N2 - THERMOCHEMISTRY

A Quick Review
(and a little new stuff)

Link to YouTube Presentation: https://youtu.be/KMr6JO8JqBc

Reminder…

There are going to be WAY more words on these slides than you need to write down. WAY more than in my Honors Chem lecture slides. A huge part of AP Chem is constantly going back and reviewing previous material, self studying, etc. So my slides are formatted so that when you come back to them you have a bit more "verbiage" there to help you!

DO NOT COPY EVERYTHING DOWN DURING LECTURE!

If you think you need to add more detail after class, that is why we do annotations as a homework assignment after we've taken the notes! Listen to me talking, take down *notes* and review and add to your notes later.

You are not a PHOTOCOPIER! You are a NOTE TAKER!

Notes Requirements

- **Highlighter line after KCQ boxes** to separate next assignment
- Big, bold, obvious title and number
  - **Example:** N2 – Thermochem a Quick Review
- Target in **RED PEN**
- Do NOT squish your notes! Do NOT write everything!
- Add **annotations** in three different colors.
  - Not JUST highlighting everything!
- **KCQ boxes** added at the end of the notes
  - K = key terms. List them, don't define them.
  - C = connection. Write a SPECIFIC connection to something you already know from another class, a TV show, real life, etc.
  - Q = two questions, one "higher level" not just a definition based question. Do not have to answer them.

N2 - THERMOCHEMISTRY

A Quick Review
(and a little new stuff)

Target: I can remember my Thermochem topics from Honors Chem, and can apply the 1st Law of Thermodynamics to various problems.

Things to Remember from Honors Chem…

If you are not comfortable, proficient, and QUICK at these then go back and review Honors Chem notes/videos/worksheets, etc.

Things to Remember from Honors Chem…

DON'T NEED TO WRITE DOWN

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Specific Heat Calculations

- $q = mC\Delta T$
- Molar Heats are the same concept, just with # moles of material not mass – UNITS!

Endothermic vs. Exothermic

- Endo, absorbed, $q = +$
- Exo, released, $q = -$
- How to draw a reaction coordinate diagram for each

Calorimetry Calculations

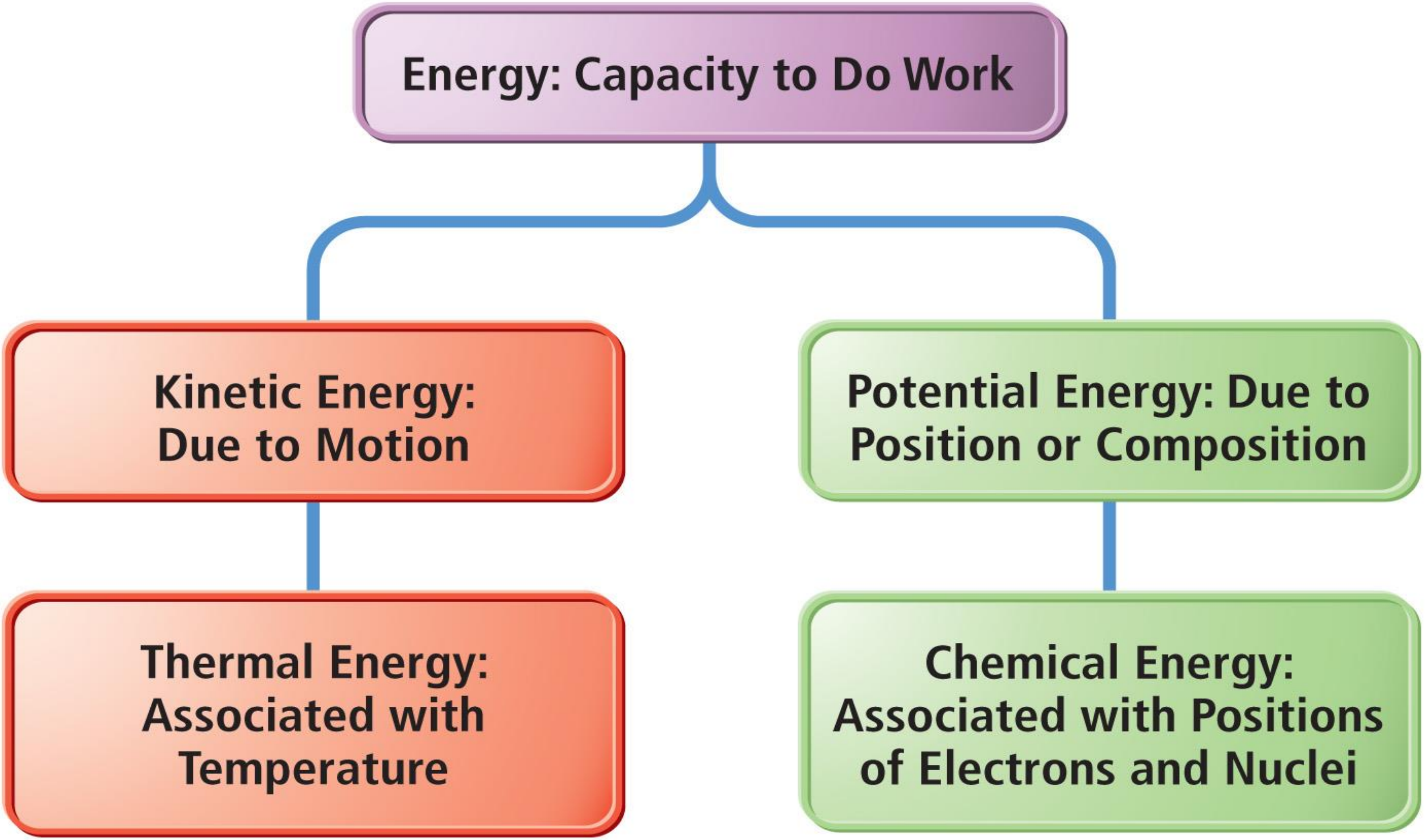
- $q_{absorbed} = -q_{released}$

Heating Curve Calculations

- Heating/cooling $q = mC\Delta T$
- Phase changes, $q = mL$

Manifestations of Energy

DON’T NEED TO WRITE DOWN



Energy: Capacity to Do Work

Kinetic Energy: Due to Motion

Potential Energy: Due to Position or Composition

Thermal Energy: Associated with Temperature

Chemical Energy: Associated with Positions of Electrons and Nuclei

Some Forms of Energy

Electrical

Kinetic energy

→ flow of electrical charge

Heat or thermal energy

Kinetic energy

→ molecular motion

Light or radiant energy

Kinetic energy

→ energy transitions in atom

Nuclear

Potential energy

→ in the nucleus of atoms

Chemical

Potential energy

→ structure of the atoms, attachment between atoms, position of atoms relative to each other in the molecule, and/or the position of the molecule relative to the larger structure

Calculating Kinetic Energy

Amount of kinetic energy an object has is directly proportional to its mass and velocity.

$$KE = \frac{1}{2}mv^2$$

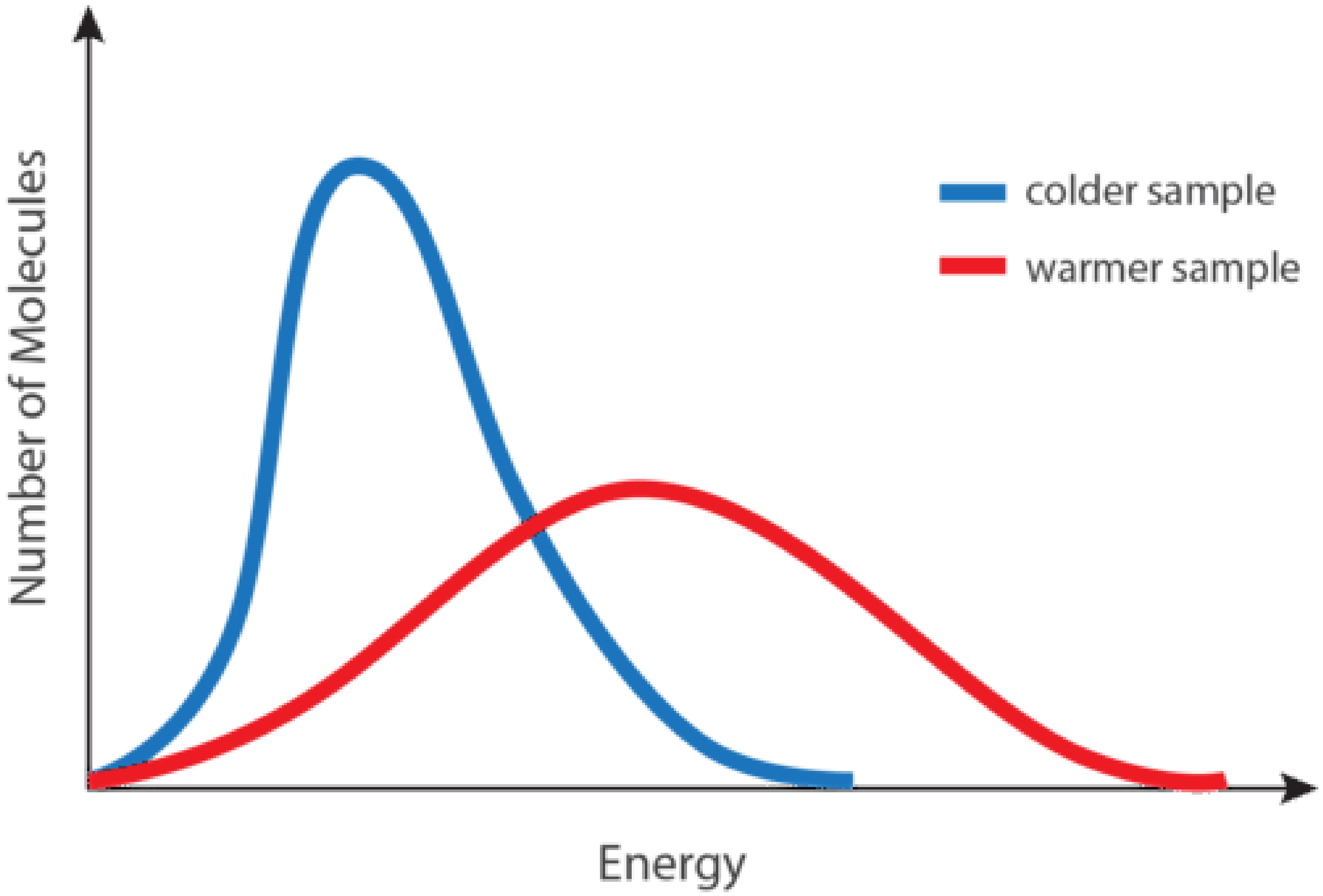
Mass	**kg**
Velocity	**m/s**
Kinetic energy	$\frac{kg \bullet m^2}{s^2}$

$$1\,Joule = 1\,\frac{kg \bullet m^2}{s^2}$$

= amount of energy needed to move a 1 kg mass at a speed of 1 m/s.

Connecting KE to Temperature

- Particles in a warmer object have higher *average* KE



KE and Speed are NOT the same thing!

Things at the same temperature have the same (average) kinetic energy, but not necessarily the same velocity!

A sample of He and Ne are at 25°C.
Which element has the higher velocity?

- A He
- B Ne
- C They both are the same

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- Ⓐ He
- Ⓑ Ne
- Ⓒ **They both are the same**

$$KE = \frac{1}{2}mv^2$$

Important Laws!

Law of conservation of energy, 1st Law of Thermodynamics

Energy cannot be created nor destroyed.
The total energy content of the universe is constant

- Can only transfer or convert energy
- Amount of energy when starting must equal energy at the end.

Convenient!

Allows us to be creative with our measurements and calculations! Can measure things INDIRECTLY!

$$\text{Energy}_{\text{absorbed}} = -\,\text{Energy}_{\text{released}}$$

Sometimes it is difficult to measure the system you are actually interested in, but it might be easy to measure the surroundings! If you know info about one, you can determine the other!

System and Surroundings

System	**Surroundings**
The material or process which we are studying the energy changes within.	Everything else with which the system can exchange energy.

We study the exchange of energy between the system and the surroundings.

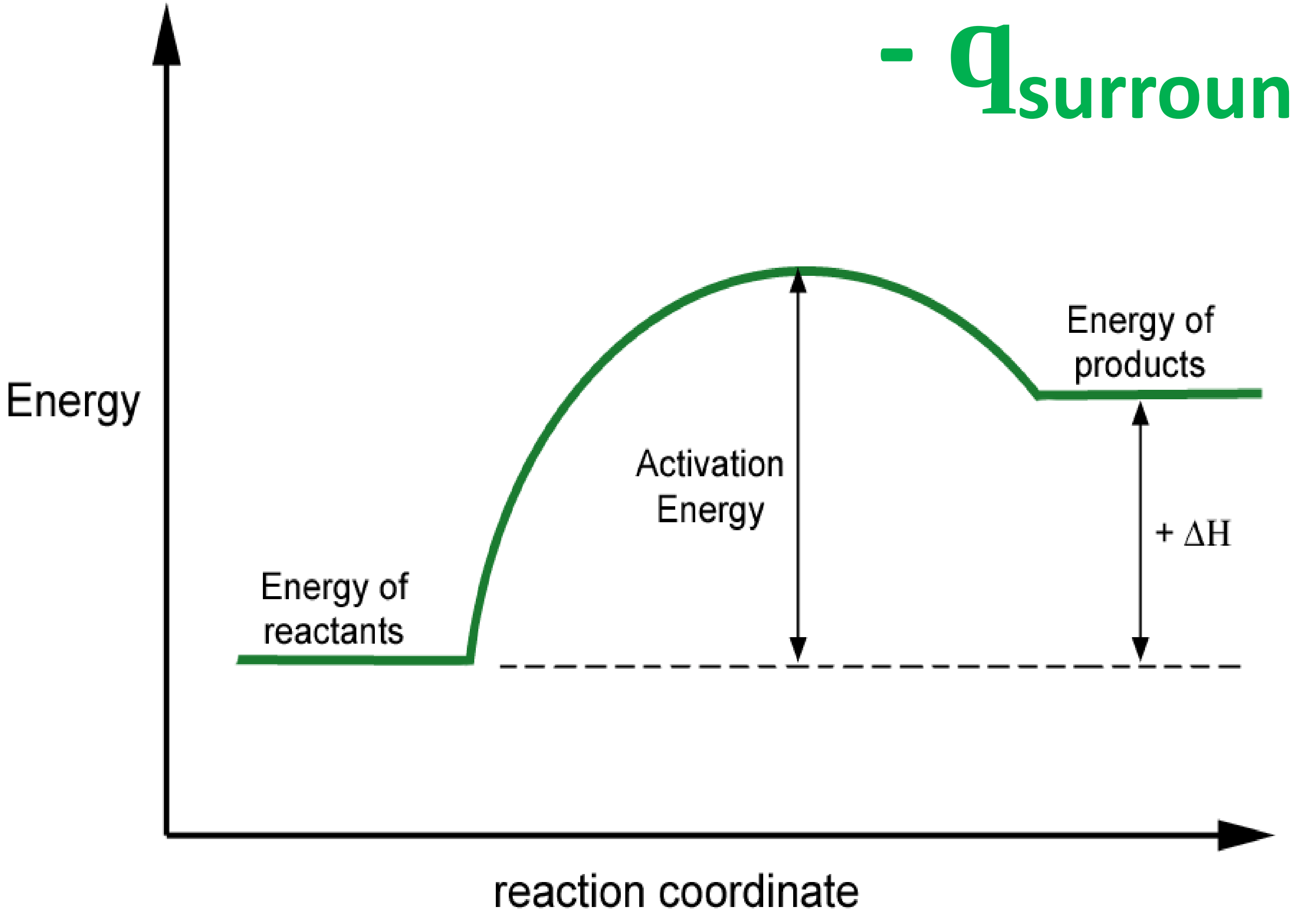
Energy Change in Chemical Processes

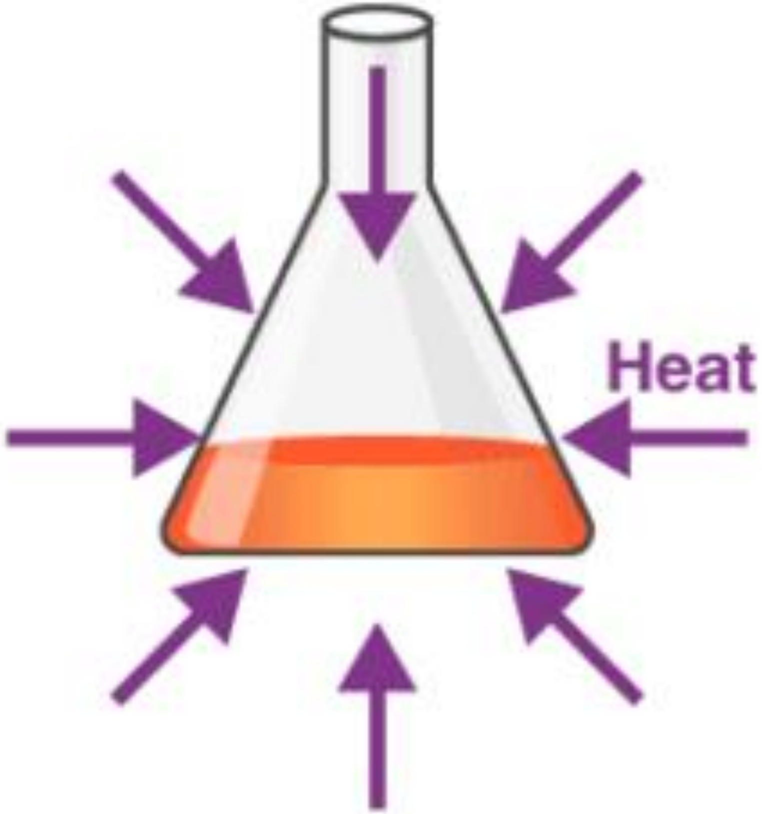
Endothermic	
System absorbs energy	Surroundings release energy
System energy increases	Surrounding energy decr.
$+ q_{system}$	$- q_{surroundings}$
If you touch the container YOU feel cold – system is taking heat away from YOU! Your thermometer is in the SURROUNDNGS so the temperature it reads decreases!	

Endothermic Reactions

$+ q_{system}$

$- q_{surroundings}$





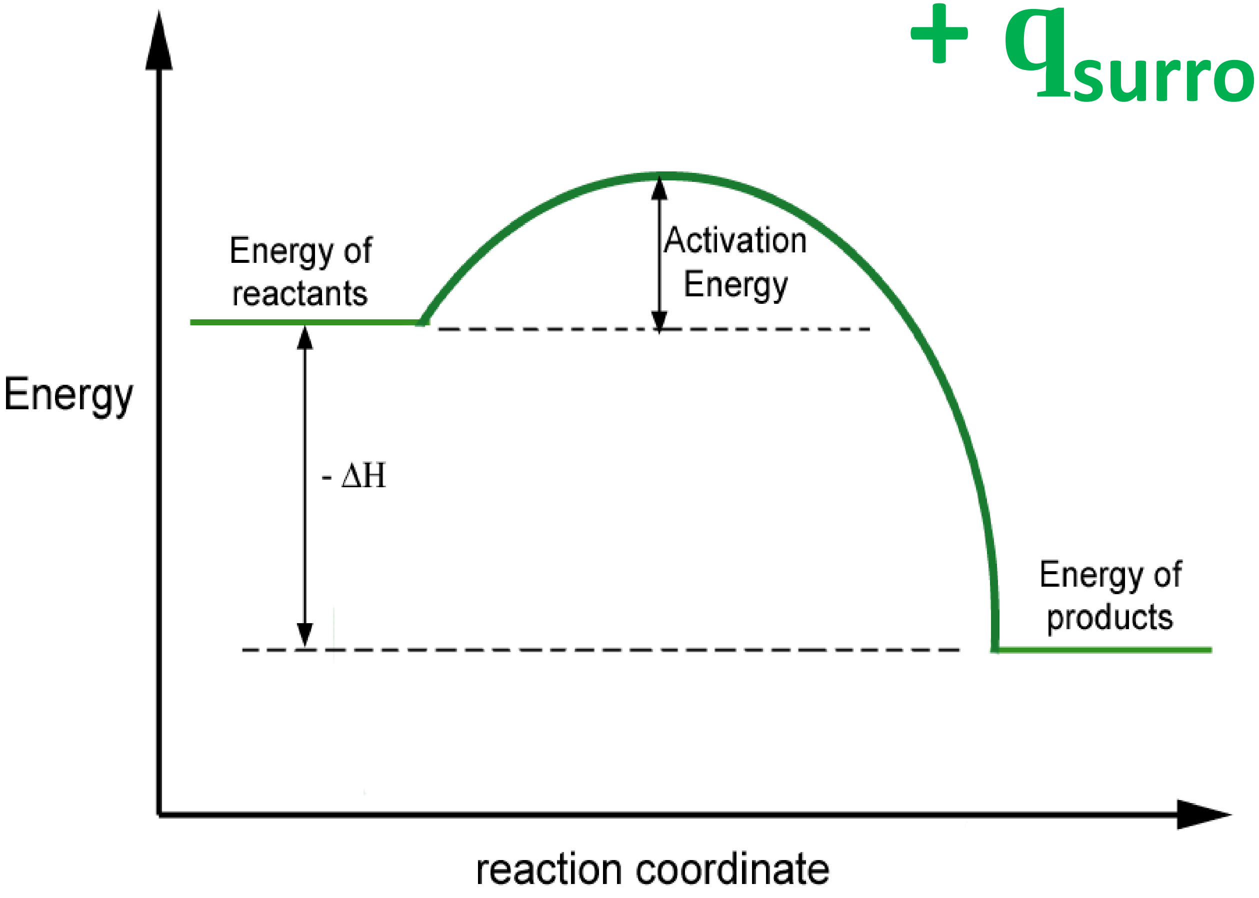
Energy Change in Chemical Processes

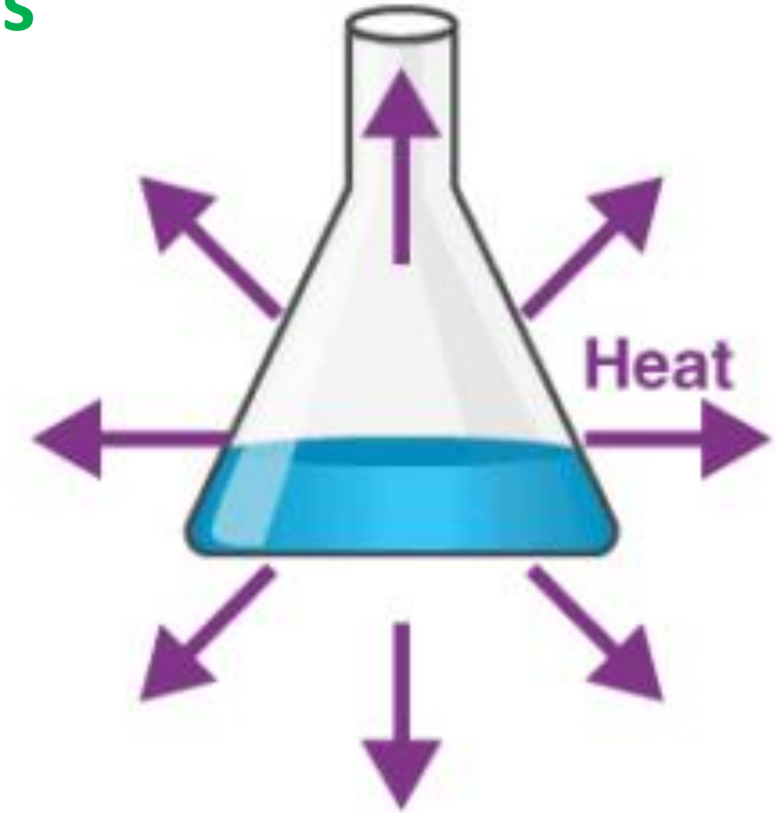
Exothermic	
System releases energy	Surroundings absorb energy
System energy decreases	Surrounding energy incr.
$-q_{system}$	**$+q_{surroundings}$**
If you touch the container YOU feel hot – system is releasing heat towards YOU! Your thermometer is in the SURROUNDINGS so the temperature it reads increases!	

Exothermic Reactions

$$- q_{system}$$

$$+ q_{surroundings}$$



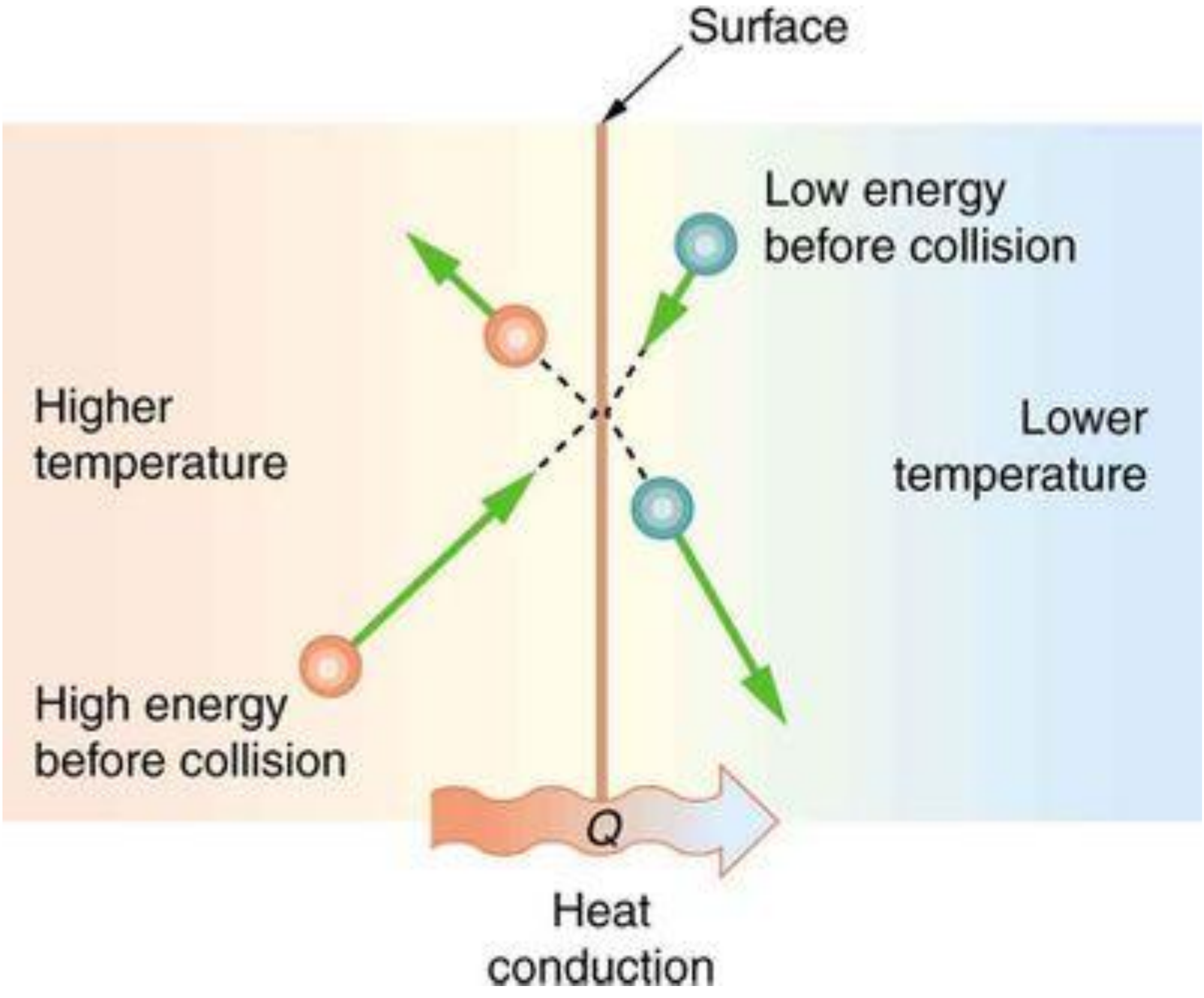


Heat Transfer

Particles will collide with each other. Energy can be transferred during these collisions.

Some particles will slow down, some will speed up.

Heat transfers from HOT → COLD



Heat Transfer

Eventually, **thermal equilibrium** is reached.

- Average KE of both substances will be the same.
- Temperatures are the same.

That's why T_{final} for both substances is the same at the end of a calorimetry experiment!

Calorimetry

Measuring heat absorbed or released.
Usually by change in temp for a known mass of water.

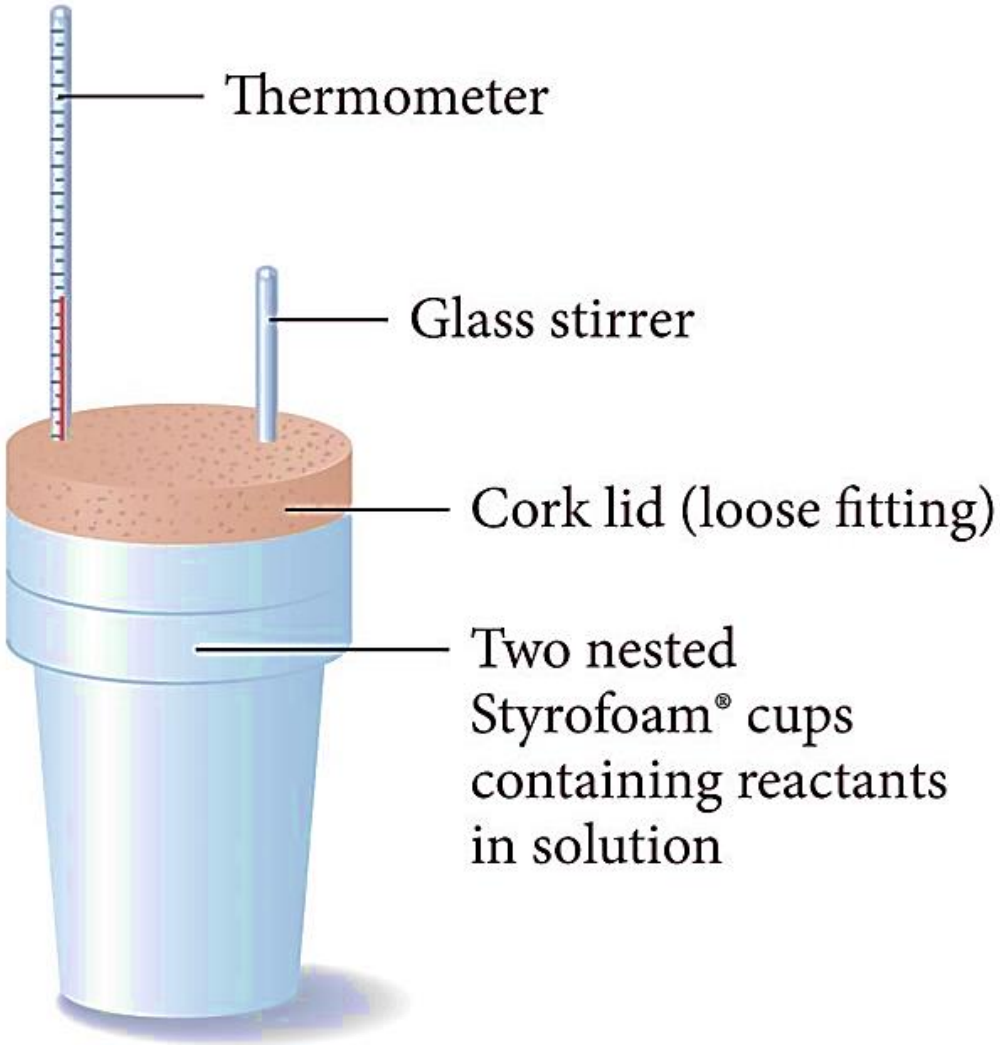
We are measuring the reaction energy INDIRECTLY – can't measure the system but we CAN measure the surroundings easily!

Water = Surroundings (usually)

1 calorie is the heat required to raise the temp of 1 gram of water by 1 °C

1 BTU is the heat required to raise the temp of 1 pound of water by 1 °F

A Cheap Calorimeter – Coffee Cup!

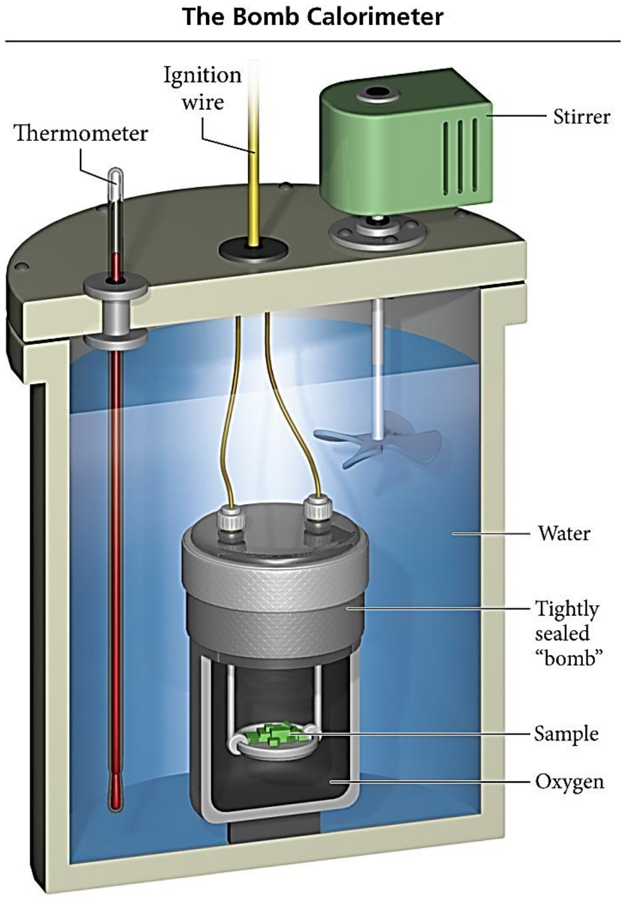


Bomb Calorimeter

- Used to measure ΔE because it is a constant volume system.

- The heat capacity of the calorimeter = amount of heat absorbed by the calorimeter for each degree rise in temperature = **calorimeter constant**.

C_{cal}, kJ/ºC

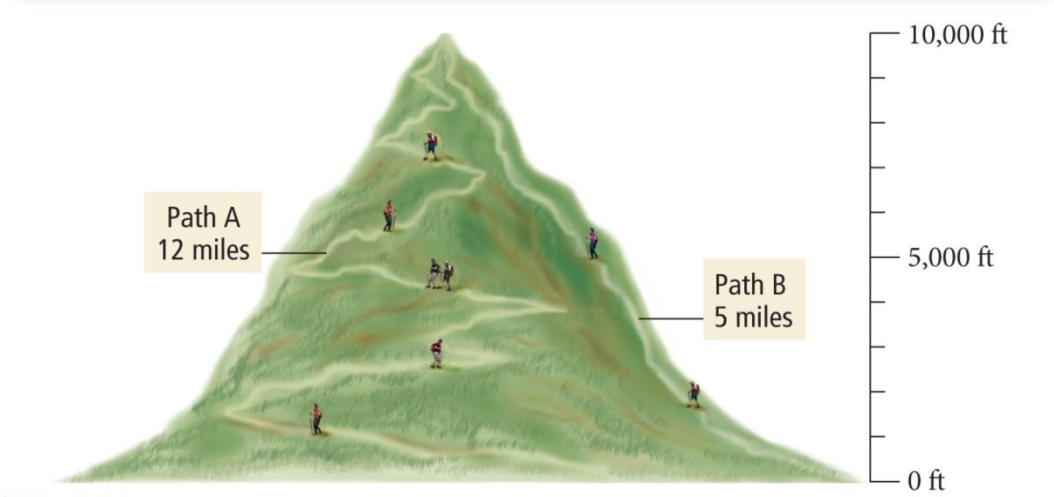


C_{cal} has different units! It is NOT J/g°C because there is no mass portion! So NOT $Q = mC\Delta T$ .... just $Q = C\Delta T$!

State Functions

Two trails to the top:

1. Long and winding
2. Short but steep



Regardless of the trail, when you reach the top you will be 10,000 ft above the base.

The elevation change is a state function. It depends only on the starting and ending heights, not on which trail!

The time it takes would NOT be a state function.

State Functions

Depend ONLY on the present state of the system

ENERGY IS A STATE FUNCTION

A person standing at the top of Mt. Everest has the same potential energy whether they got there by hiking up, or by falling down from a plane!

WORK IS NOT A STATE FUNCTION

Some Practice Problems and Reminders on Specific Heat, Latent Heat, Molar Heat, and Calorimetry

Specific Heat Capacity

Measure of a substance’s ***intrinsic*** ability to absorb heat.

Specific heat capacity - amount of heat energy required to raise the temp of one gram of a substance 1 °C.

C_s Units **J/(g · °C)**

Molar heat capacity - amount of heat energy required to raise the temp of one mole of a substance 1 °C.

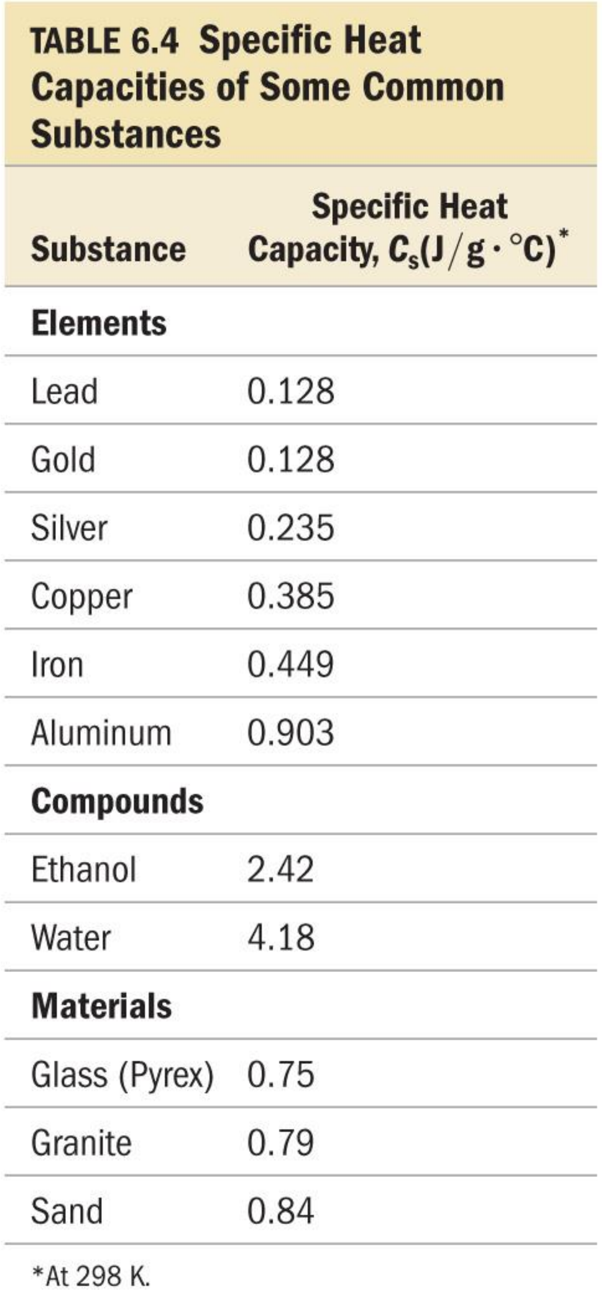


TABLE 6.4 Specific Heat Capacities of Some Common Substances

Substance	Specific Heat Capacity, C_s(J/g · °C)*
Elements	
Lead	0.128
Gold	0.128
Silver	0.235
Copper	0.385
Iron	0.449
Aluminum	0.903
Compounds	
Ethanol	2.42
Water	4.18
Materials	
Glass (Pyrex)	0.75
Granite	0.79
Sand	0.84

*At 298 K.

Calculations Involving Specific Heat

$$q = m \cdot c \cdot \Delta T$$

OR

$$c = \frac{q}{m \cdot \Delta T}$$

q = Heat lost or gained

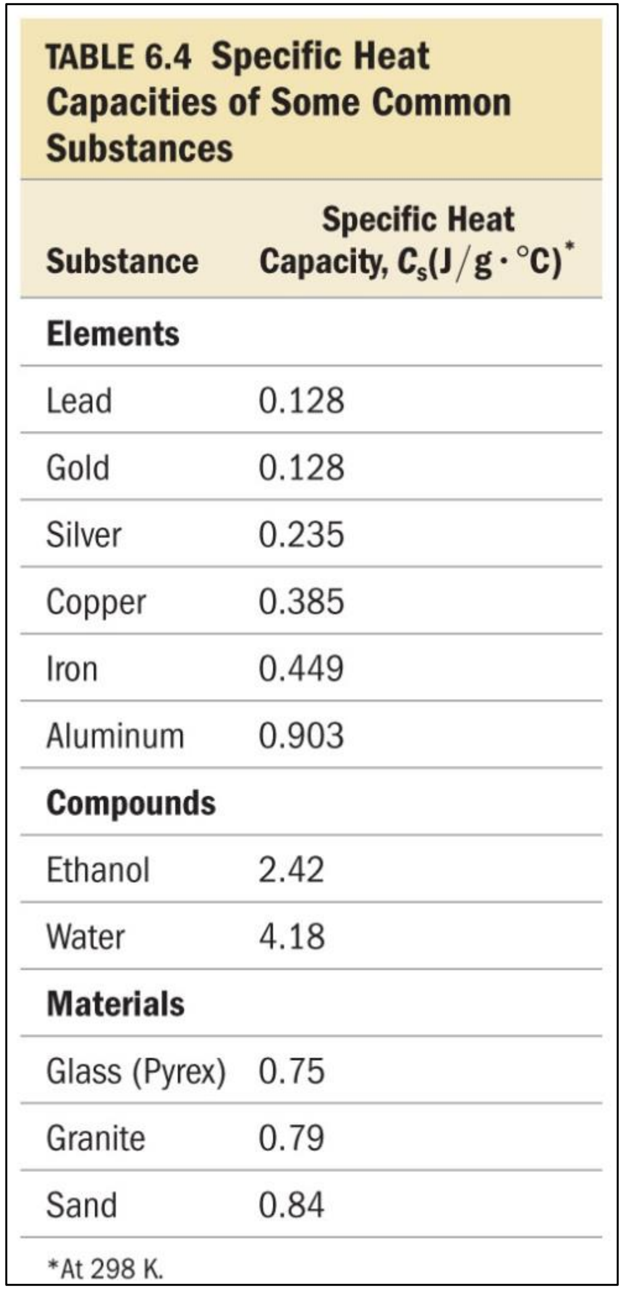
m = Mass

c = Specific Heat Capacity

ΔT = Temperature change

Q#1 Identical amounts of heat are applied to 50 g blocks of lead, silver, and copper, all at an initial temp of 25°C. Which block will have the largest increase in temp?

- A Lead
- B Silver
- C Copper
- D None, all will be at the same temp



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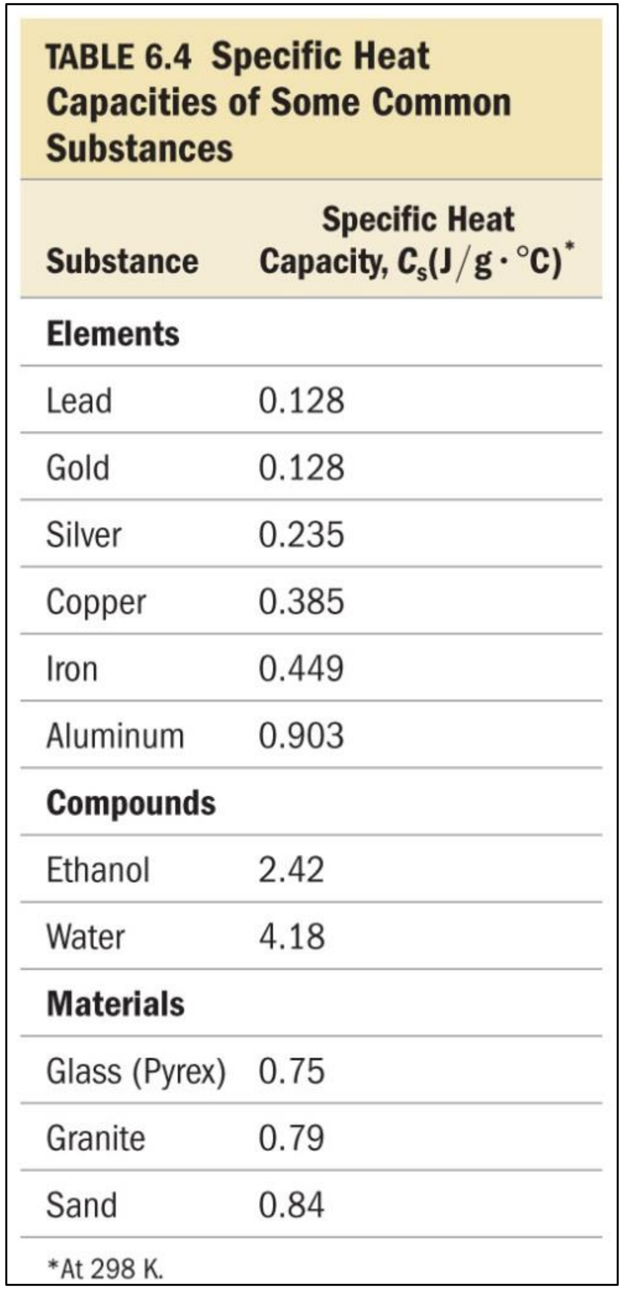
$$Q = mC\Delta T$$

$$\Delta T = \frac{Q}{mC}$$

Smallest C gives you largest ΔT



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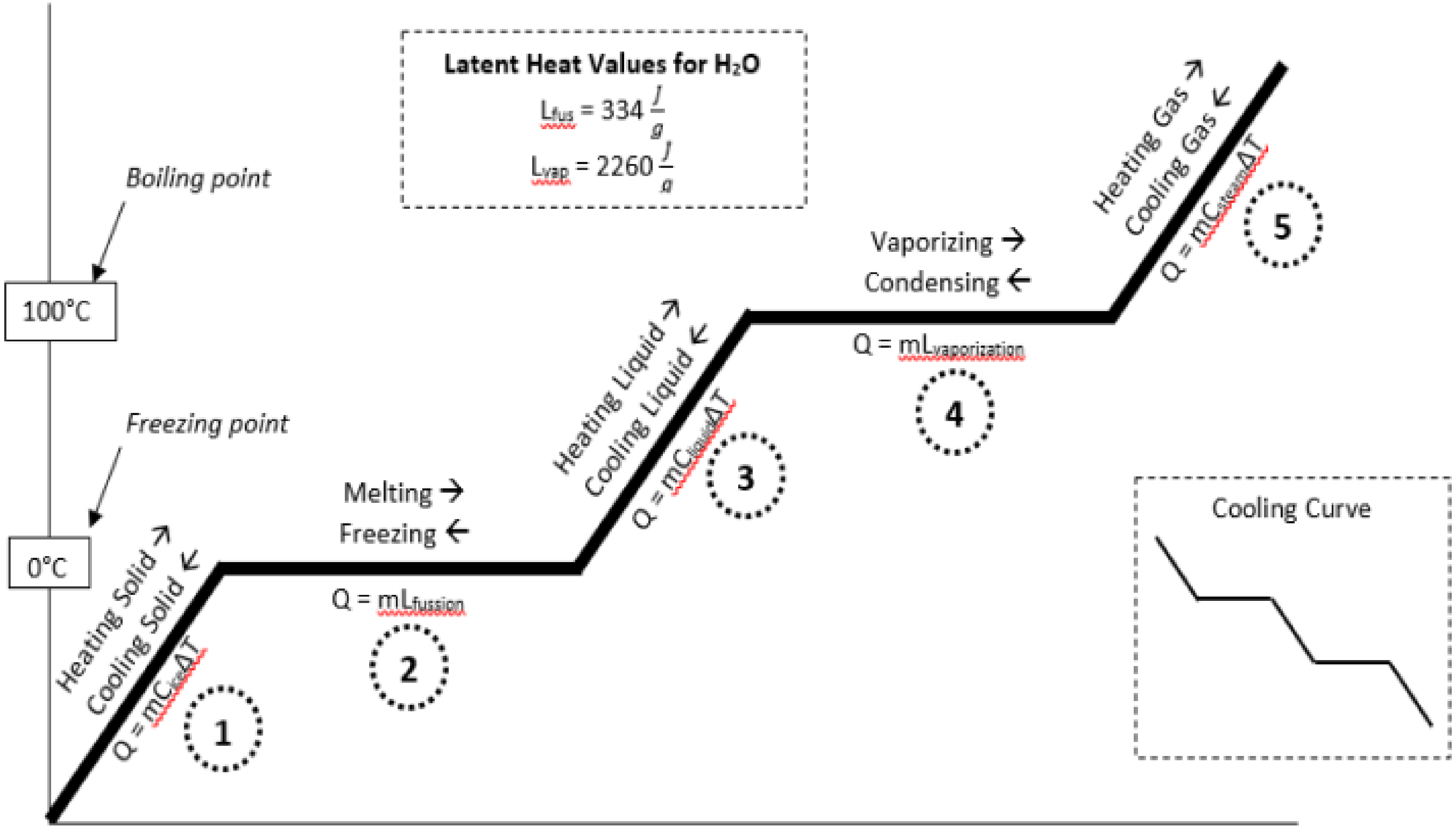
Heating Curves and Latent Heat



Latent Heat Values for H_2O

$L_{fus} = 334\,\frac{J}{g}$

$L_{vap} = 2260\,\frac{J}{g}$

Heating Curves and Latent Heat

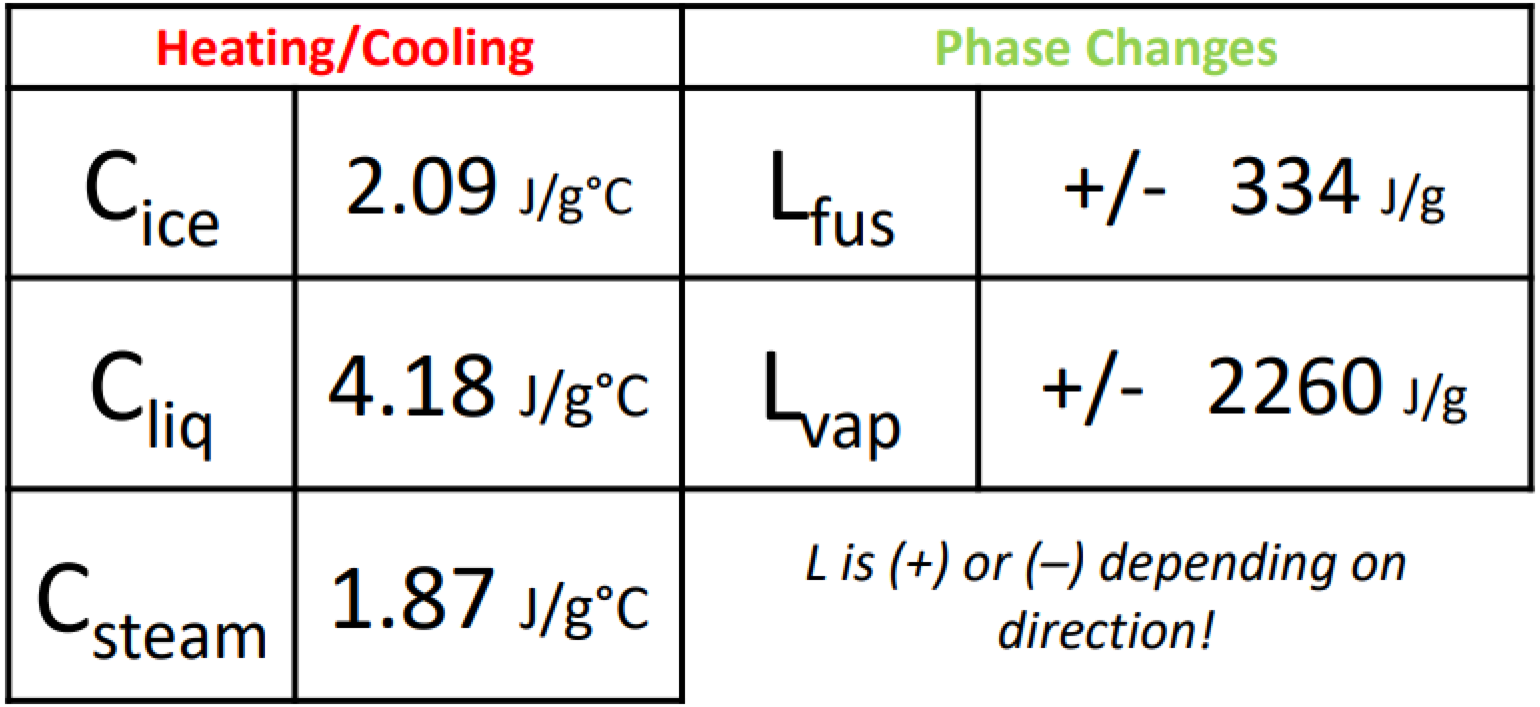
HEATING/COOLING

- $Q = mC\Delta T$
- $C = J/g°C$ → Has a temperature component.
- So…. Cant use it for phase changes

PHASE CHANGES

- $\Delta T = 0$ BUT $Q \neq 0$
- Get rid of ΔT, and replace C with something else
- **$Q = mL$**
- L = “Latent Heat” → J/g
  The energy required to phase change one gram of substance

Heating Curves and Latent Heat



Heating/Cooling		Phase Changes	
C_{ice}	2.09 J/g°C	L_{fus}	+/- 334 J/g
C_{liq}	4.18 J/g°C	L_{vap}	+/- 2260 J/g
C_{steam}	1.87 J/g°C		

L is (+) or (–) depending on direction!

Q#2 Determine the energy required to convert 21.1 grams of ice at -6°C to steam at 100°C

A 63.8 kJ

B 46.7 kJ

C 68.8 kJ

D 8.82 kJ

E 9.35 kJ

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$$Q_1 = mC\Delta T = (21.1\text{g})(2.09\,\text{J/gC})\,(0^\circ - {}^{-}6^\circ) = 264.59\text{ J}$$

$$Q_2 = mL = (21.1\text{g})(334\text{ J/g}) = 7047.4\text{ J}$$

$$Q_3 = mC\Delta T = (21.1\text{g})(4.18\,\text{J/gC})\,(100^\circ - 0^\circ) = 8819.8\text{ J}$$

$$Q_4 = mL = (21.1\text{g})(2260\text{ J/g}) = 47686\text{ J}$$

$$Q_T = Q_1 + Q_2 + Q_3 + Q_4 = 63817.79\text{ J}$$

Molar Heat

Energy required to raise the temp of one MOLE of a substance by one degree.

$$Q = nC\Delta T$$

Q#3 A sample of barium chloride is increased in temperature by 3.8C when the sample absorbed 2.4×10^2J of heat energy. Calculate the number of moles of barium chloride in the sample if its molar heat capacity is 75.1 J/mol•K

A 6.8×10^4 mol

B 4.7×10^3 mol

C 1.2 mol

D 0.84 mol

E 3.7 mol

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- B 4.7 x 10^3 mol
- C 1.2 mol
- D **0.84 mol**
- E 3.7 mol

$$2.4 \times 10^2 \text{ J} = n\,(75.1\frac{J}{K \bullet mol})(3.8 \text{ K})$$

$$n = 0.84 \text{ mol}$$

Thermal Energy Transfer (Calorimetry)

A block of metal at 55 °C is added to water at 25 °C.

- Thermal energy transfers heat from the metal to the water.
- The exact temperature change depends on:
  - Mass of the metal
  - Mass of water
  - Specific heat capacities of the metal and of water

Equal but OPPOSITE !!!

$$-q_{metal} = +q_{water}$$

So if q = mCΔT…

$$-m_{\text{metal}} \times C_{\text{s, metal}} \times \Delta T_{\text{metal}} = m_{\text{water}} \times C_{\text{s, water}} \times \Delta T_{\text{water}}$$

Q#4 The temperature of a 700.0-g bar of iron decreases by 10.0°C when the iron is plunged into 500.0 g of water. What is the temperature increase of the water, assuming that no heat is lost in the transfer? (C_{Fe} = 0.45 J/g°C)

A 3.0°C

B 1.5°C

C 1.7°C

D 1.3°C

E None of the above

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- B **1.5°C**
- C 1.7°C
- D 1.3°C
- E None of the above

$$Q_{water} = -Qmetal$$

$$mC\Delta T = -mC\Delta T$$

$$(500)(4.18)(\Delta T) = -(700)(0.45)(-10)$$

$$\Delta T = 1.51\ ^\circ\mathrm{C}$$

Q#5 50.0 g of water at 22 °C is mixed with 125 g of water initially at 36 ° C. What is the final temperature of the water after mixing, assuming no heat is lost to the surroundings?

***THINK* - Use this to check your work!**

50g @ 22°C and 125g @ 36°C with same C…
Won't end exactly halfway. Will end closer to 36°C than 22°C. Cant end at 36°C or higher than 36°C…

A 29°C

B 42°C

C 32°C

D 30°C

E None of the above

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- A 29°C
- B 42°C
- C **32°C**
- D 30°C
- E None of the above

$$Q_1 = -Q_2$$

$$mC\Delta T = -mC\Delta T$$

$$(50)(4.18)(T_f - 22°\mathrm{C}) = -(125)(4.18)(T_f - 36)$$

$$T_f = 32\ °\mathrm{C}$$

YouTube Link to Presentation

https://youtu.be/KMr6JO8JqBc