At the upper boundary of the hydrogen chloride, where the gas makes contact with moisture in the air, fumes appear. These are droplets of hydrochloric acid, the result of hydrogen chloride dissolving in water. The very great solubility of hydrogen chloride in water is shown in Figure 2.14. It is also demonstrated in Activity 2.1.

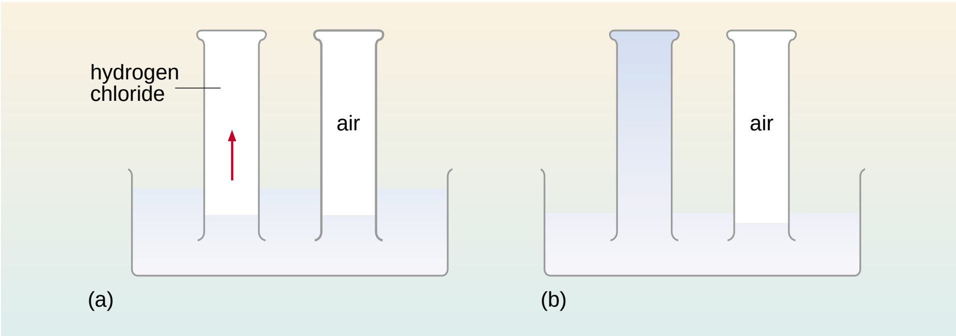

Figure 2.14 (a) Jars of air and hydrogen chloride are inverted over water. (b) The air stays put, but the hydrogen chloride is dissolved by the water, which rises and fills the jar.

At normal room temperature, one litre of water can dissolve as much as 450 litres of hydrogen chloride. The result is concentrated hydrochloric acid, a colourless, corrosive liquid. You will learn more about what it can do in the next section.

2.4 A first look at acids

The three substances that we ended up with in Sections 2.1.1, 2.2.1 and 2.3.1 were all called *acids*: sulfuric acid, nitric acid and hydrochloric acid. They are among the most important substances in any chemical laboratory, where they are usually found in two forms, both of which are solutions in water. The first is the *concentrated acid*; this contains the higher proportion of the parent substance (sulfuric acid, nitric acid or dissolved hydrogen chloride). For example, a kilogram of concentrated nitric acid contains about 0.7 kilogram of pure nitric acid and 0.3 kilogram of water. The second form is the *dilute acid*, which is much less corrosive and is made by adding lots of water to the concentrated form. For example, dilute nitric acid is made by adding about seven volumes of water to one volume of the concentrated acid.

What is it about the three chemicals that makes us call them acids? Here we shall respond to that question by showing you how the three acids, in their dilute forms, have the same effect on certain key substances.

2.4.1 The effect of acids on litmus

On cliffs in the Canary Islands, there grows the lichen, *Roccella tinctoria*, from which a blue dye, litmus, can be extracted. Litmus can be dissolved in water or used to colour paper. Sulfuric, nitric and hydrochloric acid all turn its blue colour red. *Acids turn blue litmus red.*

2.4.2 The effect of acids on limestone

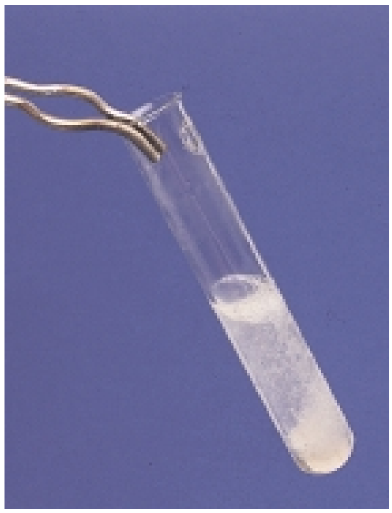

Figure 2.15 The action of an acid on calcium carbonate; carbon dioxide gas is produced.

Limestone country with its ravines and cliffs, often on inland sites, such as Malham and Cheddar Gorge, is amongst the most beautiful in the British Isles. Limestone is just one form of the chemical substance, calcium carbonate. Others are chalk and marble. When calcium carbonate is added to one of our three acids, there is vigorous effervescence as a gas is produced (Figure 2.15). This gas is carbon dioxide, which is so important in the greenhouse effect (Block 2). *Acids react with limestone and give carbon dioxide.*

Figure 2.16 shows how we can use this reaction to collect samples of carbon dioxide. Here, the particular acid that we use is hydrochloric, and the displaced carbon dioxide is first bubbled through water to remove any hydrogen chloride fumes that are carried over with it, i.e. to 'wash' the gas.

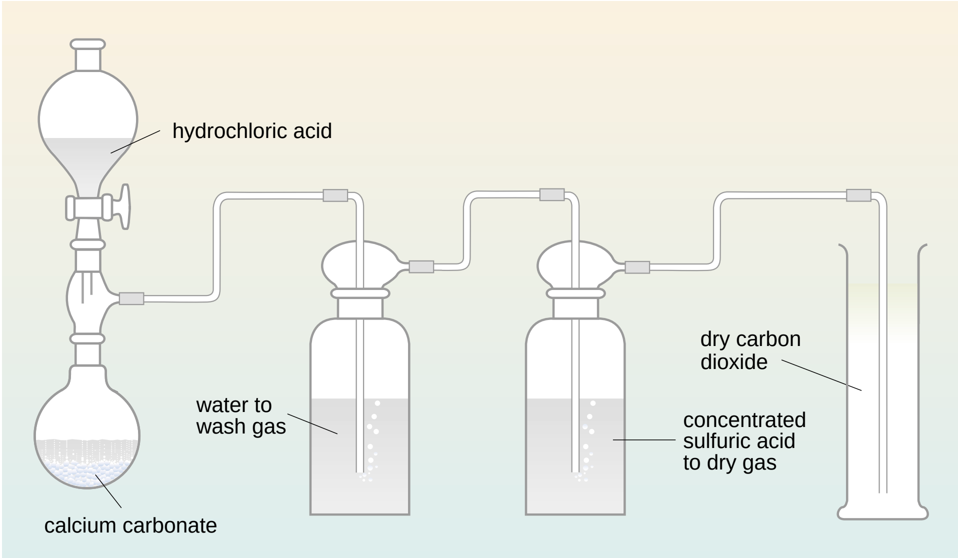

Figure 2.16 The reaction between calcium carbonate and hydrochloric acid can be used to make dry carbon dioxide.

- Why does this *remove* hydrogen chloride?
- Hydrogen chloride is very soluble in water (Section 2.3.1). Carbon dioxide is only slightly soluble, and so is not removed.

The gas is then dried by concentrated sulfuric acid and collected in a gas jar.

- What does the position of the delivery tube tip in the gas jar tell you about the properties of carbon dioxide?
- The gas is denser than air; like hydrogen chloride (Figure 2.13), it is collected by upward displacement of air.

If enough hydrochloric acid is added, all of the calcium carbonate in the flask will react and dissolve in it, and when the reaction is over, a clear solution remains. If this liquid is poured into a porcelain crucible and heated, the remaining dilute hydrochloric acid will evaporate, leaving a white solid that was dissolved in the solution. This solid can then be heated more strongly to drive off any residual water. Then, to make sure it stays dry, it is cooled in a desiccator (Figure 2.10) and finally stored in a sealed jar. It is called calcium chloride and is most useful because it is an enthusiastic absorber of water vapour.

- Name two products of the reaction between calcium carbonate and hydrochloric acid.
- One is calcium chloride; another is carbon dioxide.

In fact there is a third, which is water. This is not easily proved here because it just augments the water of the dilute hydrochloric acid in the flask, and is not easily seen.

- Now write down a word reaction for these changes, showing reactants and products.

calcium carbonate + hydrochloric acid ⟶ calcium chloride + carbon dioxide + water (2.2)

The reactants are separated by plus signs to the left of the arrow; the products are similarly separated to the right.

2.4.3 The effect of acids on magnesium

The familiar metals iron, tin and zinc react with acids to give a colourless gas. The less familiar metal magnesium also does this, but in a more lively fashion. Because magnesium has a low density, it is much used in airframes, luggage and spacecraft. More magnesium has been put into orbit than any other metal. When magnesium chippings are added to dilute hydrochloric or sulfuric acids, there is vigorous effervescence as the metal gradually reacts with, and dissolves in, the acid.* Figure 2.17 shows how the reaction can be carried out so as to collect the gas that is responsible for the effervescence.

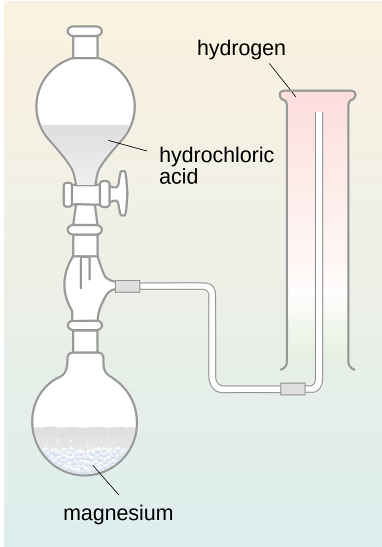

Figure 2.17 The reaction between magnesium chippings and hydrochloric acid produces a gas, which is collected as shown.

How does the position of the gas jar differ from that shown in Figures 2.13 and 2.16? Can you suggest a reason for the difference?

The jar is now upside down, showing that the gas produced in the reaction must be less dense than air. The tube carries the incoming gas to the base of the jar which is now uppermost. The light gas accumulates, thereby filling the jar from the top down: the gas is collected by *downward displacement of air*.

The gas in question is called hydrogen. *Acids react with magnesium to give hydrogen*.

Many other metals, zinc for example, also liberate hydrogen from acids. Hydrogen has the lowest density of all known substances (Figure 2.18). It explodes if mixed with air in a confined space and ignited, and this property can be used as a test for the gas (Figure 2.19). When exposed to plenty of air it burns quietly when lit. Because of this flammability, hydrogen is no longer used as a lifting-gas for airships (Figure 2.20).

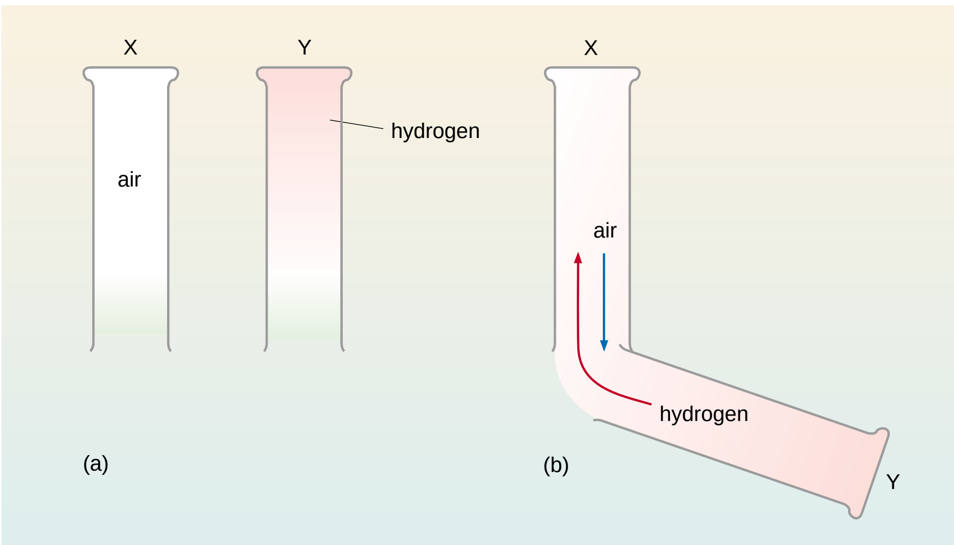

Figure 2.18 Hydrogen gas has a density only one-fifteenth that of air. It can therefore be poured upwards. In (a), the jar Y initially contains hydrogen; the jar X contains air. The upward pouring shown in (b) causes the hydrogen to move from Y to X, pushing the air in X downwards and out.

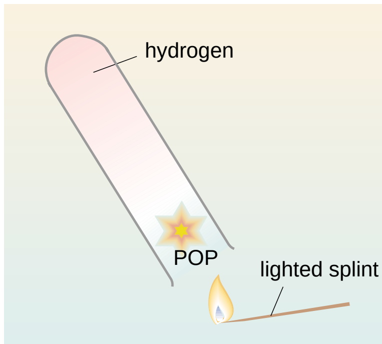

Figure 2.19 A simple laboratory test for hydrogen: the gas burns with a squeaky pop.

* The same reaction occurs with nitric acid, but only if the acid is *very* dilute. If this is not so, the reaction is of a different type.

Question 2.6 Vinegar turns blue litmus red. Predict two other chemical reactions that you would expect it to take part in. ◀

Questions: answers and comments

Question 2.6 As vinegar turns blue litmus red, it is an acid. It should therefore also react with limestone to give carbon dioxide, and with magnesium to give hydrogen. And it does, although the reactions are fairly slow.