2.21 Concentration, Yield and Atom Economy: 30-minute Pack

Total Marks

AQA 8464 · Calculator allowed · about 30 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A student, Callum, prepares copper sulfate crystals, $CuSO_4.5H_2O$. The theoretical (maximum possible) yield is 12.5 g. Callum actually obtains 9.6 g of crystals.

(a) State the formula used to calculate percentage yield. **(1)**

(b) Calculate the percentage yield of copper sulfate crystals. **(2)**

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(Total for Question 1 is 3 marks)

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2 Match each key term to its correct definition by writing the correct definition letter (A-E) next to each term (i-v).

Terms: (i) concentration (ii) atom economy (iii) percentage yield (iv) molar volume (v) concordant titres

Definitions:

A. titres that agree closely with each other (within 0.10 cm^3 of one another)

B. the volume occupied by one mole of any gas at a stated temperature and pressure

C. the mass of solute dissolved per unit volume of solution

D. the percentage of the total mass of all reactants that is converted into a desired/useful product

E. the actual yield of a reaction expressed as a percentage of the maximum theoretical yield

(Total for Question 2 is 5 marks)

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3 Describe how a student could carry out a titration to find the volume of dilute hydrochloric acid needed to exactly neutralise 25.0 cm^3 of sodium hydroxide solution, using a suitable indicator.

(Total for Question 3 is 6 marks)

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4 A stock solution of copper sulfate has a concentration of 40 g/dm3. A technician, Kwame, dilutes 50 cm^3 of this stock solution with distilled water to a total volume of 200 cm^3.

(a) Calculate the concentration of the diluted solution, in g/dm3. **(2)**

(b) State what would happen to the concentration of the diluted solution if Kwame had instead diluted the same 50 cm^3 of stock solution to a total volume of 400 cm^3. Justify your answer without further calculation. **(2)**

(Total for Question 4 is 4 marks)

5 Calcium carbonate decomposes on heating to form calcium oxide and carbon dioxide:
$CaCO_3$ -> $CaO + CO_2$
Mr: $CaCO_3$ = 100, CaO = 56, CO_2 = 44
The desired product of this reaction is calcium oxide.

(a) Calculate the atom economy for the production of calcium oxide. Give your answer to 1 decimal place. **(3)**

(b) A different method of making calcium oxide has an atom economy of 82%. Explain why a chemical company would prefer to use the method with the higher atom economy. **(3)**

(Total for Question 5 is 6 marks)

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Mark scheme · 2.21 Concentration, Yield and Atom Economy: 30-minute Pack

Question 1

(a) percentage yield = (actual yield / theoretical yield) x 100 oe **B1**

(a) Answer: percentage yield = (actual yield / theoretical yield) x 100

(b) (9.6 / 12.5) x 100 oe **M1**

(b) 76.8 (%) cao (accept 76.7 to 76.8) **A1**

(b) Answer: 76.8%

Question 2

(i) concentration = C **B1**

(ii) atom economy = D **B1**

(iii) percentage yield = E **B1**

(iv) molar volume = B **B1**

(v) concordant titres = A **B1**

Answer: i-C, ii-D, iii-E, iv-B, v-A

Question 3

use a pipette (and pipette filler) to measure 25.0 cm^3 of the sodium hydroxide solution into a clean conical flask **B1**

add a few drops of a suitable indicator (e.g. phenolphthalein) to the flask **B1**

rinse and fill a burette with dilute hydrochloric acid and record the initial (starting) reading **B1**

add the acid to the flask from the burette while swirling the flask, adding it dropwise near the expected end point **B1**

stop adding acid at the point the indicator just permanently changes colour (the end point) and record the final burette reading **B1**

repeat the titration until concordant results (titres agreeing within 0.10 cm^3) are obtained, and calculate the mean of the concordant titres oe **B1**

Answer: Pipette 25.0 cm^3 of NaOH into a conical flask with indicator; fill a burette with HCl and record the initial reading; add acid while swirling, dropwise near the end point, until the indicator just changes colour permanently; record the final reading; repeat until concordant titres are obtained and average them.

Question 4

(a) 40 x 50 = C2 x 200 oe (correct use of C1V1 = C2V2) **M1**

(a) 10 (g/dm3) cao **A1**

(a) Answer: 10 g/dm3

(b) the concentration would be lower/halved (compared to part (a)) oe **B1**

(b) because the same mass of solute is now dissolved in twice the volume of solution oe **B1**

(b) Answer: The concentration would be lower (halved, to 5 g/dm3), because the same mass of copper sulfate is now dissolved in double the volume of solution.

Question 5

(a) sum of Mr of reactants = 100 ($CaCO_3$ is the only reactant) **M1**

(a) (56 / 100) x 100 oe **M1**

(a) 56.0 (%) cao **A1**

(a) Answer: 56.0%

(b) a higher atom economy means a greater proportion of the reactant mass is converted into the useful product, so less mass is wasted as by-products oe **B1**

(b) less waste means fewer raw materials need to be extracted/purchased, and less waste needs to be safely disposed of oe **B1**

(b) this reduces the overall cost of the process and makes it more sustainable, as finite raw materials are used more efficiently oe **B1**

(b) Answer: A higher atom economy wastes less of the reactant mass as by-products, so fewer raw materials are needed and less waste has to be disposed of; this reduces costs and makes the process more sustainable.

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