Key Terms
catalyst
leaching

5.3 Reactions and Environmental Issues

An oil spill from a tanker that has run aground or from an inactive oil well makes the news because there is usually a very large area affected by the oil. As oil is released into water, it spreads over the surface in a very thin layer. A quick response is crucial for minimizing environmental harm. Oil is a mixture of many chemicals. As time passes after a spill, some of the chemicals evaporate, and the remaining chemicals become a thick, sticky mess. Cleaning up these spills involves several processes. These include initial containment, which can involve using special materials that absorb the oil, as shown in **Figure 5.18**. Subsequent steps can include using chemicals that help to break down the oil. An environmentally conscious approach includes using biological agents that hasten oil degradation. Chemical reactions that occur in the cells of these agents help to break down the molecules that make up oil into smaller, simpler, and less toxic molecules.

Thus, although chemical reactions can cause environmental issues, they can also be used to help solve environmental challenges. Begin investigating this idea by modelling a clean-up effort to remove toxic metals from a water supply in Activity 5-4.

Figure 5.18 These green pompoms are made of a special material that attracts and aborbs oil, while repelling water. Each pompom can absorb 25 times its mass in oil.

Activity 5-4

"Taking Care" of Toxic Materials

Many communities in Ontario have lead contamination in their drinking water. How can we get the lead out? In this activity, blue copper ions are used as a model for toxic lead. You will investigate one way of getting rid of a toxic material.

Safety Precautions

- Be careful with the materials. Avoid spills. If they do occur, clean them up immediately.

Materials

- 0.02 mol/L copper(II) chloride solution ("toxic" solution)
- 100 mL graduated cylinder
- two 250 mL beakers
- dropping bottle of saturated sodium phosphate
- dropping bottle of saturated copper(II) chloride

Procedure

1. Using a graduated cylinder, measure 100 mL of the "toxic" solution as accurately as you can. The blue copper ions represent toxic lead.
2. One drop at a time, add just enough sodium phosphate solution to the toxic solution to make the blue colour disappear. Record the number of drops that you added. Compare your number with your classmates' numbers.
3. Pour the clear, colourless liquid into another beaker. This represents the "clean" water. Place several drops of concentrated copper(II) chloride solution into your clean water to see if there is any excess phosphate present. If the solution turns blue, then there is no excess phosphate present.

Questions

1. A toxic metal can be removed from a solution in the form of an insoluble compound. What insoluble compound formed in this reaction?
2. Your toxic water originally contained copper ions and chloride ions. What remained in the water after you "cleaned" it?
3. Phosphate is a nutrient for plants that is often used in fertilizers. Phosphate can promote ecologically damaging algae blooms in rivers and lakes. What appears to happen when we clean up one chemical problem with another chemical?

Treating Car Exhaust

As shown in **Figure 5.19**, our society has come to rely heavily on the burning of fossil fuels for heating, energy production, and transportation. In a car's engine, gasoline burns and reacts with oxygen. The balanced chemical equation for the complete combustion of gasoline can be written as

$$2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$$

Unfortunately, conditions in an engine do not always provide the right conditions for complete combustion. Incomplete combustion, which occurs when there is not enough oxygen present, can produce poisonous carbon monoxide gas and carbon (soot). It can also cause unburned gasoline vapours to enter the exhaust.

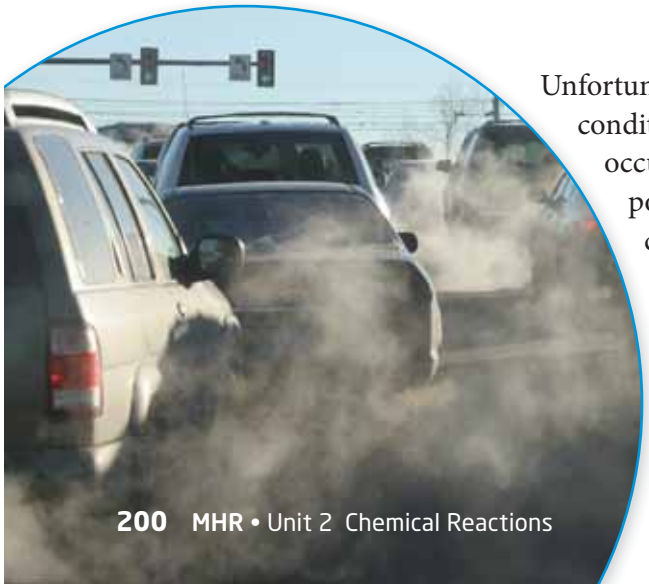

Figure 5.19 Society's reliance on the burning of fossil fuels, such as gasoline, promotes chemical reactions that contribute to pollution.

Forming Nitrogen Oxides at High Temperatures

In addition to these potential pollutants, the exhaust includes a variety of nitrogen oxides, such as NO(g) and NO_2(g), which were discussed in Section 5.1. Although nitrogen gas is fairly non-reactive, the high temperatures present in an engine provide enough energy to break the bonds between the nitrogen atoms and allow nitrogen to undergo a synthesis reaction with oxygen gas in the air. If emitted, these compounds can contribute to smog and to the formation of ground level ozone O_3(g). The contribution of these greenhouse gases to climate change is discussed in Chapter 8.

Catalytic Converters

An important device for helping to reduce the harmful emissions in a car's exhaust is a catalytic converter, shown in **Figure 5.20**. All exhaust must pass through this device before it exits the vehicle. In the catalytic converter, atoms of precious metals, including platinum, palladium, and rhodium, act as catalysts to decompose the NO(g) and NO_2(g) back into the elements N_2(g) and O_2(g). A **catalyst** is a substance that makes a reaction happen faster and is not used up in the reaction. Catalytic converters also help to change the unburned gasoline into carbon dioxide and water.

catalyst a substance that increases the rate of a reaction and is regenerated at the end of the reaction

Study Toolkit

Creating a Word Map
Create a word map like the one on page 178 for the word *catalyst*. This will help you to understand and remember the meaning of this word.

Learning Check

1. How can chemical reactions be used to help clean up oil spills?
2. What chemicals does a catalytic converter help to break down?
3. What is the advantage of having a large surface area on a catalytic converter?
4. Why is it important to maintain a catalytic converter in good working order?

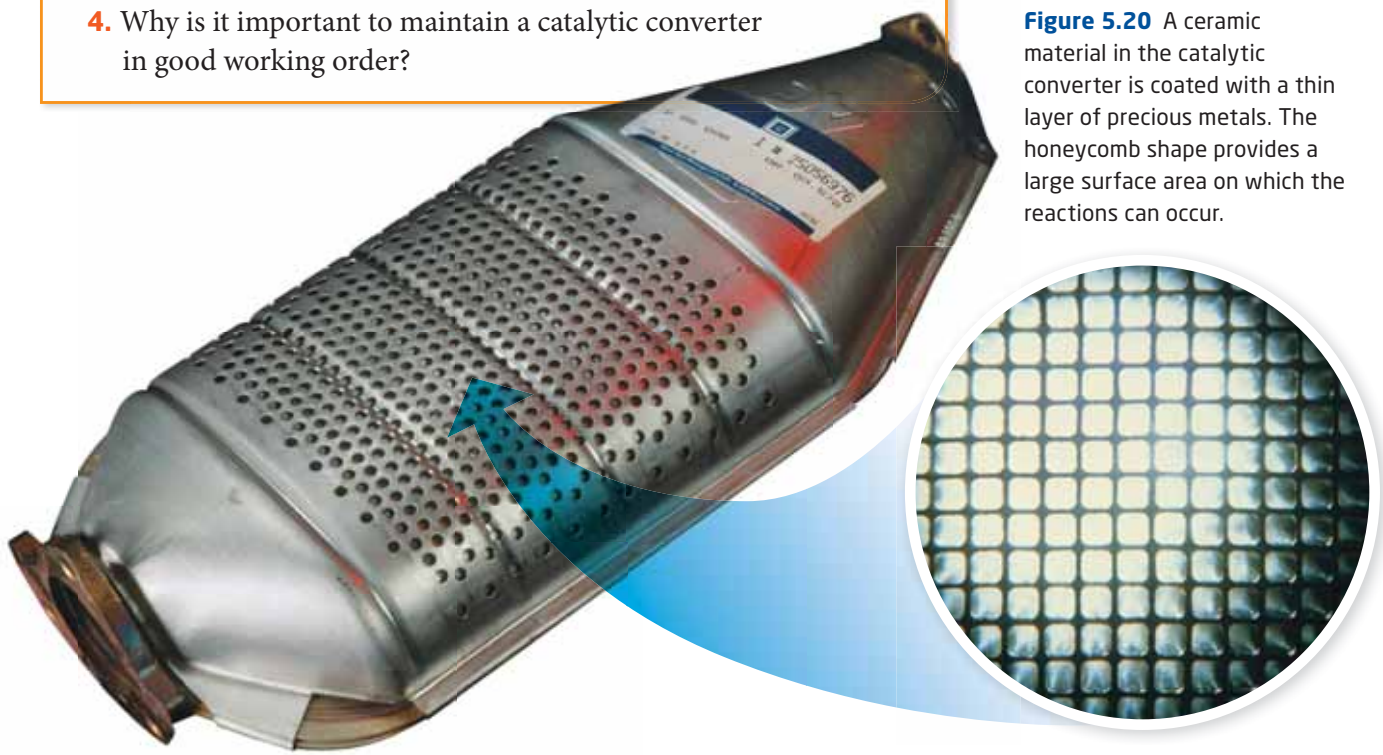

Figure 5.20 A ceramic material in the catalytic converter is coated with a thin layer of precious metals. The honeycomb shape provides a large surface area on which the reactions can occur.

Figure 5.21 Gold mining relies a great deal on chemistry. Even small pieces of gold are desirable.

Recovering Gold Using Cyanide and Zinc

Gold mining is an important part of the economy in Canada. Even small pieces of gold, shown in **Figure 5.21**, are desirable. The mining and recovery of gold relies on several reactions to separate small particles of gold from the rock, or ore, in which it is found. One method used to retrieve this gold involves reactions with cyanide ions, CN^-, and with zinc metal, Zn. Cyanide compounds are highly toxic, and even at low levels can be lethal. The use of cyanide compounds is strictly controlled, but there is a risk of cyanide ions being released into the environment. Researchers are investigating ways to use cyanide compounds more efficiently or to eliminate their use entirely.

Getting Gold Into an Aqueous Solution

In gold mining, the rock that makes up the gold ore is crushed into a fine powder to expose as much of the gold as possible. The powder is placed into carefully engineered piles, or heaps, as shown in **Figure 5.22**. When the heaps are sprayed with a sodium cyanide solution, NaCN(aq), the gold forms a soluble compound, $Na[Au(CN)_2](aq)$, according to the chemical equation

$$4Au(s) + 8NaCN(aq) + O_2(g) + 2H_2O(\ell) \rightarrow 4Na[Au(CN)_2](aq) + 4NaOH(aq)$$

leaching a technique used to extract a metal by dissolving the metal in an aqueous solution

The soluble compound containing gold is drained away from the ore. This process is referred to as **leaching**. As you can see, this reaction, like many reactions in industry and the environment, does not fit neatly into any of the four types of reactions you have learned about in this chapter.

Figure 5.22 Cyanide solution is applied to gold heaps like these, which are crushed gold ore. The soluble compound formed is drained away into ponds, which are also shown.

Getting Gold Out of the Solution

One way to recover the gold is to react the solution with zinc. Adding zinc powder to the solution displaces the gold and produces solid, metallic gold. The reaction occurs according to the chemical equation

$$2Na[Au(CN)_2](aq) + Zn(s) \rightarrow 2NaCN(aq) + Zn(CN)_2(aq) + 2Au(s)$$

Other chemicals, such as bromine and chlorine, can be used to leach gold. Some micro-organisms have also been used to remove gold biologically. However, cyanide ion leaching is still the most cost-effective method.

Cleaning and Disinfecting Pools

A cool pool on a warm day feels terrific, and a heated pool on a cool day feels really good. However, to keep pools safe, chemicals must be used to prevent the growth of bacteria and other organisms that could cause illness. The most common chemicals used for this purpose are chlorinating agents—chemicals that release chlorine when they are dissolved in water. The levels of these chemicals must be closely monitored, as shown in **Figure 5.23**. Just because a chemical is commonly used does not mean that the person using it can be careless. These chemicals have the potential to cause harm to anyone who does not use them properly.

Different types of chlorinating agents are not compatible with one another. Using the same scoop for both types or adding both types into a pool can result in an explosive mixture. Some of these chemicals are also corrosive, so contact with skin can cause chemical burns. Depending on the type of chemical and on how concentrated it is, damage can happen on contact. Before working around these chemicals, you should examine the Material Safety Data Sheet (MSDS) for each one. These sheets list hazards, safety precautions, and incompatibilities of chemicals, as well as treatment instructions in case of contact.

Sense of scale

The particles of gold that are recovered during the leaching process must be filtered from the solution using a very fine filter because the particles are generally less than 50 micrometres across. A micrometre, which is equal to 0.000 001 m, is so small that 1000 micrometres equal 1 millimetre.

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Figure 5.23 An understanding of pool chemistry is needed to monitor the levels of chlorine-based chemicals. These chemicals are used to keep pools clean and free of algae and bacteria.

Learning Check

5. Why are cyanide compounds used in gold mining, even though less dangerous methods are available?
6. Make a comparison table to list some of the positive and negative effects of using cyanide compounds to recover gold.
7. What are the most common chemical agents that are used to prevent bacterial growth in swimming pools?
8. Why is it important to take safety precautions when working with pool chemicals?

Hazards in the Home

There are also chemicals in common products in your home, like those shown in **Figure 5.24**. These chemicals could put you at risk if you are not aware of the product warning labels and do not take the necessary precautions. You have already learned about WHMIS symbols and safety precautions in the laboratory, which are reviewed on pages xiv to xvii. Take a few minutes to read through this material. There is also a system of warning labels for consumer products, called the Hazardous Household Product Symbols, or HHPS. **Table 5.2** summarizes the HHPS warnings that are included on labels to warn consumers about possible harmful effects associated with exposure to a product or the type of container used.

It is important to pay close attention to warning labels—both at home and in the laboratory at school—and to know what the warning symbols mean and what precautions are required for safe handling of the materials.

Table 5.2 Hazardous Household Product Symbols (HHPS)

Symbol	Safety Precaution
Explosive 	This **container** can explode if it is heated or punctured. Flying pieces of metal or plastic can cause serious injuries, especially to the eyes.
Corrosive 	This **product** will burn skin or eyes on contact, or throat and stomach if swallowed.
Flammable 	This **product**, or its fumes, will catch fire easily if it is near heat, flames, or sparks.
Poison 	Licking, eating, drinking, or sometimes smelling this **product** will cause illness or death.

Figure 5.24 These common household cleaners contain chemicals that require precautions when using them.

Bleach and Ammonia—A Toxic Combination

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In addition to safety precautions for specific cleaning products, there are also dangers associated with mixing some products. For example, chemical reactions between bleach and ammonia can result in the production of toxic substances. The main active ingredient in household bleach is a compound called sodium hypochlorite, NaClO. When it is mixed with ammonia, NH_3, a reaction that produces chlorine gas can occur. This reaction is represented by the chemical equation

$$2NH_3(aq) + 2NaClO(aq) \rightarrow 2NaONH_3(aq) + Cl_2(g)$$

How dangerous is chlorine gas? It was used during World War I and World War II as a chemical weapon. When inhaled, chlorine is highly reactive with molecules in a person's respiratory system. This has the potential to cause considerable damage and, if exposure is too concentrated, death.

Two other reactions that can occur between ammonia and bleach are represented in the chemical equations below. Both reactions produce chemicals called chloramines—toxic compounds that contain both nitrogen and chlorine.

$$NH_3(aq) + 3NaClO(aq) \rightarrow 3NaOH(aq) + NCl_3(g)$$

$$NH_3(aq) + NaClO(aq) \rightarrow NaOH(aq) + NH_2Cl(g)$$

This further emphasizes the importance of reading warnings on labels and taking the suggested precautions. Warnings on a container of bleach are shown in **Figure 5.25**. Additional information about the safe use of products is often available on the websites of manufacturers and government agencies, such as Health Canada.

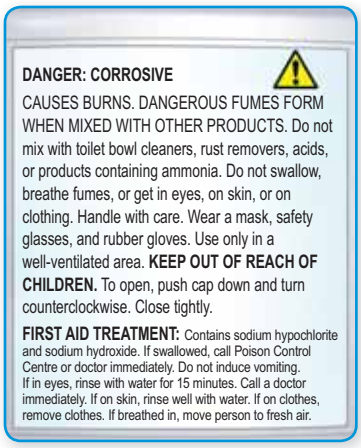

Figure 5.25 Proper safety precautions should be followed when handling bleach.

Making a Difference

In Grade 10, Nikhita Singh read a magazine article about water-repellant surfaces. She wondered if the scientific principles that cause water to repel could be used to reduce pesticide run-off.

Nikhita designed a science project to examine pesticides and run-off. Pesticide run-off often ends up in soil or water and can damage ecosystems. Nikhita tested variables such as the surface of different plant leaves, the type of pesticide, and the application method. Her results showed that it is possible to reduce pesticide run-off by up to 90 percent.

Nikhita completed her research in a laboratory supervised by researchers from the University of Western Ontario in London, Ontario. Nikhita took her project to the Intel International Science and Engineering Fair, the world's largest science competition for high school students. She won a third place award. In 2008, Nikhita was named one of Canada's Top 20 Under 20.

What do you think could be done in your community to reduce pesticide run-off?

Section 5.3 Review

Section Summary

- Catalytic converters are used to help combat pollutants from car exhausts. They act by decomposing nitrogen oxides in exhaust into the elements nitrogen and oxygen.
- The gold mining process relies a great deal on chemistry. Gold forms a soluble substance with cyanide ions. Zinc displaces the gold so that the metal can be recovered. The use of cyanide-containing chemicals, however, results in several environmental challenges.
- Bleach and other chlorine-based chemicals are used as disinfectants. Improper handling and mixing with other chemicals, such as ammonia, can result in reactions that produce toxic gases.
- Users of a product can find information about how to handle and use it safely by examining the safety precautions and symbols on the product's label. For laboratory and workplace products, WHMIS symbols are used. For consumer products, the HHPS system is used.

Review Questions

K/U **1.** How can chemistry help to clean an oil spill and reduce its impact?

A **2.** Oxygen gas is needed for the reaction in which gasoline is burned. If the formation of nitrogen oxides is an undesired additional reaction, why is nitrogen allowed into the reaction chamber?

A **3.** When the prices of palladium and platinum are high, catalytic converters become an attractive target for thieves. When a catalytic converter is removed from a vehicle, what are the negative consequences for the owner? for the environment? What types of vehicles are most often the target of these thieves? Suggest what could be done to reduce the likelihood of catalytic converter theft.

K/U **4.** Identify three environmental issues that relate to chemical reactions.

T/I **5.** What does the WHMIS symbol shown on the right represent? Draw the equivalent symbol from the HHPS system.

This is a WHMIS symbol.

T/I **6.** Describe where catalysts are placed on the catalytic converter shown in **Figure 5.20** on page 201. Explain why this is done.

K/U **7.** What harmful gases are formed when bleach is mixed with ammonia?

C **8.** Create a public service announcement (PSA) to inform your classmates about the safe use of a cleaning product of your choice. Some ideas for presenting your PSA include a pamphlet, podcast, or commercial. Include any HHPS and safety precautions that should be followed, and identify any substances that are incompatible with the cleaning product. List the sources where you found your information.