6. AIR

6.1 INTRODUCING AIR

Are the bottle and the glass on the table empty? Most people would say "Yes!" but of course we know that they are really full of air. Air is invisible. Usually we cannot feel it but we are aware of it, for example, when we breathe hard, or when we fan ourselves. When we run fast, we can sometimes feel the air holding us back. And when the wind blows, we can feel the air on our face, and see it disturbing the leaves on the trees or the dust on the ground.

Here is a practical puzzle for you. It is easy to pour a liquid from a bottle into a glass, but how can you pour air from the bottle into the glass? The answer is given in the box at the bottom of this page, but think about it before you look!

We often forget about the air because it is a gas, and gases are very "thin". There seems to be hardly anything there, except when a very strong wind blows. Compared with solids and liquids, gases have a very low density. As we learnt in Chapter 3, the density of anything is the mass of one unit volume, usually 1 cm\(^3\). Iron has a density of about 8 g/cm\(^3\), water is 1 g/cm\(^3\) and most kinds of wood are between 0.8 and 0.5 g/cm\(^2\). But the density of air is only about 0.001 g/cm\(^3\). It is 1000 times less dense than water. A whole litre of air (1000 cm\(^3\)) has a mass of about 1 g (about the mass of a very tiny coin).

When you push in the handle of a bicycle pump or a syringe, you can feel the air shooting out of the end. But what happens if you close the end, for example with your finger? Try it and see. The air inside the pump or the syringe can be compressed (squeezed into a smaller space) but you can feel it pushing back against the handle. It stops you from pushing the handle all the way down. Even though the air has a very low density, and is compressible, it is definitely there! Air gets in the way of anything that moves. When a truck or a plane tries to go fast, its speed is limited by the force of the air pushing back against it. The wind is simply air that is moving. In a really bad storm, like a cyclone or a hurricane, the force of the moving air can damage even strong modern buildings.

In this chapter, we will learn more about how air behaves and what it is made of. Air is not a single gas, but a mixture of many gases. Two of these gases are oxygen and carbon dioxide, which are essential for life on earth. We will learn how they are used by man and by other living things. We will also learn how they are recycled so that they never run out.

Pouring air into a glass. You can easily pour air from a bottle into a glass. But you have to do it under water, and you have to pour the air upwards! You will need a large bowl of water. Study the diagrams, then try it yourself.
6.2 AIR PRESSURE

The Earth is covered by a layer of air called the atmosphere. The higher we go above the surface of the Earth the less air we find. On top of the highest mountains, which are more than 8 kilometres high, there is hardly enough air to breathe.

Air has a very low density, but it does have some mass! At sea level, near the surface of the Earth, a litre of air has a mass of about 1 gram. Even at the top of Mount Everest (8850 m - the highest mountain in the world), a litre of air has a mass of about half a gram. All this air presses down on the surface of the Earth with a force of about 1 kg on every cm$^2$ at sea level. This pressing force of the atmosphere is called air pressure, or sometimes atmospheric pressure.

Atmospheric pressure is like water pressure, it pushes equally in all directions. Because of this, we do not notice it most of the time. The diagrams and notes below illustrate some of the things that atmospheric pressure can do. Try some of them for yourself. Try to understand how they work.

When you stop to think how much air there is, it is not surprising that the atmosphere can hold up the water in a bottle. In fact, it can hold up a column of water almost 10 m high! In Chapter 10 you will learn how we use atmospheric pressure for pumping water. Surprisingly, we do not usually notice air pressure at all! That is because the pressure inside most things, including ourselves, balances the pressure outside.

Air pressure and the weather. Air is always moving and atmospheric pressure varies slightly from place to place and from time to time. Measuring air pressure helps meteorologists to predict the weather. Low atmospheric pressure usually means wet, stormy weather, and high pressure means calm, sunny weather. The wind always blows from high pressure to low pressure areas.

- 1. At sea level, what is (i) the mass of 1 m$^3$ of air, (ii) the force of atmospheric pressure on 1 cm$^2$?
- 2. Why are we not crushed by the weight of the air?
- 3. What is a scientist who studies the weather?
- 4. To pour milk from a sealed tin, we make two holes in the lid. Why does it not pour if there is only one?
- 5. Water pressure increases as a diver swims downwards under water (Chapter 3). What happens to air pressure as you climb upwards on a high mountain? Explain the difference.

The mass of the air. Every litre of air has a mass of 1 g. A litre is 1000 cm$^3$. There are 100 cm in 1 metre, so 1 m$^3$ = 100 x 100 x 100 = 1000000 cm$^3$ = 1000 l. So 1 m$^3$ has a mass of 1000 g or 1 kg.

Let's try to estimate the mass of the air in a classroom. If the classroom is 6 m wide, 7 m long and 3 m high, its volume is 6 x 7 x 3 = 126 m$^3$. So the mass of the air in the classroom is 126 kg. Only a very strong man can lift 126 kg. That is about the same mass as 3 large bags of cement.
6.3 THE COMPOSITION OF THE AIR

Living things, including ourselves, need air to breathe. Fire also needs air to burn. What makes air so important for both life and fire? Try the activity described in the box.

An activity with a candle burning in air

**Activity:** Fix a short piece of candle in the middle of shallow bowl. Pour a few cm of water into the bowl and light the candle. Wait a few minutes until the candle is burning strongly. Place a glass jar over the burning candle (Figure 1). Observe carefully what happens.

**Observations:** The flame gets smaller and goes out. Then the water in the bowl rises a few cm up into the glass jar (Figure 2).

**Think about these observations:** Try to explain what has happened. This is called *interpreting* the observations.

In the activity, the water rises into the jar because the flame on the candle has used up (consumed) part of the air inside the jar. About one fifth (20%) of the air is used up and then the flame goes out. The part of the air that is used up during burning is a gas called oxygen.

Air is a mixture of several gases. The composition of dry air (by volume) is given in the table opposite. Nitrogen (79%) is the largest constituent of the air, and oxygen (20%) is the second largest. Oxygen takes an active part in both breathing and burning. Both these processes consume oxygen.

In addition to nitrogen and oxygen, air also contains about 1% of "inert gases" and a very small percentage of carbon dioxide (0.04%). There are several inert gases - one of them is argon which is used to fill light bulbs (see Module 4.5). Although the percentage of carbon dioxide in the air is small, it does a very important job as we will see later in this chapter. Life on Earth would be impossible without carbon dioxide in the air.

- 1. Name (i) the most abundant gas in the air, (ii) the gas which supports breathing and burning, (iii) the gas used to fill simple light bulbs. Why are light bulbs not filled with air?

- 2. Try to find the names of all the inert gases.

<table>
<thead>
<tr>
<th>Name of gas</th>
<th>% by volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>nitrogen</td>
<td>79%</td>
</tr>
<tr>
<td>oxygen</td>
<td>20%</td>
</tr>
<tr>
<td>inert gases</td>
<td>1%</td>
</tr>
<tr>
<td>carbon dioxide</td>
<td>0.04%</td>
</tr>
</tbody>
</table>

Composition of dry air (by volume)

Water vapour in the air: In addition to the gases in the table above, air also contains water vapour. In very dry regions, the percentage of water vapour is usually very small. In very wet climates, about 4% of the air may sometimes be water vapour.
6.4 OXYGEN

Oxygen comprises about 20% of the air by volume. We use oxygen gas when we breathe and when we burn anything. Without oxygen, the air would not support life or fire.

**Laboratory preparation of oxygen.** We can obtain small quantities of oxygen in a school laboratory as shown in the diagram below.

![Diagram of laboratory preparation of oxygen]

Purple crystals of potassium permanganate are heated in a test tube. The crystals give off oxygen gas and a dark brown mixture is left in the test tube. The following equation summarises what happens:

\[
\text{potassium permanganate} \rightarrow \text{dark brown mixture} + \text{oxygen gas}
\]

The oxygen gas passes down a delivery tube and bubbles up through water in a basin. We can collect the bubbles of oxygen over water in another test tube, which must start off full of water. When the test tube has filled up with oxygen, it can be sealed with a rubber stopper before it is removed from the water.

**Properties of oxygen.** The characteristics of a substance are called its properties. The properties of a substance include its appearance, density, solubility in water and so on, and also how it behaves with other materials. Oxygen is a gas that has no colour, no smell and no taste. It dissolves slightly in water and is slightly denser than air. Oxygen supports burning (combustion) and most other substances either burn in oxygen or interact with it in other ways. Oxygen also supports life through the process of respiration. Combustion and respiration are discussed later in this chapter.

**A test for oxygen.** Sometimes we may collect a gas and not be quite sure what gas it is! If we think it may be oxygen, we can test the gas with a splinter of wood or a piece of string. The test for oxygen is illustrated on the right. First we set fire to the end of the splinter or the string. When it is burning well, we blow it out again, but the end continues to glow for a short time. Now we push the glowing end into the gas we want to test. If the gas is oxygen, the glowing splinter or string bursts into flame again.

- 1. What are the properties of a substance? Which two important properties of oxygen are illustrated in the pictures in Module 6-6?
- 2. In the equation, what do you think the arrow means?
- 3. Name three substances that produce oxygen when heated.
6.5 CARBON DIOXIDE

Carbon dioxide gas comprises only about 0.04% of the air by volume, but it is essential for life on Earth. Plants need carbon dioxide from the air to make their food, and without plants there would be no animals.

**Laboratory preparation of carbon dioxide.** We can make small quantities of carbon dioxide for experiments in a school laboratory as shown in the illustration below.

A dilute solution of hydrochloric acid is added to marble chips in a conical flask. The mixture *effervescence* (fizzes) and bubbles of carbon dioxide gas are given off. The gas passes through a delivery tube and is collected over water.

Marble is made of calcium carbonate. If marble chips are not available, other materials that contain calcium carbonate may be used instead. These include sea shells, coral and limestone.

The laboratory preparation of carbon dioxide can be summarised by the following equation:

\[
\text{hydrochloric acid} +\text{calcium carbonate} \rightarrow \text{colourless solution} + \text{carbon dioxide gas}
\]

**Properties of carbon dioxide.** Carbon dioxide has no colour, no smell and no taste. It is moderately soluble in water. Carbon dioxide is a heavy gas that is much denser than air. Because of its high density and solubility in water, carbon dioxide is sometimes collected by *displacement of air* as shown below.

The most important property of carbon dioxide is that plants use it to make food in a process called *photosynthesis*. You will study photosynthesis later in this chapter. Carbon dioxide does not burn and it does not support combustion (it does not allow things to burn in it). The experiment illustrated shows carbon dioxide gas being poured over a burning candle. The heavy gas forms a "blanket" over the flame, which goes out because it cannot get oxygen.

**A test for carbon dioxide.** To test for carbon dioxide you need a colourless solution called lime water. You can add a little lime water to the gas in a test tube and then shake it well. Or, you can pass the gas down a delivery tube and make it bubble through the lime water. In either case, a white suspension is formed and the lime water becomes cloudy. (But note that, if carbon dioxide is bubbled through lime water for a long time, the lime water becomes clear again).

- 1. At the top of this page we said that "without plants there would be no animals." Explain why this is so.

- 2. List four materials that contain calcium carbonate.

- 3. (i) Study the diagram that shows the collection of carbon dioxide by *displacement of air* and explain how this process works. (ii) If carbon dioxide is bubbled through lime water for a long time, what would you observe after (a) a short time, (b) a long time?
6.6 USING OXYGEN AND CARBON DIOXIDE

Several industries use oxygen and carbon dioxide. Oxygen is simply extracted from the air, but carbon dioxide has to be manufactured from other materials.

**Extraction of oxygen.** In industry, oxygen is extracted from the air in a very interesting way. The air is cooled down to below -200°C; more than 200 degrees below zero. At that temperature air condenses into a liquid! The liquid air is then distilled to separate the different gases. Liquid oxygen boils (changes back into a gas) at -183°C. The pure oxygen gas is compressed into large cylinders.

**Uses of oxygen.** Pure oxygen is used in hospitals to help sick people and accident victims who have breathing problems. Other gases, such as acetylene and hydrogen, are mixed with pure oxygen and burnt in special torches to obtain very hot flames for cutting and welding metals. Large quantities of oxygen are also used to burn away impurities when steel is manufactured.

**Manufacture of carbon dioxide.** Carbon dioxide is manufactured in many ways. The most important methods are (i) heating limestone, (ii) burning materials that contain a lot of carbon (for example coal or charcoal), and (iii) as a *bi-product* when making beer.

**Uses of carbon dioxide.** The most familiar use of carbon dioxide is in fizzy drinks. These all contain carbon dioxide dissolved under pressure. When the top is removed from the bottle, the pressure is released and the carbon dioxide rises to the surface as tiny bubbles.

Some fire extinguishers use carbon dioxide. These put out fires by squirting a foam, which contains the heavy gas, over the flames. Carbon dioxide is also used to make ‘dry ice’ for keeping food cool and for making many other chemicals, including washing soda for soap powders.

- 1. Oxygen is obtained by distilling liquid air. (i) How is liquid air obtained? (ii) What is distillation? (iii) How is oxygen stored? (iv) List three ways technology uses oxygen.
- 2. Carbon dioxide is sometimes obtained as a *bi-product* during the making of beer. (i) What is a *bi-product*? (ii) List four ways technology uses carbon dioxide.

---

*Nurse learns to use an oxygen mask*  
*Oxy-acetylene welding*

**Dry ice** is carbon dioxide that has been cooled down until it becomes solid. It looks like ordinary ice but is much colder. It evaporates back to carbon dioxide gas without melting at –78°C. It is used to keep food cold, for example by mobile ice cream sellers.
6.7 NITROGEN AND THE INERT GASES

Nitrogen is the most abundant gas in the atmosphere; it accounts for 79% of the air by volume. Nitrogen can be obtained from the air in the same way as oxygen. The air is first liquefied by cooling it to below −200°C and then it is distilled. Liquid nitrogen boils (changes back into a gas) at -196°C. Nitrogen is not usually prepared in schools so we will not describe a laboratory preparation here.

Properties and uses of nitrogen. Nitrogen has no colour, smell or taste. It has almost the same density as air and is almost insoluble in water. It does not burn and it does not interact easily with other materials. However, in combination with other substances (mainly carbon, oxygen and hydrogen) it is present in all living things. In the chemical industry, nitrogen is used mainly to make fertilisers to feed plant crops, and to make explosives for quarrying and mining. These explosives include dynamite which was invented by Alfred Nobel (see Module 1.9).

The inert gases. There are six inert gases. Together they make up almost 1% of the Earth's atmosphere. The table shows their names, densities and percentages by volume in the air. They are all colourless, odourless and tasteless and they do not dissolve in water. They are called inert gases because they do not burn or interact very much with other materials. The inert gases can be extracted from the air in various ways. Helium is also found in, and extracted from, the fuel gases associated with oil wells.

The three lightest inert gases are the most useful. Helium is the second lightest gas known and is much less dense than air. It is used to fill balloons, which can go up into the atmosphere. Neon is used to fill the special strip lights used in advertising signs. The neon gas glows with a bright orange colour when the light is switched on. Argon is used for filling ordinary light bulbs and ordinary strip lights - if air was used, hot parts (such as the filament) would burn away. Both helium and argon are also used to replace air in certain industrial processes when it is necessary to keep oxygen away.

1. Why does nitrogen have almost the same density as air?
2. Describe the main differences between the properties of nitrogen and the properties of oxygen.
3. (i) What is the density of air in g/l (see Module 6.2)? (ii) Which of the inert gases are less dense than air?
4. Give two uses each for helium and argon. Explain why each one is suitable for each of these uses.

<table>
<thead>
<tr>
<th>Name</th>
<th>Density g/l</th>
<th>% by volume of air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium</td>
<td>0.2</td>
<td>0.0005</td>
</tr>
<tr>
<td>Neon</td>
<td>0.9</td>
<td>0.0018</td>
</tr>
<tr>
<td>Argon</td>
<td>1.8</td>
<td>0.9340</td>
</tr>
<tr>
<td>Krypton</td>
<td>3.8</td>
<td>0.0011</td>
</tr>
<tr>
<td>Xenon</td>
<td>5.9</td>
<td>0.00001</td>
</tr>
<tr>
<td>Radon</td>
<td>9.7</td>
<td>very little</td>
</tr>
</tbody>
</table>
Combustion means burning. Three things are needed for combustion (i) a fuel (something to burn), (ii) sufficient heat (to start the fire and keep it going), and (iii) sufficient oxygen (usually from the air).

Fuel: Anything that can burn is said to be flammable - it can become the fuel for a fire. Wood, charcoal and coal are common fuels used for cooking and heating at home. They are all flammable. Paper, cardboard, dry grass and leaves are all flammable too. They are often used for starting fires. Liquid fuels such as kerosene and methylated spirits (alcohol) are used in some cooking stoves. Some modern cooking stoves use fuel gases, which are supplied in cylinders. In many cities, fuel gases are supplied to homes through pipes. In an accidental fire (like the bush fire and house fire above) anything flammable may become a fuel.

Heat: A fire needs enough heat to get it started and keep it going. The heat for lighting a fire is often obtained by striking a match. Once it is burning, the fire makes its own heat - it will keep going as long as there is fuel and oxygen.

Oxygen: When something burns, it combines (joins) with oxygen from the air. Most fuels contain two main elements, carbon and hydrogen. You will learn about elements in Chapter 9. When a fuel burns, the carbon joins with oxygen to form carbon dioxide gas, and the hydrogen joins with oxygen to form steam. We can summarise the process of combustion in this equation:

\[
\text{fuel} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{steam} + \text{heat}
\]

Fuels that are liquids and gases burn almost completely so that nothing obvious remains. Solid fuels usually contain some parts that will not burn. These parts remain as ashes or may be suspended in the air as smoke.

1. (i) What does flammable mean? (ii) Name a flammable liquid. (iii) List three conditions that are necessary for combustion.
2. (i) What is a fuel? (ii) Name the two main elements in most fuels. (iii) What are the three main products of combustion; state how could you detect each of them?
3. What are (i) a flame, (ii) ash, (iii) smoke (iv) soot?
4. The pictures at the top of the page show a bush fire in the countryside and a domestic fire in a town. Describe how such fires may be started accidentally. Explain how such fires could be prevented. Write a story about a fire.

Flames

People used to think flames were very mysterious. Now we know that flames are simply burning vapours. The heat of a fire is enough to turn even solid fuels into vapours. These vapours burn in oxygen from the air. Tiny unburnt particles, usually carbon, become so hot that they glow and give the flame a yellow colour. These particles may escape as smoke, or cool down and condense on nearby surfaces as black soot. Soot is composed mainly of carbon.
6.9 EXTINGUISHING FIRES

We learned in the last section that a fire needs fuel, heat and oxygen. These three are sometimes called the fire triangle. To put out, or extinguish, a fire we must deprive it of at least one of these three.

Excluding air. Small accidental fires can usually be extinguished by excluding air so that the fire can not get oxygen. We say the fire is smothered. If a person’s clothing catches fire and burns strongly, the best solution is to wrap the person quickly in a blanket. This smothers the fire and it goes out at once. If a cooking pan of oil catches fire, we should cover it quickly with a lid. Similarly if a fuel such as kerosene spills and catches fire, we should smother it quickly with a thick blanket. School labs sometimes have fire blankets made of non-flammable materials. Covering a small fire with sand or soil may also be a good way to smother it.

Using water. Water is often used to extinguish accidental fires at home or in the bush. If there is enough water, the fire is extinguished in two ways. The water cools the fire by evaporation (see Module 3.4), and the water vapour that forms displaces the air around the fire and smothers it.

Water should not be used to extinguish burning liquids or electrical fires. Liquids such as cooking oil, kerosene and petrol (benzene) all float on water. If they are burning, water will spread the fire, not put it out! Water can conduct electricity so, if a fire is caused by an electrical appliance or faulty electric wiring, water may make the fire worse. There will also be a danger of electric shocks. For an electrical fire, first switch off the electricity (if that can be done fast) and then use one of the extinguishers described below.

Commercial fire extinguishers. The diagrams and notes below show three common types of commercial fire extinguishers. Study them carefully and try to understand how they work. Another important kind (not illustrated) is the foam extinguisher; this squirts a heavy carbon dioxide foam to cool and smother the fire.

When pressure is released, carbon dioxide evaporates fast. As the gas escapes, it cools to a snow-like solid (-79°C). It extinguishes the fire by cooling and smothering.

Liquid carbon tetrachloride, which is non-flammable, is sprayed onto the fire. It evaporates forming a heavy, non-flammable vapour that smothers the fire.

Dry sodium bicarbonate powder is sprayed onto the fire. It decomposes forming carbon dioxide and steam, which also help to smother the fire.

1. What is (i) smothering a fire, (ii) a fire blanket?

2. How would you extinguish the following? (i) burning oil in a saucepan, (ii) a camp fire, (iii) an electrical fire.

3. When we are burning grass, we sometimes control the spread of the fire by beating the flames with flat brooms made of twigs. Use what you know about the fire triangle and flames, to explain how you think this works.
6.10 CORROSION AND RUSTING

Metals do not usually burn! However, most metals are slowly spoilt by oxygen when they are exposed to the atmosphere for a long time. The surface of the metal becomes dull and coated with a sort of "ash". Eventually parts of the metal may crumble away. This is called the corrosion of metals.

Iron and steel (steel is just iron with small amounts of other elements dissolved in it) are metals which are widely used in modern technology: in bridges, railway lines, ships and machines, in the reinforcing rods that strengthen concrete buildings, in corrugated iron roofs, and in steel rails and fences. Unfortunately, iron and steel corrode quite quickly. The surface of the metal becomes uneven and covered with a crumbly red substance called rust. If rusting is not prevented, parts of the metal will crumble away completely!

Rusting is like combustion, except that it happens much more slowly and does not involve heat. The iron combines with oxygen from the air to form rust. The chemical name for rust is iron oxide.

\[
\text{iron} + \text{oxygen} \rightarrow \text{rust (iron oxide)}
\]

It has been observed that iron rusts only when water is present in addition to oxygen (see the experiment below). Because of this, iron and steel can be protected by paint. Paint keeps water away from the surface of the metal. Sometimes iron or steel is galvanised. This means it is covered with a thin layer of another metal called zinc, which protects the iron. Galvanised iron is often used for roofs.

Experiment to show that air and water are both needed for rusting

Find three glass jars (or test tubes) that you can seal so no air can get in or out. Label the jars A, B and C. Put two iron nails in each. Add silica gel to A - this keeps the air dry. Fill B to overflowing with water that has been boiled for several minutes to remove all the air dissolved in it. To C, add just a little water. Seal all three jars very tightly. Observe every day for a week.

What did you observe? Only the nails in jar C go rusty! Both air and water together are necessary for rusting to occur.

- 1. Explain the terms corrosion, rust, galvanised.
- 2. People who live on the coast complain that their cars go rusty very quickly. Someone says it is because of salt from the sea. Describe how you could add to the experiment above to find out if it is true that salt makes iron rust quicker. Predict what you would observe if it is true.
6.11 BREATHING AND RESPIRATION

We all have to breathe to stay alive! We *inhale* (breathe in) and *exhale* (breathe out) approximately 10 to 20 times every minute. We breathe faster when we are working hard and slower when we are relaxing or sleeping. However, the air we exhale is not the same as the air we inhale. In the box are some simple activities you can try to find out about these differences.

### Finding out about differences between inhaled and exhaled air

1. **Carbon dioxide:** Carbon dioxide turns lime water milky. Breathe in gently through the tube in flask A below. The air you inhale bubbles through the lime water first. Even after many breaths the lime water does not go milky. Now breathe out gently through the tube in flask B. The air you exhale bubbles through the lime water. After a number of breaths, the lime water in flask B goes milky. So exhaled air contains more carbon dioxide than inhaled air.

2. **Water vapour:** Breathe out onto a clean cold mirror for a few seconds. Then look carefully at the mirror. The surface becomes a bit cloudy. It is covered with tiny droplets of water which have condensed from the air you exhaled. Exhaled air contains more water vapour than inhaled air.

3. **Temperature:** Use a laboratory thermometer to read the temperature of the air. Then exhale onto the bulb of the thermometer several times while a friend reads the temperature again. You will observe that the temperature of the exhaled air is greater than that of the inhaled air.

As you can see from the experiments, the air we exhale is different from the air we inhale. It contains less oxygen, more carbon dioxide and more water vapour as shown in the table on the right. It is also warmer than inhaled air. These changes are due to a process called *respiration* which takes place inside our bodies. As you learned in Chapter 2, respiration is a characteristic of all living organisms – including plants (and the other kingdoms) as well as animals. It provides the energy they need for all the processes of life. Oxygen from the air, and food consumed by the organism, are changed into carbon dioxide, water and energy.

Respiration can be summarised by the following equation:

\[
\text{food} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water} + \text{energy}
\]

This is almost the same as the combustion equation – look back at Module 6.8 and see for yourself! We can say that respiration is like a very slow kind of combustion. Respiration uses the *food* of an organism in place of fuel, and produces many kinds of *energy* as well as heat.

<table>
<thead>
<tr>
<th>Component</th>
<th>Inhaled air</th>
<th>Exhaled air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>20%</td>
<td>16%</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>0.04%</td>
<td>4%</td>
</tr>
<tr>
<td>Water vapour</td>
<td>a little</td>
<td>much more</td>
</tr>
</tbody>
</table>

**Composition of inhaled and exhaled air**

**Respiration in different organisms:** Only mammals, birds, reptiles and amphibians breathe by inhaling and exhaling air as we do. Other organisms have different ways of obtaining the air they need for respiration.

---

- 1. What is meant by (i) *breathing*, (ii) *respiration*?
- 2. Which of the following breathe and which respire? *cows, algae, ants, grass, bacteria, mould, fish, trees, frogs.*
- 3. Why do you think we breathe faster when we are working hard and slower when we are sleeping?
- 4. What fraction of the oxygen that we inhale, do we actually use?
6.12 PHOTOSYNTHESIS

An important difference between animals and plants is that plants make their own food by a process called photosynthesis. Plants take in carbon dioxide gas from the air through their leaves and water from the soil through their roots. During photosynthesis, the carbon dioxide and water are combined to make a food called starch. Oxygen is released as a bi-product.

The process of photosynthesis uses energy, which the plant absorbs from sunlight. Sunlight energy is absorbed by a green substance, in the leaves, called chlorophyll. Chlorophyll is found in chloroplasts in most plant cells (see Module 5.3). Photosynthesis is illustrated in the diagram on the right and is summarised in the equation below.

Starch: Starch is a white substance that is the basis of many important foods. Foods which contain a lot of starch are (i) grain products like rice, corn (maize), bread and flour and (ii) vegetable crops such as yam, cassava (manioc), potato, sweet potato and plantain.

A test for starch: To find out if something contains starch, add a drop of iodine solution. If starch is present, a dark purple stain will be seen.

\[
\text{carbon dioxide} + \text{water} + \text{energy} \rightarrow \text{food (starch)} + \text{oxygen}
\]

Before you read on, compare the photosynthesis equation above with the respiration equation on the previous page. Notice that the photosynthesis equation is the respiration equation backwards! We will discuss the importance of this in the last section of the chapter. The word photosynthesis comes from two ancient Greek words phot (light) and sunthesis (to make). In the box below are some experiments that are often used in schools to confirm some facts about photosynthesis.

1. To show that chlorophyll is needed for photosynthesis:
   (i) Find a variegated leaf (partly green, partly white). (ii) Place the leaf in a test tube of alcohol. Place the test tube in a beaker of very hot water for 5 minutes. This softens the leaf and dissolves the green chlorophyll. (iii) Remove the leaf and test it with iodine solution. Result and interpretation: Only the parts of the leaf that were originally green, go purple. So starch was formed only where there was chlorophyll. No chlorophyll, no photosynthesis!

2. To show that light is needed for photosynthesis:
   (i) Partly cover a green leaf on a growing plant with a strip of black paper or kitchen foil. Wait three days. (ii) Prepare the leaf as in part (ii) of experiment 1. (iii) Remove the leaf and test it with iodine solution. Result and interpretation: Only the parts of the leaf that were NOT covered go purple. So starch was formed only where the leaf was exposed to light. No light, no photosynthesis!

3. To show that oxygen is formed during photosynthesis:
   (i) Put two green water plants under funnels in beakers of water. Invert a test tube full of water over each funnel. (ii) Leave one plant in a sunny place and the other in a dark cupboard for several days. (iii) Test any gas collected for oxygen. Result and interpretation: Only the plant exposed to sunlight makes oxygen. So photosynthesis makes oxygen. No photosynthesis, no oxygen!

- 1. Explain fully what you understand by the word photosynthesis.
- 2. Why do you think it is so important for life on Earth that photosynthesis is the reverse of respiration?
6.13 THE OXYGEN AND CARBON CYCLES

The oxygen cycle. All living things need oxygen for respiration. Oxygen and food are converted into energy and carbon dioxide. Combustion does almost the same thing. So why does the oxygen in our atmosphere never run out? And why does the percentage of carbon dioxide always remain about the same? The answer is photosynthesis. Green plants change the carbon dioxide back into oxygen. In the natural world there is a perfect balance between these opposite processes. As fast as respiration and combustion use up oxygen and make carbon dioxide, photosynthesis uses up the carbon dioxide and makes oxygen again. This is shown in the following diagram of the oxygen cycle.

![Oxygen Cycle Diagram]

The carbon cycle. An important difference between animals and plants is that plants make their own food. During photosynthesis, plants use energy from the sun to convert carbon dioxide into food (starch) and oxygen. Animals depend on plants for their food. If they are herbivores they eat the plants themselves. If they are carnivores, they eat herbivores. In the end they both depend on plants for their food (see Module 2.8 to remind yourself about food chains).

Carbon dioxide contains two elements, carbon and oxygen; water also contains two elements, hydrogen and oxygen. Photosynthesis converts carbon dioxide and water into food (starch) and releases oxygen back into the air. All living things contain a lot of carbon - in fact carbon is one of the main things that they are all made of! So all living things need plenty of carbon in their food. In the previous section you learnt how the oxygen we need for respiration is recycled so that it never runs out. The carbon we need to build our bodies is recycled in a similar way. Study the diagram of the carbon cycle on the next page - can you see how it works? It is a bit more complicated than the oxygen cycle. It involves food chains as well as respiration, combustion and photosynthesis.

An activity to show that all living things contain carbon: You will need a small container, with a narrow neck to keep out too much air, which you can heat very strongly. A test tube would be very good. Place any animal or plant material in the container – twigs, leaves or food items such as rice, meat or fish would be suitable. Heat the material as strongly as you can for a long time. Observe what happens and examine the remains in the container. You will find a black residue of carbon in the form of charcoal. This shows that living things contain plenty of carbon.
Plants use photosynthesis to convert carbon dioxide and water into a simple food called starch. They use the starch (together with water and minerals from the soil) to make every part of themselves. The starch contains all the carbon from the carbon dioxide. Food chains show how animals depend on plants for their food. They use this food to make every part of themselves. When plants and animals respire, they convert carbon from their food into carbon dioxide, which escapes into the air. Similarly, when animals or plants die they decay, or they are burnt, and their carbon is converted into carbon dioxide. When plants use this carbon dioxide for photosynthesis the cycle is complete! The carbon goes round and round the cycle but never runs out.

The carbon cycle and energy. Why do all living things respire? They respire to obtain the energy they need for all their life processes - moving and growing, feeding and reproducing and everything they do. So where does all this energy come from and why does the energy never run out? The answer can be found in the diagram of the carbon cycle. The energy comes from the sun! Plants use energy from sunlight when they make food by photosynthesis. Animals obtain the food the plants have made through food chains. Finally, all living things obtain energy by 'burning' food during respiration. So the energy of living things is not recycled like oxygen and carbon - it all comes from the sun. Fortunately the sun is so huge that we are not likely to run out of energy for many millions of years!

1. Name the two elements in carbon dioxide. Where else can each of these elements be found?
2. In the oxygen and carbon cycles, name the processes that (i) use oxygen, (ii) use carbon dioxide, (iii) pass on carbon from plants to animals.
3. In your activity to show that living things contain carbon, why do you think is it important to keep out too much air while you are heating?
4. Why do plants photosynthesise and why do all living things respire?