EVALUATING ACADEMIC READINESS FOR APPRENTICESHIP TRAINING

Revised for

ACCESS TO APPRENTICESHIP

SCIENCE SKILLS
PROPERTIES AND STATES OF MATTER

AN ACADEMIC SKILLS MANUAL
for
The Metal Work Trades

This trade group includes the following trades:
Heat & Frost Insulator, Iron Worker,
Precision Metal Fabricator, Sheet Metal Worker, and
Welder & Fitter

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:
PROPERTIES AND STATES OF MATTER

An academic skill required for the study of the Metal Work Trades

INTRODUCTION

In the metal work trades, you handle many different types of material that are classified in various ways. A metal worker can pick from different types of metals to find the one most suitable for the job, depending on whether strength is more important than weight, whether rust resistance is required or whether the texture of the material is important.

An object such as a steel rod can be described by its physical characteristics.

- A steel rod has volume and weight.
- It is heavy to carry, compared to other materials such as a 2x4, because it is denser.
- Its mass exerts a downward pressure when it is placed on the floor.
- It can be bent when it is heated but it is hard to break at room temperature.
- It can be cut, polished, drilled and welded together.

The materials found on the work site can occur as solids, liquids or gases. The physical state of a substance has an effect on how it is used. Metals alloys such as steel, tin and aluminum, are usually in a solid state. But before these ores are combined to form alloys, they are melted at high temperatures until they become liquid. As they cool, they solidify, forming as a new physical mixture with different characteristics from the original ores. The metal electrode in an arc welder melts to a liquid and then solidifies to a solid again to create a bead.

The types of gases present in the atmosphere when you weld metals together have an influence on the resulting product. An understanding of the three states of matter can help explain how metals are formed, how they acquire the properties most suitable for the requirements of a specific job and how different gases are used on the job.

Some materials must be handled carefully because they can pose a health risk. A metal polishing liquid might say, “Volatile solvent. Use only in well-ventilated area.” These types of health warning are better understood and followed if you know how these toxic materials become a part of the air that you breathe. This skills manual describes the properties of solids, liquids and gases, including changes of state. The following topics are included:

- ♦ Review of atomic structure
- ♦ Solids, liquids and gases
- ♦ Changes of state
- ♦ Direction of changes of state
- ♦ General properties of matter, including volume, weight and mass, pressure and density
- ♦ Properties of solids

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 formed by molecules made up of only one type of atom. An element cannot be broken down any further into other substances.*

- Only oxygen atoms are used in forming the molecules of the element oxygen.
- Other examples of elements include: hydrogen, carbon, iron, lead and tin.
- Atoms of an element usually join or bond together with other atoms of the same or different elements to form ***molecules or ions***
- Metals are elements such as iron and copper whose atoms bond together to form a regular crystal structure.
    - They are usually solids at the temperatures found on the earth's surface.
    - Metals can bond chemically with other elements to form compounds.
    - They can also mix physically with other metals to form alloys.

*A **molecule** is formed when atoms join together in what is called a **molecular 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.

*A **chemical change** takes place when the atoms making up a substance are rearranged to form a new substance with a completely different molecular structure and with completely new properties.* The molecular makeup of a substance remains unchanged unless there is a chemical reaction.

- Oxygen is a very reactive element that will combine with many other elements. When oxygen combines 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 combines with iron (Fe).
    - 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 $4Fe + 3O_2 \rightarrow 2Fe_2O_3$.
- 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 each a combination of carbon and oxygen - carbon dioxide and carbon monoxide.

*A **compound** is a substance formed when more than one kind of atom forms each molecule of that substance.* It is a substance formed by chemical change. The ratio of one element to another in a compound is always the same for that compound. There are about ten million compounds we know about so far.

- 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 four atoms of iron and 6 oxygen atoms.
- 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.

*A **physical change** can take place in substances without changing their underlying molecular structures.*
- 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 molten steel hardens into a solid, it changes its physical state but not its chemical makeup. It is still made of iron, carbon and small additions of metals such as chromium.
- Salt can be dissolved in water but it does not form molecular bond with water molecules.

*A **mixture*** occurs when two or more substances are blended but do not combine chemically. There is no change in the molecular structure of the substances in a mixture. Each substance in the mixture keeps its original structure and properties.
- Drinking water 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. However, the sand and gravel do not change chemically. They remain as a distinct physical mixture surrounded by the hardened, chemically changed, cement and water.
- 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 its solid appearance when it has dried.

SOLIDS, LIQUIDS AND GASES

Substances exist in one of three different physical states. These states are called ***solid, liquid and gas.*** At the molecular level all the molecules of any substance are moving in random fashion.

Solids

A **solid** has a definite shape and volume. Molecules in a solid vibrate but generally do not move from place to place. They are tightly packed, usually in a regular pattern. Most objects you work with are solids.
- Iron usually exists as a solid. It becomes liquid only if a large amount of heat is added to cause it to melt. Once molten steel 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, such as cleaning agents, are solutions with water or a mild acid used as the solvent.

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.

Heat and physical states of substances
Heat is the biggest controller of the physical state of substances. Since the range of temperatures on the earth is quite limited, most of the objects that we are familiar with exist in one state. Usually, metals are solid, water is a liquid and oxygen 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 is liquid at room temperature but it will change to a vapour or gas if the temperature is raised a small amount.
- Iron and other metals exist as solids. They become liquid only if a large amount of heat is added. After molten iron is mixed with carbon, it cools and becomes solid again.
- Gases such as oxygen and nitrogen can be liquefied by significant cooling.
- Propane is a substance that is mainly liquid at room temperature. But, propane in a torch will ignite and steadily change to a gas when the heat of a match starts it burning.

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*.

Kinetic energy
***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 types and the arrangement of the molecules that make up the substance.

- The amount of energy needed to melt the solid crystal structure of iron is much greater than the amount needed to melt the solid structure of ice, which has a different molecular arrangement.
- Solid metals don't change state at the normal temperature changes that occur on the earth but they react by expanding when the temperature rises and contracting when it falls.

Metal workers constantly have to deal with this expansion and contraction.

- Expansion joints are put into large structures like bridges to allow for the movement of the metal due to changes in the climate.
- Bimetallic strips used in thermostats are based on the different expansion and contraction rates of metals such as steel and copper.

Kinetic energy tends to moves molecules apart. That is why solids expand when the temperature rises. There are also natural forces of attraction between molecules that tend to hold them close together. Molecules must be near each other to feel the effects of these forces.

- Gas molecules have too much kinetic energy to be held together by these forces. They exist as independent particles 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. See Figure 1.

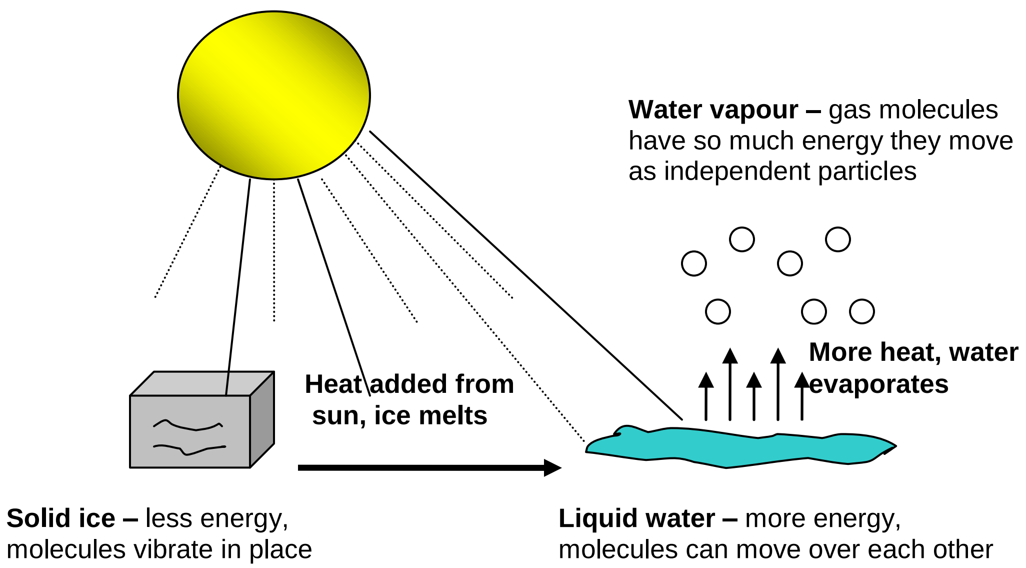

FIGURE 1: The Effect Of Heat On Water's Physical State

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 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.

If a substance has more kinetic energy, its molecules partially escape the bonding forces and the substance exists as a liquid. Liquid molecules move with more energy, allowing them to flow over each other.

If the molecules of a substance have enough kinetic energy to completely overcome the forces that hold it together as a substance, 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.

- If you leave a can containing a volatile substance such as gasoline open in a room, the smell of the liquid quickly fills the room.
  - The gasoline molecules change from a liquid to a gas to become evenly mixed with the other air molecules in the room.
- The solvents used in products such as rapidly drying glues can be toxic and they can evaporate quickly into the air where you are working. Make sure there is plenty of ventilation when you use these materials so that you don’t breath in volatile substances. These materials can dry out when their liquid components evaporate, so they should be tightly closed when they are stored.

CHANGES OF STATE

When a compound changes from one state to another, it may look and behave differently, but its chemical makeup remains the same. There is no change in the molecules that form the substance.

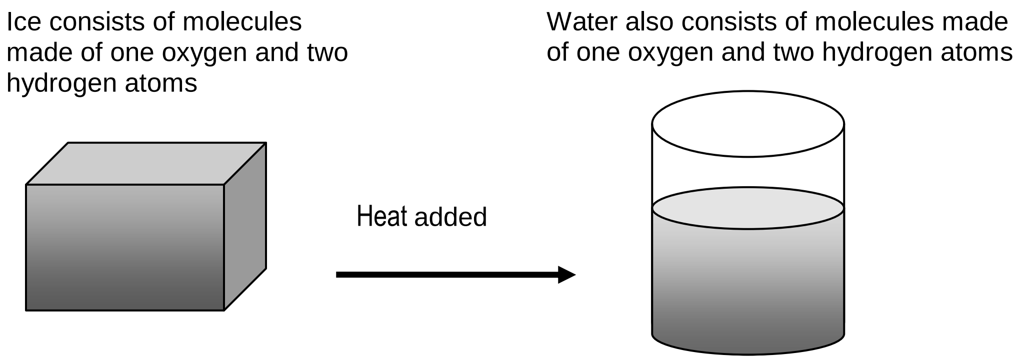

FIGURE 2: Chemical Make-Up Stays The Same When Physical State Changes

As in figure 2, when solid ice melts to liquid water, each molecule of water, which consists of two hydrogen atoms and one oxygen atom, remains the same. 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 – two atoms of hydrogen and one of oxygen – regardless of the physical 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 an enclosed 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.

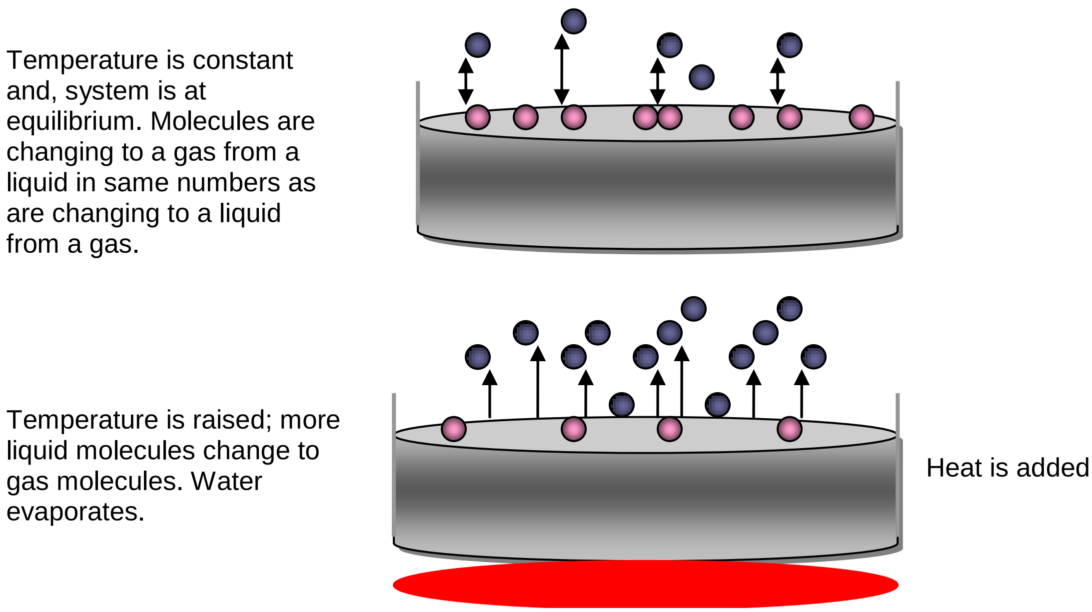

FIGURE 3: Effects Of Heat On A System At Equilibrium

If the system is not enclosed, the molecules that change to a gas escape into the air and move away from the surface of the container. This continues until all the liquid molecules have evaporated or changed into gas molecules.

***Evaporation** is the process where liquid molecules slowly change into gas molecules.* When a substance such as caulking is exposed to the air, the water molecules evaporate and the caulking hardens. When the temperature of a liquid is raised because outside heat is applied to it, liquid molecules start changing more rapidly 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 boiling point.

When gas molecules are cooled rapidly, they 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.

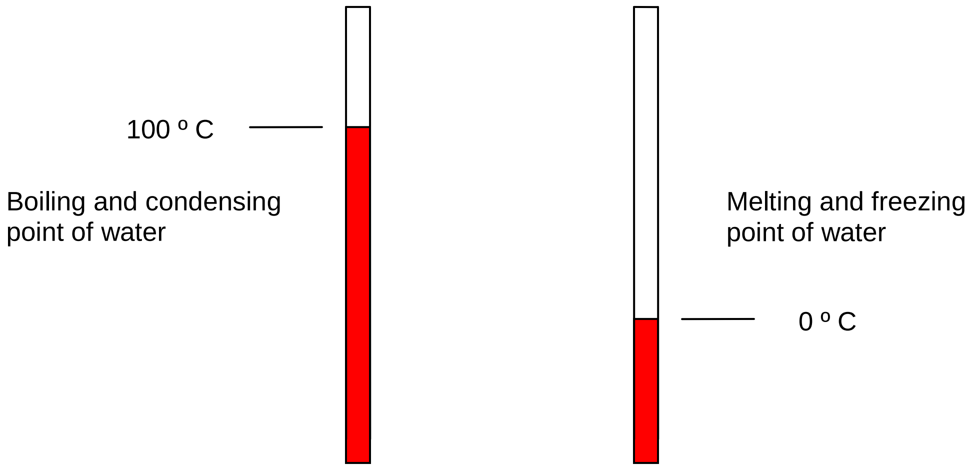

FIGURE 4: Water Boils And Condenses At 100 ºC. It Melts And Freezes At 0 ºC

The freezing point of a substance can change if different chemicals are added to it. For example, water freezes at 0º C but if antifreeze is added to it, its freezing point becomes much lower. Adding antifreeze to the radiator of a vehicle in winter keeps the liquid coolants from freezing.

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***.
- Gases change to liquids at the ***condensation point***.
- In most substances, the melting and the freezing point occur at the same temperature.
- In most substances, the boiling 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 pane of glass can change directly into water vapour. When molecules change from a solid directly to a gas, the change is called ***sublimation***.

Controlling moisture is important when working with metals that can rust. Iron alloys usually don't rust when water or oxygen are present. But when both are present, the metal will form oxides and corrode. This must be taken into consideration in the construction of bridges and ship hulls, structures that are always exposed to water.

DIRECTION OF CHANGE OF STATE

Heat always flows "downhill" from hotter molecules to cooler molecules. In an enclosed area, heat will move from warmer places or objects to cooler areas until they are all the same temperature. An equilibrium is established where all objects have the same amount of heat.

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

An object will change from a less active to a more active state, from a solid to a liquid or a liquid to a gas, if heat from an outside source, such as the sun or burning fuel, is applied to the object.

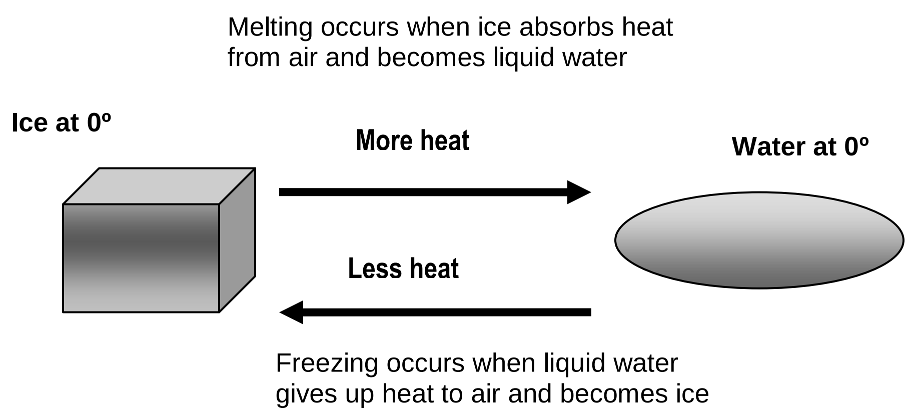

FIGURE 5: Influence Of Heat On Direction Of Changes Of State

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.

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 bonding forces that keep them in liquid form and they move off as independent gas molecules.

- When water is heated to 100°C, the liquid molecules on the surface have enough energy to vaporize rapidly into water vapour 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, the vapour cools and condenses into clouds of liquid water droplets. When the droplets become too heavy, they fall to earth as rain.

- If warm air in a room comes in contact with a colder substance such as a sheet of metal siding, the water vapour in the air gives up heat to the sheet. If the vapour gives up enough heat, the vapour condenses into liquid water on the metal.
- This can cause condensation to form and run down the inside of the siding. Insulation and vapour barrier are applied between the inside of the room and the siding to keep the warm air inside and to prevent condensation from forming.

GENERAL PROPERTIES OF MATTER

Properties such as volume, weight, mass, center of gravity, inertia, pressure and density are interconnected. They depend on the types of molecules that make up an object and whether an object is a solid, liquid or gas. For example, an object made of heavy, closely packed atoms such as iron will weigh more and exert more pressure than a similar size object made mostly of carbon atoms. We will look at some of these properties.

Volume

Volume *is the amount of space an object occupies.*

A solid has ***definite shape and volume***. The bonding forces that occur between its molecules. hold them in a fixed position. In other words, the space a solid occupies remains relatively constant, as does its external boundaries.

- The volume of a rectangular solid can be calculated by multiplying its length times its width times its height. The volume of an irregular solid can be calculated by measuring the volume of water it displaces.

*A liquid has a **definite volume but no definite shape***. The space it occupies (its volume) stays the same no matter what kind of container it is held in but it will flow to take the shape of the container.

- The volume of a liquid is found by pouring it into a graduated measuring cup. We read the amount of volume occupied by the liquid from the measurements on the side.

*Gases have **no definite volume or shape**.* Gas molecules usually exist as independent particles. Each particle has its own molecular volume. If a gas is confined in an enclosed area, the gas molecules will expand to completely fill the area they are contained in.

- The volume of a gas held in a container depends on the size of the container.
- The volume of a gas in a flexible container is not constant but varies with the temperature and the outside pressure exerted on the container.
  - If a flexible container holding a gas has outside pressure exerted on it, the volume of the gas (and the container) will get smaller as the pressure increases.
  - If the temperature of the gas rises, the gas molecules become more active, increasing the pressure on the container and expanding its walls, thereby increasing the volume of both the gas and the container.

Weight and mass
In scientific terms, weight and mass are different properties.

*The **weight** of an object is a measure of the force of the earth's gravity pulling on its mass.* The basic unit of weight in the metric system is the ***newton (n)***, while in the imperial system it is the ***pound (lb)***. Since the pull of gravity (weight) is a universal force, the units of weight, the pound and Newton, are used as the standard unit for all types of mechanical forces.

- The weight of an object can be found using a spring or digital scale.
  - A solid can be placed directly on the scale and measured.
  - A liquid or a gas must be placed in a container of a known weight before they are measured. The weight of the container is then subtracted from the total weight to get the weight of the liquid or gas.

Mass** is a measure of the amount of matter in an object.* In the metric system, the basic units of mass are the ***gram and the ***kilogram***. In the Imperial system the basic units of mass are the **ounce** and the **pound.**

- Mass is measured with a balance scale against a standard mass.
- The mass of an object remains constant while its weight can vary, depending on how close the object is to the surface of the earth.
  - The closer to the earth an object is, the stronger the pull of gravity and the greater the weight.
  - In everyday use, we tend to refer to weight and mass as being the same thing.

- The term kilogram tends to be used for both mass and weight in the metric system, just as the term pound is used for both mass and weight in the imperial system.

Inertia

Inertia *is the resistance of any physical object to a change in its state of motion or rest.*

- This means that an unmoving object will not move unless a force acts on it; and
- an object in motion will not change its speed or direction of motion unless a force acts on it.

The amount of matter or the mass of an object gives it its ***inertia***.

- The more mass an object has, the more inertia it has.
  - A bundle of metal rods has more resistance to being moved than a carton of light bulbs because it has more mass and thus it has more inertia.
  - A train is harder to stop than a bicycle.

Center of Gravity

The weight of an object is considered to be concentrated in a central point called the ***center of gravity***. The stability of an object depends on how wide a base it rests on and how low its center of gravity is.

- A slab of metal that is lying flat is more stable than one that is standing on its end because its weight distributed over a wider area and its center of gravity is lower.
- A newly constructed metal wall frame is more stable when it is still lying on the floor. Once it is raised into position, its center of gravity is high compared to the narrow area of the plate that forms its base. It must be secured by a brace until it is fastened into place.
- When you are up on a ladder, you can't reach over too far. Once the ladder starts to lean, its center of gravity moves away from the support of the wall and then the force of gravity causes it to fall to the ground.

Pressure

A solid exerts a force in a downward direction over the area it is resting on because of its weight (the pull of the earth's gravity on the object's mass). This force is called ***pressure***.

- The pressure exerted on parts of a building such as the weight of the walls on the foundation or the snow load on the roof must be considered when calculating how strong those parts should be.
- Many building regulations are concerned with making sure structures are strong enough to withstand the pressures exerted on them.

Pressure is calculated by finding its weight per unit area or by dividing its weight by the area it sits on. The formula for pressure is:

Pressure = force divided by area

or

$P = F/a$

The common unit of pressure in the metric system is the ***kilopascal*** (***kPa***). In the imperial system, the unit of pressure is ***pounds per square inch (psi)***.

Liquids exert a downward force or pressure because of their weight. Liquids also exert pressure in a sideways direction because their molecules move and flow over each other in all directions. A liquid completely enclosed, such as in a pipe, will exert pressure evenly in all directions.

Gases confined in a container also exert pressure evenly in all directions. Gas molecules are continually in motion, bouncing off any surface they collide with and then continuing in a new direction. These collisions create a pressure known as gas pressure.

The pressure exerted by a gas depends on its volume and its temperature.

- Gas can be contained in a cylinder under pressure and used to power tools such as air guns, paint sprayers, sandblasters and drills. These tools are called pneumatic tools or air tools. They are driven by compressed air supplied by a gas compressor.

Density

Density *is defined as the mass or weight per unit volume*. Density is the quality of lightness or heaviness of an object. When we pick up an object, we have a feel for whether it is light or heavy. But sometimes we need a more precise definition of heaviness and lightness. In that case, we use the term density.

- During a work day, you might struggle to lift a heavy steel beam but you can carry several bags of insulation without any problem. The insulation is easy to carry because it is light, while the joists are heavy.
- When there are two cartons the same size, one containing nails and the other containing cleaning cloths, the carton containing the cloths is less dense. Although the volumes of the two cartons are the same, the weights of the objects inside are different, resulting in different densities.
- A cubic centimeter of steel is three times as heavy as a cubic centimeter of aluminum. Steel is denser than aluminum. Wood is less dense than either of these metals and a cubic centimeter of it would weigh less than either the steel or aluminum.

The density of a solid is found by dividing its weight or mass by its volume. The formula for density is:

$$D = w/V$$

or

$$D = m/V$$

Example: You have to hoist a load that has a mass of 150 kilograms and a volume of .5 m^3. What is its density?

$$D = m/V$$
$$= 150 \text{ kg}/.5 \text{ m}^3$$
$$= 300 \text{ kg/m}^3$$

It is important to have a rough idea of the density of an object before deciding how to lift it. A package of Styrofoam insulation is relatively light and can be carried by one person but a bundle of steel rods needs to be lifted with a hoist or crane because it is too dense to be lifted safely.

Specific gravity
Sometimes it is useful to compare the density of one substance to another. The density of water has been chosen as the standard to compare the densities of all solids and liquids. *The ratio of the density of a solid or liquid to the density of water is called its* ***specific gravity****.*

$$\text{Specific gravity} = \frac{\text{density of substance}}{\text{density of water}}$$

The density of water in the metric system is 1 gram per cubic centimeter. The density of the other substance must also be in the same units as water in order to make the comparison.

- Lead acid batteries produce electrical energy by chemical processes that charge and discharge the battery. The electrolyte inside the battery is made of a solution of sulphuric acid and water. Sulphuric acid is heavier than water, so a mixture of 64% water and 36% acid will be denser than water alone. The liquid in the battery will have a specific gravity of 1.27 at 27°C when the battery is fully charged. At this point, all the electrical energy is in the form of potential energy.
- As the battery discharges, producing usable electrical energy, the sulphuric acid is transformed in the process. In the discharged state, there is about 83% water and 17% sulphuric acid. The specific gravity of the battery's liquid will now be lower than that of a fully charged battery.
- You can tell how much charge is left on a battery by reading the specific gravity. Most lead acid batteries have built-in hydrometers that read the specific gravity, comparing it to that of a fully charged battery, and telling you the state of charge.

GENERAL PROPERTIES OF SOLIDS

Hardness and Toughness
Solids possess the property of ***hardness****, which means resistance to penetration.* Steel is harder than wood. It is easier to saw through a piece of wood than a steel rod.

Toughness *is the ability to withstand heavy impact forces without fracturing.* Aluminum will bend and break more easily than steel.
Durability *relates to the combined properties of hardness and toughness*. Steel is more durable than tin.

Cohesion and Adhesion
Cohesion *is the term used to describe the way a solid remains as an individual object with definite boundaries.*

Tensile strength is related to cohesion. It *is the ability to resist being pulled apart.* If a steel wire and a copper wire of the same diameter are pulled with the same force, the copper wire will break first. The steel wire has a greater tensile strength.

Adhesion *is the ability of one solid to stick to another, the way glue sticks to the surface of a frame.* Paint will stick to a surface and it also has fairly low cohesion so it can flow into small cracks.

Ductility and Malleability

Ductility *means that metal can be pulled through two heavy rollers so its diameter decreases but its length increases.*

Malleability *means that metals can be hammered or rolled so that shape and thickness are changed considerably.*

- Because steel has these properties, it can be formed into the shape and strength needed for a specific job.

Elasticity and Stiffness

A solid also has a certain amount of ***elasticity***, *the ability of an object to resume its original shape after it has been distorted by a force.* When a solid's elastic limit is exceeded, the solid breaks or is permanently distorted. *The opposite of elastic is* ***brittle.***

- The metal body of a car can be hammered back into place when it is dented.
- A thin sheet of metal piece can be bent and held in place but it can go back to being flat if it is released.
- A piece of wallboard is brittle and if it is bent, it will usually break.

Stiffness *is a measure of how much force is required to bend a certain material.* A stiff material requires a lot of applied force before it will bend.

- Good structural materials like wood and steel are both stiff and elastic.
- Steel changes in its stiffness depending on its shape and thickness.
- A thin sheet will bend easily while a steel rod is stiff.

CONCLUSION

*Substances have both chemical and physical properties***.** Chemical properties depend on the types of atoms and their arrangement in a substance. The physical properties of a substance affect its behaviour.

A substance can exist as either 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 as they occur at the earth's temperature.

Many objects around us are solids, keeping a definite shape and volume. Liquids have a definite volume but take the shape of their container. The atmosphere is filled with invisible gases that have no definite shape or volume. Gas molecules exist as independent, fast-moving particles.

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 in what state a substance exists.

We are familiar with the rigid nature of solid objects. They maintain their shape and volume unless they are broken apart into smaller solids. Because solids have weight, they exert pressure in a downward direction.

A liquid flows but its volume stays the same when it is poured into another container. The flowing movement of liquid molecules exerts pressure in all directions, not just in a downward direction.

Gases are free-moving, independent particles that travel at high speeds in all directions. Because of their rapid motion, gases occupy all of the area in which they are contained. If different types of gases are released into a room, the molecules will move around randomly until they are mixed together evenly.

When a substance changes physically, it still maintains the same chemical properties. When a metal rod is cut in two, the new pieces are 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.

However, 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.

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

1. The three physical states that matter can exist in are__________________ , ________________and __________________.
2. When a substance changes from one state to another, such as when water freezes to ice, its physical state changes but there is no change in its ___________________ makeup.
3. Whether a substance like water exists as a solid or a liquid or a gas depends on its _____________________ .
4. Water freezes at ______ º C. This is also the temperature at which ice _________________
5. Water boils or evaporates at _______ º C. This is also the temperature at which water vapour _________________.
6. When ice melts to water, it ________________ heat from the atmosphere.
7. When water freezes to ice, it _______________ ______ heat to the air.
8. Solids have a definite shape and ________________.
9. Liquids have a definite volume but take the ________________ of their container.
10. Gases have no definite __________________ and no definite ________________
11. Volume is the amount of _______________ an object occupies.
12. Weight is a measure of the force of __________________ on an object.
13. Objects have the property of density, which is defined as weight per unit ______________.
14. Pressure is the force per unit __________________ .
15. Solids exert pressure in a ___________________ direction.
16. A material such as thin metal that will bend and then return to its original shape has high _________________ .

ANSWER PAGE

1. solid, liquid, gas
2. chemical
3. temperature
4. 0 , melts
5. 100 , condenses
6. absorbs
7. gives up
8. volume
9. shape
10. shape, volume
11. space
12. gravity
13. volume
14. area
15. downward
16. elasticity