SPH3U
UNIVERSITY PHYSICS

ENERGY & SOCIETY

☞ States of Matter & Changes of State (P.288-295)

States of Matter

Water, and all other forms of matter, can exist in three different physical states, or phases: solid, liquid, and gas.

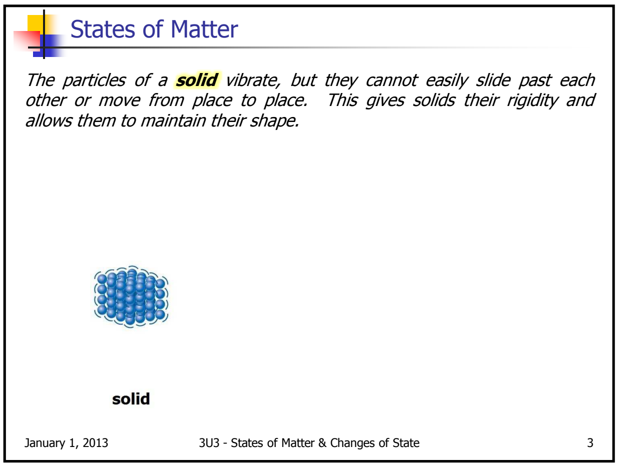
NOTE!
Plasma is considered to be a fourth state of matter. A plasma is a hot ionized gas consisting of approximately equal numbers of positively charged ions and negatively charged electrons.

States of Matter

The kinetic molecular theory can be used to explain the differences between these physical states. The ***kinetic molecular theory*** *is based on the idea that matter is composed of particles (atoms and molecules) that attract each other and have kinetic energy. It is the kinetic energy that causes particles to be in a state of constant motion which in turn determines their state.*

KINETIC MOLECULAR THEORY

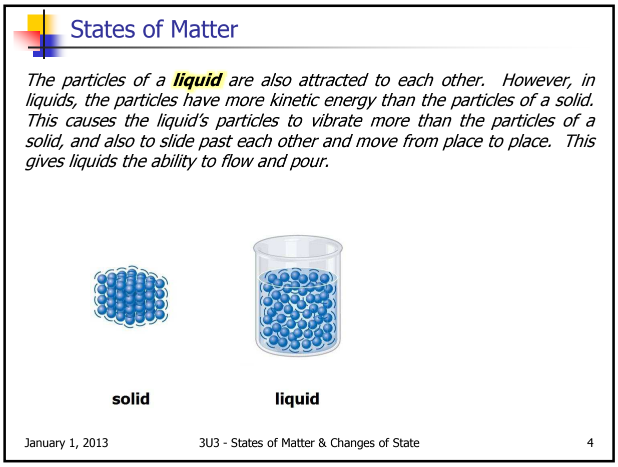
- matter is composed of particles (atoms and molecules) that attract each other and have kinetic energy (which determines their state)
- $E_{k\ solid} < E_{k\ liquid} < E_{k\ gas}$



States of Matter

*The particles of a **solid** vibrate, but they cannot easily slide past each other or move from place to place. This gives solids their rigidity and allows them to maintain their shape.*

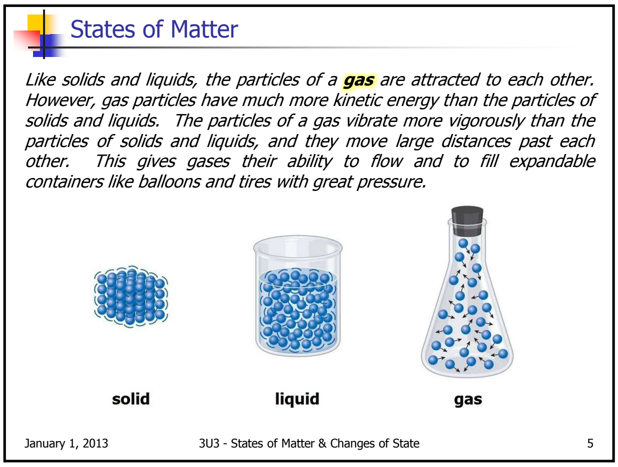
January 1, 2013 3U3 - States of Matter & Changes of State 3



States of Matter

*The particles of a **liquid** are also attracted to each other. However, in liquids, the particles have more kinetic energy than the particles of a solid. This causes the liquid's particles to vibrate more than the particles of a solid, and also to slide past each other and move from place to place. This gives liquids the ability to flow and pour.*

January 1, 2013 3U3 - States of Matter & Changes of State 4



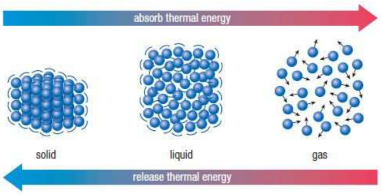
States of Matter

*Like solids and liquids, the particles of a **gas** are attracted to each other. However, gas particles have much more kinetic energy than the particles of solids and liquids. The particles of a gas vibrate more vigorously than the particles of solids and liquids, and they move large distances past each other. This gives gases their ability to flow and to fill expandable containers like balloons and tires with great pressure.*

January 1, 2013 3U3 - States of Matter & Changes of State 5

Changes of State

When solids, liquids, or gases absorb or release enough thermal energy, they may change state. For example, when a substance absorbs thermal energy, the particles of the substance begin to move faster and farther apart. This is how a solid changes into a liquid and a liquid changes into a gas. When a substance releases thermal energy the process is reversed.



Changes of State

CHANGES OF STATE

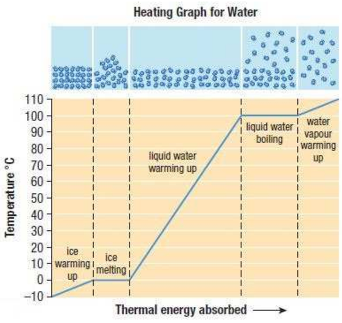
- may occur when a substance absorbs/releases thermal energy
- the thermal energy is transformed into kinetic and potential energy

NOTE!

The thermal energy is not really "absorbed"; it is transformed into the kinetic energy and potential energy of the substance's particles.

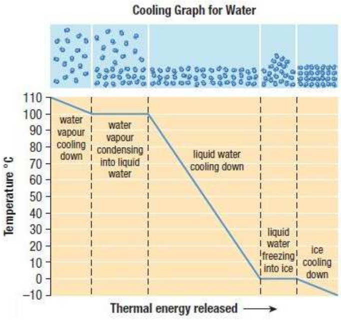
Heating & Cooling Graphs

The changes in temperature that occur when a substance absorbs thermal energy can be shown in a graph called a ***heating graph****.*



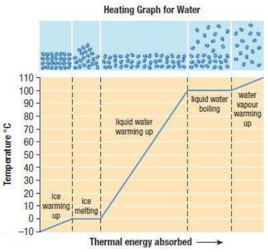
Heating & Cooling Graphs

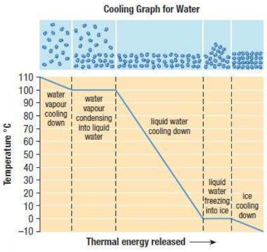
Similarly, the changes in temperature that occur when a substance releases thermal energy can be shown in a graph called a ***cooling graph****.*



Heating & Cooling Graphs

In both graphs, the vertical axis (y-axis) represents temperature and the horizontal axis (x-axis) represents the amount of thermal energy absorbed or released.

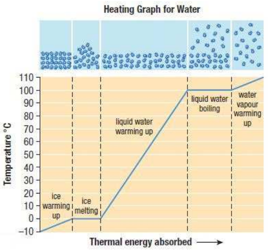


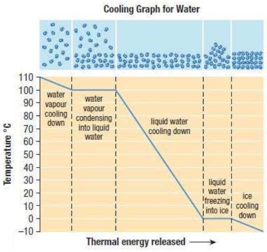


Heating & Cooling Graphs

NOTE!

① *The angled parts indicate a change in temperature. This can only occur when one state is present.*

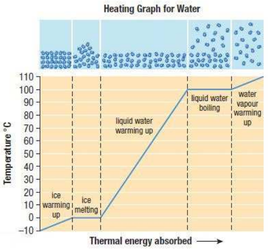


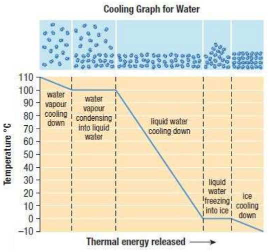


Heating & Cooling Graphs

NOTE!

② *The flat parts indicate a constant temperature. This occurs when there is more than one state because one state is changing into another.*





Heating & Cooling Graphs

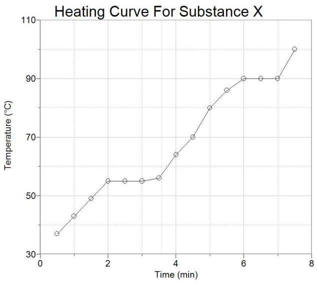
HEATING/COOLING GRAPH

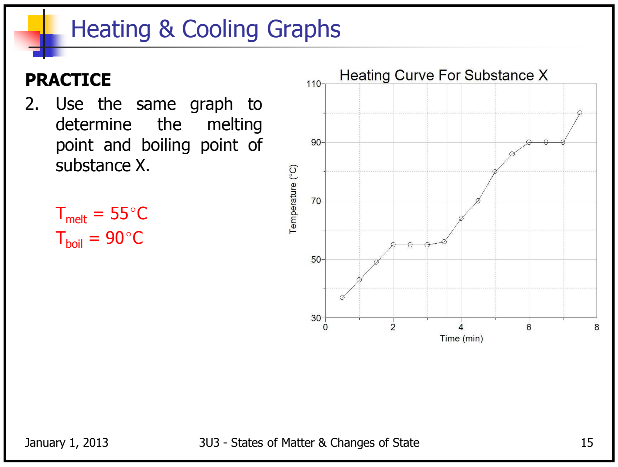
- graph that shows the temperature changes that occur while thermal energy is absorbed/released by a substance
- angled part = change in temperature ☞ one state
- flat part = constant temperature ☞ change of state

Heating & Cooling Graphs

PRACTICE

1. Label the appropriate parts of the heating graph with the following:
   - solid
   - liquid
   - gas
   - melting
   - evaporation



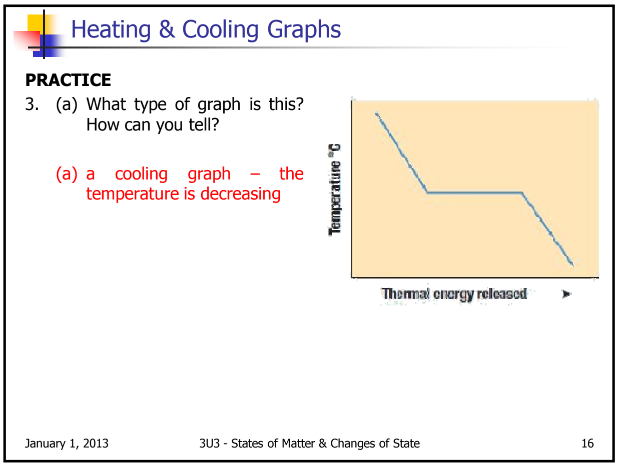


Heading & Cooling Graphs

PRACTICE

2. Use the same graph to determine the melting point and boiling point of substance X.

T_{melt} = 55°C
T_{boil} = 90°C

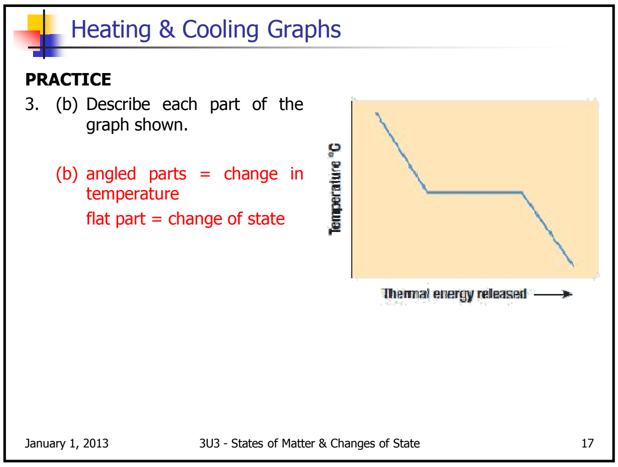


Heating & Cooling Graphs

PRACTICE

3. (a) What type of graph is this? How can you tell?

(a) a cooling graph – the temperature is decreasing



Heating & Cooling Graphs

PRACTICE

3. (b) Describe each part of the graph shown.

(b) angled parts = change in temperature
flat part = change of state

Heading & Cooling Graphs

PRACTICE

4. Why does the temperature not change during melting, freezing, boiling, or condensation? (Hint: recall the definition of temperature.)

   During melting and boiling, thermal energy must be absorbed by the particles of a substance in order to break the bonds that hold the particles together. During condensation and freezing, thermal energy must be released by the particles in order to allow the particles to move closer together and become more organized. In each of these situations, the change in thermal energy of the substance results in a change in potential energy of the particles. In other words, when a substance melts, boils, condenses, or freezes, the absorbed or released thermal energy is being transformed into potential energy, rather than kinetic energy. Since the kinetic energy of the particle does not change, the temperature of the substance remains constant during a change of state.

Latent Heat

The thermal energy absorbed or released during a change of state is called the ***latent heat (Q)*** *of the substance. The word "latent" means "hidden" because there is no measureable change in temperature. This thermal energy remains "hidden" until the opposite change of state occurs. For example, the thermal energy absorbed when ice melts remains in the liquid water until it is released when the liquid water freezes back into ice.*

LATENT HEAT (Q)

- total amount of thermal energy absorbed or released when a substance changes state
- SI unit is J

Latent Heat

NOTE!

Q represents both the latent heat and the quantity of heat. This is because both are measures of the amount of thermal energy absorbed or released. The only difference is that ***latent heat*** *relates to a substance changing state whereas* ***quantity of heat*** *relates to a substance in a particular state warming up or cooling down.*

Latent Heat

PRACTICE

5. To prevent fruit on trees from freezing and becoming inedible, fruit farmers in Ontario often spray their crops with water if they know the temperatures are going to drop below zero. Use your knowledge of latent heat to explain why this will help prevent the fruit from freezing.

   It's not the frost itself, or even the cold temperatures that cause damage to fruit trees, it is the formation of ice in the tissues of leaves, twigs, flowers and fruit that causes the damage. Water keeps the tree and the fruit from freezing due to the fact that water releases heat when it freezes – in fact, each gram of water that freezes releases 80 calories of heat. It is this heat that raises the temperature of the tree, the air around the tree and the soil, preventing ice formation in the tissues of the tree and the fruit.

Latent Heat

Every substance has a latent heat of fusion and a latent heat of vaporization. The ***latent heat of fusion*** **(Q_f)** *is the amount of thermal energy absorbed when a substance melts or is released when it freezes.*

LATENT HEAT OF FUSION (Q_f)

- the total amount of thermal energy required to change a solid into a liquid or a liquid into a solid

NOTE!

These energy values are the same for a particular substance because the amount of energy absorbed when a solid melts into a liquid is the same as the amount of energy released when that liquid freezes back into a solid. The term "latent heat of fusion" is used for both values.

Latent Heat

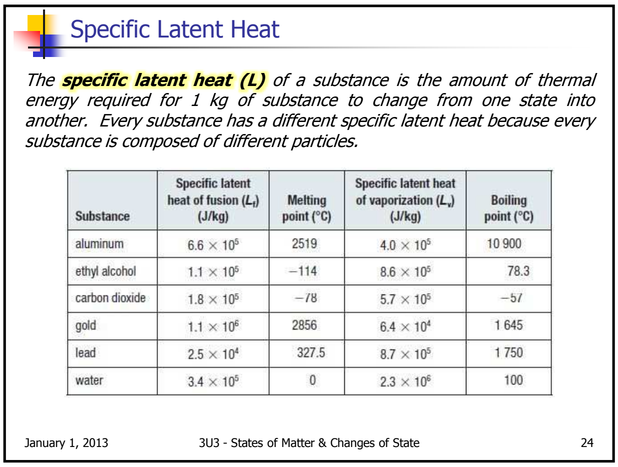
The ***latent heat of vaporization*** **(Q_v)** *is the amount of thermal energy absorbed when a substance evaporates or is released when it condenses.*

LATENT HEAT OF VAPORIZATION (Q_v)

- the total amount of thermal energy required to change a liquid into a gas or a gas into a liquid

NOTE!

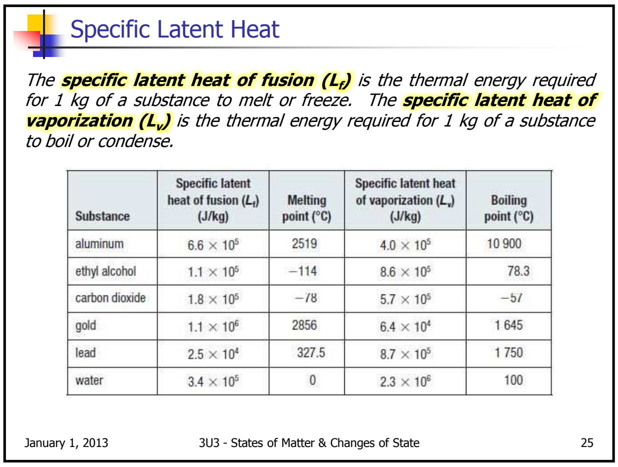
As with latent heats of fusion, the energy values required to cause a substance to evaporate or condense are the same, and we use the term "latent heat of vaporization" for both values.



Specific Latent Heat

*The **specific latent heat (L)** of a substance is the amount of thermal energy required for 1 kg of substance to change from one state into another. Every substance has a different specific latent heat because every substance is composed of different particles.*

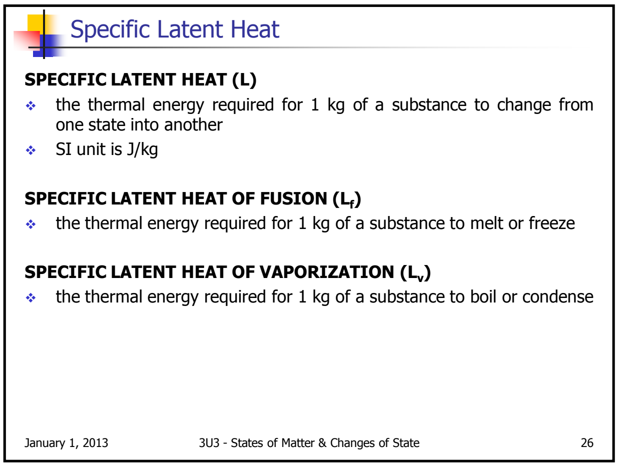
Substance	Specific latent heat of fusion (L_f) (J/kg)	Melting point (°C)	Specific latent heat of vaporization (L_v) (J/kg)	Boiling point (°C)
aluminum	6.6×10^5	2519	4.0×10^5	10 900
ethyl alcohol	1.1×10^5	−114	8.6×10^5	78.3
carbon dioxide	1.8×10^5	−78	5.7×10^5	−57
gold	1.1×10^6	2856	6.4×10^4	1 645
lead	2.5×10^4	327.5	8.7×10^5	1 750
water	3.4×10^5	0	2.3×10^6	100



Specific Latent Heat

*The **specific latent heat of fusion (L_f)** is the thermal energy required for 1 kg of a substance to melt or freeze. The **specific latent heat of vaporization (L_v)** is the thermal energy required for 1 kg of a substance to boil or condense.*

Substance	Specific latent heat of fusion (L_f) (J/kg)	Melting point (°C)	Specific latent heat of vaporization (L_v) (J/kg)	Boiling point (°C)
aluminum	6.6×10^5	2519	4.0×10^5	10 900
ethyl alcohol	1.1×10^5	−114	8.6×10^5	78.3
carbon dioxide	1.8×10^5	−78	5.7×10^5	−57
gold	1.1×10^6	2856	6.4×10^4	1 645
lead	2.5×10^4	327.5	8.7×10^5	1 750
water	3.4×10^5	0	2.3×10^6	100



Specific Latent Heat

SPECIFIC LATENT HEAT (L)

- the thermal energy required for 1 kg of a substance to change from one state into another
- SI unit is J/kg

SPECIFIC LATENT HEAT OF FUSION (L_f)

- the thermal energy required for 1 kg of a substance to melt or freeze

SPECIFIC LATENT HEAT OF VAPORIZATION (L_v)

- the thermal energy required for 1 kg of a substance to boil or condense

Latent Heat

To calculate the latent heat (Q) involved during a change of state, you can use the following equations:

$Q_f = mL_f$ *for substances that are melting or freezing*
$Q_v = mL_v$ *for substances that are boiling or condensing*

where m is the mass of the substance, L_f is the specific latent heat of fusion, and L_v is the specific latent heat of vaporization.

Latent Heat

LATENT HEAT (Q)

$Q_f = mL_f$ (for substances that are melting or freezing)
$Q_v = mL_v$ (for substances that are boiling or condensing)

where Q_f , Q_v is the latent heat of fusion/vaporization (J)
m is the mass of the substance (kg)
L_f , L_v is the specific latent heat of fusion/vaporization (J/kg)

NOTE!
Latent heat relates to a substance changing state whereas quantity of heat relates to a substance in a particular state warming up or cooling down.

Latent Heat

PRACTICE

6. How much thermal energy is released by 652 g of molten lead when it changes into a solid? The specific latent heats for lead are:
   - $L_f = 2.5 \times 10^4$ J/kg
   - $L_v = 8.7 \times 10^5$ J/kg

$Q_f = 1.6 \times 10^4$ J ☜ since lead is changing from a liquid to a solid we need to use the latent heat of fusion

Latent Heat

PRACTICE

7. How much thermal energy is absorbed when a 350 g bar of gold melts? The specific latent heats for gold are:
   - $L_f = 1.1 \times 10^4$ J/kg
   - $L_v = 6.4 \times 10^4$ J/kg

$Q_f = 3.9 \times 10^5$ J ☜ since gold is changing from a solid to a liquid we need to use the latent heat of fusion

✔ Check Your Learning

TEXTBOOK

P.295 Q.6-8

P.303 Q.1 (PJ: When a Brewer Becomes a Scientist)