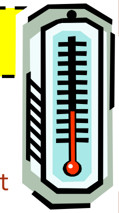
CHAPTER 14

Heat and Temperature

Temperature



- Related to the average kinetic energy of an object's atoms or molecules
  - The degree of "hotness" or "coldness" of an object
- What makes something hot?
  - Particles that make up matter are in constant motion
  - They have kinetic energy
  - When you heat something the particles move faster

So, what kind of energy does temperature measure?

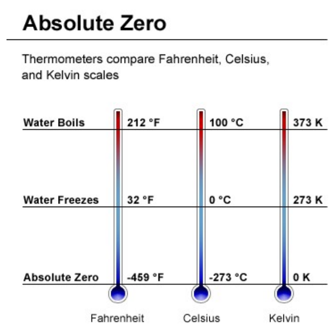
Measuring Temperature

- The absolute temperature scale is called the **Kelvin** scale.

-Absolute zero is 0 K.

-The melting point of ice is 273 K, and the boiling point of water is 373 K.

-There are **<u>no negative</u>** numbers on the Kelvin scale.

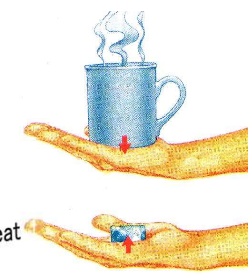


Heat

Cup gets cooler while hand gets warmer

- **Heat is the thermal energy transferred from one thing to another due to a temperature difference.**

Heat always flows from warmer to cooler objects.



Temperature tells you direction of heat transferring.

- Faster molecules (high temperature) hit slower molecules (low temperature) and speed them up

Ice gets warmer while hand gets cooler

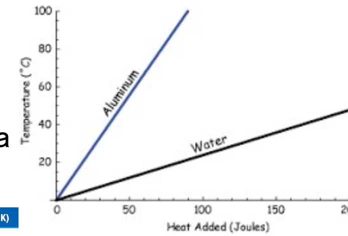
Specific Heat

- The amount of energy required to change the temperature of substance.
- Identifies type of conductor.

Substance	c (J/kg•K)	Substance	c (J/kg•K)
Water (liquid)	4,186	Copper	385
Ethanol (liquid)	2,440	Iron	449
Ammonia (gas)	2,060	Silver	234
Steam	1,870	Mercury	140
Aluminum	897	Gold	129
Carbon (graphite)	709	Lead	129

Specific Heat

- Heat capacity depends on:
  - Temperature of object
  - Mass of object
  - Type of object
- Substance with high specific heat, require a lot of energy.



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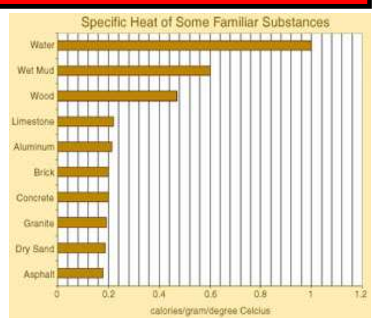
Specific Heat

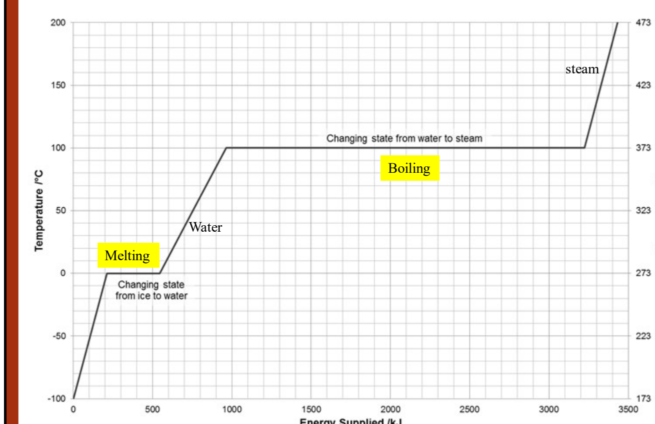
Different materials have specific heat capacities.

Some substances change temperature more easily than others.



- Water has a high specific heat of 4186 J/kg K
- Metals have a low specific heat

Specific Heat of Water



Specific Heat

C of water = 4186 J/kg/K

- Big value of Energy= slower increase in temperature

C of iron = 450 J/kg/K

- Small value of Energy = faster increase in temperature.

Calculating Specific Heat

- Energy = mass x change in temp x Specific heat

$$Q = m \times \triangle T \times C$$

Q = change in thermal energy (Joules)

m = mass of substance (kg)

$\triangle T$ = change in temperature ($T_f - T_i$) (Kelvin)

C = specific heat of substance J/Kg K

Understanding Specific Heat

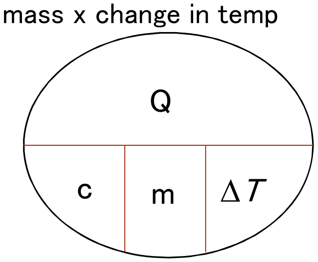
$$Q = m \times \triangle T \times C$$

As mass, Temperature, or specific heat increases, the energy required also increases.

As mass, Temperature, or specific heat decreases, the energy required also decreases.

Calculating Specific Heat

- Energy = Specific heat x mass x change in temp
- Energy (Q) = $cm\Delta T$
- mass= kg
- energy= Joules
- Temperature= K
- c= specific heat



Specific heat is the "price" to change 1 kg of a substance.

Practice Problems: Specific Heat

1. How much energy must be transferred as heat to 200 kg of water in a bathtub to raise the water's temperature from 25 °C to 37 °C?

$Q = cm\Delta T$

ΔT= 37 °C– 25 °C
ΔT= 12 K

m= 200 kg

c= 4,186 J/kg x K

Q = ?

Q = 4186 x 200 kg x 12 k

Q= 10,000,000 J or 1.0 x 10^7 J

Substance	c (J/kg•K)	Substance	c (J/kg•K)
Water (liquid)	4,186	Copper	385
Ethanol (liquid)	2,440	Iron	449
Ammonia (gas)	2,060	Silver	234
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Practice Problems: Specific Heat

2. How much heat does it take to change the temperature of 3 kg of water by 75 K?

Q = 4186 x 3 kg x 75 k

Q = 900000 J or 9.0 x 10^5 J

$Q = cm\Delta T$

ΔT= 75 K

m= 3 kg

c= 4,186 J/kg x K

Q = ?

Substance	c (J/kg•K)	Substance	c (J/kg•K)
Water (liquid)	4,186	Copper	385
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Practice Problems: Specific Heat

3. In order to make tea, 322,000 J of energy were added to 10 kg of water. What was the temperature change of water?

$\Delta T = Q/(cm)$

Q = *322, 000 J*

m= 10 kg

c= 4,186 J/kg x K

ΔT = ?

ΔT= 322,000 J/ (4,186 J/kg*K x 10 kg)

ΔT= *7.7* K

Substance	c (J/kg•K)	Substance	c (J/kg•K)
Water (liquid)	4,186	Copper	385
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Practice Problems: Specific Heat

4. How much energy is needed to increase the temperature of 0.755 kg of iron from 283 K to 403 K?

$Q = cm\Delta T$

ΔT= 403 K –283 K
ΔT= 120 K

m= 0.755 kg

c= 449 J/kg x K

Q = ?

Q = 449 x 0.755 kg x 120 k

Q = 40,700 J

Substance	c (J/kg•K)	Substance	c (J/kg•K)
Water (liquid)	4,186	Copper	385
Ethanol (liquid)	2,440	Iron	449
Ammonia (gas)	2,060	Silver	234
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Specific Heat Practice

- Which material on the specific heat chart heats up the fastest? Lead
- Which material on the specific heat chart heats up the slowest? Liquid water
- Which material needs the most amount of energy to raise its temperature? Liquid water
- In set below, circle the 3 materials that would heat up the fastest?

Water Iron Copper
Ice Basalt Granite
Lead Water Iron

- Compare the heating and cooling rate of land and water, using the terms "specific heat" to explain your comparison.

Water has a higher specific heat than land, so it takes long to heat and cool.

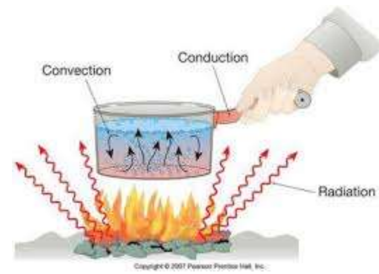
Specific Heats of Common Materials

MATERIAL	SPECIFIC HEAT (Joules/gram • °C)
Liquid water	4.18
Solid water (ice)	2.11
Water vapor	2.00
Dry air	1.01
Basalt	0.84
Granite	0.79
Iron	0.45
Copper	0.38
Lead	0.13

14.2 Energy Transfer

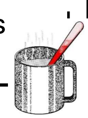
Heat can be transferred 3 different ways:

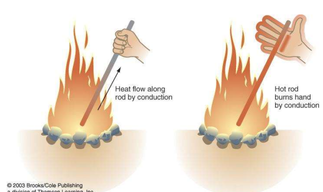
1. Conduction
2. Convection
3. Radiation

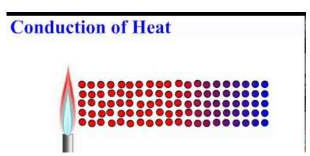


Energy Transfer: Conduction

- Transferred of energy by direct contact with materials
- Works best in some solids, then liquids least in gases.



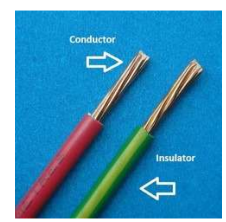




Energy Transfer: Conduction

- Conductors– materials that allow heat to pass through them
- Most metals (copper, aluminum, steel

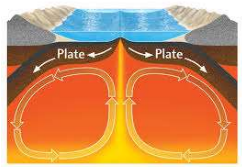
- Insulators– materials that don't let heat pass through them well
- Rubber, plastics, glass, air



Energy Transfer: Convection

- Transferring energy by moving fluids
- Liquids and gases are fluids
- When heated they expand, become less dense
- They rise, replaced by cooler denser fluids
- Make a circular flow called a convection current

Remember:
Hot-Rises → Less Dense
Cold-Falls → More Dense



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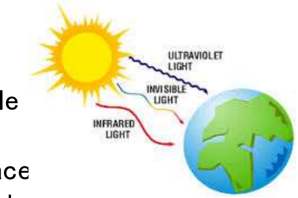
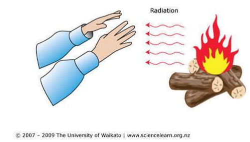
Energy Transfer: Radiation

- Energy transferred by electromagnetic waves
  - Ex: infrared radiation, visible light, ultraviolet rays
- Can travel through empty space
- When wave hit object they make the molecules move faster.

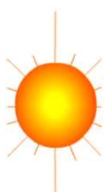


Can travel without the need of a medium (material)



The third method of heat transfer

How does heat energy get from the Sun to the Earth?



?

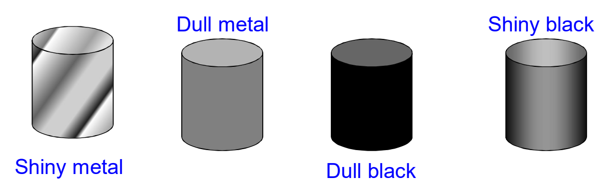
No medium

There are no particles between the Sun and the Earth so it CANNOT travel by conduction or by convection.

RADIATION

Emission experiment

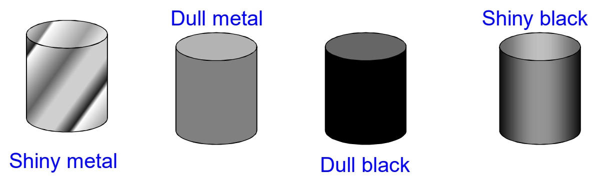
Four containers were filled with warm water. Which container would have the warmest water after ten minutes?



The shiny metal container would be the warmest after ten minutes because its shiny surface reflects heat radiation back into the container so less is lost. The dull black container would be the coolest because it is the best at emitting heat radiation.

Absorption experiment

Four containers were placed equidistant from a heater. Which container would have the warmest water after ten minutes?



The dull black container would be the warmest after ten minutes because its surface absorbs heat radiation the best. The shiny metal container would be the coolest because it is the poorest at absorbing heat radiation.

3. How does heat energy reach the Earth from the Sun?

A. Radiation
B. Conduction
C. Convection
D. Insulation

4. Which is the best surface for reflecting heat radiation?

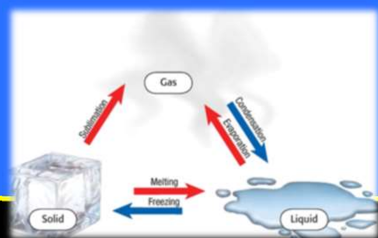
A. Shiny white
B. Dull white
C. Shiny black
D. Dull black

5. Which is the best surface for absorbing heat radiation?

A. Shiny white
B. Dull white
C. Shiny black
D. Dull black

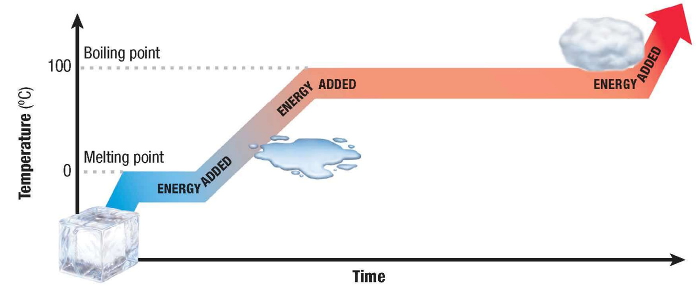
Chapter 3.2 Changes of State

- What happens when a substance changes from one state of matter to another?
- What happens to mass and energy during physical and chemical changes?



Temperature vs. Time

Adding energy either raises T or changes state, not both at the same time.



Energy and Changes of State

- The identity of a substance does not change during a change in state
- The ability to change or move matter
  - As you add energy to a liquid, the temperature goes up separating molecules
- Some changes of state require energy
  - Melting, evaporation and sublimation

melting

evaporation

sublimation

Energy and Changes of State

Evaporation

- The change of state from a liquid to a gas

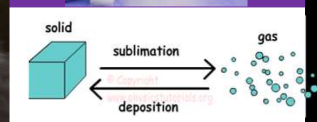
- Boiling Point- The temperature at which a liquid boils.

Energy and Changes of State

Sublimation

- The process in which a solid changes directly into a gas

  Ex. Dry ice (Carbon dioxide in the solid form) changes directly from a solid to a gas

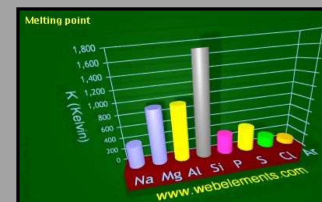


Video Clip

Energy and Changes of State

Melting Point

- The temperature at which a substances changes from solid to liquid. 32 degrees F 0 degrees C
- Melting point depends on the pressure.



Energy and Changes of State

- Energy is released in some changes of state
  - Freezing, condensation & deposition

Freezing

Condensation

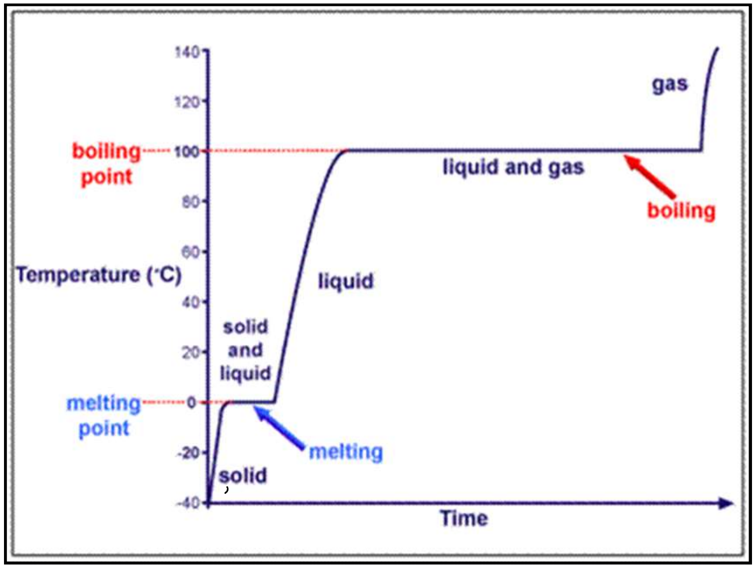
Deposition

Dry ice (solid carbon dioxide) sublimes to form gaseous carbon dioxide but no liquid.

sublimation

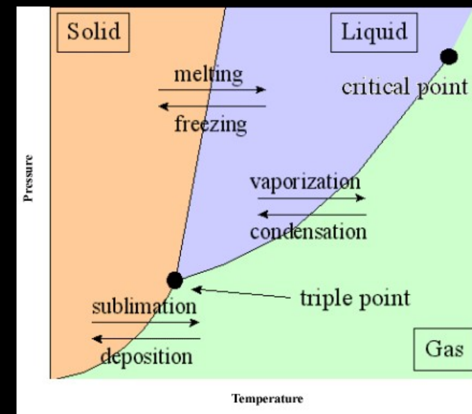
Solid —Melting→ Liquid —Boiling or evaporation→ Gas

Solid ←Freezing— Liquid ←Condensation— Gas



Phase Change Diagram

Lines on the graph represent equilibrium between phases.



Energy and Changes of State

Temperature

The temperature of a substance does not change during a change of state.

– For example, if you add energy to ice at 0°C, the temperature will **NOT rise until all of the ice has melted.**

– When energy is added –

– When energy is removed –