

**EVALUATING
ACADEMIC READINESS
FOR APPRENTICESHIP TRAINING**
Revised for
ACCESS TO APPRENTICESHIP

**SCIENCE SKILLS
BASIC ATOMIC STRUCTURE AND THEORY**

**AN ACADEMIC SKILLS MANUAL
for
The Horticulture Trades**

This trade group includes the following trades:
Arborist, and
Horticulturist

*Workplace Support Services Branch
Ontario Ministry of Training, Colleges and Universities*

Revised 2011

In preparing these Academic Skills Manuals we have used passages, diagrams and questions similar to those an apprentice might find in a text, guide or trade manual.

This trade related material is not intended to instruct you in your trade. It is used only to demonstrate how understanding an academic skill will help you find and use the information you need.

SCIENCE SKILLS

BASIC ATOMIC STRUCTURE AND THEORY

*An academic skill required for the study of the
Horticulture Trades*

INTRODUCTION

Hey, did you hear about the two atoms coming out of the movies? As they were leaving, one of the atoms said to the other, “*I think I forgot an electron back at my seat.*” The second atom said, “*Are you sure?*” The first atom answered, “*Yes, I’m positive.*” If you didn’t get the punch line, it should be obvious by the time you finish reading this skill manual about atoms.

Importance of Atomic Structure

Matter is made up of basic building blocks called atoms. Atoms are very small particles with a specific organization and design. Atoms bond together with other atoms to form all the materials found on earth including living plants and the many chemical products used in horticulture.. Every different material or compound has a different type or configuration of atoms. The properties and behavior of everything you use in the horticulturist trades depends on this basic atomic structure.

Because the basic atomic structure of each compound that you use at work is different, they vary in their characteristics. Understanding how atomic structure influences these materials helps explain why they react the way they do. In your trade, you use many different kinds of materials, including pesticides and fertilizers. Some of these materials are potentially hazardous. Your courses include a section on handling hazardous materials. During this part of the course, called WHMIS, you will have to recognize chemical compounds, such as Xylene and N-butyl acetate, and understand why they can be toxic. If you know how a compound will react physically and chemically, you will know how to use it safely.

You will also learn about plants and processes such as how herbicides affect plant growth, how plants use the nutrients in fertilizers, and how plants take up water. These processes all depend on interactions between the chemical substances that make up plants. The way these substances are formed and how they interact depends on their atomic structure.

Much of the equipment you work with is run by electricity. Knowing basic electrical theory will help you work efficiently and safely around electrical components. Electrical theory has its foundation in basic atomic structure. In this skills manual, we will look at:

- ◆ Basic structure of an atom
- ◆ Elements
- ◆ Electrical charges
- ◆ Bonding between atoms
- ◆ Compounds
- ◆ Mixtures

BASIC STRUCTURE OF AN ATOM

Subatomic Particles

All matter is made of atoms. The atom is not actually a solid particle. It is made up of several different, smaller parts called *subatomic particles*. The main subatomic particles are the **proton**, the **neutron** and the **electron**. Figure 1 shows the subatomic particles that form an atom and where they are located. Notice that there is a lot of empty space within an atom.

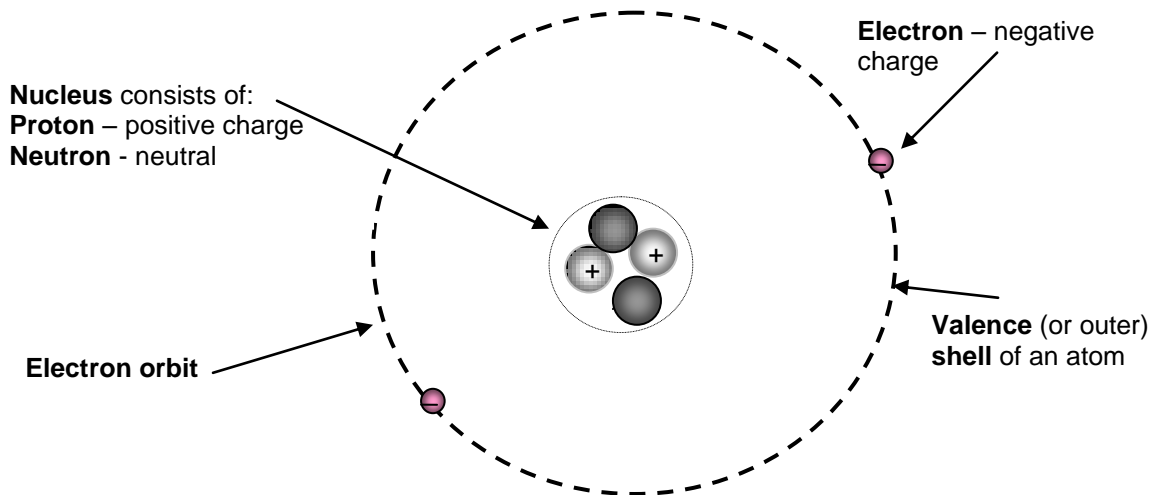


FIGURE 1: Basic Atomic Structure

Atoms are made of two main parts. The compact center of an atom is called the **nucleus**. Circling the nucleus are **orbits** or **shells** where the electrons are found. Both the nucleus and the shells contain smaller *sub-atomic particles*. The number and arrangement of these subatomic particles give each type of atom its distinctive qualities.

The nucleus, the small heavy centre of the atom, contains two main particles.

- ◆ **Protons and neutrons** are located in the nucleus.
 - The number of protons determines the kind of atom that is formed.

The **orbits**, or shells surround the nucleus.

- ◆ Each shell contains one or more **electrons**.
 - Electrons are very small particles that travel within a shell.
 - The outside shell, called the **valence shell**, is the most active.

The **number** of protons and electrons in each atom determine its characteristics.

- ◆ There are usually has the same number of protons as there are electrons in an atom.
- ◆ However, an atom can gain or lose electrons in certain circumstances.

Charges on protons and electrons

- ◆ Protons and electrons have a very important property called **charge**.
 - Protons and electrons have different types of charge.
 - Protons have **positive** charge.
 - Electrons have **negative** charge.
- ◆ The charges on electrons and protons are responsible for much of the underlying **structure** of matter.

The nucleus

The nucleus, or the centre of the atom, consists of two types of particles, the proton and the neutron. Strong nuclear forces hold them together, preventing the protons from leaving the nucleus.

- ◆ The number of protons in an atom is usually the same as the number of neutrons.
- ◆ Each proton has one positive charge.
- ◆ The neutron has no charge and is considered neutral.

Electron shells and electrons

One or more electron shells, or **energy levels**, surround the nucleus of an atom. Electrons in these shells orbit the nucleus of the atom. The area occupied by the electron shells and their electrons **forms the physical space an atom occupies** and gives the atom its distinct, indivisible nature.

Each shell can hold only a certain, **specific number of electrons before it is full**.

- ◆ There is a maximum number of electrons each shell can hold. There are:
 - **Two** in the first shell,
 - **Eight** in the second shell,
 - **Eighteen** in the third shell, etc.
- ◆ The outer shell of an atom is the most active. It is called the **valence shell**.

The outer or valence shell of an atom is the most important in determining how an atom will interact with other atoms.

- ◆ A few atoms have filled outer shells (two, eight, eighteen electrons, etc) but most do not.
- ◆ An atom is **more stable when its outermost shell is full**.
- ◆ To gain the stability of a full outer shell, an atom might give away or accept electrons, or share them. Thus, **the number of electrons in an atom can vary**.
- ◆ This is important both for the way **atoms bond together** to form molecules and for the way **electrical charges develop**.

Electrons are held in their orbit around the nucleus by the electrical attraction between electrons and protons that results from the fact that **they have different charges**.

- ◆ The attraction between electrons and protons is weaker than the force that holds protons and neutrons together in the nucleus.
- ◆ The force that holds electrons close to the nucleus can be broken, allowing the electrons in the outer valence shells to be shared with or given to other atoms.

Different kinds of atoms

Each kind of atom has a specific number of subatomic particles. Thus, the number of protons, neutrons and electrons varies in each particular kind of atom.

- Look back at Figure 1. The atom shown here has two protons, two neutrons and (usually) two electrons. This is a helium atom.
- A carbon atom has six protons, six neutrons and six electrons.
- An oxygen atom has eight of each subatomic particle, while a silicon atom has fourteen.

The number of protons and electrons an atom has is very important.

- ◆ This number determines what kind of atom is formed and how it will behave.
- ◆ Under certain conditions, the number of electrons in an atom may vary.
- ◆ But, ***the number of protons in any specific type of atom remains constant.***
- ◆ The number of protons determines what type of atom is formed.
- ◆ Because the number of protons in an atom is so important, it is called the ***atomic number.***

There are many different types of atoms – more than a hundred that we know about. Some common types of atoms include hydrogen, oxygen, nitrogen and carbon. Each type of atom has a specific, unchanging number of protons. Each type of atom forms a pure substance. These substances are called ***elements.***

ELEMENTS

Each specific type of atom forms a different element. An element cannot naturally be broken down into other, more simple substances. *Each element is a pure substance made of only one type (of the more than one hundred possible types) of atom.*

- Iron is an element - pure iron cannot be broken down any further.
- Iron oxide or rust is not an element because it is composed of atoms of iron and oxygen.
- Common salt or sodium chloride *is not* an element - it can be broken down into separate particles consisting of the elements sodium and chloride.
- Sodium and chloride *are* elements because they cannot be broken down further by physical or chemical means.
- Wood is not an element because it is made of many different elements combined together.

Each element looks and behaves differently from any other element. What makes this difference? The answer lies in the structure of each type of atom.

- ◆ Atoms of each different element have a specific *atomic number* based on the number of protons. This number differs in every element.

The *atomic number and the number of electrons* in any atom determine the following:

- ◆ The structure of the atom, including the number of subatomic particles (electrons, proton and neutrons) and the organization of the electrons in the different orbits.
- ◆ The way the atom interacts with other atoms.
- ◆ The way the atom reacts to changes in the environment.

Every different element is made up of a different, unique, type of atom, so every element has different characteristics.

Periodic Table

The elements are classified in a chart called the *periodic table*. The periodic table lists the known elements in order according to the unique structure of the atoms that form each element. The table lists all the different elements in columns and rows. There is much information encoded in the arrangement of elements in the periodic table.

Elements are listed in order by their increasing atomic number in the periodic table.

Example: Hydrogen, the smallest element with one proton and one electron, is the first element listed in the periodic table.

Example: The next element on the table is helium, which has two protons and two electrons. A helium atom has a completely filled the first shell, which holds two electrons when full.

Example: The next element in the table, lithium, has three protons and three electrons.

- Its first shell is filled with two electrons, so its third electron is in the next, or second, shell.
- This second shell is full when it has eight electrons.
 - Since the lithium atom has only one electron in that shell, it tends to give away this lone electron so that it has a filled outer shell of two electrons.

Note: When an element loses electrons to get a full outer shell, the number of shells it normally has will be reduced by one.

Elements that have characteristics in common, such as similar metals or the inert gases, are associated in columns. There is an association between the number of electrons in the outer shell of an element and the column it appears in.

Example: Carbon and silicon are in the same column. Both are very common elements.

- Each has only 4 electrons in their outer shells so they both react easily with other elements to form compounds.
- Carbon compounds form the basic materials of living organisms.
- Silicon joins with oxygen to form quartz, the most abundant rock structure on earth.
- Quartz sand grains are an important component of soil.

Carbon is the most important element in living matter such as plants. Complex substances that contain carbon and hydrogen are called organic compounds. Carbon is a major element in the chemical compounds you will find with a WHMIS label.

Metals

Elements like lithium that have only a few electrons in their outermost shell are called *metals*. Many elements on the surface of the earth are metals. They include copper, aluminum and iron.

When only a few electrons fill the outermost shell of an atom, those electrons can easily be dislodged. When many atoms of the same metal join together, they arrange themselves as a closely-spaced, ordered crystal. The outer electrons from each atom are easily dislodged and they are shared by the whole crystal. It is these free-flowing, shared electrons that carry the electrical charge in metal conductors.

Non-metals

Non-metallic elements, like oxygen and chlorine, have almost full outer shells. They need only one or two electrons to completely fill their outer shell. *Atoms which need only a few electrons to fill an outer shell readily accept electrons from other atoms such as metals.*

Elements such as carbon and silicon, which have half full outer shells, readily give away, accept or share electrons to get full outer shells. This is one reason they react so readily with other elements.

- ◆ This tendency to share, give away or accept electrons enables atoms to bond with other atoms.
- ◆ These bonded atoms come together to create all the complex substances found on earth.

In brief:

- ◆ The atom consists of two parts:
 - an inner nucleus which contains protons and neutrons, and,
 - surrounding shells which contain fast moving electrons that orbit the nucleus.
- ◆ The number of protons, called the atomic number, determines what element an atom forms.
- ◆ The number of protons is usually the same as the number of electrons.
- ◆ Forces holding neutrons and protons together in the nucleus are very strong; the forces holding electrons to the nucleus are much weaker.
- ◆ An atom is more stable when its outer electron shell is filled with the maximum number of electrons for that shell.
 - Atoms can share, give away or accept electrons to obtain a filled outer shell.
- ◆ This exchange of electrons causes atoms to bond together.

Before looking at how bonds are formed, we will look at the properties of electrical charge.

ELECTRICAL CHARGES

Recall that a force is something that exerts a push or pull on an object. If the object is not held in place, it moves as a result of the applied force. Electrons and protons exert a force of ***attraction or repulsion*** on other electrons and protons. This force is called an ***electrical force or charge***.

- ◆ Similar particles, either two protons or two electrons, feel a force that pushes them apart.
- ◆ Dissimilar particles, a proton and an electron, feel a force that pulls them together.
- ◆ In other words, protons and electrons feel a force of attraction to each other. Electrons are repelled by other electrons. Protons are repelled by other protons.

An electrical force is similar to a magnetic force. The south and north poles of a magnet are attracted to each other and will be pulled together when they are brought near each other. Two magnetic south or north poles will push apart when they are near each other.

Charges on electrons and protons

Forces of attraction and repulsion exist between subatomic particles because protons and electrons have a different kind of charge.

- ◆ Protons have a **positive charge**; a positive charge is indicated by the symbol +.
- ◆ Electrons have a **negative charge**; a negative charge is indicated by the symbol –. These symbols are used in Figure 1.
- ◆ Neutrons have no charge.

In the atom, **opposite charges attract** each other:

- ◆ Protons, with their positive charge, are attracted to electrons, with their negative charge.
- ◆ Electrons, with their negative charge, are attracted to protons, with their positive charge.

In the atom, **like charges repel, or push away**, each other:

- ◆ Protons repel other protons.
- ◆ Electrons repel other electrons.

This is summed up by the saying: **opposite charges attract and like charges repel.**

The forces of attraction and repulsion keep all the subatomic particles in their places and give the atom its size, shape and special characteristics.

- ◆ Electrons are kept from flying out of their orbits by *their attraction to the protons* in the nucleus.
- ◆ At the same time, the *electrons repel each other*, which causes them to spread as far apart from each other as possible in their orbits around the outside of the atom.

Because protons are held tightly in the nucleus by atomic forces and are not free to move, **only the movement of electrons can give an atom a charge**. This means:

- ◆ If an atom **gains** electrons, it has a **negative charge**.
- ◆ If it **loses** electrons, it has a **positive charge**.

So a negative charge comes from gaining extra electrons, while a positive charge comes from losing electrons.

Charges on a larger object

When a single atom gains extra electrons, it becomes negatively charged. In the same way, if an object such as a metal plate gains a large number of extra electrons, the whole object becomes negatively charged. On the other hand, if the atoms making up an object lose a large number of electrons, the object becomes positively charged.

If an atom has the **same number** of protons as electrons, the positive and negative charges balance each other, making the atom **neutral** (having no charge). An atom with the same number

of electrons and protons is electrically neutral. In the same way, if the negative and positive charges on a large object are balanced, the object is neutral.

In Brief

The theory of charge:

- ◆ Each electron has one negative charge; each proton has one positive charge.
- ◆ Like charges repel; unlike charges attract.
- ◆ An extra electron transferred to an atom gives the atom a negative charge of -1 .
- ◆ The loss of an electron gives an atom a positive charge of $+1$.
- ◆ An excess or deficiency of electrons determines the charge on a larger object.
 - **More electrons** than protons give a **negative charge**.
 - **Fewer electrons** than protons give a **positive charge**.

BONDING BETWEEN ATOMS

Atoms of different elements without filled outer shells can share, give away or accept electrons. When atoms exchange electrons, they become joined into more complex structures.

Atoms can bond with other atoms of the same element or, more usually, they join with atoms of different elements. When two or more atoms bond together, they form a **molecule**. Molecules in turn combine to form all the different substances found on earth.

Different types of bonds

There are three main types of bonds:

- ◆ When atoms or molecules **transfer** electrons, the bonds formed are called **ionic bonds**.
- ◆ When atoms or molecules **share** electrons, **molecular** or **covalent bonds** are formed.
- ◆ When metal atoms share electrons, **metallic bonds** are formed.

Substances on earth usually occur as molecules, not single atoms. This happens because one kind of atom will interact with another kind of atom so that both end up with a more stable, filled outer shell. These interactions result in molecules being formed. These molecules, in turn, often combine with other molecules to form new compounds.

All bonds are formed because of atomic interaction but the type of interaction varies in the three different kinds of bonds.

Remember, bonds are formed because:

- ◆ Atoms with filled outer shells are more stable.
- ◆ The outer shell of an atom might lose or gain electrons or share electrons so it can have a filled outer shell.

How Different Types Of Bonds Are Formed

Ionic bonds

An ionic bond is formed when an atom donates an electron to a different kind of atom so that both end up with stable, filled outer shells.

- Each of these atoms has now become charged. Because they are now charged particles, they are called ions.
- One atom or ion has more protons than electrons, giving it a positive charge.
- The other has one more electron than protons, giving it a negative charge.
- The negatively charged atom (which donated the electron) is attracted to the positively charged atom (which accepted the electron).
- This results in a molecule held together by an *ionic bond*.

Covalent bonds: A covalent bond is formed when atoms share electrons so that each ends up with a stable, filled outer shell.

- The shared electrons hold the atoms together in this more stable arrangement.
- This results in a molecule held together by a *covalent bond*.

Metallic bonds: A metallic bond is formed when atoms of solid metals pack closely together in a stable crystal formation. They release and share their loosely-held outer electrons so they each have filled outer shells.

- The free electrons are shared by all of the now stable atoms and move in a cloud around the outside.
- This results in molecules held together in a metallic bond.

When atoms join together in these different ways, we say they are *chemically bonded*.

Ions

If an atom or molecule loses electrons, it becomes positively charged. If an atom gains electrons, it becomes negatively charged. Atoms that gain a charge in this way are called *ions*. Ions with opposite charge are attracted to each other.

Example: Salt is a compound made of ions. A sodium atom that loses an electron to an atom of chlorine, the sodium atom gains a positive charge of +1. It is now a positively charged sodium ion. The chlorine atom gains an electron and a negative charge of -1. It is now a negatively charged chlorine ion.

The oppositely charged ions are attracted to each other and form ionic bonds. When many such sodium and chlorine ions are joined by ionic bonds, the compound salt is formed. See Figure 2.

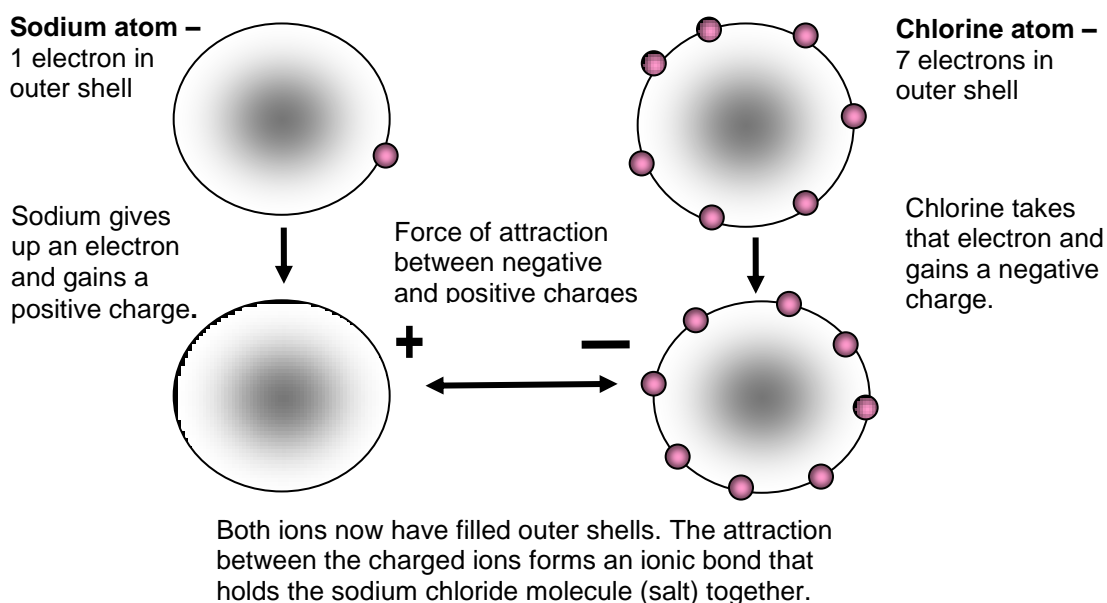


FIGURE 2: Ionic Bond Holds Sodium and Chlorine Atoms Together to Form Salt

Molecules

If atoms share electrons, they form a *molecule*, which is held together by a covalent bond. The area where the different atoms come together to share electrons (and create the molecular bond), has more electrons than the rest of the molecule. This area becomes more negatively charged. The other area of the molecule has wider spaces between the electrons and now has more positive charge than the shared area.

Although the molecule has areas where the charge is unequally distributed, the molecule itself is not a charged particle because the total number of protons still equals the total number of electrons.

Because the unequal distribution of electrons in the molecule causes areas of negative and positive charge, the negative part of one molecule will be attracted to the positive part of another, similar molecule. This attraction is what holds individual molecules together as larger substances.

Molecules can be formed by bonds between similar atoms, or more usually, by bonding between different types of atoms.

- ◆ Oxygen gas is formed from molecules made of only oxygen atoms. To form an oxygen molecule, two oxygen atoms each share two electrons so they both have eight in their outer shell. This gives them both a filled outermost shell.
- ◆ Most molecules are made of combinations of atoms from two or more different elements.
 - Two hydrogen atoms and one oxygen atom combine to make a water molecule. The two hydrogen atoms and the one oxygen atom share their outer shell electrons so

they each get a filled outer shell. This creates a molecular or covalent bond between the two different elements and a water molecule is formed. See Figure 3.

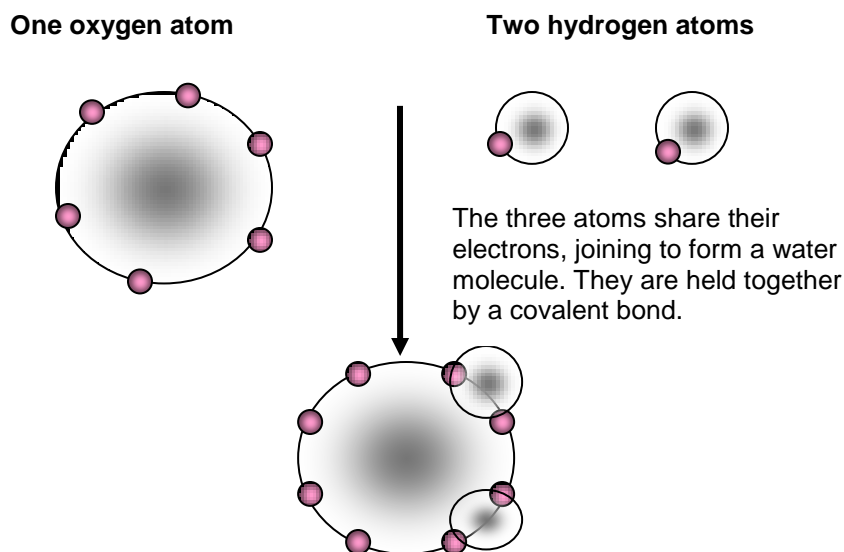


FIGURE 3: Water Molecule

Metals Metal atoms are held together because each atom gives up or donates the loosely-held electrons in their outer shell. They pack close together in a stable, regularly-arranged crystal. The donated electrons are shared by all the atoms in a free-flowing cloud of electrons.

- ◆ When metal atoms share a large number of free electrons, there is a general attraction between all the protons and all the electrons.
 - This force of attraction holds metals together as strong solids.
- ◆ Electrons on the outside of thin wires of metal can move freely. This structure enables metals to be excellent conductors of electricity.
 - Because of this property, metal wire is used to send electrical currents long distances to where it is needed to do electrical work such as running an electric hedge trimmer or a battery recharger.

COMPOUNDS

When molecules are formed by a covalent bond, the sharing of electrons can give the atom an unequally distributed charge. The more negatively charged area of one molecule is attracted to the more positively charged area of another molecule. This attraction holds individual molecules together as larger substances.

When large numbers of similar molecules bond together, a **compound** is formed. We are aware of about ten million compounds so far, many of them man-made. A compound is formed when numerous molecules of two or more elements **chemically combine** in a definite proportion. The ratio of one element to another in a compound is always the same for that compound.

Example: There is one atom of sodium for every atom of chlorine in a molecule of salt.

Example: Water is a common, naturally occurring compound. Each individual water molecule is made from two atoms of the element hydrogen (H) and one atom of the element oxygen (O). We write the name of the water molecule H₂O using the symbols that represent hydrogen (H) and oxygen (O). The ₂ tells us there are two hydrogen atoms in each molecule of water.

A compound has different properties from the elements that form it.

Example: Water is made of hydrogen and oxygen but it has very different properties from the elements that make it up. Oxygen and hydrogen are both flammable gases at room temperature, while water is a liquid.

Note: Water is an unusual substance for several reasons. It can be found in each of the three states, solid, liquid or gas, at temperatures that occur on earth. It is the most commonly found liquid and it often acts as a solvent, dissolving many other substances.

Chemical changes

The chemical properties of a substance are determined by the types of atoms that make up the substance, and by the bonds that hold the atoms together. When the bonds holding a compound together are broken, the compound undergoes a chemical change. Its basic chemical structure is changed. A new substance different from the original substance is formed.

When a chemical change occurs, the process releases energy.

Example: A simple electrical circuit gets its energy from a lead-acid battery. Grids of lead and lead dioxide are immersed in sulphuric acid solution. The sulphuric acid combines with the lead to cover the grids with the newly formed compound, lead sulfate.

This chemical change reduces the amount of sulphuric acid but, in the process, energy is released that causes negative and positive charges to accumulate on the different plates. These built up charges can be used to do electrical work when needed.

Chemical change can occur at different rates.

Example: When iron, a solid metal, is exposed to oxygen, the iron and oxygen slowly combine chemically. The resulting new substance, iron oxide, or rust, is a solid that is rusty red and much softer than iron.

Example: Oxygen gas combines slowly with iron but it can combine rapidly with other substances such as wood and gas in a rapid chemical process called combustion or burning. Burning gives off energy as heat and light.

Many chemical changes involve another substance called a *catalyst*. Catalysts speed up the rate

of a chemical reaction and help organize the molecules involved.

Example: In a catalytic converter of a car, catalysts speed up the rate at which the harmful molecules that result from the combustion of gasoline are broken down to less harmful molecules.

Chemical names of compounds

You will be working with complex substances that have long names. These materials must be labeled with a Material Safety Data Sheet. Sometimes the chemicals making up the compounds are written using a type of short hand.

The ratio of one element to another in a compound is always the same for that compound. Water is a common, naturally occurring compound. Each individual water molecule is made from two atoms of hydrogen and one atom of oxygen.

- ◆ The short way of representing a water molecule is H₂O.
 - The symbol H stands for hydrogen and the symbol O stands for oxygen.
 - The ₂ tells us there are two hydrogen atoms in each molecule of water.

When talking about a water molecule, we noted that the symbol for hydrogen is H and the symbol for oxygen is O. All elements have a shorthand form represented by one or two letters. Some common elements and their symbols are:

- C for carbon
- H for hydrogen
- Cl for chlorine
- O for oxygen
- N for nitrogen
- K for potassium
- P for phosphorous

Every part of a compound's chemical name tells you something about its chemical composition. Information, such as the types and numbers of atoms which make up a molecule of a compound, is given by its chemical name.

Example: The chemical short form for carbon dioxide is CO₂.

- The name CO₂ tells you that the compound consists of carbon (C) and oxygen (O) atoms.
- The number ₂ after the O tells us that there are two oxygen atoms in every molecule.
 - The prefix “di” in front of oxygen in the name carbon dioxide means two.
- Because there is not a subscript number written after the C, we assume there is one carbon atom.
- So every molecule of carbon dioxide consists of one atom of carbon and two atoms of oxygen.

Example: Ammonium nitrate is a substance used in some herbicides. The chemical formula for ammonium nitrate is NH_4NO_3 .

- There are a total of 9 atoms in one molecule of this substance: two nitrogen atoms, four hydrogen atoms and three oxygen atoms.
- The fact that one N is grouped with O_3 and the other N is grouped with H_4 provides additional information on the structure of the molecule.

MIXTURES

A **mixture** is a combination of two or more substances that are combined physically but which retain their individual chemical properties. Two or more substances can be mixed closely together without being chemically joined.

- ◆ In a mixture substances are held together by physical, not chemical, means.
 - A basin of detergent and water is a simple mixture. The detergent and the water are combined but they are not chemically joined.
- ◆ The elements in a mixture can sometimes be separated by physical means such as filtering or settling.
 - Paint is a complex mixture that consists of chemical compounds such as finely ground pigments, binders and solvents that are shaken together until the pigments are evenly distributed. If paint has been sitting for a period of time, it needs to be rapidly shaken to mix the settled pigments back into the solvent and binders.
- ◆ Although the substances that make up a mixture do not change chemically when mixed, a mixture can behave differently than its individual parts.
 - A mixture of ethylene glycol and water will freeze at a lower temperature than ordinary water. That is why it is used as antifreeze. However, the water and glycol still exist as separate entities and can be physically separated.

Kinds of mixtures

A mixture can have the same, uniform composition throughout, or its components can be randomly distributed.

- ◆ A non-uniform mixture is **heterogeneous**. *Heterogeneous mixtures* such as sand and gravel or sugar and flour are called **mechanical mixtures**.
 - If you sort out two pails filled with sand and gravel, you will find that there is a different amount of sand and a different amount of gravel in each pail.
- ◆ A uniform mixture is **homogeneous**. The substances that make it up are evenly distributed.
 - When salt is mixed with water, the tiny particles of salt are evenly disbursed throughout. However, unlike compounds, the amounts of salt and water are not in the same proportions in every mixture of saltwater. Within limits, differing proportions of salt can be mixed with the same amount of water.

Solutions, solvents and solutes

Homogeneous mixtures are more commonly called solutions. A **solution** is a uniform mixture in which the substances that it is composed of are intermixed as atoms or molecules or ions.

- ◆ One substance in a solution is called the dissolving agent or the **solvent**.
- ◆ The other substance is the **solute**.
- ◆ There is usually a lot more solvent than solute in a solution.

Many compounds that are liquid at room temperature, such as water and oil, are solvents.

Example: In a solution of sulphuric acid and water, molecules of water are evenly intermixed with molecules of sulphuric acid. The substances are evenly intermixed but they do not combine chemically with each other. (In a battery, the water and acid combine chemically with the lead and lead dioxide but they do not form chemical bonds with each other.)

*Solvents which react rapidly when exposed to air are called **volatile solvents**.* We usually notice a strong odour as volatile solvents evaporate into the air. Some solvents can be irritating to the lungs and can cause allergic reactions after a lot of exposure. That is why areas where volatile solvents are used should be well ventilated.

Example: In a substance like tree sealer, the solvent is a volatile liquid. A volatile liquid changes from a liquid to a gas rapidly when it is released at room temperatures. The solvent is used to carry the oils and pigments so they will flow smoothly from the paintbrush to the open area that is to be sealed. After paint has been applied, the solvent that carried the pigments changes to a gas as the paint dries, leaving the solid sealer behind to form a scab.

Example: The liquid solvent that carries the active ingredient in a pesticide is very volatile. Some of the chemicals in pesticide solvents can be harmful to breathe. That is why you wear a mask to protect your lungs when you apply these products.

Solutions can be composed of a gas solute dissolved in a liquid solvent like water.

Example: The acetylene gas used in welding is dissolved in liquid acetone so it will not break down into carbon and hydrogen gas, which can be explosive.

A gas can be dissolved in other gases.

Example: Air is a heterogeneous mixture of gases, including nitrogen, oxygen and carbon dioxide gases, dissolved or evenly mixed together with each other.

Concentration of Solutions

The amount of the solute and the solvent in a solution can vary within certain limits.

- ◆ An unsaturated solution with a low amount of solute compared to the amount of solvent is **dilute**.
- ◆ When more solute is added to a dilute solution, it will reach a point where no more solute can be dissolved in a solution. The solution is **saturated**.

Alloys

We usually think of solutions as being liquids, but solid solutions can also be formed.

- ◆ In a solid solution, both the solvent and the solute are solids at room temperature. They dissolve when both solvent and solute are heated and become liquid. When the solution cools back to a solid, the intermixed materials remain in solution.
- ◆ A **metal alloy** is formed when one metal element dissolves another metal or nonmetallic element. Usually the solvent metal makes up most of the alloy. Alloyed metals are used to manufacture many of the tools used by horticulturists.

Examples:

Steel, an alloy of iron and carbon (and other elements), is about 99% iron.

Bronze is an alloy of copper and tin. Copper, the solvent, is the dominant element in brass.

The different elements in an alloy are held close together but each retains some of its individual properties. The alloy steel has much more iron than other elements, so most of its characteristics resemble iron. An alloy also has physical properties that are unique to it. A steel alloy of iron and nickel will have a lower melting point than either iron or nickel alone.

Acids and Bases

Some of the substances you handle on the job are classified as acids or bases.

- ◆ A strong acid, such as the solution in a lead-acid battery, can burn your skin.
- ◆ A strong base such as sodium hydroxide, which is used as a solvent for oil and grease, is caustic and can also damage skin tissue.
- ◆ Pure water is considered neutral, that is, neither acidic nor basic.

CONCLUSION

The basic structure and organization of the atom is responsible for many of the characteristics of matter. Two facts about the atom are especially important in helping us understand why things act the way they do.

First is the fact that the number of protons and electrons in different types of atoms varies. The number of protons in an atom, called the atomic number, determines what element it forms.

The second is that electrons and protons have the property of being charged. An individual atom is neutral when it has the same number of positively charged protons and negatively charged electrons because their charges balance each other. But because an atom is more stable when its outer shell is full, it will gain, lose or share electrons in order to get a full outer shell. If an atom gains an extra electron, it has a charge of - 1. If an atom loses an electron, it has a charge of + 1.

Some elements donate or accept electrons to obtain filled outer shells, causing them to become charged. The charged particles are called ions. Ions will be attracted to other ions with the opposite charge, resulting in molecules held together by ionic bonds.

Other elements share electrons to fill their outer shells. The need to share electrons causes the atoms to bond together. These bonds are called covalent bonds.

Metals are solids that have only a few electrons in their outer shell. Metal atoms join together to form atomic crystals by sharing the easily dislodged, outer electrons. These shared electrons are free to flow along the surface of the metal. This is why metals are good conductors of electricity. You cannot see the underlying atomic structure of the objects around you. You see an object's colour, shape and texture, but not the atoms and molecules that make up the object. This is the same as the way the underlying structure of a tree is not visible. You see branches, leaves and the bark but not the structural proteins and carbohydrates that support the trunk.

Being familiar with basic atomic structure helps to explain why the different materials you use in the horticulturist trades have unique qualities that make them useful for different applications.

And now you know why the atom coming out of the movie was *positive* about losing its electron.

Answer the following questions about the structure of the atom. The answers are on the next page.

1. How many different types of atoms is an element made up of? _____
2. What two kinds of elements form the substance water? _____, and _____
3. The centre of an atom is called the _____ .
4. The nucleus has two types of particles, the _____ and the _____ .
5. The tiny, fast-moving particles that orbit around the nucleus are called _____.
6. The number of protons determines which _____ an atom forms.
7. In the nucleus, the particles called _____ have no charge and are electrically neutral.
8. Protons have a _____ charge; electrons have a _____ charge.
9. Like charges _____ ; unlike charges _____ .
10. It is either the absence of or an excess of _____ which determines the charge on an atom.
11. If an atom had six protons and eight electrons, it would have a negative charge of _____.
12. An atom with the same number of protons and electrons is electrically _____.
13. An atom is more stable with a filled outer _____ .
14. When an atom shares electrons, it forms a _____ bond.
15. The flow of _____ occurs because electrons can move easily through conductors made of metals such as silver or copper.

ANSWER PAGE

1. one
2. hydrogen, oxygen
3. nucleus
4. proton, neutron
5. electrons
6. element
7. neutrons
8. positive, negative
9. repel, attract
10. electrons
11. two
12. neutral
13. shell
14. molecular or covalent
15. electricity