EVALUATING
ACADEMIC READINESS
FOR APPRENTICESHIP TRAINING
Revised for
ACCESS TO APPRENTICESHIP

SCIENCE SKILLS
CHEMICAL PROPERTIES OF MATTER

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
CHEMICAL PROPERTIES OF MATTER

An academic skill required for the study of the Horticulture Trades

INTRODUCTION

Arborists and horticulturists work with many different kinds of materials. All of the materials in the natural world exist in one of the three possible physical states: a solid, liquid or gas. For example, a tree trunk is a solid made of wood. Water is a liquid. The carbon dioxide used in photosynthesis is a gas.

Materials are recognized by their characteristics or properties. You won't have to know the chemical composition of the materials you use, but you should know the effects of their chemical and physical properties. For example, you don't want to choose a metal that will chemically react with water and corrode if it is being used in a place that is exposed to moisture.

There are two main types of properties – chemical properties and physical properties. Chemical properties depend on the compositions and arrangement of the molecules that make up a substance. Because the chemical properties of a material result from its atomic characteristic, we can't directly observe them. However, the chemical properties of a substance determine all its other features – its physical characteristics and how it reacts in the environment.

Physical properties are the features of a substance that we can see or measure, such as its colour, physical state or electrical conductivity. Because the physical properties of a material depend on its chemical composition, they are closely linked. We use physical properties to assess the chemical make-up of a substance.

This skill manual looks at the chemical characteristics of substances, and how they influence its physical properties, including changes of state. The following topics are covered:

- Review of atomic structure
- Chemical properties
- Chemical change
- Physical states of matter
- Kinetic energy
- Changes of state
- Direction of changes of state

REVIEW OF ATOMIC THEORY

*An **atom** is the smallest building block of matter.*

- Atoms are composed of subatomic particles called ***protons, neutrons*** and ***electrons.***
- The number of protons in an atom determines what element that atom forms.

*An **element** is a substance made up of only one type of atom. An element cannot be broken down by a chemical reaction into other, more basic substances.*

- Oxygen is an element because pure oxygen can't be broken down into smaller particles.
- Other examples of elements include: hydrogen, carbon, iron, lead and silicon.
- Water is not an element because it can be broken down into atoms of the elements oxygen and hydrogen.

*A **molecule** is formed when individual atoms are joined together by a **covalent, ionic or metallic bond.***

- An oxygen molecule is formed when two oxygen atoms bond.
- A carbon monoxide is formed when one oxygen atom and one carbon atom bond.
- A molecule of water consists of one oxygen atom and two hydrogen atoms.
- A molecule of silica consists of two oxygen atoms and one silicon atom.

*The molecules of a **compound** consist of atoms of two or more different elements bonded together in an unchanging ratio.* A compound is a substance formed by chemical reaction. The molecular makeup of a substance remains unchanged unless there is a chemical change.

- Pure water is a compound. Every molecule of water formed by the bonding of two hydrogen atoms with one oxygen atom.
- Molecules of rust all contain both iron and oxygen.
- Silica molecules join together in a crystal structure to form glass. Silica is the main component of porcelain tiles and Portland cement.
- Polychloroethanediyl (PVC) consists of repeating molecules of polyvinyl chloride. A molecule of polyvinyl chloride consists of the following atoms: two carbon, three hydrogen and one chlorine.

CHEMICAL PROPERTIES OF MATTER

***The chemical properties of matter** are those that relate to its atomic and molecular structure and how it changes in composition or how it interacts with other matter.*

The chemical properties of any substance are controlled by the stability of the outer electron shells of its atoms and by the stability of the molecular bonds that form the substance. We examine the chemical properties of a substance by looking at how it reacts when it comes in contact with other substances

Some examples of chemical properties are:

- paper burns
- nitrogen does not burn
- iron rusts
- gold does not rust
- wood rots
- silver does not react with water
- sodium reacts with water

In each of these, the substance's chemical property is its tendency to:

- react
- tarnish
- corrode
- explode

CHEMICAL CHANGE

The chemical properties of a substance determine all of its characteristics, including its physical features. Most chemical properties of a material are described in terms of how it reacts with other substances to undergo chemical changes. For example, some materials, such as living cells, react chemically with carbon dioxide in the air. This reaction results in the production of carbohydrates (sugar) being produced in the leaf. Dead cells or wood react with oxygen when they burn, resulting in carbon dioxide being released back into the air, along with a small residue of ash.

*A **chemical change** takes place when the atoms making up a substance are rearranged to form a new substance with a different molecular structure and with completely new properties.* Chemical properties change when a substance undergoes a chemical change.

Rusting

A chemical change takes place when iron, a solid metal, changes to a crumbly, reddish brown material called iron oxide or rust.

- Rusting is a chemical change in which molecules of iron, a solid metal, slowly bond with molecules of oxygen to form iron oxide molecules (rust).
- Iron oxide (rust) results from the chemical reaction between the element iron and the element oxygen, which is found as a common gas in air and also as one of the elements, along with hydrogen, that makes up water.
- As a result of the chemical reaction, the molecule of a new substance, iron oxide, is formed.
- The iron oxide molecule is made of two atoms of iron joined with three atoms of oxygen.
- The individual components iron and oxygen are quite different from the substance that results when they combine to form a flaky, porous material called rusted iron.

What is important here is that ***a chemical reaction is a process which rearranges atoms and the bonds that hold them together to produce a new substance with characteristics unlike any of the individual elements which form it.***

Let's look at how the reaction occurs.

- Oxygen is a very reactive element and will combine with many other elements.
- When oxygen does combine with another element, the process is called oxidation and the resulting substance is called an oxide.
- When rusting occurs, the oxygen (O_2) in moist air comes in contact with iron (Fe). The oxygen in air slowly combines with the iron molecules.
- Four single atoms of iron (4Fe) combine with the three oxygen molecules ($3O_2$), resulting in two molecule of iron oxide. Iron oxide is written in its chemical format as $2Fe_2O_3$.
- The chemical formula for rusting of iron is:
  $4Fe + 3O_2 \rightarrow 2Fe_2O_3$

Corrosion and combustion

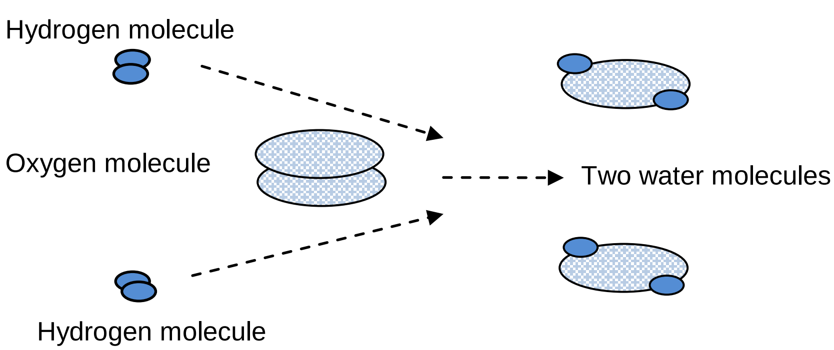
This rusting reaction is also called corrosion. Corrosion is a slow oxidation process. When oxygen combines rapidly with other elements, the reaction gives off heat and light and is called combustion.

- Burning in a wood fire is a rapid chemical change in which the carbon molecules in wood bond with oxygen in the air, forming two new molecules. These molecules, carbon dioxide and carbon monoxide, are both combinations of carbon and oxygen.

Creation of a water molecule

Let's now look more closely at another chemical reaction, the formation of water. As we said, water is very different from the oxygen and hydrogen gas molecules it is made from.

Example; Water is formed when two hydrogen molecules ($2H_2$) combine with one oxygen molecule (O_2) to form two molecules of H_2O. The chemical formula for the formation of water is: $2H_2 + O_2 \rightarrow 2\ H_2O$



A Chemical Change: Formation of water molecules.
Two hydrogen molecules and one oxygen molecule react to form two water molecules.

Catalysts

Many chemical changes involve other substances called ***catalysts***. They speed up the rate of a chemical reaction and help organize the molecules involved.

- A catalytic converter on a vehicle contains catalysts which increase the rate at which the polluting molecules that result from the combustion of gasoline are broken down to less harmful molecules.

All the complex substances used in your trades are made of molecules that have chemically combined in different arrangements.

Relation of physical change to chemical change

Chemical and physical properties are closely related because a substance's physical properties are a result of its chemical structure. When a chemical change takes place, a new substance is produced. When a physical change takes place, the substance might look and behave differently but it is still the same substance.

*In a **chemical change** a substance will change both physically and chemically.*

- When water undergoes a process called electrolysis, an electric current is passed through liquid water causing a chemical change to occur.
- The water molecules break apart and separate into independent molecules of hydrogen and oxygen gases.
- Gases still bubble up from the water but now they have chemically split into hydrogen and oxygen gas, not water vapour.

*A **physical change** can take place in a substance without changing its underlying chemical structure.*

- Water changes only its physical structure when it changes from a liquid to a gas.
  - We can see bubbles of water vapour evaporating into the air as water boils.
  - Each water vapour molecule is still made of two hydrogen atoms and one oxygen atom.
  - The water only changes physically, not chemically. The molecules of water vapour remain unchanged.

*A **mixture*** occurs when two or more substances are physically blended but do not combine chemically. There is no change in the molecular structure of any of the substances in a mixture. Each substance in the mixture keeps its original structure and properties when it is separated out of the mixture.

- Salt can dissolve in water but it does not form molecular bonds with water molecules.
- Water flowing up a tree trunk is a mixture of pure water (H_2O) and salts and minerals that are dissolved in it.
- Wet concrete is a mixture of water, Portland cement and aggregates (cleaned sand and/or gravels). It remains a mixture until it begins to cure at which point it undergoes a chemical change. Cured concrete is a compound. .
- Latex paint is a mixture of water, particles of a polymer, or plastic, (which eventually forms the hard paint coat when the paint dries) and. pigments to give the paint color.

- Steel is a solid mixture of iron, carbon and other metals. These substances are mixed in a liquid state. They don't combine chemically in either the liquid state or when they cool to the solid state. Each component remains physically distinct.

PHYSICAL STATES OF MATTER

All substances exist in one of three different ***physical states***. These states are called ***solid, liquid and gas***. A wire is a solid made from copper. Mercury, found in a control switch, is a liquid. The air used in pneumatic controls is a gas.

The state of a substance depends on its temperature (and pressure, if the substance is a gas). If the temperature changes enough, a substance can change to a different state. The physical state of a substance depends on the amount of heat or kinetic energy in the molecules making up the substance.

Heat determines the physical state of a substance. Since the range of temperatures on the earth is quite limited, most of the objects that we are familiar with exist in one state. Metals are solid while ethanol is a liquid and carbon dioxide is a gas.

Water is an important exception. It can exist in any of the three physical states, that is, as a solid, a liquid or a gas, depending on the temperature. Water is a liquid at temperatures from 0 to 100 degrees Celsius. Above 100 °C, it changes into a gas. Below 0 °C, it changes into a solid.

- Gasoline is another substance that can easily change state. It consists of long molecules of hydrogen and carbon with other additives. It is liquid at room temperature but it will change to a vapour or gas if the temperature is raised a small amount. Note that although we use the short form "gas" when speaking of gasoline, it is found as a liquid at room temperature.

Solids

Many of the objects you work with in the horticultural trade are solids. *A **solid*** has a definite shape and volume. Molecules in a solid vibrate in place. They are tightly packed in a regular crystal pattern or in irregular arrangements of long chain molecules. Solids can be held together by ionic, covalent or metallic bonds.

- Iron is an example of a regularly arranged solid. It becomes liquid only if a large amount of heat is added to cause it to melt. Once molten iron cools, it becomes solid again.

Liquids

A ***liquid*** has a definite size or volume but not a definite shape. The molecules in a liquid vibrate, move about, and slide past each other. They are close together with no regular arrangement. A liquid takes the shape of the container in which it is held and presses on the container in the same amount in all directions.

- Many liquids you work with are solutions that are based on water.

Gases

*A **gas** has no definite volume or shape.* The molecules in a gas vibrate and move freely at high speeds. They are well separated with no regular arrangement.

- Air, the most common gas found in a building, is actually a mixture of different gases such as oxygen gas and carbon dioxide gas.

Changes of state

The chemical composition of a substance determines what state it occurs in at a given temperature. But when a substance changes from one state to another, only the physical state changes, not the chemical properties.

- Liquid oxygen has the same molecular structure as oxygen gas; each molecule of it is formed by the bonding of two oxygen atoms. They look different but structurally they are the same.
- When water melts from its solid form (ice) into its liquid state, it changes its physical state but not its chemical makeup. Its molecules still all have the same structure: two hydrogen atoms combined with one oxygen atom.

When solid ice melts to liquid water, only the physical state changes. Ice, liquid water and water vapour have quite different appearances and behave differently, but each water molecule has the same chemical structure regardless of the physical state. See Figure 1.

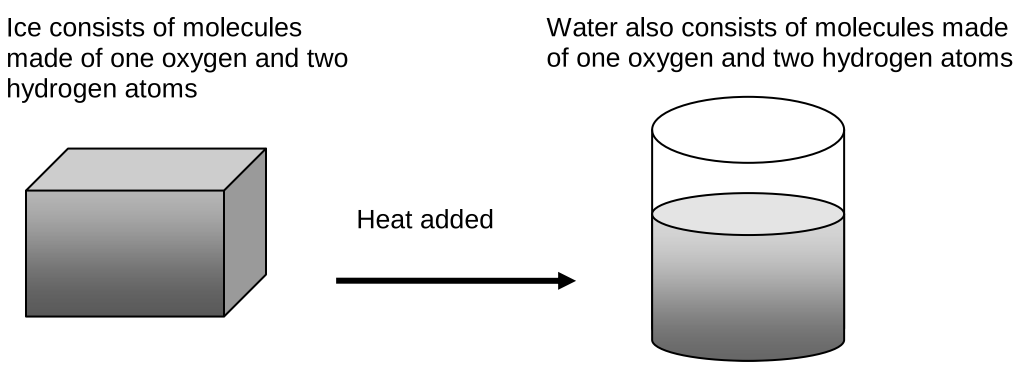


FIGURE 1: Chemical Make-Up Stays The Same When Physical State Changes

KINETIC ENERGY

The amount of heat in a substance determines its physical state. *At the molecular level, the amount of **heat** is similar to the amount of **motion** in the molecules making up a substance*.

At the molecular level, all molecules of any substance have a certain amount of heat. This causes them to be in constant motion. The motion can vary from vibration in place to rapid, random motion in space. The amount of motion depends on the amount of heat or kinetic energy present in the molecules.

***Kinetic energy** is another name for the molecular motion of an object.* Every substance has a different amount of kinetic energy for a given temperature. This energy depends on the chemical makeup of the substance.

Kinetic energy tends to move molecules apart. There are also natural forces of attraction between molecules that tend to hold them close together.

- Gas molecules have too much kinetic energy to be held together by these forces. They exist as independent molecules that move around rapidly.
- The molecules of solid and liquid substances have less kinetic energy or motion in their molecules. The amount of kinetic energy in solids and liquids is too weak to allow them to escape the force of attraction between their individual molecules. They are held together by these forces of attraction.

In other words, there are two different forces working within a substance and these forces are in opposition. The force of attraction causes molecules to stay close together; the force of motion, caused by the amount of heat a substance has, causes molecules to move apart. ***A substance's physical state depends on the relative strength of these two forces.***

If the molecules of a substance have a low amount of heat or kinetic energy, the forces that work to hold it together are strong enough to keep its molecules in a fixed position. It exists as a solid (See Figure 2).

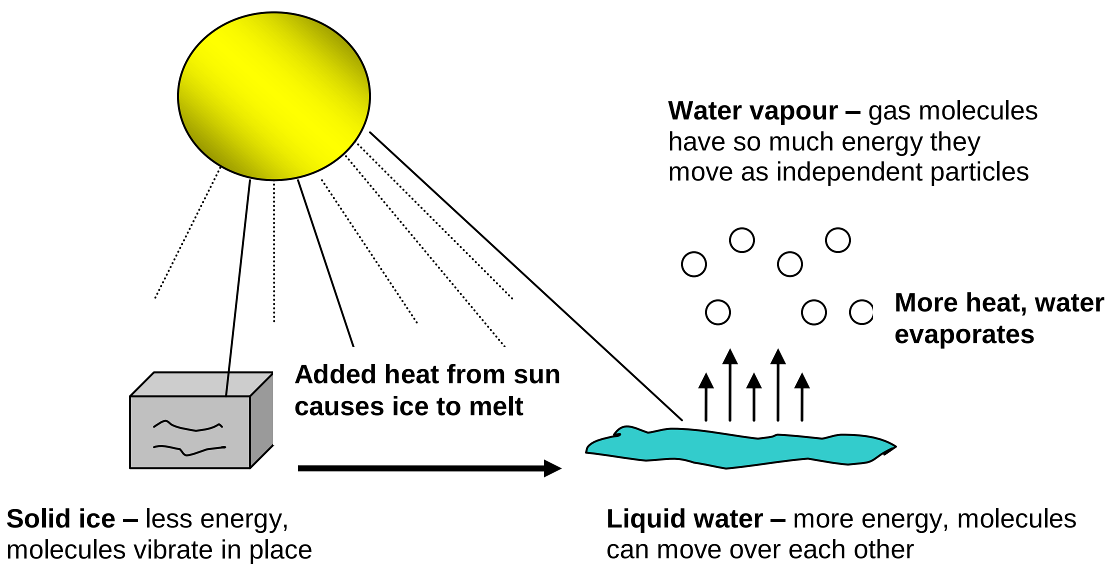


FIGURE 2: **The Effect of Heat on Water's Physical State**

If a substance gains kinetic energy, its molecules partially escape the bonding forces and begin to move more rapidly. The substance exists as a liquid. Liquid molecules have more energy, enabling them to flow over each other.

If the molecules of a substance have enough kinetic energy to overcome the forces that hold it together as a solid or liquid, it will exist as a gas. The molecules forming the gas exist as independent particles that move rapidly in random directions. Gas molecules expand to completely fill the area they are contained in.

Kinetic energy causes materials to expand when the temperature rises and contract when it falls.

- Metal expands when it is heated and contracts when it cools.
- If you leave a can containing a volatile solution such as acetone open in a room, the smell of acetone quickly fills the room. (A volatile solution is a one that will start to change to a gas at room temperature if it is free to escape.) The acetone molecules evaporate rapidly to become evenly mixed with the other air molecules in the room.
  - This is why you should have plenty of ventilation when you use materials such as rapidly drying glues.
  - The solvents used in the glues, which can be toxic, evaporate quickly into the air where you are working as the material dries.
  - When you have finished using these types of solvents, they should be tightly closed so they don't dry out in their containers and so they can't escape into the room.

Water is unusual in that it expands when it freezes and contracts when it melts. This is an important factor in the production of soil. When water in the ground freezes and thaws, it breaks up heavy clumps in the soil and improves its texture. When frozen soil expands, it can cause rocks to shift during the winter.

In Brief

- ♦ The molecules of a substance have a certain attraction to each other.
- ♦ All molecules also have a certain amount of kinetic or heat energy that causes them to tend to move apart.
- ♦ Since the amount of heat is measured as temperature, we say that the temperature of a substance determines its state as a solid, liquid or gas.

Pressure and molecular activity

The amount of pressure can also influence the motion of molecules. Pressure doesn't have much effect on the motion of solids, since they mostly vibrate in one place. The pressure exerted on the surface of a liquid, however, can influence how easily the liquid molecules can escape into the atmosphere.

If the air pressure above a *liquid* surface is increased, more pressure bears down on the liquid molecules. As a result of this pressure, they will need more energy or more heat before they can change to gas molecules. If the pressure is decreased, the liquid molecules change into a gas more quickly.

If the outside pressure exerted on a *gas* is increased, the gas is compressed. The gas molecules move with less kinetic energy. This increases the number of molecules changing to a liquid.

- Liquid petroleum gas is held as a liquid under pressure in a metal container, although it is normally a gas at room temperature.
- When liquid gasoline is compressed and then sprayed out as small droplets into the cylinder of an engine, the sudden decrease in pressure and the heat in the walls of the cylinder cause the gasoline molecules to rapidly change into a gas and then combust.

CHANGES OF STATE

The molecules which make up a substance, whether it is a solid, liquid or gas, have an average kinetic energy that depends on the temperature of the substance. Some individual molecules, however, possess a higher or lower amount of energy. For this reason, individual molecules, especially of substances like gasoline or water, can and do change state at any time.

Consider a half full, closed container of water. When an individual molecule of water gains enough energy, it overcomes the bonding forces that hold it as a liquid and it vaporizes into a gas molecule.

At the same time, any of the escaped vapour molecules floating above the liquid might lose energy so that they condense back into the liquid. If the temperature remains constant, there are usually the same number of molecules changing into a higher state as there are changing into a lower state. The substance remains in *equilibrium* until the temperature changes. See Figure 3.

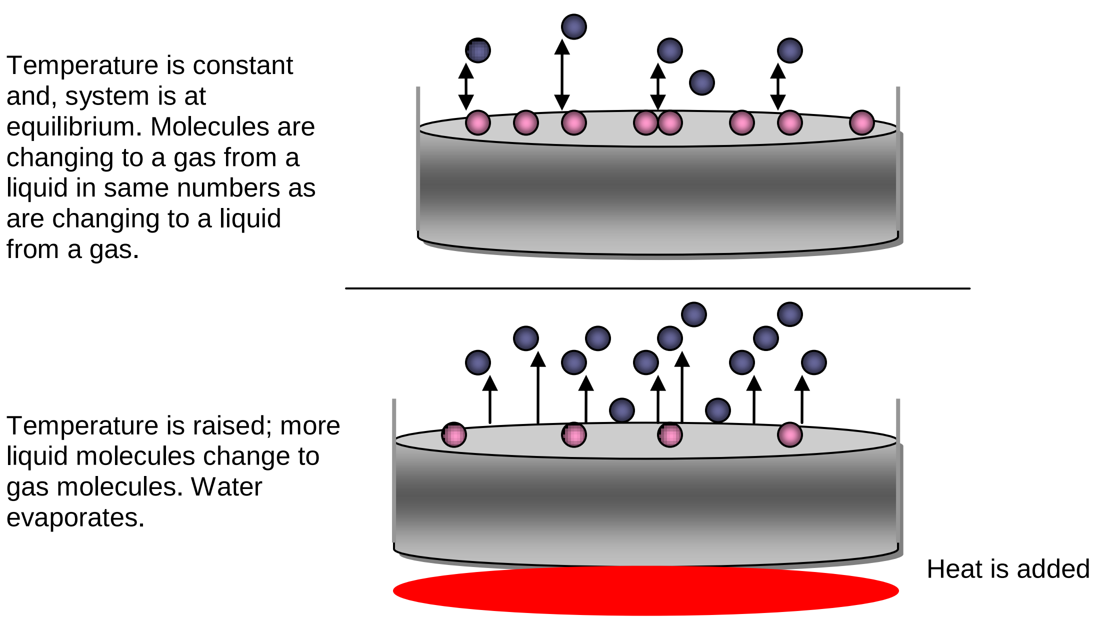


FIGURE 3: Effects Of Heat On A System At Equilibrium

When the temperature of a liquid is raised because heat is applied to it, the equilibrium is broken. Many liquid molecules now start changing to vapour molecules. At a certain temperature, all the liquid molecules change quickly into gas molecules. This is called the ***boiling or vapourization point***. Each different substance has its own vapourization point.

Gas molecules that are cooled rapidly change back into liquid molecules at a certain temperature called the ***condensation point***. For an individual substance, this is the same temperature as its boiling point.

When a solid changes to a liquid, we say it melts. The temperature at which a solid melts rapidly into a liquid is called the ***melting point.*** Similarly, when a liquid changes to a solid, we say it freezes. The temperature at which this occurs rapidly is called the ***freezing point***. Each substance has an individual freezing point that is the same temperature as its melting point.

Chemicals can be added to a substance so that the new mixture will have a different freezing point than the original substance. For example, water freezes at 0° C but if antifreeze is added to it, the freezing point of the new mixture becomes much lower. That is why adding antifreeze to the radiator of a vehicle in winter keeps the liquid coolants from freezing. Plants produce their own forms of antifreeze to prevent their cells from freezing during the winter.

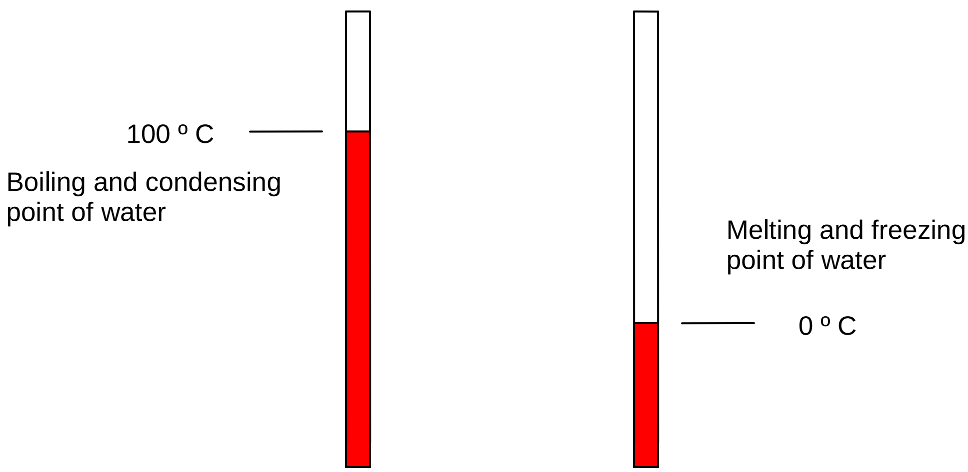


FIGURE 4: Water Boils And Condenses At 100 ºC. It Melts And Freezes At 0 ºC

In Brief:

- Solids change to liquids at the ***melting point.***
- Liquids change to solids at the ***freezing point***.
- Liquids change to gases at the ***boiling point***. This is also called the ***vapourization point***.
- Gases change to liquids at the ***condensation point***.
- In most substances, the melting point and the freezing point occur at the same temperature.
- In most substances, the boiling or vapourization point and the condensation point occur at the same temperature.

Molecules in solid substances can change directly into a gas without changing into a liquid first. For example, ice on a window can change directly into water vapour. When molecules change from a solid directly to a gas, the change is called ***sublimation***.

DIRECTION OF CHANGE OF STATE

Heat always flows "downhill" from hotter molecules to cooler molecules. In a closed area, equilibrium is established - all nearby objects have the same amount of heat. If no heat is added to a closed system, all objects within the system will eventually reach the same temperature. This helps explain why changes of state occur in a specific direction.

- If iron is heated until it melts and the source of heat is removed, the very hot liquid iron gives up heat to the atmosphere until it reaches the same temperature as its surroundings. As the iron cools, it reaches a point at which it rapidly solidifies into a solid object once again. The solid iron eventually reaches the same temperature as its environment.

When an object is hotter than its surroundings, it gives up heat until it reaches equilibrium with its surroundings. As it gives up heat, it might reach the temperature at which a downward change of state (from gas to liquid, or liquid to solid) occurs.

An object will only reach the temperature at which an upward change of state (from solid to liquid, or liquid to gas) occurs if heat from an outside source, such as the sun or a fire, is applied to the object.

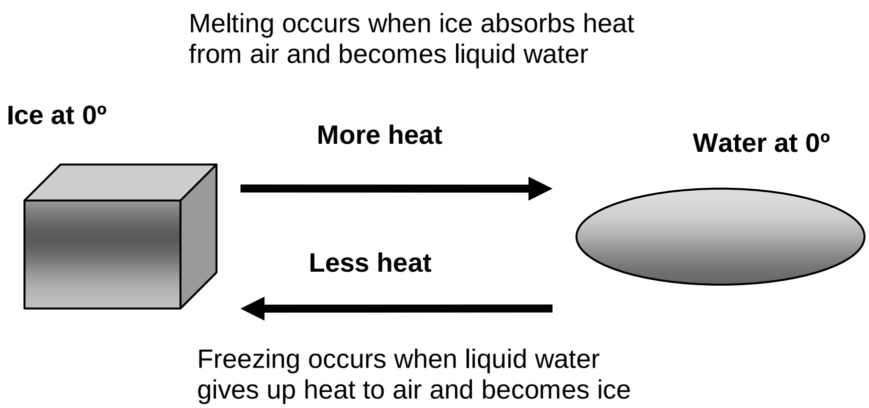


FIGURE 5: Influence Of Heat On Direction Of Changes Of State

Freezing and melting occur at the same temperature but the direction of the change of state depends on whether heat is given up or if it is absorbed.

- Ice melts into water at 0°C and water freezes into ice at the same temperature.
- If the surrounding air is colder than the water at 0°C, the water will give up heat to the colder air and freeze into ice.
- If the surrounding air is warmer than the water at 0°C, the water will absorb heat from the air and melt to a liquid.

This happens because heat always flows from hotter objects to cooler objects until an equilibrium is reached in which all nearby objects are at the same temperature.

The condensation point is the same as the boiling point, but the changes are in opposite directions. The direction of the change depends on whether heat is given up or absorbed.

- Water boils at 100 °C and water vapour condenses at the same temperature.
- If the surrounding air is colder than water vapour at 100 °C, the water vapour loses heat to the air and condenses into a liquid.
- If the surrounding air is warmer than liquid water at 100 °C, the water will absorb heat from the air and change to water vapour.

When water is heated to 100°C, the liquid molecules on the surface have enough energy to vaporize rapidly into water vapour molecules.

A liquid that is boiling does not increase in temperature if more heat is added.

- Instead the liquid molecules vaporize more quickly. They use the added heat to gain enough kinetic energy to overcome the attractive forces that keep them in liquid form and they move off as independent gas molecules.
- Only when all of the water has been vaporized does the temperature of any substances mixed in the water begin to rise. That is why wet wood is more difficult to burn than dry wood.

As water vapour molecules rise into the cooler atmosphere, they condense into clouds of liquid water droplets. When the droplets become too heavy, they fall to earth as rain.

- If warm air, which contains water vapour, comes in contact with a colder substance such as glass, the water vapour gives up heat to the glass. If the vapour gives up enough heat, the vapour condenses into liquid water on the glass.

- This is why we see condensation on windows on a cold morning. The air in the room is warmer than the glass. The water vapour in the air gives up heat to the glass and cools enough that it condenses or changes from a gas to a liquid.

The direction of the change of state and the resulting changes in temperature are shown as a heating or cooling curve in Figure 6.

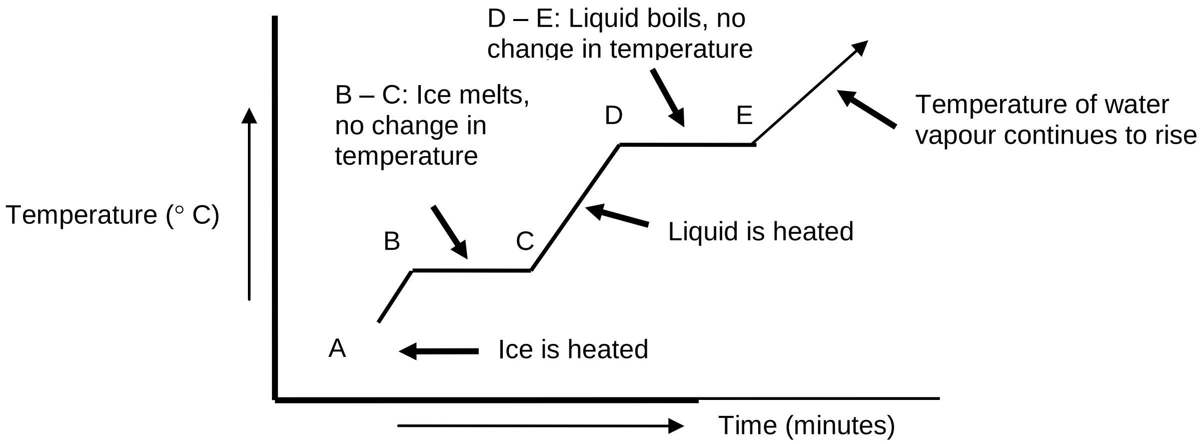


FIGURE 6: Graph Of Heating Curve Showing How Temperature Of Water Changes As Physical State Changes

The heating curve shows the changes in temperature of solid water (ice) as it gains heat, becomes a liquid at the melting point, continues to gain heat as a liquid and then becomes a gas at the boiling point.

This process is used to operate a greenhouse cooling system.

- A liquid coolant inside the coils is forced into a small space.
- The increase in pressure causes it to change to a gas.
- This change of state requires heat, which is taken from the inside of the greenhouse, causing it to become cooler.
- The gas then goes to an area at the back of the system where it changes back to a liquid.
- This change gives off heat, which is released into the outside air.
- The heat absorbed and released during changes of state is used to cool a greenhouse in summer.

CONCLUSION

The chemical properties of a substance depend on the types and arrangement of atoms that make up the substance. When a substance changes physically, it still maintains the same chemical properties. When a metal rod is cut in two, the new pieces weigh less than the original piece but the types and arrangement of atoms in the smaller pieces are the same as when they were in one, larger piece.

Only when a substance undergoes a chemical change does it then change into a new substance. When oxygen gas combines with iron, a chemical change takes place and a new substance, iron oxide or rust, is formed.

When a substance undergoes a physical change, it can behave in a different way. For example, molten iron flows while solid bar is rigid. The unique characteristics of a substance depend on both its chemical and its physical properties.

Molecules possess differing amounts of heat, which gives them kinetic energy - the ability to vibrate or move. Whether a substance exists as a solid, liquid or gas depends on the kinetic energy of its molecules. The amount of kinetic energy molecules have depends on the amount of heat present. The strength of this active force relative to the bonding force determines the state of a substance.

Any substance can exist as a solid, a liquid or a gas if its temperature is raised or lowered enough, but we are mostly concerned with the state of substances at the earth's temperature. Most objects you work with occur as solids, keeping a definite shape and volume. Liquids have a definite volume but take the shape of their container. Water is the most common liquid on earth. The atmosphere is filled with invisible gases that have no definite shape or volume.

Substances change state from solid to liquid and a liquid to a gas at specific temperatures. These temperatures are called the melting and boiling point of that substance. If the change is in the opposite direction, the changes are called the condensation and the freezing point. Heat must be added to change a solid to a liquid or a liquid to a gas. Heat is released if a gas condenses to a liquid or if a liquid freezes to a solid.

Answer the following questions. Answers are on the last page.

1. The three physical states that matter can exist in are_________________ , _______________ , and _________________.

2. The chemical properties of a substance depend on the type of ___________ it is made of and their arrangement.

3. When a substance undergoes a chemical change, such as iron changing to rust, it becomes a different _______________ .

4. Whether a substance exists as a solid, liquid or gas depends on its ____________________ .

5. When a solid changes directly into a gas, the process is called _________________ .

6. When gas molecules lose enough heat, they ______________ and change to the liquid state.

7. The melting point of a substance is at the same temperature as the _______________ point.

8. Water freezes at ______ C. This is also the temperature at which ice ________________ .

9. Water boils at _______ C. This is also the temperature at which water vapour ___________.

10. When ice melts to water, it _______________ heat from the atmosphere.

11. When water freezes to ice, it ______________ ______ heat to the air.

Answer page

1. solid
   liquid
   gas

2. atoms (or elements)

3. substance (or compound)

4. temperature

5. sublimation

6. condense

7. freezing

8. 0°, melts

9. 100°, condenses

10. absorbs

11. gives up