Worksheet: Atom Economy Calculations

ChemistrySheets

Specification: GCSE Chemistry (AQA 5.3.2.3 / Edexcel SC14 / OCR Gateway C4.1)

Core Concept: Atom Economy is a measure of the amount of starting materials that end up as useful products. A higher atom economy means less waste.

Formula: Atom Economy $= \frac{M_r \text{ of desired product}}{\sum M_r \text{ of all reactants}} \times 100$

Rearranged Forms:

$\sum M_r$ of all reactants $= \frac{M_r \text{ of desired product}}{\text{Atom Economy}} \times 100$

M_r of desired product $= \frac{\text{Atom Economy} \times \sum M_r \text{ of all reactants}}{100}$

Units: M_r (Relative Formula Mass) has no units. Atom Economy is expressed as a percentage (%).

Section A: Understanding the Formula & M_r

1. State the unit for each of the following terms in the atom economy formula:

   a) Atom Economy: _____

   b) M_r of desired product: _____

   c) Sum of M_r of all reactants: _____

2. Write down the rearranged forms of the atom economy formula:

   a) To find the sum of M_r of all reactants: _____

   b) To find the M_r of the desired product: _____

3. Calculate the relative formula mass (M_r) for the following compounds. Use the atomic masses: H=1, C=12, O=16, Na=23, Cl=35.5.

   a) H_2O: _____

   b) CO_2: _____

   c) C_2H_4: _____

   d) C_2H_5OH: _____

   e) NaCl: _____

Section B: Practice Calculations

1. Ethene reacts with steam to produce ethanol. Ethanol is the desired product.

$$C_2H_4\ (g) + H_2O\ (g) \rightarrow C_2H_5OH\ (g)$$

   Calculate the atom economy for this reaction.

2. Methane can be combusted to produce carbon dioxide and water. If carbon dioxide is the desired product:

$$CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)$$

   Calculate the atom economy for this reaction. (Atomic masses: C=12, H=1, O=16)

3. A chemical process has an atom economy of 75%. If the relative formula mass (M_r) of the desired product is 60, calculate the total relative formula mass of all reactants.

4. A reaction has an atom economy of 90%. The total relative formula mass (M_r) of all reactants is 120. Calculate the relative formula mass of the desired product.

Section C: Challenge Context

1. Hydrogen gas (H_2) is an important fuel. One industrial method for its production is the steam reforming of methane, as shown in the reaction scheme below.

$$CH_4(g) + 2H_2O(g) \longrightarrow CO_2(g) + 4H_2(g)$$

Figure 1: Steam reforming of methane

If hydrogen (H_2) is the desired product, calculate the atom economy for this reaction. (Atomic masses: C=12, H=1, O=16)

2. Magnesium oxide (MgO) is used in refractory linings. Consider two different routes for its production:

Route 1: $2Mg\ (s) + O_2\ (g) \rightarrow 2MgO\ (s)$
Route 2: $MgCO_3\ (s) \rightarrow MgO\ (s) + CO_2\ (g)$

For both routes, magnesium oxide (MgO) is the desired product. (Atomic masses: Mg=24, O=16, C=12) Calculate the atom economy for each route and state which route is more atom economical.