InkChemistry

ANSWER BOOK

Reacting masses, percentage yield and atom economy

Amount of substance · Unit C02

AQA 3.1.2.5, 3.3.14 · OCR A 2.1.3 (h), 2.1.3 (j)

17 questions · 51 marks

NAVY EDITION

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SECTION A · Short, 1 to 2 marks

A1 RMP-Q9

B1 in an addition reaction the reactants join to form a single product. **B1** all the atoms of the reactants end up in the desired product, so its mass equals the total mass of the reactants. [2]

A2 RMP-Q11

B1 an excess of the cheaper reactant makes the expensive reactant the limiting reagent, so as much of it as possible reacts. **B1** esterification is an equilibrium, and an excess of one reactant moves the position of equilibrium towards the ester, raising the yield. [2]

A3 RMP-Q12

B1 find a use for the by-product, or sell it, so that it is not disposed of as waste. **B1** change to a different route, for example one with fewer steps or an addition reaction, that has a higher atom economy. [2]

A4 RMP-Q20

B1 atom economy is calculated from the balanced equation, and solvents, washes and recrystallisation liquids are not in the equation. **B1** the mass of solvent used can be many times the mass of the product, so most of the waste is not counted. [2]

A5 RMP-Q1

B1 the reactant that is completely used up first, and so determines the maximum amount of product. [1]

SECTION B · Standard, 3 to 5 marks

B1 RMP-Q4

M1 n(Mg) = 0.486 ÷ 24.3 = 0.0200 mol and n(HCl) = 1.00 × 0.0200 = 0.0200 mol. **M1** 0.0200 mol of Mg would need 0.0400 mol of HCl, so the hydrochloric acid is the limiting reagent. **M1** $n(H_2) = 0.0200 \div 2 = 0.0100$ mol. **A1** volume of hydrogen = 0.0100 × 24.0 = 0.240 dm^3, to three significant figures. [4]

B2 RMP-Q15

B1 percentage yield measures only how much of the theoretical product is collected. **B1** a process with a high yield can still have a low atom economy, turning much of its reactant mass into by-products. **B1** sustainability also depends on energy use, whether the raw materials are renewable, and whether by-products are used or sold. **B1** so the claim is not justified on yield alone; the two processes need comparing on atom economy and these other factors as well. [4]

B3 RMP-Q18

M1 n(Na) = 4.60 ÷ 23.0 = 0.200 mol and $n(Cl_2) = 5.68 \div 71.0 = 0.0800$ mol. **M1** dividing by the coefficients gives Na 0.100 and Cl_2 0.0800, so chlorine is the limiting reagent. **M1** n(NaCl) = 2 × 0.0800 = 0.160 mol, so the theoretical mass = 0.160 × 58.5 = 9.36 g. **A1** percentage yield = 8.42 ÷ 9.36 × 100 = 90.0%, to three significant figures. [4]

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B4 RMP-Q3 **M1** $n(Fe_2O_3) = 500 \div 159.6 = 3.133$ mol. **M1** $n(Fe) = 2 \times 3.133 = 6.266$ mol, and mass $= 6.266 \times 55.8$. **A1** mass of iron $= 3.50 \times 10^2$ g, to three significant figures. [3]

B5 RMP-Q6 **M1** mass of desired product $= 2 \times 55.8 = 111.6$. **M1** total mass of reactants $= 159.6 + 3 \times 28.0 = 243.6$. **A1** atom economy $= 111.6 \div 243.6 \times 100 = 45.8\%$, to three significant figures. [3]

B6 RMP-Q8 **B1** the reaction may not go to completion, for example because it reaches equilibrium. **B1** side reactions turn some of the reactant into other products. **B1** product is lost on glassware, during transfer and in purification steps such as filtration, recrystallisation or distillation. [3]

B7 RMP-Q10 **B1** atom economy is calculated from the equation and depends only on which products form, not on how much reacts. **B1** $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$ has ethanol as its only product, so the atom economy is 100%. **B1** the 5% per pass is a measure of conversion or yield, which is limited by the equilibrium and conditions; unreacted ethene is recycled. [3]

B8 RMP-Q13 **B1** esterification is reversible, so the mixture reaches equilibrium with some ethanol and ethanoic acid unreacted. **B1** some ester is lost in the separating funnel and washings, or left on the drying agent. **B1** some ester is left in the flask and still head, or evaporates, during distillation. [3]

B9 RMP-Q17 **M1** Mr of $CH_3Cl = 50.5$ and total Mr of the reactants $= 16.0 + 71.0 = 87.0$. **A1** atom economy $= 50.5 \div 87.0 \times 100 = 58.0\%$, to three significant figures. **A1** mass of HCl $= 1000 \times 36.5 \div 50.5 = 723$ g per kilogram, to three significant figures; accept 0.723 kg. [3]

B10 RMP-Q19 **B1** a solvent must be bought and then separated from the product, so it adds cost and waste. **B1** recovering the solvent by distillation uses energy, and solvent that is not recovered must be disposed of. **B1** many organic solvents are flammable or toxic and escape as volatile organic compounds, so removing them reduces the hazard. [3]

B11 RMP-Q21 **B1** magnesium carbonate is insoluble, so when the acid is used up the unreacted excess stays as a solid and is removed by filtration. **B1** the acid is the limiting reagent, so none is left in the filtrate to contaminate the crystals; an excess of acid cannot be filtered off and would stay in the solution. **B1** the end of the effervescence shows that all the acid has reacted, so the filtrate holds only magnesium sulfate and water and evaporation gives a pure product. [3]

SECTION C · Long, 6 marks or more

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C1 RMP-Q14 **Indicative content** [6]

B1 hydration has an atom economy of 100% because ethanol is the only product, whereas fermentation has 51.1% because carbon dioxide is formed as well. **B1** only about 5% of the ethene reacts on each pass, but unreacted ethene is recycled so the overall conversion is about 95%; fermentation stops when the ethanol reaches about 15%. **B1** hydration uses ethene from crude oil, a finite resource, whereas fermentation uses sugars from crops that can be grown again each year. **B1** hydration is fast and continuous over a phosphoric acid catalyst, whereas fermentation is a slow batch process that takes days at about 35 °C. **B1** hydration needs high temperature and pressure, which costs energy, whereas fermentation runs warm at atmospheric pressure but needs energy for distillation. **B1** hydration gives nearly pure ethanol, whereas fermentation gives a dilute aqueous solution that must be fractionally distilled before use.

Levels

Level 3 (5–6 marks) all six aspects named in the question are compared, each with both processes in the same point and a correct figure where one applies, such as the 100% and 51.1% atom economies and the 95% conversion with recycling; no point describes one process without the other.

Level 2 (3–4 marks) four or five of the aspects are compared with both processes in each point, or all six appear and some describe one process only or carry a wrong figure.

Level 1 (1–2 marks) two or three statements, mostly about one process; fermentation is usually called the 'greener' method on every count, with no figures.

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