Insight Publications

INSIGHT

Trial Exam Paper

2007

CHEMISTRY

Written examination 1

Solutions book

This book presents:

- correct solutions with full working
- explanatory notes
- mark allocations
- tips and guidelines

SECTION A – Multiple-choice questions

Question 1

Aspirin is an organic compound used widely in headache preparations. The concentration of aspirin in a particular tablet is best determined by

A. flame tests
B. atomic absorption spectroscopy
C. paper chromatography
D. **high performance liquid chromatography**

Answer is D.

Explanatory notes

- D is correct because high performance liquid chromatography is a quantitative analytical technique best used for organic compounds.
- A is incorrect because flame tests are used for analysis of inorganic compounds, such as metal ions, and are qualitative only.
- B is incorrect because atomic absorption spectroscopy is best used for analysis of inorganic compounds.
- C is incorrect because paper chromatography is a qualitative type of analysis only and, hence, can't be used to determine concentration.

Tips

- *Whether the compound to be analysed is organic or inorganic is a good clue as to which is the best type of analysis. Organic compounds are best suited to chromatographic techniques whereas inorganic compounds are best suited to spectroscopic techniques.*

Question 2

In which of the following species does sulfur have the lowest oxidation number?

A. SO_4^{2-}
B. $\mathbf{SO_2}$
C. SO_3
D. H_2SO_4

Answer is B.

Explanatory notes

- B is correct because the oxidation number of S in this species is +4.
- A is incorrect because the oxidation number of S in this species is +6.
- C is incorrect because the oxidation number of S in this species is +6.
- D is incorrect because the oxidation number of S in this species is +6.

Tips

- *Use the oxidation rules, primarily that H is nearly always +1 and O is nearly always –2 to determine the oxidation number of S. Remember that* ***in a neutral compound the sum of the oxidation numbers of individual elements is zero****, and in a* ***polyatomic ion the sum of the oxidation numbers equals the charge on the ion.***

Question 3

1.50 g of calcium carbonate reacts with 20.0 mL of 1.0 M HCl according to the equation

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

In a second reaction mixture, the volume of HCl is increased to 50.0 mL. Which of the following best describes the difference between the first and second reaction mixtures?

A. The increased amount of HCl in the second reaction will cause it to proceed at a greater rate than the first.

B. A shorter period of bubbling will be observed in the second reaction mixture.

C. Equal volumes of carbon dioxide will be produced by the first and second reaction mixtures.

D. **A greater amount of $CaCl_2$ will be produced in the second reaction.**

Answer is D.

Explanatory notes

- D is correct because the greater amount of HCl in the second mixture allows more of the $CaCO_3$ to react. $CaCO_3$ is in excess in the first mixture. This can be determined by the following steps.
  Step 1: Calculate the number of mole of both reactants.

$$n(CaCO_3) = \frac{m}{M}$$

$$= \frac{1.50}{(40.1 + 12.0 + (3 \times 16.0)}$$

$$= \frac{1.50}{100.1}$$

$$= 0.0150 \text{ mol}$$

$$n(HCl) = cV$$

$$= 0.0200 \times 1.0$$

$$= 0.020 \text{ mol}$$

Step 2: Identify the limiting reactant by dividing the amount of each reactant by its coefficient in the chemical equation. The reactant with the lowest answer is the limiting reactant.

$$CaCO_3: \ \frac{0.0150}{1}$$

$$= 0.0150$$

$$HCl: \ \frac{0.020}{2}$$

$$= 0.010$$

- HCl is the limiting reagent and determines the amount of product formed in the first mixture. Increasing the amount of HCl allows more products to be formed in the second mixture.

- A is incorrect because simply increasing the amount of a reactant does not increase the reaction rate. The **concentration** of the reactant must be increased to increase the rate.
- B is incorrect because the greater amount of HCl will cause more $CaCO_3$ to react and more $CO_2(g)$ to be produced so more bubbling will be observed.
- C is incorrect because the second reaction will produce more carbon dioxide as HCl is no longer the limiting reactant.
- Whenever quantities of both reactants are given, the limiting and excess reactants will need to be determined. If calculations of product are required, the amount, in mol, of the limiting reactant must be used.

Question 4

The number of carbon atoms present in 5.00 g of butane is

A. 0.345

B. 5.19×10^{22}

C. $\mathbf{2.08 \times 10^{23}}$

D. 2.73×10^{23}

Answer is C.

Explanatory notes

- C represents the number of carbon atoms calculated, using the following steps.
  Step 1: Identify the correct molecular formula of butane; it has four carbon atoms and is an alkane with the general formula $C_nH_{2n+2} = C_4H_{10}$.

  Step 2: Calculate the amount, in mol, of butane molecules.

$$n(C_4H_{10}) = \frac{m}{M}$$

$$= \frac{5.00}{(4\times12.0)+(10\times1.0)}$$

$$= \frac{5.00}{58.0}$$

$$= 0.0862 \text{ mol}$$

  Step 3: Calculate the amount, in mol, of carbon atoms.

  There are four carbon atoms in each butane molecule.

$$n(C) = 4 \times n(C_4H_{10})$$

$$= 4 \times 0.0862$$

$$= 0.345 \text{ mol}$$

  Step 4: Calculate the number of carbon atoms.

$$n(C) = n(C) \times N_A$$

$$= 0.345 \times 6.02 \times 10^{23}$$

$$= 2.08 \times 10^{23}$$

- A is incorrect because it represents the amount, in mol, of carbon atoms – not the actual number.
- B is incorrect because it represents the number of butane molecules – not the number of carbon atoms.
- D is incorrect as it uses the molecular formula for propane, C_3H_8, instead of C_4H_{10}.

Tips

- *Reading these types of calculation questions carefully is very important to ensure you calculate the actual quantity requested.*

Question 5

A colorimeter is used to determine the concentration of phosphate in a detergent. A blue solution is prepared for analysis by treating detergent solution with sodium molybdate. Which of the following best describes the colour of the light source used?

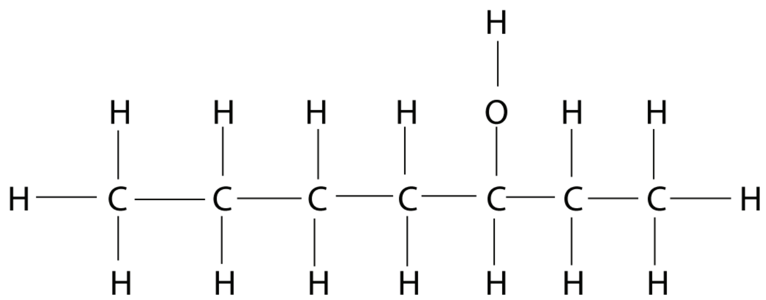
A. **Orange as it will mainly be absorbed by the detergent solution.**
B. Orange as it will mainly be reflected and transmitted by the detergent solution.
C. Blue as it will mainly be absorbed by the detergent solution.
D. Blue as it will mainly be reflected and transmitted by the detergent solution.

Answer is A.

Explanatory notes

- A is correct because orange is the complementary colour of blue and so will mainly be absorbed by blue solution. The amount of absorbance by a solution is directly proportional to the concentration of the solution This allows quantitative analysis.
- B is incorrect because orange light will be absorbed by blue solution – not reflected and transmitted. C is incorrect because blue light will not be absorbed by blue solution.
- D is incorrect because colorimetry requires the use of a light source of complementary colour that will be absorbed by solution. Light that is reflected and transmitted cannot be used for colorimetric analysis.

Question 6



The best name for the hydrocarbon with the structural formula shown above is

A. heptane-3-hydroxide.
B. heptanoic acid.
C. **3-heptanol.**
D. 5-heptanol.

Answer is C.

Explanatory notes

- C is correct because the hydroxyl group (–OH) is located on the third carbon of a seven-carbon chain.
- A is incorrect because the functional group is a hydroxyl, making the compound an alcohol.
- B is incorrect because the compound is not a carboxylic acid as it does not have the carboxyl functional group.
- D is incorrect because it starts numbering the carbons in the carbon chain from the wrong end. Numbering must start at the end the functional group is closest to.

Question 7

A student used gravimetric analysis in a laboratory to determine that the percentage, by mass, of sodium chloride in a biscuit is 0.35%. This result was lower than expected. The error that could have produced the lower result is

A. The precipitate was not dried completely before weighing.

B. Some co-precipitation occurred.

C. When the biscuit was dissolved and filtered, not all of the solids were removed before the precipitation was carried out.

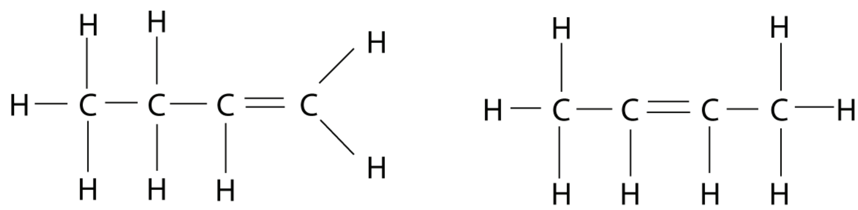
D. **Not all of the biscuit was dissolved before solids were filtered and the precipitation was carried out.**

Answer is D.

Explanatory notes

- D is correct because if not all of the biscuit was dissolved, fewer ions would be present in solution and able to be precipitated. The mass of precipitate would be decreased, resulting in a lower percentage by mass.
- A is incorrect because this error would result in a higher mass of precipitate, hence, an increased percentage by mass.
- B is incorrect because another ion being precipitated would result in a higher mass of precipitate, hence, an increased percentage by mass.
- C is incorrect because any remaining solids would have added to the mass of the filtered precipitate and increased the percentage by mass.

Question 8



Which of the following is **incorrect** about the two molecules represented above?

A. They have the same empirical formula.

B. They contain the same percentage, by mass, of hydrogen.

C. They can both react with water to produce 2-butanol.

D. **They have the same semi-structural formula.**

Answer is D.

Explanatory notes

- D is the incorrect statement because the semi-structural formulas are $CH_3CH_2CH{=}CH_2$ and $CH_3CH{=}CHCH_3$, respectively.
- A is a correct statement because the two molecules are isomers, meaning that they have the same number and type of atoms but with different arrangements. The empirical formula is the simplest ratio of atoms present, which is CH_4 for each molecule.

- B is a correct statement because having the same empirical formula means that they must have the same percentage by mass of elements present.

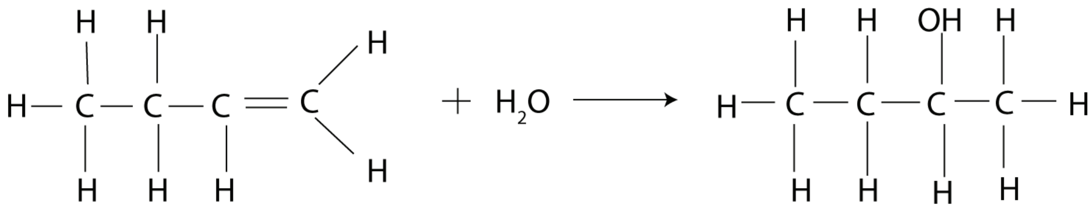
$$\% \text{ by mass} = \frac{\text{mass of the element in 1 mol of compound}}{\text{molar mass of the compound}} \times 100$$

$$\% \text{ H} = \frac{8 \times 1.0}{4 \times 12.0 + 8 \times 1.0} \times 100$$

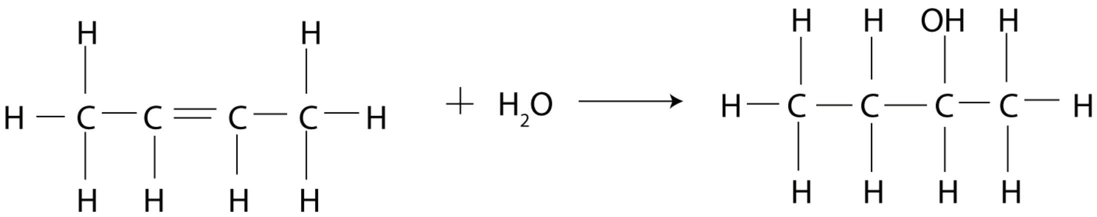
$$= \frac{8.0}{56.0} \times 100$$

$$= 14\%$$

- C is a correct statement because both molecules have a double bond connected to the second carbon; hence, an addition reaction with water can result in a hydroxyl group on the second carbon.



2-Butanol



2-Butanol

Question 9

The molecule that is **not** a possible product of the thermal cracking of a mixture of pentane, C_5H_{12}, is

A. C_3H_6

B. C_4H_8

C. C_5H_{10}

D. $\mathbf{C_6H_{12}}$

Answer is D.

Explanatory notes

- D is the correct answer as cracking can only produce molecules smaller than the starting molecule.
- A can be produced by cracking as in the equation $C_5H_{12}(g) \rightarrow C_3H_6(g) + C_2H_6(g)$
- B can be produced by cracking as in the equation $C_5H_{12}(g) \rightarrow C_4H_8(g) + CH_4(g)$
- C can be produced by cracking as in the equation $C_5H_{12}(g) \rightarrow C_5H_{10}(g) + H_2(g)$

Question 10

1.50 kg of aluminium oxide is used to produce aluminium metal and oxygen gas according to the equation

$$2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g)$$

All of the oxygen produced is collected and reacted with solid carbon according to the equation

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

The volume, in L, of carbon dioxide produced, at STP, is closest to

A. 988
B. **494**
C. 220
D. 110

Answer is B.

Explanatory notes

- B is correct according to the following steps.
  Step 1: Calculate the amount, in mol, of aluminium oxide.
  $$n(Al_2O_3) = \frac{m}{M}$$
  $$= \frac{1.50 \times 10^3}{2 \times 27.0 + 3 \times 16.0}$$
  $$= \frac{1.50 \times 10^3}{102.0}$$
  $$= 14.7 \text{ mol}$$
  Step 2: Calculate the amount, in mol, of oxygen produced.
- The coefficients in a balanced chemical equation provide the ratio of amounts, in mol, of reactants and products consumed or produced in the reaction.
- According to the equation provided:
  $n(Al_2O_3) : n(O_2)$
  2 : 3
  So, $n(O_2) = \frac{3}{2} \times n(Al_2O_3)$
  $= \frac{3}{2} \times 14.7$
  $= 22.1$ mol
  Step 3: Calculate the amount, in mol, of carbon dioxide produced.
  According to the equation provided:
  $n(O_2) : n(CO_2)$
  1 : 1
  $n(CO_2) = 1 \times n(O_2)$
  $= 22.1$ mol
  Step 4: Calculate the volume of carbon dioxide produced.
  $V(CO_2) = n \times V_M$
  $= 22.1 \times 22.4$
  $= 494$ L
- A is incorrect because the $n(Al_2O_3) : n(O_2)$ ratio used is incorrect, i.e. $n(O_2)$ is not $\frac{3}{1} \times n(Al_2O_3)$.

- C is incorrect because the $n(Al_2O_3) : n(O_2)$ ratio is used the wrong way round, i.e. $n(O_2)$ is not $\frac{2}{3} \times n(Al_2O_3)$.
- D is incorrect because the $n(O_2)$ calculated from the $n(Al_2O_3)$ is divided by 3 for use in the ratio of the second equation. This is not correct because all of the oxygen gas produced reacts with carbon to produce carbon dioxide.

Tips

- *Molar volume of a gas at STP can be found on the data sheet. It gives the volume of 1 mole of a gas at 0°C and 1 atm.*
- *The coefficients given in a chemical equation provide a ratio only in terms of amount, in mol.*

Question 11

8.40 g of metal X reacted completely with oxygen to produce 11.32 g of a metal oxide with the formula X_2O. The identity of metal X is

A. Li

B. **Na**

C. Ti

D. Y

Answer is B.

Explanatory notes

- B is correct according to the following steps.
  Step 1: Determine the mass of oxygen in the oxide.
  $m(O)$ = mass of metal oxide – mass of X
  $= 11.32 - 8.40$
  $= 2.92$ g
  Step 2: Calculate the amount, in mol, of oxygen in oxide.
  $n(O) = \frac{m}{M}$
  $= \frac{2.92}{16.0}$
  $= 0.183$ mol
  Step 3: Calculate the amount, in mol, of metal X.
  The empirical formula, X_2O, gives the simplest whole number ratio of atoms, so
  $n(X) = \frac{2}{1} \times n(O)$
  $= \frac{2}{1} \times 0.183$
  $= 0.365$ mol
  Step 4: Calculate the molar mass of metal X.
  $M(X) = \frac{m}{n}$
  $= \frac{8.40}{0.365}$
  $= 23.0 \text{ g mol}^{-1}$
  Step 5: Determine the identity of metal X, using the periodic table.
- The metal with a relative atomic mass of 23.0 is sodium.

- A is incorrect because 11.32 g is the mass of the entire oxide, not just the oxygen.
- C is incorrect because the ratio X : O in the compound is not 1 : 1.
- D is incorrect because the ratio X : O is not 1 : 2,. i.e. n(X) is not $\frac{1}{2}$ × n(O).

Tips

- *The equation* $n = \frac{m}{M}$ *can be rearranged to make mass or molar mass the unknown.*
- *The molar mass of an element is the same as its relative atomic mass, except that it is expressed in g mol^{-1}. Relative atomic masses are listed on the periodic table on the data sheet.*

Question 12

The volume, in L, occupied by 4.50 g of N_2(g) at 100°C and 500 mmHg is

A. 1.00

B. 2.00

C. **7.48**

D. 209

Answer is C.

Explanatory notes

- C is correct, according to the following steps.
  Step 1: Calculate the amount, in mol, of N_2.

$$n(N_2) = \frac{m}{M}$$
$$= \frac{4.50}{2 \times 14.0}$$
$$= \frac{4.50}{28.0}$$
$$= 0.161 \text{ mol}$$

  Step 2: Convert all quantities to the units required for the general gas equation.

$$T \text{ in K} = t \text{ in °C} + 273$$
$$= 100 + 273$$
$$= 373 \text{ K}$$

$$\frac{P \text{ in kPa}}{101.325} = \frac{P \text{ in mmHg}}{760}$$
$$P \text{ in kPa} = \frac{500}{760} \times 101.325$$
$$= 66.7 \text{ kPa}$$

  Step 3: Calculate the volume of N_2, using the general gas equation.

$$PV = nRT$$
$$V = \frac{nRT}{P}$$
$$= \frac{0.161 \times 8.31 \times 373}{66.7}$$
$$= \frac{499}{66.7}$$
$$= 7.48 \text{ L}$$

- A is incorrect because the pressure must be expressed in kPa for use in the general gas equation.
- B is incorrect because the temperature must be expressed in K for use in the general gas equation.
- D is incorrect because the amount of N_2 must be in number of moles for use in the general gas equation.

Question 13

Which statement regarding the pH of pure water is correct?

A. **Pure water at different temperatures is always neutral, however, the pH may vary slightly.**

B. Pure water at different temperatures is always neutral and always has a pH of 7.00.

C. Pure water at a temperature less than 25°C has a pH below 7.00 and is acidic.

D. Pure water at a temperature less than 25°C has a pH above 7.00 and is basic.

Answer is A.

Explanatory notes

- A is correct because the self-ionisation of pure water is an endothermic reaction.

$$H_2O(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq) \qquad \Delta H \text{ is positive}$$

- The pH is 7.00 at 25°C only. Temperatures higher or lower than this will change the extent of ionisation and vary the $[H_3O^+]$ concentration. pH = $-\log_{10}[H_3O^+]$ so pH also varies with varying temperature. However, $[H_3O^+]$ and $[OH^-]$ will always be equal so the solution will always be neutral.
- B is incorrect because pure water does not always have a pH of 7.00. pH is only 7.00 at 25°C. Temperatures above or below this will cause a change to the pH.
- C is incorrect because pure water is always neutral because $[H_3O^+]$ always equals $[OH^-]$. Also, the self-ionisation of water is endothermic. A decreased temperature will result in a net backward reaction. $[H_3O^+]$ will decrease and pH will increase.
- D is incorrect because pure water is always neutral because $[H_3O^+]$ always equals $[OH^-]$.

Question 14

35.0 g of magnesium nitrate is dissolved in 1.50 L of distilled water. The concentration of $NO_3^-(aq)$ ions, in mol L^{-1}, in the solution is

A. 0.157

B. 0.270

C. **0.315**

D. 0.541

Answer is C.

Explanatory notes

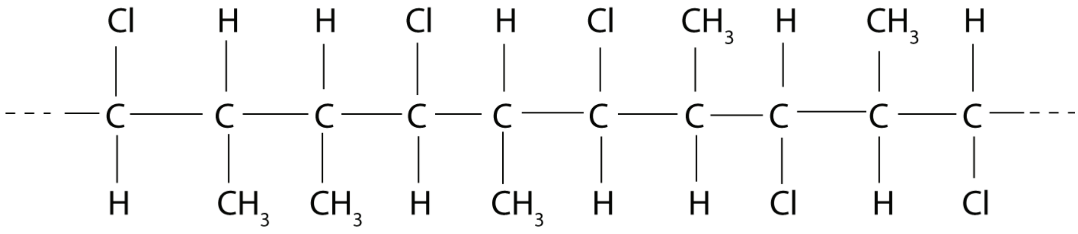
- C is correct according to the following steps.
  Step 1: Calculate the amount, in mol, of $Mg(NO_3)_2$.
  $$n(Mg(NO_3)_2) = \frac{m}{M}$$
  $$= \frac{35.0}{24.3 + 2 \times (14.0 + 3 \times 16.0)}$$
  $$= \frac{35.0}{148.3}$$
  $= 0.236$ mol
  Step 2: Calculate the amount, in mol, of NO_3^- ions.
  There are two NO_3– ions in each $Mg(NO_3)_2$ molecule so
  $n(NO_3^-) = 2 \times n(Mg(NO_3)_2)$
  $= 2 \times 0.236$
  $= 0.472$ mol
  Step 3: Calculate the concentration of NO_3– ions.
  $$c(NO_3^-) = \frac{n}{V}$$
  $$= \frac{0.472}{1.50}$$
  $= 0.315$ M
- A is incorrect because the $n(NO_3^-)$ is twice the $n(Mg(NO_3)_2)$ because there are two ions in each molecule.
- B is incorrect because the molecular formula of magnesium nitrate is $Mg(NO_3)_2$, not $MgNO_3$.
- D is incorrect because the molecular formula of magnesium nitrate is $Mg(NO_3)_2$, not $MgNO_3$ and $n(NO_3^-)$ is twice the $n(Mg(NO_3)_2)$ because there are two ions in each molecule.

Tips

- *Students are expected to know valencies to common ions. It is handy to remember that you can use the periodic table to remember that the valency of all Group 1 metals is +1 and all Group 2 metals is +2.*

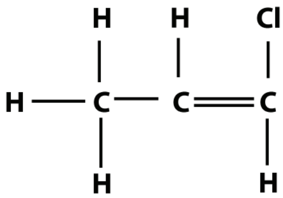
Question 15

Consider the polymer

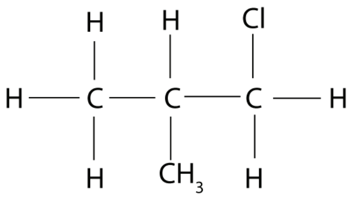


The structure of the monomer from which this polymer was produced by addition polymerisation would be

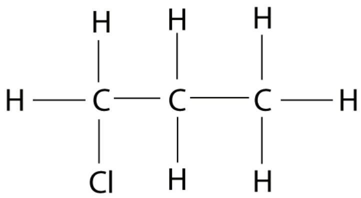
A.



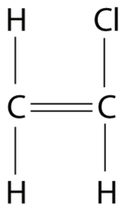
B.



C.



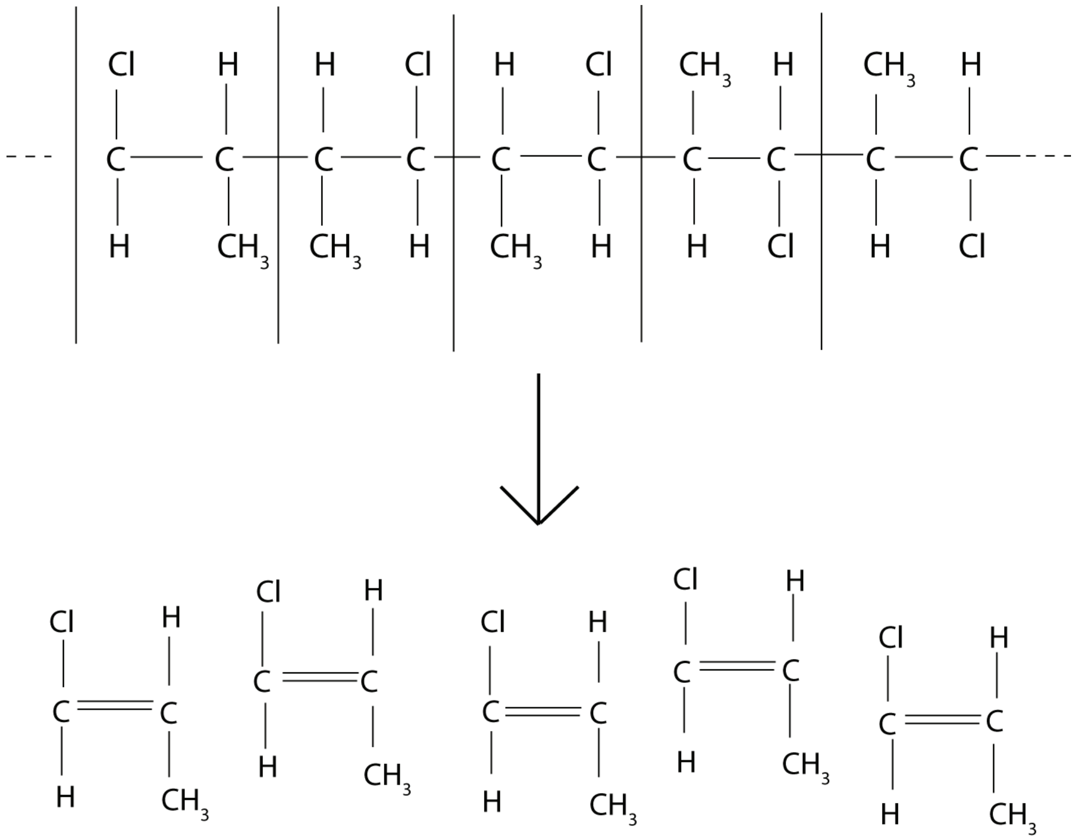
D.



Answer is A.

Explanatory notes

- A is correct because it is unsaturated and Cl is attached to a carbon atom on one side of the double bond and CH_3 is attached to the carbon on the other side, i.e. the monomer contains three carbon atoms. The monomer is deduced by splitting the polymer chain into lots of two carbons and adding a double bond between the pairs of carbons as illustrated.



- B is incorrect because it is saturated. Monomers for addition polymerisation must be unsaturated.
- C is incorrect because it is saturated. Monomers for addition polymerisation must be unsaturated.
- D is incorrect because it does not have CH_3 attached to a carbon atom on one side of the double bond. The monomer contains only two carbon atoms.

Tips

- *To split an addition polymer into its monomers, pair off the carbons in the central chain and add a double bond between them.*

Question 16

Consider the reaction

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad K = 0.052 \text{ at } 400°C$$

A 500 mL flask contains a mixture of these gases at 400°C. At equilibrium, 0.90 mol of $H_2(g)$ and 0.075 mol of $NH_3(g)$ are present. The amount, in mol, of $N_2(g)$ present is

A. **0.037**
B. 0.074
C. 0.15
D. 0.80

Answer is A.

SECTION A – continued

Explanatory notes

- A is correct according to the following steps.
  Step 1: Calculate the concentrations of H_2 and NH_3.

$$c(H_2) = \frac{n}{V} = \frac{0.90}{0.500} = 1.8\ M$$

$$c(NH_3) = \frac{n}{V} = \frac{0.075}{0.500} = 0.15\ M$$

  Step 2: Calculate the concentration of N_2, using the equilibrium law.

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$$0.052 = \frac{(0.15)^2}{[N_2](1.8)^3}$$

$$0.052 = \frac{0.023}{[N_2]5.8}$$

$$[N_2] = \frac{0.023}{5.8 \times 0.052} = \frac{0.023}{0.30} = 0.074\ M$$

  Step 3: Calculate the amount, in mol, of N_2.

$$n(N_2) = cV = 0.074 \times 0.500 = 0.037\ mol$$

- B is incorrect because 0.074 is the concentration of N_2, not the amount, in mol.
- C is incorrect because the amounts, in mol, of H_2 and NH_3 have to be converted to concentrations for use in the equilibrium law.
- D is incorrect because the coefficients of the species in the equation need to be used in the equilibrium law. For a reversible reaction written as

$$xA + yB \leftrightharpoons zC$$

The equilibrium law expression will be

$$K = \frac{[C]^z}{[A]^x[B]^y}$$

SECTION A – continued

Question 17

Consider the reaction

$$C(s) + H_2O(g) \leftrightharpoons CO(g) + H_2(g) \qquad \Delta H = +129.6 \text{ kJ mol}^{-1}$$

Carrying out the reaction at a higher temperature will increase the yield of H_2. Which one of the following gives the best explanation for this?

A. Increasing the temperature decreases the activation energy of the forward reaction, making it easier to form products.

B. **Increasing the temperature causes a net forward reaction because the forward reaction is endothermic.**

C. Increasing the temperature causes a net forward reaction because the forward reaction is exothermic.

D. Increasing the temperature increases the number of collisions between reactant particles, increasing the rate of reaction.

Answer is B.

Explanatory notes

- B is correct because, according to Le Chatelier's Principle, if the temperature of a reaction system is increased it adds energy to the system and it will respond by shifting in the endothermic direction to absorb some of the energy, which is the forward direction in this reaction.
- A is incorrect because increasing the temperature does not reduce the activation energy; it just makes it easier for the reactant particles to overcome the activation energy barrier and have successful collisions. Also, overcoming the activation energy more successfully will lead to an increase in the rate of both forward and reverse reactions and will not affect yield.
- C is incorrect because the positive ΔH value indicates that the forward reaction is endothermic. The reverse reaction is exothermic.
- D is incorrect because increased collisions increase the rate of both the forward and backward reactions and do not cause a change in yield.

Question 18

Of the hydrocarbons listed below, which has the highest boiling temperature?

A. pentane

B. hexane

C. heptane

D. **octane**

Answer is D.

Explanatory notes

- D is correct because octane is the biggest alkane present and has the highest boiling temperature.
- A is incorrect because pentane is the smallest molecule and will have the lowest boiling temperature.
- B is incorrect because hexane is not the biggest alkane listed.
- C is incorrect because heptane is not the biggest alkane listed.

Tips

- *Boiling temperature is determined by the strength of intermolecular forces. The more strongly that molecules are held together, the more energy that is required to separate them.*
- *Alkanes are non-polar molecules with dispersion forces as the only intermolecular force. Dispersion forces increase with increasing size, so the bigger the molecule the higher the boiling temperature.*

Question 19

Consider the reaction

$$2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g) \quad \Delta H = -571.6 \text{ kJ mol}^{-1}$$

Which statement regarding this reaction is correct?

A. The activation energies for the forward and backward directions are of the same magnitude.

B. The activation energy of the forward reaction is greater than that of the backward reaction.

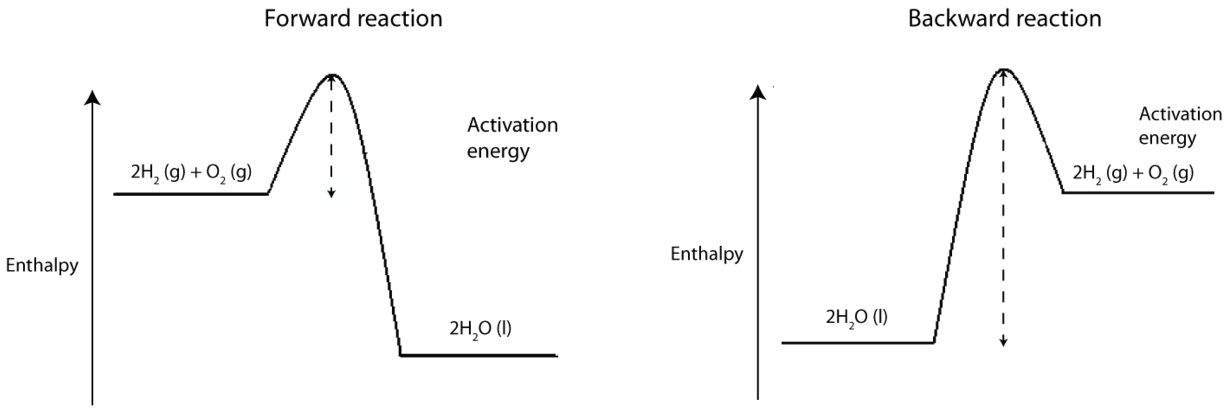
C. The activation energy of the forward reaction is less than that of the backward reaction.

D. Increasing the pressure will increase the reaction rate because it lowers the activation energy.

Answer is C.

Explanatory notes

- C is correct according to the following energy profiles.



- A is incorrect because in a reversible reaction the activation energy of the reaction in the endothermic direction is higher than the activation energy of the reaction in the exothermic direction.
- B is incorrect because the backward reaction is the endothermic reaction and so has the greater activation energy.
- D is incorrect because increasing the pressure increases the reaction rate by increasing the number of collisions. It does not affect the magnitude of the activation energy.

Question 20

The active ingredient in Grofast plant fertiliser is ammonium sulfate, $(NH_4)_2SO_4$. The mass, in kg, of nitrogen present in a 20 kg bag is

A. 0.21

B. 2.1

C. 2.5

D. **4.2**

Answer is D.

Explanatory notes

- D is correct according to the following steps.
  Step 1: Calculate the percentage, by mass, of N in $(NH_4)_2SO_4$.
  $$\% \text{ by mass} = \frac{\text{mass of the element in 1 mol of compound}}{\text{molar mass of the compound}} \times 100$$
  $$\%\text{N} = \frac{2 \times 14.0}{2 \times (14.0 + 4 \times 1.0) + 32.1 + 4 \times 16.0} \times 100$$
  $$= \frac{28.0}{132.1} \times 100$$
  $$= 21.2\ \%$$
  Step 2: Calculate the mass of nitrogen in the 20 kg bag.
  $$m(\text{N}) = \frac{21.2}{100} \times 20$$
  $$= 4.2 \text{ kg}$$
- A is incorrect because the percentage of nitrogen in 20 kg must be calculated.
- B is incorrect because there are two nitrogen atoms in ammonium sulfate.
- C is incorrect because there are two ammonium ions contributing to the molar mass of ammonium sulfate.

END OF SECTION A

SECTION B – Short-answer questions

Question 1

Give concise explanations for each of the following.

1a. The rate of a chemical reaction can be increased by increasing the temperature.

Solution

Increasing the temperature increases the average kinetic energy of the particles. This increases the number of collisions and also increases the proportion of fruitful collisions because it is easier for colliding particles to overcome the activation energy barrier.

2 marks

Mark allocation

- 1 mark for increased number of collisions.
- 1 mark for increased proportion of fruitful collisions.

Tips

- *A common error is for students to refer to the increased number of collisions only. This is actually a minor contribution to the increased rate. The increased proportion of fruitful collisions is the significant contributor to the increased rate due to increased temperature.*

1b. The pH of a solution of 0.10 M H_2SO_4 is lower than the pH of a solution of 0.10 M HCl, even though they are both solutions of acids with the same concentration.

Solution

H_2SO_4 is a diprotic acid and HCl is monoprotic.

1 mark

Explanatory notes

- The pH of a solution is a measure of the hydronium ion $[H_3O^+]$ concentration in solution. A hydronium ion forms when a proton is added to water according to

$$H_2O(l) + H^+(aq) \rightleftharpoons H_3O^+(aq)$$

- The definition of an acid is that it donates protons. H_2SO_4 molecules can donate two protons per molecule whereas HCl molecules can donate only one proton per molecule. 0.10 M H_2SO_4 has a greater concentration of H_3O^+ ions than 0.10 M HCl.

Tips

- *Remember that pH is simply a convenient way of stating $[H_3O^+]$. It is a logarithmic scale so if $[H_3O^+]$ increases, the solution becomes more acidic and pH decreases.*

Total 3 marks

Question 2

Atomic absorption spectroscopy (AAS) is used to analyse a wide range of substances. One such analysis involves determining the lead (Pb^{2+}) concentration in paint.

2a. Explain why a lead lamp is used for this analysis.

Solution

A lead lamp produces the precise wavelength of light absorbed by lead atoms.

1 mark

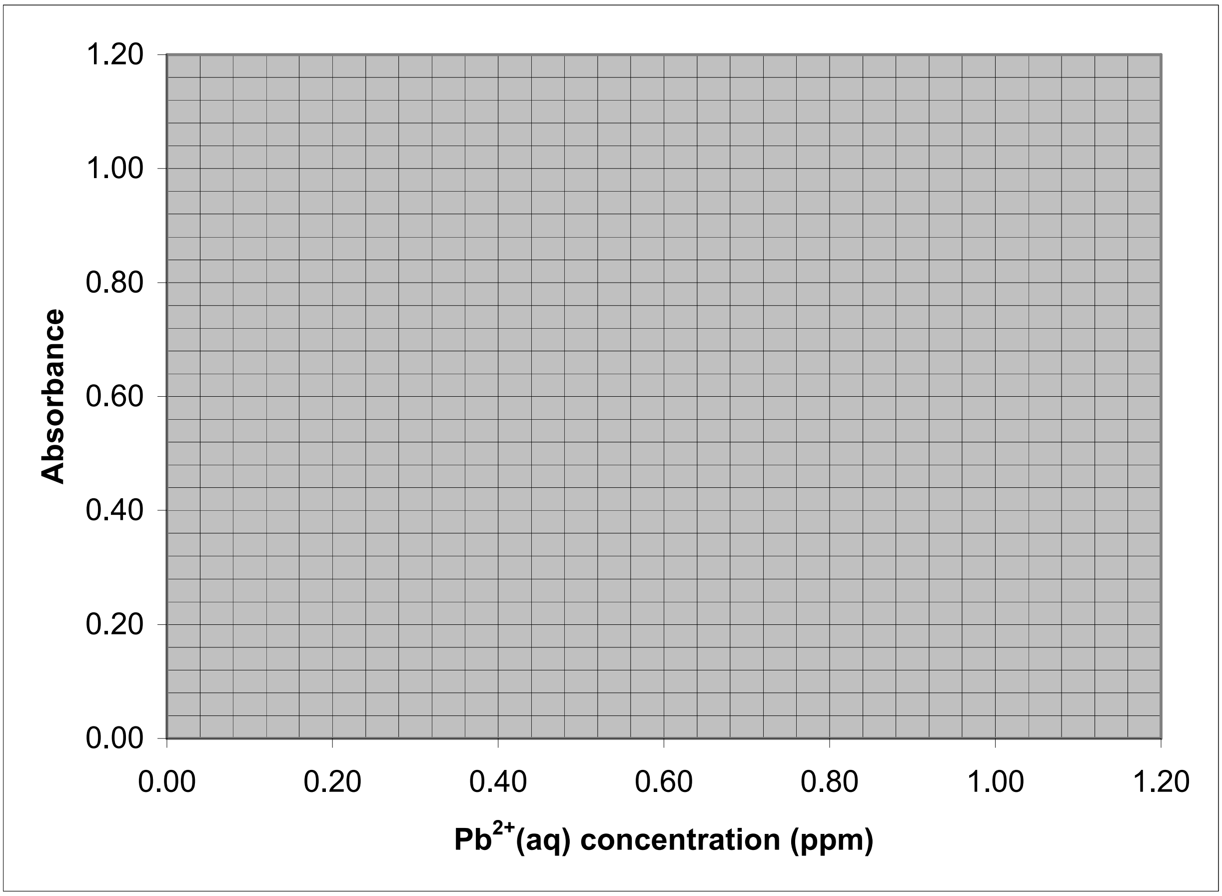
Explanatory notes

- Atomic absorption spectroscopy relies on the absorption of light by the sample being analysed. Electrons in atoms of the element being analysed are promoted to higher energy levels as they absorb some of the energy of the light beam. A lamp of the element being analysed will produce the precise wavelength of energy required to promote the electrons in atoms of that element.

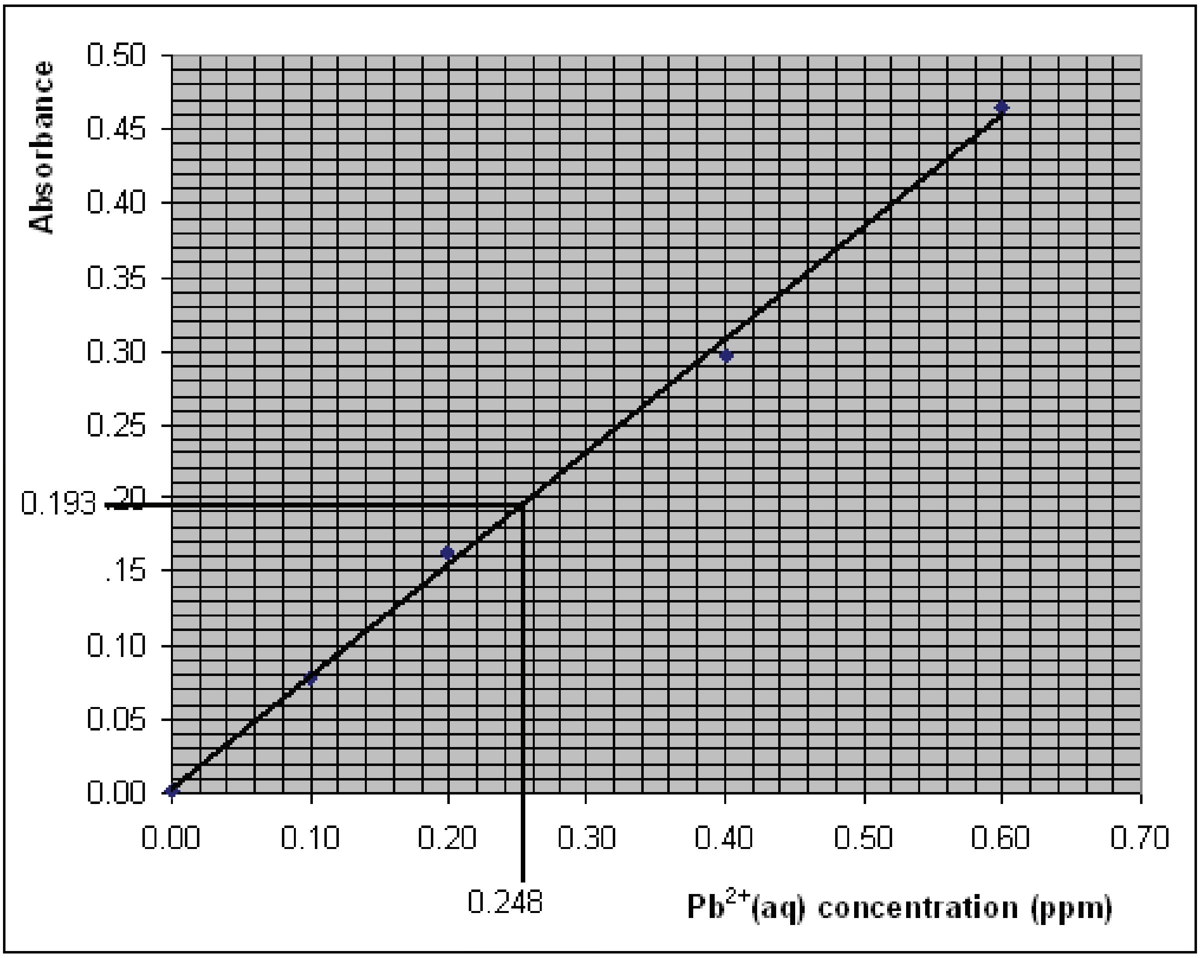
The student prepares several standard solutions of different concentrations and measures the absorbance of each.

Pb^{2+}(aq) concentration (ppm)	Absorbance
0	0.002
0.1	0.078
0.2	0.163
0.4	0.297
0.6	0.464

2b. Use the data above for the Pb^{2+}(aq) standards to plot a calibration line on the graph below.



Solution



2 marks

Mark allocation

- 1 mark for correct plotting of points.
- 1 mark for line of best fit.

Tips

- *Calibration curves are always a line of best fit. This is to overcome any random errors that may occur in the preparation and analysis of the individual samples.*
- *A common error is for students to read the scale incorrectly when plotting points, so students should take their time and do so very carefully.*

2c. A 10.0 mL sample of paint is diluted to 1000 mL, filtered and a sample taken for analysis. Its absorbance is measured as 0.193.

i. Determine the concentration of lead in the paint, in ppm.

Solution

$c(Pb^{2+})$ in diluted sample = 0.248 ppm (0.235–0.265 would be accepted)

$$c(Pb^{2+}) \text{ in original sample} = \frac{1000}{10.0} \times 0.248$$
$$= 248 \text{ ppm}$$

2 marks

Mark allocation

- 1 mark for reading the concentration off the graph correctly.
- 1 mark for using dilution factor to calculate concentration in the original sample.

Tips

- *Students can earn consequential marks if their graph is incorrect but they read the concentration off it correctly.*
- *Students can earn a consequential mark if they read the concentration off the graph incorrectly but they use the correct dilution to calculate the concentration in the original sample.*

ii. A concentration of 1.00 ppm is the same as a concentration of 1.00 mg L^{-1}. Calculate the concentration of $Pb^{2+}(aq)$ in the paint, in mol L^{-1}.

Solution

Step 1: Calculate the concentration of $Pb^{2+}(aq)$ in mg L^{-1}.

If 1 ppm = 1.00 mg L^{-1}

then 248 ppm = 248 mg L^{-1}.

Step 2: Convert the concentration of $Pb^{2+}(aq)$ to g L^{-1}.

If 1 mg = 1.00×10^{-3} g

then 248 mg L^{-1} = 248×10^{-3}

= 0.248 g L^{-1}.

Step 3: Calculate the concentration in mol L^{-1}.

$$n(Pb^{2+}) = \frac{m}{M}$$
$$= \frac{0.248}{207.2}$$
$$= 1.20 \times 10^{-3} \text{ mol}$$
$$[Pb^{2+}] = 1.20 \times 10^{-3} \text{ M}$$

2 marks

Mark allocation

- 1 mark for conversion to 0.248 g L^{-1}.
- 1 mark for calculating concentration of 1.20×10^{-3} M.

Tips

- *Students can earn consequential marks if their graph and/or reading from the graph were incorrect in part **ci** but they use the values correctly in part **cii**.*
- *Students can earn a consequential mark if they incorrectly use mg to calculate the amount in mol but use the correct molar mass of Pb^{2+}, resulting in an answer of 1.20 M.*

Total 7 marks

Question 3

A student wishes to determine the purity of a sample of calcium carbonate. The student dissolves a 1.15 g sample of calcium carbonate in water in a 250 mL volumetric flask and adds 50.0 mL of 1.00 M hydrochloric acid. Once the solution has stopped fizzing it is made up to the mark with deionised water. A 20.0 mL aliquot of this solution is pipetted into a conical flask and three drops of phenolphthalein indicator are added. The mixture is titrated with a 0.100 M standard solution of sodium hydroxide until a permanent faint pink colour is reached. This is repeated three times. The titres obtained are shown below.

Titre	Volume (mL)
1	22.30
2	22.35
3	23.00
4	22.35

3a. Write an equation for the reaction between

i. calcium carbonate and hydrochloric acid.

Solution

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

1 mark

Explanatory notes

- The valency of a calcium ion is +2 and the valency of the carbonate ion is –2, giving the ionic formula $CaCO_3$.
- The general equation between an acid and a metal carbonate tells us that the products are salt, water and carbon dioxide.

Tips

- *Students sometimes neglect to thoroughly revise their knowledge of valencies, which causes errors when writing formulas and equations.*
- *Students should always ensure equations are balanced correctly and include states.*

ii. hydrochloric acid and sodium hydroxide.

Solution

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

1 mark

Explanatory notes

- The valency of a sodium ion is +1 and the valency of the hydroxide ion is –1, giving the ionic formula NaCl.
- The general equation between an acid and a metal hydroxide tells us that the products are salt and water.

3b. Calculate the amount, in mol, of sodium hydroxide in the average titre.

Solution

Step 1: Calculate the volume of the average titre.

$$\text{Average } V(\text{NaOH}) = \frac{22.30 + 22.35 + 22.35}{3}$$

$$= 22.33 \text{ mL}$$

Step 2: Calculate the amount, in mol, of sodium hydroxide.

$$n = cV$$
$$= 0.100 \times 22.33 \times 10^{-3}$$
$$= 2.23 \times 10^{-3} \text{ mol}$$

2 marks

Mark allocation

- 1 mark for calculating average titre volume o 22.33 mL.
- 1 mark for calculating 2.23×10^{-3} mol of NaOH.

Explanatory notes

- Only concordant titres are included in the calculation of average titre. The titre of 23.00 mL is discarded.

Tips

- *A common error students make is forgetting to convert mL to L for use in calculation of number of moles.*

3c. **i.** Calculate the amount, in mol, of hydrochloric acid added to the 250 mL flask.

Solution

$$\text{Added } n(\text{HCl}) = cV$$
$$= 1.00 \times 50.0 \times 10^{-3}$$
$$= 0.0500 \text{ mol}$$

1 mark

ii. Use the appropriate reaction equation to calculate the amount, in mol, of excess hydrochloric acid in the 250 mL volumetric flask.

Solution

Step 1: Calculate the excess n(HCl) in the 20.0 mL aliquot that reacted with the NaOH(aq).

n(HCl) : n(NaOH)

1 : 1

$$\text{Excess } n(\text{HCl}) \text{ in aliqout } = \frac{1}{1} \times n(\text{NaOH})$$
$$= \frac{1}{1} \times 2.23 \times 10^{-3}$$
$$= 2.23 \times 10^{-3} \text{ mol}$$

Step 2: Calculate excess n(HCl) in 250 mL volumetric flask.

$$\text{Excess } n(\text{HCl}) = \frac{250}{20} \times 2.23 \times 10^{-3}$$
$$= 0.0279 \text{ mol}$$

2 marks

Mark allocation

- 1 mark for calculating 2.23×10^{-3} mol of HCl in aliquot.
- 1 mark for calculating excess HCl in volumetric flask of 0.0279 mol.

Explanatory notes

- The coefficients in a balanced chemical equation give a mole ratio by which the amount, in mol, of any reactant consumed or product produced can be determined from the amount, in mol, of any other.
- The HCl(aq) in the aliquot is a portion of what remained unreacted after the first reaction with $CaCO_3$(s).

iii. Calculate the amount, in mol, of hydrochloric acid that reacted initially.

Solution

n(HCl) reacted = added n(HCl) – excess n(HCl)
= 0.0500 – 0.0279
= 0.0221 mol

1 mark

3d. Use the appropriate reaction equation to determine the amount, in mol, of calcium carbonate in the sample.

Solution

$n(CaCO_3) : n(HCl)$
1 : 2

$$n(CaCO_3) = \frac{1}{2} \times n(HCl)$$
$$= \frac{1}{2} \times 0.0221$$
$$= 0.0111 \text{ mol}$$

1 mark

Explanatory notes

- This is an example of a back titration. The amount of calcium carbonate cannot be determined by direct titration because it would not produce a sharp enough colour change in an indicator. Instead its concentration is determined indirectly by reacting it with a known amount of a strong acid, HCl, that is then titrated with a strong base to determine how much remains after the first reaction. The difference between the amount, in mol, added and the amount, in mol, remaining indicates the amount, in mol, of HCl that reacted with the calcium carbonate. This is then used to determine the amount, in mol, of calcium carbonate that reacted.

3e. Calculate the percentage purity, by mass, of the calcium carbonate.

Solution

Step 1: Calculate the mass of calcium carbonate.

$m(CaCO_3) = nM$

$= 0.0111 \times (40.1 + 12.0 + 3 \times 16.0)$

$= 0.0111 \times 100.1$

$= 1.11$ g

$$\% \ CaCO_3 = \frac{m(CaCO_3)}{m(\text{sample})} \times 100$$

$$= \frac{1.11}{1.15} \times 100$$

$= 96.6\%$

3 marks

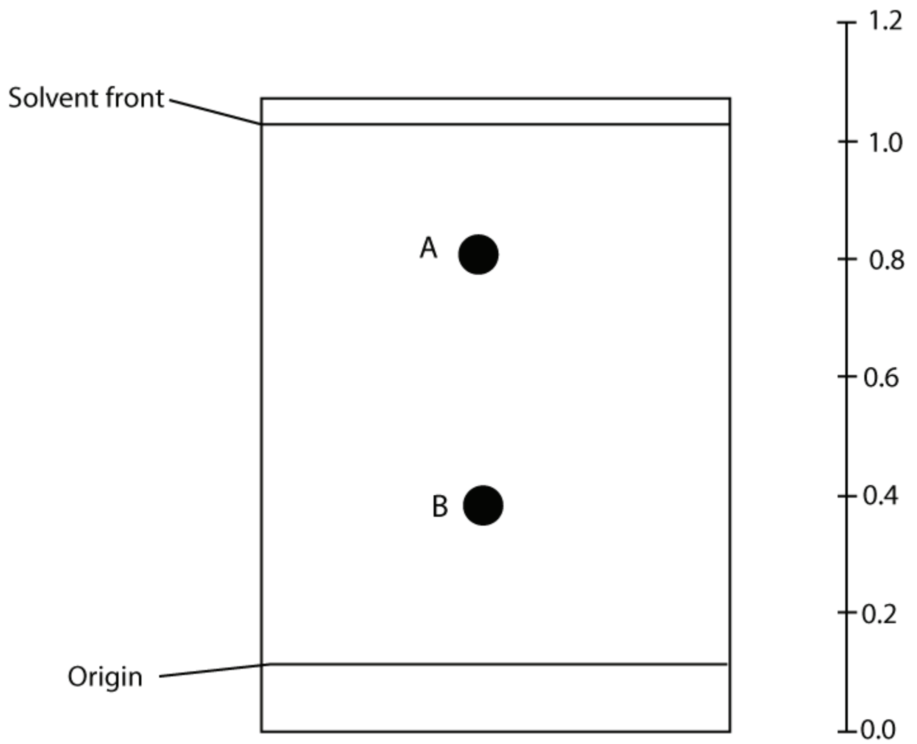
Mark allocation

- 1 mark for calculating molar mass is 100.1 g mol^{-1}.
- 1 mark for calculating mass is 1.11 g.
- 1 mark for calculating percentage is 96.6%.

Total 12 marks

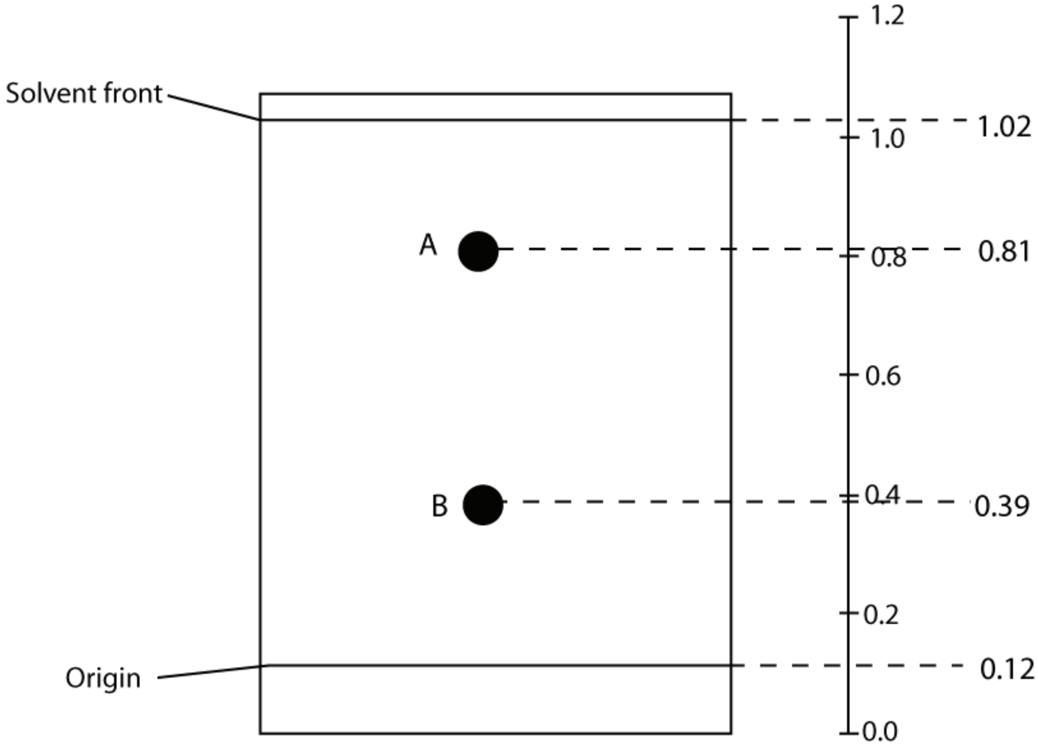
Question 4

The diagram below represents a paper chromatograph obtained by a student who was analysing the colours present in a particular brand of blue ink.



4a. Calculate the Rf values of each component shown.

Solution



For component A:

$$R_f = \frac{\text{distance travelled by component from the origin}}{\text{distance travelled by solvent front from the origin}}$$

$$R_f = \frac{0.81 - 0.12}{1.02 - 0.12}$$
$$= \frac{0.69}{0.90}$$
$$= 0.77$$

For component B:

$$R_f = \frac{0.39 - 0.12}{1.02 - 0.12}$$
$$= \frac{0.27}{0.90}$$
$$= 0.30$$

2 marks

Mark allocation

- 1 mark for correct calculation of each R_f value.

Explanatory notes

- The origin is at 0.12, so the distance travelled by the components and solvent front from this point needs to be determined.

Tips

- *A common error is to miss that the origin is at 0.12 and simply to use* $\frac{0.81}{1.02}$ *and* $\frac{0.39}{1.02}$ *in the calculations of* R_f *values. Students need to examine diagrams and graphs very carefully.*

4b. Which component was most strongly absorbed to the stationary phase?

Solution

Component A

1 mark

Explanatory notes

- The component most strongly absorbed will travel the slowest and move the least distance on the paper. It will have the lowest R_f value.

4c. Suggest a way that the student could ensure that each of the spots evident on the chromatogram represents only one component in the ink.

Solution

Repeat the experiment using a different stationary phase *or* a different mobile phase *or* a longer piece of paper.

1 mark

Explanatory notes

- Two components that behave the same way in the first set-up may behave differently with a different stationary phase or mobile phase due to the different levels of attraction or solubility, which will enable them to separate. Using a longer piece of paper may exploit any small differences in attraction to the stationary phase or solubility in the mobile phase in the current set-up.

Total 4 marks

Question 5

The following chemical reactions both represent the ionisation of an acid in water.

$$HCl(g) + H_2O(l) \rightarrow Cl^-(aq) + H_3O^+(aq)$$

$$CH_3COOH(l) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

5a. Explain, with reference to acid strength, why the two equations use different arrows.

Solution

HCl is a strong acid and completely ionises in water, hence the complete reaction arrow.
CH_3COOH is a weak acid and incompletely ionises in water, hence the equilibrium arrow.

1 mark

Tips

- *Students should always use the appropriate arrow notation when writing their own equations.*

5b. Calculate the pH of 100 mL of 0.500 M HCl solution.

Solution

$$\begin{aligned}[H_3O^+] &= [HCl] \\ &= 0.500 \text{ M} \\ pH &= -\log_{10}[H_3O^+] \\ &= -\log_{10}(0.500) \\ &= 0.301\end{aligned}$$

1 mark

Explanatory notes

- HCl is a strong monoprotic acid, so $[H_3O^+] = [HCl]$.

Tips

- *When calculating the pH of a solution, students should always first identify whether the species is an acid or a base, and if it is monoprotic or diprotic. These factors both affect the steps to follow when calculating pH.*

5c. Calculate the pH of 100 mL of 0.500 M CH_3COOH solution that has the K_a value 1.7×10^{-5}.

Solution

Step 1: Calculate $[H_3O^+]$.

$$K_a = \frac{[CH_3COO^-][H_3O^+]}{CH_3COOH}$$

$$1.7 \times 10^{-5} = \frac{[H_3O^+]^2}{0.500}$$

$$[H_3O^+]^2 = 0.500 \times 1.7 \times 10^{-5}$$

$$[H_3O^+]^2 = 8.5 \times 10^{-6}$$

$$[H_3O^+] = \sqrt{8.5 \times 10^{-6}}$$

$$= 0.0029 \text{ M}$$

Step 2: Calculate the pH.

$$\text{pH} = -\log_{10}[H_3O^+]$$

$$= -\log_{10}(0.0029)$$

$$= 2.5$$

3 marks

Mark allocation

- 1 mark for $1.7 \times 10^{-5} = \frac{[H_3O^+]^2}{0.500}$, i.e. recognition that $[HCOO^-] = [H_3O^+]$.
- 1 mark for calculating $[H_3O^+]$ is 0.0029 M.
- 1 mark for calculating pH is 2.5.

Explanatory notes

- The pH of a weak acid cannot be calculated directly from the concentration of the acid because the ionisation of the acid in water is not complete.
- A number of assumptions are made when calculating the pH of a weak acid:
  - $[HCOO^-] = [H_3O^+]$
  - There is minimal ionisation, so the $[CH_3COOH]$ at equilibrium is still 0.500 M.

Tips

- *If the concentration is given, the volume of the acid is irrelevant when calculating pH.*

5d. Bases such as sodium hydroxide also ionise in water.

i. Give a definition of a base.

Solution

A proton acceptor

1 mark

Explanatory notes

- Bases are the opposite of acids in terms of behaviour. An acid is a proton and a base is a proton acceptor.

ii. Calculate the pH of 100 mL of 0.500 M NaOH solution.

Solution

Step 1: Calculate the concentration of OH^- ions in solution.

$[OH^-] = [NaOH]$
$= 0.500$ M

Step 2: Calculate $[H_3O^+]$.

$$[H_3O^+] = \frac{10^{-14}}{[OH^-]}$$
$$= \frac{10^{-14}}{0.500}$$
$$= 2.00 \times 10^{-14} \text{ M}$$
$$\text{pH} = -\log_{10}[H_3O^+]$$
$$= \log_{10}(2.0 \times 10^{-14})$$
$$= 13.7$$

2 marks

Mark allocation

- 1 mark for calculating $[H_3O^+] = 2.00 \times 10^{-14}$ M.
- 1 mark for calculating pH is 13.7.

Explanatory notes

- Bases ionise in water to produce OH^- ions. In water $K_w = [H_3O^+][OH^-] = 10^{-14}$ M^2 at 25°C, which can be used to calculate $[H_3O^+]$ and therefore the pH of a basic solution.

Total 8 marks

Question 6

A student investigating equilibrium uses a mixture of NO_2 and N_2O_4 in a container of fixed volume. The reaction is exothermic.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

6a. Complete the table by placing ticks in the appropriate boxes to indicate the effect of each change the student made to the mixture on

I. the amount, in mol, of NO_2; and
II. the concentration of NO_2.

Change to the equilibrium	**I.** Amount, in mol, of NO_2 at new equilibrium compared with initial equilibrium		**II.** $[NO_2]$ at new equilibrium compared with initial equilibrium	
	decreased	increased	decreased	increased
Sample 1: The container is heated				
Sample 2: The pressure is decreased by pulling out the piston				
Sample 3: More NO_2 gas is added				

Solution

Change to the equilibrium	**I.** Amount, in mol, of NO_2 at new equilibrium compared with initial equilibrium		**II.** $[NO_2]$ at new equilibrium compared with initial equilibrium	
	decreased	increased	decreased	increased
Sample 1: The container is heated		✓		✓
Sample 2: The pressure is decreased by pulling out the piston		✓	✓	
Sample 3: More NO_2 gas is added		✓		✓

6 marks

Mark allocation

- 1 mark per tick.

Explanatory notes

- Le Chatelier's Principle states that if an equilibrium system is subject to change it will adjust itself to partially oppose the effects of the change.
- For Sample 1: Heating the container adds energy to the system. It responds by shifting in the endothermic direction, which in this case is backwards. Both the amount and concentration of NO_2 increases.
- For Sample 2: Decreasing the pressure by increasing the volume causes $[NO_2]$ to decrease. The system responds by moving in the direction of more particles. There are two particles on the reactant side to one on the product side, hence, a net backward reaction results and the amount of NO_2 increases. However, the response only partially opposes the change and $[NO_2]$ is still lower than it was at the initial equilibrium due to the increased volume.
- Sample 3: Removal of a reactant causes a net forward reaction in order to remove some of the added NO_2, however, the opposition is only partial and once equilibrium is re-established, the concentration and amount will remain higher than at the initial equilibrium.

6b. The equilibrium reaction for the transport of oxygen in the blood by haemoglobin (Hb) can be represented as:

$$Hb(aq) + O_2(aq) \rightleftharpoons HbO_2(aq)$$

Carbon monoxide (CO) reacts with haemoglobin in the same way as oxygen, but with a much higher *K* value.

$$Hb(aq) + CO(aq) \rightleftharpoons HbCO(aq)$$

Explain how relatively low levels of carbon monoxide in air can cause carbon monoxide poisoning.

Solution

The very high *K* value for the Hb with CO reaction means that any CO present causes a net forward reaction in the second reaction, reducing the amount of Hb in the blood. The Hb with O_2 reaction then undergoes a net backward reaction in order to replace some of the Hb.

2 marks

Mark allocation

- 1 mark for CO reduces the amount of Hb present in blood.
- 1 mark for Hb withO_2 reaction undergoes a net backward reaction.

Total 8 marks

Question 7

7a. Write the name and molecular formula of an alkane that has three carbon atoms.

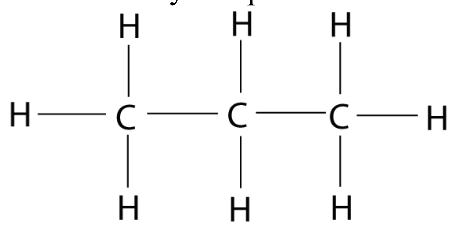
Solution

propane, C_3H_8

1 mark

Explanatory notes

- An alkane with three carbons has only one possible structural formula, given below.



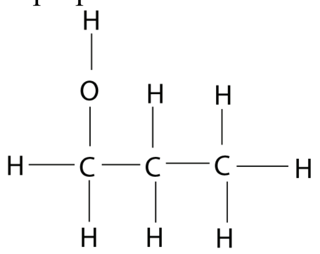
- The three carbons in an unbroken chain give the prefix *prop*-.

7b. This alkane can be converted to a chloroalkane, which can then be used to produce an alcohol.

i. Give a name and structural formula of the alcohol.

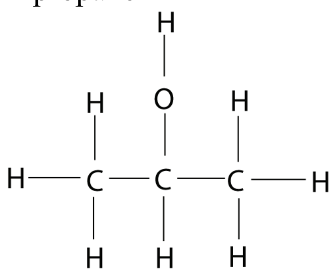
Solution

1-propanol



OR

2-propanol



2 marks

Mark allocation

- 1 mark for 1-propanol *or* 2-propanol.
- 1 mark for appropriate correct structural formula.

Explanatory notes

- There are two possible alcohols, depending on where the hydroxyl group is located. The name of the alcohol must indicate the location of the hydroxyl functional group. If simply 'propanol' is given with a correct structural formula, students receive only 1 mark.

Tips

- *When asked for structural formula, students should ensure they write the structural formula for the functional group as well as the hydrocarbon section of the molecule.*

ii. Name the type of reaction in the production of the alcohol from the chloroalkane.

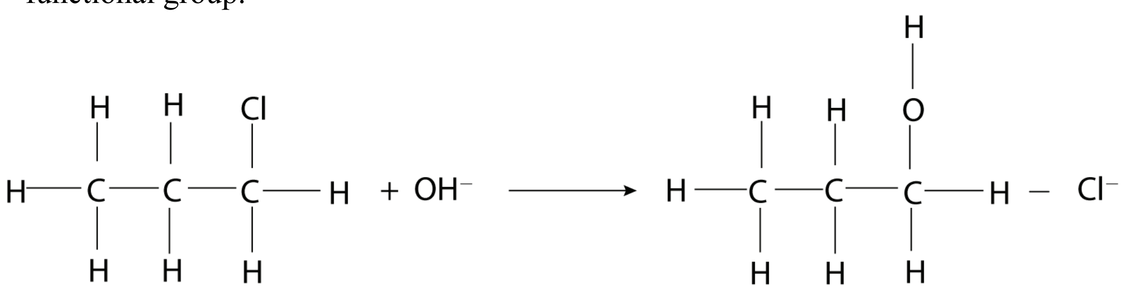
Solution

Substitution

1 mark

Explanatory notes

- The full reaction involves the substitution of a chloro functional group for a hydroxyl functional group.



Tips

- *Alkanes are already saturated so a new functional group cannot be added.*

7c. Describe, in a series of steps, how you could use a sample of the alcohol above to produce an ester in the laboratory.

Solution

Step 1: Divide the 1-propanol into two samples and keep one aside.

Step 2: Add some acidified MnO_4^- *or* $Cr_2O_7^{2-}$ to the other sample to oxidise the 1-propanol to propanoic acid.

Step 3: React the 1-propanol and propanoic acid together, with a catalyst of concentrated sulfuric acid, to produce an ester.

5 marks

Mark allocation

- 1 mark for keep aside a sample of alcohol.
- 1 mark for convert propanol to propanoic acid.
- 1 mark for acidified MnO_4^- *or* $Cr_2O_7^{2-}$ as oxidizing agent for reaction above.
- 1 mark for react 1-propanol with propanoic acid.
- 1 mark for $H_2SO_4(l)$ for reaction above.

Tips

- *A common error would be for student responses to lack detail. Students are asked how they would carry out the process in a laboratory and they must answer this question. A general answer should be avoided.*
- *A sequence of reactions/equations would also be acceptable.*

Total 9 marks

Question 8

A number of steps are involved in the conversion of mined sulfur to sulfuric acid via the Contact Process.

Step 1: The Burner

8a. Write an equation for the reaction that occurs here.

Solution

$S(l) + O_2(g) \rightarrow SO_2(g)$

1 mark

Explanatory notes

- Liquid sulfur is sprayed into the burner and reacted with air. The reaction is virtually complete.

Tips

- *Always include states and the correct reaction arrow.*

Step 2: The Converter

8b. **i.** Write an equation for the reaction that occurs here.

Solution

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

1 mark

Explanatory notes

- $SO_2(g)$ reacts with more air to produce $SO_3(g)$ in an equilibrium reaction.

ii. Explain why a catalyst is used to increase the reaction rate in the converter, rather than increasing the temperature.

Solution

The reaction is exothermic. Increasing the temperature would cause a net backward reaction, reducing the yield of $SO_3(g)$.

2 marks

Mark allocation

- 1 mark for exothermic reaction.
- 1 mark for net backward reaction being caused.

Explanatory notes

- This is an illustration of Le Chatelier's Principle and the conflict that can arise between achieving optimum rate and optimum yield. Increasing the temperature would increase the reaction rate, however, it increases the rates of the forward and backward reactions to the same extent.

Step 3: The Absorber

8c. The reaction that produces oleum in the absorber is represented by the equation

$$SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$$

i. Explain why SO_3 isn't simply reacted with water to produce sulfuric acid in one step.

Solution

The reaction is highly exothermic and results in a fine mist of sulfuric acid, which is difficult to collect.

2 marks

Mark allocation

- 1 mark for exothermic.
- 1 mark for fine mist *or* difficult to collect.

ii. Write an equation for the production of sulfuric acid from oleum.

Solution

$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$

1 mark

8d. Sulfuric acid is a very useful chemical that can react in a number of ways. Write equations to show sulfuric acid

i. acting as an acid when reacting with calcium carbonate.

Solution

$H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + H_2CO_3(aq)$

OR

$H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$

2 marks

Mark allocation

- 1 mark for correct formulas.
- 1 mark for correct balancing of equation.

Tips

- *Students may obtain 1 mark if they use the incorrect ionic formula for sodium carbonate but the equation is still balanced overall.*

ii. dehydrating a sample of sucrose, $C_{12}H_{22}O_{11}$.

Solution

$C_{12}H_{22}O_{11}(s) \xrightarrow{H_2SO_4(l)} 12C(s) + 11H_2O(l)$

1 mark

Explanatory notes

- Sulfuric acid dehydrates by removing water from organic compounds. It will remove as many H_2O molecules as possible.

Total 10 marks

END OF SOLUTIONS BOOK