## C4.1 Relative masses and moles

<table>
<thead>
<tr>
<th>Question number</th>
<th>Answer</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The mean (average) relative mass of an atom of an element, taking into account the proportions of different isotopes naturally occurring in that element, using the scale carbon-12 = 12.</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 a</td>
<td>62</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 b</td>
<td>180</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3 a</td>
<td>0.005 moles</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3 b i</td>
<td>0.3 moles</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3 b ii</td>
<td>500 000 moles</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4 a</td>
<td>5000 g or 5 kg</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4 b</td>
<td>0.1 g</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4 c</td>
<td>74.4 g</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>due to averaging relative masses of different isotopes in a naturally occurring sample</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
# C4.2 Equations and calculations

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 molecules of HCl or 2 moles of HCl molecules</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4.0 g</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3 a</td>
<td>$2\text{H}_2\text{O}_2(aq) \rightarrow 2\text{H}_2\text{O}(l) + \text{O}_2(g)$</td>
<td>3</td>
<td>1 mark for correct reactants. 1 mark for correct products. 1 mark for correct state symbols.</td>
</tr>
<tr>
<td>3 b</td>
<td>3.4 g</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4 a</td>
<td>$\text{Ca(s)} + 2\text{H}_2\text{O}(l) \rightarrow \text{Ca(OH)}_2(aq) + \text{H}_2(g)$</td>
<td>3</td>
<td>1 mark for correct reactants. 1 mark for correct products. 1 mark for correct state symbols.</td>
</tr>
<tr>
<td>4 b</td>
<td>2.0 g</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
## C4.3 From masses to balanced equations

<table>
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<tbody>
<tr>
<td>1</td>
<td>reactant used up first in a reaction</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 a</td>
<td>0.1 mol Cu 0.05 mol O₂ 0.1 mol CuO</td>
<td>1 1 1</td>
<td></td>
</tr>
<tr>
<td>2 b</td>
<td>Cu : O₂ : CuO (0.1 : 0.05 : 0.1) = 2 : 1 : 2 2 moles of Cu react with 1 mole of O₂ → 2 moles of CuO, so balanced equation is 2Cu + O₂ → 2CuO</td>
<td>1 1 1</td>
<td></td>
</tr>
<tr>
<td>3 a</td>
<td>Fe₂O₃(s) + 2Al(s) → Al₂O₃(s) + 2Fe(s)</td>
<td>3 1 1</td>
<td>1 mark for correct reactants. 1 mark for correct products. 1 mark for correct state symbols.</td>
</tr>
<tr>
<td>3 b</td>
<td>Fe₂O₃ = ( \frac{32.0}{160} ) = 0.2 mol (reacts completely with (0.2 × 2) = 0.4 mol of Al) Al: ( \frac{16.2}{27} ) = 0.6 mol so Al in excess and Fe₂O₃ is limiting reactant</td>
<td>1 1</td>
<td></td>
</tr>
<tr>
<td>3 c</td>
<td>0.2 mol Fe₂O₃ → 0.2 mol Al₂O₃ mass 0.2 mol Al₂O₃ = ( 10² \times 0.2 = 20.4 ) g</td>
<td>1 1</td>
<td></td>
</tr>
</tbody>
</table>
# C4.4 The yield of a chemical reaction

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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>conserve Earth’s resources, reduce waste and pollution</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>reaction reversible, some reactants give unexpected products, some product lost in handling or left in apparatus, reactants impure, losses in separating target product</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>21% (21.2%)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4 a</td>
<td>(2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4 b</td>
<td>86.8%</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>
# C4.5 Atom economy

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>% atom economy = ( \text{relative formula mass of desired product} \times 100% )</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>( \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 ) [\quad \text{atom economy} = \frac{56}{100} \times 100% = 56% ]</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3 a</td>
<td>( \frac{64.5}{46 + 36.5} \times 100% = 78.2% )</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
| 3 b             | Reaction 1: atom economy = 100\%  
|                 | no waste products to find alternative uses for, to dispose of, or treat before disposal (better for environment and saves money) | 1     |          |
| 3 c             | any two from:  
|                 | if starting materials renewable: \( \text{C}_2\text{H}_5\text{OH} \) from fermentation of sugar cane or sugar beet is renewable whereas \( \text{C}_2\text{H}_4 \) from crude oil is non-renewable,  
|                 | reaction conditions: if high temperatures or pressures are needed these usually require fossil fuels, causing pollution, and diminishing supplies of crude oil,  
|                 | whether reactions are reversible: reactions that are not give higher percentage yield of product | 4     | 1 mark for example. 1 mark for reason. Credit any other valid example |
## C4.6 Expressing concentrations

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>1 a</td>
<td>20 g/dm³</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1 b</td>
<td>2.1 g/dm³</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>70 g/dm³</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>greater mass of solute in a certain volume of water → more concentrated solution, greater volume of water for a certain mass of solute → less concentrated solution</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>( 93.6 \times \frac{25.0}{1000} = 2.3 \text{ g} )</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
## C4.7 Titrations

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1 a</td>
<td>meniscus</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1 b i</td>
<td>pipette burette</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 b ii</td>
<td>bottom of meniscus eye level with that point</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2 a</td>
<td>measure known volume of sodium hydroxide solution into conical flask using pipette, add a few drops of indicator, pour dilute nitric acid into burette, recording burette reading, slowly add acid into flask, swirling to mix two solutions, continue until indicator changes colour, repeat titration until two results concordant, then average</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2 b</td>
<td>NaOH(aq) + HNO₃(aq) → NaNO₃(aq) + H₂O(l)</td>
<td>3</td>
<td>1 mark for correct reactants. 1 mark for correct products. 1 mark for correct state symbols.</td>
</tr>
<tr>
<td>3 a</td>
<td>for example, methyl orange, phenolphthalein</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3 b</td>
<td>different colours in acidic and alkaline conditions to make end point clear</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3 c</td>
<td>repeat titration until get two results / titres within 0.1 cm³ of each other</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
### C4.8 Titration calculations

<table>
<thead>
<tr>
<th>Question number</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.002 moles</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>KOH(aq) + HNO₃(aq) → KNO₃(aq) + H₂O(l)</td>
<td>3</td>
<td>1 mark for correct reactants. 1 mark for correct products. 1 mark for correct state symbols.</td>
</tr>
<tr>
<td>3</td>
<td>0.0040 ((4.0 \times 10^{-3})) moles</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.0040 ((4.0 \times 10^{-3})) moles</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.32 mol/dm³</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>20 g/dm³ to 2 significant figures or 20.2 g/dm³ to 3 significant figures</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
### C4.9 Volumes of gases

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>volume of gas occupied by 1 mole of gas at room temperature and pressure</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 a i</td>
<td>1.5 mol</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 a ii</td>
<td>417 mol</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2 b i</td>
<td>216 dm$^3$ (or 216000 cm$^3$)</td>
<td>2</td>
<td>1 mark each for correct answer and correct unit</td>
</tr>
<tr>
<td>2 b ii</td>
<td>7.2 dm$^3$ (or 7200 cm$^3$)</td>
<td>2</td>
<td>1 mark each for correct answer and correct unit</td>
</tr>
<tr>
<td>2 c</td>
<td>0.064 g</td>
<td>2</td>
<td>1 mark each for correct answer and correct unit</td>
</tr>
<tr>
<td>3</td>
<td>300 dm$^3$ (or 300000 cm$^3$)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.48 dm$^3$ (or 480 cm$^3$)</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>