Stoichiometry

This is the balanced equation for the reaction between hydrochloric acid and sodium hydroxide:

HCl + NaOH 🡪 NaCl + H2O

The reactants and products are in a 1:1:1:1 stoichiometric ratio. This means that if react 1 mole of HCl with 1 mole of NaOH I will get 1 mole of NaCl and 1 mole of water. However, if I have uneven amount of the reactants then 1 reactant will run out before the other so the reaction would stop. For example, if I start with 1 mole HCl and 2 moles NaOH then the reaction will stop as soon as the HCl has been used up. This would leave 1 mole of unreacted NaOH.

1. How many moles of NaCl would I get if I start with:

1. 2 moles of HCl and 2 moles NaOH? 2
2. 10 moles of HCl and 10 moles NaOH? 10
3. 5 moles of HCl and 1 mole NaOH? 1
4. 5 moles of HCl and 10 moles NaOH? 5
5. 5 g HCl and 5 g NaOH? (*Workout the number of moles*) 0.13
6. 18 g HCl and 25 g NaOH? 0.5

The reactant that runs out first is called the “limiting reactant”. The reactant of which we have more than we require is called the “excess reactant”. Which is the limiting reactant in:

Part c 🡪 NaOH

Part d 🡪 HCl

Part e 🡪 NaOH

Part f 🡪 HCl

If we have an equation in which the stoichiometric ratios are not 1:1 then to work out the limiting and excess reactant we also consider their stoichiometric coefficient (the big number infront of them). For example:

H2SO4 + **2**NaOH 🡪 Na2SO4 + **2**H2O

If I start with 1 mole of sulfuric acid and 2 moles of sodium hydroxide then I will get 1 mole of sodium sulphate and 2 moles of water. In this case there is a perfect amount of each reactant to react completely with each other. However, if I start with 10 moles of both reactants it is slightly more complicated as I need 2 moles of NaOH to react with every mole of H2SO4.

To work out the limiting reactant I must compare the amount of each reactant BUT taking into account the stoichiometric ratio. To do this we must divide the number of moles of each reactant by their stoichiometric coefficient (SC) and compare the numbers:

* Sulfuric acid = 10 moles ÷ 1 = 10
* Sodium hydroxide = 10 moles ÷ 2 = 5

Sodium hydroxide has the proportionally lowest number of moles when we take into account the SC and is therefore the limiting reactant.

Once we have identified the limiting reactant we can then look again at the starting number of moles of each and calculate the amount of products we will get:

H2SO4 + **2**NaOH 🡪 Na2SO4 + **2**H2O

The NaOH is the limiting reactant and we start with 10 moles of it. So if I start with 10 moles of NaOH then I will need half the amount of H2SO4 (as they are in a 1:2 ratio) which will be 5 moles. From this reaction I will get 5 moles of Na2SO4 (because the ratio of NaOH to Na2SO4 is 2:1) and I will get 10 moles of water (because the ratio of NaOH to H2O is 2:2 🡪 the same as 1:1). Notice how this is all based around the limiting reactant.

Balance each equation below and answer the questions.

\_\_SnO2 + \_2\_H2 🡪 \_\_Sn + \_2\_H2O

1. If I use 2 moles of each reactant then:
2. Which will be the limiting reactant? H2
3. How many moles of each product will I get? 1 mole Sn, 2 moles H2O
4. What mass of each product will I get? 118.7 g Sn, 36.0 g H2O

\_\_ KOH + \_\_ H3PO4 → \_\_ K3PO4 + \_\_ H2O

1. If I react 10 g of KOH and 20 g H3PO4:
2. How many moles will I have of each? 0.18 moles KOH and 0.26 moles H3PO4
3. Which will be the limiting reactant? KOH
4. How many moles of product will I get? 0.06 moles K3PO4 and 0.18 moles water
5. What mass of each product will I get? 12.72 g K3PO4 and 3.24 g water

216 g of aluminium are made to react with excess hydrochloric acid. Calculate

a. The number of grams of salt obtained. 1068 g AlCl3

b. The number of moles of acid used up the reaction. 24 moles

*(Hint – Acid + Metal 🡪 Salt + Hydrogen)*

Reaction percentage yield

*“Yield” = How much of something we get*

Chemical reactions do not always produce 100% of the products that they should do. We can describe the amount of product formed by comparing it with how much “theoretically” should have been formed. For example, if a chemical reaction should theoretically give 10 moles of a product but we actually only get 8 moles:

**Percentage yield = (Actual yield ÷ theoretical yield) x 100** = (8 ÷ 10) x 100 = 80% yield

An experiment should theoretically give 0.05 moles of a product. When it was carried out only 0.03 moles were produced. What was the percentage yield? *60 %*

\_\_ Na3PO4 + \_\_ HCl → \_\_ NaCl + \_\_ H3PO4

a. Balance the equation.

b. If I react 0.2 moles of sodium phosphate with 0.3 moles of HCl, what is the limiting reactant? *HCl*

c. How many moles of Na Cl should I produce? *0.3 moles*

d. When I carry out the experiment I collect 0.15 moles of NaCl. What is the percentage yield? *50 %*

e. I complete the experiment again and collect 14.6 g NaCl. What is the new percentage yield? 83 *%*

Mercury(II) oxide thermally decomposes into mercury and oxygen. Given a reaction yield of 80 %, how much oxide was used if 2 L of oxygen were released at 273 °C and 646 Torr? *(760 Torr = 1 atm) 20.4 g HgO*