UNIT I: MATTER AND ENERGY

Matter is considered to be anything which has mass and occupies space.

There are two types of matter, **pure substances**, and **mixtures.**

Pure substances consist of elements and compounds. Pure substances have a definite composition and distinct properties.

Mixtures are a combination of two or more substances in which each substance retains its properties. There are two types of mixtures, **homogeneous mixtures** and **heterogeneous mixtures**. Mixtures can be separated by physical means into pure substances.

PURE SUBSTANCES

All samples of a particular pure substance have the same melting point, boiling point, and other properties related to composition which can be used for identification.

The two types of pure substances are:

Elements - Matter which is composed of only one kind of atoms. The smallest particle of an element is an **atom**. Elements can not be decomposed by chemical means.

Compounds - Matter that is composed of two or more different kinds of atoms chemically combined in definite proportions. Compounds can be decomposed by chemical means into their elements.

Binary compounds - Compounds consisting of only two elements regardless of their ratio are called **binary compounds.**

NaCl, NH_3, $MgCl_2$, or Al_2O_3 are examples of binary compounds.

Law of Definite Proportions.

Any sample of a pure compound always consists of the same elements combined in the same proportions by mass. This observation is known as the "**Law of Constant Composition**" or the **"Law of Definite Proportions."**

For example, every sample of water collected anywhere in the universe is composed of 11% hydrogen and 89% oxygen. Every water molecule contains two atoms of hydrogen to one atom of oxygen to give the formula, H_2O.

If the formula of the compound is not H_2O (11% hydrogen and 89% oxygen), the compound is not water but some other substance.

MIXTURES

A mixture consists of two or more distinct substances differing in properties and composition. The composition of a mixture can be varied.

The two types of mixtures are:

Homogeneous mixtures - Are mixtures in which the composition is the same throughout. All the substances in a homogeneous mixture are uniformly dispersed in each other. Solutions are the best examples of homogeneous mixtures. A solution has exactly the same composition regardless of where the sample is taken.

Heterogeneous mixtures - A mixture in which the particles of each component remain separated and can be observed as individual substances. Earth (dirt) and concrete are both good examples of heterogeneous mixtures.

Kinetic Molecular Theory

To understand the physical properties of matter, we need a model that helps us picture these particles. Such a model, known as the **kinetic molecular theory**, was developed over 100 years but was finalized by Rudolf Clausius (1822-1885) in 1857. The kinetic molecular theory is summarized below.

â All matter is made up of a large number of tiny particles. These particles may be atoms, molecules, or ions.

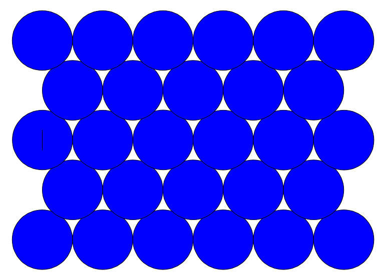
ã These molecules are always moving in a continuous, random motion except at "absolute zero" where all molecular motion ceases.

ä The collisions between molecules are perfectly elastic. While molecules may exchange energy when they collide, the total amount of energy possessed by all the particles remains constant.

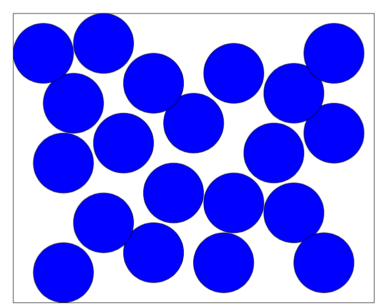
Phases or States of Matter

The term "**phase**" or "**state**" is used to refer to the gas, liquid, or solid forms of matter.

Solids - Solids have a definite shape and a definite volume. All true solids have a crystalline structure or regular geometric pattern. The particles in a solid are constantly vibrating in a fixed position.

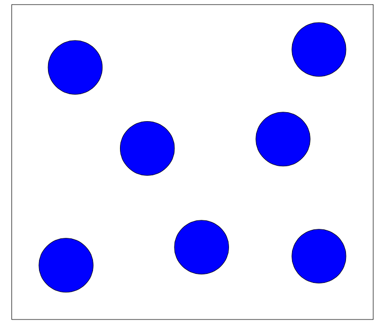


Liquids - Liquids have a definite volume but take the shape of their container. The particles in the liquid phase have no regular arrangement and are in constant motion moving freely about their container.



Liquid

Gases - Gases take both the shape and volume of their container. The particles in a sample of a gas are constantly moving freely and randomly about their containment vessel.



<u>Symbols for Some Different Forms of Matter</u>

Solid (s)

Liquid (ℓ)

Gas (g)

Aqueous or water solution (aq)

What information is given by the symbols below?

NaCl(s)	H_2O(ℓ)	CO_2(g)
KCl(aq)	Fe(s)	CH_3OH(ℓ)

ALLOTROPES

Allotropes are different forms of the same element that exist in the same physical state under the same temperature and pressure.

Diamond and graphite are one of the more common examples of allotropes. Some properties of these allotropes are

Property	Diamond	Graphite
Density	3.51 g/ml	2.22 g/ml
Color	colorless	black
Hardness	extremely hard	very soft
Conductivity	nonconductive	semiconductor
Physical Form	crystalline	flat sheets

Molecular oxygen, O_2, and ozone, O_3, are another allotropic pair. Molecular oxygen, O_2, is a colorless, diatomic gas with a boiling point of -183.0°C and melting point of -218.4°C. Ozone, O_3, is a blue gas with a strong irritating odor. Ozone has a boiling point of -111.9°C and melting point of -192.5°C.

PHYSICAL AND CHEMICAL CHANGES

Chemical Change - A chemical change results in a permanent change in the physical properties as a result of a change in chemical composition.

Physical Changes - A change in the physical form (solid, liquid, or gas) of a substance without altering the composition of the substance.

PHASE CHANGES

As a sample of matter is heated from below its melting point to above its boiling point, it readily changes from one phase to another.

Phase changes are always accompanied by either the absorption or release of energy.

The terms for the absorption of energy during the two phase changes are called the **Heat of Fusion** and the **Heat of Vaporization**.

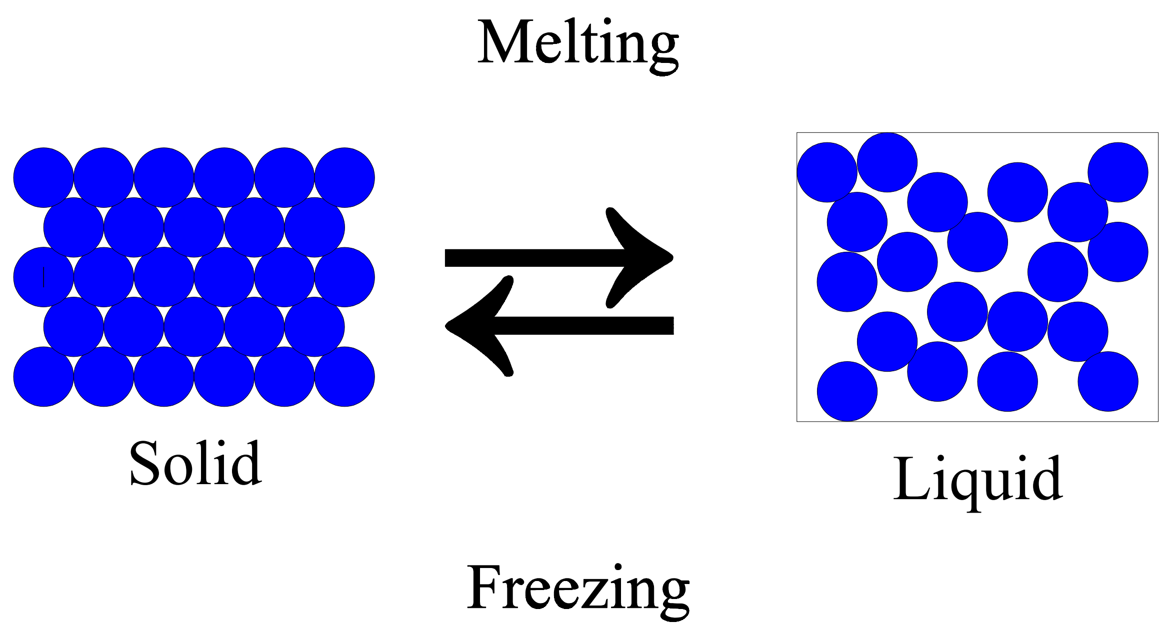
The heat of fusion is the energy required to melt a given of amount of solid. This energy is needed to break down the rigid solid structure producing the random liquid phase.

The **heat of vaporization** is the energy required to boil a given amount of liquid. This energy is needed to completely separate the particles in the liquid phase forming the scattered gaseous phase.

Melting - The change from the solid phase to the liquid phase is called "**melting.**"

When melting occurs, the substance absorbs energy resulting in a break down of the regular geometric arrangement of the particles. The result is a collection of particles with no orderly pattern.

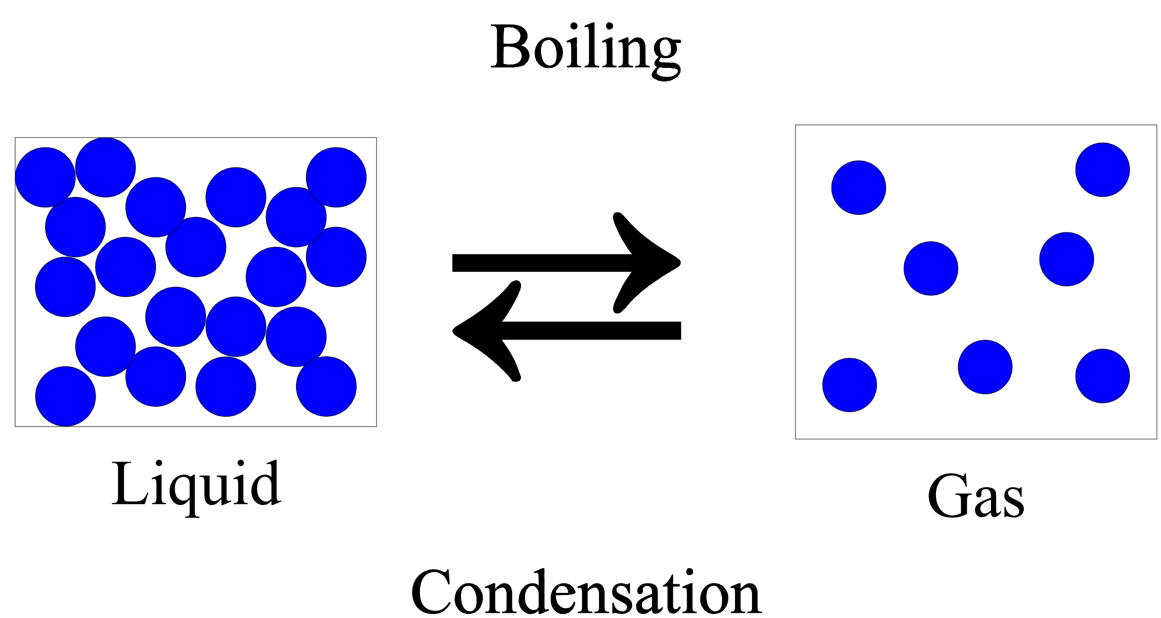
The reverse process to melting is called "**freezing.**" There is a release of energy during freezing.



Boiling - The phase change from the liquid phase to the gaseous phase is called **"boiling."**

When boiling occurs, the particles absorb energy and separate completely leaving particles which are scattered and random.

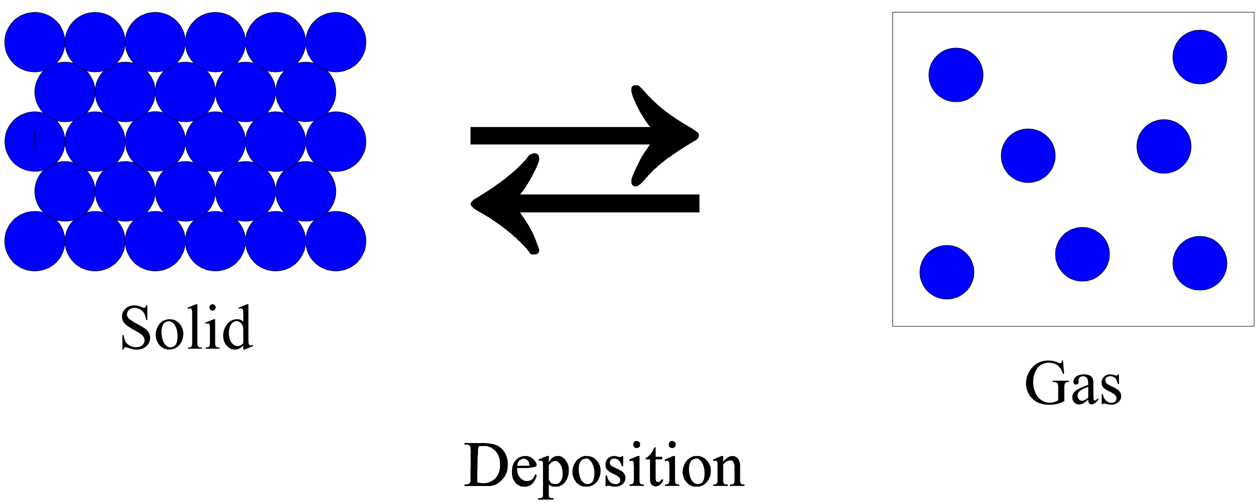
The opposite process to boiling is called **"condensation."** There is a release of energy during condensation.



Sublimation - The phase change from the solid state directly to the gaseous state without passing through the liquid state is called **“sublimation.”**

Typical solids which sublime are dry ice (carbon dioxide), paradichlorobenzene (moth balls), and iodine. The odor of some solids is attributed to sublimation.

The opposite process to sublimation is called **“deposition.”**



Identify which of the following equations are phase changes and which are chemical reactions. Name the phase changes where applicable.

â NaCl(R) 6 NaCl(s)

ã H_2O(s) 6 H_2O(g)

ä NH_3(g) + HCl(g) 6 NH_4Cl(s)

å CO_2(g) 6 CO_2(s)

æ H_2(g) + Cl_2(g) 6 2HCl(g)

ç C_2H_5OH(R) 6 C_2H_5OH(g)

è I_2(s) 6 I_2(g)

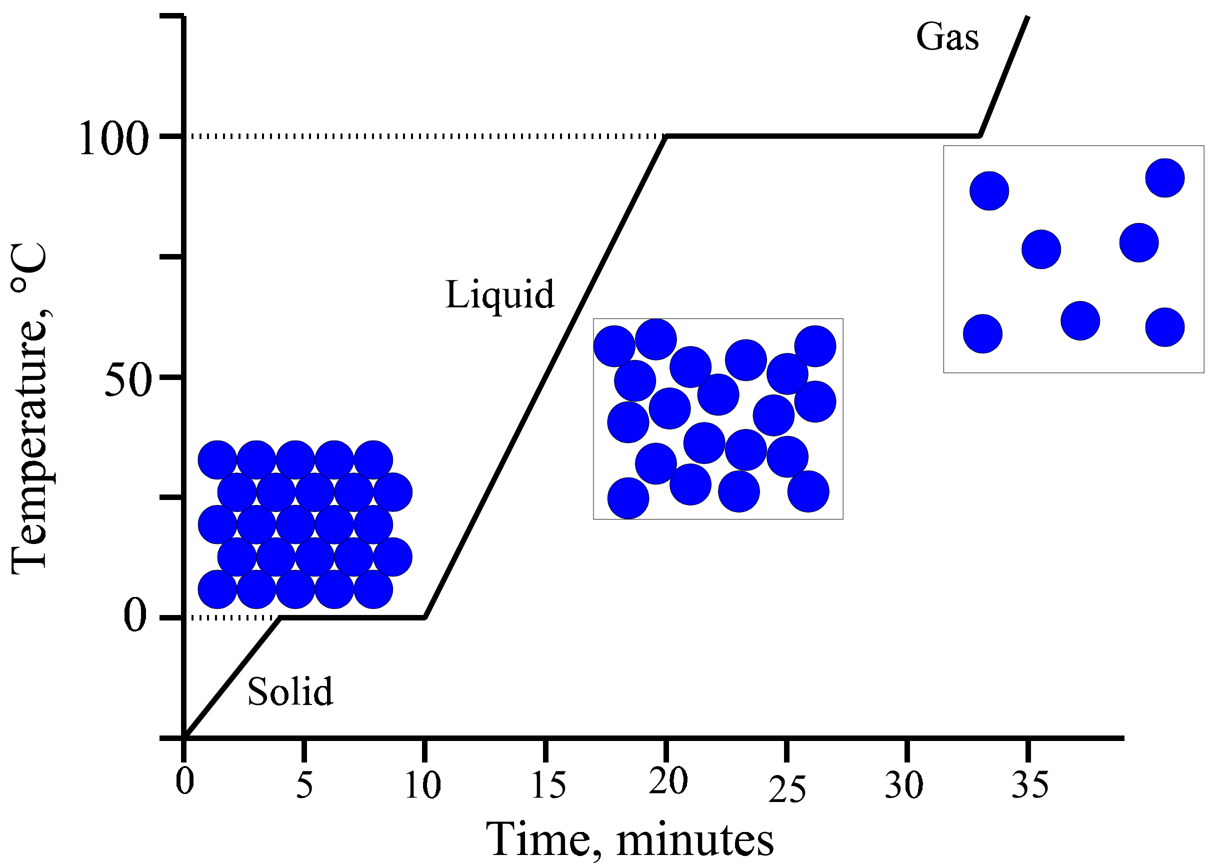
é $2H_2O$(R) 6 $2H_2$(g) + O_2(g)

ê Ar(g) 6 Ar(R)

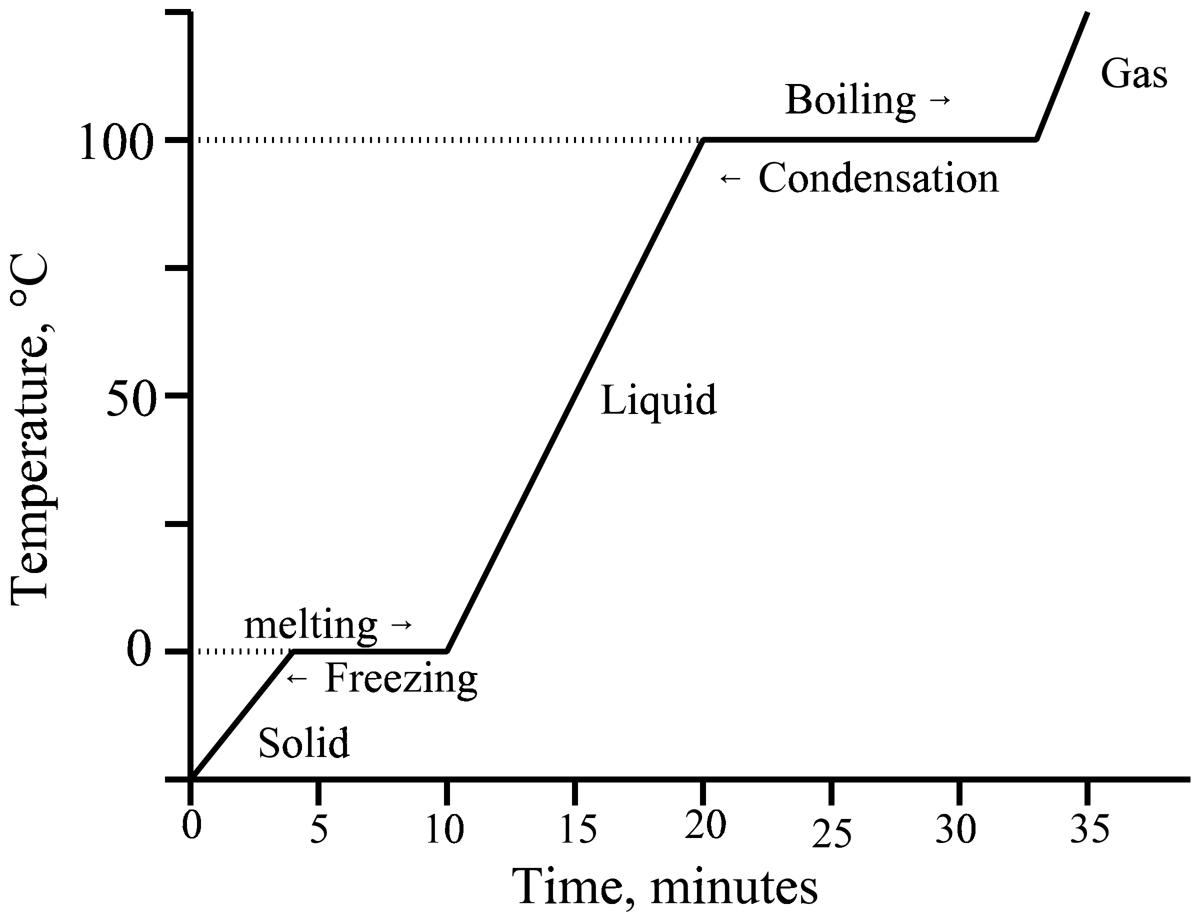
ë $C_6H_4Cl_2$(s) 6 $C_6H_4Cl_2$(g)

The Heating Curve for Water

When solid water (ice) is heated at a constant rate from -25°C to 125°C, its phase changes to the first the liquid phase and then to the gaseous phase.

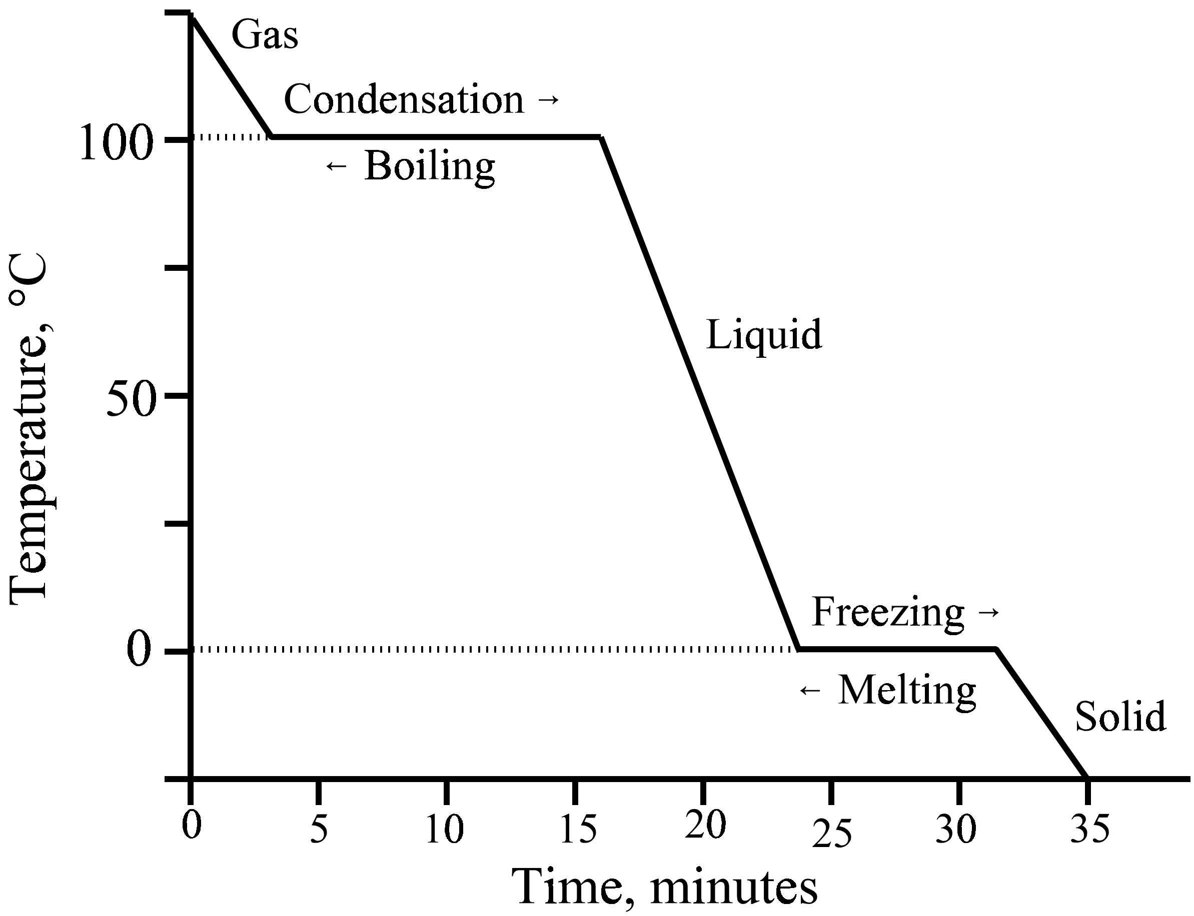


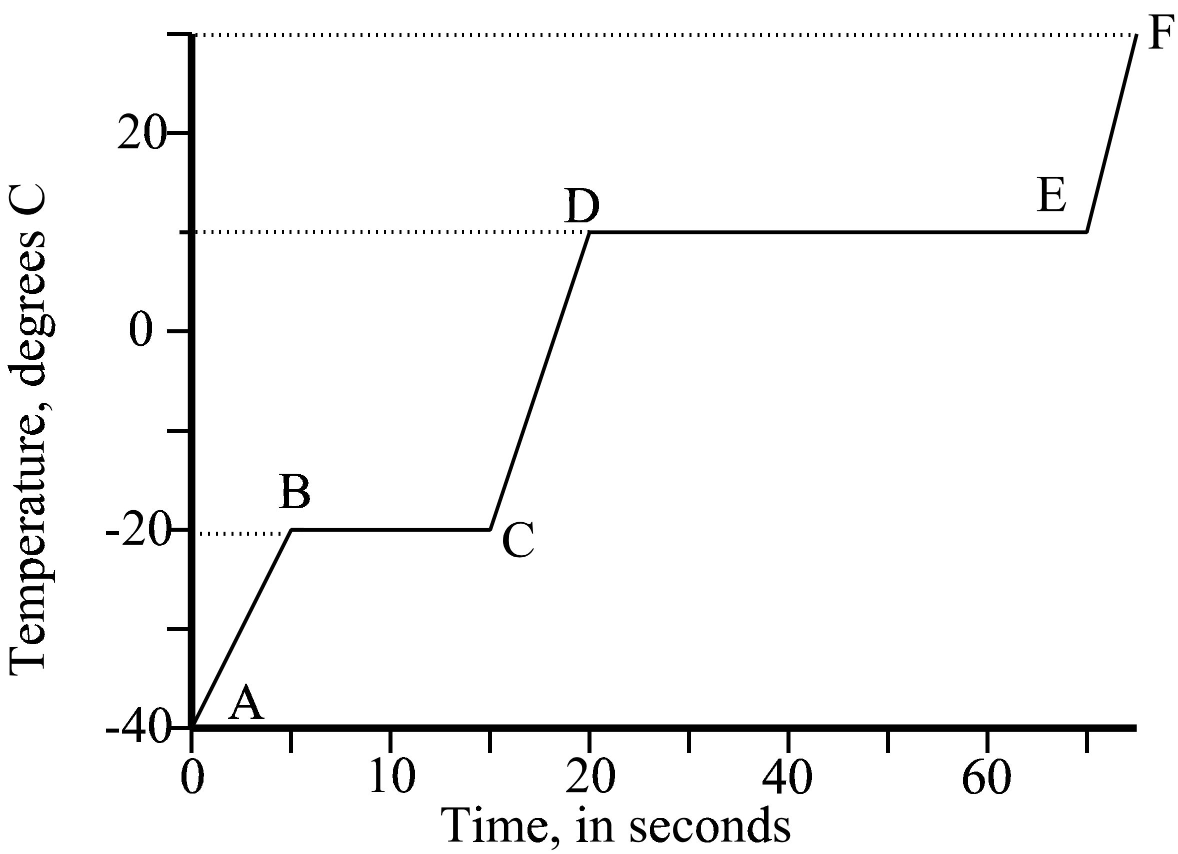
Each of the two plateaus on a heating curve represent a phase change. The lower plateau always represents the solid-liquid transition (melting) and the upper plateau always represents the liquid-gaseous transition (boiling).



Cooling Curve for Water

As water vapor is cooled from 125°C to -25°C on the cooling curve below, the gaseous water first condenses into liquid water and finally freezes to form ice. As in a heating curve, a phase change always occur at a plateau.

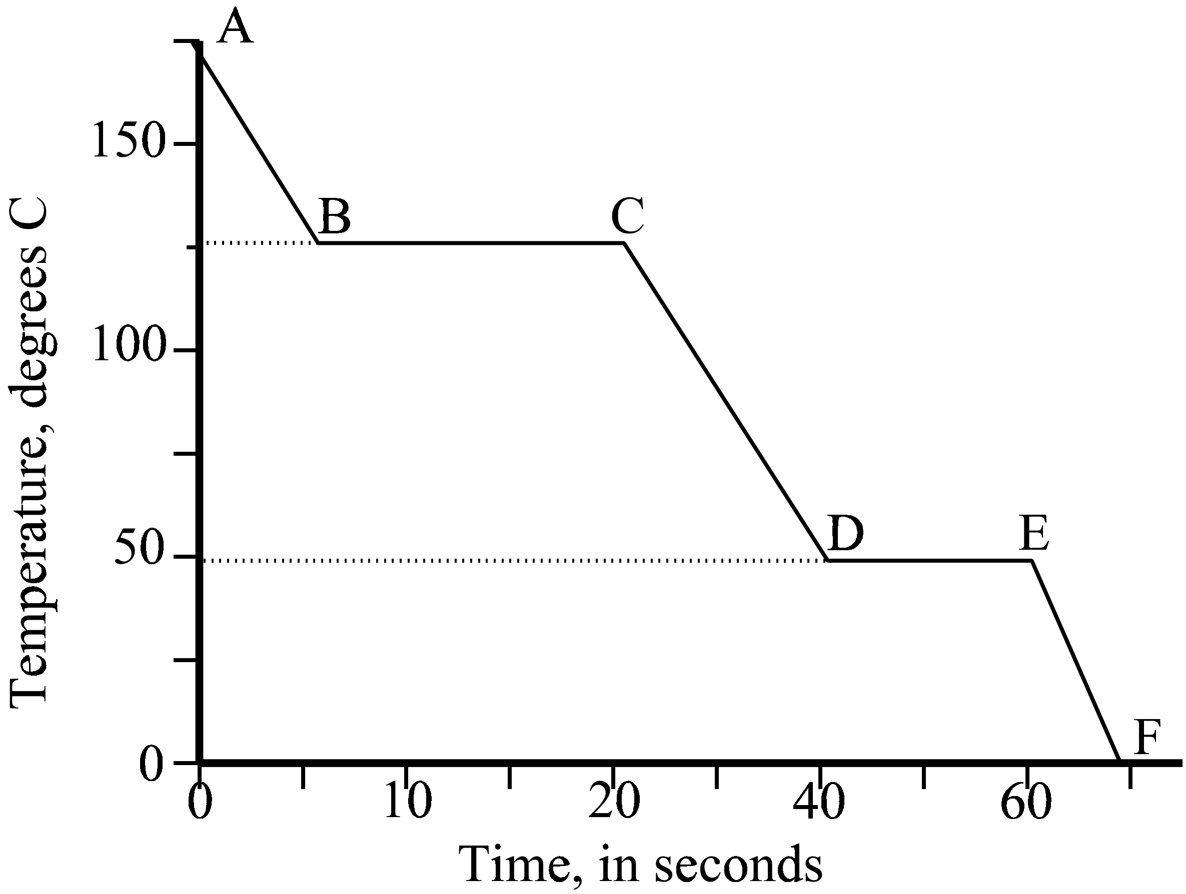




1. What is the melting point and boiling point for the substance given in the heating curve above?

2. On which portion of the curve does the substance have a definite shape and a definite volume?

3. Which process requires more energy, melting or boiling?

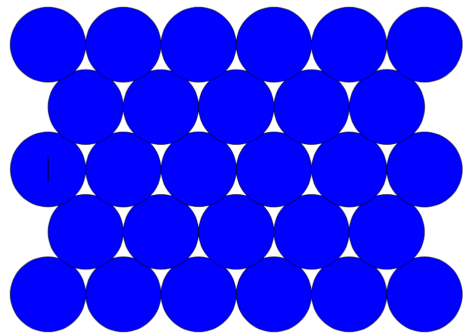


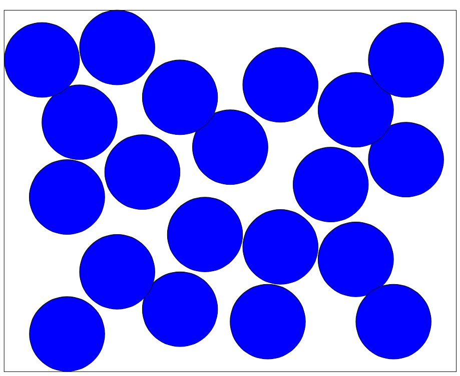
A
B
C
D
E
F
150
100
50
0
0
10
20
40
60
Temperature, degrees C
Time, in seconds

ENTROPY

The entropy of a collection of particles is a measure of the degree of disorder or randomness of the particles.

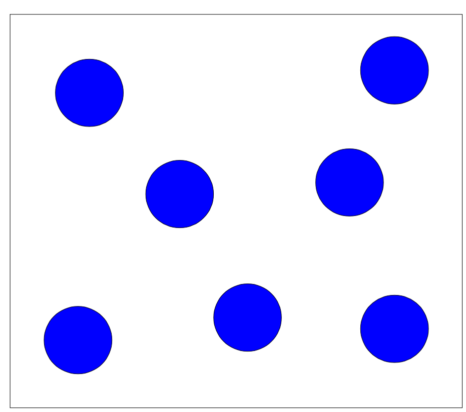
Solids have a regular arrangement of particles and therefore have a low entropy.

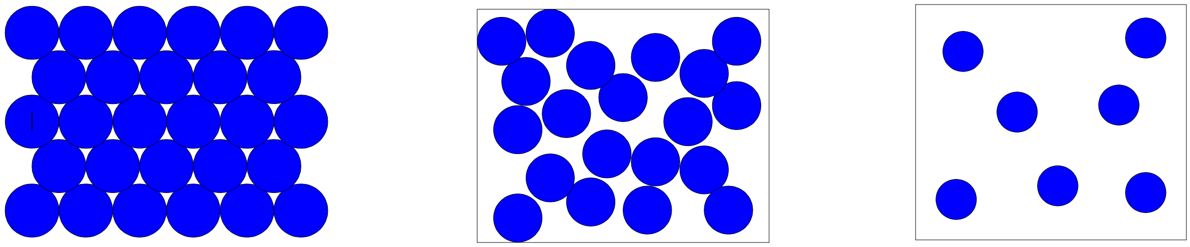




Liquids have a random collection of particles and therefore have a higher entropy than solids.

Gas have the most disordered collection of particles and therefore have the highest entropy.





Solid 6 liquid 6 gas

increasing entropy 6

Which phase change represents an increase in entropy?

1. CO_2(g) 6 CO_2(R)
2. NaCl(s) 6 NaCl(R)
3. H_2O(R) 6 H_2O(g)
4. Sn(R) 6 Sn(s)
5. KBr(s) 6 KBr(aq)
6. I_2(s) 6 I_2(g)