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A volume measured in a volumetric flask is very precise. It holds the specified volume when the meniscus of the solution sits on the engraved marking on the neck of the flask.

If it is necessary to dissolve a solid in water to make the solution to place in a volumetric flask, care is needed. It is usual to dissolve the solid first in a container such as a beaker using a volume of distilled water that is less than that required for the solution. A beaker is used so that, if necessary, the contents can be warmed to encourage the solid to dissolve. Once dissolved, the solution must be allowed to cool to room temperature before being transferred to the volumetric flask, using a funnel. Any solution remaining in the beaker is washed into the flask. Distilled water is added carefully to the flask until the meniscus sits on the engraved mark on the neck. With the stopper firmly in place, the flask is inverted a few times to ensure that the solution is completely mixed.

Exam tip

The volume of solution held by a volumetric flask will depend on its temperature, so that hot solutions must not be poured into a volumetric flask.

Solutions made up in a volumetric flask are sometimes referred to as **standard solutions** (see Figure 18).

A **standard solution** is a solution with a precisely known concentration.

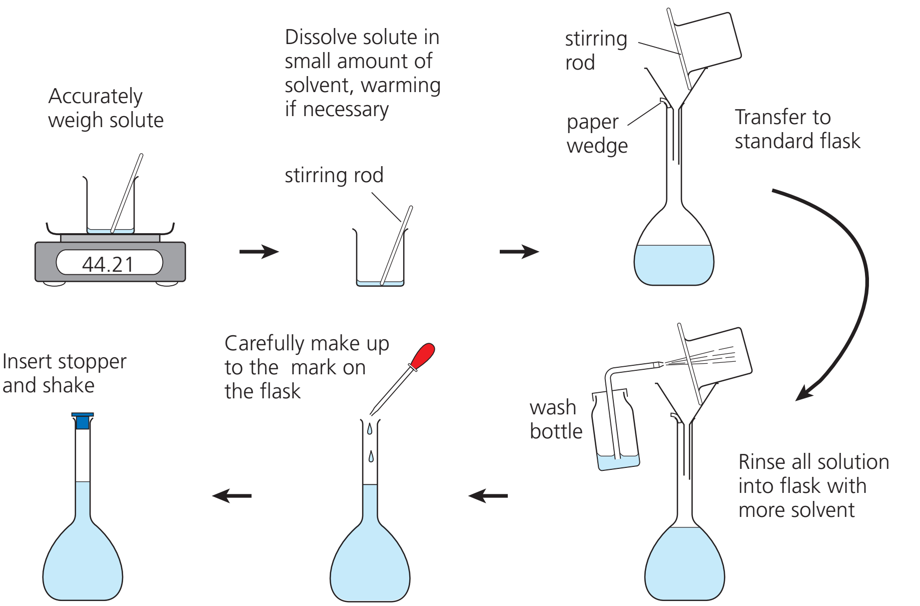

Figure 18

Example

It was found that 18.60 cm^3 HCl(aq) exactly neutralised 25 cm^3 0.100 mol dm^{-3} NaOH(aq). Calculate the concentration of the HCl(aq) solution.

Answer

Step 1: Work out how many moles of sodium hydroxide were neutralised. This is possible, as it is the solution for which you know both the concentration used, *c*, and the volume, *V*:

$$n = cV = 0.100 \times 0.0250$$

The concentration of the sodium hydroxide is 0.100 mol dm^3 of solution. Since 25.0 cm^3 was used, this would contain:

$$0.100 \times \frac{25.0}{1000} = 0.00250\,\text{mol}$$

Step 2: Refer to the balanced equation to see how many moles of hydrochloric acid would be needed to react with this number of moles of sodium hydroxide. The equation for the reaction is:

$$NaOH + HCl \rightarrow NaCl + H_2O$$

The mole ratio is: 1 : 1 : 1 : 1

and therefore 1 mole of NaOH reacts with 1 mole of HCl.

It is known that 0.00250 mol of NaOH were neutralised, and this must have required 0.00250 mol of HCl to react completely. Since 18.60 cm^3 of HCl were added from the burette, it must follow that 18.60 cm^3 contained 0.00250 mol of acid.

Step 3: Convert the information obtained about the hydrochloric acid into its concentration in mol dm^{-3}.

$$c = \frac{n}{V} = \frac{0.00250}{18.6/1000}$$

$$= \frac{0.00250}{0.0186} = 0.134\,\text{mol dm}^3$$

So concentration of HCl was 0.134 mol dm^{-3}.

Knowledge check 27

If 0.0264 mol of hydrochloric acid is neutralised by 25.0 cm^3 of sodium carbonate, what amount (in moles) of sodium carbonate is present in the 25.0 cm^3?

Redox

Redox reactions are reactions in which electrons are transferred from one substance to another. There are numerous everyday examples of redox reactions, including the combustion of fuels and the rusting of iron. Oxidation was originally defined as the gaining of oxygen. For example, when zinc reacts with oxygen to form zinc oxide, the zinc has clearly been oxidised:

$$Zn(s) + \tfrac{1}{2}O_2(g) \rightarrow ZnO(s)$$

A closer inspection of this reaction shows that the zinc atom has been converted to a zinc ion, and in the process has lost two electrons:

$$Zn \rightarrow Zn^{2+} + 2e^-$$

The definition of oxidation therefore has been extended, so that a species is said to be oxidised if it loses electrons. The converse is true for reduction. One way of remembering this is:

OILRIG

Oxidation Is Loss Reduction Is Gain

e Both students have done well, scoring 13 and 14 out of 16 marks, respectively. If they maintained this standard throughout an exam they would both get a grade A.

Question 13 Redox; bonding and structure

Time allocation: 11–13 minutes

In this question, 1 mark is available for the quality of written communication. (1 mark)

(a) A chemist reacts oxygen separately with magnesium and with sulfur to form MgO and SO_2, respectively. Write an equation for:

(i) the reaction of magnesium and oxygen (1 mark)

(ii) the reaction of sulfur and oxygen (1 mark)

(b) The reactions in (a) are both redox reactions, in which reduction and oxidation take place. Explain, using the changes in oxidation number for sulfur, whether sulfur undergoes oxidation or reduction. (2 marks)

(c) The chemist adds water to MgO and to SO_2, forming two aqueous solutions. Write equations for the reactions that take place and suggest a value for the pH of each solution. (4 marks)

(d) Magnesium oxide is a solid with a melting point of 2852°C; sulfur dioxide has a melting point of –73°C. Explain, in terms of structure and bonding, why there is such a large difference between the melting points of these two oxides. (5 marks)

Total: 14 marks

e The bulk of the marks in this question are in parts (c) and (d) and it is worth working out a strategy for answering these parts before starting. Part (c) has 4 marks and requires two equations (1 mark each) and two pH values (1 mark each). Part (d) has 5 marks and requires an explanation of the structure (1 mark) and the bonding (1 mark) of both MgO and SO_2. The fifth mark is for an explanation of the difference in melting points.

Student A

(a) (i) $Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$

Student B

(a) (i) $2Mg + O_2 \rightarrow 2MgO$

e Both students score the mark.

Student A

(a) (ii) $S + O_2(g) \rightarrow SO_2(s)$

Student B

(a) (ii) $S + O_2 \rightarrow SO_2$

e Student A could have lost a mark by missing out the state symbol for sulfur, but state symbols are not required here. However, if you do include them, the examiner may penalise you if they are wrong or partly omitted. The best advice is that unless you are asked for state symbols, don't include them in your answer. Both students score the mark.

Student A

(b) Initial oxidation state of sulfur is 0 and the final oxidation state of sulfur is +4. Therefore, sulfur has undergone oxidation.

Student B

(b) The oxidation state of sulfur changes from 0 to 4.

e Student A scores both marks but student B only scores 1 because they have not stated that the sulfur has been oxidised. Oxidation number has a sign as well as a value. The minus sign should always be included for negative oxidation numbers. If the oxidation number is positive, the + sign should be written, but if there is no sign, the examiner will assume the number to be positive.

Student A

(c) $MgO + H_2O \rightarrow Mg(OH)_2$ pH of the aqueous solution = 11

$SO_2 + H_2O \rightarrow H_2SO_3$ pH of the aqueous solution = 2

Student B

(c) $MgO + H_2O \rightarrow MgOH_2$ pH = 9

$SO_2 + 2H_2O \rightarrow H_2SO_4 + H_2$ pH = 5

e Student A scores all 4 marks. The pH depends on the concentration, so a value between 8 and 13 is acceptable for $Mg(OH)_2$, as is a value between 1 and 6 for H_2SO_3. Student B gets 2 marks for the pH predictions but loses both equation marks. The first equation is almost correct, but the formula for magnesium hydroxide must have brackets around the OH. The second equation is incorrect, because the student tries to form H_2SO_4 instead of H_2SO_3.

Student A

(d) MgO has a high melting point because it has a giant ionic lattice. SO_2 has a low melting point because it is a covalent molecule with weak intermolecular forces.