

Quantify changes in energy by Quantifying heat

- Heat depends on position

Q: When I think of energy: PE + KE are only 2 forms of energy

x transfer of energy as heat or work
- no objects moving on it

• Potential E. (PE) (J)
Energy due to position or composition (Bonds + IMF)

• Kinetic Energy (KE) (J)
Energy of the motion of an object or particle (mass)

• Heat (q) (temp difference)
transfer of energy from high temp to low temp

• Work (W) = -PΔV if $\Delta V \neq 0$ need gas
transfer of energy via applied force over distance

universe = system + surroundings
↑
environment everything else

Final State \leftarrow Initial State = ΔU

Products - Reactants = ΔU

Heat (q)

1 Cal = 4.184 J

quantity of heat needed to raise temp by 1°C
(Joules) (Calories)

higher heat capacity

Demo: Large + small beaker
Energy would transfer from hot plate (\uparrow Temp) to beaker (\downarrow Temp)

small beaker will have \uparrow temp, same amount of energy went in, but it has smaller volume and heat capacity

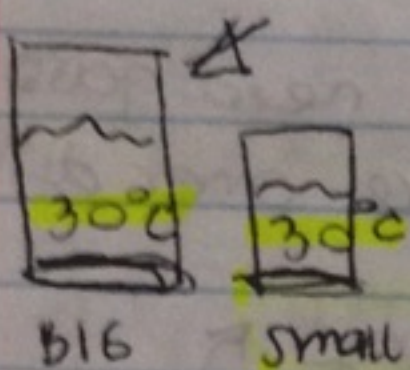
Thermal Energy (micro)

- KE of particles directly related to the temp of the system. (Total for All molecules)

Heat Capacity: heat absorbed

$$q = C \Delta T$$

CQ: Beaker had \uparrow TE? Larger Beaker because there is more stuff!



CQ: Beaker had \uparrow Heat Capacity? Larger Beaker (more stuff)

needs more E for same ΔT .

Heat Capacity

measure the heat trans into or out of a system

$$q = C \Delta T$$

$$C = \frac{q}{\Delta T}$$

Specific:

$$q = m c_s \Delta T \text{ (per gram)}$$

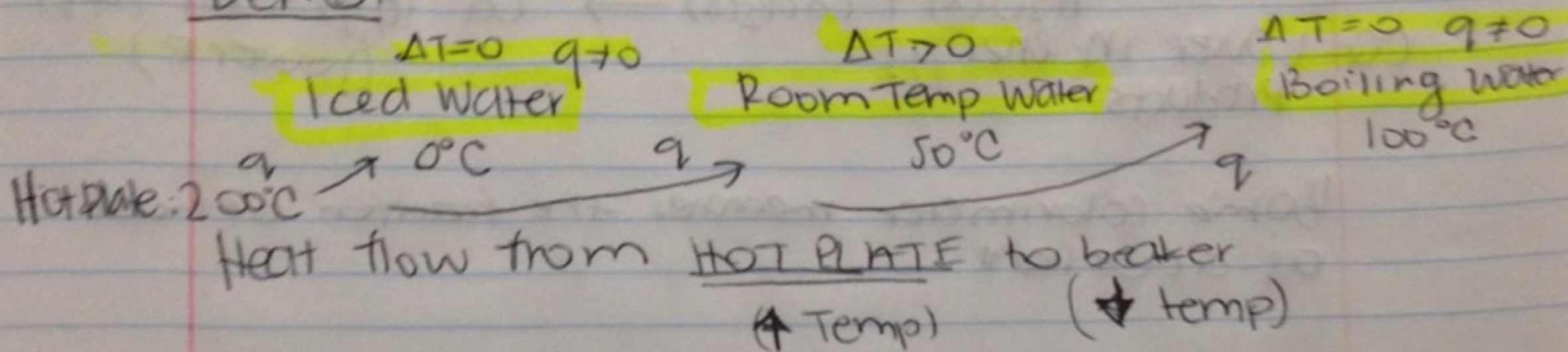
molecular:

$$q = n C_m \Delta T \text{ (per mole)}$$

Heat capacity is an Extensive Property > depends on amount of material

Specific Heat is an Extensive Prop. FALSE > (ratio)

Demo:



CQ: 2 systems w/ constant temp; +E is transferred from HOT plate to: water/system in the form of P.E.

* can + change Thermal Energy w/out changing Temp

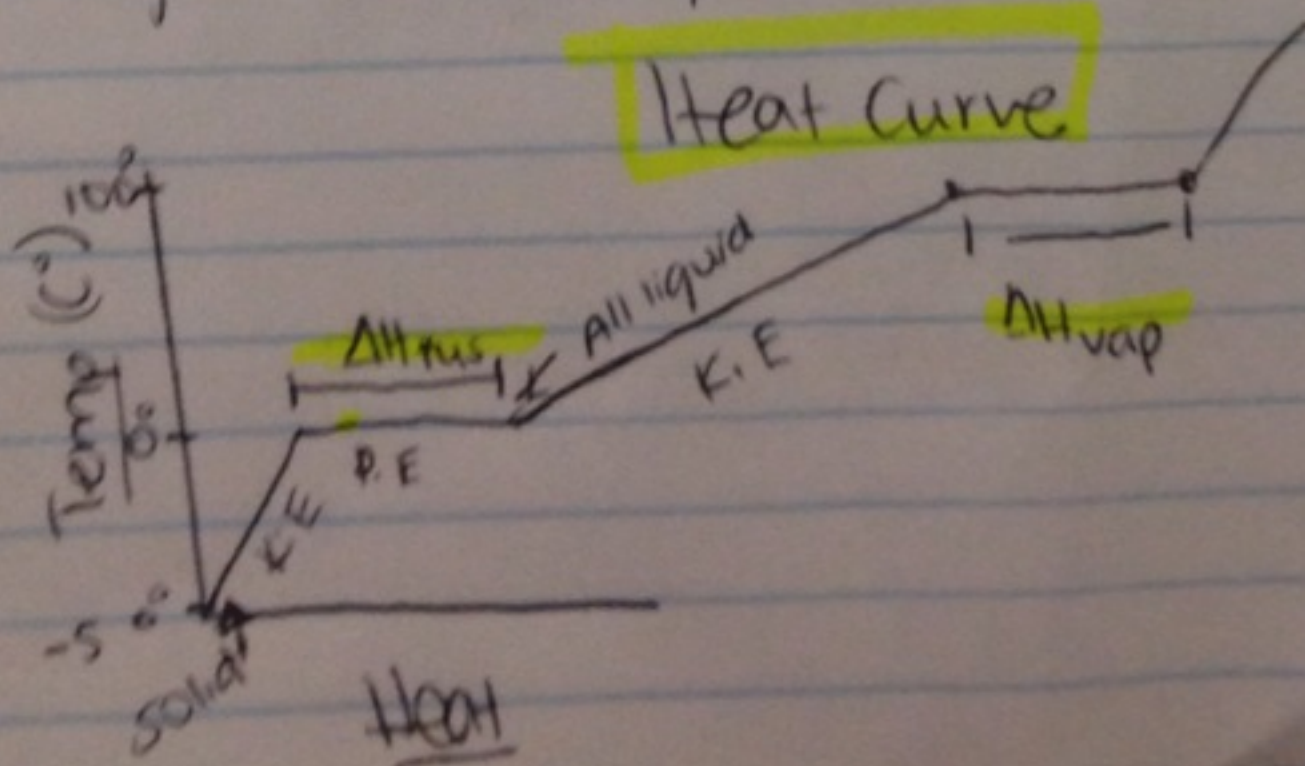
Enthalpy : energy

- transfer of heat into or out of system
transfer into P.E (change of position) of particles

Enthalpy of vaporization (ΔH_{vap}) LIQ \rightarrow VAP

$$q_p = \Delta \text{Energy} \quad q_p = \Delta H$$

change of enthalpy = heat flow @ constant P



calorimeter

measuring of calories / heat

• measure ΔT in water to see how much energy was released

Demo

CaCl_2 in water

(higher e^-)



CQ: Lower in energy?
Products.

Bomb calorimeter measures the transfer of heat
as a constant

Quantifying heat flow - physical change
Unit 4, days
LM 28, 29, 30

$W = -P_{\text{ex}} \Delta V$ only time there's work is when volume changes.

Heat depends on context!

PE - position/composition; bonds IMF
KE - motion of object or particle; microscopic
Units: J

Heat (q) - transfer from high T to low T
(NOTE: not temp)

Work (w) - transfer of ϵ via applied force over distance.

$W = -P \Delta V \leftarrow \Delta V \neq 0$ need gas

Universe = system + surroundings

$\Delta \text{State} = \text{state end} - \text{state beginning}$
know about everything else

Reactants \rightarrow products

$\Delta U = \text{final (products)} - \text{initial (reactants)}$

1 calorie = quantity of heat needed to raise the temp of 1g of water 1°C.

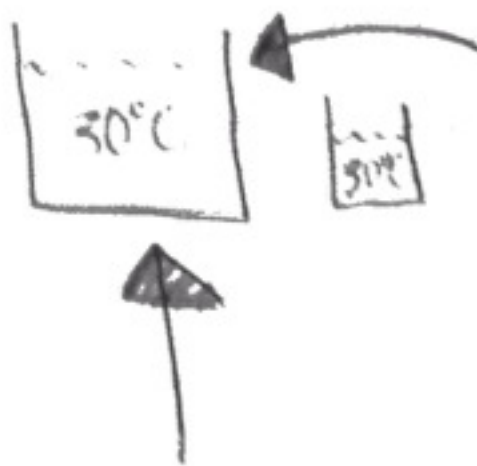
Temp = average KE per molecule

Thermal ϵ - (microscopic) KE of the particles, directly related to temp.

Heat capacity - heat absorbed required to increase in temp.

$$q = C \Delta T$$

Heat capacity ΔT temp



has higher Thermal Energy.
 More molecules = higher Thermal Energy.
 Thermal Energy = total for all molecules
 Temp is per molecule.

Also has higher heat capacity. How much energy would it take to get the same temp change?

Heat capacity (C) heat transfer into or out of a system.

$$q = C \Delta T \quad C = \frac{q}{\Delta T} \quad \text{J/K}$$

specific heat capacity

$$q = m c_s \Delta T \quad \text{Heat capacity per gram J/kg}$$

molar heat capacity

$$q = n C_m \Delta T \quad \text{heat capacity per mole. J/K} \cdot \text{mol}$$

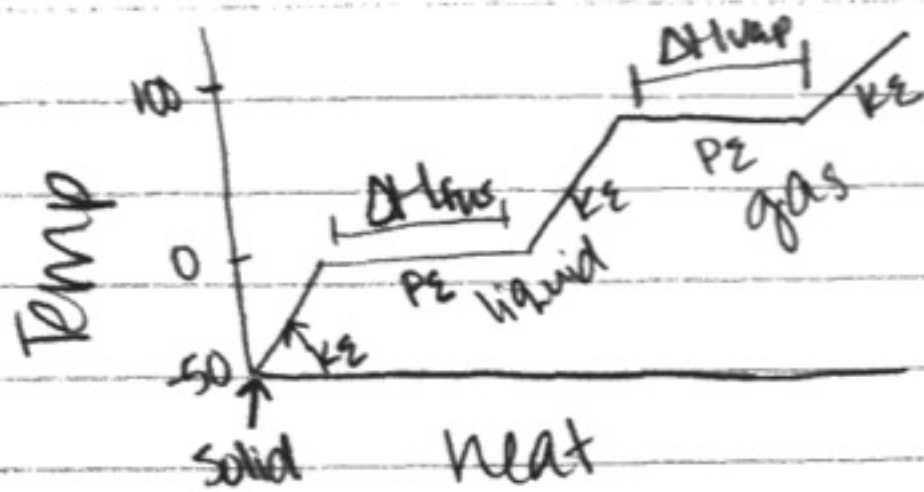
Enthalpy of physical change - transfer of heat into or out of the system. Heat is transferred into PE (change of position) of the "particles".

Change in enthalpy = heat flow @ constant pressure

$$q_p = \Delta H$$

$$q_p = \Delta \text{Energy}$$

Heat related to: temp change, phase change, chemical change!



Quantify energy on the move
Calorimeter

$\Delta H = q_{hp} = C \Delta T$ ← coffee cup calorimeter
difference in enthalpy between reactants & products. (constant pressure) ΔH

$q_{hv} = \Delta U$ ← bomb calorimeter
constant volume ΔU

$$\Delta U = q_h + w$$

$$\Delta U = q_h - P \Delta V$$

$$\Delta U = q_v$$

Nov. 12

Conceptualise E on move.

$$\Delta U = q + w$$

reactants \rightarrow products

$$\Delta U = \text{Final} - \text{Initial}$$

Heat

$$1 \text{ cal} = 4.184 \text{ J}$$

* change in temp of water \rightarrow change of E in system

$$q_{\text{system}} = -q_{\text{surroundings}}$$

Demo

large beaker

small beaker



• move mass
↑ higher TE
higher heat capacity
(extensive)



~~higher heat cap~~

Thermal E

~~KE of particles~~

↑ T, ↑ KE, ↑ TE

Heat Capacity

- heat absorbed to rise temperature by 1°C

- unit: J/°C

- extensive property

$$K = \frac{1}{2} m v^2 \quad \text{more mass} \rightarrow \text{more KE}$$

Heat capacity (C)

$$q = C \Delta T \quad \text{J/°C}$$

heat absorbed

Specific heat capacity

raise 1g by 1°C

; intensive property ; $q = m C_s \Delta T$

Molar heat capacity

raise 1 mole by 1°C

; intensive property ; $q = n C_m \Delta T$

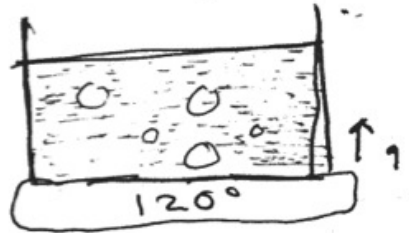
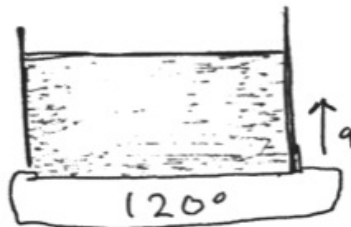
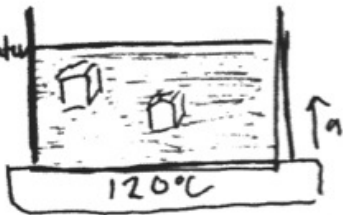
Demo: transition phase

ice

water

boiling water

Sys = heater + water
Surr = hot plate



$$T_i = 0^\circ\text{C}$$

$$T_f = 0^\circ\text{C}$$

$$\Delta T = 0$$

TE \rightarrow PE \rightarrow phase change
 $q = n \Delta H_{\text{fus}}$

$$T_i = 28^\circ\text{C}$$

$$T_f = 35^\circ\text{C}$$

$$q = m c_s \Delta T$$

$$q = 400\text{g} \cdot 4.184 \text{ J/g}^\circ\text{C} (7^\circ\text{C}) = - \text{J}$$

$$T_i = 100^\circ\text{C}$$

$$T_f = 100^\circ\text{C}$$

$$\Delta T = 0$$

TE \rightarrow PE \rightarrow phase change
 $q = n \Delta H_{\text{vap}}$

Enthalpy (H)

\uparrow state function

- transfer of heat into/out of system @ constant pressure

\rightarrow PE

$$q_p = \Delta \text{Energy} = \Delta H$$

$$-\Delta H = H_{\text{final}} - H_{\text{initial}}$$

ΔH_{vap}

l \rightarrow g

$$\Delta H_{\text{vap}} = \Delta H_{\text{gas}} - \Delta H_{\text{liquid}}$$

ΔH_{fus}

s \rightarrow l

$$\Delta H_{\text{fus}} = \Delta H_{\text{liquid}} - \Delta H_{\text{solid}}$$

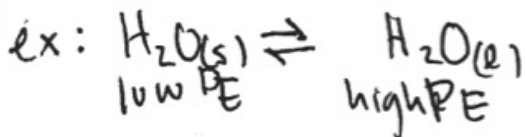
ΔH_{sub}

s \rightarrow g

$$\Delta H_{\text{sub}} = \Delta H_{\text{gas}} - \Delta H_{\text{solid}}$$

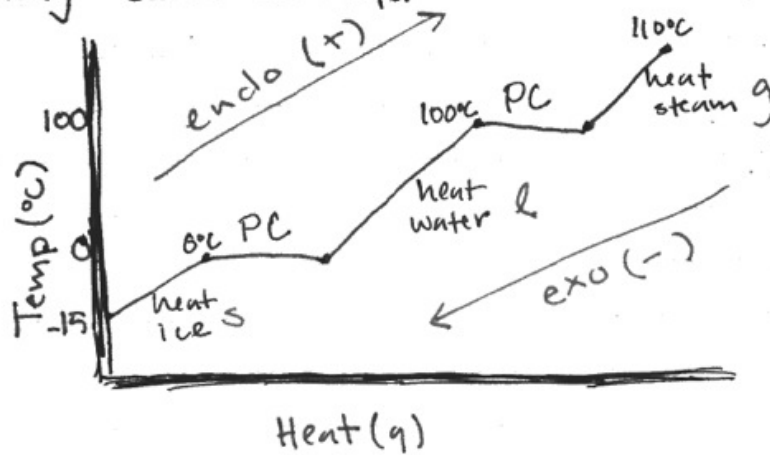
+ endothermic

- exothermic



$$\Delta H = \text{high PE} - \text{low PE} = (+) \text{ endothermic}$$

★ Heating Curve (5 steps)



-15°C ice
↓
110°C steam

— phase change $q = n\Delta H$
/ heat/cool $q = mc\Delta T$
 $q = nC_m\Delta T$

$\Delta H_{\text{fus}} = +2.6 \text{ kJ/mol}$

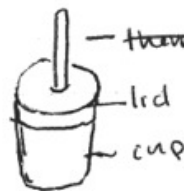
$n = 5 \text{ g} \times \frac{1 \text{ mol}}{23 \text{ g}} = .217 \text{ mol}$

$q = n\Delta H$

$.217 \text{ mol} \cdot \frac{2.6 \text{ kJ}}{\text{mol}} = .5564 \text{ kJ}$
 556.4 J

Quantity E on the Move

- calorimeter measure heat flow in or out of a system

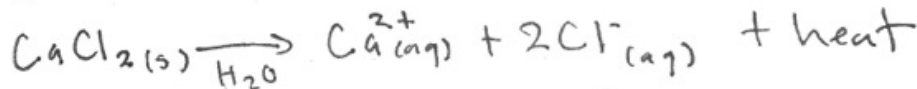


thermometer
lid coffee cup
cup
@ constant pressure
 $q_p = \Delta H$



tricky/bomb like
calorimeter @ constant
P & Volume
 $\Delta U = q_v$

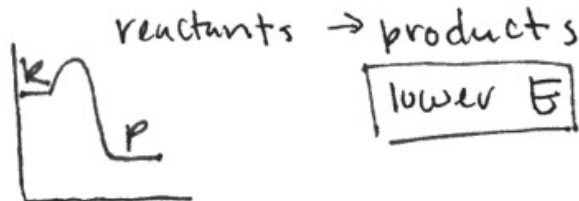
Demo



$\Delta U = q + w$
 $= - + (-P\Delta V) \rightarrow 0$

$\Delta T \uparrow$, exothermic
↳ gave off heat

$\Delta U = q_v$ in coffee cup



Enthalpy & Internal E

- Enthalpy proportional to internal E + work

$$H = U + PV$$

$$\Delta H = \Delta U - w$$

$$\Delta H = \Delta U + \Delta(PV)$$

$$\Delta H = \Delta U - w = q_p$$

$$\Delta H = \Delta U + P\Delta V$$