# Chapter 17

# Change of Phase

# This lecture will help you understand:

- Phases of Matter
- Evaporation
- Condensation
- Boiling
- Melting and Freezing
- Energy and Changes of Phase

# Phases of Matter

Matter exists in four common phases that involve transfer of internal energy:

- Solid phase (ice)
- Liquid phase (ice melts to water)
- Gaseous phase (water turns to vapor; addition of more energy vaporizes water to vapor)
- Plasma phase (vapor disintegrates to ions and electrons)

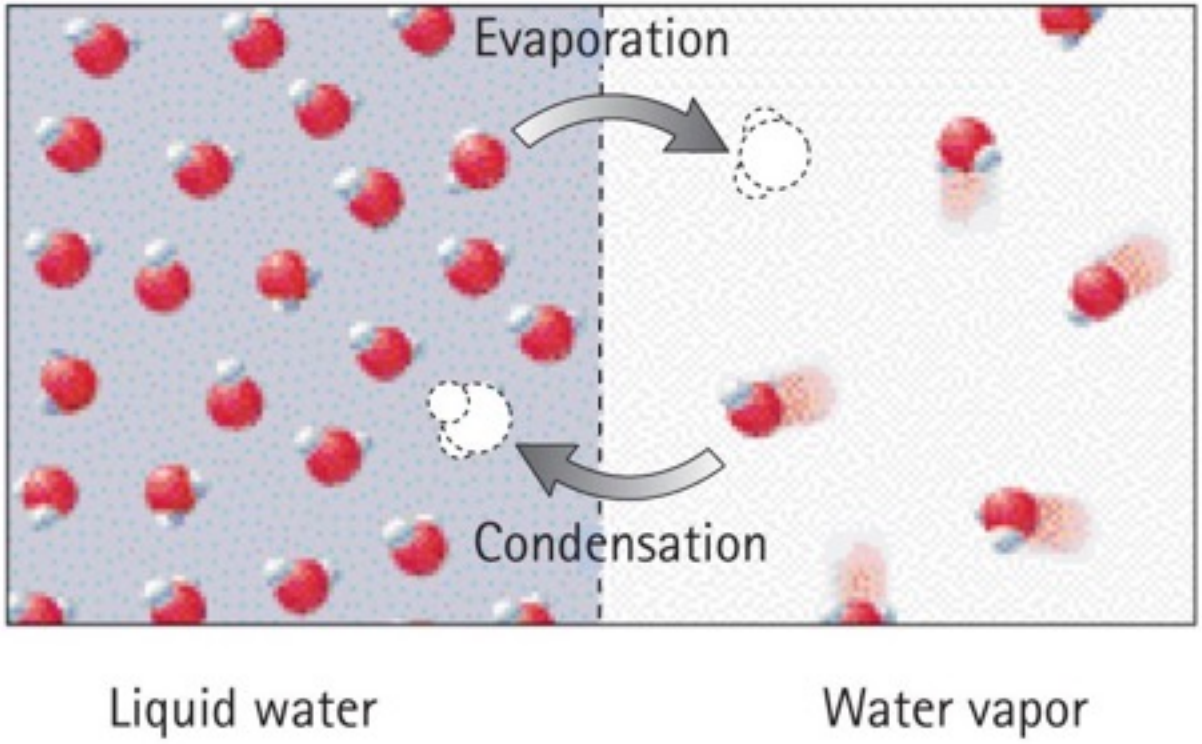
# Phases of Matter

- The phase of material depends upon the temperature and pressure.
- Change from Solid → Liquid → Gas → Plasma requires energy to be added to the material.
- Energy causes the molecules to move more rapidly.

# Evaporation

## Evaporation

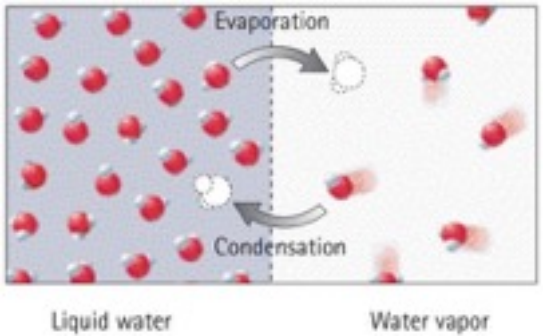
- Change of phase from liquid to gas



# Evaporation

- Molecules in liquid move randomly at various speeds, continually colliding into one another.
- Some molecules gain kinetic energy while others lose kinetic energy during collision.
- Some energetic molecules escape from the liquid and become gas.
- Average kinetic energy of the remaining molecules in the liquid decreases, resulting in cooler water.

→ evaporation is a cooling process.



# Evaporation

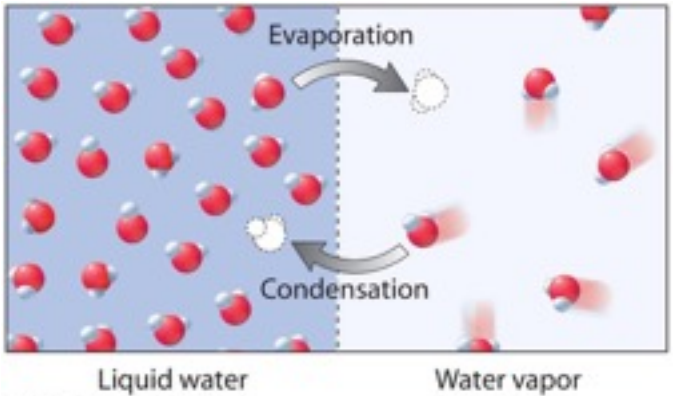
Evaporation is important in cooling our bodies when we overheat

- Sweat glands produce perspiration.
- Water on our skin absorbs body heat as evaporation cools the body.
- Helps to maintain a stable body temperature.

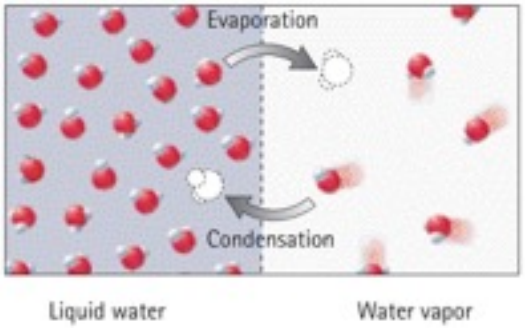
# Condensation

## Condensation process

- Opposite of evaporation
- Warming process from a gas to a liquid
- Gas molecules near a liquid surface are attracted to the liquid
- They strike the surface with increased kinetic energy, becoming part of the liquid



# Condensation



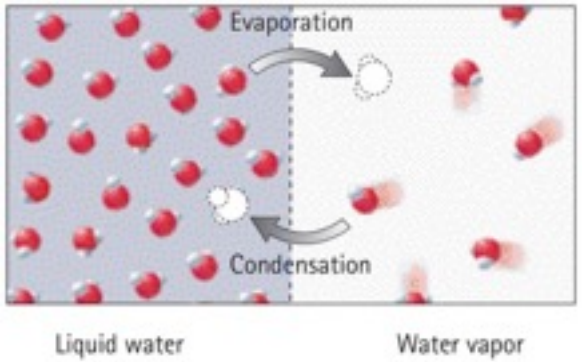

- Kinetic energy is absorbed by the liquid, resulting in increased temperature.

  Examples:

  - Steam releases much energy when it condenses to a liquid and moistens the skin—hence, it produces a more damaging burn than from same-temperature 100°C boiling water.

  - You feel warmer in a moist shower stall because the rate of condensation exceeds the rate of evaporation.

# Condensation




Examples:

- In dry cities, the rate of evaporation from your skin is greater than the rate of condensation, so you feel colder.
- In humid cities, the rate of evaporation from your skin is less than the rate of condensation, so you feel warmer.
- A cold soda pop can is wet in warm air because slow-moving molecules make contact with the cold surface and condense.

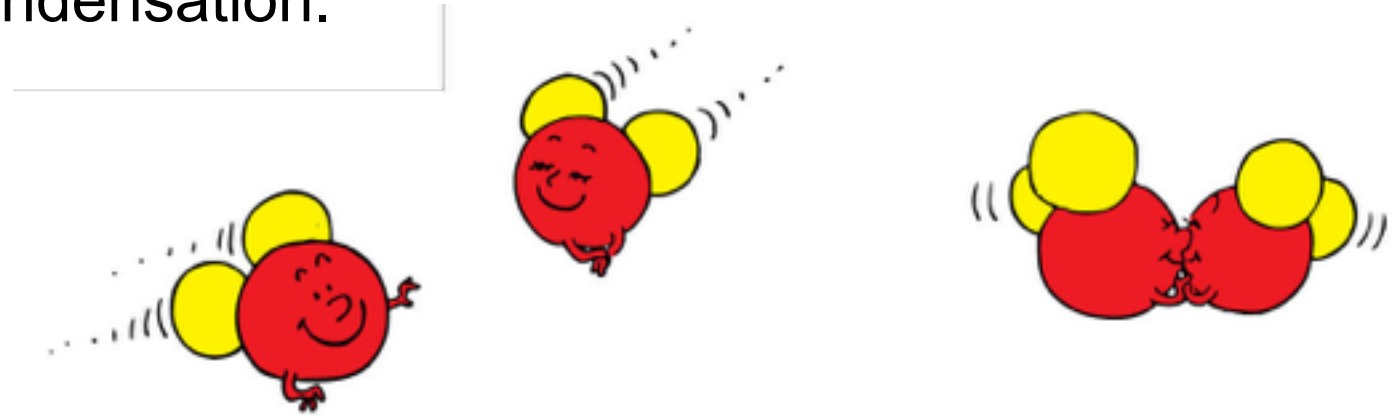
# Condensation in the Atmosphere

- The measure of the amount of water vapor in the air is **humidity** or mass of water per volume of air.
- Relative humidity is the ratio of the present humidity to the greatest humidity or amount of water the air could hold at that temperature.
- Saturation occurs when air temperature drops and water vapor begins condensing.

# Condensation

## **Condensation** in the atmosphere

- When the temperature of the atmosphere is low, the water molecules in the air move slowly.
- Slow-moving water molecules stick together, causing condensation.



Slow-moving $H_2O$ molecules coalesce upon collision

- Example:  Fog and clouds created when air rises

When you step out after a hot shower you feel cold, but you can feel warm again if you step back into the shower area. Which process is responsible for this?

A. Evaporation
B. Condensation
C. Both of these.
D. None of the above.

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B. **Condensation**
C. Both of these.
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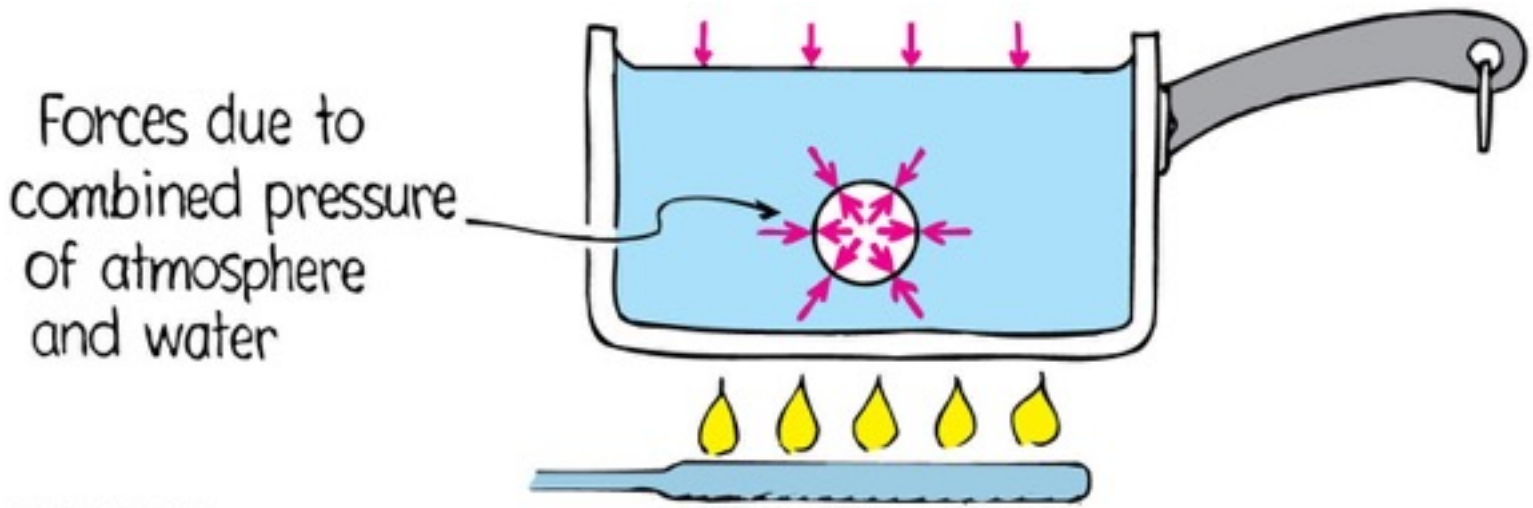
*Explanation*:
When you step back into the shower area, the steam that is present condenses on your body, causing it to warm up.

# Boiling

## Boiling process

- Rapid evaporation from beneath the surface of a liquid.



# Boiling

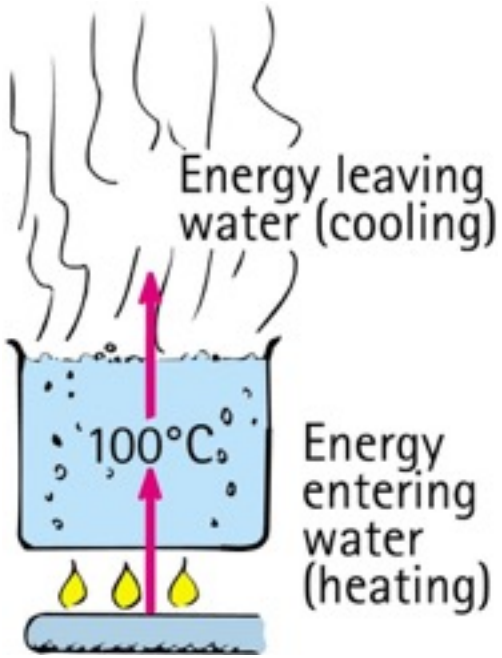
Boiling process

- Rapid form of evaporation beneath the surface forms vapor bubbles.
- Bubbles rise to the surface.
- If vapor pressure in the bubble is less than the surrounding pressure, then the bubbles collapse.
- Hence, bubbles don’t form at temperatures below boiling point (vapor pressure is insufficient).

# Boiling

## Boiling process

- Boiling water at 100°C is in thermal equilibrium—boiling water is being cooled as fast as it is being warmed.
- In this sense, boiling is a cooling process.



# Boiling

- Boiling point depends on pressure.

  Example: Buildup of vapor pressure inside a pressure cooker prevents boiling, thus resulting in a higher temperature that cooks the food.

- Boiling point is lower with lower atmospheric pressure.

  Example: Water boils at 95°C in Denver, CO (high altitude) instead of at 100°C (sea level).

The process of boiling

A. cools the water being boiled.
A. depends on atmospheric pressure.
B. is a change of phase below the water surface.
C. All of the above.

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C. **All of the above.**

# Melting and Freezing

**Melting**

- Occurs when a substance changes phase from a solid to a liquid
- Opposite of freezing
- When heat is supplied to a solid, added vibration breaks molecules loose from the structure and melting occurs.

# Melting and Freezing

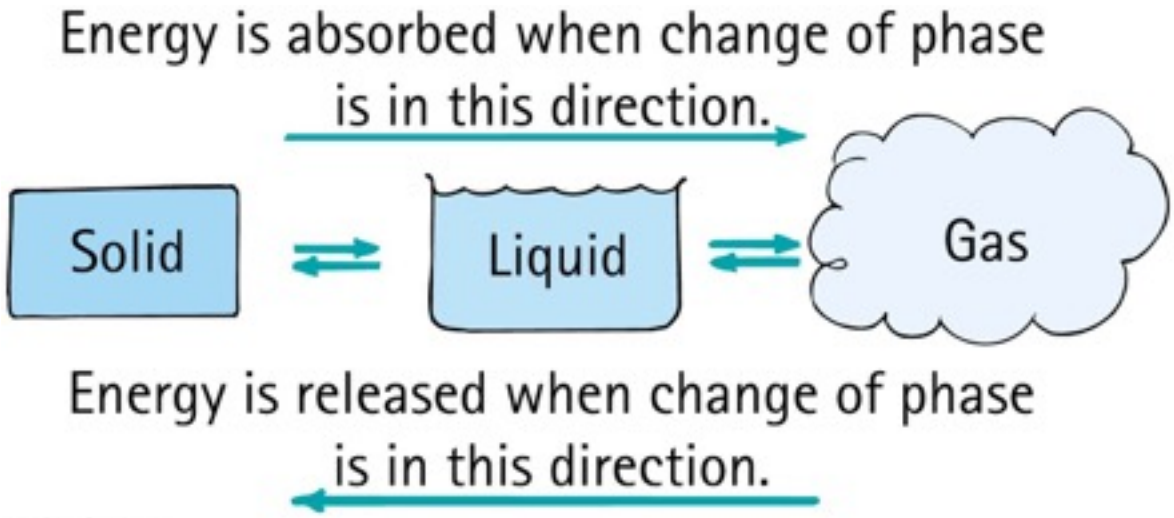
**Freezing**

- Occurs when a liquid changes to a solid
- Opposite of melting
- When energy is continually removed from a liquid, molecular motion decreases until the forces of attraction bind them together and formation of ice occurs.

# Energy and Change of Phase

## Energy and Change of Phase

A. From solid to liquid to gas phase
   A. add energy
- From gas to liquid to solid phase
  – remove energy



# Energy and Change of Phase

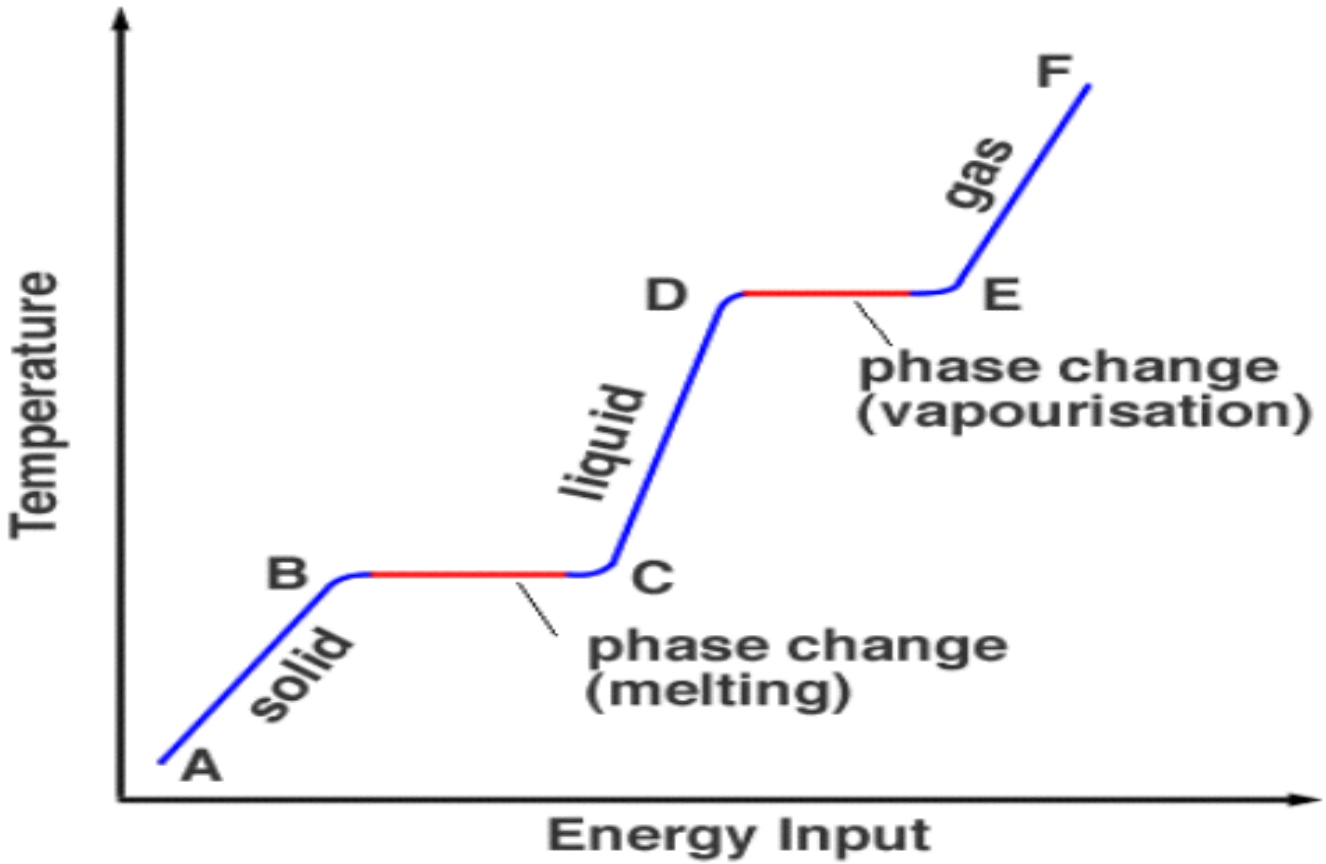
## Heat of fusion

- Amount of energy needed to change any substance from solid to liquid and vice versa
  - Heat of fusion for water is 334 joules/g.

# Energy and Change of Phase

## Heat of vaporization

- Amount of energy needed to change any substance from liquid to gas and vice versa
  - Heat of vaporization for water is 2256 joules/g.




http://www.splung.com/content/sid/6/page/latentheat

When snow forms in clouds, the surrounding air is

A. cooled.
A. warmed.
B. insulated.
C. thermally conducting.

*Hint: the change of phase is from gas to solid.*

When snow forms in clouds, the surrounding air is

A. cooled.
A. **warmed.**
B. insulated.
C. thermally conducting.

*Explanation*:

The change of phase is from gas to solid, which releases energy.

Ice is put in a picnic cooler. To speed up the cooling of cans of beverage, it is important that the ice

A. melts.
A. is prevented from melting.
B. be in large chunks.
C. None of the above.

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**A. melts.**

A. is prevented from melting.

B. be in large chunks.

C. None of the above.

*Explanation*:

For each gram of ice that melts, 540 calories is taken from the beverage.

# Homework

Exercises 1, 3, 11, 15, 23, 31, 41, 49, 55, 57

Due: July 11