Skillsheet Name _____

Matter and Energy

What is matter? **Matter** is simply everything around us; everything that has **mass** and takes up space (has a **volume**). In other words, matter has **density**. Chemistry is the study of matter and its changes. Matter comes in an extremely large variety of forms, so it is helpful to classify matter into categories. The first classification is identifying matter.

You try

Identify the following as matter or not matter.

Carbon dioxide gas	Water
Potential energy	A human thought or idea
Time	A tree
A human brain	Motion

Mass is an important property of matter. Mass is the quantity of matter in an object. **Weight** is the effect of gravity on that mass. An object has the same mass on Earth as in outer space, however because the amount of gravity is different, things weigh less in outer space. Mass is commonly measured on a _____ while weight is measured with a _____.

Classifying Matter

Matter can be classified as a **pure substance** or a **mixture**. In a pure substance all of the particles are exactly the same; the material has a uniform and definite composition. A pure substance may be further classified as a **compound** (made of atoms of more than one type of element chemically combined) or an **element** (all the same type of atom). **Mixtures**, a combination of matter with a variable composition, may be classified as **heterogeneous** (different properties in different in different parts) or **homogeneous** (identical properties in all parts).

You try

Draw a flowchart showing the categories of matter using the words in bold.

Identify the following types of matter as a **Pure Substance** or a **Mixture**

Milk	Sugar
Sodium Bicarbonate	Oxygen
Water from the bay	Distilled water
Steel	Iron
Air	Orange Juice

Identify the following pure substances as **Elements** or **Compounds**

Gold	Hydrochloric Acid
Sulfur Dioxide	Sulfur
Sucrose	Hydrogen
Sodium	Sodium Chloride

Identify the following mixtures as **Heterogeneous** or **Homogeneous**

A salad	Tomato soup
A saline solution for contacts	Soil
A living cell	Potting Soil
An alloy of gold and silver	mayonnaise

Properties of Matter

Matter can best be described by its physical and chemical properties. **Physical properties** can be observed without changing the identity of the matter. For instance, if I observe that water is in the liquid form (state of matter is an important physical property), it remains water while I observe. **Chemical properties** are those observed while a substance undergoes a chemical reaction, while the identity of matter changes. If I observe water is formed by the reaction of an acid with a base, I have observed the formation of a new material (water) from different starting materials (the acid and base).

Physical properties can be further described as intensive properties or extensive properties. **Intensive properties** result from the way matter is structured; it does not depend on how much matter is present. The intensive properties of gold, like density, remain the same in a few milligrams or a few tons. **Extensive properties** depend on the amount of matter present. Properties such as mass and shape are extensive properties. Intensive properties are far more valuable to the chemist in describing matter because the do not change from sample to sample.

You Try

Describe 3 physical properties that would be useful in identifying an unknown sample of matter as water in a laboratory setting. Describe one chemical property that would be useful in identifying an unknown sample as water.

Physical Properties

1.

2.

3.

Chemical Property
1.

Consider an iron nail. List three physical properties that identify the matter as a nail. List one chemical property.
Physical Properties
1.

2.

3.

Chemical Property
1.

How do these properties differ from an aluminum nail?

States of Matter

An important property of matter is the state of matter. The three most common states of matter on Earth are **solid**, **liquid** and **gas**. The state of matter a material has is determined by the energy of the individual particles that make up the matter. As water goes from solid ice to liquid water (it melts), the molecules of water are increasing in energy. As liquid water turns to gaseous steam (it boils), the molecules of water are increasing in energy. Two additional higher energy states exist, plasma found in stars like our sun or in fluorescent lights, and neutron stars, which we know very little about because it has not been created on Earth. An additional low energy state called a Born Einstein Condensate is found near absolute zero.

The states of matter can be described by their observed properties (macroscopic observations) and the arrangement and movement of the particles (micromodels):

You Try

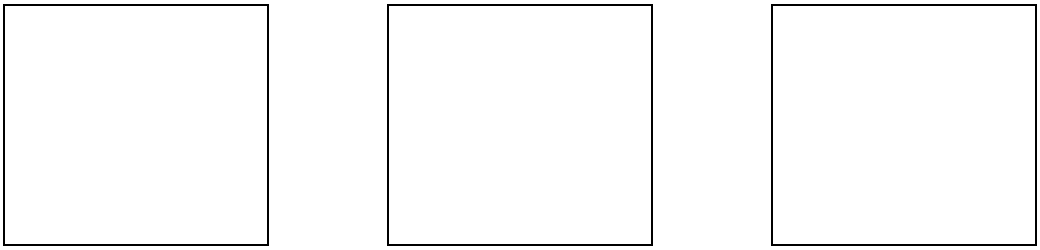
Complete the following by circling the correct choice in parenthesis.

A solid is rigid. It has a (definite, indefinite) shape and a (definite, indefinite) volume. This can be explained because the particles of a solid are arranged (close together, far apart) and are moving (slowly, rapidly).

A liquid takes the shape of its container. It has a (definite, indefinite) shape and a (definite, indefinite) volume. This is because the particles of a liquid are moving (faster, slower) than the particles of solid, and (faster, slower) than the particles of a gas. The particles in a liquid are spaced close together like a solid but with a more (ordered, disordered) arrangement.

A gas has an extremely low density and can be easily compressed. It has a (definite, indefinite) shape and a (definite, indefinite) volume. This can be explained because the particles of the gas are arranged (close together, far apart) and are moving (slowly, rapidly).

Sketch a micromodel of each state of matter showing the relative spacing and motion of the particles



Solid Liquid Gas

Changes in State

We use specific vocabulary terms to describe the changes between one state and another. **Melting** refers to the change from solid to liquid. **Freezing** refers to the change from liquid to solid. Any type of matter has the same **melting point** and **freezing point**. For instance, ice melts at 0°C and water freezes at 0°C. While a substance is changing state the temperature remains constant. A liquid turns to a gas at its **boiling point**, a gas changes to the liquid by **condensation**. These points such as melting and boiling points are important intensive properties of matter, and can be useful for identifying matter.

A more unusual situation is sublimation. **Sublimation** is the change directly from solid to gas. Have you ever noticed a pile of snow decrease in size disappear without melting, or ice cubes left in the freezer shrink in size over time? In both cases the water is subliming, the molecules are going directly from a solid to a gas. Solid carbon dioxide also sublimes; it is also called dry ice because we never see the liquid form. The reverse process, **deposition**, is when a gas directly forms a solid. Deposition is important in the formation of rain in cold clouds. The water goes directly from gas to solid which falls from the cloud, the solid then melts as the ice falls in the atmosphere forming cold rain.

Classifying Energy

Everything in the universe can be classified as **matter** or **energy**, we have already discussed matter. Energy is the capacity to do **work**. However when a scientist refers to work, we are using a common word in a very specific way. To a scientist work means a **force** applied over a **distance**. In simple terms work causes matter to move. Therefore, any mass (matter) that is moving possesses energy. We call this energy of motion **kinetic energy**. In Chemistry we often talk about two different levels of kinetic energy. Imagine

an ice cube thrown across the room. The entire ice cube is moving it has kinetic energy. However, consider the same ice cube sitting on the table. On the macroscopic scale it is not moving; on the macroscopic scale it does not possess kinetic energy. But the molecules that make up the ice are vibrating in the solid. The molecules themselves have kinetic energy. As the ice warms up and melts to a liquid, the molecules are gaining kinetic energy. The kinetic energy of the molecules is directly related to the temperature of the molecules. As a matter of fact the definition of **temperature** is based on the kinetic energy of the molecules.

Another broad category of energy is **potential energy**. Potential energy is energy an object possesses because of its position. It is sometimes called stored energy because we do not observe it unless it is converted into another form of energy. A ball sitting at the top of a ramp possesses potential energy due to gravity. If the ball rolls down the ramp the potential energy is converted into kinetic energy. Two atoms that are near each other in a chemical compound have a **chemical potential energy** by virtue of their position. While kinetic and potential energy are the broadest classifications of energy, we often speak of other types of energy in chemistry. The kinetic energy associated with the movement of charged particles such as electrons is called **electrical energy**. The kinetic energy associated with the change in the motion of atoms and molecules is called **heat energy**. Energy that moves in the wave form at the speed of light is **light energy**.

You Try

What is the formula for kinetic energy?

A ball with the mass of 1.5 kg is moving with a velocity of 32 m/sec. How much kinetic energy does it possess?

A hydrogen atom with the mass of 1.67×10^{-27} kg is moving at 650 m/sec. How much kinetic energy does it possess?

Conservation of Energy

The law of **conservation of energy** tells use that in any chemical or physical change, energy is neither created nor destroyed. Energy is converted from one form to another. The conversion of potential energy into kinetic energy is a common example of conservation of energy (remember the ball on the ramp). Conservation of energy allows use to keep track of many energy changes in a system, often in the form of heat. If a process releases heat to the surroundings, the process is **exothermic**. If a process absorbs heat from the surroundings, the process is **endothermic**. We may observe energy

absorbed or released in other forms, such as sound or light, but chemists prefer to focus on the heat energy because it is easily measured.

You Try

Identify the following changes as exothermic or endothermic

- Gasoline burning
- Water boiling
- Water freezing
- Sodium metal reacts with water
- Copper hydroxide decomposes when heated
- Mixing rock salt and ice when making ice cream
- Hydrogen exploding

What is the famous equation from Einstein that tells use how matter and energy are related?

Describe a situation where the following energy changes would be observed:

Gravitational Potential Energy converted to Kinetic Energy

Chemical Potential Energy converted to Kinetic Energy

Chemical Potential Energy Converted to Heat Energy

Identify the following micromodels as representing a compound, element, or mixture