2.21 Concentration, Yield and Atom Economy: 1-hour Pack

AQA 8464 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A solution has a concentration of 250 ppm of a dissolved substance. What mass of that substance (in grams) is present in 2.00 dm3 of the solution? Note: 1 ppm = 1 mg/dm3.

(a) Calculate the mass in grams present in 2.00 dm3. **(3)**

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(Total for Question 1 is 3 marks)

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2 A student dissolves 0.50 mol of sodium chloride (NaCl, Mr 58.5) in enough water to make 250 cm^3 of solution. Calculate the concentration in g/dm3 of NaCl in the solution.

(Total for Question 2 is 2 marks)

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3 Calculate the mass of sodium sulfate, Na_2SO_4 (Mr 142.0), required to prepare 500.0 cm^3 of a 0.100 mol/dm3 solution.

(a) Calculate the mass in grams. **(2)**

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(Total for Question 3 is 2 marks)

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4 A student repeats a titration and records three titre values (cm3): 25.12, 25.30 and 25.05. Which two results are concordant under the common rule that concordant results differ by no more than 0.10 cm^3? Use those concordant results to calculate the mean titre, to two decimal places.

(a) Identify the concordant pair and calculate their mean titre (to two decimal places). **(3)**

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(Total for Question 4 is 3 marks)

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5 A reaction has a theoretical product mass of 12.0 g but the chemist isolates only 9.00 g. Calculate the percentage yield.

(Total for Question 5 is 2 marks)

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6 Ethene, C_2H_4, reacts with steam in the only reaction taking place, forming ethanol, C_2H_5OH, as the sole product:

$C_2H_4 + H_2O \rightarrow C_2H_5OH$

Mr: $C_2H_4 = 28$, $H_2O = 18$, $C_2H_5OH = 46$

(a) State the formula used to calculate atom economy. **(1)**

(b) Calculate the atom economy for the production of ethanol in this reaction. Give your answer to 1 decimal place. **(3)**

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(Total for Question 6 is 4 marks)

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7 A pharmacy technician, Fatima, needs to prepare a salt solution of concentration 20 g/dm3.

(a) Calculate the mass, in g, of salt needed to make 1.5 dm3 of this solution. **(2)**

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(b) Fatima only has 12 g of salt available. Calculate the maximum volume, in dm3, of this solution that can be made at the same concentration. **(2)**

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(Total for Question 7 is 4 marks)

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8 A reaction has a theoretical yield of 25.0 g of product. The percentage yield obtained is 88%.

(a) Rearrange the percentage yield formula to make actual yield the subject. **(1)**

(b) Calculate the actual mass of product obtained. **(2)**

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(Total for Question 8 is 3 marks)

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9 A water sample contains sodium ions at a concentration of 50.0 mg/dm3. Convert this concentration to mol/dm3 for Na^+ (Mr 23.0).

(a) Give the concentration in mol/dm3. **(2)**

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(Total for Question 9 is 2 marks)

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10 12.0 g of hydrogen chloride, HCl (Mr 36.5), is dissolved to make 250 cm^3 of solution.
Calculate the concentration of HCl in mol/dm3. Give your answer to three significant figures.

(a) Calculate the concentration in mol/dm3. **(3)**

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(Total for Question 10 is 3 marks)

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11 In a titration a student uses 25.09 cm^3 of 0.100 mol/dm3 hydrochloric acid, HCl, to neutralise 20.0 cm^3 of sodium hydroxide solution, NaOH.
Equation: $HCl + NaOH \rightarrow NaCl + H_2O$
Calculate the concentration of the NaOH solution in mol/dm3. Give your answer to three significant figures and include units.

(a) Calculate the concentration of NaOH. **(4)**

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(Total for Question 11 is 4 marks)

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12 In the industrial production of vinegar, ethanol is oxidised by oxygen to form ethanoic acid as the only desired product:
$C_2H_5OH + O_2 \rightarrow CH_3COOH + H_2O$
Mr: $C_2H_5OH = 46$, $O_2 = 32$, $CH_3COOH = 60$, $H_2O = 18$ Calculate the atom economy for making ethanoic acid. Give your answer to 1 decimal place.

(Total for Question 12 is 3 marks)

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13 Consider the cracking reaction: $C_3H_8 \rightarrow C_3H_6 + H_2$.
Calculate the atom economy for producing propene (C_3H_6) from propane (C_3H_8). Give your answer to three significant figures.

(a) Calculate the atom economy as a percentage. **(2)**

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(Total for Question 13 is 2 marks)

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14 Ammonia production and yield: 4.00 g of nitrogen gas reacts with 10.0 g of hydrogen gas to form ammonia according to the equation $N_2 + 3H_2 \rightarrow 2NH_3$. If the actual mass of ammonia obtained is 4.20 g, calculate the percentage yield. Give your answer to three significant figures.

(a) Calculate the percentage yield. **(3)**

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(Total for Question 14 is 3 marks)

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15 Evaluate two practical strategies to increase percentage yield in an organic synthesis. Discuss how each method increases yield and any limitations or trade-offs.

(Total for Question 15 is 6 marks)

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Mark scheme · 2.21 Concentration, Yield and Atom Economy: 1-hour Pack

Question 1

(a) convert ppm to mg/dm3 and multiply by volume: 250 mg/dm3 x 2.00 dm3 **M1**

(a) convert mg to g **M1**

(a) 0.500 g cao **A1**

(a) Answer: 0.500 g

Question 2

calculate mass of NaCl: mass = moles x Mr = 0.50 x 58.5 **M1**

117 g/dm3 cao **A1**

Answer: 117 g/dm3

Question 3

(a) calculate moles required: moles = concentration x volume = 0.100 x 0.500 **M1**

(a) 7.10 g cao **A1**

(a) Answer: 7.10 g

Question 4

(a) identify 25.12 and 25.05 as concordant (difference 0.07 cm^3) **B1**

(a) calculate mean of concordant pair **M1**

(a) 25.09 cm^3 cao **A1**

(a) Answer: 25.09 cm^3

Question 5

substitute into percentage yield = (actual / theoretical) x 100 **M1**

75% cao **A1**

Answer: 75%

Question 6

(a) atom economy = (Mr of desired product / sum of Mr of all reactants) x 100 oe **B1**

(a) Answer: atom economy = (Mr of desired product / sum of Mr of all reactants) x 100

(b) sum of Mr of reactants = 28 + 18 (= 46) **M1**

(b) (46 / 46) x 100 oe (ft from their sum) **M1**

(b) 100.0 (%) cao **A1**

(b) Answer: 100.0%

Question 7

(a) 20 x 1.5 oe **M1**

(a) 30 (g) cao **A1**

(a) Answer: 30 g

(b) 12 / 20 oe **M1**

(b) 0.6 (dm3) cao **A1**

(b) Answer: 0.6 dm3

Question 8

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

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

(b) (88 / 100) x 25.0 oe **M1**

(b) 22.0 (g) cao **A1**

(b) Answer: 22.0 g

Question 9

(a) convert mg to g: 50.0 mg/dm3 = 0.0500 g/dm3 and divide by Mr **M1**

(a) 2.17 x 10^{-3} mol/dm3 cao **A1**

(a) Answer: 2.17 x 10^{-3} mol/dm3

Question 10

(a) calculate moles: moles = 12.0 / 36.5 **M1**

(a) convert volume to dm3 and divide: concentration = moles / 0.250 **M1**

(a) 1.32 mol/dm3 cao **A1**

(a) Answer: 1.32 mol/dm3

Question 11

(a) calculate moles HCl: moles = 0.100 x (25.09 / 1000) **M1**

(a) use 1:1 mole ratio so moles NaOH = moles HCl **M1**

(a) calculate concentration = moles NaOH / 0.0200 **A1**

(a) 0.125 mol/dm3 cao **A1**

(a) Answer: 0.125 mol/dm3

Question 12

sum of Mr of reactants = 46 + 32 (= 78) **M1**

(60 / 78) x 100 oe (ft from their sum) **M1**

76.9 (%) cao (accept 76.8 to 76.9) **A1**

Answer: 76.9%

Question 13

(a) substitute Mr: desired product Mr = 42; reactant Mr = 44; perform division **M1**

(a) 95.5% cao **A1**

(a) Answer: 95.5%

Question 14

(a) calculate limiting reagent and theoretical mass: moles N_2 = 4.00 / 28.0 = 0.14286; theoretical moles NH_3 = 2 x 0.14286 = 0.28571; theoretical mass = 0.28571 x 17.0 **M1**

(a) calculate actual/theoretical x100 **M1**

(a) 86.5% cao **A1**

(a) Answer: 86.5%

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Question 15

Level 3 Detailed evaluation: clearly explains two strategies, gives scientific reasons how each increases yield, and discusses limitations or trade-offs with specific examples.	**5-6**
Level 2 Clear explanation of two strategies with some reasoning of how they increase yield and at least one limitation or trade-off.	**3-4**
Level 1 Simple statements of one or two strategies with limited or no reasoning and no discussion of limitations.	**1-2**

Indicative content:

- Use Le Chatelier approach for reversible reactions: remove product continuously (for example distillation, decanting) to shift equilibrium to products; increases yield but may require extra apparatus, energy and may not be suitable if product and reactant boiling points are similar.
- Purify product quickly by extraction or filtration to prevent reverse reaction and reduce loss to side reactions; increases isolated yield but may cause losses during transfer and require solvents which introduce cost and waste.
- Use excess of one reactant to push equilibrium to product side; increases theoretical yield but requires recovery or disposal of excess and lowers atom economy.
- Improve selectivity and reduce side reactions by optimising temperature, solvent and catalysts; increases yield but may need expensive catalysts and careful control; sometimes increases formation of unwanted by-products if conditions not ideal.
- Consider trade-offs: higher yield vs purity, cost, energy use, environmental impact and atom economy.

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