# 2.21 Concentration, Yield and Atom Economy: Test Pack

AQA 8464 · Calculator allowed · about 45 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

**Answer ALL questions. Show all your working.**

**1** Define the term 'concentration' when referring to a solution.

**(a)** Give a short definition of concentration. **(1)**

**(Total for Question 1 is 1 mark)**

**2** A required practical investigates the volume of dilute hydrochloric acid needed to exactly neutralise a fixed volume of sodium hydroxide solution, using a suitable indicator.

**(a)** Name one piece of apparatus used to measure accurately a fixed volume of 25.0 $cm^3$ of sodium hydroxide solution. **(1)**

**(b)** Name the piece of apparatus, marked in cm3, that is used to add the acid gradually and to measure the volume of acid added. **(1)**

**(c)** Give one safety precaution that should be taken when carrying out this titration. **(1)**

**(Total for Question 2 is 3 marks)**


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**3** Required practical style: To prepare 250.0 $cm^3$ of 0.100 mol/dm3 sodium carbonate solution, what mass of sodium carbonate ($Na_2CO_3$, Mr 106.0) should be weighed out? Also state one control the student must keep the same during the preparation and why it should be controlled.

**(a)** Calculate the mass of $Na_2CO_3$ required (give answer to three significant figures). **(2)**

.....

**(b)** Give one control variable to keep constant during preparation and explain why. **(1)**

**(Total for Question 3 is 3 marks)**


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**4** A student obtains these titres in a titration (cm3): 12.30, 12.45 and 12.35.
Identify any anomalous result, suggest a plausible cause for the anomaly and give one improvement to reduce this type of error in future titrations.

**(a)** Identify the anomalous result and suggest a plausible cause. **(2)**

**(b)** Give one improvement to reduce this error in future titrations. **(2)**

**(Total for Question 4 is 4 marks)**

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**5** A student, Aaliyah, carries out a titration and records the following burette readings:
Rough titration: 23.20 $cm^3$
Titration 1: 22.60 $cm^3$
Titration 2: 22.55 $cm^3$
Titration 3: 22.65 $cm^3$

**(a)** State why a rough (preliminary) titration is carried out before the accurate titrations. **(1)**

**(b)** Identify, using the data given, which titre(s) should be used to calculate the mean titre. Give a reason for your answer. **(2)**

**(c)** Calculate the mean titre, giving your answer to 2 decimal places. **(2)**

**(d)** Give one reason why a pipette, rather than a measuring cylinder, is used to measure the 25.0 $cm^3$ of alkali. **(1)**

**(Total for Question 5 is 6 marks)**


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**6** Magnesium reacts with excess dilute hydrochloric acid:

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

Mr: Mg = 24, $MgCl_2$ = 95

A student, Rhys, reacts 3.6 g of magnesium with excess acid and collects 13.8 g of magnesium chloride.

**(a)** Calculate the number of moles of magnesium used. **(1)**

.....

**(b)** Use the equation to calculate the maximum (theoretical) mass of magnesium chloride that could be made. **(3)**

.....

**(c)** Calculate the percentage yield of magnesium chloride obtained by the student. **(2)**

.....

**(Total for Question 6 is 6 marks)**


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**7** A student weighs 0.5000 g (with a balance uncertainty of ±0.0005 g) of a solute (Mr 150.0) and dissolves it to make 100.0 $cm^3$ of solution. Calculate the nominal concentration in mol/dm3 and the maximum and minimum concentrations allowed by the weighing uncertainty. Give answers to five significant figures where applicable.

**(a)** Calculate the nominal concentration and the range due to weighing uncertainty. **(5)**

**(Total for Question 7 is 5 marks)**

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**8** A pharmaceutical company can manufacture ibuprofen using either Route 1 (six reaction steps, atom economy 40%) or Route 2 (three reaction steps, atom economy 77%). Both routes give a percentage yield of about 65%.

Evaluate the advantages of using Route 2 rather than Route 1 to manufacture ibuprofen.

**(Total for Question 8 is 6 marks)**


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# Mark scheme · 2.21 Concentration, Yield and Atom Economy: Test Pack

## Question 1

(a) amount of solute dissolved per unit volume of solution, expressed as mol/dm3 or g/dm3, oe **B1**

**(a) Answer: Amount of solute dissolved per unit volume of solution (for example mol/dm3 or g/dm3).**

## Question 2

(a) (volumetric/graduated) pipette (with pipette filler) oe **B1**

**(a) Answer: A (volumetric) pipette, used with a pipette filler.**

(b) burette **B1**

**(b) Answer: A burette.**

(c) wear eye protection / goggles oe (accept: wash any acid or alkali spilt on skin immediately with water; accept other sensible precaution) **B1**

**(c) Answer: Wear eye protection (safety goggles) throughout the practical.**

## Question 3

(a) calculate moles = 0.100 x 0.250 and mass = moles x Mr **M1**

(a) 2.65 g cao **A1**

**(a) Answer: 2.65 g**

(b) any one reasonable control and brief reason, for example: final volume must be 250.0 $cm^3$ so concentration is correct **B1**

**(b) Answer: Keep the final volume at 250.0 $cm^3$ so the concentration is correct.**

## Question 4

(a) identify 12.45 $cm^3$ as anomalous (12.30 and 12.35 are concordant, differing by only 0.05 $cm^3$, while 12.45 lies 0.10 $cm^3$ or more above both) **B1**

(a) plausible cause given, e.g. overshoot end point, parallax when reading burette, air bubble in burette, poor mixing **M1**

**(a) Answer: 12.45 $cm^3$ is anomalous; possible cause: overshot the end point or parallax error when reading the burette.**

(b) improvement such as: perform a preliminary titration, add indicator dropwise near end point, ensure burette vertical and read bottom of meniscus at eye level, repeat titrations and use concordant mean **B1**

(b) explanation of how this reduces error, eg adding dropwise reduces overshoot **B1**

**(b) Answer: Add indicator dropwise near the end point and read the burette at eye level; this reduces the chance of overshooting and minimises parallax error.**

## Question 5

(a) to give an approximate volume/idea of where the end point is, so acid can be added dropwise near the end point in the accurate titrations oe **B1**

**(a) Answer: It gives an approximate idea of the volume needed, so the acid can then be added slowly (dropwise) near the expected end point in the accurate titrations.**

(b) Titrations 1, 2 and 3 (not the rough titration) **B1**

(b) because they are concordant, i.e. all within 0.10 $cm^3$ of each other, so give a reliable/reproducible result, whereas the rough titre is not close to the others oe **B1**

**(b) Answer: Titrations 1, 2 and 3, because they are concordant (all within 0.10 $cm^3$ of each other); the rough titre is not close to these values so is excluded.**

(c) (22.60 + 22.55 + 22.65) / 3 oe (using only the concordant titres, ft from (b)) **M1**

(c) 22.60 (cm3) cao **A1**

**(c) Answer: 22.60 $cm^3$**

(d) a pipette measures a fixed volume much more accurately/precisely than a measuring cylinder oe **B1**

**(d) Answer: A pipette measures a fixed volume far more accurately/precisely than a measuring cylinder, reducing the uncertainty in the titration result.**

## Question 6

(a) 0.15 (mol) cao (= 3.6 / 24) **B1**

**(a) Answer: 0.15 mol**

(b) moles of $MgCl_2$ = moles of Mg (1:1 ratio) = 0.15 (mol) ft from (a) **M1**

(b) 0.15 x 95 oe **M1**

(b) 14.25 (g) cao (accept 14.3) **A1**

**(b) Answer: 14.25 g**

(c) (13.8 / 14.25) x 100 oe (ft from (b)) **M1**

(c) 96.8 (%) cao (accept 96.6 to 96.9) **A1**

**(c) Answer: 96.8%**

## Question 7

(a) calculate nominal moles and concentration: moles = 0.5000 / 150.0; conc = moles / 0.1000 **M1**

(a) calculate moles and conc for minimum mass 0.4995 g **M1**

(a) calculate moles and conc for maximum mass 0.5005 g **M1**

(a) state numeric range **M1**

(a) gives correct range to stated sig figs, eg 0.033300 to 0.033367 mol/dm3 **A1**

**(a) Answer: Nominal 0.033333 mol/dm3; minimum 0.033300 mol/dm3; maximum 0.033367 mol/dm3**


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## Question 8

| | |
|---|---|
| **Level 3** A detailed and coherent evaluation is given, linking atom economy to waste, sustainability of raw materials, and cost of both materials and waste disposal, with clear reference to the data for both routes, and a reasoned overall judgement is made. | **5-6** |
| **Level 2** Relevant points linking atom economy to waste, sustainability or cost are made, with some reference to the data given, but the evaluation is not fully developed or lacks a clear overall judgement. | **3-4** |
| **Level 1** Basic, mostly isolated statements about atom economy or sustainability are made, with little or no reference to the specific data given. | **1-2** |
| **Level 0** No relevant content. | **0** |

**Indicative content:**

- Route 2 has a much higher atom economy (77%) than Route 1 (40%)
- a higher atom economy means a greater proportion of the mass of the reactants ends up as the useful product (ibuprofen)
- Route 1 therefore produces much more waste by-product mass for the same amount of reactants used
- more waste means more raw materials are used up/wasted, which is less sustainable as many raw materials are finite/limited
- more waste also increases raw material costs and the cost of safely disposing of the waste
- Route 2 also uses fewer reaction steps, which is likely to reduce energy costs and production time, adding to its advantage
- since both routes have a similar percentage yield (about 65%), the difference in atom economy is the main factor affecting efficiency and cost
- overall, Route 2 is more sustainable and more economical, so is the better choice for large-scale manufacture


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