Finding equations from experiments

Example 1: The effect of heat on potassium nitrate crystals

If you heat potassium nitrate crystals, they melt and fizz, giving off oxygen gas. At the end of the experiment, when it is cooled again, an off-white solid is left. This experiment shows how you might set about working out the equation for the reaction.

A crucible was weighed, and then reweighed with some potassium nitrate crystals. It was heated strongly for a while until no more bubbles were seen to be coming from the molten compound. Then it was cooled and reweighed.

To check that the reaction was complete, it was then reheated until it melted again, kept molten for a couple of minutes, and then cooled again. It was weighed again. This was repeated until there was no further change in the mass. This is known as "heating to constant mass", and is the only way you can be sure that a reaction has finished.

Results

Mass of crucible = 24.00 g
Mass of crucible + potassium nitrate crystals = 26.02 g
Mass of crucible + residue = 25.70 g

Calculations

Mass of potassium nitrate = 26.02 – 24.00 g
= 2.02 g

Mass of oxygen given off = 26.02 – 25.70 g
= 0.32 g (assuming that nothing else is given off apart from oxygen)

1 mol KNO_3 weighs 39 + 14 + (3 x 16) g = 101 g

No of moles of KNO_3 = 2.02/101
= 0.0200 mol

1 mol O_2 weighs 2 x 16 g = 32 g

No of moles of O_2 = 0.32/32
= 0.0100 mol

That means that 2 mol KNO_3 gives 1 mol O_2

The equation therefore must be $2KNO_3 \rightarrow X + O_2$

If you look at what is left, and assume that there is only one solid product, you can work out that you are missing 2 x K, 2 x N and 4 x O. That could be $2KNO_2$. So that the final equation *might* be

$$2KNO_3 \rightarrow 2KNO_2 + O_2$$

You could, of course, have done this differently, and collected the oxygen evolved and measured its volume, in which case you would end up with a molar volume calculation to find how many moles of oxygen you had.

Example 2: Experiments investigating the reactions between sodium carbonate solution and dilute hydrochloric acid.

If you titrate sodium carbonate solution using dilute hydrochloric acid, the amount of acid you need for a given volume of sodium carbonate solution depends on the indicator you use. It is completely different if you use phenolphthalein than if you use methyl orange.

Suppose you have a solution of sodium carbonate containing 0.500 mol dm^{-3}, and a solution of hydrochloric acid containing 1.00 mol dm^{-3}.

a) Using methyl orange as indicator

25.0 cm^3 of the sodium carbonate solution needed 25.0 cm^3 of the hydrochloric acid to reach the end point using methyl orange as the indicator. Bubbles of gas (shown to be carbon dioxide) were seen coming off during the reaction.

No of moles of sodium carbonate	= 25.0/1000 x 0.500 = 0.0125 mol
No of moles of HCl	= 25.0/1000 x 1.00 = 0.025 mol

The reaction involves twice as many moles of acid as of sodium carbonate and produces carbon dioxide. The equation must look like this:

$$Na_2CO_3 + 2HCl \rightarrow X + CO_2$$

So what are you left with? 2 x Na, 1 x O, 2 x H, and 2 x Cl.

A reasonable guess might be that you had 2NaCl + H_2O – but it is just a guess, and you would have to do more work to confirm it. So the equation *might* be

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

b) Using phenolphthalein as indicator

25.0 cm^3 of the sodium carbonate solution needed 12.5 cm^3 of the hydrochloric acid to reach the end point using phenolphthalein as the indicator. No gas was evolved during the reaction.

No of moles of sodium carbonate	= 25.0/1000 x 0.500
	= 0.0125 mol
No of moles of HCl	= 12.5/1000 x 1.00
	= 0.0125 mol

The reaction involves the same number of moles of acid as of sodium carbonate and doesn't produce carbon dioxide. The equation must look like this:

$$Na_2CO_3 + HCl \rightarrow X$$

So what have you got on the right-hand side? 2 x Na, 1 x C, 3 x O, 1 x H, and 1 x Cl.

It is going to be a guess, but it would seem reasonable that one of the sodiums and the chlorine might end up as NaCl. That would leave you with $NaHCO_3$, sodium hydrogencarbonate.

So the equation *might* be

$$Na_2CO_3 + HCl \rightarrow NaCl + NaHCO_3$$

Obviously, there are as many experiments that you could do as there are reactions, but these examples give a feel for the sort of thing you might do.