GCSE · AQA · Chemistry

2 hours 18 questions

Exam Questions

Concentration of Solutions

Using Concentrations in mol/dm3

Easy (5 questions)	/31
Medium (6 questions)	/28
Hard (7 questions)	/56
Total Marks	**/115**

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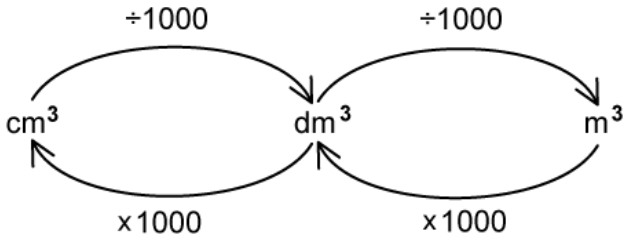
Easy Questions

1 (a) Use the conversion factors in **Figure 1** to convert the volumes in parts (a) - (e):

Figure 1



1000 cm^3 = ____ dm^3

Answer

The correct conversion is:

- 1000 cm^3 = 1 dm^3; [1 mark]

[Total: 1 mark]

- cm^3 to dm^3 = divide by 1000

(1 mark)

(b) 2500 cm^3 = ____ dm^3

Answer

The correct conversion is:

- 2500 cm^3 = 2.5 dm^3; [1 mark]

[Total: 1 mark]

- cm^3 to dm^3 = divide by 1000

(1 mark)

(c) 50 cm^3 = ____ dm^3

Answer

The correct conversion is:

- 50 cm^3 = <u>0.05</u> dm^3; [1 mark]

[Total: 1 mark]

- cm^3 to dm^3 = divide by 1000

(1 mark)

(d) ____ cm^3 = 3.2 dm^3

Answer

The correct conversion is:

- <u>3200</u> cm^3 = 3.2 dm^3; [1 mark]

[Total: 1 mark]

- dm^3 to cm^3 = multiply by 1000

(1 mark)

(e) ____ cm^3 = 0.75 dm^3

Answer

The correct conversion is:

- <u>750</u> cm^3 = 0.75 dm^3; [1 mark]

[Total: 1 mark]

- dm^3 to cm^3 = multiply by 1000

(1 mark)

2 (a) Write the equation to calculate concentration in terms of moles and volume.

Answer

The equation to calculate concentration in terms of moles and volume is:

- $\text{Concentration} = \frac{\text{moles}}{\text{volume}}$; [1mark]

[Total: 1 mark]

- This is one of the most used equations in Chemistry so make sure you know how to use it and rearrange it

(1 mark)

(b) How many moles of sodium hydroxide are present in 1.5 dm^3 of a 0.25 mol dm^{-3} sodium hydroxide solution?

Answer

The number of moles of sodium hydroxide present in 1.5 dm^3 of a 0.25 mol dm^{-3} solution is:

Moles = concentration x volume

- Moles = 0.25 x 1.5; [1 mark]
- Moles = 0.375 moles; [1 mark]

[Total: 2 marks]

(2 marks)

(c) What is the concentration in g dm^{-3} of the 0.25 mol dm^{-3} solution of sodium hydroxide?

Relative formula mass (M_r): NaOH = 40

Answer

The concentration in g dm^{-3} of a 0.25 mol dm^{-3} solution of sodium hydroxide is:

- 0.25 x 40 = 10 g dm^{-3}; [1 mark]

[Total: 1 mark]

- **Remember:** To convert from mol dm^{-3} to g dm^{-3}, you should multiply by the molar mass of the chemical in question

(1 mark)

3 (a) In a titration experiment, 25.0 cm^3 of dilute hydrochloric acid, HCl (aq), was neutralised by 23.5 cm^3 of 0.100 mol dm^{-3} sodium hydroxide solution, NaOH (aq) to produce sodium chloride (NaCl) and water.

hydrochloric acid + sodium hydroxide → sodium chloride + water

Write the balanced symbol equation, including state symbols, for this reaction.

Answer

The balanced symbol equation, including state symbols, for this reaction is:

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

- Correct chemical formulae for reactants and products; [1 mark]
- Correct state symbols for reactants and products; [1 mark]

[Total: 2 marks]

- You are given enough information in the question to definitely write the reactants with correct state symbols
- You should know that this reaction will form sodium chloride and water, as this is one of the first neutralisation reactions that you will have come across
- You should know that sodium chloride (salt) is soluble in water and therefore has the (aq) state symbol
- You should also know that water has the (l) state symbol for a liquid

(2 marks)

(b) Convert 23.5 cm^3 into dm^3.

Answer

To convert 23.5 cm^3 into dm^3:

- $\frac{23.5}{1000}$ = 0.0235 dm^3; [1mark]

[Total: 1 mark]

- **Remember:** To convert cm^3 to dm^3 you divide by 1000
- **Careful:** A lot of concentration calculations will require you to convert from cm^3 to dm^3 (or vice versa)
    - This is a step that examiners often comment on students missing in their calculations

(1 mark)

(c) Calculate the number of moles of sodium hydroxide used in the titration.

Answer

To calculate the number of moles of sodium hydroxide used in the titration:

- Moles = concentration x volume (in dm^3)
- Moles = 0.100 x 0.0235; [1 mark]
- Moles = 2.35×10^{-3}
  OR
  Moles = 0.00235; [1 mark]

[Total: 2 marks]

- **Remember:** The concentration in this question is given in mol dm^3 so your volume needs to be in dm^3

(2 marks)

(d) State the number of moles of hydrochloric acid neutralised by the sodium hydroxide.

Answer

The number of moles of hydrochloric acid neutralised by the sodium hydroxide is:

- 2.35×10^{-3}
  OR
  0.00235; [1 mark]

[Total: 1 mark]

- The ratio of hydrochloric acid to sodium hydroxide is 1 : 1
- Therefore, 0.00235 moles of hydrochloric acid will be neutralised by 0.00235 moles of sodium hydroxide

(1 mark)

(e) Calculate the concentration of the dilute hydrochloric acid.

Answer

To calculate the concentration of the dilute hydrochloric acid:

- Concentration = $\frac{\text{moles}}{\text{volume (in dm}^3\text{)}}$
- Concentration = $\frac{0.00235}{(25.0/1000)}$
  OR
  Concentration = $\frac{0.00235}{0.025}$; [1 mark]
- Concentration = 0.094 mol dm^{-3}; [1 mark]

[Total: 2 marks]

- It is common for titration calculation questions to use the moles = concentration x volume (in dm^3) equation twice
  - This is shown in parts (c) and (e)
- It is also common to have to convert volumes from cm^3 to dm^3

    - This is shown in parts (d) and (e)
- A foundation tier paper might break a titration calculation up like this but a higher tier paper will, usually, give you the information and ask you for the final concentration

(2 marks)

4 (a) A student neutralised dilute sulfuric acid with potassium hydroxide solution.

Balance the chemical equation for this reaction.

$$\_\_\_ KOH + \_\_\_ H_2SO_4 \rightarrow \_\_\_ K_2SO_4 + \_\_\_ H_2O$$

Answer

The balanced chemical equation for the neutralisation of sulfuric acid by potassium hydroxide is:

$$\mathbf{2}KOH + H_2SO_4 \rightarrow K_2SO_4 + \mathbf{2}H_2O$$

- 2 in front of KOH (with no number or 1 in front of H_2SO_4); [1 mark]
- 2 in front of H_2O (with no number or 1 in front of K_2SO_4); [1 mark]

[Total: 2 marks]

- Looking at the K_2SO_4 product, you should see that 2KOH are needed
  - $\mathbf{2}KOH + H_2SO_4 \rightarrow K_2SO_4 + H_2O$
- This means that the reactants (left hand side) now have 4 hydrogen and 6 oxygen atoms, which make 2 water molecules
  - $\mathbf{2}KOH + H_2SO_4 \rightarrow K_2SO_4 + \mathbf{2}H_2O$

(2 marks)

(b) The student found that 31.0 cm^3 of 0.250 mol / dm^3 dilute sulfuric acid completely reacted with 25.0 cm^3 of potassium hydroxide solution.

How many moles of sulfuric acid are used in the reaction?

Answer

The number of moles of sulfuric acid used in the reaction is:

- Convert 31.0 cm^3 to dm^3: $\frac{31.0}{1000}$ = 0.031 dm^3; [1 mark]
- Moles = concentration x volume = 0.250 x 0.031; [1 mark]

- Moles = 7.75 x 10^{-3} moles
  OR
  0.00775 moles; [1 mark]

[Total: 3 marks]

- **Careful:** The concentration is given in mol / dm^3 and the volume is given in cm^3

(3 marks)

(c) Calculate the concentration of the potassium hydroxide solution in mol / dm^3.

Answer

To calculate the concentration of the potassium hydroxide solution in mol / dm^3.

- Moles of potassium hydroxide: 2 x (7.75 x 10^{-3}) = 0.0155 moles
  OR
  2 x 0.00775 = 0.0155 moles; [1 mark]

- Convert 25.0 cm^3 to dm^3: $\frac{25.0}{1000}$ = 0.025; [1 mark]

- Concentration of potassium hydroxide in mol / dm^3: $\frac{0.0155}{0.025}$ = 0.62 mol / dm^3; [1 mark]

[Total: 3 marks]

- The ratio of sulfuric acid to potassium hydroxide is 1 : 2
  - This means that there are twice as many moles of potassium hydroxide required
- **Careful:** The volume used in the calculation needs to be in cm^3

(3 marks)

(d) Calculate the concentration of the potassium hydroxide solution in g / dm^3.

Relative atomic masses (A_r): H = 1; K = 39; O = 16

Answer

To calculate the concentration of the potassium hydroxide solution in g / dm^3.

- Molar mass of potassium hydroxide: 39 + 16 + 1 = 56; [1 mark]
- Concentration of potassium hydroxide in g / dm^3: 56 x 0.62 = 34.7 g / dm^3; [1 mark]

[Total: 2 marks]

- **Remember:** To convert from mol / dm^3 to g / dm^3, multiply by the molar mass

(2 marks)

5 (a) A technician needs to make a 0.150 mol / dm^3 solution of barium chloride, $BaCl_2$.

What mass of barium chloride does the technician need to weigh out?

Relative atomic masses (A_r): Ba = 137; Cl = 35.5

Answer

The mass of barium chloride that the technician needs is:

- M_r of barium chloride = 137 + (2 x 35.5) = 208; [1 mark]
- Mass = moles x M_r = 0.150 x 208 = 31.2 g; [1 mark]

[Total: 2 marks]

(2 marks)

(b) The technician only has 250 cm^3 volumetric flasks available to make the barium chloride solution.

What mass of barium chloride should the technician use to make the same concentration solution in a 250 cm^3 flask?

Answer

The mass of barium chloride that the technician should use is:

- $\frac{31.2}{4}$; [1 mark]
- 7.8 g; [1 mark]

[Total: 2 marks]

- The technician required 31.2 g to make a 0.15 mol / dm^3 solution, assuming that the volume was 1 dm^3 or 1000 cm^3
  - 250 cm^3 is a quarter of 1 dm^3 or 1000 cm^3
  - Therefore, the technician will require a quarter of the mass (31.2 ÷ 4)
- This type of question might not be very common in past papers but it can potentially appear as this is a higher tier topic

(2 marks)

Medium Questions

1 A solution of sulfuric acid, H_2SO_4, contains 9.8 g of the acid in 250 cm^3 of solution.

What is the concentration in mol/dm^3?

Relative atomic masses (A_r): H = 1 S = 32 O= 16

A. 0.10 mol/dm^3

B. 0.20 mol/dm^3

C. 0.40 mol/dm^3

D. 0.80 mol/dm^3

Answer

The correct answer is C because:

- **Step 1:** Convert the volume into dm^3

volume = 250 cm^3 ÷ 1000

= 0.250 dm^3

- **Step 2:** Calculate the amount of solute from its mass and molar mass

molar mass of H_2SO_4 = (2 x 1) + 32 + (4 x 16) = 98 g/mol

$$\text{amount of } H_2SO_4 \text{ in mol} = \frac{\text{mass in g}}{\text{molar mass in g/mol}}$$

$$= \frac{9.8 \text{ g}}{98 \text{ g/mol}} = 0.10 \text{ mol}$$

- **Step 3:** Calculate the concentration from the amount and volume

$$\text{concentration in mol/dm}^3 = \frac{0.10}{0.250} = 0.40 \text{ mol/dm}^3$$

(1 mark)

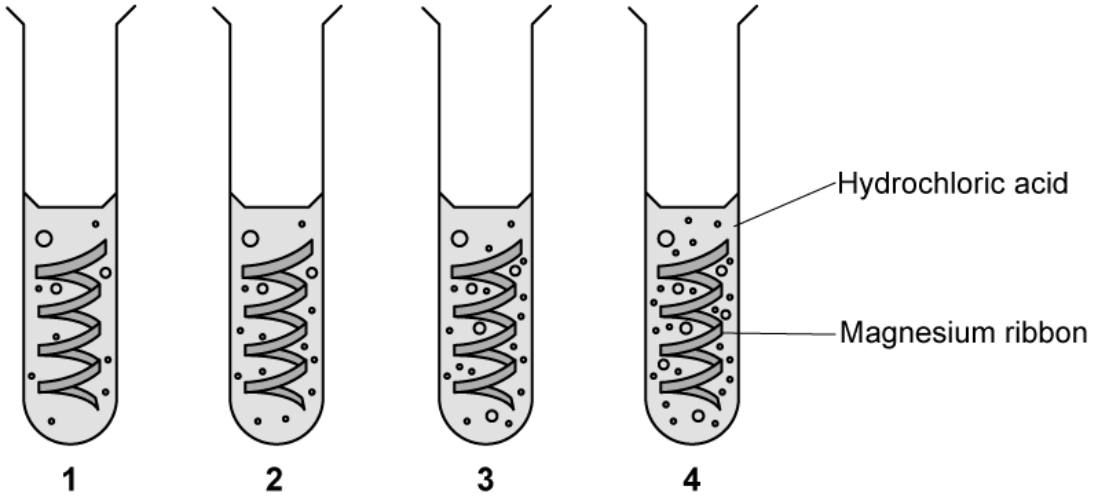
2 (a) A student investigated the rate of reaction between magnesium ribbon and hydrochloric acid.

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

The experiment involved changing the concentration of the acid and observing its effect on the rate of reaction.

The student did this by measuring the time taken for the magnesium to stop reacting. She set up the experiment as shown in **Figure 1**.

Figure 1



The concentration and results of the experiment were recorded in **Table 1**.

Table 1

	Concentration / mol dm^{-3}	Time for reaction to finish / s
Test tube 1	0.5	78
Test tube 2	1.0	62
Test tube 3	1.5	50
Test tube 4	2.0	36

State **three** variables that the student should control.

Answer

Three variables that the student should control are:

Any **three** from:

- Volume of hydrochloric acid / HCl; [1 mark]
- Mass of the magnesium; [1 mark]
- Surface area of the magnesium; [1 mark]
- Temperature of the HCl; [1 mark]

[Total: 3 marks]

- **Remember:** Control variables are ones that you aim to keep the same so that the experiment is valid / a fair test
- Be specific with your answers
    - e.g. magnesium on its own might not get you any marks but it could stop you from scoring 2 potential marks

(3 marks)

(b) The rate of reaction increased as the concentration of hydrochloric acid increased.

Explain why increasing concentration has this effect.

Answer

Increasing the concentation increases the rate of reaction because:

- There are more particles per unit volume; [1 mark]
- As the particles are closer together
  OR
  There is less space between the particles; [1 mark]
- Therefore, there are more frequent (successful) collisions; [1 mark]

[Total: 3 marks]

- Tell them what happens to the number of particles when concentration is increased
- Then relate this to the number **AND** frequency of collisions
  - You might find older exam papers focus on the number of successful collisions but more recent ones focus on the frequency of the collisions
    - You won't be penalised for talking about successful collisions
    - You will lose marks if you don't talk about the frequency of collisions / how often the particles collide

(3 marks)

(c) Suggest how the student prepared solutions with differing concentrations.

Answer

The student prepared solutions with differing concentrations by:

- Using a stock solution / standard solution / solution of known concentration; [1 mark]
- (And) diluting it with deionised / distilled water to the required concentration; [1 mark]

[Total: 2 marks]

- In this question, you are explaining how to use a known solution to create further solutions
    - Apart from some key words such as stock / standard solution and deionised / distilled water, this is no different to describing how to make a drink using cordial

(2 marks)

(d) The student had a stock solution of sodium hydroxide with an exact concentration of 0.200 moles per dm^3.

She wanted to use this solution to find the concentration of a solution of hydrochloric acid.

She used a pipette to transfer 10.00 cm^3 of the hydrochloric acid into a conical flask and filled a burette with the 0.200 moles per dm^3 sodium hydroxide solution.

Describe how a titration could be used to obtain accurate results.

Answer

The description of how a titration could be used to obtain accurate results is:

- Add a few drops of a suitable indicator to the conical flask; [1 mark]
- Add NaOH dropwise from the burette; [1 mark]
- While swirling the contents of the conical flask; [1 mark]
- Until the indicator changes colour; [1 mark]
- Repeat the titration until concordant results are obtained; [1 mark]
- Calculate the average volume of NaOH used; [1 mark]

[Total: 6 marks]

- Titrations are one of the more common Chemistry practicals, so you need to be able to describe how to perform them

(6 marks)

3 (a) Convert the volumes in parts (a) - (e).

1050 cm^3 = _____ dm^3

Answer

The conversion is:

- 1050 cm^3 = 1.05 dm^3; [1 mark]

[Total: 1 mark]

- To convert from cm^3 to dm^3 you divide by 1000

(1 mark)

(b) 865 cm^3 = _____ dm^3

Answer

The correct conversion is:

- 865 cm^3 = 0.865 dm^3; [1 mark]

[Total: 1 mark]

- cm^3 to dm^3 = divide by 1000

(1 mark)

(c) 37250 cm^3 = _____ dm^3

Answer

The correct conversion is:

- 37250 cm^3 = 37.25 dm^3; [1 mark]

[Total: 1 mark]

- cm^3 to dm^3 = divide by 1000

(1 mark)

(d) _ cm^3 = 1.63 dm^3

Answer

The correct conversion is:

- 1630 cm^3 = 1.63 dm^3; [1 mark]

[Total: 1 mark]

- dm^3 to cm^3 = multiply by 1000

(1 mark)

(e) ____ cm^3 = 0.805 dm^3

Answer

The correct conversion is:

- 805 cm^3 = 0.805 dm^3; [1 mark]

[Total: 1 mark]

- dm^3 to cm^3 = multiply by 1000

(1 mark)

4 (a) Calculate the concentration of the following solutions of NaOH in g dm^{-3}. You must show your working.

Relative formula mass (M_r): NaOH = 40

1 mol NaOH in 500 cm^3.

Answer

The concentration calculation is:

- 500 cm^3 = 0.5 dm^3
  OR
  Concentration of NaOH in mol dm^{-3} = $\frac{1}{0.5}$; [1 mark]
- Concentration of NaOH in mol dm^{-3} = 2.0 mol dm^{-3}; [1 mark]
- Concentration of NaOH in g dm^{-3} = 2 x 40 = 80 g dm^{-3}; [1 mark]
  A final concentration of 80 g dm^{-3} scores 3 marks

[Total: 3 marks]

- 500 cm^3 contains 1 moles, therefore 1000 cm^3 contains 2 moles
- 2 moles of NaOH = 2 x 40 = 80 g
- Therefore, the concentration of NaOH in g dm^{-3} is 80 g dm^{-3}

(3 marks)

(b) 2.5 mol NaOH in 2000 cm^3

Answer

The concentration in g dm^{-3} is:

- 2000 cm^3 = 2 dm^3; [1 mark]
- Concentration of NaOH in mol dm^{-3} = 1.25 mol dm^{-3}; [1 mark]
- Concentration of NaOH in g dm^{-3} = 1.25 x 40 = 50 g dm^{-3}; [1 mark] *A final concentration of 50 g dm^{-3} scores 3 marks*

[Total: 3 marks]

- 2000 cm^3 contains 2.5 moles, therefore 1000 cm^3 contains half of 2.5 moles = 1.25 moles
- 1.25 moles of NaOH = 1.25 x 40 = 50 g
- Therefore, the concentration of NaOH in g dm^{-3} is 50 g dm^{-3}

(3 marks)

5 How much solute is present in 2 dm^3 of a 0.5 mol/dm^3 solution of potassium iodide?

A. 0.5 mol

B. 1.0 mol

C. 2.0 mol

D. 10 mol

Answer

The correct answer is B because:

- **Step 1:** Rearrange the formula for calculating concentration

$$\text{concentration in mol/dm}^3 = \frac{\text{moles}}{\text{volme in dm}^3}$$

$$\text{moles} = \text{concentration} \times \text{volume in dm}^3$$

- **Step 2:** Substitute the numbers in the question

$$\text{amount of potassium iodide} = 0.5\ \text{mol/dm}^3 \times 2\ \text{dm}^3 = 1.0\ \text{mol}$$

(1 mark)

6 In a titration 25.00 cm^3 of 0.20 mol/dm^3 sodium hydroxide reacted with 26.50 cm^3 of hydrochloric acid.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

What is the concentration of the acid?

A. 0.19 mol/dm^3

B. 0.23 mol/dm^3

C. 0.55 mol/dm^3

D. 0.82 mol/dm^3

Answer

The correct answer is A because:

- **Step 1:** Convert all the volumes to dm^3:

volume of HCl = 26.50 cm^3 ÷ 1000 = 0.02650 dm^3

volume of NaOH = 25.00 cm^3 ÷ 1000 = 0.02500 dm^3

- **Step 2:** Calculate the amount of NaOH:

moles = concentration x volume in dm^3

amount of NaOH = 0.20 mol/dm^3 x 0.025 = 0.0050 mol

- **Step 3:** Calculate the amount of HCl:

from the balanced equation the reacting ratio of HCl : NaOH is 1 : 1

therefore, the amount of HCl reacted = 0.0050 mol

- **Step 4:** Calculate the concentration of the HCl:

$$\text{concentration} = \frac{\text{moles}}{\text{volume in dm}^3}$$

$$= \frac{0.0050}{0.02650} = 0.19 \text{ mol / dm}^3$$

(1 mark)

Hard Questions

1 (a) This question is about citric acid ($C_6H_8O_7$).

Citric acid is a solid.

A student used a solution of sodium hydroxide to determine the concentration of a solution of citric acid by titration.

The student made a 250 cm^3 standard solution of sodium hydroxide of concentration 0.150 mol / dm^3

Calculate the mass of sodium hydroxide required.

Relative atomic masses (A_r): Na = 23, O = 16, H = 1

Answer

To calculate the mass of sodium hydroxide required.

- M_r of NaOH = 40; [1 mark]
- Moles of NaOH = $\frac{250}{1000} \times 0.150$ = 0.0375 moles; [1 mark]
- Mass of NaOH = 0.0375 × 40 = 1.5 (g); [1 mark]

  Allow correct use of an incorrectly calculated M_r
  Allow correct use of an incorrectly calculated number of moles

[Total: 3 marks]

- **Careful:** The concentration of the sodium hydroxide solution is given in mol / dm^3
- This means that you will have to convert the volume of the solution from cm^3 to dm^3

(3 marks)

(b) The student used this method to titrate citric acid with sodium hydroxide solution.

1. Pipette 25.0 cm^3 of citric acid solution into a conical flask.
2. Add a few drops of thymol blue indicator to the citric acid solution. Thymol blue is blue in alkali and yellow in acid.
3. Add sodium hydroxide solution from a burette until the end-point is reached.

Explain what would happen at the end-point of this titration.

Answer

At the end-point of this titration:

- The indicator changes colour; [1 mark]
- From yellow to blue; [1 mark]
  Accept from yellow to green
  Accept that the indicator starts yellow [1 mark] and finishes blue [1 mark]
- When the acid and alkali are (exactly) neutralised
  OR
  When there is no excess of either acid or alkali; [1 mark]

[Total: 3 marks]

- You are given the colours of the indicator in different conditions and expected to use this to state the colour change

(3 marks)

(c) Give **two** reasons why the sodium hydroxide solution is measured using a burette.

Answer

Two reasons why the sodium hydroxide solution is measured using a burette are:

Any **two** from:

- The sodium hydroxide can be added drop by drop / in small increments / slowly; [1 mark]
- A burette can measure variable/different volumes; [1 mark]
- A burette is more accurate than a measuring cylinder / dropping pipette; [1 mark]

[Total: 2 marks]

- It is common to get one mark in questions about the use of a burette in experiments
- The second mark proves more challenging in the majority of answers
    - The idea that a burette can measure variable volumes is often missed
    - The idea that a burette is more accurate is often stated but this will not get a mark without a comparison
        - A burette is more accurate than a measuring cylinder / dropping pipette but it is not more accurate than a (volumetric) pipette

(2 marks)

(d) The student's titration results are shown in **Table 1**.

Table 1

Titration	**1**	**2**	**3**	**4**	**5**
Volume of sodium hydroxide solution in cm^3	24.60	23.05	23.15	23.30	23.10

The equation for the reaction is:

$$C_6H_8O_7 + 3NaOH \rightarrow C_6H_5O_7Na_3 + 3H_2O$$

Concordant results are those within 0.10 cm^3 of each other.

Calculate the concentration of the citric acid solution in mol / dm^3

Use only the concordant results from the table in your calculation.

You must show your working.

Answer

To calculate the concentration of the citric acid in mol / dm^3:

- Calculate the average titre: $\frac{23.05 + 23.15 + 23.10}{3}$; [1 mark]
- Average titre = 23.10 cm^3; [1 mark]
- Moles of NaOH = $\frac{23.1}{1000} \times 0.150$ = 0.003465 moles; [1 mark]
- Moles of citric acid = $\frac{0.003465}{3}$ = 0.001155 moles; [1 mark]
- Concentration of citric acid = $\frac{0.001155}{25.0} \times 1000$ = moles / vol) = 0.0462 mol / dm^3; [1 mark]
  Errors can be carried forward (ecf) from any of the individual steps in the calculation An answer of 0.0462 mol / dm^3 without working scores 1 mark only

[Total: 5 marks]

- Titration calculations are the standard question for concentration in mol / dm^3
- They allow for a range of supplementary questions such as the use of indicators as shown in part (b) as well as describing the steps involved to complete a titration

(5 marks)

2 (a) A student attempted to make pure zinc chloride crystals using the following method.

- Add 5.00 g of zinc carbonate to 25.0 cm^3 hydrochloric acid of 1.25 mol / dm^3 concentration
- Filter the mixture
- Leave until crystals form

Explain why the student must add the zinc carbonate in excess.

Answer

The student must add the zinc carbonate in excess:

- To ensure that all of the acid has reacted; [1 mark]

[Total: 1 mark]

(1 mark)

(b) The student then completed three separate experiments to produce zinc chloride by reacting 15.0 g of zinc carbonate with hydrochloric acid.

$$ZnCO_3\,(s) + 2HCl\,(aq) \rightarrow ZnCl_2\,(aq) + CO_2\,(g) + H_2O\,(l)$$

The highest percentage yield of zinc chloride that the student achieved in a single experiment was 82.4%.

Calculate the mass of zinc chloride the student actually produced in this experiment.

Relative atomic masses (A_r): C = 12, Zn = 65, O = 16, Cl = 35.5, H = 1

Answer

To calculate the mass of zinc chloride the student actually produced:

- Moles of zinc carbonate = $\frac{15.0}{(65 + 12 + (3 \times 16))}$ = 0.12 moles; [1 mark]
- Theoretical mass of zinc chloride = 0.12 x (65 + (2 x 35.5)) = 16.32; [1 mark]
- Actual mass of zinc chloride = $\frac{82.4}{100} \times 16.32$ = 13.4 g; [1 mark]

[Total: 3 marks]

- You have to calculate the moles of zinc carbonate
- This is also the moles of zinc chloride since there is a 1 : 1 ratio
- Then you have to apply the 82.4%
- One of the first examiner comments for this type of question is how the percentage / final step is missed

(3 marks)

(c) The lowest yield of zinc chloride crystals that the student achieved was 10.86 g.

The student used these zinc chloride crystals to make a 250 cm^3 solution.

Calculate the concentration of this solution in g / dm^3.

Answer

To calculate the concentration of this solution in g / dm^3:

- $\frac{10.86}{250} \times 1000$ = 43.44 g / dm^3
  OR
  10.86 x 4 = 43.44 g / dm^3; [1mark]

[Total: 1 mark]

- You can approach the answer to this question in two ways:
  1. Calculate the mass in 1 cm^3 and then multiply by 1000 as shown in the first possible answer
  2. Recognise that 250 cm^3 is one quarter of 1 dm^3 and, therefore, multiply the mass by 4

(1 mark)

(d) The student's third experiment produced 12.24 g of zinc chloride.

The student used these zinc chloride crystals to make a 50.0 cm^3 solution.

Calculate the concentration of this solution in mol / dm^3.

Answer

To calculate the concentration of this solution in mol / dm^3:

- $\frac{12.24}{50} \times 1000$ = 244.8 g / dm^3
  OR
  12.24 x 20 = 244.8 g / dm^3; [1 mark]

- M_r of zinc chloride = 65 + (2 x 35.5) = 136
  AND
  $\frac{244.8}{136}$ = 1.8 mol / dm^3; [1 mark]

[Total: 2 marks]

- You can approach the answer to this question in two ways:
  1. Calculate the mass in 1 cm^3 and then multiply by 1000 as shown in the first possible answer
  2. Recognise that 50 cm^3 is one twentieth of 1 dm^3 and, therefore, multiply the mass by 20
- To convert g / dm^3 to mol / dm^3, you divide by the molar mass

(2 marks)

3 A student titrated 25.00 cm^3 of 0.40 mol/dm^3 potassium hydroxide solution against sulfuric acid and found that 23.55 cm^3 of the acid was required to reach the end point.

$$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$$

What is the concentration of the sulfuric acid?

A. 0.42 mol/dm^3

B. 0.105 mol/dm^3

C. 0.35 mol/dm^3

D. 0.21 mol/dm^3

Answer

The correct answer is D because:

- Step 1: Convert all the volumes to dm^3:

volume of KOH = 25.00 cm^3 ÷ 1000 = 0.02500 dm^3

volume of H_2SO_4 = 23.55 cm^3 ÷ 1000 = 0.02355 dm^3

- **Step 2:** Calculate the amount of KOH:

moles = concentration x volume in dm^3

amount of KOH = 0.40 mol/dm^3 x 0.025 = 0.010 mol

- **Step 3:** Calculate the amount of HCl:

from the balanced equation the reacting ratio of H_2SO_4 : KOH is 1 : 2

therefore, the amount of H_2SO_4 reacted = 0.010 ÷ 2 = 0.0050 mol

- **Step 4:** Calculate the concentration of the H_2SO_4:

$$\text{concentration} = \frac{\text{moles}}{\text{volume in dm}^3}$$

$$= \frac{0.0050}{0.02355} = 0.21 \text{ mol / dm}^3$$

(1 mark)

4 (a) This question is about the reactions of copper compounds.

A student was asked to make copper(II) oxide, CuO, from copper(II) sulfate, $CuSO_4$ using the following method.

- Measure out 25.0 cm^3 of 0.500 mol / dm^3 copper(II) sulfate solution
- Add an excess of sodium hydroxide solution
- Do not filter out the copper(II) hydroxide, $Cu(OH)_2$, precipitate that forms
- Carefully heat the reaction mixture to decompose the copper(II) hydroxide

Write **two** balanced symbol equations, including state symbols, for the two reactions that occur.

Answer

The **two** balanced symbol equations, including state symbols, for the two reactions are:

$CuSO_4$ (aq) + 2NaOH (aq) → $Cu(OH)_2$ (s) + Na_2SO_4 (aq)

- All chemical formulae correct; [1 mark]
- Correct balancing of the equation; [1 mark]

$Cu(OH)_2$ (s) → CuO (s) + H_2O (l)

- All chemical formulae correct; [1 mark]
- All state symbols included and correct in both equations; [1 mark]

[Total: 4 marks]

- You are given the formulae of copper(II) oxide, copper(II) hydroxide and copper(II) sulfate in the question
- For the first equation
  - You are expected to know the formula of sodium hydroxide
  - You are expected to be able to deduce that sodium sulfate will be produced
  - **Careful:** Sodium is a 1+ ion while sulfate is a 2- ion, which leads to Na_2SO_4

- This means that you will need 2NaOH to balance the two sodium in sodium sulfate and the two hydroxides in copper(II) hydroxide
- For the state symbols, you are:
  - Using copper(II) sulfate solution, which is (aq)
  - Using sodium hydroxide solution, which is (aq)
  - Forming a copper(II) hydroxide precipitate, which is (s)
  - Forming sodium sulfate, which is a soluble ionic compound and, therefore, (aq)

- For the second equation
  - You are given the formula of copper(II) hydroxide, told that you are decomposing it and told that the final product is copper(II) oxide
  - This means that the other product must be water
  - There is no balancing required for this equation
  - For the state symbols:
    - Copper(II) hydroxide is a precipitate (as previously discussed) and, therefore, (s)
    - You are expected to know that most metal oxides are insoluble and, therefore, copper(II) oxide is (s)
    - You are expected to know that water is (l)

(4 marks)

(b) Calculate the number of grams of copper(II) sulfate present in the student's solution.

Give your answer to three significant figures.

Relative atomic masses (A_r): Cu = 63.5, S = 32, O = 16

Answer

To calculate the number of grams of copper(II) sulfate present in the student's solution:

- Moles of copper(II) sulfate = $0.500 \times \frac{25.0}{1000}$ = 0.0125 moles; [1 mark]

- M_r of copper(II) sulfate = 63.5 + 32 + (4 x 16) = 159.5
  AND
  Mass of copper(II) sulfate = 0.0125 x 159.5 = 1.99375 g; [1 mark]

- Answer given to three significant figures = 1.99 g; [1 mark]

[Total: 3 marks]

- You are given the volume and concentration of the copper(II) sulfate solution

- This means that you have to use this information to calculate the number of moles of copper(II) sulfate

- Then you use your answer and the M_r of copper(II) sulfate to calculate the mass

(3 marks)

(c) What mass of copper(II) oxide will the student produce?

Give your answer to three significant figures.

Answer

The mass of copper(II) oxide that the student will produce is:

- Overall ratio of $CuSO_4$: CuO is 1 : 1; [1 mark]
- Moles of copper(II) oxide = 0.0125 moles
  AND
  Mass of copper(II) oxide = 0.0125 x (63.5 + 16) = 0.99375 g; [1 mark]
  Allow error carried forward using an incorrect number of moles from part (b)
- Answer to three significant figures = 0.994 g; [1 mark]
  Allow error carried forward using an incorrect number of moles from part (b)

[Total: 3 marks]

- This question puts a lot of students off because you are being asked the mass of product formed as the result of two chemical reactions
- The correct equations in part (a) show that one mole of copper(II) sulfate forms one mole of copper(II) hydroxide, which in turn forms one mole of copper(II) oxide
- So, overall one mole of copper(II) sulfate will form one mole of copper(II) oxide
- This means that you can apply the number of moles of copper(II) sulfate from part (b) to copper(II) oxide
- Then, you multiply by the molar mass of copper(II) oxide to get your answer

(3 marks)

(d) Another student produces 1.27 g of pure, dry copper(II) oxide.

The student's copper(II) oxide is placed into a 100 cm^3 conical flask. After adding 50.0 cm^3 of distilled water, the conical flask is stirred.

The student completed a calculation and concluded that they had made a 25.4 g / dm^3 solution.

Explain how the student achieved this concentration and why it is incorrect.

Answer

The student achieved this concentration by:

- $\frac{1.27}{50.0} \times 1000$ = 25.4 g / dm^3; [1 mark]

The student is incorrect because:

- The copper(II) oxide is / forms a precipitate
  OR
  The copper(II) oxide is not / does not form a solution
  OR
  Concentrations apply to solutions
  OR
  Concentrations do not apply to solids; [1 mark]

[Total: 2 marks]

- **Careful:** The question does not ask you to show that the student's calculation is incorrect
  - This is a very technical point but many people will complete the calculation and arrive at the correct concentration of 25.4 g / dm^3
  - From this point, many people will assume that they have made a mistake because they proved the conclusion correct
- Actually, the student is incorrect because they are using an insoluble solid which cannot dissolve in water to give a solution
  - Concentrations by definition are:
    - $\frac{\text{mass of solute}}{\text{volume of solution}}$ for g / dm^3 concentrations
    - $\frac{\text{moles of solute}}{\text{volume of solution}}$ for mol / dm^3 concentrations
  - There is no solute or solution for the calculation since the copper(II) oxide does not dissolve

(2 marks)

5 (a) This question is about acids and alkalis.

A student titrated 25.0 cm^3 portions of sodium hydroxide solution with a 0.121 mol / dm^3 dilute sulfuric acid.

Table 1 shows the student's results.

Table 1

	Titration 1	**Titration 2**	**Titration 3**	**Titration 4**	**Titration 5**
Volume of dilute sulfuric acid in cm^3	11.75	11.10	11.05	10.55	11.10

The equation for the reaction is:

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$$

Calculate the concentration of the sodium hydroxide in mol / dm^3

Use only the student's concordant results.

Concordant results are those within 0.10 cm^3 of each other.

Answer

a) To calculate the concentration of the sodium hydroxide in mol / dm^3:

- Choose titrations 2, 3 and 5
  OR
  $\frac{11.10 + 11.05 + 11.10}{3}$; [1 mark]

- Average titre = 11.08 cm^3; [1 mark]
  Allow 11.083(3...) cm^3 for this mark
  Allow a correctly calculated average from an incorrect choice of titrations

- Moles of sulfuric acid = $0.121 \times \frac{11.08}{1000}$ = 0.00134 moles; [1 mark]

  Allow use of incorrect average titre from previous step

- Moles of sodium hydroxide = 0.00134 x 2 = 0.00268 moles; [1 mark]

  Allow use of incorrect number of moles from previous step

- Concentration of sodium hydroxide = $\frac{0.00268}{25.0} \times 1000$ = 0.107 mol / dm^3; [1 mark]

  Allow use of incorrect number of moles from previous step

[Total: 5 marks]

- This is a relatively standard titration question for higher tier papers with a stoichiometric ratio to consider

  1. Identify the concordant results
  2. Calculate the average titre
  3. Calculate the moles of the chemical that you now have the concentration and volume of
  4. Determine the moles of the chemical with an unknown concentration – use the stoichiometric ratio from the balanced symbol equation if necessary
  5. Calculate the unknown concentration

(5 marks)

(b) A second student plans to perform the same titration described in part (a).

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

The second student will replace the sodium hydroxide solution of unknown concentration with a potassium hydroxide solution that has the exact same unknown concentration.

The equation for the new reaction is:

$$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$$

Before the student starts, they state that the concentration of the potassium hydroxide solution will be the same as the concentration of the sodium hydroxide solution.

State the assumption that the student makes in their statement and explain whether the student is correct.

Answer

The assumption that the student has made is:

- The titres / average titre will be the same
  OR
  The volume(s) / average volume of sulfuric acid used will be the same; [1 mark]

Is the student's statement correct?

- The student's statement is correct because the concentration in mol / dm^3 will be the same
  OR
  The student's statement is correct because the ratio of potassium hydroxide : sulfuric acid is the same; [1 mark]

- The student's statement is incorrect because the concentration in g / dm^3 will not be the same
  OR
  The student's statement is incorrect because the concentration in g / dm^3 depends on the molar mass of the potassium / sodium hydroxide; [1 mark]
  Accept the student is both correct and incorrect or the student is partly correct as long as both reasons are given in the answer.

[Total: 3 marks]

- Your exam technique should suggest that one (of the three) marks is for the assumption
    - This leaves two marks for the explanation
- Your knowledge from practicing exam questions should suggest that it is highly unlikely for a higher tier question to award a mark for saying if the student is correct, partly correct it incorrect
    - This means that there are two marks for the explanation and that you should be making two points
    - Concentration has two different units – mol / dm^3 and g / dm^3
    - It is likely that these are your two marking points
- Since the reaction of sulfuric acid with sodium hydroxide will have the same ratio (stoichiometry) as the reaction of sulfuric acid with potassium hydroxide, the concentration in mol / dm^3 will be the same
    - Assuming that the titration(s) produce the same titre volume(s) / average titre
- The concentration in mol / dm^3 cannot be the same as the concentration in g / dm^3
    - This is because the concentration in g / dm^3 depends on the molar mass of the substance in question
    - NaOH has a molar mass of 40 g / mol while KOH has a molar mass of 56 g / mol

(3 marks)

(c) A third student plans to perform the same titration described in part (a).

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$$

They intend to replace the sulfuric acid with hydrochloric acid of the same 0.121 mol / dm^3 concentration.

The equation for the new reaction is:

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

The final concentration of the sodium hydroxide should be the same as part (a).

Explain the difference that the student can expect to see in their experimental results.

Answer

The difference that the student can expect to see in their experimental results is:

- The titration volume(s) / titre(s) / average titre will be larger / double; [1 mark]

Explanation:

- The ratio of sodium hydroxide : acid has changed from 2 : 1 to 1 : 1
  OR
  There is now a 1 : 1 ratio so twice as much acid will be needed; [1 mark]

[Total: 2 marks]

- The sodium hydroxide solution has not changed
  - This means that the final concentration of the sodium hydroxide solution must be the same as part (a)
- Changing the acid changes the ratio of sodium hydroxide : acid as shown in the two balanced symbol equations
  - In part (a), one mole of sulfuric acid reacted with **two moles of sodium hydroxide**
  - Now, one mole of hydrochloric acid reacts with **one mole of sodium hydroxide**
  - This means that you will need twice as much hydrochloric acid to complete the titration, therefore, the titration volumes / average titre should be twice as

much

(2 marks)

6 Sodium hydroxide solution is neutralised by citric acid.

The equation for the reaction is:

$$C_6H_8O_7 + 3NaOH \rightarrow C_6H_5O_7Na_3 + 3H_2O$$

Calculate the mass of the citric acid needed to neutralise 12.0 cm^3 of 1.02 mol/dm^3 sodium hydroxide solution.

Relative formula mass (M_r): $C_6H_8O_7$ = 192

A. 0.783 g

B. 0. 852 g

C. 1.22 g

D. 2.35g

Answer

The correct answer is A because:

- **Step1:** Convert the volume to dm^3:

volume of NaOH= 12 cm^3 ÷ 1000 = 0.012 dm^3

- **Step 2:** Calculate the amount of sodium hydroxide:

moles = concentration x volume in dm^3

amount of NaOH = 1.02 mol/dm^3 x 0.012 dm^3 = 0.0122 mol

- **Step 3:** Deduce the amount of citric acid needed using the balanced equation:

from the equation the reacting ratio of $C_6H_8O_7$: NaOH is 1 : 3

therefore the amount of $C_6H_8O_7$ = 0.0122 mol ÷ 3 = 0.00408 mol

- **Step 4:** Calculate the mass of citric acid

mass = moles x molar mass

= 0.00408 x 192 = 0.783 g

(1 mark)

7 (a) Sodium hydroxide neutralises sulfuric acid.

The equation for the reaction is:

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

Write the ionic equation, including state symbols, for this reaction.

Answer

The ionic equation, including state symbols, for the reaction of sodium hydroxide and sulfuric acid is:

$H^+ (aq) + OH^- (aq) \rightarrow H_2O (l)$

- Correct reactants and product; [1 mark]
- All state symbols correct; [1 mark]

[Total: 2 marks]

- The question tells you that this is neutralisation
- Therefore, you are writing the ionic equation for neutralisation

(2 marks)

(b) Explain why the reaction of sodium hydroxide with sulfuric acid is not a redox reaction.

Answer

The reaction of sodium hydroxide with sulfuric acid is not a redox reaction because:

- There is no gain or loss of oxygen; [1 mark]
- There is no gain or loss of electrons by any atom / ion; [1 mark]

[Total: 2 marks]

- As soon as redox is mentioned, you should think about the different criteria for redox
- Your two main criteria for redox (at this level) are:
    1. Gain/loss of oxygen
    2. Gain/loss of electrons – OILRIG

(2 marks)

(c) Sodium hydroxide solution is considered corrosive at concentrations above 0.5 mol / dm^3 and a low hazard at concentrations below 0.125 mol / dm^3.

Concentrations between these values should be labelled as a health hazard as they can be irritating to the skin and eyes. These concentrations are acceptable for use in the school laboratory, although the lowest possible concentration of sodium hydroxide solution should always be used.

Calculate the maximum and minimum mass of sodium hydroxide required to make a 500 cm^3 sodium hydroxide solution that can be used in the school laboratory.

Relative atomic masses (A_r): Na = 23, O = 16, H = 1

Answer

To calculate the maximum and minimum mass of sodium hydroxide required to make a 500 cm^3 sodium hydroxide solution that can be used in the school laboratory:

Moles calculation:

- Maximum moles = 0.5 x $\frac{500}{1000}$ = 0.25 moles

  AND

  Minimum moles = 0.125 x $\frac{500}{1000}$ = 0.0625 moles; [1 mark]

Mass calculation:

- Maximum mass = 0.25 x 40 = 10 g
  AND
  Minimum mass = 0.0625 x 40 = 2.5 g; [1 mark]

[Total: 2 marks]

- This question is basically asking for you to calculate the mass of sodium hydroxide required to make 0.5 mol / dm^3 and 0.125 mol / dm^3 solutions
- **Careful:** You are making 500 cm^3 **not** 1 dm^3 solutions

(2 marks)

(d) A student was given a bottle of sodium hydroxide solution of unknown concentration.

The student used a pipette to transfer 25.0 cm^3 of this sodium hydroxide solution into a conical flask for titration with 0.150 mol / dm^3 sulfuric acid.

The results of the student's titrations are shown in **Table 1**.

Table 1

	Rough	**Titration 1**	**Titration 2**	**Titration 3**	**Titration 4**
Volume of 0.150 mol / dm^3 sulfuric acid in cm^3	25.25	24.75	25.20	25.00	25.15

Concordant results are within 0.10 cm^3 of each other.

Use the student's concordant results to determine if the bottle of sodium hydroxide solution of unknown concentration should be labelled as:

- Corrosive
- Health hazard
- Low hazard

Show your working.

Answer

To determine how the bottle of sodium hydroxide solution of unknown concentration should be labelled:

- Calculate the average titre = $\frac{25.20 + 25.15}{2}$; [1 mark]
- Average titre = 25.175 cm^3; [1 mark]
- Moles of H_2SO_4 = $\frac{25.175}{1000} \times 0.150$ = 0.00377625 moles; [1 mark]
- Moles of NaOH = 0.00377625 x 2 = 0.0075525 moles; [1 mark]
- Concentration of NaOH = $\frac{0.0075525}{25.0} \times 1000$ = 0.3021 mol / dm^3; [1 mark]
  Allow errors to be carried forward from each step
- Therefore, the bottle should be labelled as a health hazard; [1 mark]
  This mark cannot be achieved without workings

[Total: 6 marks]

- Do not be put off by the unorthodox presentation of this question, you know that you will be:
  - Calculating an average titre – **Careful:** The rough titre does not feature in the average titre calculation
  - Calculating the moles of one reactant (in this case, sulfuric acid)
  - Calculating the moles of the other reactant (NaOH) using the stoichiometric ratio if necessary – 2NaOH : $1H_2SO_4$
  - Calculating the concentration of the other reactant (NaOH)

- You then have to use the information in part (c) to decide whether the solution should be labelled as:
    - Corrosive = above 0.5 mol / dm^3
    - Health hazard = above 0.125 mol / dm^3 and below 0.5 mol / dm^3
    - Low hazard = below 0.125 mol / dm^3

(6 marks)