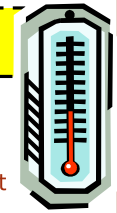
CHAPTER 14

Heat and Temperature


Temperature



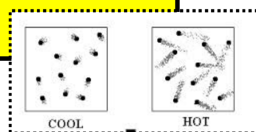
- The average thermal energy of an object's atoms or molecules
- The degree of "hotness" or "coldness" of an object

- **What makes something hot?**
  - Particles that make up matter are in constant motion
  - When you heat something the particles move faster

So, what kind of energy does temperature measure?

Thermal

Thermal Energy



- Transferred as particles collide
- Particles are always in motion no matter what state they are in.

Explain how the coffee is being heated.

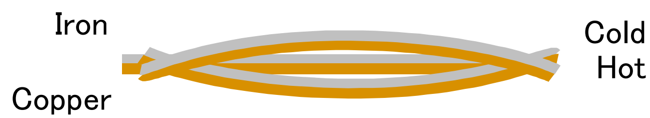
What type of heat transfer is this an example of?

Thermal Energy

Temperature

Measuring Temperature

- Metals expand when heated
- Different materials expand at different amounts



Temperature

-Upper Limit

- No upper limit exists.
- Plasma found in starts= millions of degrees C

-Lower Limit

- Definite limit called **absolute zero**.
- Molecules will slow down SO much, they will essentially stop moving
- Out of energy, so they can’t get any colder.

Temperature Scales

- Three different scales:
  1. Fahrenheit- the one we use
  2. Celsius- metric standard
  3. Kelvin- starts at absolute zero but same degree size as Celsius

Fahrenheit scale.

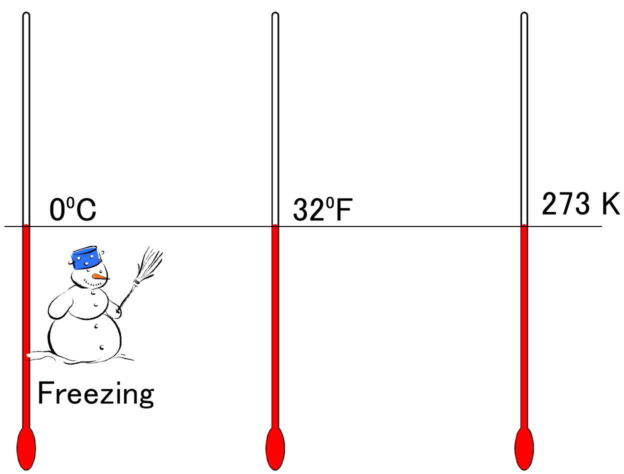
Water freezes 32 °F

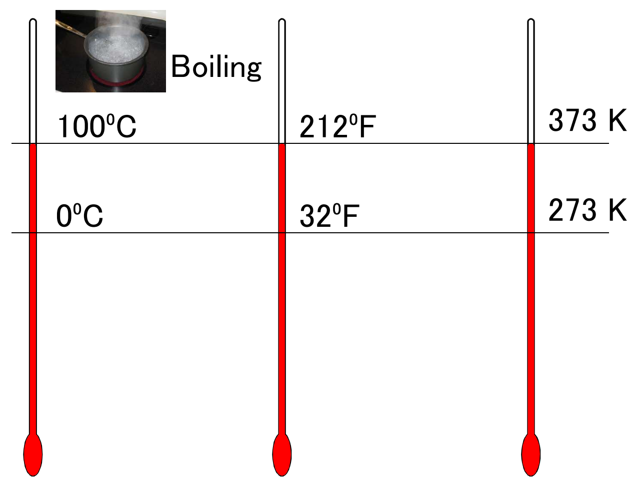
Water boils 212 °F

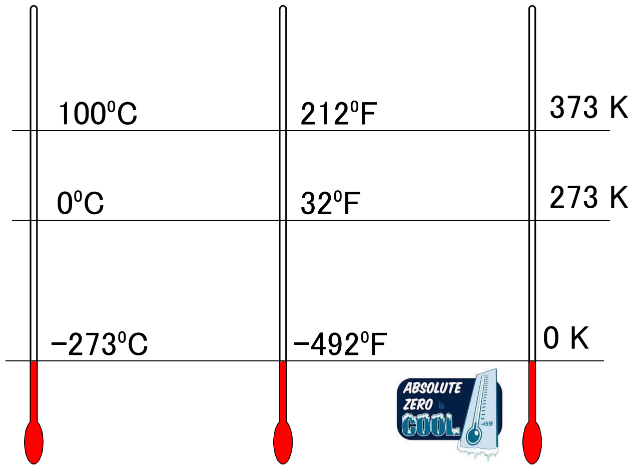
Celsius scale”

Freezing 0 ° C

Boiling 100 ° C







Temperature Conversion

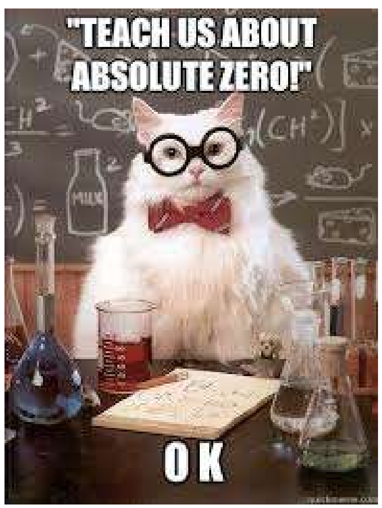
$K = C + 273$ $C = K - 273$

Convert the following to Celsius

1) 32 K −241°C
2) 1020 K 747°C
3) 45 K -228°C
4) 0 K -273°C
5) 70 K -203°C
6) 273 K 0°C

Convert the following to Kelvin

7) -50° C 223 K
8) -150° C 123 K
9) 90° C 363 K
10) 27 ° C 300 K



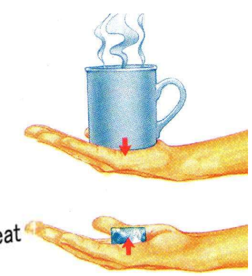
Heat, T and Energy Video

Thermal Energy

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

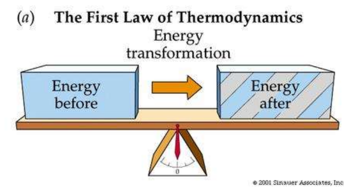
Check For Understanding

Which way will the energy move?

1^{st} Law of Thermodynamics

- First law of Thermodynamics:
  - For any system, the net change in energy equals the energy transferred as work and as heat.
  - A version of the law of conservation of energy
    - Energy can change forms, but cannot be created or destroyed

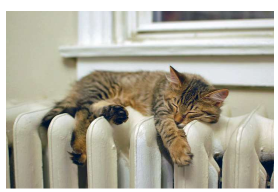
Whenever the total energy in a system increases, it must be due to energy that enters the system from an external source.



2^{nd} Law of Thermodynamics

- Energy spontaneously spreads from regions of <u>higher concentrations</u> to regions of <u>lower concentration</u>.
- Energy transfers as heat always moves from a hot to cold objects.

Will the heat move from the cat to the radiator?



Specific Heat

- The amount of energy required to change the temperature of 1 gram of a substance by 1° C.
- How easy or hard an object is to heat up.
- How fast does it absorb heat energy

- Metals have a low specific heat
- Water has a high specific heat

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 in Metals Clip

Specific Heat

- Heat capacity depends on:
  - Temperature of object
  - Mass of object
  - Type of object

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

- Substance with high specific heat, require a lot of energy.
- Substance with low specific heat, require small amount of energy.

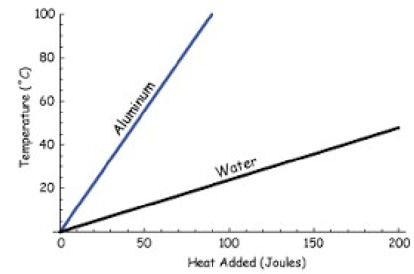
Specific Heat

1. Does aluminum have a high or low specific heat?

   Low specific heat

2. Does aluminum require a lot of heat to change temperature?

   Small amount of heat



3. Which took longer to change temperature, aluminum or water? Water

4. What are the temperatures both aluminum and water if they both have be heated by 50 Joules?

   Aluminum– 55 ° C
   Water – 10 ° C

Specific Heat

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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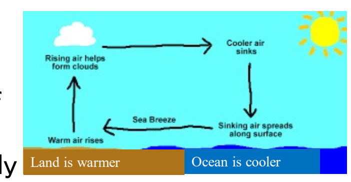
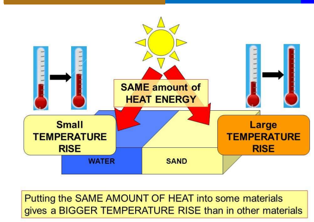
- <u>Conductor</u>
  - Low specific heat
  - Usually metals
  - Require small amount of heat to change T
  - Lose their energy quickly
- <u>Insulator</u>
  - High specific heat
  - Require a lot of heat to change T
  - Do not give up their energy easily

Water's Specific Heat

- Water has a high specific heat of 4186 J/kg K
- Water's specific heat is more than 4 times that of most metals
- Water helps moderate daily air temperatures around large bodies of water.



What does the diagram say about sands specific heat compared to the water?



Why does land heat up faster than water?

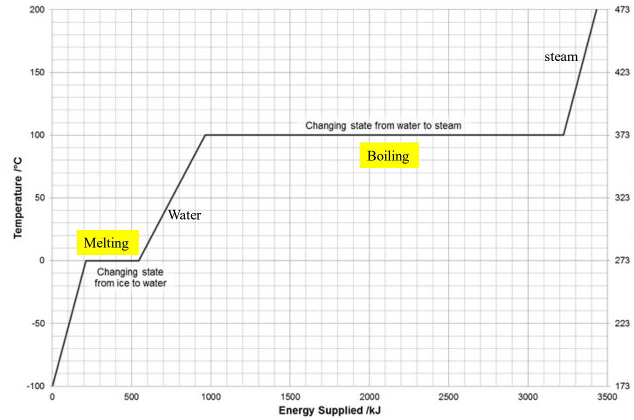
Land heats up and cools down faster than water, and aren't we lucky for that!?

C $_{water}$ = 4184 J / kg K ("holds" its heat)

C $_{sand}$ = 664 J / kg K (Release energy easily)

This is why land (low specific heat) heats up quickly during the day and cools quickly at night and why water takes longer.

Specific Heat of Water



Specific Heat

C of water = 4186 J/kg/K

- Big value of Energy= slower increase in temperature

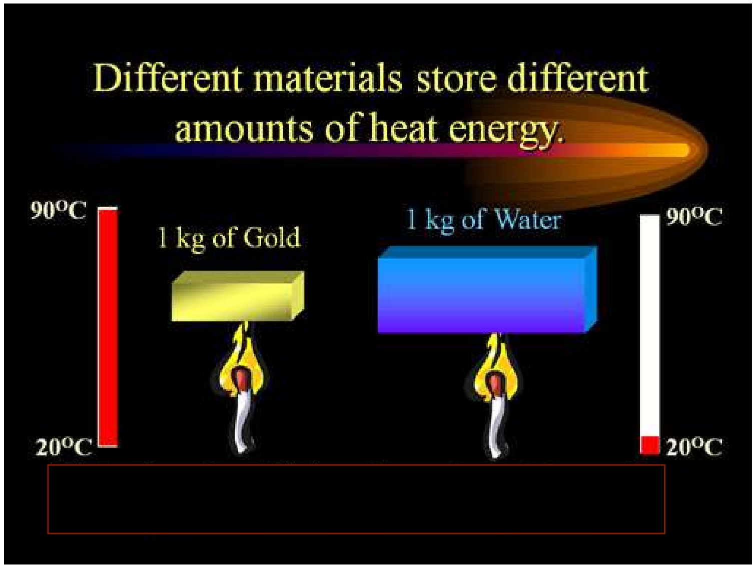
C of iron = 450 J/kg/K

- Small value of Energy = faster increase in temperature.

Observation:

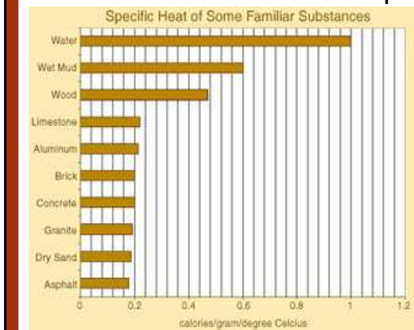
Different materials heat up at different rates.

What does that say about Gold's specific heat?



Specific Heat

Different materials have specific heat capacities.



What material on the graph requires the least amount of heat to change temperature?

What material has a higher specific heat, dry sand or wood?

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

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)

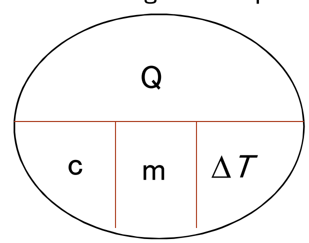
m = mass of substance (kg)

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

C = specific heat of substance J/kgK

Calculating Specific Heat

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



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

Understanding Specific Heat

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

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

Practicing Change in Temperature

ΔT = change in temperature ($T_f - T_i$)

1. A 15.75-g piece of iron absorbs 1086.75 joules of heat energy, and its temperature changes from 25 K to 175 K.

T_f= 175 K

T_i= 25 K

(175 K – 25 K)

150 K

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 K to 37K?

Q = $cm\Delta T$

ΔT= 37 K– 25 K
ΔT= 12 K

m= 200 kg

c= 4,186 J/kg x K

Q = ?

Q = 4186 x 200 kg x 12 k

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

Q= 10,046,400 J or 1.0 x 10^7 J

What does that say about it's specific heat?

Practice Problems: Specific Heat

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

Q = $cm\Delta T$

ΔT= 75 K

m= 3 kg

c= 4,186 J/kg x K

Q = ?

Q = 4186 x 3 kg x 75 k

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

Q = 941,850 J or 9.41 x 10^5 J

What does that say about it's specific heat?

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

$\Delta T = ?$

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

ΔT= 322,000 J/ (4,186 J/kg*K x 10 kg)

$\Delta T = 7.7$ K

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 = ?

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

Q = 449 x 0.755 kg x 120 k

Q = 40,679 J

Practice Problems: Specific Heat

5. A wooden block has a mass of 20.0 kg and a specific heat of 1,700 J/(kg· °C). Find the change in thermal energy of the block as it warms from 15.0 °C to 25.0 °C.

K = C + 273

A. Convert the initial temperature into Kelvin.

T_i = 15.0 °C K = 15.0 + 273 K = 288

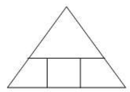
B. Convert final temperature into Kelvin.

T_f = 25.0 °C K = 25.0 + 273 K = 298

C. What is the change in Temperature in Kelvin?

$(T_f - T_i)$ 298 K −288 K K = 10

Name: ______________________________ Date: ______________



Determining Specific Heat Worksheet

Instructions: Use the following information to help you answer the questions.
Q = mcΔT, where **Q = heat energy, m = mass, c= specific heat capacity**, and **ΔT = change in temp.**
Remember, $\Delta T = (T_{final} - T_{initial})$.
Show all work and proper units.

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
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1. I have two substances A and B. A is at 293K and B is at 323 K. When they are mixed together:
   a. Heat will flow from ____________ to ____________.
   b. Substance A will __________________ (lose/gain) heat.
   c. After some time A and B will have the _________________ temperature.

2. Define a conductor.

3. Define an insulator.

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

3. A. How much energy must be transferred as heat to 400 kg of water in a bathtub to raise the water's temperature from 2 °C to 8 °C?

B. Why does water require this amount to increase the temperature by only 6 °C?

4. A. How much heat does it take to change the temperature of 12 kg of water by 145 K?

B. How does the mass of water affect the amount of energy to raise the temperature?

5. A. In order to make tea, 175,250 J of energy were added to 25.5 kg of water. What was the temperature change of water?

B. How would temperature be affected if only 100,000 J of energy were applied instead?

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

6. How much energy is needed to increase the temperature of 2.75 kg of gold from 144 K to 287 K?

7. A. A 0.016 kg piece of an unknown substance absorbs 1086.75 joules of heat energy, and its temperature changes from 25°K to 175°K. Calculate the specific heat capacity. Identify the unknown substance using the table above.

B. Is this substance a good conductor or a good insulator? ________________

C. Provide evidence supporting your claim above.

8. How many joules of heat are needed to raise the temperature of 0.010 kg of aluminum from 22°K to 55°K?

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

9. Calculate the specific heat capacity of a piece of wood if 1.5 kg of the wood absorbs 67,500 joules of heat, and its temperature changes from 32°K to 57°K.

10. A 0.10 kg of 4.0°K water is heated until its temperature is 37°K. Calculate the amount of heat energy needed to cause this rise in temperature.

11. A. A 0.025 kg of an unknown substance is heated from 25°K to 155°K, and absorbs 455 joules of heat in the process. Calculate the specific heat capacity. Identify the unknown substance.

B. Is this substance a good conductor or a good insulator? ____________

C. Provide evidence supporting your claim above.

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

12. Calculate the specific heat capacity and identify the unknown metal if 0.055 kg of the metal absorbs 193 J of heat and the temperature rises 15.0°K?

13. What mass of water will change its temperature by 3 °K when 525 J of heat is added to it?

14. A 0.3 kg piece of copper is heated and fashioned into a bracelet. The amount of energy transferred by heat to the copper is 66,300 J. If the specific heat of copper is 385 J/kg °K, what is the change of the copper's temperature?

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.

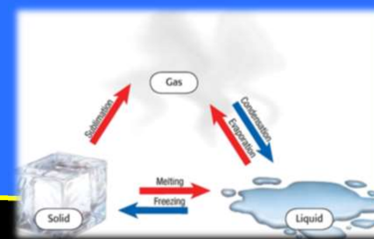
Water has a higher specific heat than land, so it takes long to heat and cool.

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

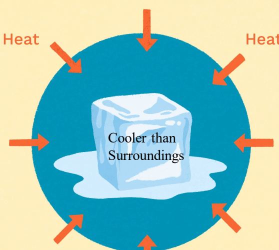
Chapter 3.2 Changes of State

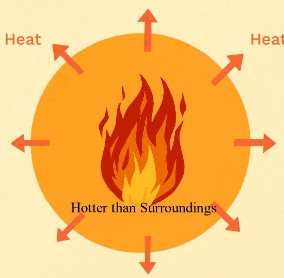
- What happens when a substance changes from one state of matter to another?
- What happens to mass and energy during physical and chemical changes?



Endothermic vs. Exothermic Reactions

Energy is conserved in chemical reactions. The total energy of the system is the same before and after a reaction





Endothermic

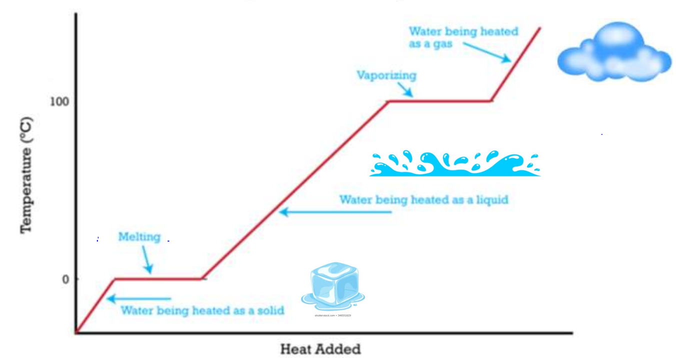
The endothermic reaction is cooler than surroundings

Exothermic

The exothermic reaction is hotter than surroundings

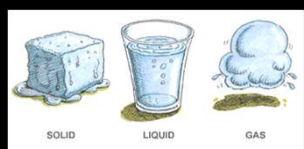
Heating Curve - Endothermic

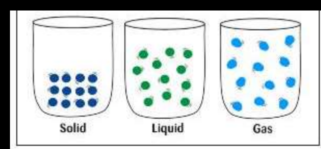
Adding energy either raises T or changes state, not both at the same time.



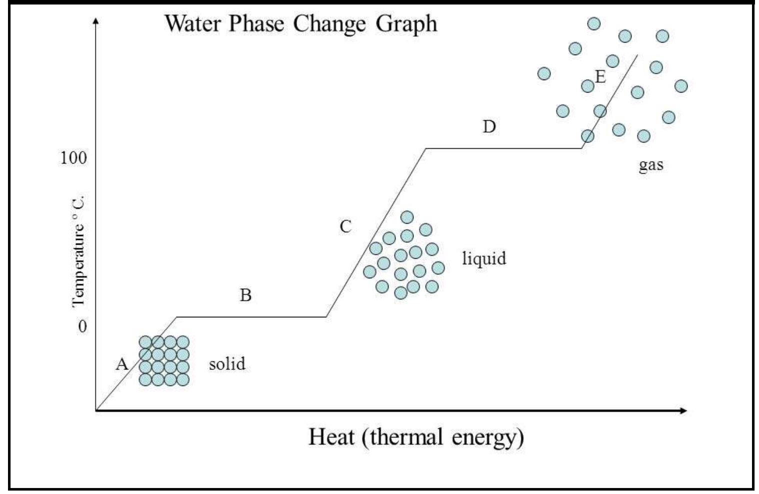
Energy and Changes of State

- The identity of a substance does not change during a change in state (Physical change)
- The ability to change or move matter
  - As you add energy to a liquid, the temperature goes up separating molecules



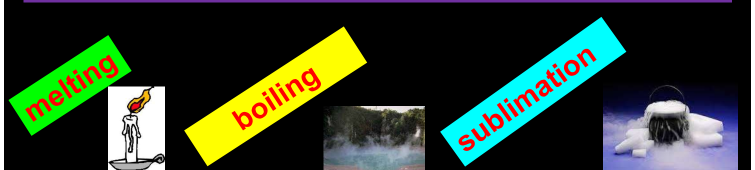


Heating Curve



Energy and Changes of State

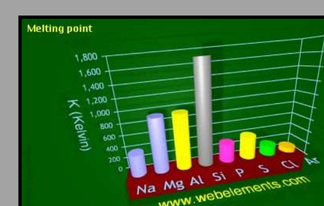
- Some changes of state require energy.
- Thermal energy increases
- Molecules speed up.
  - Melting, boiling and sublimation



Increase in Energy

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.



Increase in Energy

Boiling Point

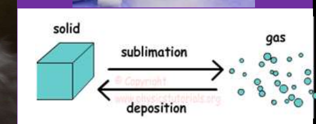
- The temperature at which a liquid turns into a gas.

Increase in Energy

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 is Released

- Energy is released in some changes of state. Loss of thermal energy
- Molecules slow down.
  - Freezing, condensation & deposition

Freezing

Condensation

Deposition

Energy is Released

Freezing

- Change of state from water to solid.
- Loss of thermal energy

Energy is Released

Condensation

- Change of state from gas to liquid.
- Loss of thermal energy

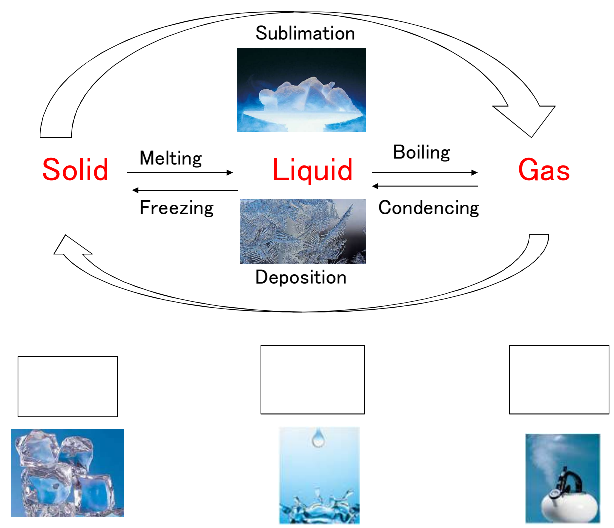
Energy is Released

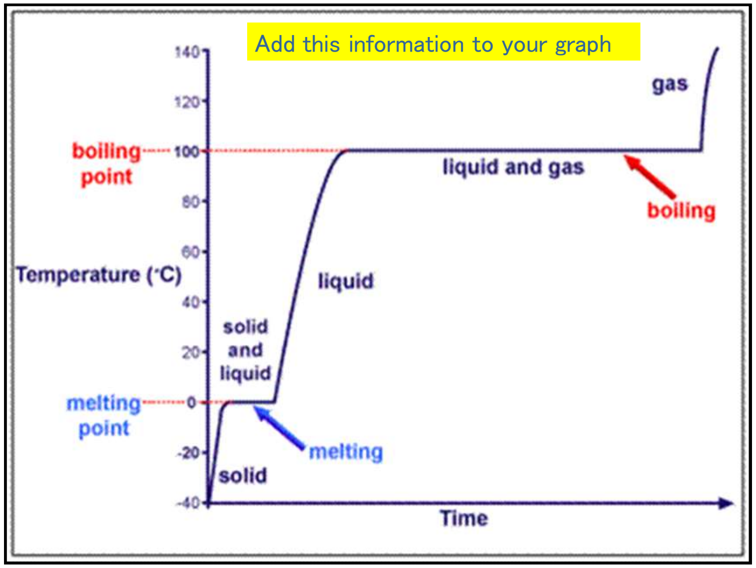
Deposition

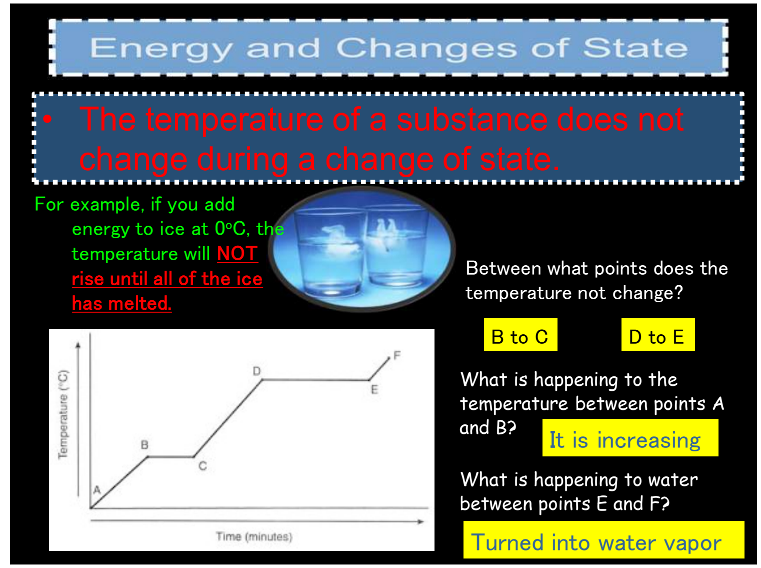
- Change of state from gas directly to solid.
- Skips the liquid state.

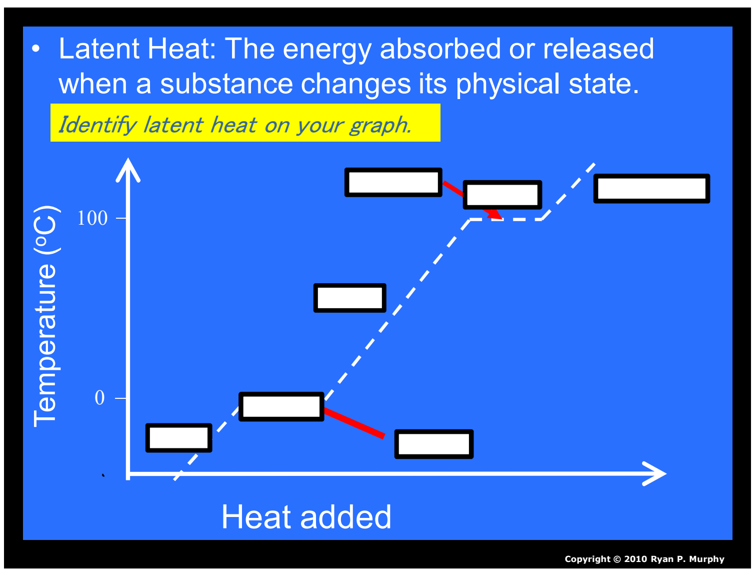
Name the physical phase change

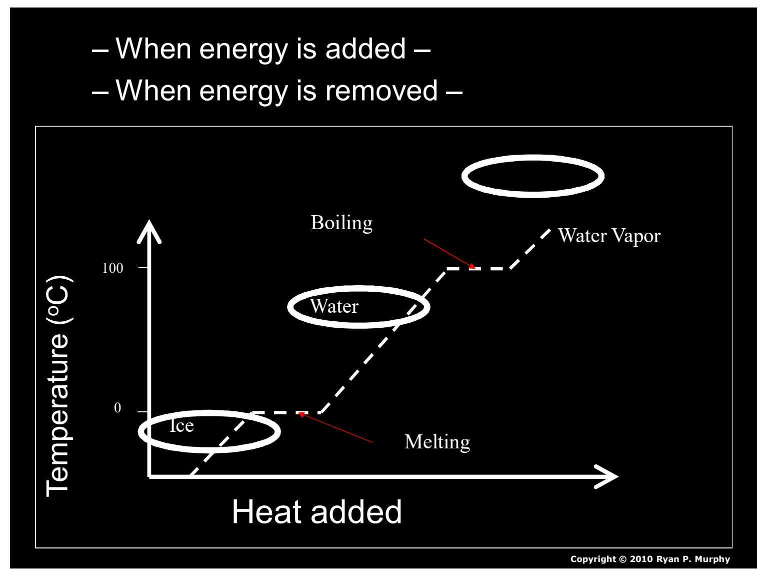
- Melting
- Freezing
- Sublimation
- Evaporation
- Condensation
- Deposition



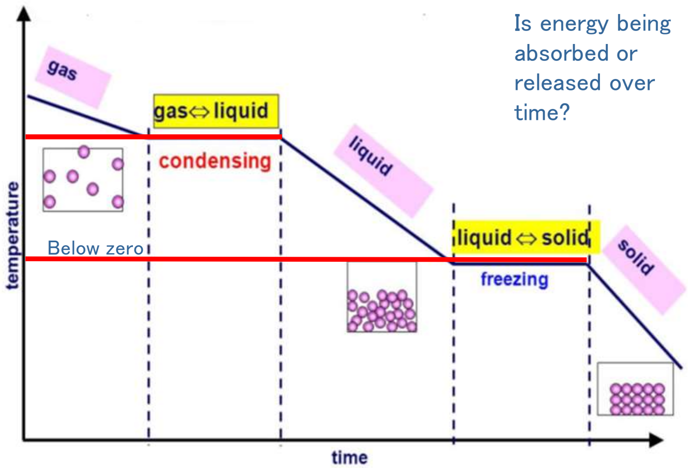

Add this information to your graph
Temperature (°C)
140
120
100
80
60
40
20
0
-20
-40
boiling point
melting point
gas
liquid and gas
boiling
liquid
solid and liquid
melting
solid
Time


Energy and Changes of State
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.
Temperature (°C)
Time (minutes)
A
B
C
D
E
F
Between what points does the temperature not change?
B to C
D to E
What is happening to the temperature between points A and B?
It is increasing
What is happening to water between points E and F?
Turned into water vapor


Latent Heat: The energy absorbed or released when a substance changes its physical state.
Identify latent heat on your graph.
Temperature (°C)
100
0
Heat added
Copyright © 2010 Ryan P. Murphy

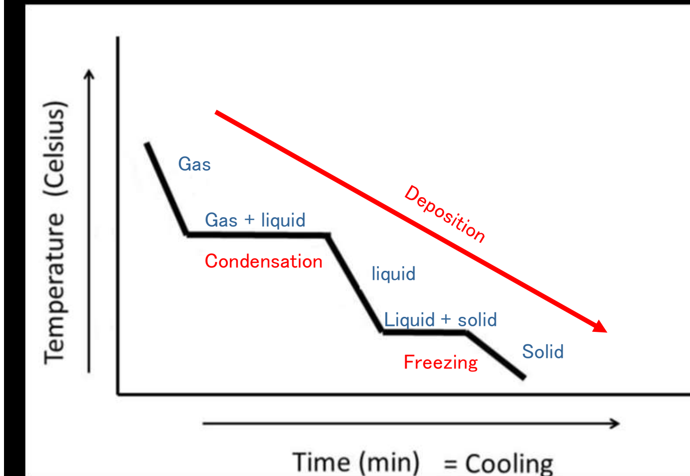

– When energy is added –
– When energy is removed –
Boiling
Water Vapor
100
Water
0
Ice
Melting
Temperature (°C)
Heat added
Copyright © 2010 Ryan P. Murphy

Cooling Curve – Exothermic



Is energy being absorbed or released over time?

Fill in the following phase diagram



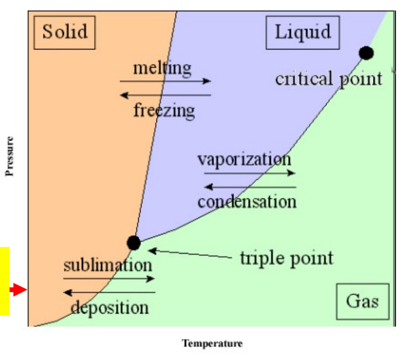
Phase Change Diagram

- A phase diagram shows the temperature and pressures necessary for each state of matter to exist.
- The **temperature** at which a phase change happens can change depending on the **pressure.**

This is why there are different cooking directions for "high altitudes".

Lines on the graph represent equilibrium between phases.

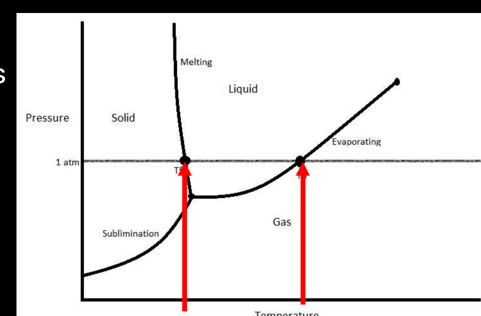
At this pressure, what states of matter can exist?



Phase Change Diagram

At 1 atm, what phases changes can occur?

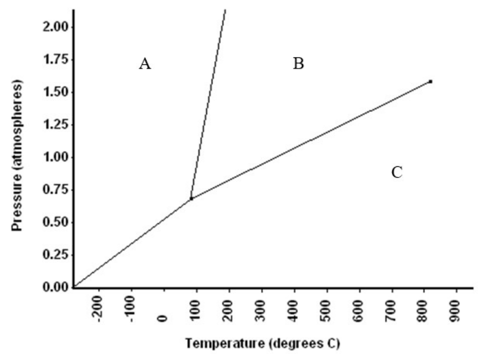
Melting and Evaporating (boiling)



Do they occur at the same temperature? No

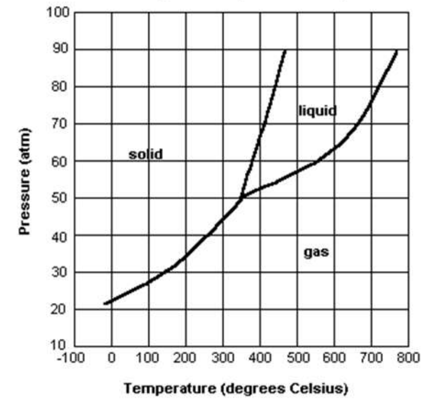
Worksheet

Phase Change Diagrams



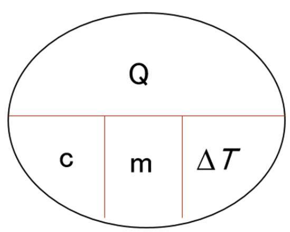
Worksheet

Phase diagram for mysterious compound X



Energy = mass x specific heat x change in Temperature

$$Q = m \times c \times \Delta T$$



$$K = C + 273 \qquad C = K - 273$$