YEAR 12 *Trial Exam Paper*

2018

CHEMISTRY

Written examination

Worked solutions

This book includes:

- correct solutions, with full working
- explanatory notes
- mark allocations
- tips on how to approach the exam.

SECTION A – Multiple-choice questions

Question 1

Answer: D

Explanatory note

Option A is incorrect. Diesel generators produce CO_2 and a range of other pollutants.

Option B is incorrect as diesel is a petroleum product that is non-renewable.

Option C is incorrect. Many galvanic cells and fuel cells will be more efficient than a diesel generator.

Option D is correct. If demand for electrical energy is unexpectedly high, the diesel generators can be switched on to meet this demand very quickly.

Question 2

Answer: A

Explanatory note

Option A is correct. Alkanes have the general formula C_nH_{2n+2}. For the alkane molecule to have 38 atoms, the formula must be $C_{12}H_{26}$.

Option B is incorrect. It is an alkene.

Option C is incorrect as it contains too many atoms.

Option D is incorrect as it contains too many atoms.

Question 3

Answer: C

Explanatory note

Option A is incorrect as the $n(CO_2)$ will be $4n$(butane), not 1 : 1.

Option B is incorrect as the $n(CO_2)$ will be $4n$(butane), not 1 : 2.

Option C is correct.

$n(\text{butane}) = \frac{116}{58} = 2 \text{ mol}$

$n(CO_2) = 4n(\text{butane}) = 4 \times 2 = 8 \text{ mol}$

$$V = \frac{nRT}{P} = \frac{8 \times 8.31 \times 473}{100} = 314 \text{ L}$$

Option D is incorrect as the $n(CO_2)$ will be $4n$(butane), not 1 : 8.

Tip

- *There are aspects to the Chemistry course that are highly likely to appear on the exam. You must focus on these areas. Use of the ideal gas equation to calculate emission volumes fits the 'highly likely' category. Examiners value the skill to complete stoichiometry and this is one of the few topics that provides an opportunity to assess this skill.*

Question 4

Answer: B

Explanatory note

Option A is incorrect as 24.8 L represents only 1 mole of ethane.

Option B is correct.

Energy produced by butane = 150 × 49.7 = 7460 kJ

$$n(\text{ethane}) = \frac{7460}{1560} = 4.78 \text{ mol}$$

$V = n \times 24.8 = 4.78 \times 24.8 = 119 \text{ L}$

Option C is incorrect as 1560 represents 1 mole of ethane only.

Option D is incorrect as 7460 is the total amount of energy, not the volume of ethane.

Question 5

Answer: C

Explanatory note

Option A is incorrect. The answer must be M^2.

Option B is incorrect. The answer must be M^2.

Option C is correct.

$$K = \frac{M \times M^4}{M \times M^2} = M^2$$

Option D is incorrect. The answer must be M^2.

Question 6

Answer: B

Explanatory note

Option A is incorrect. An increase in temperature will cause the system to shift in the endothermic direction in order to reduce the added heat. Therefore, the back reaction is favoured, decreasing the yield.

Option B is correct. If the pressure is decreased, the system will oppose this change by moving to the side with more particles. There are more products than reactants so the forward reaction is favoured, improving the yield.

Option C is incorrect as a decrease in volume will increase the pressure and concentration. The back reaction is favoured in order to decrease the concentration of particles.

Option D is incorrect as the addition of CO_2 will favour the back reaction, to remove CO_2.

Question 7

Answer: D

Explanatory note

Option A is incorrect. The low activation energy means the reactants are unstable and it is not endothermic.

Option B is incorrect as the reactants are not stable.

Option C is incorrect as the amount of energy released will be significant.

Option D is correct. The activation energy is very low, meaning the reactants will be unstable. The enthalpy of the products is much lower than that of the reactants, so the reaction is highly exothermic.

Question 8

Answer: A

Explanatory note

Option A is correct. If the temperature is increased in an exothermic reaction, the reverse reaction is favoured. The amount of reactants will increase in stoichiometric amounts and the amount of product will decrease. The amounts in option A are consistent with the balanced equation.

Option B is incorrect as the ratios in the equation have not been taken into account.

Option C is incorrect as the amounts of all chemicals cannot increase.

Option D is incorrect as the system does not go in the forward direction.

Question 9

Answer: C

Explanatory note

Option A is incorrect as the formula of ethanol is wrong.

Option B is incorrect as it shows a reduction equation.

Option C is correct. The correct formula for ethanol is C_2H_6O. The reaction is oxidation, so the electrons need to be on the right-hand side of the equation. The equation is balanced. The stem of the question contains a useful clue when it says ‘in acidic conditions’. This phrase alerts you to look for the presence of H^+ ions.

Option D is incorrect as the reaction does not occur in alkaline conditions and hydrogen gas will not be produced.

Tip

- *You should be well versed in writing half-equations for the reaction of ethanol, dichromate ions ($Cr_2O_7^{2-}$) or permanganate ions (MnO_4^-). These three chemicals are often examined.*

Question 10

Answer: D

Explanatory note

Option A is incorrect as Li_2MnO_2 is not present in the cell.

Option B is incorrect as lithium metal is a reactant, and oxygen gas is not.

Option C is incorrect as lithium metal is a reactant, not a product.

Option D is correct.

The half-equations in this cell are

$MnO_2(s) + Li^+ + e^- \rightarrow LiMnO_2(s)$

$Li(s) \rightarrow Li^+ + e^-$

The overall equation is obtained by adding these half-equations together

$Li(s) + MnO_2(s) \rightarrow LiMnO_2(s)$

It is possible to deduce the overall equation from the diagram rather than working through the two half-equations.

Question 11

Answer: C
Explanatory note

Option A is incorrect as it is represents the change at the anode. It is an oxidation reaction that will occur at the anode.

Option B is incorrect as the manganese ends up as Mn^{3+}.

Option C is correct. When going from MnO_2 to $LiMnO_2$, the manganese is changing from Mn^{4+} to Mn^{3+}.

Option D is incorrect as the manganese ends up as Mn^{3+}.

Tip

- *To work out the oxidation states, use the following rules.*
  - *Oxygen will usually have an oxidation number of –2.*
  - *Hydrogen will usually have a charge of +1.*
  - *An element (e.g.* Cl_2*) will have an oxidation state of zero.*
  - *The periodic table can be used for many elements like calcium, chlorine etc.*
  - *Oxidation: increase in oxidation number. Reduction: decrease in oxidation number.*

Question 12

Answer: B

Explanatory note

Option A is incorrect because it is the discharge reaction at the cathode, as it is reduction.

Option B is correct. When the cell is being recharged, the anode is the positive electrode, where oxidation occurs.

Option C is incorrect as it will occur at the cathode.

Option D is incorrect as it is the anode discharge reaction.

Question 13

Answer: A

Explanatory note

Option A is correct. The spontaneous reaction will be between iodine and aluminium metal. The iodine will be reduced and the aluminium oxidised, therefore the metal is the reductant.

Option B is incorrect as aluminium ions are not the oxidising agent.

Option C is incorrect as iodine is reduced.

Option D is incorrect as iodide ions are not oxidised.

Tip

- *You are expected to know how to analyse the galvanic cell that can be constructed from any two half-cells shown on the electrochemical series. Analyse means write half-equations and predict the direction of electron flow and polarity.*

Question 14

Answer: D

Explanatory note

Option A is incorrect as oxygen gas will not form. Oxidation of water to oxygen is non-spontaneous and would require energy.

Option B is incorrect as hydrogen and oxygen gases do not form. Water is not electrolysed as no energy is being supplied and, more importantly, zinc ions and copper metal are, respectively, the strongest oxidant/reductant present.

Option C is incorrect as the zinc ions react at the cathode.

Option D is correct. Zinc ions are the strongest oxidising agent present. They react to form zinc metal on the cathode. Copper metal is the strongest reducing agent present. It reacts to form copper(II) ions at the anode.

Question 15

Answer: C

Explanatory note

Option A is incorrect as it is a reaction that would occur at the anode, not the cathode.

Option B is incorrect as the equation is the wrong way around.

Option C is correct.

$Q = It = 10 \times 193 = 1930$ C

$$n(\text{e}) = \frac{1930}{96\,500} = 0.02 \text{ mol}$$

The number of mole of metal obtained has to be consistent with 0.02 mol and a balanced half-equation.

To identify the metal, we need to know its molar mass.

From options C and D remaining, we can see that n(metal) = n(e).

$$M(\text{metal}) = \frac{m(\text{metal})}{n(\text{metal})} = \frac{0.138 \text{ g}}{0.02 \text{ mol}} = 6.9 \text{ g mol}^{-1}$$

Therefore, the metal is lithium.

Option D is incorrect as the mass of sodium would not be consistent with the calculated molar mass.

Question 16

Answer: A

Explanatory note

Option A is correct.

n(gas) at standard laboratory conditions (SLC) = $\frac{0.248}{24.8}$ = 0.01 mol

n(gas) is therefore half the number of mole of electrons calculated in Question 15.

The gas must have a ratio of 1 : 2 between the number of mole of gas and the number of mole of electrons. $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$ has the correct ratio.

Option B is incorrect as the ratio between oxygen and electrons would be 1 : 4.

Option C is incorrect as the ratio between carbon dioxide and electrons would be 1 : 4.

Option D is incorrect as the ratio between nitrogen and electrons would be 1 : 6, as the equation would be $2N^{3-} \rightarrow N_2 + 6e^-$.

Question 17

Answer: B

Explanatory note

Option A is incorrect. An amine is needed to form an amide.

Option B is correct. The molecule shown is an amide formed from the condensation reaction of an amine with a carboxylic acid. The amine has three carbon atoms so is propan-1-amine, and the carboxylic acid is ethanoic acid.

Option C is incorrect as the amine is propan-1-amine rather than butan-1-amine.

Option D is incorrect as neither an amine nor a carboxylic acid is suggested.

Question 18

Answer: D

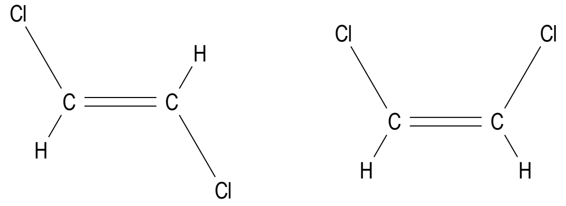
Explanatory note

Option A is incorrect. Each carbon needs to have different atoms attached.

Option B is incorrect as it does not have a carbon-to-carbon double bond.

Option C is incorrect as the first carbon does not have different atoms attached.

Option D is correct. The two geometric isomers are



Question 19

Answer: A

Explanatory note

Option A is correct. The molecule should contain a carbon-to-carbon double bond if it reacts with bromine, and it should contain a carboxyl group to react with NaOH. It will not react with $Cr_2O_7^{2-}$, as the COOH group is already fully oxidised. Molecule A has all the above features.

Option B is incorrect. It does not contain a carbon-to-carbon double bond.

Option C is incorrect as it contains neither functional group.

Option D is incorrect as it does not contain a carboxyl group.

Question 20

Answer: C

Explanatory note

Option A is incorrect. The two concentrations cannot be equal given the titre obtained.

Option B is incorrect as the answer would be 0.133 M for a monoprotic acid.

Option C is correct.

n(NaOH) = 0.1 × 0.02 = 0.002 mol

Each answer needs to be trialled for consistency with this 0.002 mol.

If the acid is diprotic, the number of mole will be $\frac{1}{2} \times n(\text{NaOH}) = 0.001$ mol.

$c = \frac{n}{V} = \frac{0.001}{0.015}$ = 0.066 M, matching option C.

Option D is incorrect as it is double the answer of a diprotic acid.

Tip

- *Titrations provide another opportunity for the examiner to test stoichiometry. The focus of the course is on organic acids and bases, so ethanoic acid, oxalic acid and ethanamine will be commonly referred to.*

Question 21

Answer: D

Explanatory note

Option A is incorrect. A burette should be rinsed with the solution going into it rather than water, so as not to dilute the solution.

Option B is incorrect as the titre will be high.

Option C is incorrect as the titre will be high.

Option D is correct. The extra water dilutes the acid, meaning a higher titre is required to achieve the same number of moles of acid. This will lead to a low estimate of the concentration.

Question 22

Answer: D

Explanatory note

Option A is incorrect as propan-2-ol contains only two carbon environments.

Option B is incorrect as propanone contains only two carbon environments.

Option C is incorrect as the shifts do not match propanoic acid.

Option D is correct. The molecule must have three different carbon environments, therefore ruling out propanone and propan-2-ol. The shifts shown match propan-1-ol (10 ppm = $R–CH_3$, 25 ppm = $R–CH_2–R$ and 65 ppm = $R–CH_2OH$) rather than propanoic acid.

Question 23

Answer: B

Explanatory note

Option A is incorrect. There might be two molecules present with the same retention time or components that do not travel thorough the column.

Option B is correct. Since it is a sample of petrol, most components should be hydrocarbons. The shorter molecules will have the lowest retention times as the solvent is a non-polar one.

Option C is incorrect as low molecular mass molecules will have the shortest retention time.

Option D is incorrect as the response of one compound cannot be assumed to be the same as another compound.

Question 24

Answer: B

Explanatory note

Option A is incorrect. The reaction is much faster at 40 °C.

Option B is correct. The fastest rate of reaction is when the time taken is the shortest time – this is 40 °C.

Option C is incorrect as the rate is faster at 40 °C.

Option D is incorrect. The long time taken for the reaction shows that the enzyme is barely functioning at this temperature.

Question 25

Answer: A

Explanatory note

Option A is correct. Benedict's reagent detects the presence of reducing sugars (such as monosaccharides). The glucose formed from the hydrolysis of sucrose is a reducing sugar.

Option B is incorrect. Sucrose will not react with Benedict's Solution.

Option C is incorrect as invertase is an enzyme and not a sugar.

Option D is incorrect as the Benedict's Solution does not contain protein.

Question 26

Answer: B

Explanatory note

Option A is incorrect. Chewing will not cause hydrolysis.

Option B is correct. Saliva contains amylase that can hydrolyse starch to smaller, sweeter sugars.

Option C is incorrect as proteins will not contribute to sweetness.

Option D is incorrect as bread often contains few simple sugars.

Question 27

Answer: D

Explanatory note

Option A is incorrect. There are six possibilities.

Option B is incorrect. Keep in mind that the order of the amino acids is significant.

Option C is incorrect. There are six possibilities.

Option D is correct. The six combinations are Ile-Leu-Lys, Ile-Lys-Leu, Leu-Lys-Ile, Leu-Ile-Lys, Lys-Ile-Leu and Lys-Leu-Ile

Question 28

Answer: A

Explanatory note

Option A is correct. Bile emulsifies large blobs of fat to smaller globules. Lipase can then hydrolyse the triglycerides to fatty acids and glycerol.

Option B is incorrect. Lipase does not play a role in transport.

Option C is incorrect as lipase is relative to triglycerides, not proteins. The name lipase means cutting lipids.

Option D is incorrect. It is bile that leads to the formation of emulsions.

Question 29

Answer: C

Explanatory note

Option A is incorrect. Time needs to be in seconds, not minutes.

Option B is incorrect as the answer is out by a factor of 10.

Option C is correct.

Calibration factor = $\dfrac{VIt}{\Delta T} = \dfrac{5.4 \times 3.4 \times 5 \times 60}{6.4}$ = 861 J °C^{-1}

Option D is incorrect as it is double the correct answer's value.

Question 30

Answer: B

Explanatory note

Option A is incorrect. Answer is 8.30 kJ g^{-1}.

Option B is correct.

Energy = calibration factor × ΔT = 861 × 10.8 = 9300 J

Heat combustion = $\dfrac{9300}{1.12} = 8300 \text{ J g}^{-1} = 8.30 \text{ kJ g}^{-1}$

Option C is incorrect as the temperature change has not been used.

Option D is incorrect. Answer is incorrect, as well as units.

SECTION B

Question 1a.i.

Worked solution

Coal is burning, releasing thermal (heat) energy. This is an exothermic reaction.

Mark allocation: 1 mark

- 1 mark for stating thermal energy is released from coal

Question 1a.ii.

Worked solution

Moving hot steam is turning a turbine.

Mark allocation: 1 mark

- 1 mark for stating steam is turning a turbine

Question 1a.iii.

Worked solution

The turbine turning in a magnetic field leads to the transformation of mechanical energy to electrical energy.

Mark allocation: 1 mark

- 1 mark for stating the turning of a turbine generates electrical energy

Question 1b.i.

Worked solution

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

Explanation

The complete combustion of methane will produce carbon dioxide gas and water.

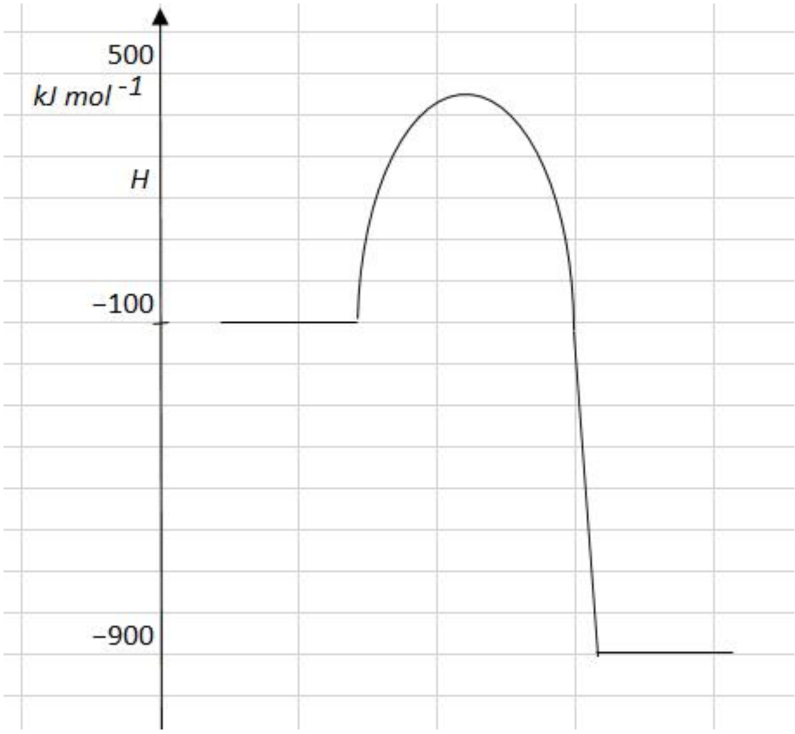
Mark allocation: 1 mark

- 1 mark for a balanced equation, including states

  Note: The value of ΔH is not required, as the question does not ask for a thermochemical equation.

Question 1b.ii.

Solution



Explanation

The combustion of methane will produce CO_2 and H_2O. The state of H_2O needs to be listed as liquid to match the data book, if conditions are at SLC and/or the quoted energy values are used. Always ensure that you take the context and reaction conditions into consideration when determining if H_2O is liquid or gas.

The value of ΔH for the combustion of methane is listed as –890 kJ mol^{-1}, making the enthalpy of the products –990 kJ. The activation energy of the exothermic reaction will be 1440 – 890 = 550 kJ.

Mark allocation: 2 marks

- 1 mark for correct shape of graph
- 1 mark for activation energy peaking at 450 kJ and enthalpy finishing at around –990 kJ

Tips

- *You are expected to know how to write combustion equations. This includes incomplete combustion.*
- *To balance equations for complete combustion, use the following process.*
    - *Balance carbon atoms:* $CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$
    - *Balance hydrogen atoms:* $CH_4(g) + O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
    - *Balance oxygen atoms last:* $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

Question 1c.i.

Worked solution

Mass (CH_4) = $d \times V$ = 0.66 g mL^{-1} × 50 000 mL = 33 000 g

Energy = 33 000 × 55.6 *(from data book)* = 1.8 × 10^6 kJ or 1.8 × 10^3 MJ

Explanation

The heat of combustion of methane is provided in the data book, in grams. Therefore, the first step is to calculate the mass of methane present. Note that it is easier to use the combustion value in kJ g^{-1} than the other value provided in the data book of kJ mol^{-1}.

Mark allocation: 1 mark

- 1 mark for correct answer

Question 1c.ii.

Worked solution

$$n(\text{methane}) = \frac{33\,000}{16} = 2063 \text{ mol}$$

$n(CO_2)$ = n(methane) = 2063 mol

$$V = \frac{nRT}{p} = \frac{2063 \times 8.31 \times 1073}{250} = 7.3 \times 10^4 \text{ L}$$

Explanation

The balanced equation shows that the number of mole of CO_2 will equal that of methane. The volume can be calculated using the ideal gas equation. Make sure you convert temperature to degrees K.

Mark allocation: 3 marks

- 1 mark for calculation of $n(CO_2)$
- 2 marks for correct substitution and calculation of volume, in L

Tip

- *This question is another example of how the data book is useful. The heat of combustion values for common fuels are included in a table in the data book. So, too, is the ideal gas equation. Be very familiar with the contents of the data book.*

Question 2a.i.

Worked solution

Ni^{3+} to Ni^{2+}

Explanation

Nickel goes from $2NiO(OH)$ to $Ni(OH)_2$. Knowing the charge on oxygen ions is usually –2 and hydroxide ions is usually –1, the oxidation state of nickel can be shown to change from +3 to +2.

Mark allocation: 1 mark

- 1 mark for Ni^{3+} to Ni^{2+}

  Note: The answer could be as simple as +3 to +2, although an answer such as 'decreases by +1' does not give sufficient evidence from the question to back up the answer.

Question 2a.ii.

Worked solution

Cadmium – its oxidation number increases from 0 to +2.

Explanation

Cadmium metal is replacing nickel ions in this cell, therefore cadmium is lower on the electrochemical series and is a stronger reducing agent.

Mark allocation: 1 mark

- 1 mark for cadmium

Question 2a.iii.

Worked solution

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

Explanatory notes

The overall equation shows cadmium metal reacting to form $Cd(OH)_2$. This reaction of Cd to Cd^{2+} will involve the release of two electrons.

Mark allocation: 1 mark

- 1 mark for correct half-equation (the OH^- ions must be included in the half-equation)

  Note: Ignore states.

Question 2b.i.

Worked solution

positive $Ni(OH)_2(s) + OH^-(aq) \rightarrow NiO(OH)(s) + H_2O(l) + e^-$

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

Explanation

When a cell is recharging, the half-equations are the reverse of the discharge equations. The polarity of the electrodes will not change between discharge and recharge.

Mark allocation: 2 marks

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

  Note: Ignore states.

Question 2b.ii.

Worked solution

A little over 1.2 V.

Explanation

The voltage used in a recharger needs to be slightly higher than the discharge voltage in order to push the reactions in the opposite direction. The voltage should not be too high however, or side reactions might occur, making unwanted products.

Mark allocation: 1 mark

- 1 mark for a voltage over 1.2 with a warning that there is a limit to how high the voltage can be

Question 2b.iii.

Worked solution

Electrons travel from the anode to the cathode in both cells.

Explanatory notes

Fuel cells and rechargeable batteries are both galvanic cells that produce electric current from spontaneous chemical reactions. Electrons will flow from the negative anode to the positively charged cathode.

Mark allocation: 1 mark

- 1 mark for a valid answer.

  Note: The answer could refer to the polarity or non-disposability or direction of electron flow.

Question 2c.

Worked solution

Anode half-equation: $CH_4(g) + 2H_2O(l) \rightarrow CO_2(g) + 8H^+(aq) + 8e^-$

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

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

Explanatory notes

The overall equation in a fuel cell is the same as for combustion in air; that is, methane and oxygen reacting to form CO_2 and H_2O.

The oxygen half-equation in acidic conditions will be the one at +1.23 on the electrochemical series. The methane will form CO_2 and hydrogen ions.

Mark allocation: 3 marks

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

Note: States must be included.

Question 3a.

Worked solution

Since methanol is the only reactant, the concentration of H_2 gas formed will be double that of CO.

Let x = [CO], then [H_2] will be $2x$.

$$K = \frac{[\mathrm{CO}][\mathrm{H_2}]^2}{[\mathrm{CH_3OH}]} = \frac{x(2x)^2}{0.84} = 3.52\times10^{-3}$$

$$4x^3 = 0.84\times3.52\times10^{-3} = 2.96\times10^{-3}$$

$$x = \sqrt[3]{7.39}\times10^{-3} = 0.090 \text{ M}$$

Explanatory note

The key to the question is that methanol is the sole reactant. When it reacts, the amount of H_2 forming will be double that of CO. If x is used to denote the amount of CO, then the amount of H will be $2x$ and these symbols can be substituted into the expression for K.

Mark allocation: 4 marks

- 1 mark for recognising the concentration of H_2 will be double that of CO
- 1 mark for correct expression for K
- 2 marks for solving for the concentration of CO

Question 3b.i.

Worked solution

Halving the volume doubles the pressure. To oppose the increase in pressure the back reaction is favoured, as the ratio of reactants to products is 1 : 3.

Mark allocation: 2 marks

- 1 mark for comparison of products and reactants
- 1 mark for concluding the back reaction is favoured

Question 3b.ii.

Worked solution

The concentration of CO is greater after equilibrium is re-established. The change of volume doubles the concentration. The back reaction is favoured but it will only partially oppose the original change.

Mark allocation: 1 mark

- 1 mark for answer of greater

Question 3b.iii.

Worked solution

The rate of reaction is greater at the new point of equilibrium because the particles are all closer together. The rate of the back reaction has also increased so the value of K is unchanged.

Explanatory notes

The balanced equation $CH_3OH(g) \rightleftarrows CO(g) + 2H_2(g)$ shows there are two product molecules and only one reactant molecule. To partially oppose an increase in pressure, the reverse reaction is favoured. This reduces the amount of molecules present.

When the volume is halved, the concentration is doubled. The system will move in the reverse direction to re-establish equilibrium, but the concentration of CO will still be higher than before the change.

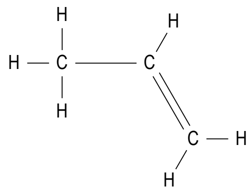
If the volume is halved, the particles will collide more. The rate of the forward and back reactions are both increased.

Mark allocation: 1 mark

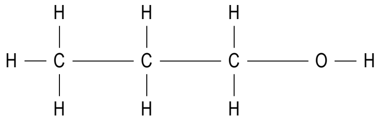
- 1 mark for answer that the reaction rate is increased

Question 4a.

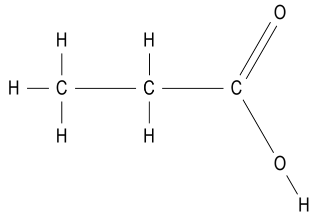
Worked solution



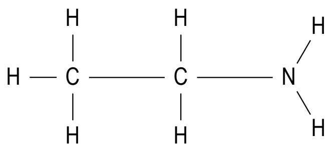
A: propene



B: propan-1-ol



C: propanoic acid



D: ethanamine

Explanatory note

The amide molecule must be the starting point for this question. It was formed from a carboxylic acid reacting with an amine. The number of carbon atoms in the amide suggests the reaction was between propanoic acid (molecule C) and ethanamine (molecule D).

The catalysts used to make molecules B and C indicate that molecule B is an alcohol (propan-1-ol) and molecule A is an alkene (propene).

Mark allocation: 8 marks

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

Tip

- *A flowchart like this appears on the end-of-year examination often. Ensure that you are familiar with each reagent and its use; for example, $Cr_2O_7^{2-}$ will oxidise primary or secondary alcohols. Also be aware that you are expected to spell the names of organic chemicals correctly.*

Question 4b.

Worked solution

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

Explanatory note

Dichromate ions ($Cr_2O_7^{2-}$) are reduced to Cr^{3+} ions. Each dichromate ion produces two Cr^{3+} ions. Six electrons are required to reduce the two chromium ions and an acidic environment is also required to supply the hydrogen ions.

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation, including states

Question 4c.i.

Worked solution

$HCl(aq) + C_2H_5NH_2(aq) \rightarrow C_2H_5NH_3^+(aq) + Cl^-(aq)$

Mark allocation: 1 mark

- 1 mark for a balanced equation

Note: States must be included.

Tip

- *There are likely to be several instances where you will have to write balanced equations for polyatomic ions. This process usually follows three steps. See below for the reduction of IO_4^- to IO_3^-.*

  1. *Balance the O atoms, using water.*
     $IO_4^-(aq) \rightarrow IO_3^-(aq) + H_2O(l)$
  2. *Balance the H atoms, using H+.*
     $IO_4^-(aq) + 2H^+(aq) \rightarrow IO_3^-(aq) + H_2O(l)$
  3. *Balance charges, using electrons.*
     $IO_4^-(aq) + 2H^+(aq) + 2e^- \rightarrow IO_3^-(aq) + H_2O(l)$

Question 4c.ii.

Worked solution

n(HCl) = $c \times V$ = 0.0165 × 0.25 = 0.004125 mol

n(ethanamine) = n(HCl) = 0.004125 mol

c(ethanamine) = $\frac{n}{V} = \frac{0.004125}{0.050}$ = 0.083 M

Explanatory note

Ethanamine is a base. It accepts a proton from the HCl, forming the ion $C_2H_5NH_3^+$.

The other product is chloride ions. The equation is important as it shows the mole ratio of ethanamine to HCl is 1 : 1.

The calculation of the concentration of the ethanamine solution is a standard titration calculation. The concentration and volume of the HCl are known, allowing the number of mole to be calculated. The number of mole of ethanamine equals the number of mole of HCl.

Mark allocation: 2 marks

- 1 mark for calculation of mole of ethanamine
- 1 mark for correct calculation of concentration and for unit of M

Question 5a.

Worked solution

$3CaO(s) + 2Al(s) \rightarrow Al_2O_3(s) + 3Ca(s)$

Explanatory note

The equation is straightforward, with aluminium replacing calcium ions. The oxidation number of aluminium will be +3, so the formula of aluminium oxide is Al_2O_3.

Mark allocation: 1 mark

- 1 mark for a correctly balanced equation.

Note: Ignore states.

Question 5b.i.

Worked solution

$2Cl^{-}(l) \rightarrow Cl_2(g) + 2e^{-}$

Marking allocation: 1 mark

- 1 mark for correct equation, with state

Question 5b.ii.

Worked solution

$Ca^{2+}(l) + 2e^{-} \rightarrow Ca(l)$

Marking allocation: 1 mark

- 1 mark for correct equation, with state

Question 5b.iii.

Worked solution

$Ca^{2+}(l) + 2Cl^{-}(l) \rightarrow Ca(l) + Cl_2(g)$

Explanatory note

During electrolysis, calcium ions are reduced to calcium metal, and chloride ions are oxidised to chlorine gas. Both half-equations are found in the data book. Chloride ions are stronger reductants than fluoride ions, so they react in preference at the anode.

Mark allocation: 1 mark

- 1 mark for correct equation, with state

Tip

- *The Study Design refers to the industrial extraction of metals using electrolysis. Keep in mind that one of the half-equations is likely to be the reduction of metal ion to the metal, using a liquid electrolyte.*

Question 5c.

Worked solution

$$n(\text{Ca}) = \frac{1000\,000}{40.1} = 24\,900 \text{ mol}$$

n(e) = 2n(Ca) = 49 900 mol

Q = 49 900 × 96 500 = 4.81 × 10^9 C

$$t = \frac{Q}{I} = \frac{4.81 \times 10^9}{125\,000} = 38\,500 \text{ s} = 10.7 \text{ h}$$

Explanatory note

1 tonne is 10^6 grams of calcium. The number of mole of calcium needs to be determined and then doubled to give the number of mole of electrons (due to calcium ions being Ca^{2+}). The charge can be calculated from the number of mole of electrons, and the time determined using the formula $t = \frac{Q}{I}$.

Mark allocation: 3 marks

- 1 mark for n(e)
- 1 mark for charge
- 1 mark for the time (can be expressed as 10 h 42 min)

Question 5d.

Worked solution

Calcium ions are stronger oxidising agents than potassium ions. The potassium ions will not be reduced and will not interfere with the process.

Explanatory note

A comparison of the half-equations for calcium and potassium shows calcium ions will react with chloride ions before potassium ions.

$Cl_2(g) + 2e^- \rightarrow \underline{2Cl^-(l)}$

$\underline{Ca^{2+}(l)} + 2e^- \rightarrow Ca(l)$

$\underline{K^+(l)} + e^- \rightarrow K(l)$

Mark allocation: 2 marks

- 1 mark for comparison of the relative oxidising strengths
- 1 mark for conclusion that the potassium ions will not be a problem

Question 6a.

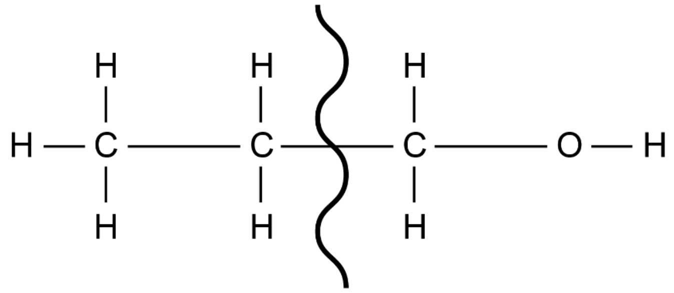
Worked solution

Propan-1-ol produced the spectrum. Both molecules will have a parent molecular ion with m/z ratio of 60, so this cannot be used to distinguish the molecules. The peak at 31 is consistent with the $–CH_2OH^+$ fragment of a primary alcohol, and the peak at 29 is consistent with an ethyl group. Additionally, the peak at 43 is consistent with the $–CH_3CH_2CH_2^+$ fragment. Propan-1-ol contains all these features.

Ethanoic acid would likely have a bigger peak at 15 matching the methyl group, and a large peak at 45 matching the $–COOH^+$ fragment. These peaks are not evident.

Explanatory note

A characteristic fragmentation of a primary alcohol forms the $–CH_2OH^+$ fragment shown in the diagram below.



This will also form a peak with an m/z ratio of 29 due to the $–CH_3CH_2^+$.

Mark allocation: 3 marks

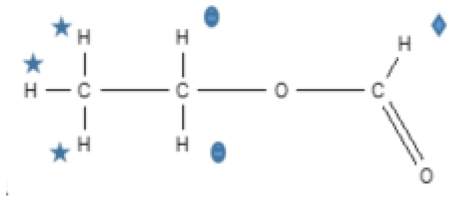
- 1 mark for nominating propan-1-ol as the correct structure
- 1 mark for valid reasons why it is propan-1-ol
- 1 mark for valid reasons why it is not ethanoic acid

Tip

- *When asked to select the correct alternative, you are expected to also explain why other possibilities are not acceptable. In this question, for example, it is not enough to nominate that you think it is propan-1-ol; you must also suggest why it is unlikely to be ethanoic acid.*

Question 6b.

Worked solution



This molecule is likely to be ethyl methanoate.

The spectrum provided shows three different hydrogen environments, as indicated on the molecule. The splitting pattern of each of these environments should be, respectively, a triplet, a quartet and a singlet, and this matches the spectrum.

The shifts on the spectrum do not suggest a carboxylic acid so propanoic acid is unlikely, and methyl ethanoate will have a different splitting pattern.

Explanatory note

The spectrum of any other isomer will be different. Propanoic acid would also have three hydrogen environments, but one of those environments would have a much greater shift due to the carboxylic acid.

Methyl ethanoate would have only two hydrogen environments.

The chemical shifts listed in the data book will offer limited help for this question, as two of the functional groups in the correct molecule are not listed.

Mark allocation: 3 marks

- 1 mark for nominating ethyl methanoate
- 1 mark for valid reasons for ethyl methanoate
- 1 mark for valid reasons to reject other possibilities

Tip

- *Students are often reluctant to draw the molecule as part of their response. This should not be the case – an annotated diagram is often a very clear way to answer questions about spectra.*

Question 6c.

Worked solution

The spectrum is of methyl ethanoate. Methyl ethanoate has a carbonyl bond (C=O) that leads to the absorption around 1720–1840 cm^{-1}. This ester will not have a broad band absorption around 3000–3500 cm^{-1} because it does not contain an –OH bond.

It is not propan-1-ol because the spectrum does not have a broad absorption above 3000 cm^{-1} and propan-1-ol would not have an absorption around 1750 cm^{-1}.

It is not propanoic acid because the spectrum does not include a broad absorption above 3000 cm^{-1} that the –OH (acid) bond would produce.

Explanatory note

Methyl ethanoate contains a –C=O group but no –OH (consistent with spectrum provided).

Propan-1-ol contains an –OH group but no –C=O group (spectrum shows a C=O group).

Propanoic acid contains both –C=O and –OH (acid) (spectrum shows no –OH).

Mark allocation: 3 marks

- 1 mark for nominating methyl ethanoate
- 1 mark for valid reasons for methyl ethanoate
- 1 mark for valid reasons to reject other possibilities

Question 6d.

Worked solution

The most polar molecule should have the shortest retention time if a polar solvent is used. Propan-1-ol is the most polar of the three molecules, therefore it will have the shortest retention time.

Explanatory note

In high-performance liquid chromatography (HPLC) the solvent is usually contrasting with the stationary phase, where one will be polar and the other not. If a polar solvent is used, polar substances will spend more time in the solvent and have short retention times.

Mark allocation: 2 marks

- 1 mark for nominating propan-1-ol
- 1 mark for outlining a valid reason

Question 7a.i.

Worked solution

$CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOH$ or $CH_3(CH_2)_4CHCHCH_2CHCH\ (CH_2)_7COOH$

Explanatory notes

The fatty acid is formed from hydrolysis of the ester. The semi-structural formula can be established by working carefully from the left-hand end of the molecule.

Mark allocation: 1 mark

- 1 mark for correct semi-structural diagram

Question 7a.ii.

Worked solution

Linoleic acid

Explanatory notes

Inspection of the data book confirms it is linoleic acid.

Mark allocation: 1 mark

- 1 mark for linoleic acid

Question 7a.iii.

Worked solution

An omega-6 fatty acid has its first carbon-to-carbon double bond on the sixth carbon from the methyl end of the fatty acid.

Explanatory notes

Omega-6 fatty acids are defined as acids with the first carbon-to-carbon double bond on the sixth carbon from the methyl end of the fatty acid.

Mark allocation: 1 mark

- 1 mark for recognition of the first carbon-to-carbon double bond location

Question 7a.iv.

Worked solution

Both carbon-to-carbon bonds are in *trans* formation.

Explanatory notes

Trans isomers have corresponding groups on opposite sides of the molecule.

Mark allocation: 1 mark

- 1 mark for *trans*

Tip

- *The semi-structural formulas of the fatty acids are provided in the data book. Keep looking for assistance in this book for all food structures.*

Question 7b.

Worked solution

$$\begin{array}{l} CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOCH_2 \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad | \\ CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOCH \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad | \\ CH_3(CH_2)_4(CH{=}CHCH_2)_2(CH_2)_6COOCH_2 \end{array}$$

Explanatory note

Triglycerides are formed when three fatty acid molecules combine with glycerol. Three separate ester bonds are formed when this occurs.

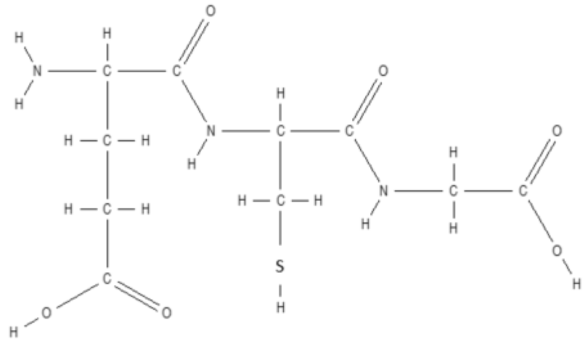
Mark allocation: 2 marks

- 1 mark for three fatty acids attached to one glycerol molecule
- 1 mark for correct ester bond representation

Note: Triglycerides are difficult to draw – accept some combinations of structural and semi-structural formats, but the ester must be correct and the presence of three fatty acid chains evident.

Question 8a.

Worked solution



Explanatory note

The structures of the three amino acids can be found in the data book. When the amino acids join, peptide links are formed.

Mark allocation: 3 marks

- 1 mark for each side group correct
- 1 mark for each correct amide link
- 1 mark for correct ends to the tripeptide

Question 8b.i.

Worked solution

Ionic bonding because –COOH is likely to donate a proton. (H-bonding can also occur.)

Mark allocation: 1 mark

- 1 mark for ionic bonding

Question 8b.ii.

Worked solution

Disulfide covalent bonds between sulfur atoms

Mark allocation: 1 mark

- 1 mark for disulfide or covalent

Question 8b.iii.

Worked solution

Dispersion forces, as hydrogen has a low value of electronegativity.

Explanatory note

Glutamic acid has a carboxyl side group, –COOH. This can donate a proton to form an ion. Cysteine contains a sulfur atom that can bond with the sulfur atom on a nearby structure. Glycine has only a hydrogen atom for a side group. This can form dispersion forces.

Mark allocation: 1 mark

- 1 mark for dispersion forces

Question 9a.i.

Worked solution

$q = 1.6 \times 17 + 4.2 \times 37 + 18.6 \times 16 = 480$ kJ

Mark allocation: 1 mark

- 1 mark for correct energy value

Question 9a.ii.

Worked solution

There are other items in the biscuit, such as fibre, that release energy but have not been accounted for.

Explanation

In the data book, the amount of available energy for each macronutrient is provided. These values are used with the amounts on the biscuit label. This value will usually be low, as it doesn't take into account other ingredients that might also produce some energy.

Mark allocation: 1 mark

- 1 mark for mention of other ingredients contributing to energy

Question 9b.

Worked solution

$q = mc\Delta T$

$495\,000 = 2500 \times 4.18 \times \Delta T$

$\Delta T = 47.4°\text{C}$

Final temperature = $18.6 + 47.4 = 66.0°\text{C}$

Explanation

If the formula $q = mc\Delta T$ is used, the mass is 2.5 kg or 2500 g, the value of c is 4.18 and the value of q comes from the label. The equation can be solved for ΔT.

Mark allocation: 3 marks

- 1 mark for correct formula, with correct substitution
- 1 mark for finding ΔT
- 1 mark for finding the final temperature

Question 9c.

Worked solution

The label shows the carbohydrates in the biscuit are an even mix between simple sugars and complex carbohydrates. The simple sugars will be high GI, whereas the polysaccharides will be low GI, providing a balance of both.

Explanation

Simple sugars, especially those with glucose, usually are high GI because they release glucose quickly. Polysaccharides can be low GI if they are relatively slow to digest, like amylose.

Mark allocation: 2 marks

- 1 mark for mention of simple sugars
- 1 mark for mention of polysaccharides and the likely contrasting contributions

Question 10a.

Worked solution

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

Explanation

An acid and a metal will produce a salt and hydrogen gas.

Mark allocation: 1 mark

- 1 mark for a correct equation, with states

Question 10b.i.

Worked solution

HCl concentration

Mark allocation: 1 mark

- 1 mark for HCl concentration

Question 10b.ii.

Worked solution

Time taken for the volume to reach 20 mL

Mark allocation: 1 mark

- 1 mark for time

Question 10b.iii.

Worked solution

Two answers from: mass of magnesium, volume of acid, temperature, volume of gas collected.

Explanation

The solutions have different HCl concentrations. The time taken to produce a set amount of gas will depend on the concentration. Many variables in this experiment are controlled, such as the amount of magnesium and the volume of acid.

Mark allocation: 2 marks

- 1 mark for each controlled variable (up to 2 marks)

Tip

- *Expect to find a question relating to experiment design and hypothesis on the exam. As you are reading the question, use a highlighter to identify steps in the procedure that might not be good practice.*

Question 10c.

Worked solution

The magnesium pieces should be weighed, rather than cut to length.

The volume of acid should be measured more accurately than with a beaker.

The ability to get a stopper in the flask quickly relies upon good technique.

Explanation

A number of steps in this experiment were not performed carefully. Examples: volumes should not be measured using beakers; all flasks should not be assumed to be the same; and each length of magnesium will not necessarily provide the same mass. There is a significant number of dilutions conducted. This requires care with all measurements.

Mark allocation: 2 marks

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

Question 10d.

Worked solution

No. The time taken to obtain 20 mL reduces as the concentration increases but this is not the ‘rate’ of the reaction. A short time means a fast rate. The rate of reaction has increased with temperature.

Explanation

As the concentration increases, the rate also increases. This is evident by the shorter time required to collect a sample. The student does not realise that the time measured is moving in the opposite direction to the rate.

Mark allocation: 2 marks

- 1 mark for stating the conclusion is wrong
- 1 mark for explaining time is not the same thing as rate

Question 10e.

Worked solution

The reaction between magnesium and hydrochloric acid is highly exothermic. This means temperature is not controlled. As the concentration increases, the effect of temperature change becomes more significant.

Explanation

This is a very exothermic reaction. The temperature rise interferes with the controlled experiment environment the student is seeking. The rate increases more than expected because the temperature is so high.

Mark allocation: 2 marks

- 1 mark for nominating temperature rise
- 1 mark for explaining the impact on collisions

END OF WORKED SOLUTIONS