Lesson 8 Atom economy and percentage yield

Click to revise atom economy and percentage yield.

Atom economy is a way to measure the efficiency of a reaction. It gives a measure of the atoms wasted when making a desired product. The higher the atom economy, the more efficient a reaction is. A 100 per cent atom economy indicates that all the atoms in the reactants have been converted to the desired product. A 100% atom economy is achieved when there is only one product. For example the production of water from hydrogen and oxygen gases has a 100% atom economy. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$.

Example 1 Butane is burnt as a fuel on a particular space station. The CO_2 and H_2O produced are then used to regenerate O_2 gas using solar energy according the equation below.

$$12CO2(g) + 14H2O(g) \rightarrow 2C6H14(g) + 19O2(g)$$

What is the percentage atom economy of the production of oxygen gas according to the reaction above?

Step 1 From the equation find the mass, in grams, of reactants.

=> 12 X 44 + 14 X 18 = 528 + 252 = 780 grams

Step 2 From the equation find the mass of desired product, in this case it is O_2 gas.

=> 19 X 36 = 684 grams

Step 3 Find the % atom economy

=> (684 / 780) X 100 = 87.7%

1) Calculate the % atom economy for the production of ethanol from glucose.
   $C_6H_{12}O_6(aq) \rightarrow 2CO_2(g) + 2C_2H_6O(aq)$
   ⇨ (2 X 46.0 / 180.2) X 100 = 51.1%

2) Ethyl ethanoate is formed from the reaction of ethanoic acid and ethanol.
   Ethanol + ethanoic acid → Ethyl ethanoate + H_2O
   a) Write the chemical equation for the reaction with the word equation above.
   $C_2H_6O\ (aq) + C_2H_4O_2(aq) => C_4H_8O_2(aq) + H_2O(l)$
   b) Calculate the % atom economy for the production of ethyl ethanoate via this reaction.
   => (88.1 / (46.1 + 60.1)) X 100 = 83.0%

3) Hydrogen gas can be produced by a process called steam reformation according to the equation below.

   $$CH_4(g) + H_2O\ (g) \rightarrow 3H_2(g) + CO(g)$$

   a) Calculate the % atom economy for the production of hydrogen via this reaction.
   ⇨ (6 / 34) X 100 = 18%
   b) A student argued that it was more efficient to produce hydrogen gas via the electrolysis of water. Is the student correct? Explain why.
   It is less efficient
   => $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$
   => (4 / 36) X 100 = 11%

The percentage yield of a reaction, distinguishes the theoretical amount of product from the actual amount. Unlike percentage atom economy, to calculate the percentage yield experimental results must be obtained. Percentage yield really tells us how effective the reaction is in producing the product .

$$\frac{\text{Actual mass of desired product}}{\text{Theoretical mass of desired product}} \times 100$$

Example 1 Hydrogen gas is produced by the reaction below.

$Zn(s) + 2HCl(aq) \rightarrow H_2(aq) + ZnCl_2(aq)$

6.54 grams of zinc is placed in excess HCl solution to produce 0.0500 grams of H_2 gas. Calculate the percentage yield for the reaction.

Step 1 Find the mol of zinc.

=> 6.54 / 65.4 = 0.100

Step 2 find the mol of H_2 that should be produced.

=> 0.100

Step 3 Find the mass of H_2

=> 0.100 X 2 = 0.200 grams

Step 4 find the % yield

=> (0.0500 / 0.200) X 100 = 25.0%

1) For the balanced equation shown below, if the reaction of 0.110 grams of H_2 produces 0.852 grams of H_2O, what is the percentage yield?

   $Fe_3O_{4(s)} + 4H_2(g) \Rightarrow 3Fe(s) + 4H_2O(l)$

Step 1 Find the mol of H_2 used

=> 0.110 / 2.00 = 0.055

Step 2 Find the theoretical mass of H_2O produced

=> 0.055 X 18 = 0.99

Step 3 % yield

=> (0.852 / 0.99) X 100 = 86%

2) For the balanced equation shown below, if the reaction of 21.8 grams of $CaCO_3$ produces 5.82 grams of CaO, what is the percentage yield?

   $CaCO_3 \Rightarrow CaO + CO_2$

   Answer 48%

3) For the balanced equation shown below, if the reaction of 39.8 grams of $C_6H_6O_3$ produces a 45.0% yield, how many grams of H_2O would be produced ?

   $C_6H_6O_3 + 6O_2 \Rightarrow 6CO_2 + 3H_2O$

   Step 1 find the mol $C_6H_6O_3$

   => 39.8 / 126 = 0.316

   Step 2 find the theoretical yield of water in grams

   => 3 X 0.316 X 18 = 17.1grams

   Step 3 find the actual mass of water => 17.1 X 0.45 =7.7 grams