

SNC2D-B



**Chemical Reactions and
their Practical Applications**

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Introduction

As you saw in Unit 1, you need to understand chemical processes, like the combustion of carbon compounds, to help solve complex environmental issues like climate change. Knowledge of chemistry is very important in all aspects of life. In fact, everything you make, eat, wear, breathe, and use is made of chemicals. Even *you* are made of chemicals—you can't exist without them. Most new technological discoveries depend in part on knowledge of chemicals and their reactions.

But what is a chemical? In this unit, you will start by learning about the building blocks of chemicals—atoms, molecules, and compounds. Things really get interesting when these building blocks react together to form new molecules. Just as words can be combined to create new stories, so atoms and compounds can be combined to create new materials that can change your life.

Most industry in Canada is built on manipulating chemical reactions, from mining and forestry to manufacturing high-tech devices and medical research. You will explore how chemistry is used in many occupations, from construction, cooking, and manufacturing to environmental protection and chemical research.

Overall Expectations

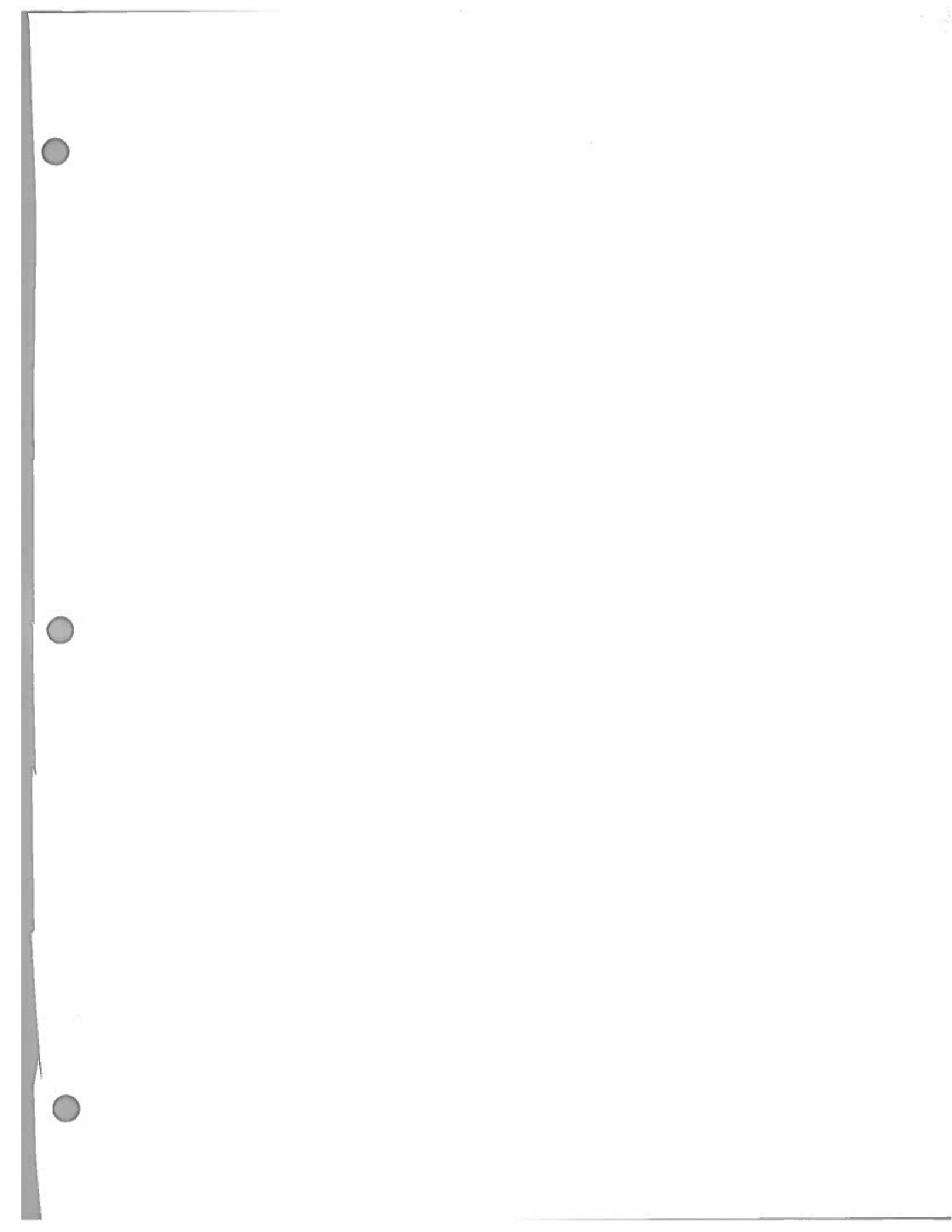
After completing this unit, you will be able to

- apply the general principles of chemical reactions, and represent them using symbols, words, and equations
- investigate the characteristics of chemical reactions, and recognize the difference between chemical and physical change
- learn how to use chemicals safely in the workplace
- recognize the safety and environmental issues associated with chemical reactions, including the ways they can be used to address environmental problems



SNC2D-B

Atoms, Molecules, and Compounds



Introduction

Science SNC2D-B

Lesson 6

1

You hear about “chemicals” every day: industrial chemicals, household chemicals, chemicals in your environment and your food. Often you hear about them in a negative way, especially around environmental issues, as you saw in Unit 1. But society couldn’t function without chemicals. For example, gasoline is a chemical used for fuel, and laundry detergent is a chemical used for cleaning. All food and medicines are chemicals, as are your clothes. In fact, it’s hard to name something in your life that’s not a chemical.

But what is a chemical? The term simply refers to a substance that is used in or produced from a chemical reaction. In this lesson, you’ll get to know the major players in the chemical game: atoms, molecules, and compounds. You will also learn how to name them and write their formulas. This will get you ready for the next lesson where you begin to learn how chemicals react.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Atoms and Molecules	1
Why Atoms React	$\frac{1}{2}$
Gaining and Losing Electrons	$\frac{1}{2}$
Naming Compounds	1
Key Questions	1

What You Will Learn

After completing this lesson, you will be able to

- distinguish between different groups of chemicals
- use the periodic table to identify different elements
- write the names and formulas of some types of chemicals

What is Chemistry?

Chemistry is the study of chemicals and their reactions. Chemicals are the foundation of everything around you, including all life. In Unit 1, you saw that we need knowledge of chemistry to solve environmental problems like climate change. Medicine, agriculture, and manufacturing all are based in part on chemistry. Even love is partly the result of chemistry—your brain cells' response to different chemical signals determines how strong your emotions are towards another person.

So what is chemistry? Chemistry is a bit like cooking; different ingredients are combined in creative ways to produce the final product. But as all cooks know, you can't cook properly until you know your ingredients. First you need to learn about the most basic ingredients in chemistry: atoms and molecules.

Atoms and Molecules

What would happen if you took a rock and smashed it to pieces with a hammer? Then took one of those pieces and smashed it into even smaller pieces? And then took one of those small pieces and kept smashing it until the bits were so small you had to use a magnifying glass or even a microscope to see them? What if you kept doing this? At what point would you be unable to break down the rock any more? People have asked themselves these questions for thousands of years, but only in the last 300 years have we developed the scientific knowledge and technology to answer them.

You probably learned at some point that all matter is composed of tiny particles that are too small to be seen and cannot be broken down. These particles are called atoms. An **atom** is the smallest indivisible particle of a type of substance called an element. An **element** is a pure substance composed of only one kind of atom. Elements are the building blocks of chemistry.

An atom has a nucleus containing neutral **neutrons** and positive **protons**. It also has negative **electrons** orbiting around the nucleus. These orbits are organized into **electron shells**. The following diagram of a carbon atom shows the main parts of the atom.

Types of Matter

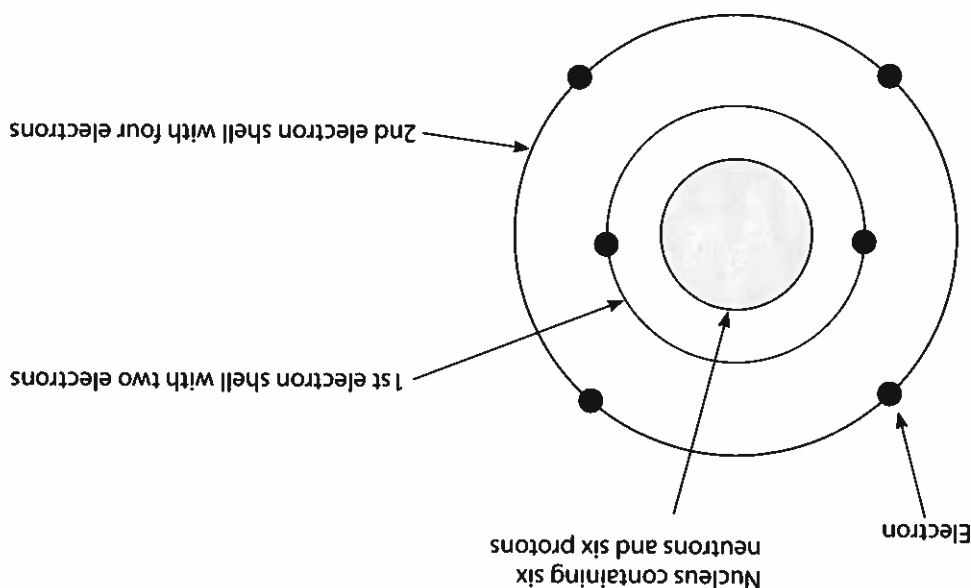
Both elements and compounds are pure substances, meaning that they are made of only one type of particle. An element contains only one type of atom. A compound contains only one type of molecule.

Mixtures are substances made of more than one type of particle mixed together. Mixtures may contain atoms of different elements as well as molecules of different compounds. All these different particles are mixed together, but not connected to each other. Because they are not connected, they can be easily separated by methods like evaporation, boiling, and filtering.

In Figure 6.1, note that the total number of electrons (six) matches the total number of protons (six). Note too that only a certain number of electrons can fit on each shell. The first shell can hold two electrons, and then each shell afterwards can hold up to eight electrons before the next shell starts. A molecule is the smallest indivisible particle of a type of substance called a compound. A molecule is formed when two or more atoms combine to form a new particle. It is very hard to separate the atoms of a molecule. The difference between elements and compounds is that elements are made of only one type of atom, while compounds are made from a combination of atoms from different elements.

The number of protons in an atom is different for every atom, and the number of electrons is equal to the number of protons. Since the protons are positively charged and the electrons are negatively charged, the atom is considered to have no overall charge—it is neutral.

Figure 6.1 Main parts of a carbon atom



A concept map is a diagram illustrating relationships among concepts. In a concept map, two or more concepts are linked by words that describe their relationship. The concepts are usually enclosed in circles or boxes, and the relationships between them indicated by labeled lines connecting them.

Concept maps help you organize your knowledge on any topic in a visual way. They help you learn new information by integrating each new idea into your existing body of knowledge. Here is an example of a simple concept map about animals and plants.

Concept Maps

Pure Substances	Mixtures
Gold is an element made up of only gold atoms. But gold jewellery is not pure; other elements are added to it to make it harder so that it wears better.	Gravel is a mixture of different types and sizes of rocks; you can easily see the different particles.
Distilled water is pure because it contains only water molecules made up of atoms of hydrogen and oxygen.	Bottled water has different elements and molecules mixed in (sodium, fluorine, calcium, salts). You can't see these different particles because they are dissolved.
Aluminum foil is pure because it is made only of aluminum atoms.	Many kinds of salad dressing have different parts that you can see; they often separate easily (oil, water, vinegar).
Carbon dioxide is a molecule. One molecule of carbon dioxide contains atoms of carbon and oxygen; they are not easily separated.	Air is a mixture of different gases such as oxygen, nitrogen, and carbon dioxide. It looks pure because the different gases are not easily visible to us.

Table 6.1 Examples of pure substances and mixtures

Examples

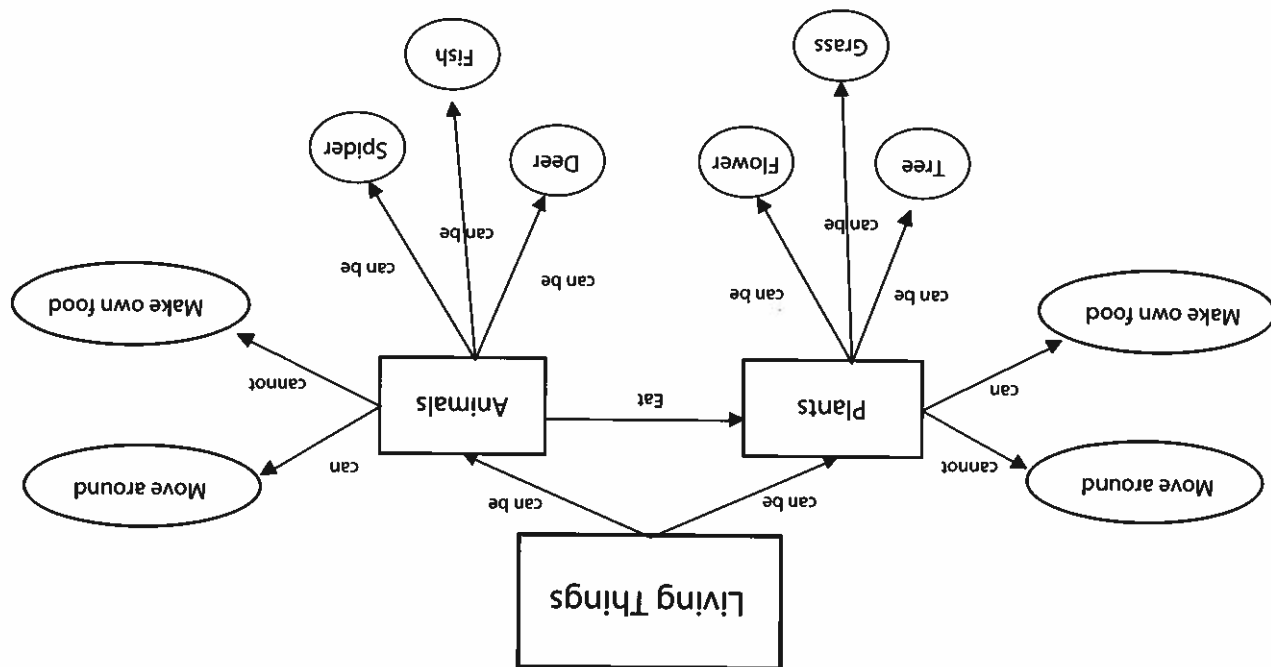


Figure 6.2 Concept map showing some differences between plants and animals

At the centre of the diagram, the big box labeled "Living Things" is the main concept under which all the rest of the boxes and labels fit. There is no standard way to display concept maps. You can do it in whatever way makes the most sense to you. Usually, though, the main concepts are shown in bigger typefaces. Concept maps can be very useful for organizing concepts and relationships, especially in science. You will be using them several times in this course. The concept map on the next page summarizes the different types of matter that you are learning about.

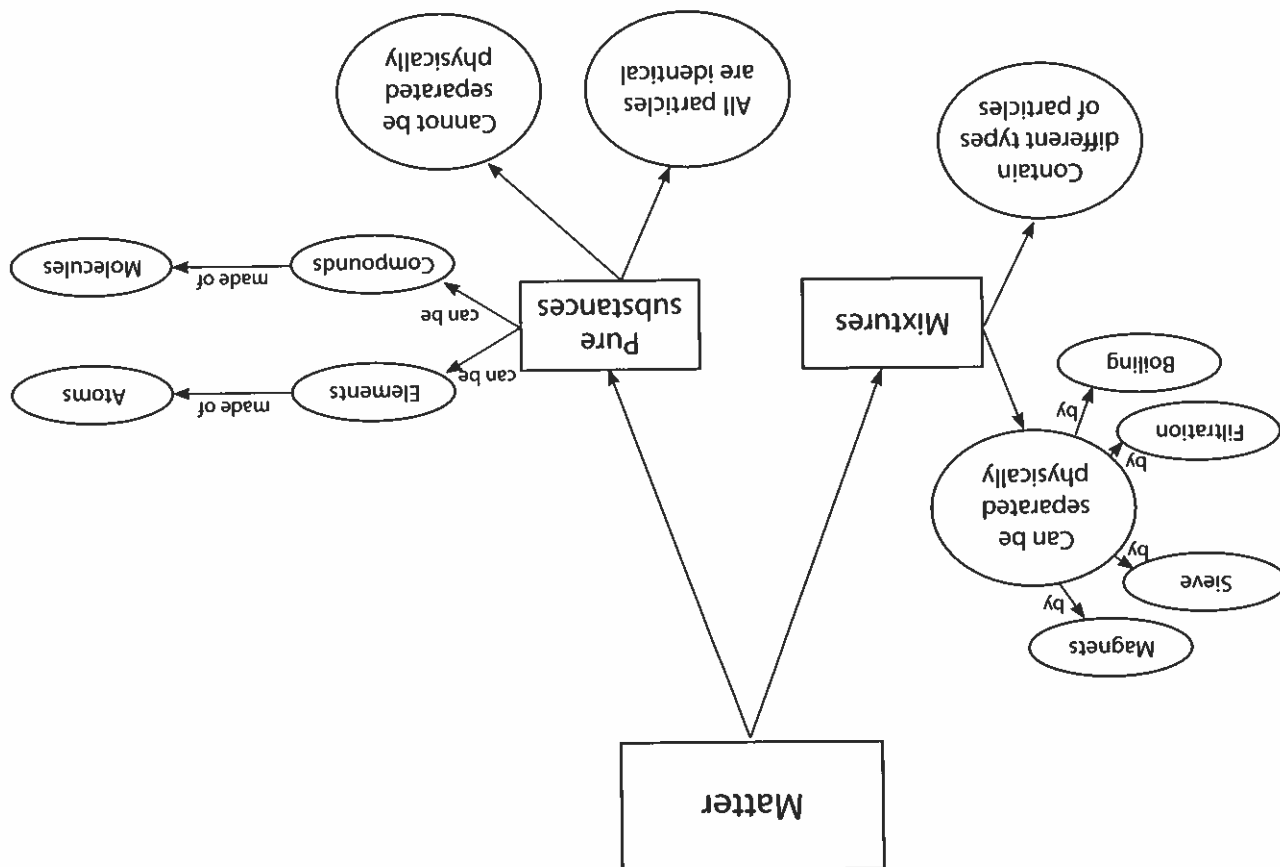


Figure 6.3 Concept map for types of matter

Support Questions

1. What is the difference between an element and a compound?
Do not send your answers in for evaluation.

2. Identify each of the following as either a pure substance or a mixture.
Explain why.
a) 2% milk

The Periodic Table

You're familiar with grouping similar things together. For example, perishable foods, like milk, cheese, and meats, must be kept in the refrigerator, while canned or boxed food, like tuna or Kraft Dinner, can be kept in a cupboard. They are kept together because they have similar properties. Scientists call this kind of grouping "classification." Classifying things lets you organize them and understand them better. Elements are classified according to their structure and properties.

The classification of elements is organized in "The Periodic Table of the Elements." The **Periodic Table** lists all the known elements and categorizes them based on their atomic properties. Everything on the planet is made of some combination of these elements. Wood, water, food ... even *you* are made from these elements combined in many different ways. If it is not listed on the Periodic Table, then it is not an element!

The Periodic Table is one of the most significant scientific achievements of all time. Learning how the various elements were related led directly to discoveries in how they were constructed, laying the foundation for modern chemistry, particle physics, and molecular biology.

Today the main value of the Periodic Table is that it allows us to predict the chemical behaviour of an element based on its location in the table, and even to predict the existence of new elements.

There are Suggested Answers to Support Questions at the end of this unit.

b) table salt

c) steam

Periodic Table

Group 1

Atomic Number
Symbol
Name
Average Atomic Mass

Common Oxidation States

Diagram illustrating the relationship between Atomic Number, Symbol, Name, Average Atomic Mass, and Common Oxidation States for Carbon (C). The diagram shows a box with 'C' in the center, with arrows pointing to '6' (Atomic Number), 'Carbon' (Name), and '12.011' (Average Atomic Mass). The box is labeled 'Common Oxidation States'.

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
IA	IIA	IIIB	IVB	VB	VIB	VIIA	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H Hydrogen 1.00794	3 Li Lithium 6.941	4 Be Beryllium 9.012182	5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797	11 Na Sodium 22.989768	12 Mg Magnesium 24.3050	13 Al Aluminum 26.981539	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.4527	18 Ar Argon 39.948	19 K Potassium 39.0983
20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.93805	26 Fe Iron 55.847	27 Co Cobalt 58.93320	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92159	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80	37 Rb Rubidium 85.4678
38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (97.90772)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.757	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29	55 Cs Cesium 132.90543
56 Ba Barium 137.327	57 La Lanthanum 138.9055	58 Ce Cerium 140.115	59 Pr Praseodymium 140.90768	60 Nd Neodymium 144.24	61 Pm Promethium (144.9127)	62 Sm Samarium 150.36	63 Eu Europium 151.965	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479
88 Ra Radium (226.0254)	89 Ac Actinium (227.0278)	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium (237.0482)	94 Pu Plutonium (244.0642)	95 Am Americium (243.0614)	96 Cm Curium (247.0733)	97 Bk Berkelium (247.0753)	98 Cf Californium (251.0796)	99 Es Einsteinium (252.083)	100 Fm Fermium (257.0951)	101 Md Mendelevium (258.10)	102 No Nobelium (259.1039)	103 Lr Lawrencium (262.111)	104 Rf Rutherfordium (261.10)	105 Db Dubnium (262.114)
108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 Ds Darmstadtium (269)	111 Rg Roentgenium (272)	112 Uub Ununbium (275)	113 Uut Ununtrium (278)	114 Uuq Ununquadium (281)	115 Uup Ununpentium (284)	116 Uuh Ununhexium (287)	117 Uus Ununseptium (290)	118 Uuo Ununoctium (293)	119 Uus Ununseptium (296)	120 Uuo Ununoctium (299)	121 Uuh Ununhexium (302)	122 Uus Ununseptium (305)	123 Uuo Ununoctium (308)	124 Uuh Ununhexium (311)	125 Uus Ununseptium (314)

7

6

5

4

3

2

1

How to Read the Periodic Table

Each box in the Periodic Table represents an element that has been discovered. Each element has its own **atomic number**. For example, the atomic number for hydrogen is 1, for carbon is 6, and for aluminum is 13. The atomic number is determined by how many protons an atom has. For example, a hydrogen atom has one proton and a carbon atom has six protons.

As you look across the rows, you will see many other elements you've heard of, including calcium, copper, gold, and lead. In addition to its own number, each one has its own symbol. The symbol is used to identify the element in chemical equations.

To see an interactive colour version of the Periodic Table, go to your course page on the ILC website and click on "Periodic Table" under Lesson 6. When you click on an element in the interactive table, you'll see more information about it, including a diagram showing you how its electrons and protons are organized. You'll also see when the element was discovered and what it is commonly used for.

For example, click on number 4, beryllium. Its symbol is Be and it has four electrons in total—two in the first shell and two in the second (outer) shell. Click on number 12, magnesium. Its symbol is Mg and it has 12 electrons in total—two of which are in the outer shell. Below it is number 20, calcium. If you click on it you will notice that its symbol is Ca and it has 20 electrons—two of which are in the outer shell. Calcium is an important element for you since it is a major component in your bones and teeth.

The elements are not randomly placed in the Periodic Table. For example, the three elements mentioned in the paragraph above are found in the second column of the table. Even though they have different symbols and sizes, these elements all have two electrons in their outer shell. This is true of all elements in the second column. That's important because the number of electrons in the outer shell affects the way an element reacts with other elements.

The electrons in the outer shell are called **valence electrons**. Atoms with less than eight valence electrons are more chemically reactive with other atoms than atoms whose outer shell is completely filled with eight electrons. Atoms with completely filled outer shells are chemically **inert** (non-reactive). Atoms with one, two, six, or seven valence electrons are the most chemically reactive, because it is relatively easy for them to lose or gain the one or two electrons necessary to achieve full outer shells. You will learn more about this later in the lesson.

Another pattern shows how carefully the Periodic Table is organized. The number of electrons in the outer shell increases as you move from left to the right across the table. You will use an element's position in the Periodic Table to figure out what kind of element it is and how many electrons it has.



Structure of the Periodic Table

Elements in the same column on the table have the same number of electrons in their outer shell, and thus react in the same way. A column is considered to be a “family.” Elements in a family have similar chemical properties because they have the same number of outer-shell electrons. The elements described before—beryllium, magnesium, and calcium—are all part of a family called the alkaline earth metals. The last column on the right of the Periodic Table contains the inert (or noble) gases, including helium and neon. They all have eight electrons in their outer shell. They are called inert because they do not react with other elements.

Elements along the same row also share similarities. A row on the Periodic Table is called a “period.” Elements in the same period have the same number of electron shells. This means they require similar amounts of energy to form bonds, something you will learn about in later courses.

Look at the online Periodic Table again. Besides columns and rows, there are also colours. The legend on the Periodic Table shows eight different colours reflecting eight different categories of elements. If you look carefully, you’ll see that everything is either a *metal* or not (therefore a *non-metal*). Halogens and the inert elements (or noble gases) are considered to be non-metals. The metals occupy the middle and left side of the periodic table, while the non-metals and inert gases are on the right side. Knowing whether an element is a metal or non-metal will help you figure out how it will react when mixed with another element.

Metals and non-metals have different physical properties.

Table 6.2 Physical properties of metals and non-metals

Metals	Non-metals
– are usually solids at room temperature (except mercury) – tend to be shiny – most are silver-grey in colour – can conduct heat and electricity – are malleable (can be shaped)	– can be solid, liquid, or gas at room temperature – most are not shiny – can be different colours – do not conduct heat or electricity – most are gases, but those that are solids are usually powders or crystals, and are not malleable

Support Questions

3.

Use the Periodic Table to identify what family the following elements are in. Complete the missing names and symbols as well. The first one is done for you.

Name	Symbol	Family
Carbon	C	Non-metals
Hydrogen		
Nitrogen	O	
Neon		
Iron	Ca	
Copper	Pb	

4.

Name one other element that has chemical properties similar to the given element.

a) phosphorus (P) _____

b) krypton (Kr) _____

c) chromium (Cr) _____

Why Atoms React

Looking at the Periodic Table, you saw that elements in the same column tended to have the same number of electrons in their outer shells: elements in column 1 tended to have one electron, elements in column 2 tended to have two, and so on. However, some elements, like many of the transition metals, do not follow this rule exactly because the location of their electrons is more complicated. In this course, you will look mainly at elements in the first two and last six columns on the Periodic Table. These do follow the rule that elements in the same column have the same number of electrons in their outer shell.

Use the Periodic Table to look at the following elements: sodium (Na), aluminum (Al), sulphur (S), and chlorine (Cl). All have three levels of electron shells. Their electron organization is as follows:

Table 6.3 Electron shell configuration for some elements

Element (symbol)	First Shell	Second Shell	Third Shell
Sodium (Na)	2	8	1
Aluminum (Al)	2	8	3
Sulphur (S)	2	8	6
Chlorine (Cl)	2	8	7

In each case, the outer shell (in this case the third shell) does not contain eight electrons. This means these shells are only partially full. A full shell has eight electrons (except for the smaller first shell, which can only hold up to two electrons). All atoms want to have the maximum number of electrons possible in their outer shell. This is an observed property of elements.

All atoms will either try to *gain electrons* so that they have eight in their outer shell, or *lose electrons* so that their outer level is empty, and therefore the next level below is full. Atoms will gain or lose according to which involves the fewest electrons. Generally, if an atom has seven electrons in its outer shell, then it's easier for it to gain one electron and end up with eight in the outer shell rather than to lose all seven.

Some elements, like carbon, have four electrons in their outer shell. So what do they do? Is it easier to gain four electrons and have a full shell, or is it easier to lose four electrons and have an empty shell? Carbon is actually able to do both, and can even share four electrons. It just depends on the element that is reacting with the carbon. If that element needs to gain electrons, then carbon can provide them, but if that atom wants to lose electrons, then carbon can take them.

If you look at an inert gas, such as neon, you will see that it has eight electrons in its outer shell, so it does not need to gain or lose any electrons. This explains why the inert gases do not react (recall that inert means non-reactive).

Element	First Shell	Second Shell	Third Shell	Action
Sodium (Na)	2	8	1	lose one electron
Aluminum (Al)	2	8	3	lose three electrons
Sulphur (S)	2	8	6	gain two electrons
Chlorine (Cl)	2	8	7	gain one electron

Table 6.4 Number of electrons in the electron shells for some elements

Look at the same elements as before. What should each one do to get a full (or empty) outer shell?

Example

Support Question

5. Use the online Periodic Table to complete the following table. The first one is done for you.

Electron shell configurations for some elements

Element	First Shell	Second Shell	Third Shell	Needs to...
Boron, B	2	3	0	lose three electrons
If boron loses three electrons from the second shell, its second shell will be empty.				
Magnesium, Mg				
Fluorine, F				
Oxygen, O				

Gaining and Losing Electrons

How do atoms gain or lose electrons? Why does a reactive metal like sodium combine with a poisonous gas like chlorine to produce sodium chloride (also known as salt, which we put on our French fries)? The atoms can't just let their electrons go, and the electrons they gain have to come from somewhere. Since some atoms want to lose electrons and some want to gain electrons, the easiest way is for atoms to *transfer* electrons from one to another. If sodium wants to lose an electron and chlorine wants to gain an electron, then they can both be satisfied if an electron is transferred from sodium to chlorine.

By losing an electron, sodium becomes positively charged; by gaining an electron, chlorine becomes negatively charged. Each has become an **ion**, an atom that has gained or lost electrons and so is no longer neutral. The resulting compound, sodium chloride, is called **ionic** because it is formed from the combination of ions. Ionic compounds are always formed between a metal and a non-metal.

1. Metals always want to lose electrons.
2. Non-metals want to gain electrons, but will also share electrons with another non-metal.
3. If the column tells you how many valence electrons there are, it will also tell you how many electrons the atom needs to gain or lose.

Three simple rules indicating whether an atom wants to gain or lose electrons

To understand how elements react, you need to determine which atoms gain and which atoms lose electrons. You also need to know how many they will gain or lose. Here the organization of the Periodic Table can help.

Type of Compound	What it is made of	Examples
Ionic compounds	Made from a metal and a non-metal	NaF, sodium fluoride (toothpaste additive) NaCl, sodium chloride (table salt) CaCl ₂ , calcium chloride (road salt) KCl, potassium chloride (water softener salt)
Molecular compounds	Made from two non-metals	CO ₂ , carbon dioxide (product of combustion) NH ₃ , ammonia (used in fertilizer) CH ₄ , methane (natural gas) H ₂ O, water

Table 6.5 Comparison of ionic and molecular compounds

Another option is *sharing* electrons. If an atom that normally gains electrons needs to combine with another atom that normally gains electrons, the two atoms can share electrons between them so that each can behave as if it had a full outer shell. For example, a sulphur atom, which has six electrons in its outer shell, can combine with an oxygen atom, which also has six electrons in its outer shell. The two atoms can share some of their electrons so that each would feel like it has eight electrons in the outer shell. The oxygen would need to share two of the sulphur's electrons to add to its own outer six electrons. The sulphur would need to share two of the oxygen's electrons to add to its own six electrons. This type of compound is called **molecular** because there are no charged particles. A molecular compound is formed between two non-metals.

Examples

- Lithium (3), a metal in column 1, has one electron in its outer shell (in other words, one valence electron). It will lose that electron when it forms an ionic bond.
- Magnesium (12), a metal in column 2, has two electrons in its outer shell. It will lose those two electrons to form an ionic compound.
- Nitrogen (7), a non-metal in column 15, has five electrons in its outer shell. It will try to gain three electrons so that its outer shell has eight, and then it can form ionic bonds or try to share three of another atom's electrons to make a molecule.
- Chlorine (17), a non-metal in column 17, has seven electrons in its outer shell. It will try to gain one electron so that it has eight on the outer shell, and then it can form ionic bonds or try to share one of another atom's electrons to make a molecule.
- Hydrogen (1), a non-metal, has one electron in its outer shell. It will lose that electron when it forms an ionic bond, but will also share that electron when it combines with other non-metals.

Support Question

6. Calcium reacts with oxygen gas to form calcium oxide, a white crystal commonly known as lime. Referring to the valence electrons of calcium and of oxygen, explain how these two elements would react to produce a new compound.

Naming Compounds

Chemicals that have been known for a long time are often called by more than one name. This can make things very confusing. For example, sodium bicarbonate is also known as baking soda, bread soda, or cooking soda. Sodium chloride is commonly called salt—even though there are hundreds of kinds of salts, most of which don't contain sodium. Because the same chemical could be known by so many different common names, it was crucial for chemists to come up with a standardized way of naming them.

The names and formulas of different compounds may seem complex and confusing, but there are helpful patterns. Chemists came up with two ways to name chemicals. One uses a formula and one uses a name. The formula uses the element symbols and numbers to tell you how many atoms of each element are in a molecule of the material. Formulas are very useful, particularly when you're balancing chemical reactions, as you'll see in later lessons.

Chemical Formulas

The chemical formula quickly tells you a lot about the molecule. Each element in a molecule is represented by its chemical symbol, found in the Periodic Table. The number beside an element refers to how many atoms of it are present in the molecule. To keep things simple, only numbers higher than 1 show up in the subscript.

Example

- NaCl: means that one atom of sodium is combined with one atom of chlorine
- NH₃: means that one atom of nitrogen is combined with three atoms of hydrogen
- H₂O: is the formula for water and means that two atoms of hydrogen are combined with one atom of oxygen

You will work a lot with chemical formulas throughout this unit.

Chemical Names

The standardized name system tells you a lot about a chemical. Like the chemical formula, the chemical name conveys information about the components and their relative abundance. For example, consider a compound called calcium chloride. Calcium chloride has uses ranging from melting ice to giving pickles their salty taste. It has two parts in its name: *calcium* and *chloride*. Calcium is obviously connected to the element calcium, and chloride sounds similar to the element chlorine. So the name calcium chloride tells you that it is probably made from calcium and chlorine. Its formula is CaCl_2 .

Another example is sulphur dioxide. The first part, *sulphur*, is obviously connected to the element sulphur. What about *dioxide*? If you break down the word, you get *di* and *oxide*. From the table below you can see that *di* means two, and *oxide* seems connected to oxygen. So we know from the name that sulphur dioxide is probably made from sulphur and two oxygens. Its formula is SO_2 .

Table 6.6 lists the prefix names used to represent the number of atoms in a molecule. You may already be familiar with some of these. For example, you've probably heard of some kinds of gasoline having a high *octane* rating. Octane is a gasoline molecule containing eight ("octa") carbon atoms, and is very high in energy.

Table 6.6 Naming prefixes used for number of atoms in a molecule

Number	Prefix
1	mono
2	di
3	tri
4	tetra
5	penta
6	hexa
7	hepta
8	octa
9	nona
10	deca

What patterns did you notice in names like calcium chloride and sulphur dioxide? Think of all compounds as having two halves—the first part and the second part. Calcium chloride is the combination of a metal and a non-metal (ionic), and sulphur dioxide is the combination of two non-metals. In both cases, the name of the first element was just as it is in the Periodic Table:

1. If it's an ionic compound, the first element is always the metal.
2. If it's a molecular compound, the first element is the non-metal that is farther left, or further down, in the Periodic Table.
3. The name of the first element does not change.
4. The name of the second element is changed to end with *-ide*.
5. If molecular, prefixes indicate the number of atoms of each element.

Five rules for writing chemical names

Molecular compounds contain two non-metals, so they might seem a little more difficult to name. The rule is that the non-metal that is FARTHER LEFT on a row or FURTHER DOWN a column in the Periodic Table goes first. So carbon comes before oxygen, sulphur, or chlorine in a name, and sulphur comes before oxygen.

For **ionic compounds**, the metal always comes first. Sodium will come before chlorine, fluorine, or any other non-metal; calcium will come before oxygen, sulphur, or bromine.

Writing Chemical Names

So now you know how to read a chemical name. But how do you know which element is listed first? Can we have chlorine sodide? Or oxygen sulphide? Luckily, you don't have to guess—there are rules.

For **ionic compounds**, the metal always comes first. Sodium will come before chlorine, fluorine, or any other non-metal; calcium will come before oxygen, sulphur, or bromine.

Molecular compounds contain two non-metals, so they might seem a little more difficult to name. The rule is that the non-metal that is FARTHER LEFT on a row or FURTHER DOWN a column in the Periodic Table goes first. So carbon comes before oxygen, sulphur, or chlorine in a name, and sulphur comes before oxygen.

As well, in both cases, the ending of the second element was changed to *-ide*.

chlorine → chloride oxygen → oxide

Calcium chloride Sulphur dioxide

Support Question

7. For each of the following formulas, write "Y" for yes in the right-hand column if the suggested name is correct, or "N" for no if it is incorrect.

Formula	Suggested Name	Correct? (Yes/No)
NaF	Sodium fluoride	
PCl ₃	Phosphorous trichloride	
CaO	Calcium oxygen	
KCl	Potassiumide chlorine	
CO	Carbon monoxide	
N ₂ O ₅	Dinitrogen pentoxide	
MgBr ₂	Magnesium bromide	
AlCl ₃	Chlorine aluminate	

Conclusion

In this lesson, you learned about the basic components of chemistry: atoms, molecules, and their arrangement in the Periodic Table. You also learned the rules for naming compounds based on the properties of their parts.

In the next lesson, you will apply your knowledge of atoms and compounds to exploring how they react.

Key Concepts

- Atom:** smallest indivisible particle of an element
- Element:** a pure substance composed of only one kind of atom
- Neutron:** sub-atomic particle with no charge that lies within the nucleus
- Proton:** sub-atomic particle with a positive charge that lies within the nucleus
- Electron:** sub-atomic particle with a negative charge that orbits the nucleus
- Electron shell:** a collection of orbiting electrons. Each shell can contain up to eight electrons.
- Molecule:** smallest indivisible particle of a compound
- Compound:** made from a combination of atoms from different elements
- Periodic Table:** a table listing all the known elements, arranged according to their atomic properties
- Atomic number:** an element's number, determined by how many protons it has
- Valence electron:** electron found in the outer shell of an atom
- Inert:** non-reactive
- Ion:** an atom that has gained or lost electrons and so is no longer neutral
- Ionic compound:** contains ions and is always formed between a metal and a non-metal
- Molecular compound:** is formed between two non-metals and contains no charged particles

Key Questions

Save your answers to the Key Questions in your Course Journal or e-Journal.

Total: 21 marks

24. a) Using the online Periodic Table, identify what family the following elements are in. (4 marks: 1 mark for each)

Element	Family
Sodium	
Fluorine, chlorine	
Nickel, copper, zinc	
Beryllium, magnesium	

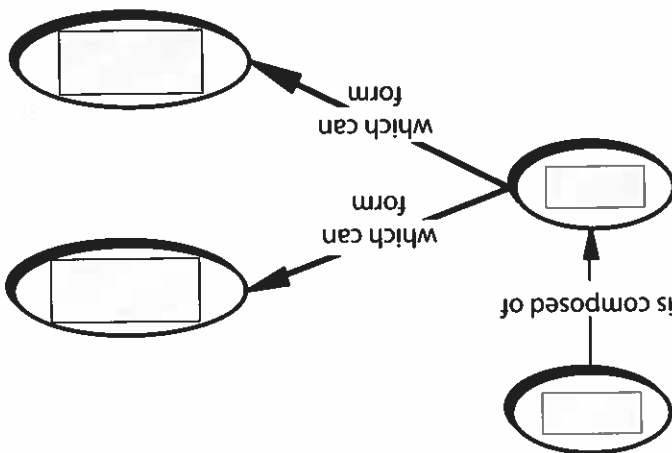
- b) Indicate two ways that you can tell if an element is a metal or a non-metal. (2 marks)

25. a) Indicate whether each of the following elements is likely to TRANSFER (T) electrons or SHARE (S) electrons when combining with sulphur. (4 marks: 1 mark for each)

Element	Electron: Transfer or Share (T or S)
Lithium	
Fluorine	
Nitrogen	
Magnesium	

- b) Explain why atoms get together to form compounds. (2 marks)

26. Fill in the blank sections of this concept map to correctly relate the following: matter, ionic compounds, molecular compounds, atoms. (4 marks)



Now go on to Lesson 7. Remember, you do not send your journal to the Independent Learning Centre until you have completed Unit 2 (Lessons 6 to 10).

Compound	Name
LiBr	
Na ₂ O	
NO ₂	
CO ₂	
CaF ₂	

27. Using the Periodic Table, write the name of the following compounds. (5 marks: 1 mark for each)



SNC2D-B



When Chemicals React

Suggested Timing for This Lesson (hours)	
What Is a Reaction?	½
Signs of a Chemical Change	½
Activity: Physical and Chemical Changes around the House	1
Using Names and Formulas	½
Polyatomic Ions	½
Types of Chemical Reactions	¾
Key Questions	¾

You may find this time grid helpful in planning when and how you will work through this lesson.

Planning Your Study

Elements and compounds are useful enough on their own, but things really get interesting when they react together to form new molecules.

Chemical reactions are an important part of your daily life. Every time you cook food, drive a car, or light a match, you are using chemical reactions. Much of the food you eat, the clothing you wear, and the products you buy are produced through chemical reactions. As you saw in Unit 1, chemical reactions are also responsible for some of the environmental problems we face. However, you will learn that we can use chemical reactions to help solve environmental problems, as in water purification or pollution controls in cars.

In Canada, industries such as mining and manufacturing use many chemical reactions to separate materials or produce new materials. As well, all medicines are created using chemical reactions. Even high-tech devices like cell phones and music players are produced by many chemical reactions.

In the last lesson, you were introduced to basic chemical reactions in which atoms combined to form simple molecules and compounds. In this lesson, you will see how atoms change slightly when they come together, combining to form new molecules that act differently than the single atoms. They also combine in certain consistent and predictable patterns.

Introduction

What You Will Learn

After completing this lesson, you will be able to

- distinguish between physical and chemical changes
- identify the signs of a chemical change
- write the names and formulas of different types of compounds
- write chemical reactions

What Is a Reaction?

The study of chemistry is really the study of **chemical reactions**—processes whereby one or more substances are changed into others. The elements and compounds you learned about in the last lesson are the building blocks from which more complex molecules are created through a series of chemical reactions. Chemical reactions come in many different forms and occur in many different places. A piece of wood burning in a fire and a car rusting in the winter don't seem to have much in common, but both are chemical reactions. They both involve substances interacting to produce something new. The piece of wood is reacting with oxygen in the air to produce carbon dioxide gas and water vapour, as well as releasing heat and light. The iron in the metal of the car reacts with oxygen in the air and produces an iron oxide we call rust.

The way chemical reactions work can be compared to building a bicycle. You take components such as the wheels and the frame and assemble them to create something new. All the parts change slightly after they are connected together. For example, a wheel on its own can turn and spin in any direction, but once it is connected to the frame, the wheel can only turn and spin with the whole bike. Its behaviour has changed. Just like bicycle assembly, chemical reactions involve creating a new product from the original parts.

Chemical reactions have the power to transform elements by creating new substances with new features. For example, sodium is a shiny grey metal that is very reactive with water. It even can burst into flames when put into water! Chlorine is a yellowish poisonous gas that has been used in chemical warfare (mustard gas). On their own, both these elements can harm you, yet they react to form a compound (salt) that is safe to touch and adds flavour to your food.

There are Suggested Answers to Support Questions at the end of this unit.

- a) Carbon monoxide reacts with oxygen gas (O_2) to produce carbon dioxide.
- b) Aluminum metal reacts with hydrogen chloride to produce aluminum chloride and hydrogen gas (H_2).
- c) Magnesium metal reacts with oxygen to produce magnesium oxide.
- d) Hydrogen gas reacts with sulphur to produce dihydrogen sulphide.
- e) Calcium reacts with hydrogen bromide to produce calcium bromide and hydrogen gas (H_2).

9. Write chemical equations using chemical formulas based on the following descriptions. Be sure to include the plus sign and the arrows as required.

Reaction	Reactants	Products
a) $Fe + O_2 \rightarrow Fe_2O_3$		
b) $CaCl_2 + MgO \rightarrow CaO + MgCl_2$		
c) $Na + HCl \rightarrow NaCl + H_2$		
d) $PbS + O_2 \rightarrow PbO_2 + S$		
e) $CuCl_2 + Al \rightarrow Cu + AlCl_3$		

8. Identify the products and the reactants in each of the following reactions.

Do not send your answers in for evaluation.

Support Questions

Signs of a Chemical Change

When a chemical reaction occurs, a new substance is always produced. Sometimes, though, it is not easy to tell that a chemical reaction has occurred. Some changes that seem very dramatic are actually just physical changes; other changes that look slow and boring may actually be chemical changes.

Look around you. How many chemical reactions are occurring around you right now? See if any of these things are happening:

- Are any cars or other vehicles running their engines?
- Is there a furnace or heater in the building you are in?
- Is a light bulb on?
- Is anyone cooking anything?
- Is there a plant in the room?

All of these involve chemical reactions—including the plant! Even you have chemical reactions going on inside your body all the time as you digest food, burn energy, and build muscle. There are even reactions related to breathing.

Five Signs of a Chemical Change

To tell whether a chemical change has taken place, look for the following:

A Colour Change

If a new colour is produced when substances are mixed together, it is likely a chemical change. For example, when copper metal on roofs and gutters turns green after time, a chemical reaction has taken place. If mixing two colourless solutions together produces a new colour such as pink, a chemical change has taken place. However, if a blue crystal mixes into water and then turns the water blue, this is *not* a chemical change because the blue is not a new colour.

Production of a New Gas

You may have seen reactions that involve bubbling—like an antacid pill producing bubbles when dropped into a glass of water, or baking soda producing bubbles when mixed with vinegar. These are examples of a new gas being produced. Different reactions produce different gases such as hydrogen, oxygen, or carbon dioxide. Also, when something such as wood or paper burns, smoke is produced. That's also an example of a new gas. When water is heated until it boils, there are bubbles and steam—but that is *not* an example of a chemical reaction because the gases produced are not new substances.

Production of a New Solid

When you burn a piece of wood, you see flames and smoke, but what is left behind? The piece of wood slowly disappears, leaving some residue, usually a white ash. This is a new solid. In other cases, when a solid such as a metal is added to water or an acid and it reacts, a solid residue is left behind. This is called a **precipitate**. Sometimes two solutions are mixed together and a solid precipitate is formed.

Production of Heat or Light

This one is probably the most obvious. When something is burning, we see light from the flame and can usually feel heat. Inside a light bulb, a wire filament heats up and releases light when electricity passes through it. The light and heat are the result of a chemical reaction. However, not all processes involving heat are chemical reactions. When water is boiled, the temperature changes but the water remains water. Since no new substance is produced, no chemical change has taken place.

Irreversibility

Can the process be reversed? Sometimes this is easy to tell. When wood is burned, it can't be returned back to what it was. A piece of metal that reacts with acid cannot be changed back into the original metal. We often use the criterion of whether the change is reversible to confirm a chemical change we suspect because of some other reason, such as a change in colour. For example, when iron rusts, we see the colour change and we can remove the rusted sections, but we cannot turn the rusted metal back to the original iron.

The main clue in all these examples of **chemical change** is the production of a *new substance*. If you see a new substance, such as the new gas or new solid, the product is probably the result of a chemical change.

What distinguishes chemical reactions from physical changes? In a **physical change**, the substance might change its state, size, shape, temperature, or amount, but it remains the same substance. When ice melts to water and then the water is boiled to a gas, there is a change in temperature, but the molecules of the water do not change—they are still water. When salt is dissolved into water, it seems to have changed, but if the water is evaporated, the salt crystals can be recovered. Neither example has produced a new substance, and these physical changes, like most, are reversible. However, sometimes when the products of a chemical reaction are invisible, it can be hard to distinguish a chemical from a physical reaction just by observation.

Support Question

10. Classify each of the following as a PHYSICAL (P) or CHEMICAL (C) change:

- a) Vinegar and baking soda bubble and fizz when mixed together. _____
- b) A silver bowl tarnishes to black. _____
- c) A loaf of bread is sliced. _____
- d) A piece of bread becomes mouldy and turns green. _____
- e) Water is evaporated, leaving salt behind. _____
- f) Water is heated until it boils. _____
- g) Grape sugar is fermented to make wine. _____
- h) Two colourless solutions combine to produce a solid. _____
- i) Sugar is heated until it turns black. _____
- j) Sugar is heated until it melts. _____
- k) A light bulb is turned on. _____
- l) Road salt corrodes a car body over the winter. _____

Activity: Physical and Chemical Changes around the House



Many chemical reactions occur frequently inside your home. Heating your home or producing hot water usually involves burning some fuel, such as oil or natural gas. Cooking usually changes the chemical nature of the foods, and metals like brass and silver tarnish because they react chemically with the air.

In this activity, you will use common household items and simple chemical solutions to demonstrate some of the signs of a chemical change. In any activity or experiment, observations are very important. You need to describe what you see before, during, and after the potential reactions. These observations form the evidence that you will use to draw your conclusions. Observations may also include what you hear or smell—but not, as general rule, what you taste.

Many of the following experiments you can do on your own at home. However, to make the process easier for you, videos of all the experiments are provided on the course web page. These videos capture exactly what happens in each experiment—before, during, and after the reactions. These videos replicate what you would have seen if you had done the experiment yourself. The videos contain no narration or explanation. It is still up to you to record your own observations and analyze what is happening.

Before watching the videos, make your own observation table like the one on the next page.

Table 7.1 Observation table for each experiment

Experiment	Initial Observations	Observations During Reaction	Final Observations
Experiment A: Calcium carbonate and water		Test with match:	
Experiment B: Calcium carbonate and vinegar		Test with match:	
Experiment C: Burning match			
Experiment D: Antacid and water		Test with match:	
Experiment E: Hydrogen peroxide and bleach		Test with match:	
Experiment F: Potassium iodide and lead nitrate		Test with match:	
Experiment G: Sodium chloride and silver nitrate		Test with match:	

- Add the pill to the water and stir the mixture.
- Observe what happens and how the materials react. Record in the table.
- While the mixture is still reacting, hold a lit match above the surface. Record what happens to the flame.

Observations during Reaction:

- Examine an antacid pill like Tums™ (or other calcium carbonate product). Observe its physical appearance (state, colour, form) and record in the table.
- Half-fill a glass with tap water. Describe the physical characteristics of the water.

Initial Observations:

A. Antacid pill (calcium carbonate) in water

Seven Experiments to Observe Signs of a Chemical Change

Go to your course page on the ILC website and click on "Signs of a Chemical Change" under Lesson 7.



- Follow all directions and safety precautions as described. You might think that household products are safe, but mixing different products can result in the release of harmful chemicals.
- Protective eyewear is recommended for all experiments.
- Rinse your hands or skin under cold running water if any of the substances make contact.
- Perform the reactions near or in a sink to avoid mess and to make clean-up easier.

SAFETY CONSIDERATIONS:

Sample observations are provided in a table at the end of this activity to assist you in answering the Support Questions.

If you decide to perform any of these experiments at home, be sure to take the following precautions.

Final Observations:

- Leave the mixture for about 10 minutes before making final observations.
- Look for evidence of new substances or a change in the physical state of the initial reactants.

Disposal:

- This mixture can be flushed in the sink with the water running for a few minutes afterwards.

- The burnt match should be rinsed in water and then put into the garbage.
- Make sure the match is no longer burning or warm when you put it into the garbage.

B. Antacid pill and vinegar*Initial Observations:*

- Examine an antacid pill like "Tums" (or other calcium carbonate product). Observe its physical appearance (state, colour, form) and record in the table.
- Half-fill a glass with vinegar. Describe the physical characteristics of the vinegar.

Observations during Reaction:

- Add the pill to the vinegar and stir the mixture.
- Observe what happens and how the materials react. Record in the table.
- While the mixture is still reacting, hold a lit match above the surface. Record what happens to the flame.

Final Observations:

- Leave the mixture for about 10 minutes before making final observations.
- Look for evidence of new substances or a change in the physical state of the initial reactants.

- Record your observations in your table.

Disposal:

- This mixture can be flushed in the sink with the water running for a few minutes afterwards.
- The burnt match should be rinsed in water and then put into the garbage.
- Make sure the match is no longer burning or warm when you put it into the garbage.

C. Burning match

Initial Observations:

- Examine an unlit wooden match. Observe its physical appearance (state, colour, form) and record in the table.

Observations during Reaction:

- Light the match using the strike surface on the match box.

- Observe what happens and how the material changes. Record in the table.

Final Observations:

- Blow out the flame and make final observations of the material. Look for evidence of new substances or a change in the physical state of the initial material.

- Record your observations in your table.

Disposal:

- Rinse the burnt match stick under water before putting it in the garbage.
- Make sure the match is no longer burning or warm when you put it into the garbage.

D. Antacid powder or tablet (Alka-Seltzer™ or Eno™) in water

Initial Observations:

- Examine a pill or packet of antacid containing sodium citrate like Alka-Seltzer™ or Eno™. Observe its physical appearance (state, colour, form) and record in the table.
- Half-fill a glass with tap water. Describe the physical characteristics of the water.

Observations during Reaction:

- Add the pill or powder to the water and stir the mixture.
- Observe what happens and how the materials react. Record in the table.
- While the mixture is still reacting, hold a lit match above the surface. Record what happens to the flame.

Final Observations:

- Leave the mixture for about 10 minutes before making final observations. Look for evidence of new substances or a change in the physical state of the initial reactants.

- Record your observations in your table.

E. Hydrogen peroxide and bleach

Initial Observations:

- Examine a small glass containing about 50 mL ($\frac{1}{4}$ cup) of 3% hydrogen peroxide. Observe its physical appearance (state, colour, form) and record in the table.
- Examine another small glass containing about 50 mL ($\frac{1}{4}$ cup) of laundry bleach (containing sodium hypochlorite). Observe its physical appearance (state, colour, form) and record in the table.
- The burnt match should be rinsed in water and then put into the garbage. Make sure the match is no longer burning or warm when you put it into the garbage.
- This mixture can be flushed in the sink with the water running for a few minutes afterwards.

Disposal:

- This mixture can be flushed in the sink with the water running for a few minutes afterwards.
- The burnt match should be rinsed in water and then put into the garbage. Make sure the match is no longer burning or warm when you put it into the garbage.

Disposal:

- Record your observations in your table.
- Leave the mixture for about 10 minutes before making final observations. Look for evidence of new substances or a change in the physical state of the initial reactants.

Final Observations:

- Add the hydrogen peroxide to the bleach and stir the mixture. Observe what happens and how the materials react. Record in the table.
- While the mixture is still reacting, hold a lit match above the surface. Record what happens to the flame.

Observations during Reaction:

- Examine another small glass containing about 50 mL ($\frac{1}{4}$ cup) of laundry bleach (containing sodium hypochlorite). Observe its physical appearance (state, colour, form) and record in the table.
- Examine a small glass containing about 50 mL ($\frac{1}{4}$ cup) of 3% hydrogen peroxide. Observe its physical appearance (state, colour, form) and record in the table.

F. Potassium iodide and lead nitrate

This experiment cannot be done easily at home because the materials are not readily available. Observe the video of this experiment on the course web page.

Initial Observations:

- Examine a small glass containing about 20 mL ($\frac{1}{2}$ cup) of potassium iodide solution. Observe its physical appearance (state, colour, form) and record in the table.
- Examine another small glass containing about 20 mL ($\frac{1}{2}$ cup) of lead (II) nitrate solution. Observe its physical appearance (state, colour, form) and record in the table.

Observations during Reaction:

- Add the potassium iodide to the lead nitrate and stir the mixture.
- Observe what happens and how the materials react. Record in the table.
- While it is still reacting, hold a lit match above the surface of the mixture. Record what happens to the flame.

Final Observations:

- Leave the mixture for about 10 minutes before making final observations. Look for evidence of new substances or a change in the physical state of the initial reactants.
- Record your observations in your table.

Disposal:

- This mixture can be flushed in the sink with the water running for a few minutes afterwards.
- The burnt match should be rinsed in water and then put into the garbage. Make sure the match is no longer burning or warm when you put it into the garbage.

G. Sodium chloride and silver nitrate

This experiment cannot be done easily at home because the materials are not readily available. Observe the video of this experiment on the course web page.

Initial Observations:

- Examine a small glass containing about 20 mL ($\frac{1}{2}$ cup) of sodium chloride solution. Observe its physical appearance (state, colour, form) and record in the table.
- Examine another small glass containing about 20 mL ($\frac{1}{2}$ cup) of silver nitrate solution. Observe its physical appearance (state, colour, form) and record in the table.

Observations during Reaction:

- Add the sodium chloride to the silver nitrate and stir the mixture.
- Observe what happens and how the materials react. Record in the table.
- While it is still reacting, hold a lit match above the surface of the mixture. Record what happens to the flame.

Final Observations:

- Leave the mixture for about 10 minutes before making final observations. Look for evidence of new substances or a change in the physical state of the initial reactants.
- Record your observations in your table.

Disposal:

- This mixture can be flushed in the sink with the water running for a few minutes afterwards.
- The burnt match should be rinsed in water and then put into the garbage. Make sure the match is no longer burning or warm when you put it into the garbage.

Sample Observations

Table 7.2 Sample observations for each experiment

Experiment	Initial Observations	Observations During Reaction	Final Observations
Experiment A: Calcium carbonate and water	Water is clear and colourless. Turns™ pill is a white solid.	When the two are added together, a white cloud starts to form around the pill. When the container is stirred, the solution becomes very cloudy white. Test with match: flame does not change.	After time, the mixture starts to settle and separate into a clear liquid and white solid.
Experiment B: Calcium carbonate and vinegar	Vinegar is clear and colourless. Turns™ pill is a white solid.	When the two are added together, bubbles start to form around the pill and rise to the top of the liquid. Test with match: flame does not change.	After time, the pill disappears completely, no white residue is left.
Experiment C: Burning match	The match is a small wooden stick. One end is coated with a red and white substance.	When struck, the match bursts into flames. Heat, light, and smoke are released.	After the flame is extinguished, smoke is released for a short time. The wood has turned black and lost its shape.
Experiment D: Antacid and water	The antacid is a fine white powder. The water is a clear, colourless liquid.	When the two are combined, lots of rapid bubbling occurs throughout liquid. Test with match: flame goes out.	After time, the pill disappears completely, no white residue is left.
Experiment E: Hydrogen peroxide and bleach	Hydrogen peroxide is a clear, colourless liquid. Bleach is a clear liquid with a slight yellow colour.	When the two are combined, the mixture turns foamy white and seems to expand in the container. Test with match: An extinguished match will relight and burn brighter than usual. This happens until the reaction has finished.	After time, the bubbles disappear and the mixture looks clear and colourless.
Experiment F: Potassium iodide and lead nitrate	The sodium chloride solution is clear and colourless. The lead (II) nitrate solution is clear and colourless.	When the two are combined, the mixture instantly turns yellow and opaque. Test with match: flame does not change.	After time, the yellow solid settles on the bottom.
Experiment G: Sodium chloride and silver nitrate	The sodium chloride solution is clear and colourless. The silver chloride solution is clear and colourless.	When the two are combined, the mixture turns cloudy white. Test with match: flame does not change.	After time, the white solid settles on the bottom.

Support Questions

11. Compare Experiment A to Experiment B.

- a) Identify which experiment involves a chemical change and which involves a physical change.

- b) What is the evidence for the chemical change?

12. For each of the following experiments, identify one sign of a chemical change that was observed (there may have been more than one sign):

Reaction	Sign of Chemical Change
Experiment B	
Experiment C	
Experiment D	
Experiment E	
Experiment F	
Experiment G	

13. The burning match is used to identify different gases. If the flame was extinguished in Experiment D and continued to burn in Experiment E, what does this indicate about the gases produced?

Using Names and Formulas

In order to identify what happens in a chemical reaction, you need to look for the presence of a new substance. But how will you know what the new substance is? A new gas being formed could be oxygen, nitrogen, carbon dioxide, or even hydrogen. The new solid that you see could be salt or sugar. You can't always tell just by looking.

To figure out what the products are, you need to look at the names of the reactants and then think about how the atoms combine.

In the last lesson, you saw that names of compounds followed a pretty consistent pattern. All the names of compounds so far involved two parts, usually a metal first and then a non-metal. The compound was formed because each of the atoms wanted to gain or lose electrons; the atoms transferred or shared electrons until each had a full outer shell of electrons.

Writing Chemical Formulas

Writing formulas is pretty consistent too. Given a name, you just have to find the right element in the Periodic Table and write the symbol down.

Molecular Compounds

Recall from Lesson 6 that a molecular compound is formed between two non-metals. With molecular compounds, the number of atoms is indicated in the name; if no prefix is used, then the symbol represents one atom. A compound such as phosphorous pentachloride has *one atom of phosphorous* and *five atoms of chlorine* (remember “penta” = 5). So its formula should be PCl_5 .

Examples

Table 7.3 Examples of molecular compounds

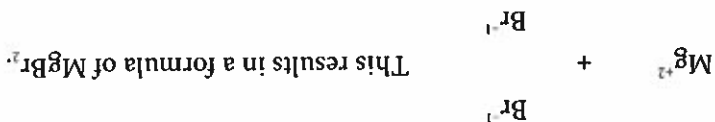
Name	Formula	Explanation
Carbon dioxide	CO ₂	One carbon atom has four electrons to share but each oxygen atom can only take two, so it takes two oxygen atoms.
Dihydrogen sulphide	H ₂ S	Hydrogen is a non-metal which can share one electron and sulphur needs to gain two electrons, so it takes two hydrogens.
Hydrogen bromide	HBr	Hydrogen has one electron to share and bromine wants to gain one.

Ionic Compounds

With ionic compounds, you have to think more about how the atoms interact. Remember that in an ionic compound, the metal will give away electrons to the non-metal. But what if they aren't transferring the same amount?

For example, in magnesium bromide, the magnesium wants to give away two electrons, but the bromine only wants to take one electron. If magnesium can get rid of its two electrons (which are negative), it will become an ion with a +2 charge because it still has all of its positive protons. Therefore it will be more positive than negative. If bromine can gain one electron, it will become an ion with a -1 charge because it would have more negative electrons than positive protons.

To balance out and make the compound neutral, one magnesium ion needs to combine with two bromine ions:



Another way to think about this is that magnesium needs to give one electron to one bromine atom, and then give another electron to a different bromine atom.

Simple rules for writing formulas

1. Write the symbol for the first element. Write the symbol for the second element beside it. This represents one atom of each element.
2. For molecular compounds, use the prefixes to tell you how many atoms of each element are present. Write a small number (subscript) beside the symbol to indicate the number of atoms.
3. For ionic compounds, use the number of electrons that the metal wants to lose to balance out the number of electrons the non-metal wants to gain. Usually you can just "criss-cross" the charges.

So the formula becomes:
(Remember, you don't need to write the 1 in a formula)



Put the new charge below each ion to get the subscript:



Switch ("criss-cross") the charge between ions:



signs):

Then write the charge below each ion (without the



Write the ions beside each other:



- Mg usually loses two electrons, becoming Mg^{+2}
- Br usually gains one electron, becoming Br^{-1}

Some people use a simple **criss-cross rule** to determine the formula. Take the charges of the ions based on the number of electrons they gain or lose:

Examples

Table 7.4 Chemical names and their associated formula with explanation

Name	Formula	Description
Potassium chloride	KCl	Potassium gives away an electron to become +1; chlorine gains an electron to become -1. One ion of each balances the other.
Calcium oxide	CaO	Calcium gives away two electrons to become a +2 ion; oxygen gains two electrons to become a -2 ion. One ion of each balances the other.
Sodium sulphide	Na ₂ S	Sodium loses an electron to become a +1 ion; sulphur gains two electrons to become a -2 ion. So two sodium ions are needed to balance the sulphur ion.

Support Question

14. Referring to the Periodic Table, fill in the blank with the corresponding name or formula. The first one is done for you.

Name	Formula
Carbon dioxide	CO ₂
Nitrogen trifluoride	
SO ₂	
Carbon tetrafluoride	
Dihydrogen monoxide	
Carbon monoxide	
Calcium fluoride	
Selenium dioxide	
Calcium bromide	
Potassium oxide	
Li ₂ S	
Calcium phosphide	
Al ₂ S ₃	
Magnesium oxide	

Polyatomic Ions

Before exploring other types of reactions, you have to look at another group of compounds. Some of the reactions that you observed in the activity involved compounds that do not fit the basic pattern of being made from only two elements. For example, baking soda has a chemical name of sodium bicarbonate. The sodium part sounds familiar, but not the rest of it. The antacid pill has calcium carbonate in it. Again, the calcium part is familiar, but what is carbonate? In fact, many common chemicals you use every day, including a lot of your food, contain compounds with unfamiliar names like “hydroxide,” “sulphate,” or “nitrate.”

All of these chemicals include a type of molecule called a polyatomic ion. If you look at the word, it has three parts: *poly*, *atomic*, and *ion*. You know that the prefix *poly* means many. *Atomic* obviously refers to atoms. And you learned that an ion is an atom that has a charge because it has lost or gained electrons. Put those parts back together: a **polyatomic ion** is a molecule (because it has more than one atom) that has a charge.

Table 7.5 Examples of common polyatomic ions

Name of the ion	Formula
Hydroxide	OH ⁻
Nitrate	NO ₃ ⁻
Carbonate	CO ₃ ⁻²
Sulphate	SO ₄ ⁻²
Phosphate	PO ₃ ⁻³
Acetate	C ₂ H ₃ O ₂ ⁻
Ammonium	NH ₄ ⁺

A polyatomic molecule will usually stay together during reactions, and so can be treated as a whole particle that bonds with other particles. For example, in sodium hydroxide (a compound found in most drain cleaners), a sodium ion (Na⁺) with a charge of +1 combines with a hydroxide ion (OH⁻), which is -1, to form sodium hydroxide, NaOH. Note that there are still two parts to the name and that the metal, sodium, still goes first. The ending of hydroxide is always the same. All polyatomic ions keep their endings.

Examples

Potassium carbonate is a chemical that is important in agriculture as a soil fertilizer. In this molecule, a potassium ion (K^+), with a charge of +1, is combining with a carbonate ion (CO_3^{2-}), which is -2. Two potassium ions are needed to balance out the carbonate ion when forming potassium carbonate, K_2CO_3 . In the name, the metal is given first and the ending of the polyatomic ion does not change, producing the name *potassium carbonate*.

You can even have a compound made from two polyatomic ions. An example is ammonium nitrate, a chemical used in fertilizers to provide the nitrogen that plants need.

The formula for ammonium is NH_4^+ and for nitrate is NO_3^- . They will balance each other out because they have equal but opposite charges, so only one ammonium will be needed to balance out one nitrate. Since they are both polyatomic ions, why does the ammonium name go first? It goes first because, even though it is not a metal, it is a positive ion, just like a metal ion.

Rules for naming and writing formulas for polyatomic ions

1. If combining a metal and polyatomic ion, place the name of the metal first.
2. If combining two polyatomic ions, place the name of the positive polyatomic ion first.
3. The formula and charge of a polyatomic ion never change.
4. Balance out the charges of the polyatomic ions to form a balanced compound.

Types of Chemical Reactions

Knowing how names and formulas work will help you understand reactions better. Just like names and formulas, reactions have patterns. Sometimes, in order to predict the products, you have to examine the names of the reactants. There are two main types of chemical reactions: synthesis reactions and displacement reactions. You will look at each in more detail.

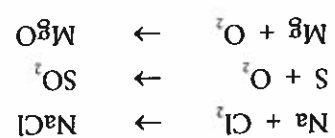
Name	Formula
<i>Potassium hydroxide</i>	KOH
Ammonium hydroxide	
	Na ₂ SO ₄
	AlPO ₄
Calcium sulphate	
Ammonium chloride	
Sodium nitrate	
Calcium carbonate	
Potassium phosphate	
	Li ₂ SO ₄
Sodium acetate	
Magnesium acetate	

15. Fill in the blank with the corresponding name or formula of these polyatomic ions in the table below. Refer to the Periodic Table and the table of common polyatomic ions on page 23. The first one is done for you.

Support Question

Synthesis Reactions

Here are some of the reactions that we have looked at so far:

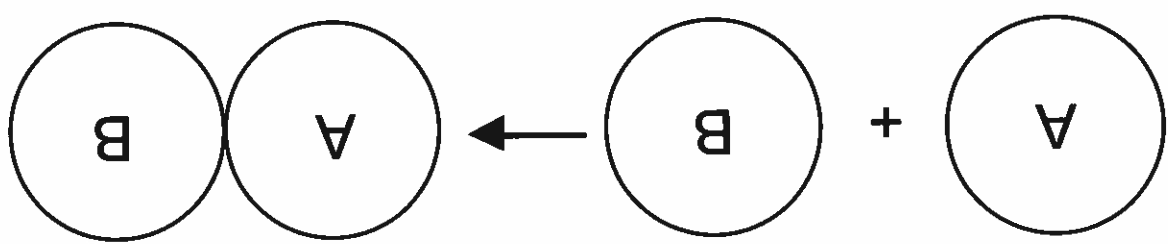


What do these three have in common? Do you notice a pattern? Look at Table 7.6 below. Compare the reactant side with the product side. Note that in each of the three reactions, there are elements as reactants and one compound on the product side.

Table 7.6 Examples of reactants and associated products in synthesis reactions

Reactants	Reactions	Products
Sodium (Na) is an element and chlorine gas (Cl ₂) is an element.	$\text{Na} + \text{Cl}_2 \rightarrow \text{NaCl}$	Sodium chloride (NaCl) is a compound.
Sulphur (S) is an element and oxygen gas (O ₂) is an element.	$\text{S} + \text{O}_2 \rightarrow \text{SO}_2$	Sulphur dioxide (SO ₂) is a compound.
Magnesium (Mg) is an element and oxygen gas (O ₂) is an element.	$\text{Mg} + \text{O}_2 \rightarrow \text{MgO}$	Magnesium oxide (MgO) is a compound.

How would you summarize the pattern? Some people describe it as two elements combining to form a compound or a compound being synthesized from two single elements.
Therefore this pattern is called a **combination or synthesis reaction**, and is graphically represented by



where A and B are the elements and AB is the synthesized compound.

Here's an example using bicycle parts. If we want to build a bicycle, we combine the frame and the two wheels to make a working bicycle:

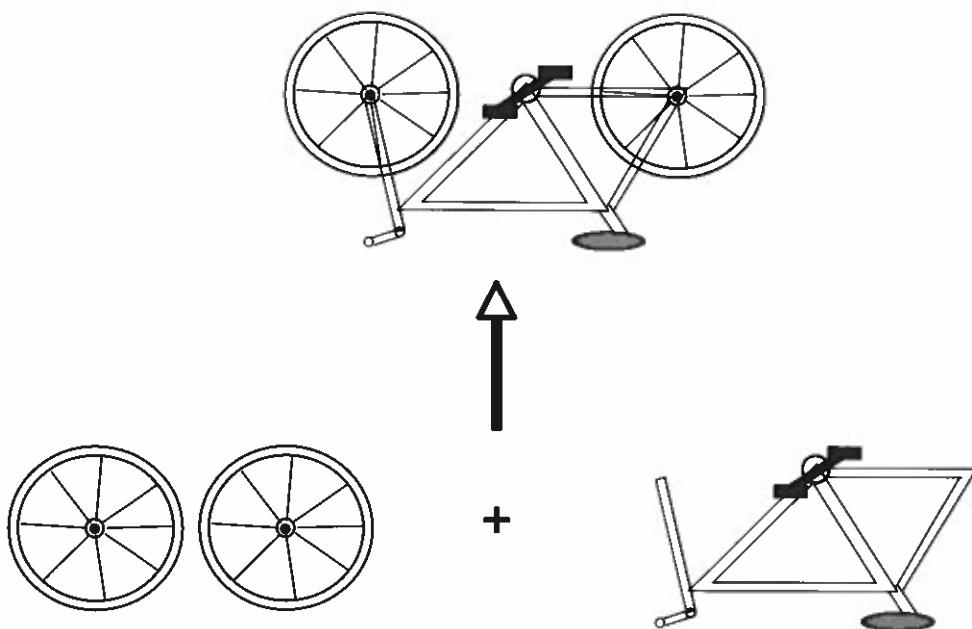


Figure 7.1 Example of a synthesis reaction using bicycle parts

We could write the word equation like this:

Frame + 2 Wheels → Bicycle

We started with individual parts and joined them to make a new, bigger object that works differently from the individual parts.

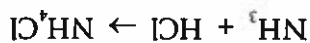
Example

For a simple compound such as table salt (sodium chloride), we combine the sodium atoms with the chlorine molecules.

We would write:

Sodium + Chlorine → Sodium chloride

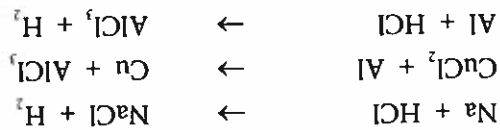
Note that there are *two* individual reactants, which combine to produce only *one* product. It is possible for more than two reactants to still produce only one product. As well, two compounds can combine to produce one larger compound. For example, ammonium chloride (NH_4Cl) is a chemical that has a variety of uses, including being an additive in shampoo and in cough medicines. It is the product of a synthesis reaction between ammonia (NH_3) and hydrogen chloride (HCl).



Ammonium chloride is an interesting chemical. Have you ever seen or used an ice pack that turns cold after you squeeze it? Many of them contain ammonium chloride crystals, also used at ski resorts to keep the snow from melting.

Single-Displacement Reactions

Synthesis reactions are only one type of reaction. There are many other reactions that don't fit into that category. Here are some other reactions that you have looked at so far:



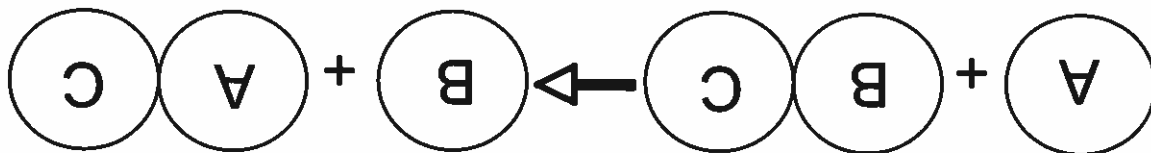
What do these three have in common? Do you notice a pattern? Look at the table below. Compare the reactant side with the product side. Note that in each of the three reactions, there are elements as reactants and two chemicals on the product side. If you look closely at the reactant side and the product side, you might notice a more specific pattern.

Table 7.7 Examples of reactants and associated products in single-displacement reactions

Reactants	Reactions	Products
Sodium (Na) is an element and hydrogen chloride (HCl) is a compound.	$\text{Na} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2$	Sodium chloride (NaCl) is a compound and hydrogen gas (H_2) is an element.
Aluminum (Al) is an element and copper chloride (CuCl_2) is a compound.	$\text{Al} + \text{CuCl}_2 \rightarrow \text{Cu} + \text{AlCl}_3$	Aluminum chloride (AlCl_3) is a compound and copper (Cu) is an element.
Aluminum (Al) is an element and hydrogen chloride (HCl) is a compound.	$\text{Al} + \text{HCl} \rightarrow \text{AlCl}_3 + \text{H}_2$	Aluminum chloride (AlCl_3) is a compound and hydrogen gas (H_2) is an element.

How would you summarize the pattern? If you look closely, the reactant side has a single element and a compound. The product side has a single element and a compound. As well, a single element takes the place of one of the elements in the compound. This is described as a **single-displacement reaction** since one atom takes the place of another in a compound.

The following represents a single-displacement reaction:



The single element replaces whatever element in the compound it is most similar to. If the single element is a metal, it will take the place of the metal in a compound. If the single element is a non-metal, it will take the place of a non-metal in a compound.

Think about the bicycle analogy again. If you had a complete bicycle but wanted to change the wheels from narrow road tires to wheels with thicker mountain bike tires, you would have to replace (or *displace*) the wheels.

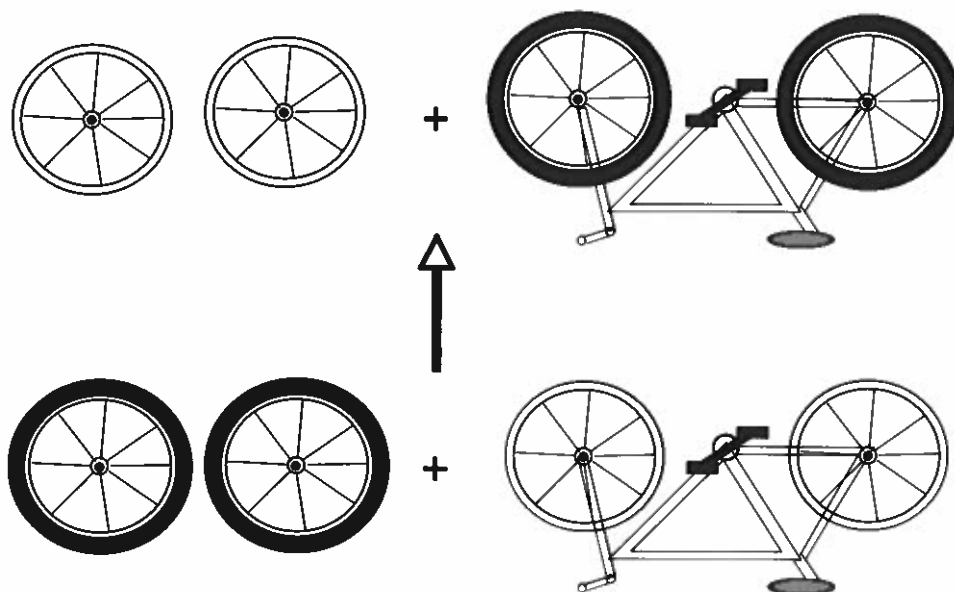


Figure 7.2 Example of a displacement procedure on a bicycle

We could write:

Bicycle (with road tires) + Mountain bike tires -> Bicycle (with mountain bike tires) + Road tires

Some parts of the original object were replaced by different parts, forming a different object.

Example

In a reaction between magnesium and zinc chloride, the magnesium will replace the zinc and form a new chloride:



Single-displacement reactions are common in industrial applications, occurring for example in most batteries. These reactions are also used in processes such as electroplating, where an electric current causes a displacement reaction to occur between a metal and a compound in solution. The displaced metal then forms a coating on an object dipped into the solution to give it a different finish. For instance, silver or gold plating would give jewellery or ornaments a silver or gold finish. Electroplating steel with other metals such as tin and zinc is sometimes used to prevent corrosion in car parts.

Support Questions

16. Identify each of the following reactions as being either a SYNTHESIS or a SINGLE DISPLACEMENT.

Reaction	Type
a) $\text{Fe} + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3$	
b) $\text{Mg} + \text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$	
c) $\text{Zn} + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2 + \text{ZnSO}_4$	
d) $\text{CO} + \text{O}_2 \rightarrow \text{CO}_2$	
e) $\text{Fe} + \text{MgSO}_4 \rightarrow \text{Mg} + \text{FeSO}_4$	
f) $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4\text{OH}$	

17. Write one sentence to explain a synthesis reaction.

Conclusion

In this lesson, you looked at what happens when atoms react with each other to form new compounds. You learned how to write chemical reactions by building on your knowledge of atomic structure, the Periodic Table, and chemical formulas. You also studied synthesis and single-displacement reactions. In the next lesson, you will learn about two more types of chemical reactions, and answer the question, where does all the material go when chemicals react?

Key Concepts

Chemical reaction: involves creating new products from the original reacting chemicals. When a chemical reaction occurs, a new substance is always produced.

Reactants: substances that are used in a chemical reaction

Products: substances that are produced in a chemical reaction

Precipitate: a solid residue resulting from a reaction

Word equation: describes a chemical reaction using the names of the chemical reactants and their products

Chemical equation: describes a chemical reaction using the chemical formulas for the chemical reactants and their products

Chemical change: the production of a new substance from a chemical reaction

Physical change: does not create a new substance. While the substance might change its state, size, shape, temperature, or amount, it still remains the same substance.

Polyatomic ion: a molecule that has a charge

Synthesis reaction: a compound being synthesized from two single elements

Single-displacement reaction: one atom takes the place of another in a compound

Key Questions

Save your answers to the Key Questions in your
Course Journal or e-Journal.

Total: 17 marks

28. For each of the following reactions, state whether a physical or chemical change has occurred. Give evidence for your answer.
(5 marks: 1 mark for each)

- A silver solid is dropped into a clear and colourless solution. After a few minutes, small bubbles are seen coming from the silver solid.
- A yellow solid is broken and ground into a fine powder.
- Small, white crystals are added to a beaker of water, which is stirred until the crystals disappear.
- A clear and colourless solution turns pink when a few drops of a colourless liquid are added.

- When a wooden splint is heated, it ignites into flames and then burns.
29. Write the proper chemical name for each of the following compounds. If necessary, look up the element names for the symbols in the Periodic Table.
(5 marks: ½ mark each)

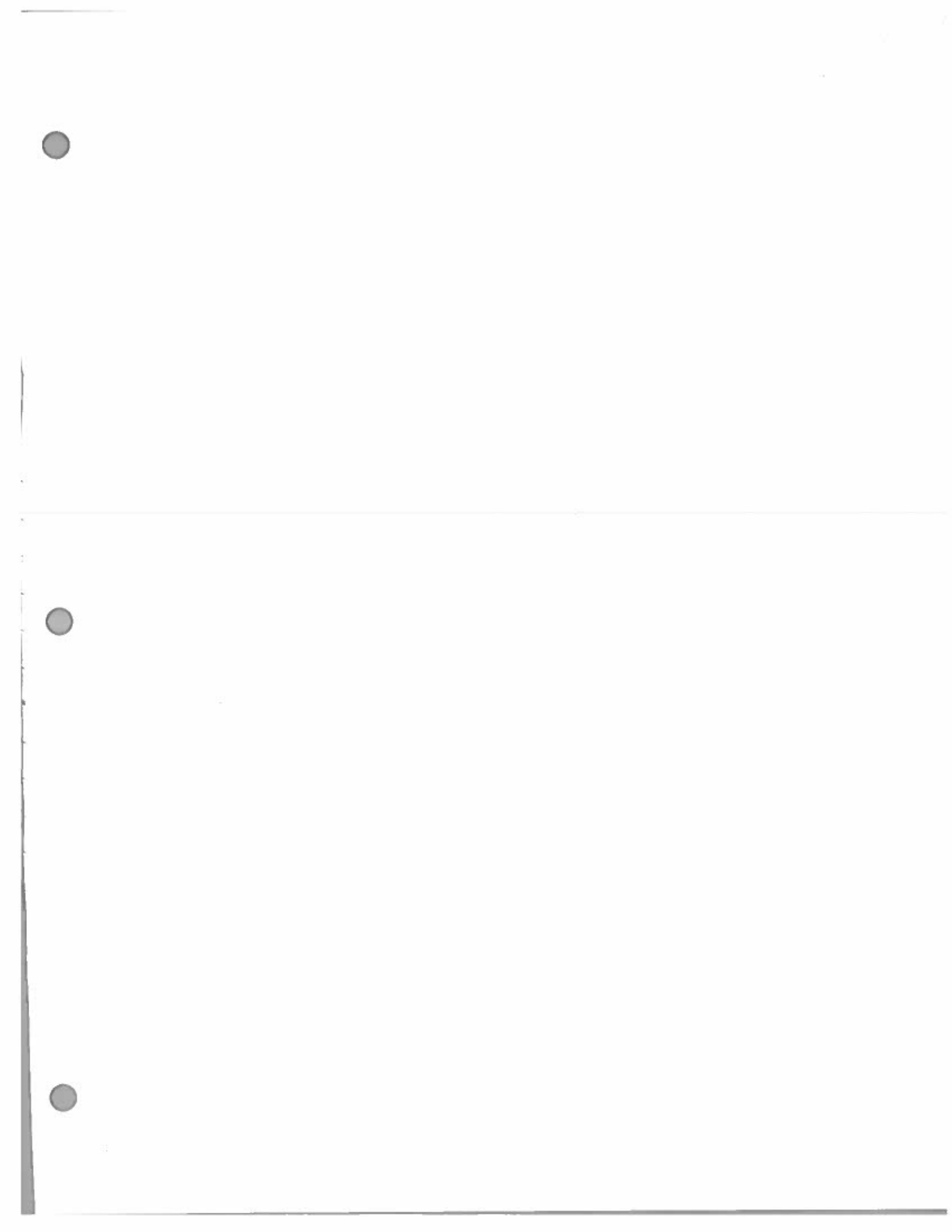
Formula	Chemical Name	Formula	Chemical Name
LiCl		$\text{Al}_2(\text{SO}_4)_3$	
KBr		BeS	
CaF_2		SO_2	
ZnCl_2		NO_2	
$\text{Ca}(\text{NO}_3)_2$		PCl_5	

Now go on to Lesson 8. Remember, you do not send your journal to the Independent Learning Centre until you have completed Unit 2 (Lessons 6 to 10).

31. In one sentence, describe a single-displacement reaction. (2 marks)

Chemical Name	Formula	Chemical Name	Formula
Calcium chloride		Sodium nitrate	
Sodium bromide		Potassium sulphate	
Potassium sulphide		Calcium carbonate	
Dihydrogen sulphide		Magnesium sulphate	
Nitrogen dioxide		Sodium acetate	

30. Write the proper chemical formula for each of the following compounds. If necessary, look up the element names for the symbols in the Periodic Table. (5 marks: ½ mark each)



SNC2D-B



Chemical Reactions and Mass Balance

Introduction

An unlimited number of chemical reactions occur around you every day. Reactions digest your food and make your muscles move. The food cooking in your kitchen, the plants growing outside your window, the industrial process that made your chair: all depend on chemical reactions. Reactions range from those that are easy to perform in a coffee cup to those that are almost completely mysterious. However, within this wide range, there are a few basic patterns that all reactions follow.

In Lesson 7, you learned that all reactions involve a set of reactants changing into a set of products. You encountered two general patterns of reactions: synthesis and single displacement. In this lesson, you will examine two more types of chemical reactions: double displacement and decomposition.

You will also consider what happens to all the matter in a chemical reaction—where does it go? This is important to know for many industrial processes, such as the production of plastics, because companies have to purchase raw materials and then make their product. They need to know how much material is required to make the product, and how much waste they will produce as a result.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Two More Types of Chemical Reactions	1
Activity: Conservation of Mass	$\frac{3}{4}$
Balancing Chemical Reactions	1
Combustion Reactions	$\frac{1}{2}$
Key Questions	$1\frac{1}{4}$

What You Will Learn

After completing this lesson, you will be able to

- identify double-displacement and decomposition reactions
- use the Law of Conservation of Mass when writing reactions
- write balanced chemical reactions

Two More Types of Chemical Reactions

As you've seen, chemical reactions produce new products with new characteristics. These new products can then take part in new reactions, producing still more novel compounds with features never before seen. That's why chemistry is such an exciting and creative field: each new compound opens up a new world of possible reactions. Every day chemists use this fact to invent new materials that affect our lives. For example, one day cars will be painted with a compound that heals over a scratch when exposed to sunshine, and you will wear clothes that clean themselves.

In Lesson 7, you were introduced to two types of reactions: synthesis and single displacement. Below you will learn about two more: double displacement and decomposition. Though they differ in specific properties, remember that all these all reactions share one thing—the reactants are always transformed. Carl Jung, the famous psychologist, alluded to this fact in one of his most famous quotes:

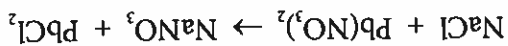
"The meeting of two personalities is like the contact of two chemical substances; if there is any reaction, both are transformed."

Carl Jung (1875–1961)

Double Displacement

Consider the bicycle analogy from the last lesson. You can *combine* the wheels and frames to make a bike and you can also *displace* one set of wheels for another. In each case, you make a new product. Is there another way to create a new bike? What if you had two different bikes and wanted to switch the parts on one with the parts on the other? You would be starting with two complete bikes and ending up with two different complete bikes. People do this with clothing—friends swap items like tops or jackets so each one ends up with a new different outfit. Chemicals can do this too.

Consider these reactions:



The products and reactants of the reactions are summarized in the table on the next page. Compare the reactant side with the product side. In each of the reactions, there are two chemicals as reactants and two chemicals as products. Look closely at the reactant side and the product side—can you see a more specific pattern?

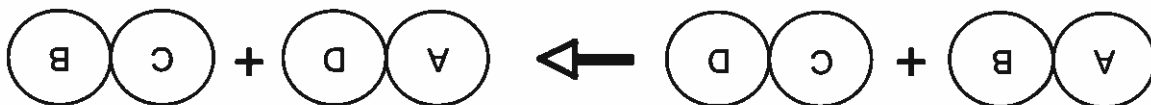
Sodium carbonate and calcium chloride can react to produce sodium chloride and calcium carbonate:

$$\text{Na}_2\text{CO}_3 + \text{CaCl}_2 \rightarrow \text{NaCl} + \text{CaCO}_3$$

The carbonate ion (CO_3^{2-}) and the chloride ion (Cl^-) switch partners and recombine with the other "first half." Usually the two new products separate because one is either a precipitate or gas. You may remember from the activity in Lesson 7 that calcium carbonate (CaCO_3) is a precipitate because it does not dissolve in water. Double-displacement reactions are commonly used in industry to produce precipitates or remove ions from solution.

Example

In a double-displacement reaction, the second half (or non-metal half) of one compound switches with the second half of the other compound to create two new compounds. Note that an atom or polyatomic ion that is the second half on the reactant side stays on the second half of the product side. It's like they traded dance partners.



The following represents a double-displacement reaction:

How would you summarize the pattern? Note that the reactant side has two compounds, and the product side has two compounds. Remember that all compounds have two halves? It seems like the second half of each compound just switched places. This is described as a **double-displacement reaction** since each compound changes its two parts. In the previous lesson, you learned about single-displacement reactions where only one compound changes parts.

Reactants	Reactions	Products
Sodium chloride, NaCl , is a compound; AgNO_3 , is a compound; silver nitrate, AgNO_3 , is a compound	$\text{NaCl} + \text{AgNO}_3 \rightarrow \text{NaNO}_3 + \text{AgCl}$	Sodium nitrate, NaNO_3 , is a compound; silver chloride, AgCl , is a compound
Sodium chloride, NaCl , is a compound; lead nitrate, $\text{Pb}(\text{NO}_3)_2$, is a compound	$\text{NaCl} + \text{Pb}(\text{NO}_3)_2 \rightarrow \text{NaNO}_3 + \text{PbCl}_2$	Sodium nitrate, NaNO_3 , is a compound; lead chloride, PbCl_2 , is a compound

Table 8.1 Examples of reactants and products in double-displacement reactions

Example

Water softeners work by using double-displacement reactions. Your water at home may get softened in this way, especially if you get your water from a well. A lot of ground water is called “hard” because it contains high amounts of calcium and magnesium. This prevents soap from lathering and can cause a build-up of minerals that block your pipes and taps. For these reasons, many people want to soften their water by removing the calcium and magnesium.

To do this they add a softener salt, usually containing sodium or potassium. The softener salt undergoes a double-displacement reaction with the calcium and magnesium in the water. The sodium (or potassium) originally on the salt is now in the water, where it remains soluble and so does not affect the soap or pipes. Pulled out of the water, the calcium and magnesium are now attached to the softener salt and so can be easily removed. The water now feels soft on your skin, and soap lathers up very easily.

Support Questions

Do not send your answers in for evaluation.

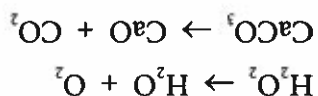
- 18.** Write a sentence describing how to identify a double-displacement reaction.

- 19.** Using the words “compound” and “element” in your answer, indicate how you distinguish between single- and double-displacement reactions.

There are Suggested Answers to Support Questions at the end of this unit.

Reactants	Hydrogen peroxide, H_2O_2 , is a compound.	Calcium carbonate, $CaCO_3$, is a compound.
Reactions	$H_2O_2 \rightarrow H_2O + O_2$	$CaCO_3 \rightarrow CaO + CO_2$
Products	Water, H_2O , is a compound; oxygen, O_2 , is an element.	Calcium oxide, CaO , is a compound; carbon dioxide, CO_2 , is a compound.

Table 8.3 Examples of reactants and products in more complex decomposition reactions



Some examples are slightly different. Consider these two reactions:

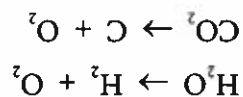
compound decomposing into elements.

How would you summarize this reaction type? The examples above show a

Reactants	Water, H_2O , is a compound.	Carbon dioxide, CO_2 , is a compound.
Reactions	$H_2O \rightarrow H_2 + O_2$	$CO_2 \rightarrow C + O_2$
Products	Hydrogen, H_2 , is an element; oxygen, O_2 , is an element.	Carbon, C , is an element; oxygen, O_2 , is an element.

Table 8.2 Examples of reactants and products in decomposition reactions

Compare the reactant side with the product side. In each of the reactions, there is one chemical on the reactant side and two chemicals on the product side.



Consider these reactions:

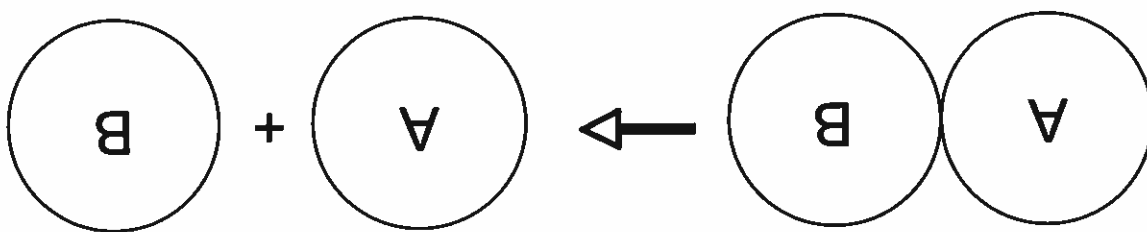
lesson.

There is one more thing you can do to your bicycle—take it apart! Like bicycles, chemical compounds can be broken down into their separate parts. The bicycle can be broken down into the frame and the wheels, and some compounds can also be broken down into their individual elements. These compounds are *decomposed*. This is the opposite of the *synthesis* reaction that you learned about in the previous

Decomposition

The pattern is not as simple as a compound breaking down into elements. A **decomposition reaction** involves a compound breaking down into two (or more) new substances. The products can be elements or compounds, depending on the chemicals involved.

The following represents a decomposition reaction:



Starting Decomposition Reactions

What starts decomposition reactions? Generally, something must trigger them; if they just happened spontaneously, eventually you wouldn't have any of the initial compounds left, unless they were being continually created by some other process.

Most decomposition reactions require the addition of heat. For example, the decomposition of calcium carbonate, like most other ionic substances, occurs at very high temperatures. Cement, the "glue" used to bind concrete, is made from the decomposition of calcium carbonate. To make cement, crushed limestone rock that is rich in calcium carbonate is heated in huge gas-fired kilns.

The production of concrete is a large contributor to greenhouse-gas production. The decomposition reaction releases CO_2 , while the burning of fossil fuels to produce the necessary heat releases even more. It is estimated that the cement industry produces around 5% of global man-made CO_2 emissions. About 50% of the emissions are produced from the chemical process itself and 40% from burning fossil fuel to power that process.

Some decomposition reactions require the addition of other types of energy to trigger the reaction. For example, electricity is used to trigger the decomposition of water that produces oxygen and hydrogen gas for industrial uses. This process is called electrolysis.

Not all decomposition reactions require the addition of energy to trigger them. Some, like the decomposition of hydrogen peroxide, naturally occur very slowly over time, without any energy being added. In fact, the decomposition of hydrogen peroxide occurs so slowly that you don't even see the bubbles of oxygen coming up. It is recommended that you keep hydrogen peroxide in a cool place because reactions usually take longer at lower temperatures.

Another set of decomposition reactions occurs so quickly that they are considered explosive—but sometimes these can save your life.

In decomposition reactions, one common sign of a chemical change is

sentence:

22. Based on the reactions discussed in this section, complete the following

21. Using the words "compound" and "element" in your answer, indicate how you distinguish between synthesis and decomposition reactions.

Reaction	Type
a) $\text{Fe}_2\text{O}_3 \rightarrow \text{Fe} + \text{O}_2$	
b) $\text{AgNO}_3 + \text{MgCl}_2 \rightarrow \text{Mg}(\text{NO}_3)_2 + \text{AgCl}$	
c) $\text{KClO}_3 \rightarrow \text{KCl} + \text{O}_2$	
d) $\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$	
e) $\text{Fe}(\text{NO}_3)_2 + \text{MgSO}_4 \rightarrow \text{Mg}(\text{NO}_3)_2 + \text{FeSO}_4$	
f) $\text{NH}_3 \rightarrow \text{N}_2 + \text{H}_2$	

displacement.

20. Identify each of the following reactions as either decomposition or double

Support Questions

Most cars now come equipped with airbags that inflate instantly during a crash to protect the occupants. How can they inflate so quickly? Many use a system based on a decomposition reaction to rapidly produce a gas to inflate the safety cushions. Older airbags used a simple decomposition reaction involving a chemical inside the airbag called sodium azide, NaN_3 . When triggered by a heat pulse, it decomposes very rapidly to produce large volumes of nitrogen gas, N_2 , in the following decomposition reaction:

$$2\text{NaN}_3 \rightarrow 2\text{Na} + 3\text{N}_2$$

The sudden release of nitrogen gas inflates the airbag before the passenger's head can hit the dashboard. Other chemicals present in the airbag use up the highly reactive sodium produced. Newer airbags use chemicals that produce less dangerous products.

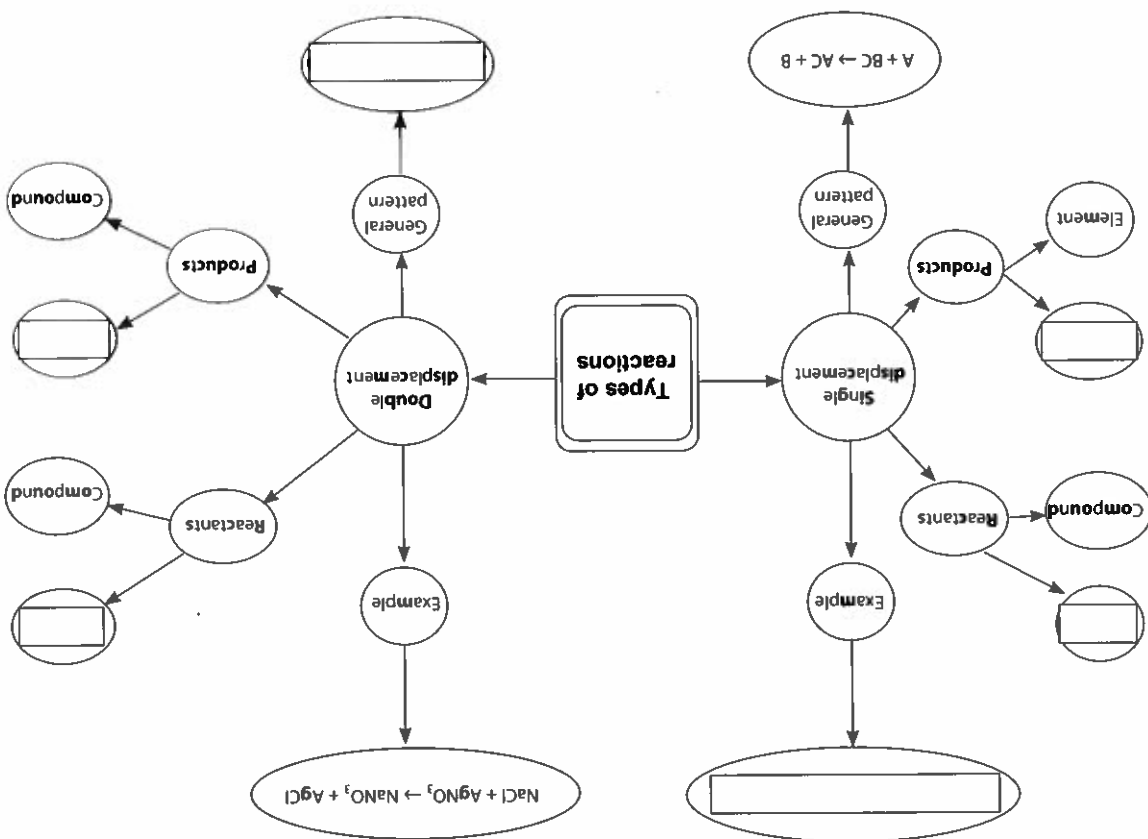
Example



Activity: Conservation of Mass

When you burn a piece of wood, what's left at the end? Sometimes there is charcoal, sometimes just ash. Most people feel that burning makes the wood disappear. But where does it go? In a precipitation reaction (where two liquids are combined and produce a new solid), does the mass increase? Is that possible? Where would the extra matter come from?

In this activity, you are going to perform a chemical reaction inside a closed container. That means that no atoms will be able to enter or leave it.



23. The following concept map compares single-displacement and double-displacement reactions. Fill in the shaded boxes.

Support Question

- 24.** Prediction: Before you begin the activity, what do you think will happen to the mass of the reactants after the reaction? Will the mass of the products be the same as the mass of the reactants? Explain your reasoning.

SAFETY CONSIDERATIONS:

- Follow all directions and safety precautions as described. Even though you will be using household products, they can still be harmful to your eyes and skin, and some can be harmful if ingested. For example, vinegar is an acid and is considered corrosive. Even though you can eat it safely, if it accidentally splashes into your eyes it can cause a severe burning sensation.
- Gloves and protective eyewear are recommended for all experiments.
- Rinse your hands or skin under cold, running water if any of the substances make contact.
- Perform the reactions near or in a sink to avoid mess and to make clean-up easier.

Materials

- large “zip-loc” style bag
- vinegar
- baking soda
- masking tape
- kitchen or bathroom weighing scale

Procedure

- Put about two tablespoons of baking soda into a bottom corner of the zip-loc bag. Try to place all the baking soda in the same corner.
 - Roll the corner of the bag so that all the baking soda is trapped inside the corner. Use a piece of masking tape or twist tie to keep the corner sealed so that it doesn't unroll.
 - Use the scale to measure the mass of the bag containing the baking soda and masking tape/twist tie. Record that amount in the observations table below. (MASS #1)
 - Measure the mass of an empty glass or cup that you will pour the vinegar into. Record that amount. (MASS #2)
 - Pour about $\frac{1}{2}$ cup of vinegar into the container and then measure the mass again. Record the amount. (MASS #3)
 - Hold the zip-loc bag on an angle with the baking-soda corner raised and the other corner hanging down.
 - Pour the vinegar into the bottom corner of the zip-loc bag away from the baking soda. Seal the zip-loc bag, squeezing out the excess air.
 - Put the whole bag onto the scale. Record the mass. (MASS #4)
 - Unroll the corner with the masking tape/twist tie on it (save the masking tape or twist tie so you can weigh it with the bag later), and allow the vinegar to mix with the baking soda.
 - When the reaction is over, record the final mass of the bag, its contents, and the tape/twist tie. (MASS #5)
- (If the bag opened up during the experiment, rinse it out and repeat with smaller amounts of vinegar and baking soda.)
- DISPOSAL:** The contents of the bag can be flushed down the sink with cold, running water.

Observations

Table 8.4 Physical Observations

Before the Reaction	During the Reaction	After the Reaction
Vinegar		
Baking Soda		

Mass of the bag and baking soda and masking tape/twist tie and vinegar after mixing
 MASS *5: 270 g

Mass of the bag and baking soda and masking tape/twist tie and vinegar before mixing
 MASS *4: 270 g

Mass of the container and vinegar
 MASS *3: 550 g

Mass of the empty container
 MASS *2: 300 g

Mass of the bag and baking soda and masking tape
 MASS *1: 20 g

Measurements:

Before the Reaction	During the Reaction	After the Reaction
Vinegar is a clear, colourless liquid with a distinct odour.	When the vinegar comes into contact with the baking soda, it bubbles and fizzes.	As the reaction occurs, the bag starts to fill up and expand.

Table 8.5 Sample Physical Observations

Sample Data

Mass of the bag and baking soda and masking tape/twist tie and vinegar after mixing
 MASS *5: _____

Mass of the bag and baking soda and masking tape/twist tie and vinegar before mixing
 MASS *4: _____

Mass of the container and vinegar
 MASS *3: _____

Mass of the empty container
 MASS *2: _____

Mass of the bag and baking soda and masking tape/twist tie
 MASS *1: _____

Measurements:

The most important finding in this activity relates to the change in mass during the chemical reaction. During the reaction, bubbles are released, indicating that a new gas has formed. Since the container is closed, the molecules of the gas cannot escape. The overall mass does not change. This is called the **Law of Conservation of Mass**: the mass of the products is equal to the mass of the reactants.

If you really think about it, it just makes sense. The mass of a bike is the same as the total mass of the frame and tires (and whatever other parts are added). If you build a garage, the final mass of the garage is the same as the total mass of the wood, nails, and all the other materials that went into building it.

In this activity, the molecules of the gas and the other products are made from atoms present in the molecules of the original reactants, so the mass of the products *has to be the same* as the mass of the original reactants. Matter cannot be created or destroyed; it can only change form.

Support Questions

25. In the above activity, what is the evidence that a chemical change occurred?

26. How does the mass before the reaction compare to the mass after the reaction? (Compare MASS #4 and MASS #5.)

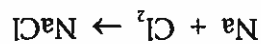
27. State the Law of Conservation of Mass.

28. Predict what would have happened to the mass of the products if the bag had not been sealed properly.

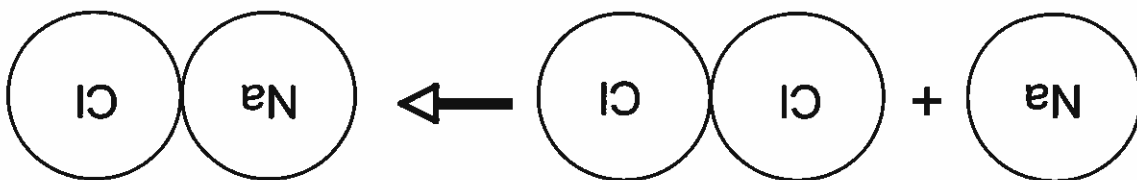
Balancing Chemical Reactions

The Law of Conservation of Matter states that matter cannot be created or destroyed. How does that affect the way chemical reactions are written?

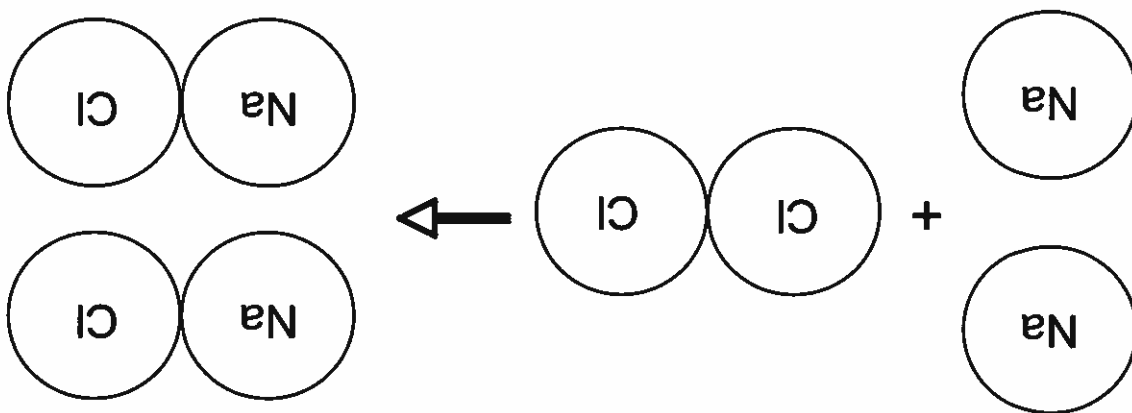
Consider one of the reactions already examined:



If you draw it out as atoms, it looks like this:

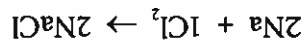


Sodium is a single element, but chlorine is a molecule made of two atoms. The final product, sodium chloride, is made up of one ion of sodium and one ion of chlorine. But there are two atoms of chlorine on the reactant side and only one atom of chlorine shown on the product side. Where is the other atom of chlorine? In reality, you can't actually do a reaction with only three atoms; there are always many millions of atoms present. When the molecule of chlorine is broken into two separate atoms, chances are there is another atom of sodium nearby to combine with the second chlorine atom. So the reaction really would look like this:

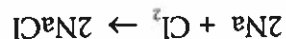


Note that now two atoms of sodium combine with one molecule of chlorine to produce two molecules of sodium chloride.

In a chemical reaction, whole numbers are placed in front of a chemical symbol to indicate how many particles are reacting. The reaction above could be rewritten as follows:



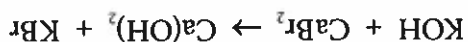
By convention, the number 1 is not shown in front of a chemical symbol because it is assumed to be there, so the reaction is correctly written as follows:



This is now a **balanced chemical reaction** because the number of atoms of each element is equal on both sides. You can confirm this for yourself. The reactant side of the equation contains two atoms of sodium (2Na) and two atoms of chlorine (Cl_2). The product side contains two molecules of sodium chloride (2NaCl), which is made up of two atoms of sodium and two atoms of chlorine. Thus there is an equal number of atoms on either side of the reaction. Note that the number appearing before a molecule applies to all the atoms in the molecule, thus 2NaCl means 2Na plus 2Cl.

How to Balance a Chemical Reaction

Balancing chemical reactions is easy if you follow a few simple steps. Here's a simple example: the reaction of potassium hydroxide (KOH) with calcium bromide (CaBr_2).



In this reaction, the potassium hydroxide has two parts: the potassium (K) and the hydroxide (OH). It is usually easiest to treat polyatomic ions such as hydroxide as one object—you can just count how many “hydroxides” are on each side.

When balancing a chemical reaction, first examine the reactants and products separately. On the reactant side, there is one atom of potassium with one hydroxide, and also one atom of calcium with two atoms of bromine. On the product side, there is one atom of calcium with two hydroxides, along with one atom of potassium and one atom of bromine.

Making a summary table can help, especially when balancing more complicated reactions.

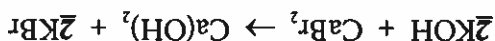
Table 8.6 Summary table with initial numbers of atoms

Initial	
Reactants	Products
1 atom of potassium	1 atom of potassium
1 hydroxide	2 hydroxides
1 atom of calcium	1 atom of calcium
2 atoms of bromine	1 atom of bromine

Final	
Reactants	Products
2 atoms of potassium	2 atoms of potassium
2 hydroxides	2 hydroxides
1 atom of calcium	1 atom of calcium
2 atoms of bromine	2 atoms of bromine

Table 8.8 Summary table with final numbers of atoms

Update the table again to see where you are. You can see from the table that each element now has the same number of atoms on either side of the reaction, so the reaction is now balanced.

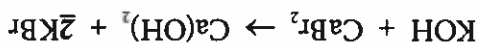


So the bromines are now balanced—but the potassiums have become unbalanced and the hydroxides are still unbalanced. You still need to get two atoms of potassium and two hydroxides on the reactant side. You can do this by adding a 2 in front of the potassium hydroxide:

Updated	
Reactants	Products
1 atom of potassium	2 atoms of potassium
1 hydroxide	2 hydroxides
1 atom of calcium	1 atom of calcium
2 atoms of bromine	2 atoms of bromine

Table 8.7 Summary table with updated numbers of atoms

Since the 2 also applies to the potassium, this change needs to be updated in the table.



Obviously the two sides are not equal. The number of hydroxides on each side and the number of bromines on each side are not the same. You *cannot* just change the formula (for example, change KBr to KBr₂) because then the formula for the compound would be wrong.

If you want to fix the bromines first, you need to ensure that there are two atoms of bromine on the product side. You can do this by adding a 2 in front of the potassium bromide:

Steps to Balancing Chemical Equations

To balance equations, follow these seven steps:

1. Write the chemical reaction using proper chemical formulas. (Learning to write correct formulas from names is very important!)

2. Make a small table to summarize how many atoms of each element you have on the reactant side and on the product side.

3. Identify a chemical that needs to be balanced.

4. Add a whole number to the front of the chemical formula in the reaction.

5. Apply that change to all the atoms in the formula and update the table.

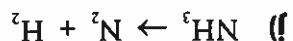
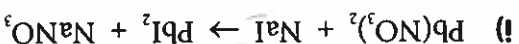
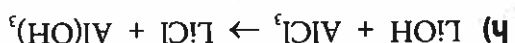
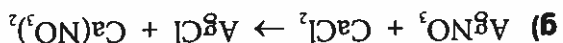
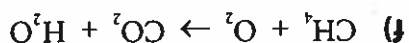
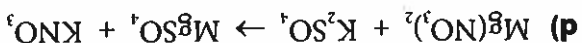
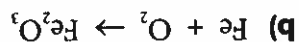
6. Continue to identify elements that need to be balanced and write the appropriate whole number in the reaction, then apply the change and update the table.

7. When each atom is equal on both sides of the table, then you have balanced the reaction.

Most reactions are balanced using small whole numbers—usually less than five. If you find that you are using very high numbers or that the changes you make cause more problems, then you have probably made a mistake. In that case, start over. Check the formulas again. Count the number of atoms again.

Support Questions

29. Balance the following chemical equations:



- 30.** Write balanced chemical equations from the following word descriptions:
- a) Sodium chloride decomposes to produce solid sodium and chlorine gas.

- b) Magnesium nitrate and potassium hydroxide react to produce potassium nitrate and magnesium hydroxide.

- c) Calcium reacts with hydrogen bromide to produce calcium bromide and hydrogen gas.

- d) Sulphur dioxide reacts with oxygen gas to produce sulphur trioxide.

- e) Aluminum chloride reacts with potassium sulphate to produce potassium chloride and aluminum sulphate.

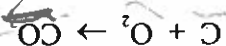
- 31.** Consider the reaction $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$.
- a) Explain why it is not balanced.

- b) A student attempted to balance it as follows: $\text{Mg} + 2\text{H}_2\text{Cl}_2 \rightarrow \text{MgCl}_2 + 2\text{H}$
- What is wrong with the way it is balanced? How would you balance it?

Combustion Reactions

One of the most common types of chemical reaction is a combustion reaction. **Combustion** means the burning of a substance. Chemically, that usually means it reacts with oxygen to produce heat and flames.

Two common combustion reactions are



and



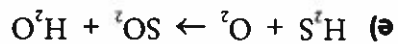
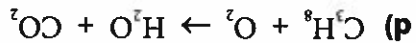
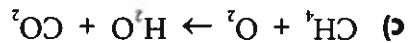
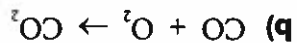
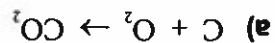
In the first reaction, carbon reacts with oxygen to produce carbon dioxide. In the second, methane (CH_4), which also contains carbon, reacts with oxygen to produce carbon dioxide and water. These combustion reactions follow a regular pattern, both resulting in the formation of "oxides" when the atoms of oxygen combine with the other elements.

These combustion reactions occur whenever any wood, coal, oil, or gasoline is burned. Most of our fuels are carbon based; they are called "fossil fuels" because they come from decomposed plants and animals from millions of years ago. As you learned in Unit 1, using these fuels as an energy source means that heating our homes, cooking our food, driving our cars, and even generating electricity can result in the formation of carbon dioxide, the main greenhouse gas.

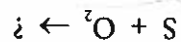
Finding ways to trap and remove the oxides produced in combustion reactions, including carbon dioxide, is one of the main problems facing the fossil-fuel industry.

Support Questions

32. Balance the following combustion reactions:



33. Many fuels contain sulphur as impurities. Predict the result from the combustion of sulphur by completing and balancing the following reaction:



34. Many fuels contain nitrogen compounds. One of the products of combustion, nitrogen dioxide, creates the brownish colour in the air on humid summer days. Write a balanced reaction showing the combustion of nitrogen in oxygen to form nitrogen dioxide.

Conclusion

You started this lesson learning about the final two types of chemical reactions, double-displacement and decomposition reactions. These useful reactions have many industrial and domestic applications. A double-displacement reaction softens your water. The building you are sitting in probably contains some concrete, a material made possible by a decomposition reaction.

Next you learned about the Law of Conservation of Mass, performing an experiment to prove that matter is neither created nor destroyed in chemical reactions. Since this is always true, the number of atoms of any compound on the reactant side of a reaction must equal the number of atoms on the product side. All reactions must result in balanced equations, yet it is not always obvious from the start how the balance will look. You ended the lesson learning how to balance equations based on their formulas using a seven-step process.

The next lesson will introduce you to a very important type of chemical compounds, acids and bases.

Key Concepts

Double-displacement reaction: a reaction in which the second (non-metal) half of one compound switches with the second half of the other compound to create two new compounds

Decomposition reaction: a reaction in which a compound breaks down into two (or more) new substances. The products can be elements or compounds, depending on the chemicals involved.

Law of Conservation of Mass: states that the mass does not change during a chemical reaction. The mass of the products is equal to the mass of the reactants.

Balanced chemical reaction: a reaction in which the number of atoms of each element is equal on both sides

Combustion reaction: the burning of a substance

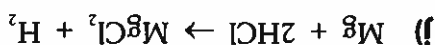
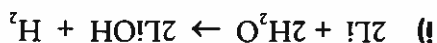
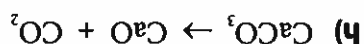
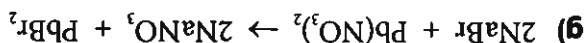
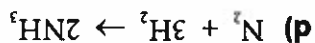
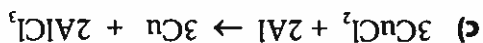
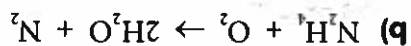
Key Questions

Save your answers to the Key Questions in your Course Journal or e-Journal.

Total: 23 marks

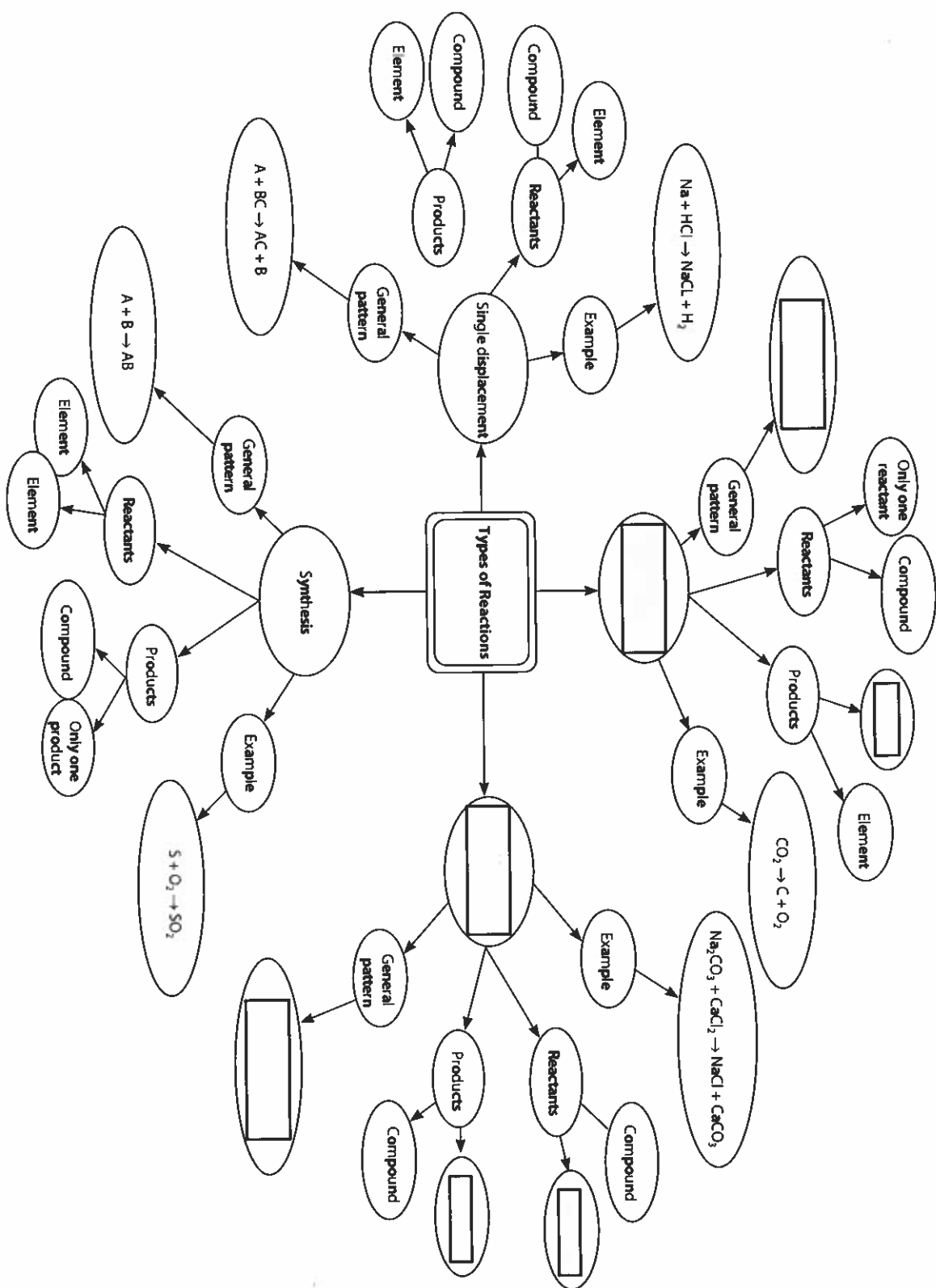
32. For each of the reactions below, identify the type of reaction (synthesis, decomposition, single displacement, or double displacement).

(5 marks: ½ mark each)

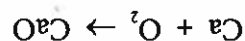


33.

The partially filled concept map on the next page summarizes the differences among single-displacement, double-displacement, synthesis, and decomposition reactions. Fill in the seven shaded boxes with the correct information. (7 marks: 1 mark each)



- 34.** Use the Law of Conservation of Mass to calculate the expected mass of the product in the following reaction if 120 g of calcium reacts with 96 g of oxygen gas:



Write a sentence to explain your answer. (2 marks)

- 35.** Balance each of the following reactions: (2 marks: 1 mark each)
- a) $\text{Fe} + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3$
- b) $\text{CuCl}_2 + \text{Al} \rightarrow \text{Cu} + \text{AlCl}_3$
- 36.** For each of the following word equations, write a balanced chemical equation. (2 marks: 1 mark each)
- a) Beryllium chloride reacts with aluminum nitrate to produce beryllium nitrate and aluminum chloride.
- b) Sulphur burns in oxygen to produce sulphur dioxide.
- 37.** Given the reaction $\text{Zn}(\text{OH})_2 + \text{AlCl}_3 \rightarrow \text{ZnCl}_2 + \text{Al}(\text{OH})_3$,
- a) explain in a sentence or two why it is not considered balanced. (1 mark)
- b) write a series of steps to explain how it would be balanced. (4 marks)

Now go on to Lesson 9. Remember, you do not send your journal to the Independent Learning Centre until you have completed Unit 2 (Lessons 6 to 10).



SNC2D-B



Properties of Acids and Bases

Introduction

The categories of chemicals you've learned about so far have included metals, non-metals, and compounds. Another category you have probably heard about contains acids and bases. Acids and bases are a group of compounds that share specific properties and react differently from other compounds, allowing them to do things that other compounds can't.

Acids and bases are very important in all kinds of chemical systems, from the rain clouds over your house to the insides of living cells. Life couldn't exist without them (even DNA is an acid—that's what the "A" stands for). They are particularly important for creating the conditions under which other chemical reactions can occur. It's the balance between acids and bases that makes old photographs and newspapers fade to yellow, gives orange juice its taste, and creates cavities in your teeth. It's also the reason many lakes around the world are dying.

In this lesson, you will explore the physical and chemical properties of acids and bases. You will learn what makes them different from other compounds and where you will encounter them. You will also learn how to identify acids and bases, and how to name them and write their formulas.

Planning Your Study

You may find this time grid helpful in planning when and how you will work through this lesson.

Suggested Timing for This Lesson (hours)	
Acids	1
Bases	1
Activity: Identifying Acids and Bases	1
Reactions of Acids and Bases	3
Key Questions	3

What You Will Learn

After completing this lesson, you will be able to

- recognize the characteristics of acids and bases as well as their importance
- use several indicators to classify substances as either acidic or basic, based on their pH
- write balanced chemical reactions for acid-base reactions
- identify the uses for acid-base neutralization reactions

Acids

You've often heard the word acid—acid rain, battery acid, acidic taste, acid-washed jeans. But what is an acid? Most people think that acids are dangerous, can dissolve anything, and will burn holes through clothes and skin. Well, some of them can. But other acids are around you every day. Acetic acid doesn't burn your skin, but does taste good on French fries—it's more commonly known as vinegar. Lemon juice is another common acid you may have in your kitchen.

Do lemon juice and vinegar have anything in common? How about their sour taste? Normally we don't taste the substances we use in experiments for safety reasons, but we've all eaten these two. And remember, the term "chemical" can refer to any substance used in a chemical reaction, which means that both vinegar and lemon juice are chemicals.

Structure of Acids

Here are the names and formulas of some common acids:

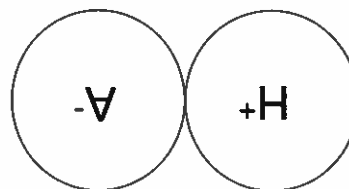
Table 9.1 Common Acids

Name	Formula	Ion (Name)
Hydrochloric acid	HCl	Cl ⁻ (Chloride)
Hydrobromic acid	HBr	Br ⁻ (Bromide)
Hydrosulphuric acid	H ₂ S	S ⁻² (Sulphide)
Acetic acid	HC ₂ H ₃ O ₂	C ₂ H ₃ O ₂ ⁻ (Acetate)
Sulphuric acid	H ₂ SO ₄	SO ₄ ⁻² (Sulphate)
Carbonic acid	H ₂ CO ₃	CO ₃ ⁻² (Carbonate)

Look at the acids' formulas. Do you notice what they all have in common? All the acids have hydrogen in the formula. The presence of a hydrogen ion is one of the key features of an acid. An acid is defined as a substance that, when dissolved in water, produces **hydrogen ions**, H⁺. It is the hydrogen ions that give acids their properties.

Naming Acids

where H^+ is the hydrogen ion and A^- is the non-metal ion it combines with.



Acids are often represented by these symbols:

If you look at the pattern in the formulas, you will see that they all have a hydrogen first, followed by another ion. Since the other ion is in the second half, it must be a negative ion to balance out the positive hydrogen ion.

Uses of Acids

In the table on page 2, you will notice that some of the acids have the prefix *hydro* in their name and some don't. Do you notice anything different about the structure of the two different sets of acids?

The ones with *hydro* in the name are all formed with just a non-metal ion. The *-ide* ending of the ion is changed to *-ic*. So a compound that looks like *hydrogen chloride* is actually called *hydrochloric acid*. The ones without *hydro* in the name are formed from polyatomic ions. The *-ate* ending of the polyatomic ion is changed to *-ic*. So a compound that looks like *hydrogen sulphate* is actually called *sulphuric acid*.

Acids have many uses. One of the most popular, hydrochloric acid, is used as a cleaning agent, especially on metal and glass, and is used to prepare the surface of concrete before repair. It is also used to produce polyvinyl chloride, commonly known as PVC, a widely used hard plastic—your drainpipe is probably made of it. It is even produced inside your stomach, as part of the gastric juices that digest your food.

Sulphuric acid is also widely used. Found in many car batteries, it is often called battery acid. It has many different industrial uses and can be used to create other compounds, like sulphates, which are often used as preservatives. Sulphuric acid is also used to create the synthetic fibre nylon.

Properties of Acids

Both hydrochloric and sulphuric acid are considered very strong acids. They are far more reactive, and therefore dangerous, than weaker acids such as vinegar and lemon juice. Yet all these acids are in the same category. So what are the common properties of acids? You will examine two main properties, conductivity and pH.

Conductivity

You may remember that something **conductive** allows electricity to pass through it. *All acid solutions are conductive.* This property is not unique to acids, however. A solution made by dissolving salt in water can conduct electricity even though it is not an acid.

Conductivity is usually tested with a device containing a light bulb and some wire. The probe sends a low current through the sample. If it is conductive, the light turns on; if it isn't, the light stays off. The brighter the light, the more conductive the sample.

pH

Another property of acids is called **pH**. This measurement lets you know if a solution is acidic or basic, and how strong it is of either type. It measures the activity of the hydrogen ions in the sample. **Activity** is a measure of how available the hydrogen ions are to take part in chemical reactions. The more active hydrogen ions there are in solution, the more reactive and stronger the acid will be. The **pH scale** ranges from a low of 0 to a high of 14. Pure water has a pH of 7—exactly in the middle of the scale—because it is neither acidic nor basic. It is called **neutral**. Acids have pH values below 7. The stronger the acid, the lower its pH value.

Strong acids like hydrochloric and sulphuric acid have really low pH values (around 0 or 1), whereas weak acids like acetic acid (vinegar) have pH values around 4 or 5. The scale is not linear. Each increment is 10 times different from the next. So if an acid has a pH of 2, it is 10 times stronger than an acid having a pH of 3 and a thousand times stronger than an acid having a pH of 5. Similarly, if a base has a pH of 12, it is 10 times stronger than a base having a pH of 11 and a hundred times stronger than a base having a pH of 10.

Scientists usually measure pH by placing an electronic device called a pH probe or pH meter in a sample of the liquid. There are other ways to measure pH, including the use of indicator dyes and pH-sensitive paper.

The diagram below shows the pH values of some chemicals you are probably familiar with.

Note that only pure water has a pH of exactly 7. Most other forms of water, such as lake water or sea water, have pH values a bit lower or higher than 7 due to reactions between the minerals they contain and the water.

pH Scale

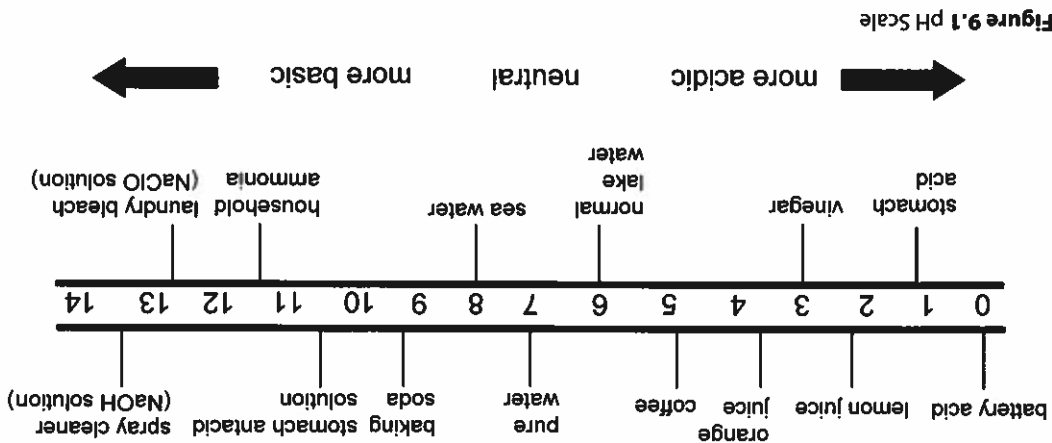


Figure 9.1 pH Scale

You have probably seen shampoo or facial cleanser advertised as being "pH balanced." This doesn't mean that it has a pH of 7, just that substances have been added into the mixture to keep the pH at a certain level. pH-balanced shampoo has a pH to match that of your hair or skin so that it doesn't cause irritation or damage.

Support Questions

Do not send your answers in for evaluation.

35. List three ways you could identify a substance as an acid.

36. Which of the following substances are likely to be acids? Explain your reasoning.

CH_4 H_3P ~~NH_3~~ HNO_3 H_2

There are Suggested Answers to Support Questions at the end of this unit.

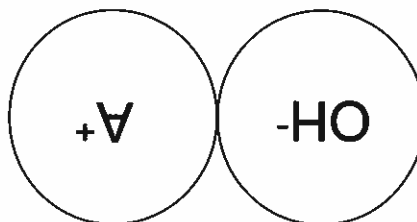
Bases

The opposite of an acid is a base. Like acids, bases are found around your home and have many industrial uses as well. Many household cleaning products, like window cleaner containing ammonia, are bases. However, while almost everyone can name at least one acid, most people aren't as familiar with bases. For example, many people believe that acids are very dangerous but bases are not. That is definitely not true. Many bases are considered **corrosive** just like acids, causing burns if spilled on your skin. You will learn more about the dangers and the safe-handling procedures of corrosive materials in the next lesson.

Because bases are not as consistent in their structure as acids, the naming system for them is more complicated. However, in many cases, the names for bases that contain the hydroxide ion (OH^-) will end with the word *hydroxide*. For example, a base found in many household cleaners, NaOH , is called sodium hydroxide. A chemical used to make concrete, $\text{Ca}(\text{OH})_2$, is called calcium hydroxide. Many common bases also contain carbon, in the form of a **carbonate ion** (CO_3^{2-}). The names of these bases end in the word *carbonate*. You may be familiar with calcium carbonate (CaCO_3), the main component of egg shells and chalk.

Naming Bases

where OH^- means the hydroxide ion and A^+ is the positive metal ion it combines with.



Bases in solution can be represented by the following symbols:

Look at the formulas for these bases. There isn't an obvious pattern as there was for acids. The polyatomic ion **hydroxide** (OH^-) is found in many bases, but you can see that some substances such as ammonia and baking soda are considered bases without having the actual hydroxide ion in them. A **base** is defined as a substance that produces the hydroxide ion when it dissolves in or reacts with water.

Name	Formula	Uses
Ammonia	NH_3	found in glass cleaners
Baking soda (sodium bicarbonate)	NaHCO_3	used in baking and for cleaning
Sodium hydroxide	NaOH	found in many cleaners
Magnesium hydroxide	$\text{Mg}(\text{OH})_2$	found in stomach remedies

Table 9.2 Common Bases

Some common bases you may have heard of are ammonia, baking soda (sodium bicarbonate), and sodium hydroxide. The following table gives the names, formulas, and uses of some common bases:

Structure of Bases

Uses of Bases

Bases have many uses in the home and in industry. As the opposite of acids, they are often used to neutralize acids. In workplace accidents, when strong acid spills onto a person's skin, a base is used to neutralize the acid to limit the damage. Being highly reactive with greases, bases are often found in cleaning products. Strong bases like sodium hydroxide can be found in many household cleaning sprays, while mild bases are found in cleaners like bath soap. Very strong bases are also used to clear out clogged drains.

Properties of Bases

What properties define a base? Just like acids, they must be dissolved in water to produce their effect. Again like acids, bases in solution conduct electricity. Many bases feel slippery, and some have a bitter taste. But the main property of bases is that their pH is the opposite of acids. Bases have a pH higher than 7. The strongest base has a pH of 14 and can be very dangerous to handle. Many bases are solids rather than liquids. They only become basic when dissolved in water, which means they can be stored safely in solid form. In the next lesson you will learn more about the safe handling and storage of bases.

Properties of Acids and Bases Compared

The following table summarizes the physical properties of acids and bases. The common properties are listed in the middle column.

Table 9.3. Properties of acids and bases compared

Properties of Acids and Bases		
Acids	Both	Bases
- taste sour - have $\text{pH} < 7$ - turn litmus paper red - contain H^+ in formula - react with metals	- are dissolved in water - conduct electricity - can be corrosive to skin	- taste bitter - have $\text{pH} > 7$ - turn litmus paper blue - produce OH^- ions in solution - feel slippery

Indicators

Some of the properties used to describe acids and bases are not easy to test. If you think something is corrosive or potentially able to burn you, you certainly don't want to taste, smell, or touch it! You know that pH is a good way to determine the strength of an acid or a base—but how do you measure pH?

The easiest way is to measure pH directly using a pH meter. Most science and industrial labs have one. If you don't have access to a pH meter, you can use **indicators**—a group of chemicals added to solutions to test their pH.

Name	Formula	Acid/Base/Neutral
Calcium chloride		
Nitric acid	HNO ₃	
	HCl	
Sodium hydroxide		

38. For each of the following substances, complete the table by providing the name or formula as required and by predicting whether it is an acid, base, or neutral.

Substance	Acid	Base	Neutral
Sea water			
Lemon juice			
Laundry bleach			
Pure distilled water			
Lake water			
Baking soda			
Coffee			
Vinegar			
Household ammonia			

37. Categorize each of the following substances as an acid, base, or neutral by placing an "X" in the appropriate column:

Support Questions

Activity: Identifying Acids and Bases



Many indicators can be made from common household items such as purple cabbage, tea, and strawberries. One very common indicator is litmus, which comes from plants called lichens. You can buy this indicator ready-made in a package of paper strips called litmus paper. Litmus paper indicates pH by changing colour—certain colours indicate acids, others indicate bases. In general, acids turn the litmus paper gets. Weak acids turn the paper an orange colour. Bases turn the paper a blue or brown colour, depending on the type of litmus paper. The stronger the base, the darker the colour. Weak bases turn the paper a pale blue or greenish-brown colour.

Imagine you were given a set of unknown solutions thought to be acids or bases. You are asked to determine their properties and identities. What tests would you perform?

This lab investigation will allow you to perform a variety of tests on unknown samples and take observations on acid and base reactions.

To start this activity, go to your course page on the ILC website and click on “Properties of Acids and Bases” under Lesson 9.



Purpose

To identify acids and bases based on their physical and chemical properties.

Materials

- 6 test tubes and a test tube rack
- 4 unknown liquids (marked A, B, C, D)
- 2 unknown powders (marked E, F)
- litmus paper
- conductivity meter with light bulb
- small pieces of magnesium
- distilled water

Procedure

1. Label the six test tubes A to F. Make an observation table like the one below to record your observations from the various tests on each sample.

	Initial Physical Observations	Addition of Water	Conductivity Test	Litmus Paper Test	Addition of Magnesium
Sample A					
Sample B					
Sample C					
Sample D					
Sample E					
Sample F					

For each of the six samples, carry out the following steps:

2. Record your observations of the sample's physical appearance, including colour, clarity, and texture.
3. Pour a small amount of the sample into a test tube.
4. Add distilled water to the sample until the test tube is about half full.
5. Insert the conductivity probes. Observe and record what happens to the light.
6. Dip a strip of litmus paper about halfway into the solution. Let it sit there for a few seconds, then remove. Observe and record any colour changes.
7. Add a small piece of magnesium to the sample. Observe and record any changes.
8. Set the test tube aside and repeat all steps for the next sample.
9. When all six samples have been tested, dispose of the solutions by flushing them down the sink one at a time with plenty of running water.

Observations

The table below shows sample observations for the test results on the six samples in the lab activity:

	Initial Physical Observations	Addition of Water	Conductivity Test	Litmus Paper Test	Addition of Magnesium
Sample A	– clear, colourless liquid	– solution looks the same	– light bulb glows dimly	– paper turns slightly orange	– tiny bubbles appear on the magnesium, and it eventually begins to bubble vigorously
Sample B	– clear, colourless liquid	– solution looks the same	– light bulb glows brightly	– paper stays yellow	– no change to solution or magnesium
Sample C	– clear, colourless liquid	– solution looks the same	– light bulb glows dimly	– paper turns slightly brown	– no change to solution or magnesium
Sample D	– clear, colourless liquid	– solution looks the same	– light bulb glows brightly	– paper turns red	– magnesium instantly starts to bubble very vigorously
Sample E	– fine white powder	– powder dissolves quickly to make a clear, colourless solution	– light bulb glows dimly	– paper turns blue	– no change to solution or magnesium
Sample F	– shiny white pellets	– pellets dissolve slowly to make a clear, colourless solution	– light bulb glows brightly	– paper turns dark brown	– no change to solution or magnesium

Analysis

The following seven Support Questions will lead you through an analysis of your results.

Support Questions

39. Which of the tests performed distinguish best between acids and bases?
40. Write a few sentences to summarize a procedure that could be used to perform the tests you suggested in Support Question 39.

41. Which of the samples in the lab activity are most likely acids? State your reasoning.

42. Which of the samples are most likely bases? State your reasoning.

43. Which sample does not seem to be either an acid or base? What characteristic separates it from the rest?

44. Write a sentence describing the reactivity of acids and bases with metals.

45. Fill in the table below to match each of the unknown samples to the following list of substances: sodium hydroxide, vinegar, hydrochloric acid, ammonia, baking soda, sodium chloride. What evidence allowed you to identify each? The first one is done for you.

Evidence		Proposed Identity
- conductivity and pH tests suggest it is an acid, but not a very powerful one. Also it does not dissolve magnesium very quickly, so it cannot be a very strong acid.	Sample A	Vinegar
	Sample B	
	Sample C	
	Sample D	
	Sample E	
	Sample F	

Reactions of Acids and Bases

What would happen if you mixed an acid and a base together? Since acids are so reactive and bases can be dangerous too, wouldn't you expect quite a vigorous reaction? You've seen how acids can react with metals, causing them to bubble and release gases, and bases are powerful enough to clean out clogged bathroom drains. So what does a reaction between an acid and a base look like? Consider sodium hydroxide, a very strong and powerful base, reacting with hydrochloric acid, one of the most reactive acids.

The reaction equation looks like this:



What pattern of reaction does this look like? It has two compounds as reactants and two compounds as products. Therefore it is a double-displacement reaction. Since it is double displacement, the halves of each molecule switch around and create NaCl and HOH. NaCl is sodium chloride, but HOH is actually H_2O or water.

So the acid and the base reaction made *salt* and *water*? In fact, that is the general reaction for most acids and bases. Not very exciting—and most of the time, there isn't even a visual clue that the reaction is taking place. The pH for this mixture should be around 7, or neutral, since it is just salt and water. Some acids and bases do react with a little more visual indication. Remember the bubbles in the vinegar and baking soda reaction from the last lesson? In that case, there is an added product.



One of the products, $\text{NaC}_2\text{H}_3\text{O}_2$, is sodium acetate. Though not table salt, it is in the class of compounds called *salts*. The water is still present and the bubbles of gas are carbon dioxide. So in this case, an acid and a base reacted to produce a salt, water, and carbon dioxide. This only happens to compounds containing the carbonate ion.

In summary, an **acid-base reaction** is a generally mild reaction that produces water, a salt, and sometimes carbon dioxide gas.

Uses of Acid-Base Reactions

Sometimes a stomach ache is caused by having too much acid in your stomach. A good solution is to add some base to neutralize the acid. The popular remedy for excess stomach acid is an antacid powder or pill. Most antacid powders or tablets contain calcium carbonate, which reacts with the water and acid in your stomach to use up the excess acid. As well, the reaction releases bubbles of carbon dioxide that help relieve the pain of indigestion.

Are there other situations where excess acid or bases causes a problem? You may have learned that acid rain has lowered the pH of lakes and rivers (more about this in Lesson 10). This often affects the lifespan and reproductive success of aquatic plants and animals. Plants don't grow as large, and fish and amphibian eggs don't always hatch in acidic water. Can you think of a possible solution?

One possible solution is to neutralize the acid in the lake. Though effective for short periods, this is expensive and can only work in small areas. Conservation groups sometimes do this by adding lime to a lake. Lime is a common name for calcium oxide (CaO). When added to water, lime makes basic calcium hydroxide (Ca(OH)_2) that counteracts the acid in the water, restoring the pH to a level beneficial for aquatic life. Lime is also added to lawns and fields that have low-pH soil to help plants, like grass, that don't grow well in acidic conditions.

Support Questions

46. Complete the word equations and write balanced chemical equations to represent the reaction between the following pairs of substances:

a) Potassium hydroxide and hydrochloric acid

b) Hydrobromic acid and calcium hydroxide

c) Ammonium hydroxide and sulfuric acid

d) Calcium carbonate and acetic acid

Acids and bases are special kinds of chemicals with unique properties that are very useful in your life. Chances are you drank some acidic solution this morning (coffee, tea, or juice) and you used a basic solution to wash yourself (soaps are mildly basic).

Acids and bases need to be associated with water to produce their effects. The strength of an acid or base is measured using the pH scale, with acids having pH readings below 7 and bases above 7. Only pure water has a reading of exactly 7, which is called neutral. Because acids and bases are opposite to each other, they can neutralize each other's effects. When an acid and a base react, you get water, salt, and sometimes carbon dioxide gas.

In the next lesson you will learn more about the safe handling and disposal of acids and bases, and conclude this unit on chemistry by exploring how chemistry is applied in a variety of careers to solve real-life problems.

Conclusion

Problem	Potential Solution
Soil with low pH has trouble growing some plants, like grass.	
A student spills a test tube of acid during science class, and you need to clean it up safely.	
A cook wants to give a soup a sour taste.	
A copper penny has turned black, and you want to make it shiny and bright again.	

47. Select the best solution from the following list to solve each problem shown in the table below.

1. Apply a strong acid such as hydrochloric acid.
2. Apply some lime (calcium oxide).
3. Apply an acid such as vinegar or lemon juice.
4. Apply a base such as sodium bicarbonate.

Key Concepts

Acid: a substance that, when dissolved in water, produces hydrogen ions, H^+ . It has a pH value below 7.

Hydrogen ion (H^+): always found in acids. Stronger acidic solutions have more free hydrogen ions.

Conductivity: measures how easily electricity can pass through a solution. All acid and base solutions are conductive.

pH: measures the activity of the hydrogen ions in the sample. It lets you know if a solution is acidic or basic and how strong it is of either type.

pH scale: measured on a scale that ranges from a low of 0 to a high of 14. Acids have pH values below 7 while bases are above 7. The stronger the acid, the lower its pH value.

Neutral pH: pure water is defined as having a pH of 7—exactly in the middle of the scale—because it is neither acidic nor basic. It is called neutral.

Corrosive: capable of destroying or eating away by chemical action

Hydroxide ion (OH^-): polyatomic ion found in many bases. It is always produced when a base reacts with water.

Base: defined as a substance that produces the hydroxide ion when it dissolves in or reacts with water. It has a pH value above 7.

Carbonate ion (CO_3^{2-}): found in many common bases whose names end in *carbonate*

Indicators: a group of chemicals added to solutions to test their pH

Litmus: an indicator of pH made from lichens. It usually turns blue in basic solutions and red in acidic ones.

Acid-base reaction: a generally mild reaction that produces water, a salt, and sometimes carbon dioxide gas

Key Questions

Save your answers to the Key Questions in your Course Journal or e-Journal.

Total: 20 marks

38. Acids and bases can be identified in different ways. In complete sentences, explain how acids and bases can each be distinguished from each other using the following: (6 marks: 2 marks each)

a) physical properties

b) chemical properties

c) names and formulas

39.

Write word and balanced equations to represent the reaction between the following pairs of substances: (6 marks: 2 marks each)

a) magnesium and hydrochloric acid

b) calcium and sulphuric acid

c) hydrochloric acid and sodium hydroxide

40.

Complete the following table by providing names or formulas as required. (4 marks: ½ mark each)

Name	Formula	Name	Formula
Ammonia		Phosphoric acid	
	H_2S	Magnesium hydroxide	
	$\text{Ca}(\text{OH})_2$	HClO_3	
Potassium hydroxide		$\text{HC}_2\text{H}_3\text{O}_2$	

41.

In complete sentences, describe one example of an acid used around the home, and one example of a base used around the home. (4 marks: 2 marks each)

Now go on to Lesson 10. Remember, you do not send your Journal to the Independent Learning Centre until you have completed Unit 2 (Lessons 6 to 10).



A World of Chemistry



SNC2D-B

Suggested Timing for This Lesson (hours)	
Chemistry in the Kitchen	½
Activity: Cake Bake-off	1½
Chemistry in the Workplace	½
Activity: Water-Quality Testing	1
Chemistry in the Environment	1
Key Questions	1

You may find this time grid helpful in planning when and how you will work through this lesson.

Planning Your Study

Chemistry is part of your everyday life. It also plays a role in many careers where you may not immediately recognize it. For example, have you ever watched chefs combine different ingredients to make a delicious meal? They might be cooking vegetables or grilling meats while adding spices and mixing sauces. All of these involve chemical reactions. The better the chef, the better that person is at manipulating chemical reactions to create delicious flavours.

What about construction workers who use glues to bind their materials together? Or use different solvents to clean materials or equipment? They are also taking advantage of chemical reactions in their work. So is the mechanic testing the emissions from your car, or the quality-control technician at the dairy. Painters and sculptors also use chemistry in their work, mixing chemicals to get the colours and textures that generate maximum impact.

As you saw in Unit 1, society is facing big challenges dealing with climate change and the development of alternative energy sources. Scientists and technicians knowledgeable in chemistry will be very important in helping to solve these problems.

In this lesson, you will examine how chemistry is involved in solving problems in many areas of society. You will learn about chemistry in the kitchen, the workplace, and the environment.

Introduction

What You Will Learn

After completing this lesson, you will be able to

- describe how chemistry is used at home and in the workplace
- identify the different WHMIS symbols and understand their use
- assess the role chemistry plays in environmental problems

Chemistry in the Kitchen

Chemistry plays a far more important role in the kitchen than most people realize. You have already come across some kitchen examples in which acids and bases are used to produce tastes and to clean. But what about actual cooking? Is there any chemistry there? When you cook something, you see many examples of chemical changes. The food often changes colour or releases gases and bubbles. Cooking often involves heating, and most of the time the changes are not reversible. Ever tried to un-cook an egg?

It's not just cooking that involves chemistry. The ability to store food for long periods has been key for human civilization. People have used different methods of food preservation for thousands of years, many involving chemistry. Examples include adding salt (salting), adding acid (pickling), and adding sugar (preserves and jams).

A relatively new field of food science is **molecular gastronomy**, which experiments with the specific physical and chemical changes that occur during cooking. For example, when you cook an egg, what actually happens to the yolk and the white? Being made of different molecules, each one changes differently when heated. Molecular gastronomists try to determine these differences so that they can cook more effectively. They experiment with new methods and ingredients, using chemical principles to mix flavours and change textures. Chefs too are discovering that knowledge of chemistry is a powerful tool. Using molecular gastronomy, chefs are creating weird, spectacular new dishes by turning vegetables into foams, milk into leathery sheets, chocolate into salt grains, and chicory root into foamy desserts.



Figure 10.1 A new dessert made from cream and chicory-root foam

Chemistry in the Food Industry

The food industry relies on people with knowledge of chemistry to preserve food and determine the safety of different ingredients and additives. Food scientists also increase the nutritional value of foods. Because of their work, you can now buy many kinds of enriched foods, including pasta enhanced with added omega-3 fats, yogurts containing probiotics, and juices with extra calcium.

These days, we see many foods described as “low calorie” or containing “no trans fats.” There are also meal substitutes and artificial sweeteners. You have probably heard of additives such as saccharin and aspartame. These compounds are several hundred times sweeter than sugar—you could replace several hundred teaspoons of sugar with one teaspoon of artificial sweetener. Obviously, something sweetened with these compounds does not need much sweetener in it to make it taste good. That’s why they are considered to be low calorie.

All food in Canada must be labelled with nutritional information. These labels identify the various nutrients in the food, and indicate how much of each nutrient is in a serving. This helps consumers make informed choices about what they are eating, especially if they are concerned about their calories or consumption of salt, sugar, or fat. This data comes from food scientists who perform tests on foods to determine how many calories they contain and how much nutrition you are receiving from each serving.

Nutrition Facts	
Per 3 crackers (28 g)	
Amount	% Daily Value
Calories 110	
Fat 2 g	3 %
Saturates 0.2 g	1 %
+ Trans 0 g	
Cholesterol 0 mg	
Sodium 140 mg	6 %
Carbohydrate 21 g	7 %
Fibre 1 g	4 %
Sugars 1 g	
Protein 3 g	
Vitamin A 0 %	Vitamin C 0 %
Calcium 0 %	Iron 2 %

Figure 10.2 Nutrition labels on packaged food help you make informed choices about your diet

Support Questions

Do not send your answers in for evaluation.

48. Label each of the following cooking examples as either a physical or chemical change.

Example	Type of Change
Boiling water	
Boiling an egg	
Toasting bread in the toaster	
Slicing a tomato	
Microwaving leftovers to heat them up	

49. For each of the following cooking examples, list the signs of a chemical change that you could observe:

a) toasting bread in a toaster

b) baking a loaf of bread

c) grilling a steak

d) trying an egg

50. Give two reasons why it is beneficial that all food has nutritional labels.

There are Suggested Answers to Support Questions at the end of this unit.

Activity: Cake Bake-off



We are all familiar with baked goods. When you look at a slice of bread or piece of cake, you can see a lot of small holes, yet the dough or the batter doesn't appear to contain a lot of holes. So where do the holes come from? In bread, bakers use yeast to help the bread "rise." In order to rise, the dough must contain gases that make it expand. The yeasts produce gas as they feed off the sugar in the dough. But a cake doesn't contain yeast, so where do the gases come from?

In this activity, you can follow the recipes to make two cakes that use two different chemical reactions. Which one is better? You be the judge.

Cake #1: Traditional Recipe

Ingredients:

1 cup unbleached white flour
 $\frac{1}{4}$ cup unsweetened cocoa powder
 2 teaspoons baking powder
 $\frac{1}{4}$ teaspoon salt
 $\frac{3}{4}$ cups granulated sugar
 $\frac{1}{2}$ cup milk
 $\frac{1}{4}$ cup butter
 1 egg, well beaten
 $\frac{1}{2}$ teaspoon vanilla extract

Directions:

1. Preheat the oven to 350°F.
2. Cream the butter and sugar together in a bowl using a wooden spoon or electric mixer.
3. Add eggs and vanilla, beating lightly.
4. Sift together the flour, cocoa, baking powder, and salt in a bowl.
5. Add the dry ingredients to the creamed mixture, alternating with milk. Beat mixture well.
6. Pour batter into a cake pan and bake for 30 minutes or until an inserted toothpick or fork comes out clean. Use oven mitts to remove cake when it is done.
7. Allow to cool before removing from pan.

Cake #2: Alternative Recipe

Ingredients:

1½ cups unbleached white flour
 ⅓ cup unsweetened cocoa powder
 1 teaspoon baking soda
 ½ teaspoon salt
 1 cup granulated sugar
 ½ cup vegetable oil
 1 cup cold water or brewed coffee
 2 teaspoons vanilla extract
 2 tablespoons vinegar

Directions:

1. Preheat the oven to 375°F.
2. Mix the dry ingredients (flour, cocoa, baking soda, salt, and sugar) together into an ungreased cake pan.
3. In a large measuring cup (at least two cups), measure and mix together the oil, vanilla, and water or coffee.
4. Pour the liquid ingredients into the baking pan and mix together with the dry ingredients. Stir or whisk until smooth.
5. Add the vinegar and quickly stir into the batter. Stir until the vinegar is evenly spread throughout the batter. Make an observation about what happens when the vinegar is mixed in.
6. Bake in the oven for 20 to 25 minutes or until an inserted toothpick or fork comes out clean. Use oven mitts to remove cake when it is done.
7. Allow to cool before removing from pan.

Support Questions

- 51.** Compare the two recipes' ingredients. Which items are different? Which do you think are important to reacting and producing the gases which create the holes in the cake?

- 52.** What visual differences did you notice between the two cakes when you mixed the wet and dry ingredients together?

- 53.** Make an observations table for the two cooked cakes. Use the following headings: Smell, Taste, Visual Appearance (be sure to note the presence or absence of holes).

- 54.** In Cake #1, the egg reacts with the baking powder to produce carbon dioxide gas, which creates the holes as the cake rises. Write a word equation to identify the reaction that occurs in Cake #2 to create the carbon dioxide and the holes.

- 55.** Imagine you are a food reviewer. Write a two-paragraph review explaining your opinion of the two different cakes. Do you think using chemistry principles to come up with an alternative recipe worked in this case?

Chemistry in the Workplace

Knowledge of chemistry is important in many jobs and careers. One essential job is ensuring that people have safe water to drink. You will examine two careers in this field in later sections. But even if a job does not appear to involve chemistry directly, it is still important for the workers to understand the risks involved when dealing with a wide range of chemicals. The government has created an education program to train everyone to handle chemicals safely in the workplace.

Workplace Safety (WHMIS)

Many people are required to have a basic knowledge of chemical safety in their jobs. Even if your job is not directly related to chemistry, the law requires Canadian workplaces where employees are exposed to hazardous products to train their employees in WHMIS (pronounced *WHIM-iss*), the **Workplace Hazardous Materials Information System**. This training helps you identify potentially dangerous chemicals and deal with them safely. Most employers will give you at least some basic training in WHMIS.

WHMIS training involves two main aspects. First, you learn to identify the hazardous warning labels and symbols that by law are placed on all hazardous substances. The WHMIS label is easily identified by its border of diagonal lines and its symbols. Second, you learn how to read the **Materials Safety Data Sheet** (MSDS) that comes with all potentially hazardous materials. This sheet lists the contents, dangers, precautions, and possible first-aid treatments. As well, the WHMIS system and the MSDS will tell you what safety clothing to wear (gloves, goggles, aprons) and how to deal with any chemical spills.

There are six categories of substances in the WHMIS program. Each is represented by a symbol along with a description of it and precautions in its use.

To learn more about the WHMIS system and the safe storage and disposal of chemicals, go to your course web page and click on “Understanding WHMIS” under Lesson 10.

After completing the online activity, answer the following two Support Questions.



Support Questions

56. Match the risks in column A with the correct WHMIS category in column B.

	Column A	Column B
a)	Can cause serious skin or eye irritation on contact	1. Compressed gases
b)	Could explode if heated or dropped	2. Flammable materials
c)	May cause birth defects	3. Poisonous material
d)	Very chemically unstable	4. Corrosive material
e)	May ignite spontaneously	5. Other toxic
f)	Potentially fatal	6. Dangerously reactive

57. What two sources of information are provided for all harmful substances in the workplace?

Water Quality Technician

One career that definitely requires WHMIS training and chemistry knowledge is that of **water quality technician**. This person collects water samples and performs chemical and biological analyses of municipal drinking water. Water quality technicians need to complete a chemistry or related program at a college or university. They need to be competent in laboratory procedures and computers. As well, they require the communication skills necessary to report their findings to their supervisors or the general public.

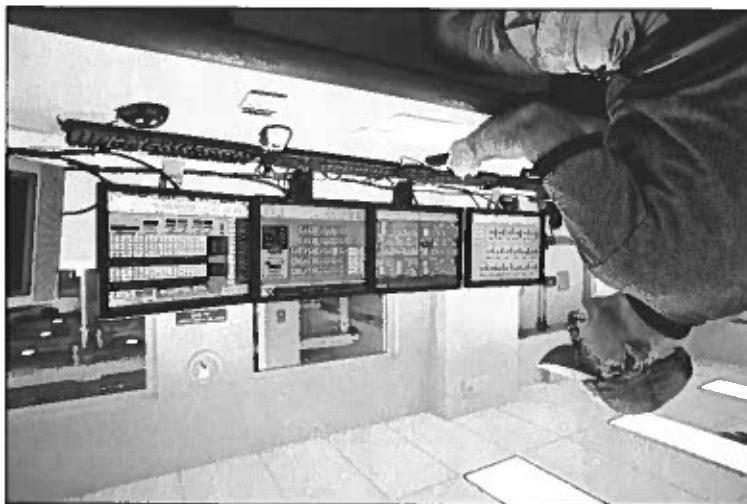


Figure 10.3 Water quality technician monitoring water wells at a public water utility plant

All municipalities need to monitor and test their water supply. In Canada, we are fortunate to have a large supply of fresh water for drinking and other household uses. However, problems can arise if the water is not tested for impurities. In 2000, the community of Walkerton, Ontario, was devastated by a public health crisis caused by improper monitoring and testing of its municipal water supply. Heavy spring rainfall resulted in contaminants from surrounding farms being washed into the wells that supplied the town's water supply. Hundreds of people got ill, and seven died. Although the contaminant, a bacterium called *E. coli*, is easily tested for, the results of the tests were not properly dealt with and were not communicated to the people of the town.

Water quality technicians conduct tests to determine if specific ions or bacteria are present in the water. Simple double-displacement reactions are performed. If certain ions are present, they precipitate out of solution, indicating a positive result.

Example

One contaminant commonly found in well water is sulphate (SO_4^{2-}). In high concentration, this ion can cause diarrhea and dehydration, particularly in children. Water quality technicians normally perform tests to detect the presence of sulphate ions, mixing the sample with a solution containing ions such as barium. Barium and sulphate produce a solid when they react together. Usually sulphate ions are bound to sodium in solution forming sodium sulphate (Na_2SO_4). The testing solution might contain barium chloride (BaCl_2), which is also soluble in water.



Activity: Water-Quality Testing

The testing reaction would then be
 sodium sulphate + barium chloride → sodium chloride and barium sulphate
 (Word equation)

or

$$\text{Na}_2\text{SO}_4 + \text{BaCl}_2 \rightarrow 2\text{NaCl} + \text{BaSO}_4 \text{ (Chemical equation)}$$

(Confirm for yourself that this is a double-displacement reaction.)

Sodium chloride is soluble in water, and so would not be seen. However, barium sulphate is not soluble, so the solution would turn cloudy, or solids would precipitate out of solution. This would indicate a positive test for sulphate, which the technician would report.

Water technicians use similar methods to test for many different ions including lead, iron, and mercury as well as many different biological compounds.

Purpose

To test for ions in water samples using double-displacement reactions.

Procedure

Go to your course page on the ILC website and click on “Water Quality Testing” under Lesson 10.

After completing the online activity, answer the two Support Questions on page 14.

You are given three samples of water to be tested for the contaminants: lead and magnesium. The water samples are labelled A, B, and C.

Each sample will undergo two separate tests. The first test will look for the presence of lead ions in the sample. The second test will look for the presence of magnesium ions.

The tests will require you to take observations of the samples before and after the testing solutions are added. Record your observations in a table like the one below.



1. Pour about 50 mL of each sample into labelled test tube.
2. Make initial observations of each of the three water samples. Record clarity and colour in a table like the one shown above.
3. When you are ready, add 10 to 15 drops of the sodium hydroxide testing solution to each water sample.
4. Make observations after the testing solution has been added. Any evidence of a cloudy precipitate indicates the presence of magnesium ions.

Test for magnesium ions:

1. Make initial observations of each of the three water samples. Record clarity and colour in a table like the one shown above.
2. When you are ready, add about 15 to 20 drops of the sodium chloride testing solution to each water sample.
3. Make observations after the testing solution has been added. Any evidence of a cloudy precipitate indicates the presence of lead ions.

Test for lead ions:

Steps

Test for lead ions	Initial	After adding test solution	Test for magnesium ions		Observations
			Initial	After adding test solution	
Sample A					
Sample B					
Sample C					

Support Questions

58. The following table contains sample observations for the two water-testing reactions similar to what you have observed.

	Test for lead ions		Test for magnesium ions	
	Initial	After adding test solution	Initial	After adding test solution
Observations	Water is clear and colourless	Solution is still clear and colourless	Water is clear and colourless	Solution is still clear and colourless
Sample A	Water is clear and colourless	Solution is still clear and colourless	Water is clear and colourless	Solution is still clear and colourless
Sample B	Water is clear and colourless	Cloudy white precipitate forms	Water is clear and colourless	Solution is still clear and colourless
Sample C	Water is clear and colourless	Solution is still clear and colourless	Water is clear and colourless	Cloudy white precipitate forms

Based on the observations, which samples contained the ions being tested?

59. Write balanced chemical reactions to describe the positive testing reactions. Assume that the ions being tested for were combined with nitrate ions. This means that if the lead ions were present, they would be bonded with nitrate in $\text{Pb}(\text{NO}_3)_2$ and if magnesium ions were present, they would be bonded with nitrate ions in $\text{Mg}(\text{NO}_3)_2$.

Chemistry in the Environment

As you learned in Unit 1, chemical reactions significantly affect our global climate. For example, the combustion reaction of fossil fuels with oxygen releases CO_2 into the atmosphere, increasing the greenhouse effect as well as making the oceans more acidic. In fact, many environmental problems are chemical in nature. Below you will learn about two other current environmental issues and see how knowledge and training in chemistry help solve them.

Pharmaceuticals in the Water

One current issue facing water-quality scientists is the presence of pharmaceuticals in our water. Some people flush excess prescription medicine down the drain when they feel they don't need it any more. Other drugs enter the water system through urine. Ultimately, even though the waste water is often treated, these drugs still end up in rivers, lakes, and groundwater—the sources of our drinking water.

Dr. Mark R. Servos is a professor and researcher at the University of Waterloo in Waterloo, Ontario. He studies the effect of these pharmaceuticals in our water. He is also the Scientific Director for the Canadian Water Network, which is focused on ensuring that there is safe and clean water across Canada and internationally. He is also associated with the International Association of Great Lakes Research (IAGLR) and the Society of Environmental Toxicology and Chemistry (SETAC). After completing his university undergraduate and graduate degrees in aquatic science, Dr. Servos worked as a research scientist with the federal government, studying water contamination in the Great Lakes. He examined what happened to various toxic chemicals, such as dioxins and PCBs, that were released from pulp mills into the rivers and lakes. This led him to study the effects of exposure of these chemicals. As a professor, his current research is on the effect of pharmaceuticals in our water system.

Most of the medicines that get into our water systems are designed to have biological effects. They may contain hormones to regulate reproduction or manage illness. They may contain alternative or artificial hormones, or have properties that mimic what hormones do. Many of the animals living in our water systems have biological systems that function much like ours. That means that a fish or turtle or frog could end up ingesting a drug that affects its own hormone levels. The drug will likely have a larger effect on these small animals since the drug dosages were designed for humans. This could lead to failed reproduction or early death, and the loss of these important species.

Acid Precipitation

Another fear is that people are being exposed to very small amounts of these drugs consistently over the course of their lifetime. With each drink of water we absorb tiny trace amounts of a whole range of drugs. Scientists are not sure what effect this may have on us.

The answer to this problem lies in finding ways to dispose of old drugs so that they do not enter the aquatic ecosystems. It also lies in finding ways to treat our waste water or drinking water to remove these chemicals. Researchers trained in aquatic chemistry, like Dr. Servos, are publicizing this problem and discovering possible solutions.

In Canada, we get a lot of rain and snow. To many of us, nothing looks cleaner than a layer of freshly fallen snow. But did you know that the rain and the snow contain chemicals from our atmosphere, and that these chemicals are capable of killing lakes?

In previous lessons, you learned about combustion reactions whose products, such as carbon dioxide, contribute to global warming. These products contribute to another environmental problem: **acid precipitation**. It used to be called acid rain, but scientists have realized that all forms of precipitation—rain, snow, fog, sleet, and hail—contribute to the problem.

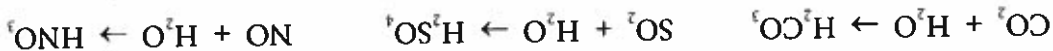
Source of the Acid

Carbon dioxide is not the only chemical pollutant produced when fossil fuels are burned for transportation, energy production, or in factories. Many fossil fuels, especially coal, contain large amounts of nitrogen and sulphur compounds. When these compounds burn, oxides of nitrogen and sulphur are also produced, as shown in the following reactions:



Sulphur dioxide and nitrogen oxide are two of the possible oxides these elements form. To keep things simple, we will examine only these two.

These two oxide compounds are not very harmful on their own, but things don't stop there. Our atmosphere is also full of water vapour. The oxides, CO_2 , SO_2 , and NO , all mix with the water in the air and react further:



Do you recognize these products? They are all acids. H_2CO_3 is carbonic acid, H_2SO_4 is sulphuric acid, and HNO_3 is nitric acid.

All rain and snow contain small amounts of acid. The amount is not large enough for you to notice—you don't feel a burning sensation on your skin when it rains—but it is enough to make the pH of rain water below 7. When the acid precipitation falls, most of it makes its way into rivers and then to lakes, or is absorbed into the ground. In lakes and rivers, the acid will cause a reduction in pH. Every time it rains or snows, a little bit more acid gets added to the lakes. Over time, the lake water gets increasingly acidic.

Effects of Acid Precipitation

The effect on life in the lakes can be dramatic. As the lakes become more acidic, especially below pH 5, the growth of plants and animals is reduced. Fish can't grow and many plants die. Their eggs and seeds fail to develop. Over time, as the acid levels increase, the amount of life in the lake decreases. Even algae stop growing in the water. This produces water that looks very clean and clear—so clear that you can see the bottom of most lakes. This is not an indication of health, but rather of a dead or dying lake.

This problem is not just confined to lakes. When the soils in fields and forests get more acidic, many plants don't grow as well and reproduce less. As you learned in the previous lesson, some plants like grasses don't grow well in acidic soil conditions. Others, such as mosses, like acid soils and may take over an area. Some trees, like sugar maples, are particularly sensitive to acid soils. Recent research has shown that acid soils prevent sugar maple seedlings from growing, which has led to widespread decline of these trees in northeastern North America. That's one reason why real maple syrup is so expensive now. Trees around the shorelines of lakes are also often affected, resulting in dead trees and shoreline erosion as the tree roots no longer hold the soil together.

Even life in our cities is affected. Remember some of the reactions you examined in previous lessons, especially those involving acids and carbonate compounds? Many buildings and structures are made from brick, rock, concrete, and limestone, all of which contain carbonates. The acid precipitation slowly breaks down these substances. The mouldings on many old stone buildings, gravestones, and stone statues are slowly losing their features. Like bars of soap left out in the rain, they are slowly dissolving in the acid.



Figure 10.4 Limestone statue eroded by acid precipitation

As well, structures such as bridges can be weakened by the effect of acid precipitation on their concrete and metal supports.

Possible Solutions

Acid precipitation has been a problem for over 100 years. It isn't likely to disappear quickly because our society is so dependent on the combustion of fossil fuels for energy, industry, and transportation. Reducing the effects of acid precipitation is a big challenge.

One way to deal with the problem is to reverse the effect. After it rains, the effect of the acid can be neutralized by adding a base. As you learned in the last lesson, one method to do this is "liming"—adding large amounts of lime (calcium oxide) to lakes to make them less acidic. This can help temporarily on a small body of water, but is impractical and too expensive to be a large-scale solution. Another approach is to reduce the production of the pollutant gases. This is a great idea—if you don't produce the chemicals, you don't have to fix the problem. If we use less fossil fuel, less pollution enters the atmosphere. But there is a limit to how much energy conservation can help. As long as fossil fuels are being burned to produce energy, there will be pollution. In addition, the gases already in the atmosphere need to be dealt with.

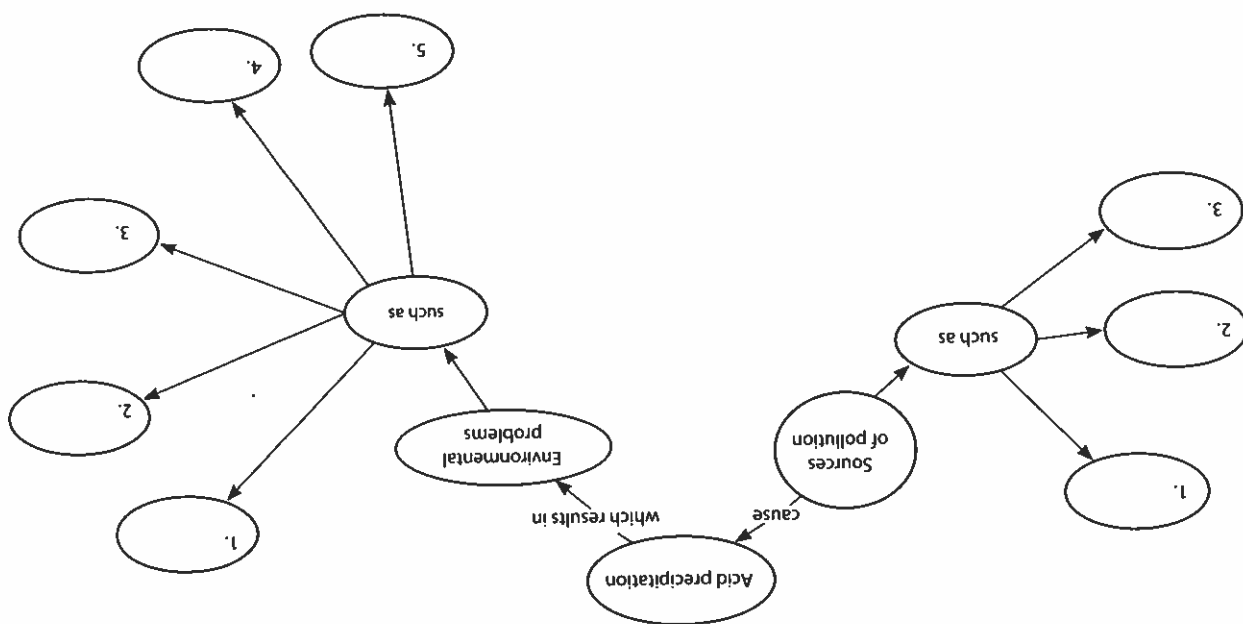
Another way to reduce the release of gases is to clean the emissions from the sources of the pollution. Gases coming out of a large smokestack can be “cleaned” or “scrubbed” before release. That may sound a little strange, but filters called “scrubbers” are placed inside the smokestacks in order to clean the pollutants out of the smoke. The scrubbers have chemicals in them that react with the pollutants like SO_2 to convert them into something safe or absorb them into the filter. Though somewhat effective, this process is also very expensive. Not all industries are willing to pay the costs of installing a chemical scrubber. However, by law, all cars have these scrubbers installed. They are called catalytic converters.

Support Questions

60. Complete the balanced reaction that would occur between nitric acid and calcium carbonate in a statue.

61. Make a flowchart indicating how driving a car can result in frog eggs not hatching.

62. Complete the concept map connecting sources of pollution to acid precipitation and other environmental problems.



Conclusion

In this last lesson in the chemistry unit, you learned how knowledge of chemistry is being applied in the home, in the workplace, and in the fight against environmental problems. You also learned how chemistry is part of many careers, even if this is not obvious at first. Because so many jobs involve exposure to chemicals, some of them harmful, the government has created the WHMIS system to educate and protect you in the workplace.

Like all sciences, chemistry is a very creative process. As you have seen, atoms, molecules, and compounds can be combined using many types of reactions to create beneficial products from food to clothing. Just like writers combine words in new ways to create new stories, chemists can combine chemicals in new ways to create new materials. And some even taste like chocolate salt.

Key Concepts

Molecular gastronomy: a very new field of food science that uses chemical principles to discover how best to prepare food and create new flavour and texture combinations

WHMIS: the Workplace Hazardous Materials Information System. This system helps you to identify potentially dangerous chemicals and deal with them safely.

Materials Safety Data Sheet (MSDS): document that comes with all potentially hazardous materials. This sheet lists a given material's contents, dangers, precautions, and possible first-aid treatments.

Water quality technician: conducts tests to determine if specific ions or bacteria are present in the water to ensure the safety of our water supply

Acid precipitation: rain, snow, or other precipitation that contains acid from the reaction of fossil-fuel pollutants, like oxides of sulphur and nitrogen, with water vapour in the atmosphere

Key Questions

Save your answers to the Key Questions in your
Course Journal or e-Journal.

Total: 14 marks

42. List four of the categories of dangerous materials used in the WHMIS system. (4 marks)
43. Describe two ways chemistry can be used to solve the acid-precipitation problem. In your answer, refer to a specific solution to a specific aspect of the problem. (4 marks)
44. In a car engine, gasoline (C_8H_{18}) is burned in oxygen (O_2) to create energy. The normal products of this are carbon dioxide and water. However, gasoline is a mixture that also contains some sulphur and nitrogen compounds. When the gasoline is burned, compounds called sulphur oxides, such as SO_2 and SO_3 , and nitrogen oxides, such as NO , NO_2 , and N_2O_5 , are formed. These compounds are pollutants that contribute to poor air quality and environmental problems such as acid precipitation. Take the position of an environmentalist and suggest three ideas that you could propose to the government to reduce the amount of air pollution formed. (6 marks: 2 marks for each idea)

This is the last lesson in Unit 2. When you are finished, do the Evaluation work in your Course Journal or e-Journal for Unit 2. Follow any other instructions you have received from LLC about submitting your journal, then send it to LLC. A teacher will mark your work, and LLC will send it back to you as soon as possible.