Chapter 4

Acids, bases and group II metals

The fourth topic of the Nuffield course concerns acid-base reactions and the chemistry of the group 2 metals. The main skill you should develop is the ability to accurately carry out a titration.

4.1 Acids and bases - Definitions

The first experiment of the topic involves testing a variety of concepts about acids and bases.

In one part we discuss the reactions of hydrogen chloride in an organic solvent. The mixture does not behave as an acid in the usual sense - it does not conduct electricity and does not change the colour of litmus paper. This is because there are no H^+ ions present. The solution needs water present to contain hydrogen ions. The mixture will react with concentrated ammonia to produce white ammonium chloride (although it is a fiddly experiment to do). This means that some form of acid-base reaction is occurring. Therefore it is necessary to challenge the idea of an acid being something which contains H^+ in aqueous solution and an alkali being something which contains OH^- in aqueous solution (this is the **Arrhenius theory of acids and bases**. The **Brönsted-Lowry definition of acid and base behaviour** is more sophisticated than the Arrhenius theory as it is valid for reactions in the gas phase as well. For the Broönsted-Lowry definition

- an acid is a proton ____________
- a base is a proton ____________

In the reaction between HCl and NH_3 the HCl is acting as a __________ and the NH3 is acting as a __________.

You need to be able to define a strong or weak acid and base. This is done in terms of **dissociation**, either complete or partial, which means how much it forms ions in solution.

- A strong acid is ____________ dissociated into ions in water
- A weak acid is ____________ dissociated into ions in water
- A strong base is ____________ dissociated into ions in water
- A weak base is ____________ dissociated into ions in water

You can view this as being how strong the interaction is with water. Does it donate all its acidic protons to water, or hardly any?

When HCl gas dissolves in water, what happens? Describe which of the HCl and the water is acid or base.

$$HCl + H_2O \longrightarrow \_\_\_\_\_ + \_\_\_\_\_ \tag{4.1}$$

What happens when ammonia dissolves in water?

$$NH_3 + H_2O \longrightarrow \_\_\_\_\_ + \_\_\_\_\_ \tag{4.2}$$

We see that a species can be a Brönsted-Lowry acid *or* base.

4.2 Concentration of solutions

Millions of chemical reactions are carried out in solution. The reactions in the cells of organisms all take place in solution. This means that a *solute* is dissolved in a *solvent*. When we want to work out the equation, rate, or amount of energy involved in a reaction we need to know how much of one thing reacts with how much of another. For solution reactions the amount of reactant substance involved is the *concentration*. The unit of concentration is described in terms of number of particles in given volume, mol dm^{-3} or molar (M).

This means that in a litre of dilute 2 M hydrochloric acid there are $2 \times 6.02 \times 10^{23}$ oxonium ions and the same number of chloride ions. We could write this as $[HCl(aq)] = 2$ mol dm^{-3}. Make yourself familiar with the example concentrations at the bottom of page 81.

4.2.1 Standard solutions

A standard solution contains an exact number of moles in a given volume. A **volumetric flask** is used to dissolve an exact amount (mass) of solute in as little solvent as possible, then it is made up to an exact amount. The common sizes of volumetric flask are 50, 100 and 250 cm^3. You should be able to do the calculations on page 82 with ease. The answers to the questions are:

1. a) 0.038, b) 0.03

2. a) 36.5 g, b) 2.72 g

3. a) 0.125, b) 0.1

4.2.2 Titrations

There is a titration procedure outlined in some detail in the topic. You need to know how to perform titration calculations. A formula which you can use some simple algebra to prove to yourself should work is that at the equivalence point (when the end-point is reached) for the reaction of an acid (A) and a base (B) is

$$\frac{[A]\,V_A}{n_A} = \frac{[B]\,V_B}{n_B} \tag{4.3}$$

where the square brackets denote concentration, V denotes volume and n denotes the number of moles of that reaction involved in the equation. The units are very important! Concentration is in mol dm^{-3} and therefore volume should be in dm^{-3}. You may have to convert from cm^3, which is the units that your titre will normally be in.

In a titration we are normally trying to find the concentration of an acid or alkali. To do this we need to know how much of a standard solution reacts with a certain amount of our unknown. It is normal practice to put the unknown in a clean conical flask using a graduated pipette of 10, 20 or 25 cm^3. The known, standard solution is then added slowly from a burette. Knowing the equation for the reaction enables us to use the simple maths above to work out the unknown concentration.

4.3 The chemistry of the alkaline earth elements

The final part of Topic 4 concerns the chemistry of Group 2 metals. This ties in with the section on acids and bases (loosely) as some of the group 2 metal compounds are basic. You should make sure you have completed the worksheet on the experiments in this section.

The thrust of this is to give you an insight into the variation in some of the properties of the elements, their reactions, and their compounds.

We see further evidence of periodic trends in behaviour. The decomposition of the nitrates illustrates this well, as they become increasingly difficult to decompose down the group. This can be related to the sizes of the metal ions involved. Which member of the group would you expect to have the largest third ionisation energy?