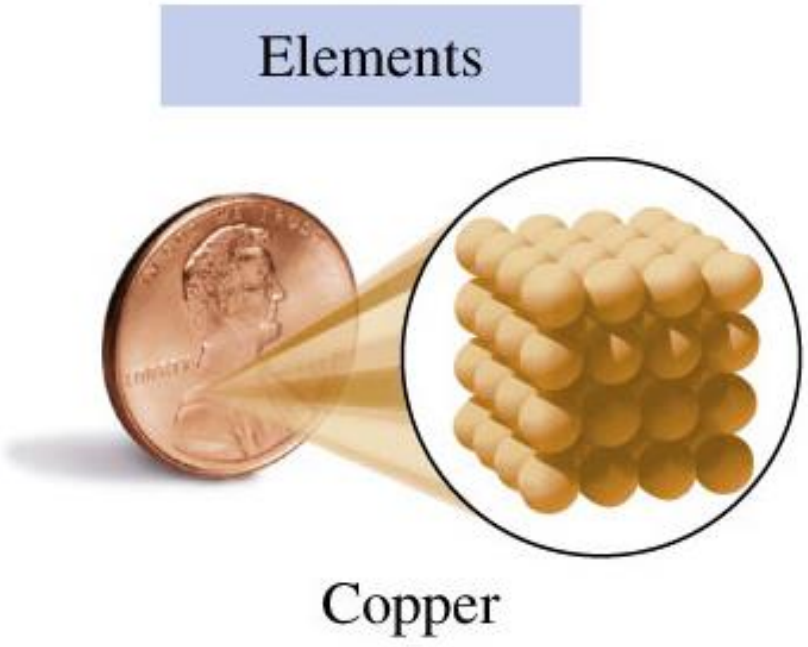
Matter and Energy

Dietitians specialize in helping individuals learn about good nutrition and the need for a balanced diet

Classification of Matter



Learning Goal Classify examples of matter as pure substances or mixtures.

Classification of Matter

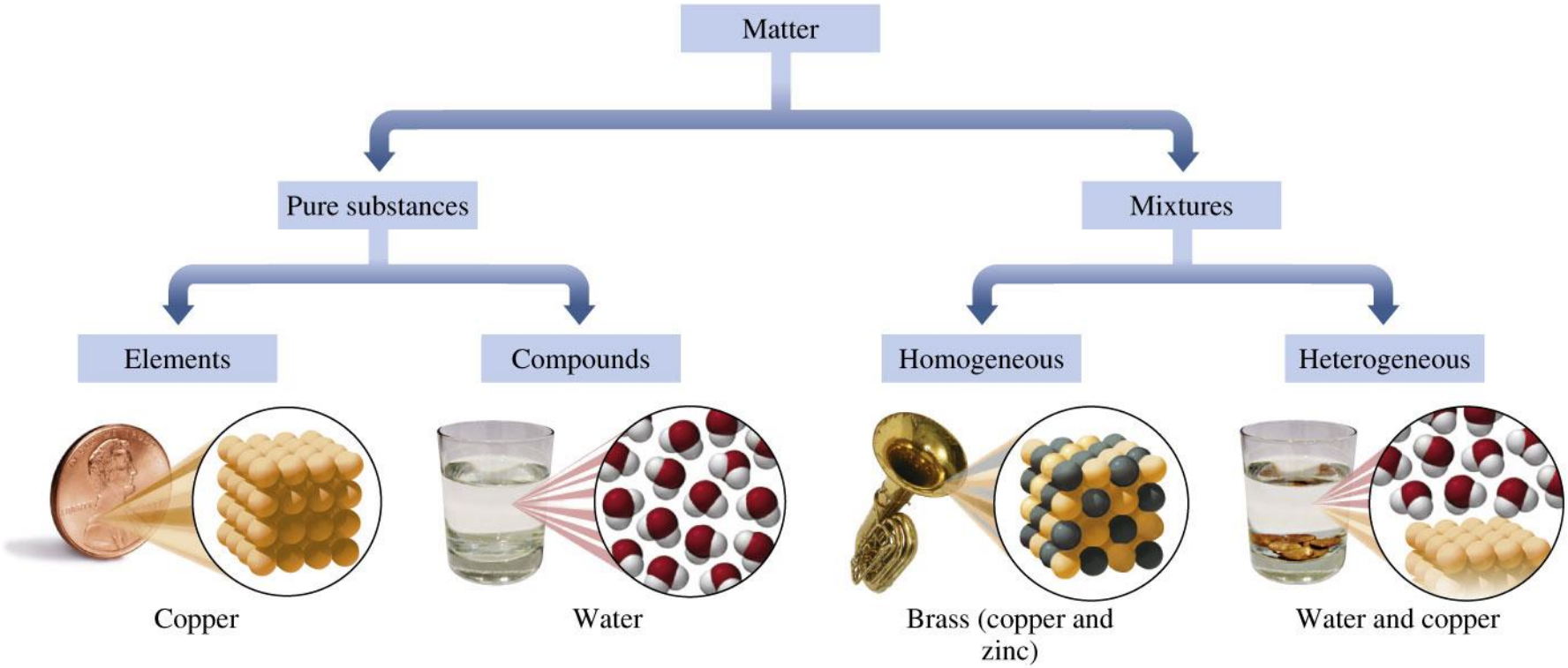
Matter is anything that has mass and occupies space. It makes up all things we use, such as

- water;
- wood; and
- plastic bags.

We can classify matter according to its composition:

- **Pure substances** have a fixed or definite composition.
- **Mixtures** contain two or more different substances that are physically mixed but not chemically combined.

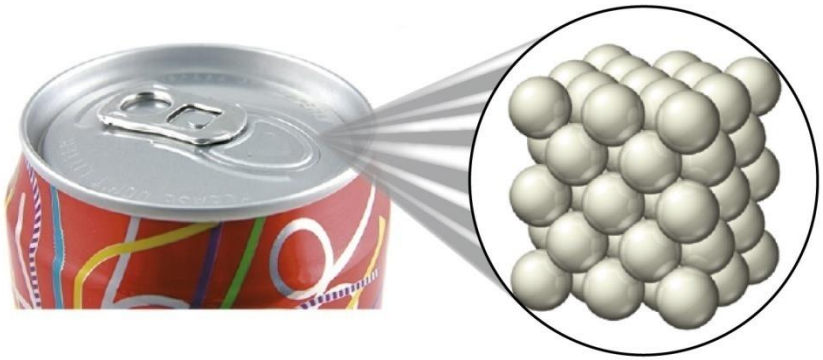
Classification of Matter



Pure Substances: Elements and Compounds

A **pure substance** is classified as

- a type of matter with a fixed or definite composition
- an **element** that is composed of one type of atom
- a **compound** that is composed of two or more elements always combined in the same proportion

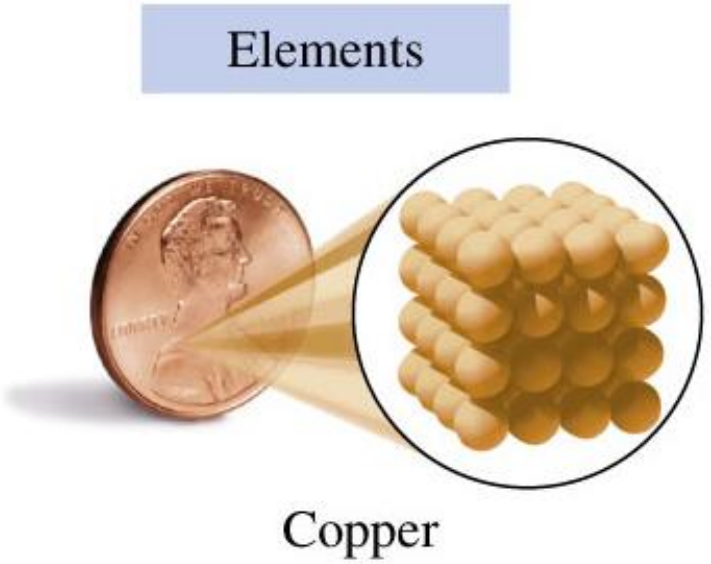


An aluminum can consists of many atoms of aluminum.

Elements

Elements are pure substances that contain only one type of material, such as

- copper, Cu
- lead, Pb
- aluminum, Al

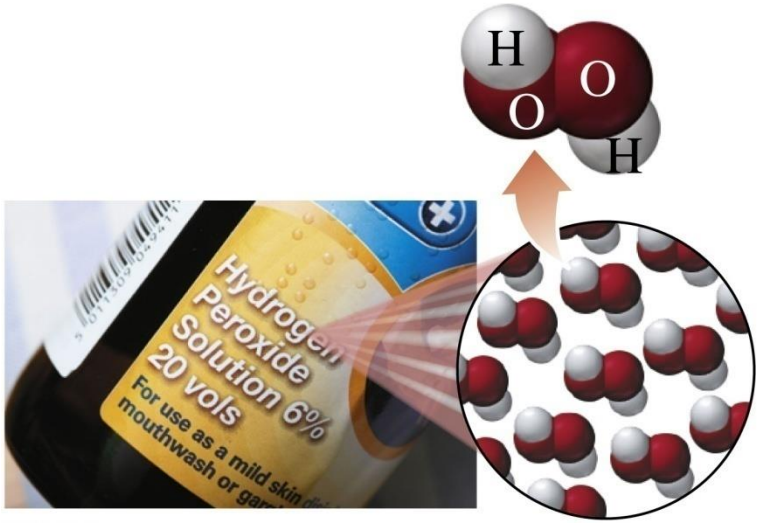


The element copper consists of copper atoms.

Compounds

A **compound** consists of two or more elements chemically combined in a definite ratio, such as

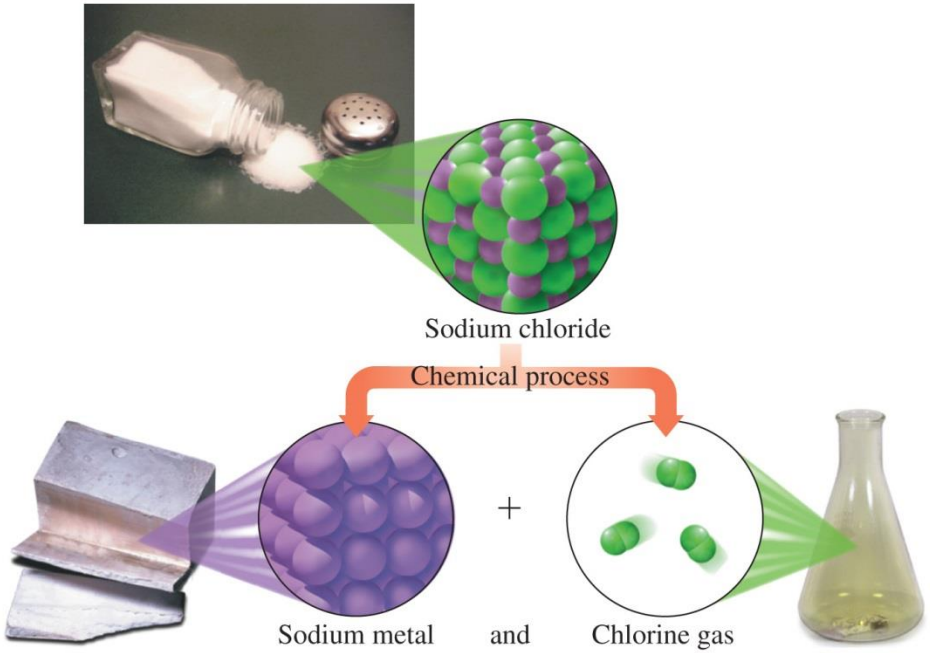
- hydrogen peroxide (H_2O_2)
- table salt (NaCl)
- sugar ($C_{12}H_{22}O_{11}$)
- water (H_2O)



Hydrogen peroxide, H_2O_2, consists of two atoms of hydrogen (white) for every two atoms of oxygen (red).

Compounds Contain Elements

"Table salt" is a compound that contains the elements sodium and chlorine.



The decomposition of salt, NaCl, produces the elements sodium and chlorine.

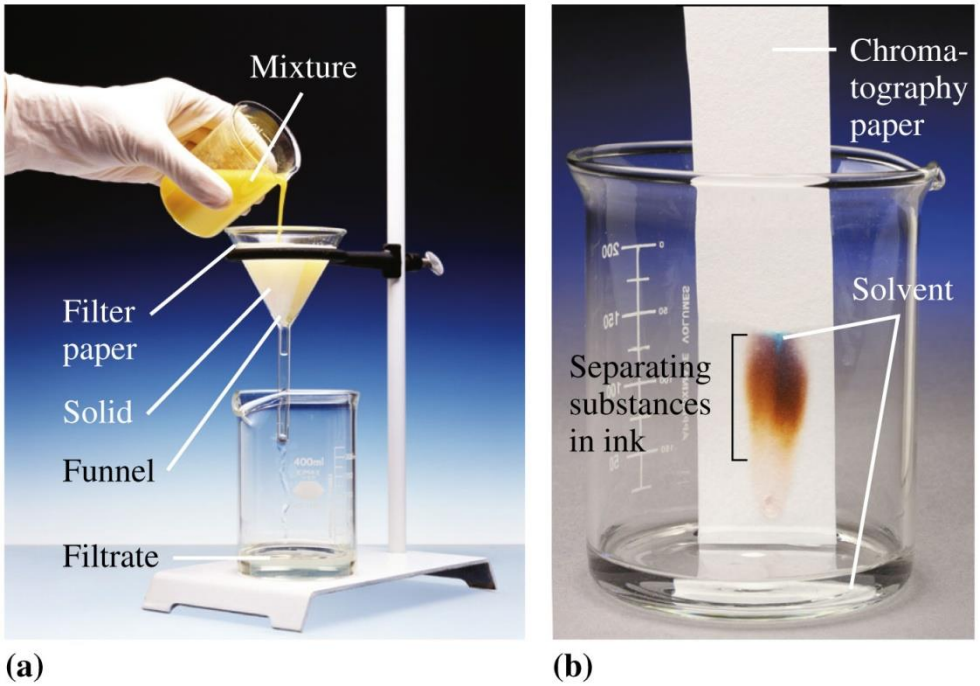
Mixtures

A **mixture** is a type of matter that consists of

- two or more substances that are physically mixed, but not chemically combined
- two or more substances in different proportions that can be separated by physical methods

A mixture of spaghetti and water is separated using a strainer, a physical method of separation.

Laboratory Separation of Mixtures



(a) A mixture of a liquid and a solid is separated by filtration.
(b) Different substances are separated as they travel at different rates up the surface of chromatography paper.

Homogeneous Mixtures

In a **homogeneous mixture**,

- the composition is uniform throughout the sample
- the different parts of the mixture are not visible

Brass (copper and zinc)

Brass is a homogeneous mixture of copper and zinc atoms.

Scuba Breathing Mixtures

Breathing mixtures for scuba are homogeneous mixtures. Some examples are

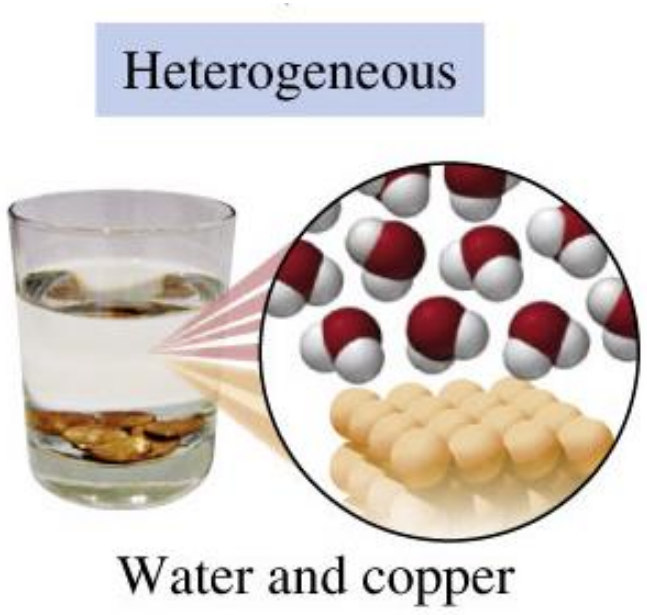
- nitrox (oxygen and nitrogen gases)
- heliox (oxygen and helium gases)
- trimix (oxygen, helium, and nitrogen gases)

A nitrox mixture is used to fill scuba tanks.

Heterogeneous Mixtures

In a **heterogeneous mixture**,

- the composition varies from one part of the mixture to another
- the different parts of the mixture are visible



Copper metal and water form a heterogeneous mixture.

Learning Check

Identify each of the following as a pure substance or a mixture:

A. pasta and tomato sauce

B. aluminum foil

C. helium

D. air

Learning Check

Identify each of the following as a homogeneous or heterogeneous mixture:

A. hot fudge sundae

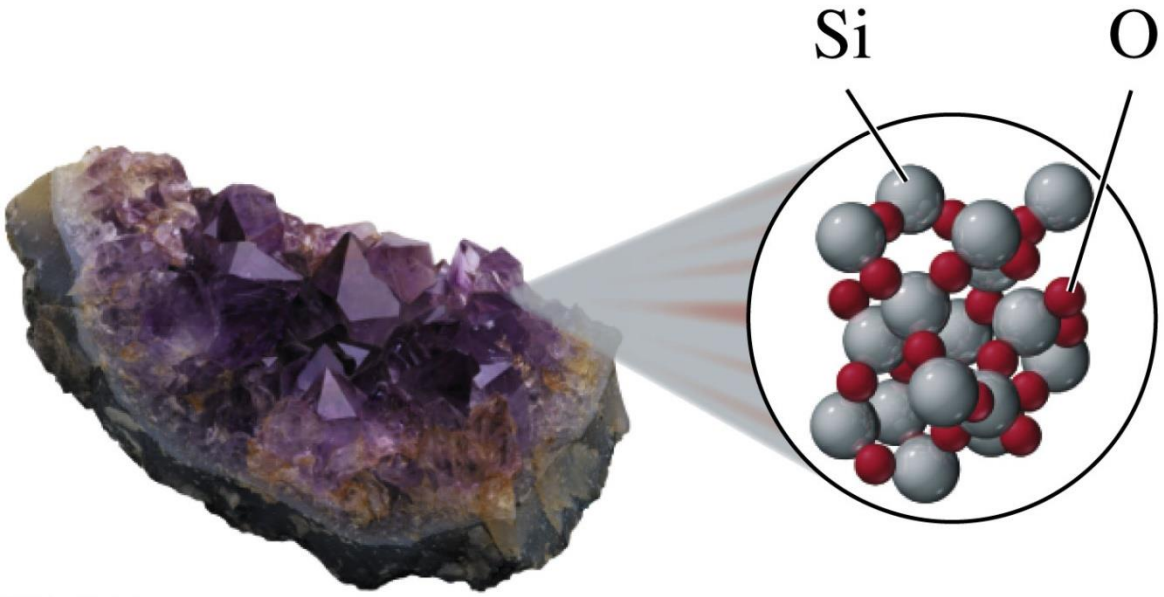
B. baby shampoo

C. sugar water

D. peach pie

3.2 States and Properties of Matter

Matter on Earth exists in one of three physical states: solid, liquid, or gas.

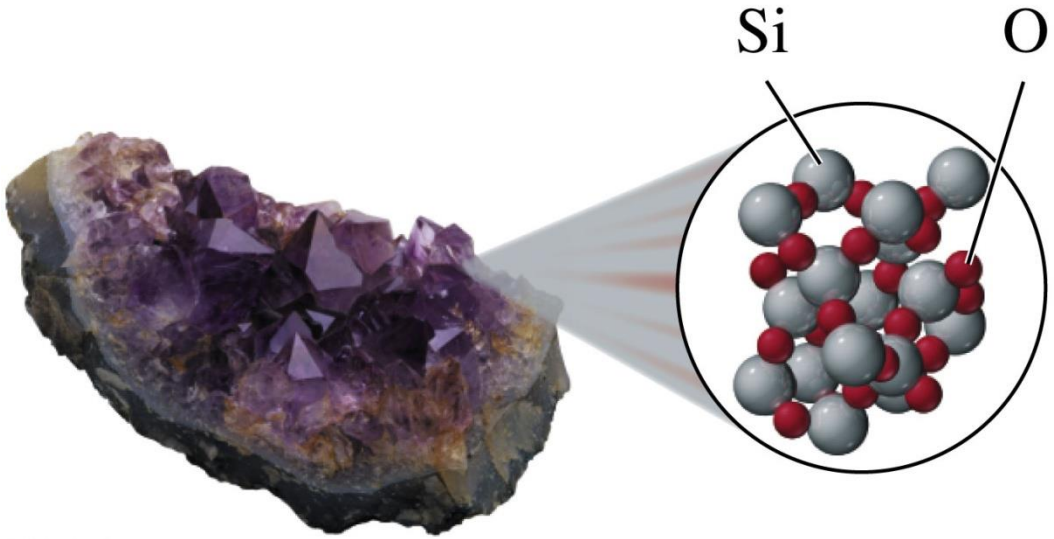


Learning Goal Identify the states and physical and chemical properties of matter.

Solids

Solids have

- a definite shape
- a definite volume
- particles are held close together by strong attractive forces
- particles are arranged in a rigid pattern and can only vibrate slowly in fixed positions

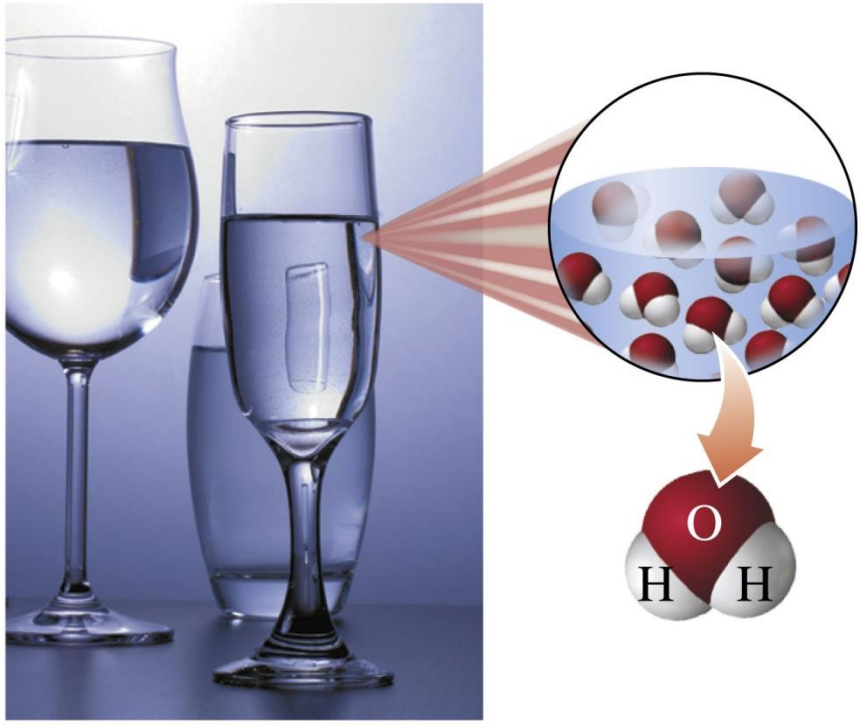


Amethyst, a solid, is a purple form of quartz (SiO_2).

Liquids

Liquids have

- a definite volume, but not a definite shape
- the same shape as their container
- particles that move slowly in random directions

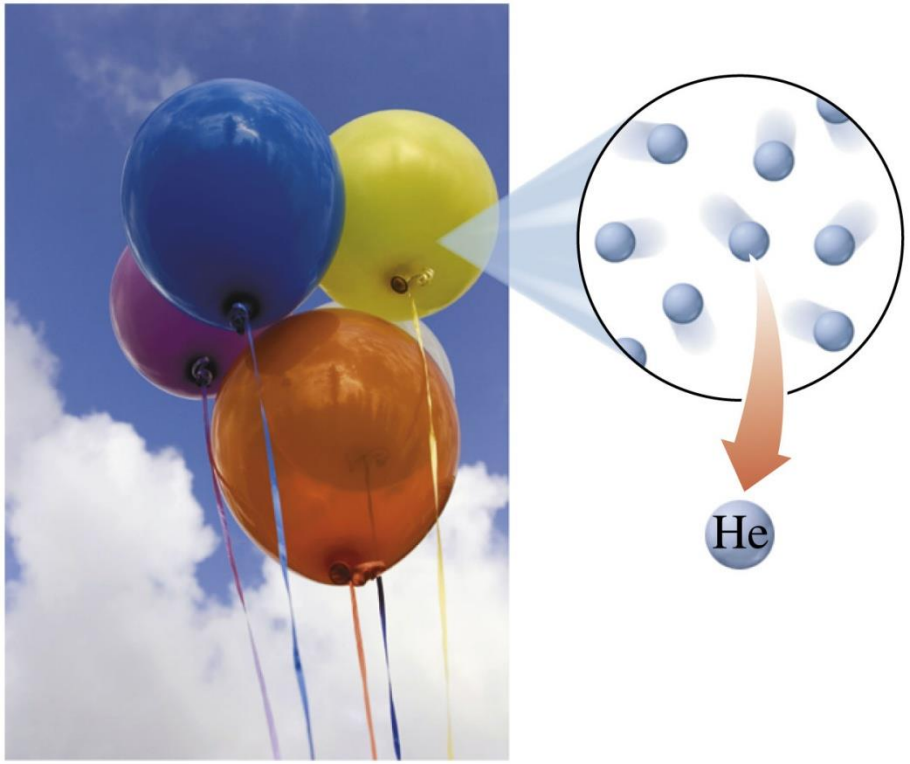


Water as a liquid takes the shape of its container.

Gases

Gases have

- an indefinite shape
- an indefinite volume
- the same shape and volume as their container
- particles that are far apart, move at high speeds, and have little attraction to each other



A gas takes the shape and volume of its container.

Physical States of Matter

TABLE 3.1 A Comparison of Solids, Liquids, and Gases

Characteristic	Solid	Liquid	Gas
Shape	Has a definite shape	Takes the shape of the container	Takes the shape of the container
Volume	Has a definite volume	Has a definite volume	Fills the volume of the container
Arrangement of Particles	Fixed, very close	Random, close	Random, far apart
Interaction between Particles	Very strong	Strong	Essentially none
Movement of Particles	Very slow	Moderate	Very fast
Examples	Ice, salt, iron	Water, oil, vinegar	Water vapor, helium, air

Learning Check

Identify each description as that of particles of a

1) solid 2) liquid 3) gas

__ **A.** has definite volume but takes the shape of the container

__ **B.** particles are moving rapidly

__ **C.** particles fill the entire volume of a container

__ **D.** particles have a fixed arrangement

__ **E.** particles are close together but moving randomly

Learning Check

Identify the state of matter for each of the following:

A. vitamin tablets

B. eye drops

C. vegetable oil

D. a candle

E. air in a basketball

Physical Properties

Physical properties

- are characteristics observed or measured without changing the identity of a substance.
- include the shape, physical state, boiling and freezing points, density, and color of that substance.

Physical Properties of Copper

Copper has these physical properties:

- reddish-orange color
- shiny
- excellent conductor of heat and electricity
- solid at 25 °C
- melting point 1083 °C
- boiling point 2567 °C

Copper, used in cookware, is a good conductor of heat.

Physical Changes

Physical changes occur when matter undergoes a physical change of state, but its composition remains constant.

Water exists in three states: (1) ice, (2) water, and (3) steam.

Physical Changes

CORE CHEMISTRY SKILL
Identifying Physical and Chemical Changes

The physical appearance of a substance can also change with a physical change.

For example, when salt is dissolved in water, the salt crystals are no longer visible but can be re-formed when the water evaporates.

A gold ingot undergoes a physical change when it is hammered to form gold leaf.

Learning Check

Classify each of the following as a

1) change of state 2) change of shape

A. chopping a log into kindling

B. water boiling in a pot

C. ice cream melting

D. ice forming in a freezer

E. cutting dough into strips

Chemical Properties and Changes

Chemical properties describe the ability of a substance

- to interact with other substances
- to change into a new substance

When a **chemical change** takes place, the original substance is turned into one or more new substances with new physical and chemical properties.

Chemical Changes

During a **chemical change**, a new substance forms that has

- a new composition
- new physical properties
- new chemical properties

For example, when iron nails corrode in the presence of water, a new substance forms on them, a red-orange powder called rust (Fe_2O_3).

Sugar caramelizing at a high temperature is an example of a chemical change.

Physical and Chemical Changes

TABLE 3.3 Examples of Some Physical and Chemical Changes

Physical Changes	Chemical Changes
Water boils to form water vapor.	Shiny, silver metal reacts in air to give a black, grainy coating.
Copper is drawn into thin copper wires.	A piece of wood burns with a bright flame and produces heat, ashes, carbon dioxide, and water vapor.
Sugar dissolves in water to form a solution.	Heating sugar forms a smooth, caramel-colored substance.
Paper is cut into tiny pieces of confetti.	Iron, which is gray and shiny, combines with oxygen to form orange-red rust.

Physical and Chemical Properties and Changes

TABLE 3.4 Summary of Physical and Chemical Properties and Changes

	Physical	Chemical
Property	A characteristic of a substance: color, shape, odor, luster, size, melting point, or density.	A characteristic that indicates the ability of a substance to form another substance: paper can burn, iron can rust, silver can tarnish.
Change	A change in a physical property that retains the identity of the substance: a change of state, a change in size, or a change in shape.	A change in which the original substance is converted to one or more new substances: paper burns, iron rusts, silver tarnishes.

Learning Check

Classify each of the following properties as physical or chemical:

A. Ice melts in the sun.

B. Copper is a shiny metal.

C. Paper can burn.

D. A silver knife can tarnish.

E. A magnet removes iron particles from a mixture.

Learning Check

Classify each of the following changes as physical or chemical:

A. burning a candle

B. ice melting on the street

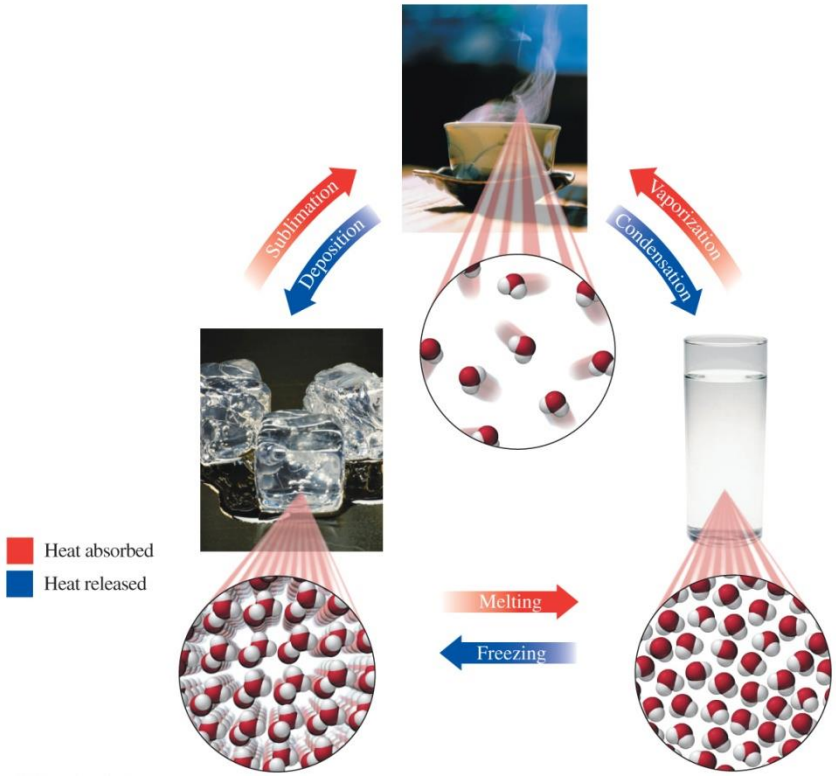
C. toasting a marshmallow

D. cutting a pizza

E. iron rusting in an old car

Changes of State

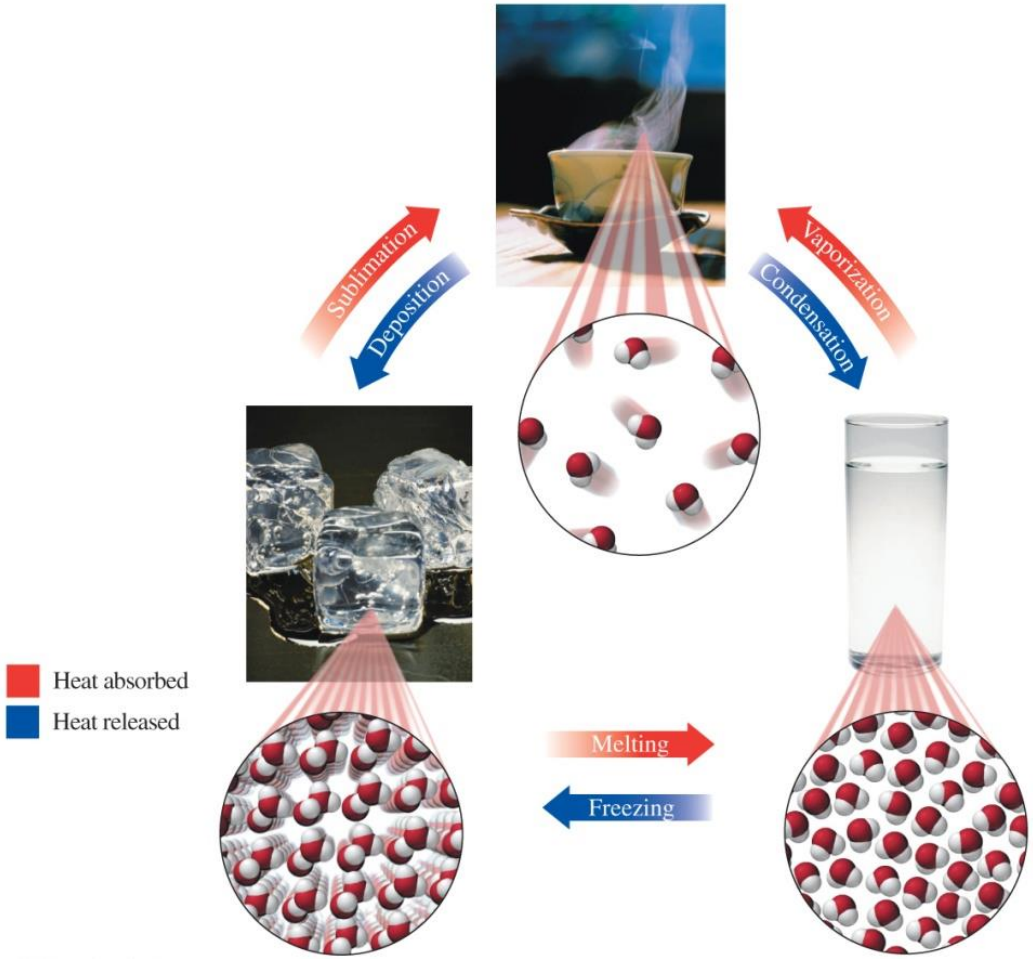
Changes of state include melting and freezing, boiling and condensation, and sublimation and deposition.



Learning Goal Describe the changes of state between solids, liquids, and gases; calculate the energy released or absorbed.

Changes of State

Matter undergoes a **change of state** when it is converted from one state to another state at a constant temperature.

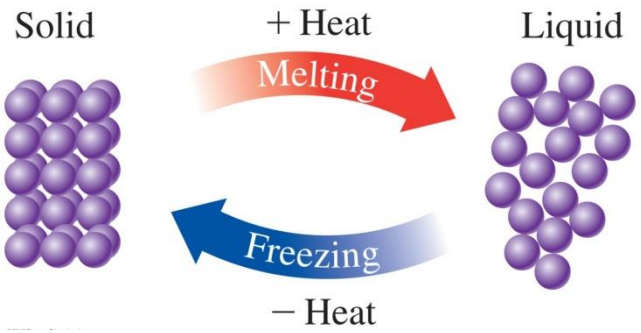


Melting and Freezing

A substance

- is **melting** while it changes from a solid to a liquid at its **melting point (mp)**
- is **freezing** while it changes from a liquid to a solid at its **freezing point (fp)**

Water has a freezing (melting) point of 0 °C.



Melting and freezing are reversible processes.

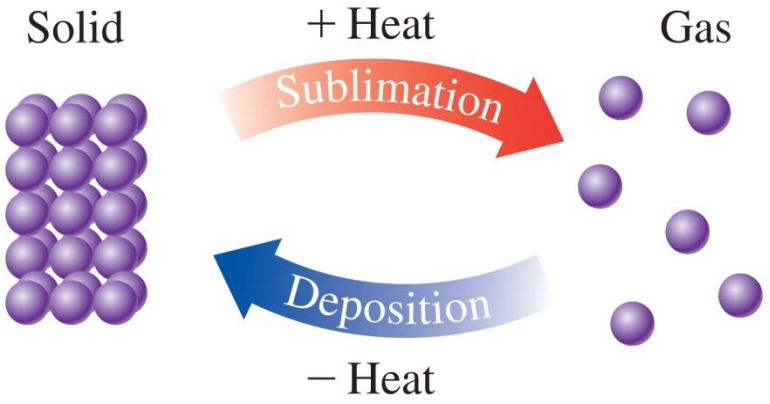
Sublimation and Deposition

When **sublimation** occurs,

- the particles on the surface of a solid change directly to a gas without going through the liquid state
- there is no change in temperature

In the reverse process, called **deposition**, gas particles change directly to a solid.

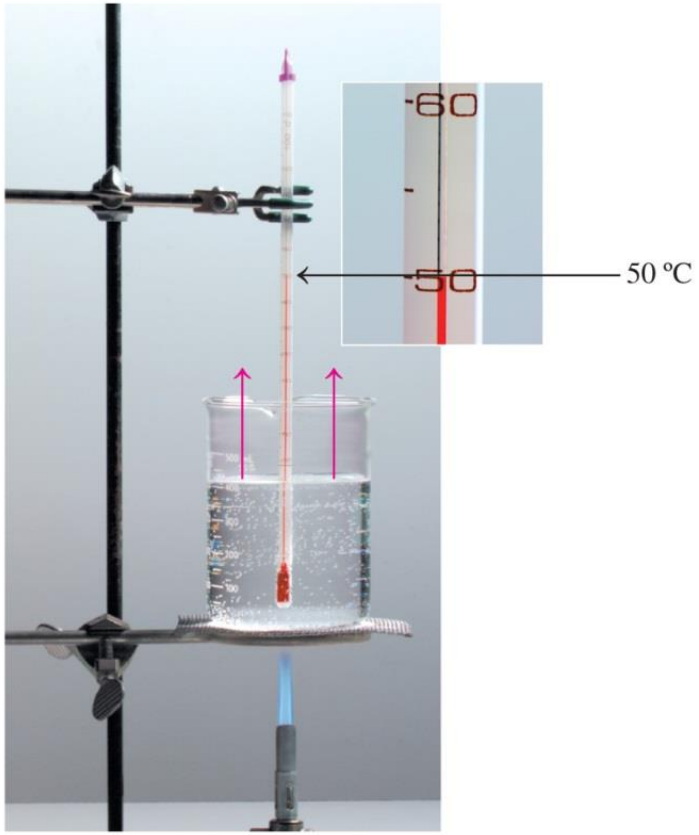
Dry ice undergoes sublimation.



Sublimation and deposition are reversible processes.

Evaporation, Boiling, and Condensation

Evaporation occurs when water molecules gain sufficient energy to escape the liquid surface and enter the gas phase.

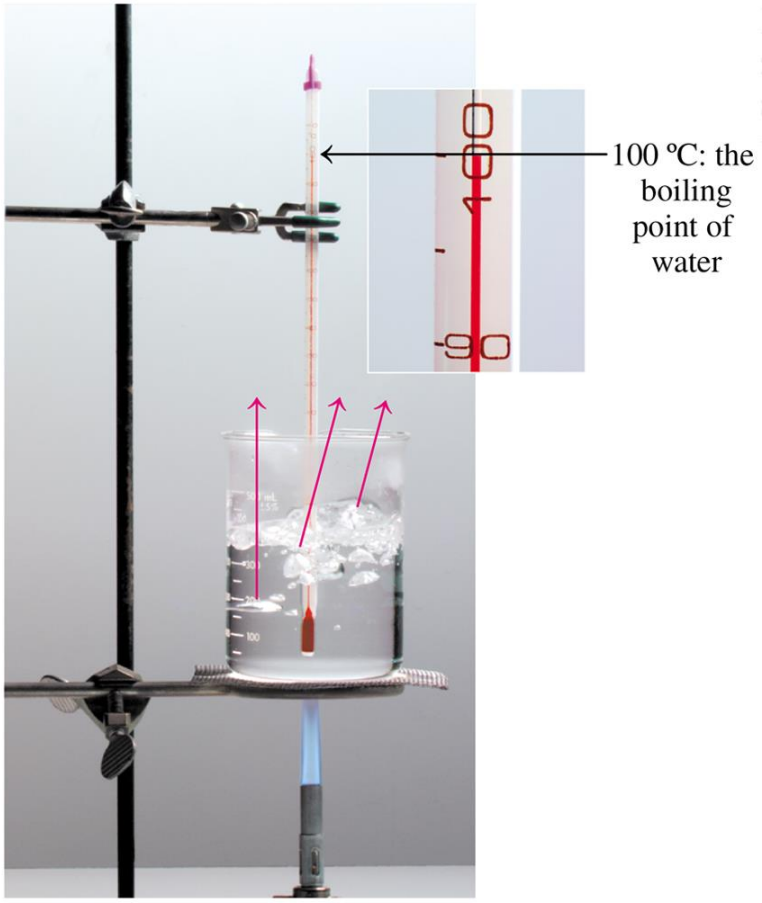


(a)

During evaporation, molecules of the liquid are converted to gas at the surface of the liquid.

Evaporation, Boiling, and Condensation

At the **boiling point**, the molecules have enough energy to overcome their attractive forces and become a gas.

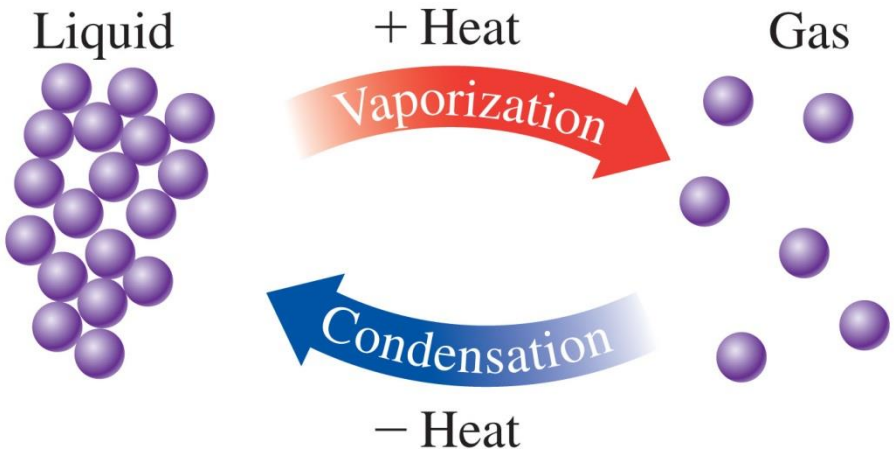


Boiling occurs as bubbles of gas form throughout the liquid.

Evaporation, Boiling, and Condensation

In **condensation**, water vapor is converted to a liquid as the water molecules lose kinetic energy and slow down.

Condensation occurs at the same temperature as boiling, but heat is removed.

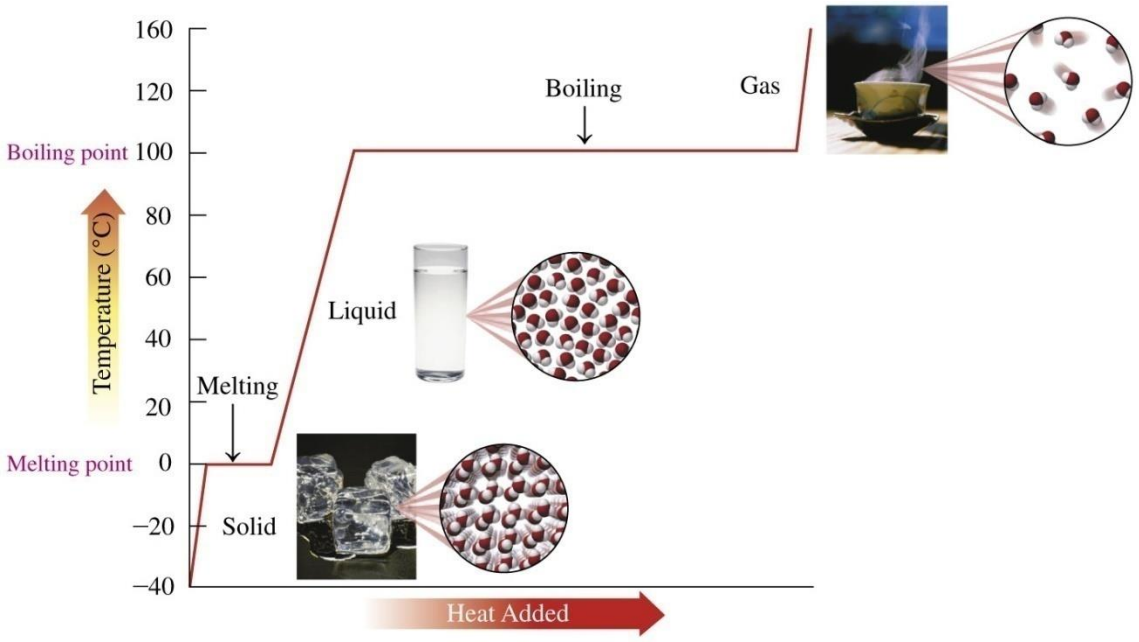


Vaporization and condensation are reversible processes.

Heating Curve

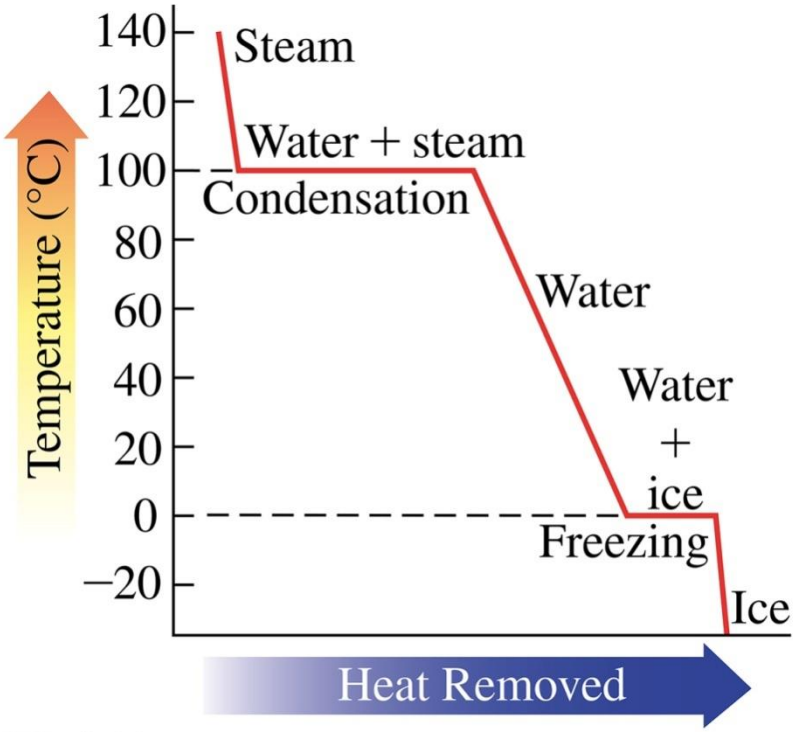
On a **heating curve**, diagonal lines indicate changes in temperature for a physical state, and horizontal lines (plateaus) indicate changes of state.

A heating curve for water diagrams the temperature increases and changes of state as heat is added.



Cooling Curve

On a **cooling curve**, diagonal lines indicate changes in temperature for a physical state, and horizontal lines (plateaus) indicate changes of state.



A cooling curve for water diagrams the temperature increases and changes of state as heat is added.

Learning Check

1. A plateau (horizontal line) on a heating curve represents

A. a temperature change

B. a constant temperature

C. a change of state

2. A sloped line on a heating curve represents

A. a temperature change

B. a constant temperature

C. a change of state

Learning Check

Use the cooling curve for water to answer each of the following:

1. Water condenses at a temperature of

A. 0 °C **B.** 50 °C **C.** 100 °C

2. At a temperature of 0 °C, liquid water

A. freezes **B.** melts **C.** changes to a gas

3. At 40 °C, water is a

A. solid **B.** liquid **C.** gas

4. When water freezes, heat is

A. removed **B.** added

Learning Check

A 175-g sample of steam at 100 °C is emitted from a volcano. It condenses, cools, and falls as snow at 0.0 °C. How many kilojoules were released?

A. 396 kJ

B. 528 kJ

C. 133 kJ

Concept Map