid) and a strong base (NaOH). A pH curve can be used to show that an indicator changing around pH 9 will provide accurate results, and phenolphthalein is the only indicator of the three with a colour change around pH 9. (Transition values are shown in the data book.)

The titres obtained for phenolphthalein support this hypothesis, as they are concordant. The titres for the other indicators fluctuate and are low, as the indicator is changing colour before the equivalence point has been reached.

Mark allocation: 4 marks

- 1 mark for explaining how an indicator should be chosen
- 1 mark for explaining why the student's conclusion is not justified
- 2 marks for outlining a valid alternative hypothesis and conclusion

Note: The reason the equivalence point does not occur at pH 7 is that the salt formed in the titration is a weak base.

Question 9a.

Worked solution

The function of a catalyst is to increase the rate of a reaction. It does this by providing an alternative pathway for the reaction that has a lower activation energy.

Both inorganic catalysts and enzymes can increase a reaction rate. Interactions on the surface of the catalyst are important in both cases because the bonding between the substrate and the catalyst weakens bonds in the substrate, lowering the activation energy required. Enzymes and inorganic catalysts are not changed in the reaction and their catalytic action is repeated multiple times during a reaction.

Organic catalysts affect one biochemical reaction only, whereas some inorganic catalysts are effective in more than one reaction. Inorganic catalysts are less affected by high temperatures, whereas enzymes are denatured at high temperatures.

In the context of this question, manganese dioxide is an inorganic catalyst. It is not affected greatly by temperature and its effectiveness is due to the adsorption of hydrogen peroxide onto its surface. Catalase is an enzyme. Its 3D shape is the key to its effectiveness and it is denatured at elevated temperatures.

Explanatory notes

Catalysts are used to increase the rate of reactions by lowering the activation energy of the reaction.

Both inorganic catalysts and enzymes increase reaction rates without being permanently changed in the reaction. They have no impact on the position of equilibrium. They both rely on interactions between their surfaces and the surface of the substrate.

Enzymes catalyse one reaction only, whereas inorganic catalysts are not necessarily specific to only one process. Enzymes are more sensitive to heat than inorganic catalysts and are usually rendered ineffective at temperatures over 70 °C.

Mark allocation: 5 marks

- 1 mark for explaining how catalysts function
- 2 marks for giving two valid similarities between inorganic catalysts and enzymes
- 2 marks for giving two valid differences between inorganic catalysts and enzymes

Question 9b.

Worked solution

Denaturation is a disruption of the tertiary and secondary structure of an enzyme. Temperature or pH changes can disrupt the links between R groups on amino acids, causing the shape of the enzyme to change. If the enzyme shape changes, it is unlikely to be able to catalyse the required reaction. The appearance of the casein will change but it is still a protein.

Hydrolysis is the breakdown of the primary structure of a protein, whereby the covalent bonds between neighbouring amino acids are broken. The broken covalent bonds are peptide bonds. Casein is converted to amino acids.

Explanatory notes

Denaturation: Enzymes have a particular 3D shape that suits a particular substrate, allowing temporary bonding to form between the enzyme and substrate. Changes in pH or temperature can disrupt this 3D shape, meaning that the enzyme will no longer catalyse the desired reaction. This is referred to as denaturation. The change in shape occurs because the tertiary and secondary structures of the enzyme have been disrupted. The bonding between amino acid R groups is the main bonding affected.

Hydrolysis: Hydrolysis is the breakdown of the primary structure of a protein, whereby the covalent bonds between neighbouring amino acids are broken. Casein is converted to amino acids. The action of an acid or base, or other enzymes, can hydrolyse the covalent bonds. It is the peptide bonds that are broken.

Mark allocation: 4 marks

- 2 marks for an explanation of denaturation and its effect on the enzyme's 3D shape.

Note: It must be stated that the tertiary and secondary structures are disrupted.

- 2 marks for an explanation of hydrolysis and its effect on the primary structure of a protein.

Note: It must be stated that casein is broken down to amino acids.

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END OF WORKED SOLUTIONS