11.5 Gas Applications

Section Preview/ Specific Expectations

In this section, you will

- **identify** technological products based on compressed gas
- **describe** how a knowledge of gases is used in other areas of study
- **communicate** your understanding of the following term: *fuel cell*

In the previous section, you learned about the colourless, odorless mixture of gases that make up the atmosphere. It is easy to take the air around us for granted. You know that you need oxygen to breathe, but does it serve any other purposes? Nitrogen is not required for respiration, but it composes about four-fifths of our atmosphere. Is nitrogen a "useless" gas? In this section, you will learn about how gases are used. You will find out more about oxygen and nitrogen, and discover the importance of gases in deep-sea exploration.

Compressed Oxygen

You may never really think about breathing—until it becomes hard to do. In certain situations, normal human respiratory functions are disrupted. Hospitals use compressed oxygen for patients with respiratory disorders such as emphysema, pneumonia, or lung cancer.

You may have heard of hyperbaric oxygen (HBO) chambers being used to treat sports injuries. A high oxygen concentration in the blood causes blood vessels to constrict. This lowers the swelling that can occur in injured tissues. How is this high oxygen content delivered to the blood? In an HBO chamber such as that shown in Figure 11.28, air is compressed to three times normal atmospheric pressure. The patient breathes pure oxygen ($O_{2(g)}$) through a mask. The highly compressed air forces $O_{2(g)}$ in the lungs into the blood. This increases of dissolved $O_{2(g)}$ in the bloodstream. Consequently, oxygen is delivered rapidly to all the blood vessels of the body. In fact, oxygen can reach the injured tissue at 15 times the normal rate!

The use of compressed oxygen can benefit not only athletes, but also vulnerable premature babies. Premature babies can be afflicted with hyaline-membrane disease. This condition prevents the alveoli in their lungs from inflating, which leads to serious breathing difficulties. Placing these babies in an oxygen-rich environment such as an HBO or an incubator (Figure 11.28) helps inflate the alveoli. This increases the infants' chances for survival.

Figure 11.28 Medical applications of pressurized oxygen can help the very strong, the very weak, and everyone in between.

Oxygen at High Altitudes

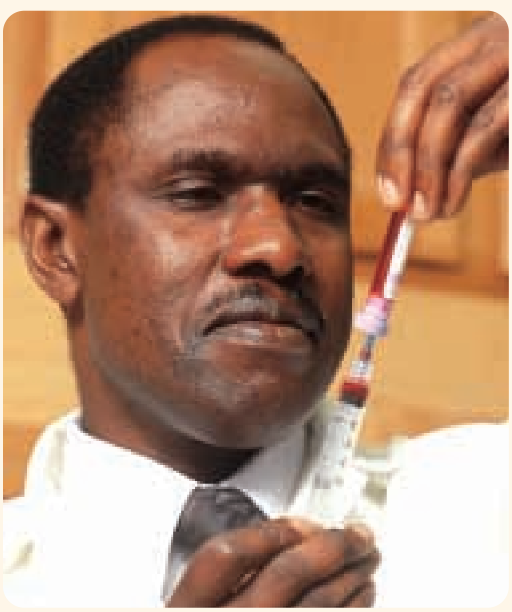
At other times, respiratory functions may be normal, but the environment poses problems. Commercial jet planes fly at an altitude of around 9.5 km. Airplanes carry pressurized oxygen for their passengers to breathe as they fly at high altitudes. Mountain climbers also need compressed oxygen when climbing to great heights. Those exploring ocean depths need oxygen as well. Scuba divers and submarine crews need compressed oxygen to breathe when they are underwater. You will learn more about undersea exploration later in this section.

Careers in Chemistry

Cancer Research Specialist

The National Cancer Institute of Canada estimates that in the year 2000 there were more than 132 000 new cases of cancer and 65 000 deaths caused by cancer in Canada. People are desperate for treatment.

Dr. Abdullah Kirumira, President and lead scientist at BioMedica Diagnostics in Windsor, Nova Scotia, has developed a way to speed up drug testing. This method uses compressed carbon dioxide and a dry chemistry diagnostics system including the firefly enzyme, luciferase.



Growing Cancer Cells for Testing

To obtain a consistent supply of cancer cells to test, CO_2 is pumped from a compressed gas cylinder. It is depressurized through a regulator into a specially designed incubator kept at about 37°C, the optimum temperature for cell growth. This CO_2-enriched atmosphere plays two roles:

- it is required for rapid cellular metabolism; and
- it interacts with a bicarbonate buffer in the growth medium to maintain an optimum pH balance.

Global Ties

In 1975, during the reign of dictator Idi Amin, Dr. Kirumira fled his native Uganda to Iraq, where he earned a B.Sc. in food technology. He then travelled to England for a Master's degree in dairy chemistry. From there, he moved to Australia where he earned his Ph.D. in biotechnology. In 1990, he and his wife moved to Nova Scotia in search of a slower-paced lifestyle.

At BioMedica, Dr. Kirumira oversees 12 employees, six of whom have advanced degrees, three technicians and three administrators. In addition, Dr. Kirumira teaches biochemistry and biotechnology at Acadia and Dalhousie Universities.

He frequently visits his home in Uganda. From Uganda, Dr. Kirumira says he can "take back what I have learnt from the West to help the people who probably need it the most."

Make Career Connections

1. To learn more about the biotech applications of using the firefly enzyme, luciferase, you can go to BioMedica's web site.
2. What universities offer degrees in biotechnology? Do research to find two universities near you that offer this program.

Web LINK

www.school.mcgrawhill.ca/resources/
CO_2 is a greenhouse gas, thought to contribute to global warming. Many countries around the world have sought to reduce their emissions of CO_2. International climate control treaties, such as the Montréal Protocol, have set targets to do this.

Since plants cycle CO_2 out of the atmosphere, several countries including Canada have argued that countries with large forest resources should be able to claim them as "carbon sinks." Rather than cutting their CO_2 emissions by the target amount, Canada and other countries maintain that they should be allowed to claim a reduction for the CO_2 absorbed by their large forests.

Research the current debate over "carbon sinks." Do you agree with the idea that CO_2 absorbed by plant life provides a valid strategy for controlling pollution? Go to the web site above. Go to **Science Resources**, then to **Chemistry 11** to find out where to go next.

Oxygen and Combustion

A fire breaks out and smoke begins to fill the room. Breathing becomes difficult. Should you open a window to let the smoke out before you leave through the door? You may have learned you should never open windows before leaving the area of a fire. A fire can only burn as long as it has sufficient oxygen. (See Figure 11.29.)

Oxygen is an extremely important gas because it supports combustion. (You will learn more about combustion reactions in Unit 5.) The more oxygen available, the hotter a fire will burn. Pressurized oxygen is used in the manufacture of steel and specialized alloys. In the manufacture of steel, oxygen is used to remove excess carbon by burning the carbon into carbon monoxide or carbon dioxide. High levels of carbon make steel too brittle for many uses.

A remarkable invention called the **fuel cell** is used by the space industry. Some fuel cells burn hydrogen and oxygen gas, leaving water as a by-product (which astronauts can then drink). Companies such as Ballard Power Systems Inc. of Vancouver, British Columbia are working to make this technology practical for automobiles. Fuel cells are completely non-polluting. However, the current process for making large amounts of hydrogen gas does create a good deal of pollution, in the form of CO_2. Coal or another hydrocarbon is used to heat up and decompose water in a reaction similar to the following:

$$CH_{4(g)} + 2H_2O_{(g)} \xrightarrow{\text{heat}} CO_{2(g)} + 4H_{2(g)}$$

Before astronauts can use the fuel cell in space, they first have to get there! Liquid oxygen is an important component of rocket fuel. Liquid hydrogen and liquid oxygen are mixed and ignited in a combustion chamber. This reaction provides a very rapid expansion of gas. It produces enough energy to lift extremely heavy rockets carrying crewed vessels, such as the Space Shuttle, into orbit (Figure 11.30).

Figure 11.29 Liquid water becomes water vapour when exposed to the heat of a fire. Firefighters must take precautions to avoid steam burns.

Figure 11.30 The large centre tank that is attached to the shuttle orbiter has two compartments, one containing liquid hydrogen and the other containing liquid oxygen. The energy released by the reaction between these two substances provides the thrust needed to propel the orbiter into space.

Nitrogen's Many Uses

Inert gases are not very reactive. The word *inert* is also a synonym for sluggish and slow. Something with the property of inertness hardly sounds useful! Yet this very property makes nitrogen extremely valuable in technological and industrial applications.

Because nitrogen gas reacts with very few substances, it can be used to blanket substances, preventing them from reacting with oxygen. (A reaction with oxygen is called oxidation.) *Blanketing* means covering something with nitrogen, displacing all of the oxygen. This usually happens in a closed container. For example, ground coffee can taste bitter when exposed to oxygen for long periods of time. Packaging coffee in a nitrogen-enhanced container helps coffee keep its flavour. Gaseous nitrogen is also used for the long-term storage of fruits such as apples, allowing us to enjoy a wide variety of produce out of season.

Liquid nitrogen's low boiling point (77 K) means that it can be used in food preservation. Foods frozen quickly in liquid nitrogen retain more nutrients than slowly frozen foods. Less damage is done to cell structure during the quick-freezing process. Freezing foods this way also removes moisture, decreasing their weight and size. Freeze-dried foods are often used by people who require easily portable, lightweight food, such as campers, the military, and space explorers.

In cryosurgery, liquid nitrogen is used to fast-freeze cancerous tissues and warts. This proven new technique kills the cancerous area and allows surgeons to safely remove the dead tissue.

Gases and Undersea Exploration

Throughout history, humans have tried to explore the little-known world of the deep seas. Even with modern diving gear, the deep oceans are a dangerous place for humans. The air that a diver breathes to stay alive underwater can itself be one of the greatest hazards. That's because of the tremendous pressure exerted by the waters above a diver. For roughly every 10 metres of depth, water pressure on the diver's body adds the equivalent of one unit of atmospheric pressure (Figure 11.31).

The air that a diver breathes (mainly nitrogen and oxygen) must equal the pressure of the surrounding water if the diver's lungs are to stay inflated. Of course, this gas pressure increases as a diver goes deeper. As the gas pressure increases, the diver's bloodstream and body tissues absorb higher and higher volumes of gases.

Beyond depths of roughly 40–60 metres, the increased volumes of gas in the diver's body can cause *nitrogen narcosis*. When nitrogen narcosis strikes, normal feelings become dangerously exaggerated. A diver may experience a blissful giddiness, along with disorientation and impaired judgement. This condition is called "rapture of the deep." Divers in this state have been known to remove their breathing apparatus to swim like fish, mistake up for down, or simply lose track of how long they have been underwater.

At the other extreme, a diver's normal sense of caution may degenerate into irrational fear or even panic. A panicked diver may do the very

Figure 11.31 At 50 m underwater, a diver experiences pressure about five times higher than normal.

worst thing—rush to the surface without pausing to decompress on the way up. Why is this dangerous?

The dissolved gases such as nitrogen in the diver's bloodstream are under pressure. This is much like the carbon dioxide that is dissolved in a can of soda. If the diver returns to the surface too quickly, these dissolved gases behave similarly to the gas in soda when a can is opened. The gases escape from the blood as bubbles in the diver's blood vessels. These bubbles can block the flow of blood. They produce a painful and potentially fatal condition called "the bends."

Both nitrogen narcosis and the bends make prolonged deep diving a risky business. They limit both the safe depth and safe duration of human diving. Even skilled professional divers rarely descend beyond about 50 metres. Also, they rarely remain at that depth for much more than 30 minutes.

Section Wrap-up

In this section, you learned about some technological products and applications involving gases. You also learned that a knowledge of gases is important in other areas of study, such as medicine and deep-sea exploration.

In Chapter 12, you will find out about the ideal gas law. This law covers the many different gas laws you explored in this chapter. You will also discover a practical application for Dalton's law of partial pressures. You will learn how to do stoichiometric calculations for reactions that consume or produce a gas. In the laboratory, you will have a chance to produce and collect a gas. At the end of the next chapter, you will examine some of the chemistry that takes place in our atmosphere.

Electronic Learning Partner

Your Chemistry 11 Electronic Learning Partner has a demonstration of CO_2 fire extinguishers and the chemistry behind their use.

Section Review

Unit Issue Prep

What gases are produced as a result of human technologies such as fuel-burning engines?

1. C Why is fuel-cell technology, in its present state, not a pollution-free alternative to the internal combustion gasoline engine?
2. K/U Describe three industrial uses for liquid nitrogen.
3. MC How might covering apples with nitrogen or carbon dioxide gas preserve them longer through the winter?
4. K/U How does a hyperbaric oxygen chamber work to assist human healing?
5. MC Look up the standard mixture of gases for scuba diving tanks. What problem arises in using nitrogen gas in scuba tanks? How is this problem solved?
6. MC What does lightning (or bacteria) do to the nitrogen in the diatomic gas in order to make the atoms useful to plants? Use what you know about compounds and elements to answer this question.
7. MC Interview the science teachers at your school. Are there any compressed gas cylinders in the school? Ask the teachers about the appropriate safety precautions for compressed gases. Then prepare a short safety report on compressed gases in your school.