EXAM INSIGHTS

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A-LEVEL Chemistry

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Suitable for: AQA, Pearson Edexcel, OCR, WJEC, CCEA

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Contents

1 Amount of substance

Overview

Knowledge recap

- The chosen standard for relative masses is carbon-12.
- **Relative atomic mass**, $A_r = \dfrac{\text{average mass of an element's atoms}}{\frac{1}{12} \times \text{mass of one atom of } {}^{12}C}$
- **Relative formula mass**, $M_r = \dfrac{\text{average mass of an 'entity'}}{\frac{1}{12} \times \text{mass of one atom of } {}^{12}C}$

  An **entity** is a unit of the substance as given by its formula. M_r is called **relative molecular mass** when discussing a simple molecular substance.
- Mass = moles × M_r (or A_r). Mass has units of grams and moles has units of mol. The number of particles in a mole is called the **Avogadro number** (or constant) = 6.022×10^{23} particles mol^{-1}.
- Moles = concentration × volume. Concentration has units of mol dm^{-3} and volume has units of dm^3.
- Ideal gas equation: $pV = nRT$, where p = pressure in pascals, V = volume in m^3, n = number of moles, R = gas constant (8.31 $JK^{-1} mol^{-1}$) and T = temperature in kelvin.
- The **empirical formula** of a substance is the *simplest whole number ratio of atoms of each element* present in a compound. The **molecular formula** is the *actual number of atoms of each element* present in one molecule of an element or compound.
- The **percentage atom economy** is a measure of the amount of atoms of the reactants which end up in the desired product.

Practice questions

1 Define the term 'relative atomic mass, A_r' (1)

Insight

Examiner reports show that students lose marks by not stating that the relative atomic mass is a *mean* or an *average*. Definitions are worth learning thoroughly as they tend to be the easiest marks to obtain in an exam.

2 Calculate the percentage atom economy for the manufacture of CH_2Cl_2, dichloromethane, in the following process.

$CH_4(g) + 2Cl_2(g) \rightarrow CH_2Cl_2(l) + 2HCl(g)$

State how a company making dichloromethane could maximise its profits. (3)

3 Calculate the mass, in mg, required to make 250.0 cm^3 of a solution of sodium carbonate, Na_2CO_3, with a concentration of 0.050 mol dm^{-3}. (3)

Insight

Examiner reports show that students often get the conversion from g to mg wrong, or they forget to convert their answer into mg.

Extended responses

Worked example

1 Magnesium reacts with hydrochloric acid according to the following equation:

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

Magnesium is reacted with excess hydrochloric acid ($50.00\,cm^3$, $1.00\,mol\,dm^{-3}$). The resulting solution is made up to $250.0\,cm^3$. $25.0\,cm^3$ portions of this solution are then titrated against a standard $1.00 \times 10^{-1}\,mol\,dm^{-3}$ sodium hydroxide solution. Outline how you would conduct an experiment to determine the relative atomic mass, A_r, of magnesium, Mg. (6)

Plan your answer to this question in the space below. Start by circling the command word, and then highlight or underline any useful information. When writing your plan, consider numbering your points in the order you would write them.

Here is a sample answer with expert commentary:

Moles of HCl originally = $1.00 \times (50.00 \div 1000) = 5.00 \times 10^{-2}$ mol Mass of Mg required = $2.50 \times 10^{-2} \times 24.3 = 0.6075$ g
Pipette 50.00 cm^3 of 1.00 mol dm^{-3} HCl into a beaker and add 0.3 g of magnesium. Make up to 250.0 cm^3 in a volumetric flask. Pipette out 25.00 cm^3 of this solution into a conical flask and titrate against the 1.00×10^{-1} mol dm^{-3} sodium hydroxide solution. This will allow you to calculate the moles of sodium hydroxide and hence the moles of unreacted acid.

A good start which shows the student has a clear understanding of the calculations required to work out the amount of each reactant needed.

This would pick up marks as they have made the link between the moles of HCl originally used at the start of the experiment and the unreacted HCl in the diluted solution.

Scale up from 25.00 cm^3 to calculate the moles of unreacted acid in 250.0 cm^3. Work out the moles of HCl which reacted by taking the moles of HCl originally and subtracting the moles of unreacted HCl. Use the moles of HCl which reacted to work out the moles of magnesium and the A_r using mass ÷ moles.

This shows good understanding of how the moles of HCl are used to determine the A_r of magnesium. It could be improved further by showing how the moles of HCl which reacted are used to calculate the moles of magnesium by referring to the reaction equation.

This answer would get 4/6 marks because it shows good knowledge and understanding of an experiment that can be used to determine the relative atomic mass of magnesium. All steps are in a logical order and the reasons behind most of the steps are clearly provided and communicated. A little more detail is required in the answer, such as how the solution will be made up to 250.0 cm^3 in a volumetric flask. The other missing part is to show that the number of moles of magnesium is half the number of moles of HCl.

Be the examiner

2 Outline a method to prepare 250.0 cm^3 of a standard solution of sodium hydrogen carbonate, $NaHCO_3$, with a concentration of 0.100 mol dm^{-3}. (6)

Read through the sample answer below and comment on what is good and bad about it.

Weigh *X* g of sodium hydrogen carbonate on a balance. Transfer the solid to a beaker and add distilled water. Using a funnel, pour the solution into a volumetric flask. Rinse the beaker a few times above the funnel. Add distilled water to the volumetric flask until you are close to the line. Using a plastic pipette, add distilled water dropwise until the bottom of the meniscus reaches the line. Invert the solution several times to ensure it is fully mixed.

Use the mark scheme below to help identify how the student did. Use your comments and what you have checked off to give the answer a mark.

Level descriptors	Marks	☑/☒

Indicative content
• A correct calculation that shows the mass of $NaHCO_3$ required is 2.1 g.
• A description of the process as follows:
  • Solid must be measured out using weighing by difference.
  • Solid is dissolved in distilled water and stirred with a glass rod.
  • Solution is transferred to a volumetric flask using a funnel.
  • Glass rod and beaker are rinsed with distilled water above the funnel in the volumetric flask.
• Finally, a statement that the solution is made up to 250.0 cm^3 using distilled water and thoroughly inverted.
		☐
		
		☐
		☐
		☐
		☐
		☐

Level 3: A detailed, accurate method which demonstrates a good knowledge and understanding of all aspects of making a standard solution. All steps are in the correct order and good scientific terminology is used. A correct calculation has been used to work out the mass of sodium hydrogen carbonate required.	5–6	☐
Level 2: A method which demonstrates a reasonable knowledge and understanding of some parts of making a standard solution. There may be some steps missing. A correct calculation has been used to work out the mass of sodium hydrogen carbonate required.	3–4	☐
Level 1: A method which demonstrates some knowledge of making a standard solution. The method is not logically ordered and has significant gaps.	1–2	☐

I would give this _____/6 because _____

_____

_____

Practice question

3 Describe how you would determine the exact concentration of an unknown solution of approximately 1 mol dm^{-3} hydrochloric acid. You are provided with a standard 0.100 mol dm^{-3} solution of sodium hydroxide, a bottle of phenolphthalein and normal laboratory apparatus. (6)

Read through the sample student answer below and make notes on how you would improve it.

Transfer 25.00 cm^3 of the approximately 1 mol dm^{-3} hydrochloric acid solution into a 250.0 cm^3 volumetric flask and make up to 250.0 cm^3 using distilled water. Pipette 25.00 cm^3 of this diluted hydrochloric acid solution into a conical flask and add a few drops of phenolphthalein indicator.
Titrate the solution in the conical flask against the standard 0.100 mol dm^{-3} solution of sodium hydroxide and repeat to obtain two concordant titres. The average titre can be calculated using the concordant results and this can be used to calculate the exact concentration of the hydrochloric acid solution.

Write an improved response to this question that would get full marks.

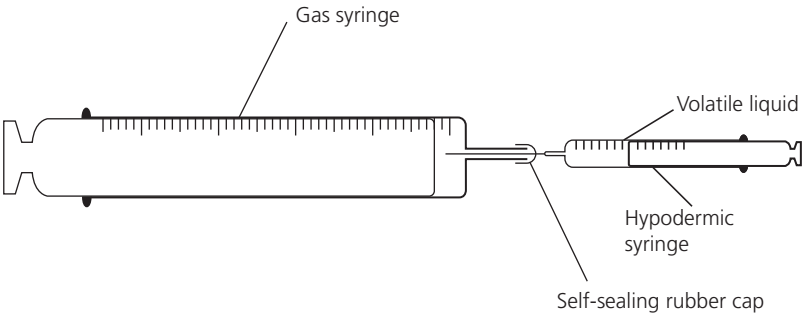
Practical chemistry

Practice questions

This question is about an experiment used to determine the M_r of a volatile liquid using the ideal gas equation. The application of the ideal gas equation is something that is frequently assessed in exam questions and that students have been shown to struggle with.

1 By finding the volume of the vapour formed from a known mass of a liquid, at a known temperature and pressure, the relative molecular mass, M_r, of the liquid can be calculated.

The simplest way to do this is to allow a known mass of liquid to vaporise in a heated graduated gas syringe by placing it in a hot water bath. The liquid is injected into the gas syringe using a hypodermic syringe. A diagram of the apparatus is shown below.



Mass of hypodermic syringe and liquid before injection	14.292 g
Mass of hypodermic syringe and liquid after injection	14.144 g
Volume of air in gas syringe before injection	5.0 cm^3
Volume of vapour and air in gas syringe after injection	81.0 cm^3
Temperature of apparatus	86 °C
Atmospheric pressure	100 kPa
Ideal gas constant	8.31 $JK^{-1}mol^{-1}$

The data recorded by a student carrying out this experiment is shown in the table.

1–1 Calculate the mass of liquid used in the experiment. (1)

1–2 Use the data provided to calculate the relative molecular mass, M_r, of the liquid. (6)

Insight

Examiner reports show that many students get the conversion for volume wrong. Make sure you can convert from cm^3 to dm^3 to m^3 and vice versa.

1–3 The relative molecular mass that you calculated in the experiment was different to the expected value. Give one reason why and explain your answer. (3)

1–4 The student repeated the experiment using the same gas syringe, the same volume of volatile liquid, and the same temperature. Give one reason why the volume of gas recorded by the student was higher than expected. (1)

UpGrade

Some explanations can be challenging to write. It may be useful to add equations to your answer to help you get your point across.

Questions about titrations are very common in exam papers – these questions will test your ability to apply practical knowledge to calculations on titrations.

2 Succinic acid is a white crystalline solid which is very soluble in water. Succinic acid is diprotic, and its molecular formula is $HOOC(CH_2)_nCOOH$, where n is a whole number between 1 and 4.

Like sulfuric acid, a solution of succinic acid can be completely neutralised by sodium hydroxide solution. If succinic acid is represented as H_2A, the equation for full neutralisation is:

$H_2A(aq) + 2NaOH(aq) \rightarrow Na_2A(aq) + 2H_2O(l)$

A student made 250.0 cm^3 of a standard solution using 1.400 g of succinic acid. They transferred 25.00 cm^3 of the solution to a conical flask and titrated it against 0.100 mol dm^{-3} sodium hydroxide solution. Their results are shown below.

Titration	Rough	1	2	3
Final volume / cm^3	23.8	24.10	47.90	25.20
Initial volume / cm^3	0.0	0.00	24.10	1.00
Titre / cm^3				

2–1 Use the data provided to calculate the mean titre. (2)

2–2 Calculate the moles of sodium hydroxide used in the student's titration. (1)

Insight

Examiner reports show that students do not always calculate the mean titre using concordant results, but this is a key requirement for a titration.

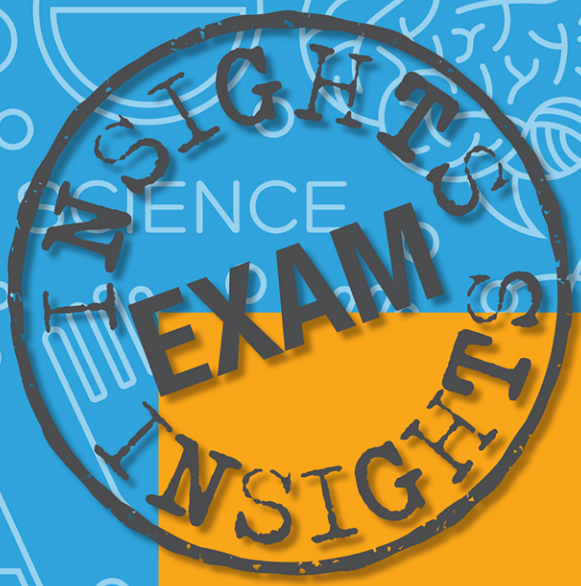
2–3 Calculate the amount, in moles, of succinic acid in the 1.400 g sample that was weighed out. (2)

2–4 Calculate the relative M_r of succinic acid and state the value of n to the nearest whole number. (3)

UpGrade

Once you have calculated the moles of one substance, you can determine the moles of other substances using the reaction equation. This may be provided in the question (as in this example) or you may have to work it out.

2–5 The student thought that the largest source of uncertainty in the experiment came from the burette. Suggest and explain how the method could be improved to reduce this uncertainty. (2)



A-LEVEL *Chemistry*

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