3.3 Physical and Chemical Changes

Chemical changes produce new substances with new properties. Physical changes, such as changes of state, do not change the identity of a substance. Both physical and chemical changes are accompanied by energy changes. Evidence that a chemical change has occurred includes colour change; heat, light, sound produced or consumed; appearance of bubbles of gas form; and/or formation of precipitate forms; and the change is difficult to reverse.

Words to Know

endothermic
exothermic

Change is a central part of our world. We change as we grow, first from childhood to adolescence, then to adulthood. Freshly baked cookies change from powders and liquids into tasty treats with fragrant aromas. Open a cellphone, and chemicals inside the battery immediately begin to move around and transform into new materials. These transformations cause electric currents to flow through the phone's computer chips. For anything to happen anywhere, there must be change.

There are different kinds of change. Some changes produce entirely different substances, such as when the wood in your campfire burns to produce smoke, ashes, and some gases (Figure 3.13). In other changes, only the appearance of the substance changes, such as when the ice cubes in your soft drink melt into liquid water or when you crush the ice cubes between your teeth to form tiny ice crystals. Is there anything that these processes have in common? As you may have already guessed, the answer is yes.

Figure 3.13 A fire is a dramatic example of rapid change that produces different substances.

Did You Know?

Glow sticks contain chemicals separated into two compartments. When these are "cracked," the chemicals mix and begin a reaction that releases light energy. Because the reaction does not release a noticeable amount of heat, the light of a glow stick is called "cold light."

All of cooking, all of electronics, and all the life processes that keep us alive happen in essentially the same way—through changes in the position and movement of atoms or groups of atoms. The world you see around you, the one in which you live, eat, sleep, play, and work, is built out of another world, equally complex, but on a scale a billion times smaller. This other world is occupied by an immense number of tiny atoms, ions, and molecules. The properties of matter and the way that matter changes result from the structures and interactions of the world of particles.

How do changes in the atomic world affect your everyday world? Consider ice cream (Figure 3.14). All ice cream flavours are determined at the atomic level. For example, ice cream flavour can change from spearmint to caraway just by moving a few carbon atoms around. The colour of a solution can turn from red to blue in an instant just by removing a hydrogen ion from a pigment molecule.

This section focusses on two kinds of change. Chemical changes produce new substances with new properties. Physical changes change the appearance of substances but do not produce new substances. Energy can be an important part of these changes. Some kinds of chemical changes absorb energy, whereas other kinds of chemical changes release it.

Figure 3.14 Changes that turn starting materials into wonderful flavours happen at the atomic level.

3-3A Calcium in Water

Find Out ACTIVITY

In this activity, you will observe a chemical reaction between calcium metal and water.

Safety

- Calcium reacts with moisture, including the moisture naturally found on hands.
- Be careful around open flames.
- Tie back long hair.

Materials

- two 400 mL beakers
- two medium-sized test tubes
- water
- calcium metal
- paper towel
- test tube clamp or tongs
- candle and lighter or matches
- wooden splints
- phenolphthalein indicator solution

What to Do

1. Place about 300 mL of water in a 400 mL beaker. Fill a test tube with water and place it upside down in the beaker. Keep out the air as much as possible.
2. Make sure your hands are dry. Obtain a few pieces of calcium metal directly from your teacher, who will place them on a piece of paper towel.

3. Observe the calcium and then drop it into the water. Cover the calcium with the test tube to catch the gas that is produced.
4. As soon as the test tube is filled with gas, lift it out of the water. Be careful to keep the mouth of the test tube pointed down.
5. Hold the test tube with a test tube clamp. Using the candle and a wooden splint, test to see whether the gas produced is hydrogen (flaming splint will cause a "pop") or oxygen (glowing splint will reignite).
6. Using a clean beaker and test tube repeat the experiment from the beginning. This time add 5 drops of phenolphthalein indicator solution to the water in the beaker before adding calcium.
7. Clean up and put away the equipment you have used.

What Did You Find Out?

1. What changes (state, colour, shape of solid, formation of gas) did you observe during the chemical reaction?
2. What is the likely identity of the gas that was produced?

Physical Changes

A chocolate candy left out in the Sun on a hot day gradually changes into a small puddle of warm, brown liquid. What kind of change has the candy undergone? In a physical change, the appearance of a substance may change, but the bonds holding the atoms together in molecules and ions have not been broken and new bonds have not been made.

Physical changes are also accompanied by energy changes. Melting is a good example of this, as explained by the kinetic molecular theory. The particles vibrate so much when a solid melts that instead of remaining locked in place, they begin to flow past each other. This is what happened to the chocolate candy. This is also what happens when ice turns into liquid water. The water molecules begin to flow, but they do not break up into atoms. That is, the change is physical, not chemical.

Ripping, cutting, grinding, and tearing are examples of physical changes. All changes of state are physical changes. Although melting, boiling, condensing, and solidification or freezing will change the appearance of a substance, they do not produce new substances.

Dissolving is usually considered to be a physical change as well. For example, when salt dissolves in water, the salt seems to disappear. However, this does not cause the individual sodium and chloride ions or the water molecules to change. The only reason we can no longer see the salt is that, once dissolved, the ions are slightly separated from each other. This makes them too small to see.

Evidence of Chemical Changes

Figure 3.15 As it rots, an apple gives off ethene gas (C_2H_4), a chemical messenger. This signals neighbouring apples to rot, too, which is why one bad apple spoils the bunch.

A chemical change produces new substances with new properties and is always accompanied by energy changes, which might or might not be noticeable. In a chemical change, new bonds are formed while other bonds are broken.

You start with the substances that are going to react. These substances are called **reactants**. The new substances produced are called **products**.

Some chemical reactions are easy to spot. When fireworks explode, energy is released in the form of heat, light, and sound. Smoke may be produced, and you might be able to smell the reaction products. This does not guarantee that new products have been produced, but it is strong evidence for it. At other times, it can be harder to determine whether a chemical reaction has taken place. Evidence that a chemical change has occurred includes:

- colour change
- heat, light, sound produced (or consumed)
- bubbles of gas form
- a precipitate may form

Is it a chemical change when a ripe apple turns rotten? Tests show that in fact many new chemicals are produced (Figure 3.15). This means that rotting involves many chemical reactions. As well, some of the water in the rotting apple may evaporate, which is a physical change.

Chemical and Physical Changes and Energy

Figure 3.16 Chemical and physical changes can happen rapidly at the same time, as in this highway construction blast.

Chemical and physical changes often happen at the same time. When an explosive is used to blast rock during highway construction, the chemical reaction turns a small amount of solid explosive chemicals into a large amount of gas (Figure 3.16). The gas is formed under great pressure and tends to expand. This part of the explosion is caused by chemical change. The heat produced in the reaction causes the newly formed gas molecules to move around much more quickly. This increased motion results in the gas expanding even more. As the hot gas pushes outward, the gas molecules cool down, so this part of the explosion is a physical change. The total blast is a combination of physical and chemical changes.

Both chemical and physical changes are accompanied by energy changes. In an explosion, the driving force is the rapid release of energy. This kind of a process is described as **exothermic** ("exo-" means leaving). An exothermic reaction involves the overall release of energy in the form of heat and light. For example, rechargeable batteries power most electronic devices. When the battery is in use, electricity is produced by exothermic chemical reactions. On the other hand, charging the battery causes electrical energy to be absorbed by the chemicals. This is an **endothermic** process ("endo-" means entering). An endothermic reaction involves the overall absorption of energy by the system.

Suggested Activities

Design an Investigation 3-3B on page 101
Conduct an Investigation 3-3C on page 102

Reading Check

1. In a natural gas fireplace, the natural gas combines chemically with oxygen gas. The new substances made in this reaction are carbon dioxide and water. Identify the reactants and products in this reaction.
2. Identify each of the following processes as mainly a chemical change or a physical change: (a) boiling water, (b) tearing clothes, (c) rusting of a nail, and (d) lighting a match.
3. Identify each change below as chemical or physical and as exothermic or endothermic: (a) melting an ice cube, (b) burning a candle, (c) grinding up sea salt, and (d) rain turning to snow.

Explore More

Many deep-sea creatures living off our coast attract prey using a chemical reaction that produces a glow. Find out more about bioluminescence at **www.bcscience9.ca**.

Applications of Chemical Changes

We can apply our knowledge of chemical change in endless ways. Here are several examples.

Figure 3.17 The Legislature Building in Victoria

Solving the corrosion problem

Corrosion is a process by which metals are broken down. Steel ferries, such as the many that operate in British Columbia, are prey to rust. Rust is the product of a chemical reaction between iron and water containing dissolved oxygen gas. One way to protect the ships is to apply several coats of paint. Another method is to clamp blocks of zinc metal to the ferry's hull—the zinc tends to corrode instead of the iron.

While corrosion is often a problem, it is not always destructive. Aluminum corrodes easily, but this can be a benefit. The product of corrosion, aluminum oxide, forms a smooth, transparent surface that prevents further corrosion. It is as if the aluminum paints itself!

Some kinds of corrosion can even improve the appearance of a metal. The attractive blue-green "patina" that forms on copper contains several corrosion products, including copper(II) sulphate. The Legislature Building in Victoria and the Hotel Vancouver are landmark buildings with blue-green copper roofs (Figure 3.17).

Using chemical change for traditional products

First Nations people in British Columbia and beyond use many traditional chemical technologies for managing their natural resources. These include curing or tanning hides, making dyes and medicines from plants, and preserving food (Figure 3.18).

Figure 3.18 Drying fish

For the people of the Pacific Coast, including the Haida, Tsimshian, Nuxalk (Bella Coola), Nisga'a, Gitxsan, Kwakwaka'wakw (Kwakiutl), Nuu-chah-nulth (Nootka), and Coast Salish, the ocean is a major source of food. Fish such as salmon is dried in smokehouses. Drying is a physical change that removes water from the cells of the fish and from any bacteria present. This prevents the bacteria from attacking the flesh. The smoke causes chemical changes in the meat that kill bacteria (Figure 3.18).

One of the best known chemical reactions in First Nations technology is burning the oil of oolichan, a kind of smelt. Oolichan oil improves the flavour of smoked meat and provides a dietary source of fat, iodine, and vitamins. Oolichan contain so much oil that, when dried, the fish will burn if set alight. For this reason, it is nicknamed "candlefish."

3-3B Detecting Vitamin C in Fruit Drinks

Design an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Measuring
- Controlling variables
- Communicating

Safety

- Iodine and starch solutions will cause stains.

Materials

- 1 vitamin C tablet, 100 mg or less
- mortar and pestle
- 100 mL beaker
- water
- stirring rod
- 10 mL graduated cylinder
- 2 medicine droppers
- iodine-starch solution
- up to 8 medium test tubes
- samples of fruit juices or other beverages

We can use chemical change to help us analyze foods for the presence of certain chemicals such as vitamin C (chemical formula $C_6H_8O_6$). In this activity, you will test for the presence of vitamin C in different drinks.

Question

How can chemical changes be used to detect vitamin C in fruit drinks?

Procedure

Part 1 Preparing a Vitamin C Test Solution

1. Grind up the vitamin C tablet using a mortar and pestle.
2. Transfer the grindings to a 100 mL beaker. Use about 100 mL of water to wash the grindings out of the mortar and into the beaker. Stir the liquid in the beaker using a stirring rod. Some of the grindings will not dissolve but this is not a problem, because all of the vitamin C will be dissolved.
3. With the graduated cylinder, measure 5 mL of the iodine-starch solution into a test tube.
4. Use a clean medicine dropper to add some of your vitamin C solution to the iodine-starch solution. Keep adding until you see a definite change in colour. Note the colour change. This colour change indicates that the vitamin C solution has destroyed the iodine in the iodine-starch solution.
5. Do a similar test with water. Measure 5 mL of the iodine-starch solution into a clean test tube. Using a second, clean medicine dropper, add water to the iodine/starch solution. Note what happens. Remember that water does not contain vitamin C.

Part 2 Testing Fruit Juices for Vitamin C

6. Select several fruit drinks for testing. Choose some that advertise that they contain vitamin C and some that have an unknown vitamin C content.
7. With your group, plan a procedure to measure vitamin C in the fruit drinks. Make sure to plan a fair test. For example, it is important that the same amount of fruit drink is in each test tube so you can compare results.
8. Test the fruit drinks to see which have more vitamin C. You can do this by counting the number of drops needed to cause a colour change.
9. Clean up and put away the equipment you have used.

Conclude and Apply

1. Explain how a chemical change involving the chemical reaction of vitamin C with an iodine solution can produce a test for the presence of vitamin C.
2. List the fruit drinks in decreasing order of amount of vitamin C. Support your conclusions by presenting your experimental data along with your results.

3-3C Observing Changes in Matter

SkillCheck

- Observing
- Evaluating information
- Predicting
- Explaining systems

Safety

- Be careful around open flames.
- Handle chemicals safely. One chemical is mildly toxic.
- Tie back long hair.
- Wash your hands thoroughly after you finish the activity.

Materials

- calcium chloride solution ($CaCl_2$)
- two 100 mL beakers
- 100 mL graduated cylinder
- 3 small test tubes, labelled Ca^{2+} ion, Li^+ ion and "unknown ion"
- 3 wooden splints
- lithium carbonate solution (Li_2CO_3)
- ring stand and ring
- funnel
- filter paper
- Bunsen burner
- crucible tongs
- felt pen
- test tube rack

Science Skills

Go to Science Skill 10 for information about how to fold a filter paper.

When the two colourless solutions in this activity are mixed, the chemicals react, producing a white solid and a second, invisible substance that stays dissolved. In this activity, you will separate the two new substances and identify them.

Question

What substances are produced in a chemical reaction?

Procedure

Part 1 Observing a Chemical Change and Separating Products

1. Measure 25 mL of calcium chloride solution into a 100 mL beaker using a graduated cylinder. Pour a small amount of this solution into a test tube labelled "Ca^{2+} ion." Put a wooden splint into the test tube and set the test tube aside.
2. Rinse the graduated cylinder with water. Measure 25 mL of lithium carbonate solution into the second beaker. Pour a small amount of this solution into a test tube labelled "Li^+ ion." Put a wooden splint into the test tube and set the test tube aside.
3. Pour the contents of the beaker containing lithium carbonate into the beaker containing calcium chloride. You should see a cloudy white solid form.
4. Set up a ring stand and funnel. Fold a piece of filter paper as directed by your teacher and place it in the funnel. Rinse the empty beaker with water and place it under the funnel to catch the liquid that passes through.

Step 4

Step 4

5. Pour the contents of the beaker into the filter paper so that the liquid portion can drain through the filter. Not all of the product will drain into the funnel from the beaker.
6. One of your products will be a white solid trapped in the filter. The other product is still in solution and will slowly pass through the filter with the water. If time permits, you may wish to add a small amount of water to the funnel to wash the white product.
7. Once enough solution has passed through the filter to fill a small test tube, pour it into the remaining test tube, labelled "unknown ion."

Part 2 Flame Test to Identify Products

This test will work best in a darkened room.

8. Set up a Bunsen burner and adjust it so that it has a blue flame with very little yellow in it.
9. Place the wooden splint that has been soaking in the test tube labelled "Ca^{2+} ion" into the Bunsen burner flame. Note the colour. This is the colour of Ca^{2+}.
10. Place the wooden splint that has been soaking in the test tube labelled "Li^{+} ion" into the Bunsen burner flame. Note the colour. This is the colour of Li^{+}.
11. Using metal tongs, pick up some of the white product in the filter and heat it in the Bunsen burner flame. As you observe the colour, decide whether the white powder contains the Ca^{2+} ion or the Li^{+} ion. If your products are not completely separated, you may get a mixture of colours. Try to decide which colour is the main one.
12. Place the wooden splint that has been soaking in the test tube labelled "unknown ion" into the Bunsen burner flame. As you observe the colour, decide whether the unknown ion solution contains the Ca^{2+} ion or the Li^{+} ion.
13. Clean up and put away the equipment you have used.

Analyze

1. The reactants in this investigation were solutions of lithium carbonate and calcium chloride. From the two chemical names of the reactants, you can write the names of the two products. **Hint:** Each name has two parts, so exchange the parts. Make sure that each product compound has one positive ion and one negative ion.

Conclude and Apply

1. Use your results to identify the white powder and the chemical present in the liquid that passed through the filter.

Wild, Weird, Wonderful

www Science

Simulating Core Chemicals

Studies of Earth reveal that it is formed in layers. At the centre is a ball of solid iron, and this is surrounded by a sea of molten iron several hundred kilometres thick. Measurements of earthquake energy tell us that 2900 km below our feet the molten iron gives way to rock, which floats on the hot, liquid iron. This rock is called the mantle. Because it is so hot, the rock is capable of flowing slowly, like molasses. Chemists would like to study the compounds at the boundary between the molten iron and the mantle. Since no one can get a sample of this material, the next best thing is to simulate it in the lab. All that is needed is a temperature of 5000°C and 1 million times the pressure at sea level. Does this sound impossible? It is not, if you have access to a laser, a couple of diamonds, and a creative mind.

You start with a diamond anvil small enough to hold in one hand. Diamond is the hardest substance known and can be cut to a tiny point. The points of two diamonds are pressed together against a tiny piece of iron and rock of the type known to exist deep inside Earth. (Material has come to the surface through volcanoes.)

When two diamonds are pressed together this way, a hand-turned screw, like a nutcracker, can reach high pressures. Pressure is force over area. Because the tips of the diamonds are so small, it does not take much force to generate a lot of pressure. Researchers squeeze the device, and a powerful laser blasts the point at which the diamonds touch. With a twist of the thumbscrew, the hottest, most pressurized bit of matter outside Earth's core is produced. The sample is then analyzed to see what is in it.

Researchers now believe that the types of chemicals produced in reactions at the boundary of Earth's core affect features we see at the surface. These include mountain ranges and even the slow movement of continents.

Two diamonds are used to press together samples of rock and iron at a pressure of 1 million atmospheres. A laser then heats the sample to 5000°C. Only the test samples heat up.

Check Your Understanding

Checking Concepts

1. (a) Name two kinds of changes that can affect matter.
(b) Which kind of change involves the formation or breaking of bonds between atoms?
(c) Which kind of change involves only changes to the appearance of a substance?

2. (a) Give one specific example of a change that produces new substances with new properties.
(b) Give one specific example of a change that changes a substance without producing a new substance.

3. When sodium metal burns in oxygen gas it gives off a brilliant white light and a white solid forms.
(a) Identify the reactants and the product.
(b) State whether this reaction is exothermic or endothermic.

4. Lots of chemistry happens in the kitchen, including, sometimes, the making of curry. A simple curry involves frying onions and garlic together and then adding curry spices. Keeping this in mind, decide whether each step below is primarily a chemical change, a physical change, or a mixture of both.
(a) slicing onions, crushing garlic
(b) getting onion vapour in your eyes (causes stinging)
(c) frying onion slices and garlic in vegetable oil
(d) stirring curry spices into the fried portions
(e) tasting the curry to check the flavour

5. Each of the following involves both chemical and physical changes. Identify both in each of the examples.
(a) flattening a flower in a book and leaving it there for a few weeks
(b) leaving a banana to become overripe and then decompose
(c) baking bread

6. Explain why liquid water changing into steam is a physical and not a chemical change.

Understanding Key Ideas

7. A white crystal is ground up into a fine powder and then placed into a beaker full of water. The mixture is stirred until the white powder disappears. After two weeks, the water is gone and a number of white crystals are crusted onto the inside of the beaker. Make a brief list of the physical changes that occurred.

8. Two clear and colourless solutions are mixed together and stirred. Almost immediately, the mixture becomes cloudy white. After a while, a white powder settles out on the bottom of the beaker. Explain whether the process of forming a white powder was likely to be a physical change or a chemical change.

Pause and Reflect

When mould grows on a tomato, many chemical and physical changes take place. Describe the process from ripe to mouldy, listing as many physical and chemical changes as you can.

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated compounds and chemical change. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 12 for help with graphic organizers.) Use the following headings to organize your notes:

1. Distinguishing Between Ionic and Covalent Compounds
2. Names of Ionic Compounds
3. Formulas of Ionic Compounds
4. Comparing Chemical and Physical Change
5. Applications of Chemical Change

Checking Concepts

1. How is a chemical compound different from an element?
2. (a) State the names of the two basic kinds of compounds.
   (b) For each kind of compound, describe how the atoms of the elements join together.
3. (a) Draw a diagram of a water molecule.
   (b) Highlight the location of the covalent bonds.
4. Why is the smallest possible sample of water a single water molecule?
5. Are the atoms in one water molecule covalently bonded to atoms in a neighbouring water molecule? Explain.
6. Are the ions in one part of an ionic lattice attracted to oppositely charged ions in another part of the same ionic lattice? Explain.
7. The polyatomic ion called dichromate is used in the detection of alcohol on a person's breath.
   (a) How many chromium atoms and how many oxygen atoms are in this ion?
   (b) What is the overall electric charge on the dichromate ion?
8. Decide whether a compound formed from each of the following combinations of elements will be an ionic compound or a covalent compound:
   (a) potassium and sulphur
   (b) lithium and chlorine
   (c) oxygen and fluorine
   (d) sulphur and bromine
   (e) copper and iodine
9. Why is it important that a chemical name refer to only one specific compound?
10. (a) Give the full name of the scientific organization IUPAC.
    (b) What important responsibility does it have?
11. Define the terms:
    (a) reactant
    (b) product
12. Distinguish between an exothermic change and an endothermic change.

Understanding Key Ideas

13. How is a polyatomic ion such as CO_3^{2-} like a molecule, and how is it like an ion?
14. Name the ionic compound that forms when each of the following pairs of elements are combined chemically:
    (a) sodium and iodine
    (b) magnesium and nitrogen
    (c) zinc and oxygen
    (d) aluminum and fluorine
15. Write the name of each of the following compounds:
    (a) K_3N
    (b) CaS
    (c) Ag_2S
    (d) AlP
    (e) Sr_3N_2
    (f) Cs_2O

16. Write the formula for each of the following compounds:
(a) potassium bromide
(b) potassium oxide
(c) calcium oxide
(d) aluminum oxide
(e) aluminum chloride
(f) aluminum sulphide
17. Write the name of each of the following compounds:
(a) $CrCl_3$
(b) $CrCl_2$
(c) $FeCl_2$
(d) Fe_2O_3
(e) Au_2O
(f) Au_2O_3
18. Write the formula for each of these compounds:
(a) iron(II) fluoride
(b) iron(III) fluoride
(c) copper(I) fluoride
(d) copper(I) oxide
(e) copper(II) oxide
(f) tin(IV) oxide
19. Write the name of each of these compounds:
(a) $(NH_4)_3P$
(b) $(NH_4)_3PO_3$
(c) $(NH_4)_3PO_4$
(d) Na_3PO_4
(e) $Mg_3(PO_4)_2$
(f) $FeCO_3$
20. Write the formula of each of the following compounds:
(a) sodium sulphate
(b) calcium nitrate
(c) aluminum hydroxide
(d) strontium hydrogen sulphate
(e) ammonium hydrogen sulphate
(f) nickel(III) chlorate

Pause and Reflect

In this chapter, you studied how elements combine to create compounds. Using diagrams, illustrate the different ways compounds can be formed.

Unit Summary

1 Atomic theory explains the composition and behaviour of matter.

- Safe practice in the science laboratory includes knowledge of hazards, awareness of safe procedures during lab work, and the ability to take action to correct a problem. (1.1)
- Warning labels and WHMIS labels identify materials that are risky. (1.1)
- A physical property is anything you can observe about matter, such as density, state, colour, melting point, and boiling point. (1.2)
- The kinetic molecular theory describes matter as made up of tiny particles in constant motion. (1.2)
- A pure substance is made of one kind of substance and can be either an element or a compound. (1.2)
- John Dalton proposed that matter is made of atoms, which can be part of an element (one kind of atom) or a compound (more than one kind of atom joined together). (1.3)
- Ernest Rutherford discovered the nucleus, a tiny dense region at the centre of an atom.
- Most of the volume of an atom is occupied by electrons, which exist in specific electron shells first discovered by Niels Bohr. (1.3)

2 Elements are the building blocks of matter.

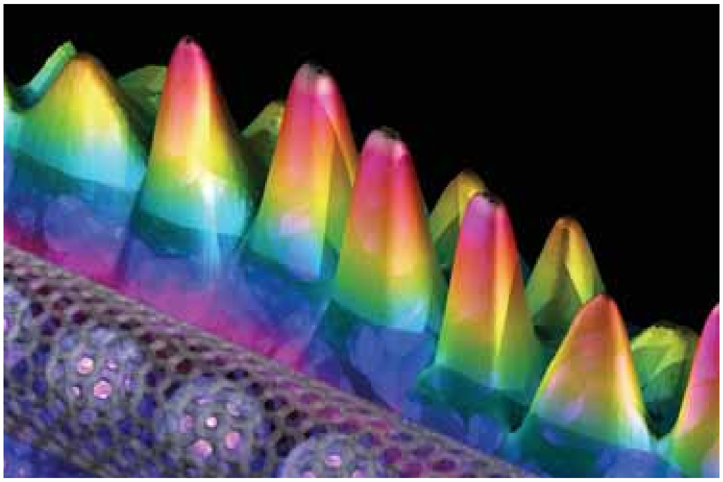
- Each element contains only one kind of atom, and all other forms of matter are made from combinations of these atoms and elements. (2.1)
- The periodic table lists the elements in order of increasing atomic number, arranged into families according to their properties. (2.2)
- In the periodic table, metals are on the left side, non-metals on the right, and metalloids form a diagonal line near the right side. (2.2)
- Electrons can be pictured as arranged in shells in a specific pattern around the nucleus. (2.3)
- Elements in the same chemical family have the same number of valence electrons in their outermost occupied electron shell. (2.3)
- A Bohr model diagram shows the arrangement of electrons in a specific pattern around the nucleus. (2.3)

3 Elements combine to form compounds.

- A compound is a pure substance made up of two or more different elements in which the atoms are connected. (3.1)
- In covalent compounds, atoms join together by sharing electrons, whereas in ionic compounds, oppositely charged ions attract each other. (3.1)
- Polyatomic ions are groups of atoms that are joined to each other by covalent bonds and to other ions by electrical attraction. (3.1)
- In an ionic compound with only two elements, the first ion is always a positive metal ion, and the second ion is always a negative non-metal ion. (3.2)
- A metal that can form an ion in more than one way is described as multivalent. Its name includes a Roman numeral to indicate the positive ion charge. (3.2)
- Chemical changes produce new substances with new properties, whereas physical changes do not change the identity of a substance. (3.3)

Key Terms

- atom
- boiling point
- conductivity
- density
- electron
- element
- mass
- melting point
- neutron
- proton
- state
- subatomic particle
- volume



Key Terms

- alkali metal
- alkaline earth metal
- atomic mass
- atomic number
- Bohr model
- halogens
- metal
- metalloid
- multiple ion charge
- noble gases
- non-metal

Key Terms

- covalent compound
- ionic compound
- molecule
- polyatomic ion

Corroding Nails

Corrosion is an example of a chemical change. Commonly called rusting, this chemical change can cause damage to a variety of iron structures. The amount of corrosion depends on a variety of factors including the amount of moisture, amount of oxygen, and whether the iron has a protective coating. In this activity, you will investigate what conditions cause the most corrosion of an iron nail.

Problem

What conditions are required to cause the most corrosion of an iron nail?

Safety

- Do not mix any chemicals without your teacher's knowledge or approval.

Materials

- 6 test tubes
- 6 iron nails
- cotton ball
- water
- calcium chloride
- vegetable oil
- 2 stoppers
- test tube holder

Criteria

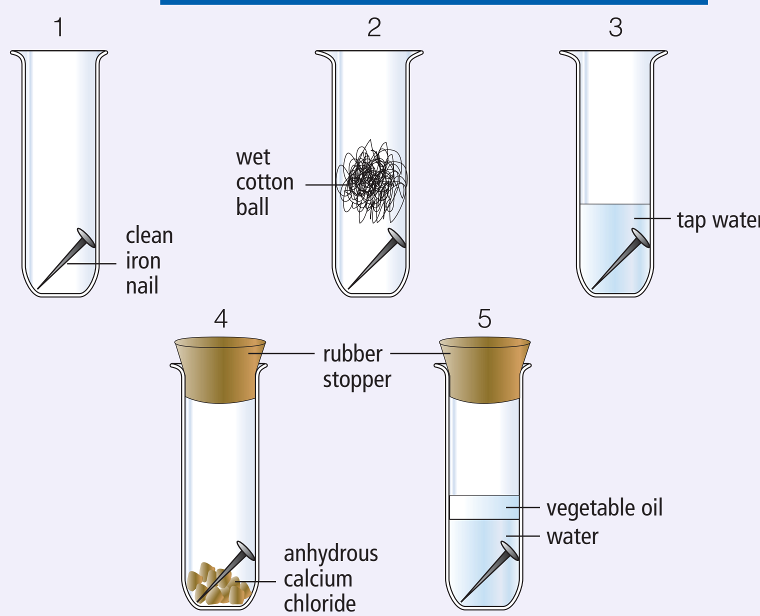
- Develop a procedure to test the rate of corrosion in iron nails.
- Have your teacher approve your procedure.
- Safely carry out your experiment.
- Collect experimental data describing the conditions in each of the test tubes.
- Correctly identify and describe the appropriate conditions for corroding nails.

Procedure

1. With your group create a procedure to test six different conditions for testing how fast an iron nail will corrode. The illustration below shows the materials to be placed in each of the first five test tubes. Use the sixth tube to create your own set of conditions.

Science Reference

Go to Science Skill 2 for more information on designing and carrying out an experiment.



2. Have your teacher approve your procedure.
3. Perform your experiment.
4. Gather and record your data and observations.
5. Clean up and put away the equipment you have used. Follow your teacher's instructions for the disposal of chemicals.

Report Out

Create a report describing your experiment. The titles for each section in your report are:

1. Question Investigated
2. Outline of Procedure Used in the Experiment
3. Data Collected
4. Conclusion

Chemical Contents

Chemicals are used in almost every aspect of our society. Many of the most important ones may be unfamiliar to you because you do not use them directly. Instead, you use the materials made from them, or they are included in complex mixtures such as a natural product, cosmetics, or paint. Using your research skills, find out more about one particular chemical. Some ideas to get you started are provided.

Natural products

Products described as "natural" contain chemicals from natural sources, such as from plants or the sea. For example, bearberry plants produce useful berries and leaves. The berries are a good source of protein and may be eaten raw. The leaves are used to make medicinal teas.

Cosmetics and hygiene products

Read the label of a cosmetics or hygiene product and you may be interested to discover the very long names of chemicals that have been used to create the product. How do the chemicals contribute to the effectiveness of the product? Why are they added?

Paints

What chemicals produce the rainbow variety of colours in paints? What chemicals help the paint to remain liquid in the container, go onto a brush or roller without dripping, spread evenly, add colour, dry quickly, and clean up easily?

Medicines

Acetaminophen is used in many flu and cold medications, as well as by itself, to reduce pain. Other chemicals used to reduce mild pain are ibuprofen and acetylsalicylic acid (aspirin).

Industrial chemicals

Benzene is a chemical that is too dangerous to handle without professional training. Yet it is used in the manufacture of gasoline, acetate overhead plastic sheets, and decaffeinated coffee.

Find Out More

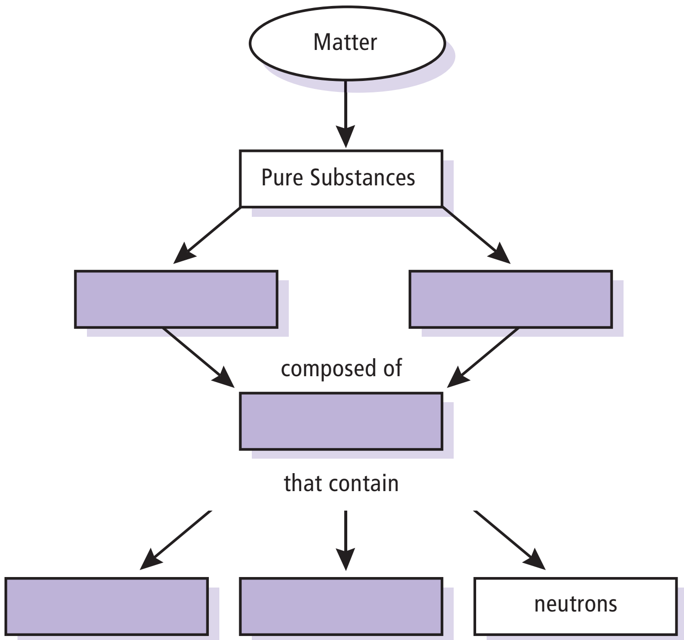
Choose one particular chemical or product and research how it is made and what it is used for. Use the Internet (start at **www.bcscience9.ca**), encyclopedias, or interviews with experts to gather facts on your topic. Carefully record the information you discover. Be sure to note and credit the sources of your information.

Report Out

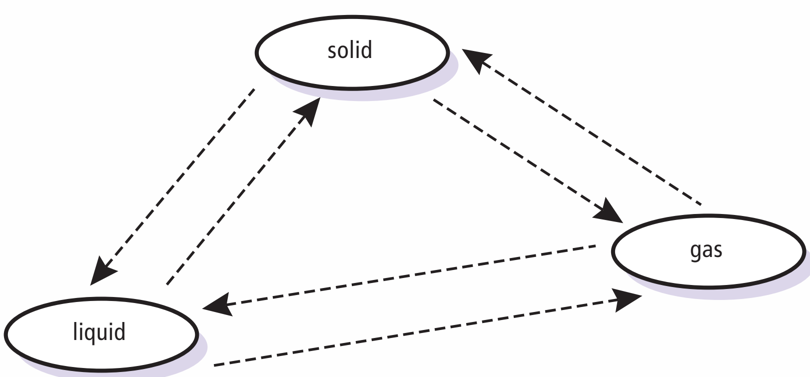
1. Make a pamphlet including illustrations, photographs, and a description of the chemical you researched. Be sure to include a description of how the chemical is produced and what it is used for.
2. Create an Internet page that has links to sources for more information on the chemical you have researched. One link might be to a Material Data Safety Sheet (MSDS) that will explain safety hazards related to your chemical.

Visualizing Key Ideas

1. Copy and complete the following chart about matter.



2. Copy and complete the chart below by attaching one of the following words to each arrow: solidification, evaporation, deposition, sublimation, condensation, melting.



Using Key Terms

3. State whether the following statements are true or false. If a statement is false, rewrite it to make it true.
   (a) Matter is anything that has volume and colour.
   (b) Physical changes involve changes in appearance without the formation of any new substances.
   (c) The three types of subatomic particles in an atom are the proton, the electron, and the nucleus.
   (d) Elements can be divided into metals, metalloids, and gases.
   (e) A group of elements that have similar chemical properties is called a period.
   (f) The atomic number counts the number of neutrons in the nucleus of an atom.
   (g) A valence electron is an electron in the lowest occupied energy level of an atom.
   (h) In a covalent bond, a pair of electrons is shared by two atoms.
   (i) A group of atoms joined by covalent bonds is called a molecule.
   (j) A chemical change that results in the release of heat is called an exothermic reaction.

Checking Concepts

1

4. (a) List the three states of matter.
   (b) Draw a simple diagram showing how the particles are arranged in each state.
5. List the four main statements of the kinetic molecular theory.
6. Define a physical property.
7. (a) What are the subatomic particles that make up an atom?
   (b) Where is each kind of particle located in an atom?
8. (a) Where is most of the mass of an atom located?
   (b) What part of an atom makes up most of the volume?

2

9. (a) What is an element?
   (b) Approximately how many different elements have been identified?
10. List six properties typical of a metallic element.
11. List four properties typical of a non-metallic element.
12. Describe what elements in the same column of the periodic table have in common.
13. In the periodic table, what is another name for
    (a) row?
    (b) group?
14. List five pieces of information usually recorded in the periodic table for each element.
15. (a) What are the names of two families of metals in the periodic table?
    (b) What are the names of two families of non-metals in the periodic table?
16. How many electrons are in each of the four occupied electron shells in an atom of calcium (atomic number 20)?
17. (a) What is a valence electron?
    (b) How many valence electrons are in elements belonging to the alkali metal family?
18. Describe the arrangement of electrons that noble gases have that makes them very stable.

3

19. What is a compound?
20. (a) Name the kind of compound that involves the attraction of oppositely charged ions.
    (b) Name the kind of compound that involves atoms sharing a pair of electrons.
21. What is a polyatomic ion?
22. What are the two kinds of ions in an ionic compound made from only two elements?
23. Explain the difference between a chemical change and a physical change.
24. What is the difference between an exothermic and an endothermic reaction?

Understanding Key Ideas

25. Using the kinetic molecular theory, describe how a solid can turn into a liquid.
26. List five physical properties of water. For example, water has a low viscosity (because it flows easily). (**Hint:** You can use Table 1.1, on page 22, to help you.)
27. Why can sodium not be used to make a container in which to boil water? Provide at least two reasons.
28. Write a brief description of how the periodic table is organized.
29. In the periodic table, where are each of the following groups of elements located?
    (a) metals
    (b) non-metals
    (c) metalloids

30. Which chemical family is composed of elements that have full valence shells?
31. Write the formulas of the following compounds:
    (a) sodium bromide
    (b) calcium sulphide
    (c) aluminum fluoride
    (d) magnesium nitride
    (e) silver nitride
    (f) cesium oxide
    (g) gold(III) iodide
    (h) copper(I) sulphide
    (i) tin(IV) phosphide
    (j) lead(IV) sulphate
    (k) ammonium chloride
    (l) potassium permanganate
    (m) iron(II) hydroxide
    (n) sodium hydrogen carbonate
    (o) aluminum chromate
    (p) lithium dichromate
    (q) manganese(III) sulphate
    (r) titanium(IV) hydrogen sulphate
    (s) chromium(III) hydroxide
32. Write the names of the following compounds:
    (a) $NaCl$
    (b) K_2O
    (c) Cs_3P
    (d) CaF_2
    (e) $AlBr_3$
    (f) Mg_3N_2
    (g) CuI
    (h) CuI_2
    (i) HgS
    (j) $Fe(NO_3)_2$
    (k) $NiSO_4$
    (l) $(NH_4)_2SO_3$
    (m) $Pb(OH)_4$
    (n) $CaCrO_4$
    (o) $Mn(CN)_2$
    (p) $Al(ClO_4)_3$
    (q) NH_4NO_3
    (r) $MgCO_3$
    (s) KCH_3COO
33. Look at Figure 3.8 on page 80, which shows a model for an ionic lattice including potassium ions and dichromate ions. There are twice as many potassium ions as there are dichromate ions. What is the formula for potassium dichromate?

Thinking Critically

34. (a) Draw a simple diagram of the Rutherford gold foil experiment. Using arrows, show how the alpha particles were deflected in different ways as they struck the gold.
    (b) What did this deflection indicate about the gold atoms?
35. Explain how mercury can be used to make an electrical switch that does not produce a spark.
36. Mendeleev predicted the properties of the element germanium before it was actually discovered. How was he able to do this?
37. (a) What is the atomic number of an element?
    (b) How do atomic numbers change as you move through the periodic table?
38. (a) Name the families in groups 1, 2, 17, and 18.
    (b) Provide two properties typical of elements in each family.
39. Refer to valence electrons to explain why the halogens (F, Cl, Br, I, and At) are all in the same chemical family.
40. Explain the difference between a covalent compound and an ionic compound.
41. Draw a diagram of an ionic lattice including six positive ions and six negative ions.

Developing Skills

42. Draw a diagram of an atom containing seven protons, eight neutrons, and as many electrons as are needed to make the atom neutral. Show the correct number of electrons in each energy level.

43. Explain why sodium and chlorine atoms are extremely reactive but sodium ions and chloride ions are not. (**Hint:** Refer to the number of valence electrons in your explanation.)

44. Use a periodic table to find the atomic number, atomic mass, and most common ion charge for these elements.
(a) iron
(b) gold
(c) Cu
(d) U

45. Use a periodic table to identify these elements:
(a) the metal in period 4, group 2
(b) the non-metal in period 3, group 17
(c) the element that has an atomic number of 13
(d) the element that has an atomic mass of 19.0 amu

46. (a) Draw a Bohr model diagram of each of the following atoms: (a) O (b) F (c) Ne (d) K (e) Mg
(b) Draw a Bohr model diagram of each of the following ions: (a) O^{2-} (b) F^{-} (c) Na^{+} (d) Mg^{2+}
(c) Compare the pattern of electrons in atoms to the pattern of electrons in ions.

Pause and Reflect

Even though it is difficult to observe atoms without special equipment, the atomic theory describes our current understanding of atoms. How has the use of models helped explain the structure of atoms?