Unit4Day2-VandenBout

Monday, November 11, 2013
12:48 PM

Vanden Bout/LaBrake/Crawford

CH301

THERMODYNAMICS
Quantifying Heat Flow – Physical Change

UNIT 4 Day 2

CH301 Vanden Bout/LaBrake Fall 2013

Important Information

PRE - Thurs

LM28, 29, 30 DUE Th 9AM

~~HW10 DUE T 9AM~~

CH301 Vanden Bout/LaBrake Spring 2013

What are we going to learn today?

Quantify Change in Energy by Quantifying Heat

Derive State Function - Heat Flow at Constant Pressure

Calorimetry

$w = -P_{ex} \Delta V$

Heat depends on context

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QUIZ: iClicker Question 1

When I think of types of energy, I think:

a) KE and PE are the same as heat & work
b) PE and KE are the same as heat & work
c) PE and KE are the only two forms of energy ← 80%
d) Heat and work are the only two forms of energy

transfer of E as heat or work

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Energy Definitions

What is Energy?

BONDS & IMF

Potential Energy (PE)
energy due to position or composition

Kinetic Energy (KE)

What is Energy?

Potential Energy (PE)

energy due to position or composition

Kinetic Energy (KE)

energy of the motion of an object or particle

MICROSCOPICALLY

atomic motion

vibrations

Units: J

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Energy Definitions

How does Energy move? TRANSFER

Heat (q)

HIGH T LOW T

transfer of energy from a hotter body to a colder body (NOTE: This is **not** temperature)

Work (w)

transfer of energy via applied force over distance

PV work

$w = -P\Delta V$

$\Delta V \neq 0$

need gas

Units: J

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System and State

A system is the part of the universe on which we want to focus our attention. The *surroundings* are everything else

The *universe* is the system and the surroundings

Universe = system + surroundings

We also describe chemical changes with beginning and end *states*

A change in a chemical reaction is described as

$$\Delta \text{ State} = \text{State}_{end} - \text{State}_{beginning}$$

Conceptualize Energy on the Move

Think about a Power Plant

FUEL → WATER → STEAM → TURBINE → GENERATOR

How much energy would it take to boil enough water to generate enough electricity for the entire UT Campus?

REACTANTS → PRODUCTS

ΔU = Final - Initial

Heat (q)

Prescott Joule is famous because he found the relationship between heat and energy. He dropped weights into water and moved a paddle, while monitoring the change in temperature. He was able to conclude that 1 cal = 4.184 J.

Heat (q)

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We can measure the changes in the temperature of water and correlate that to the change of energy in a system.

1 calorie = quantity of heat needed to raise the temperature of 1 gram of water 1 °C.

1 Joule = 1 N force over 1 m

$\Delta E = mg\Delta h$

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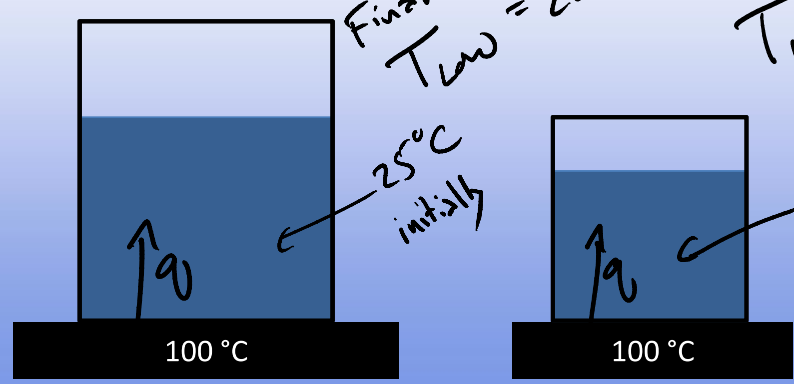
Demonstration

Large Beaker of Water

Small Beaker of Water



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Conceptualize Energy on the Move

Thermal Energy
The kinetic energy of the particles, which is directly related to the temperature of the system

Heat Capacity
The heat absorbed relative to the increase in temperature

Heat Capacity

The heat absorbed relative to the increase in temperature

heat capacity change T

$$q = C\Delta T$$

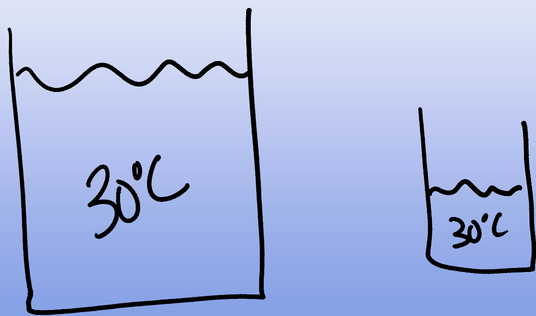
Thermal capacity.

POLL: iClicker Question 2

Thermal E total for all molecules.

Which beaker had the higher Thermal Energy?

A. Large
B. Small
C. Same



T is per molecule.

POLL: iClicker Question 3

Which beaker had the higher Heat Capacity?

- A. Large
- B. Small
- C. Same

Heat Capacity (C)

We use *heat capacity (C)* to measure the heat transferred into or out of a system

$$q = C\Delta T$$

$C = \frac{q}{\Delta T} = \frac{\text{energy}}{T \text{ change}} = J K^{-1}$

Specific heat capacity (s)

$$q = mC_s\Delta T$$

(mass) $mC_s = C$ — heat capacity per gram — $C_s = J K^{-1} g^{-1}$

Molar heat capacity

$$q = nC_m\Delta T$$

$nC_m = C$ — heat capacity per mole — $C_m = J K^{-1} mol^{-1}$

POLL: iClicker Question 4

Heat Capacity is an Extensive Property.

- A. True
- B. False

POLL: iClicker Question 4

Heat Capacity is an Extensive Property.

A. True

B. False

Depends on amount of material

POLL: iClicker Question 5

Specific Heat Capacity is an Extensive Property.

A. True

B. False

$$\frac{C}{\text{mass}} = C_s = J\,K^{-1}\,g^{-1}$$

POLL: iClicker Question 6

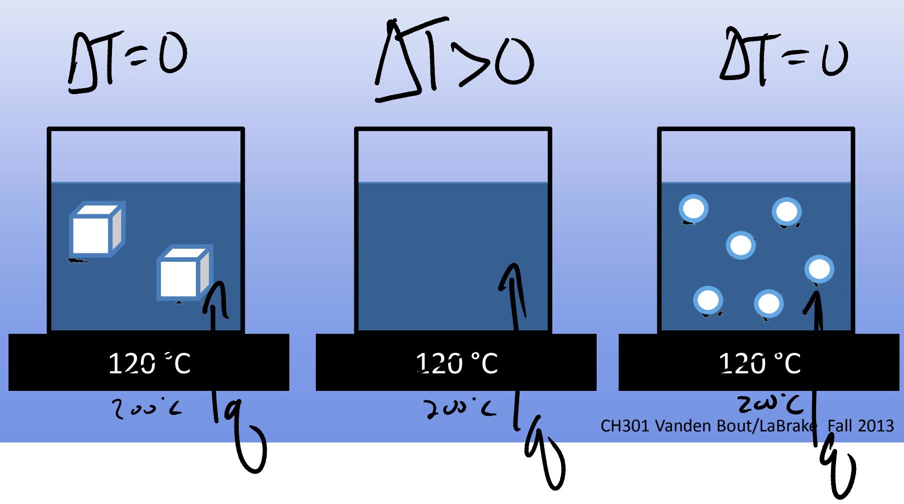
Molar Heat Capacity is an Extensive Property.

A. True

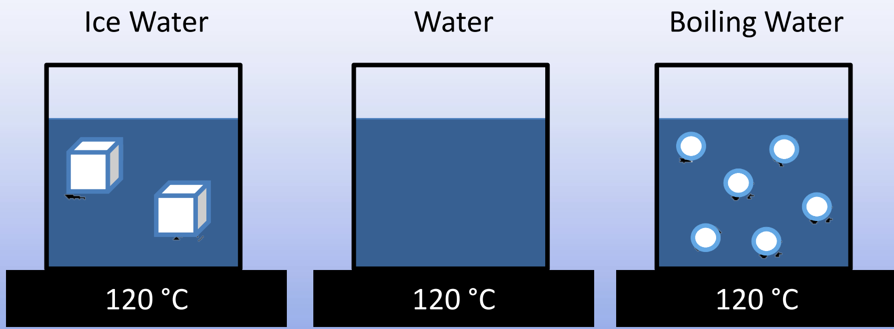
B. False

Demonstration

Ice Water | Water | Boiling Water



Demonstration



$\Delta T = 0$
$q \neq 0$

$$q = mC_s\Delta T$$

$\Delta T = 0$
$q \neq 0$

POLL: iClicker Question 7

Think about the two systems in which the temperature remains constant. In these cases the thermal energy is being transferred from the hot plate heat hot plate → beaker

A. To the surroundings, bypassing the water/beaker system
B. To the water/beaker system in the form of thermal energy (kinetic energy)
C. To the water/beaker system in the form of potential energy
D. There is no energy transfer. If there is no change in temperature, then there is no flow of heat energy.

Enthalpy

Enthalpy of Physical Change

The transfer of heat into or out of the system. The heat is transferred into potential energy (change of position) of the "particles"

Enthalpy of Vaporization (ΔH_{vap}) LIQ → VAP ΔH_{VAP}

Enthalpy of Fusion (ΔH_{fus}) SOL → LIQ ΔH_{fus}

Enthalpy of Sublimation (ΔH_{sub}) SOL → VAP ΔH_{sub}

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Enthalpy

The change in heat transfer between the system and the surroundings at constant pressure is represented by q_p

$q_p = \Delta$ Energy

$q_p = \Delta H$

change in Enthalpy is equal to heat flow @ const P

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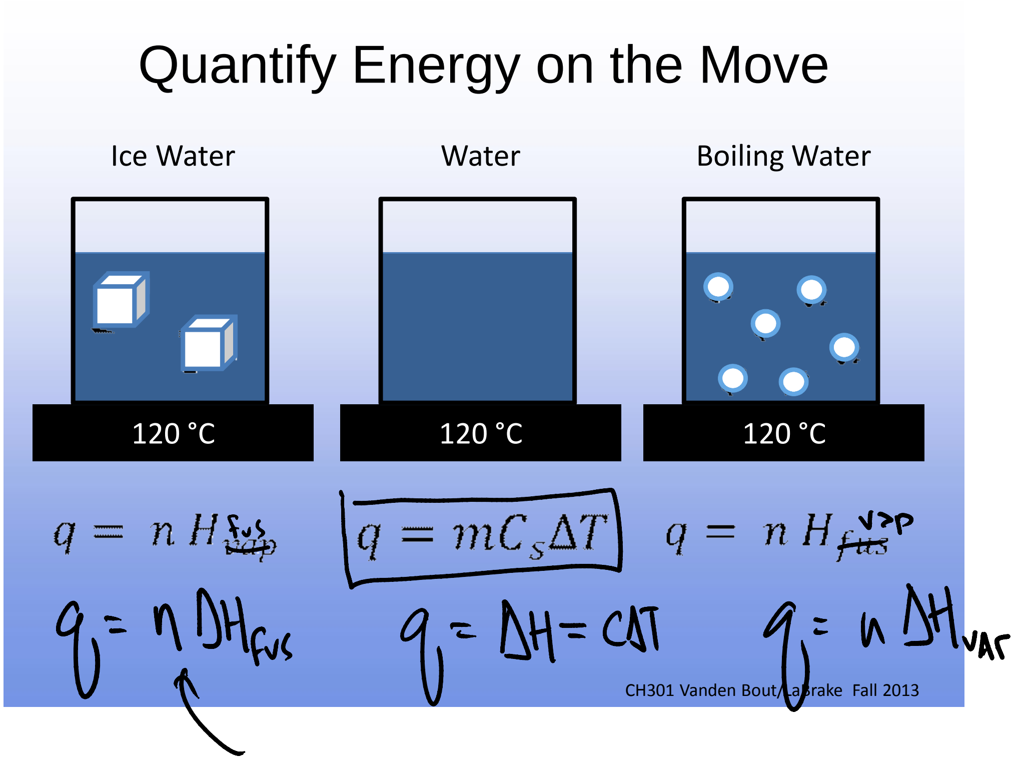
Quantify Energy on the Move
Ice Water
Water
Boiling Water
120 °C
120 °C
120 °C
$q = n H_{vap}$
$q = mC_s\Delta T$
$q = n H_{fus}$
$q = n\Delta H_{fus}$
$q = \Delta H = C\Delta T$
$q = n\Delta H_{vap}$
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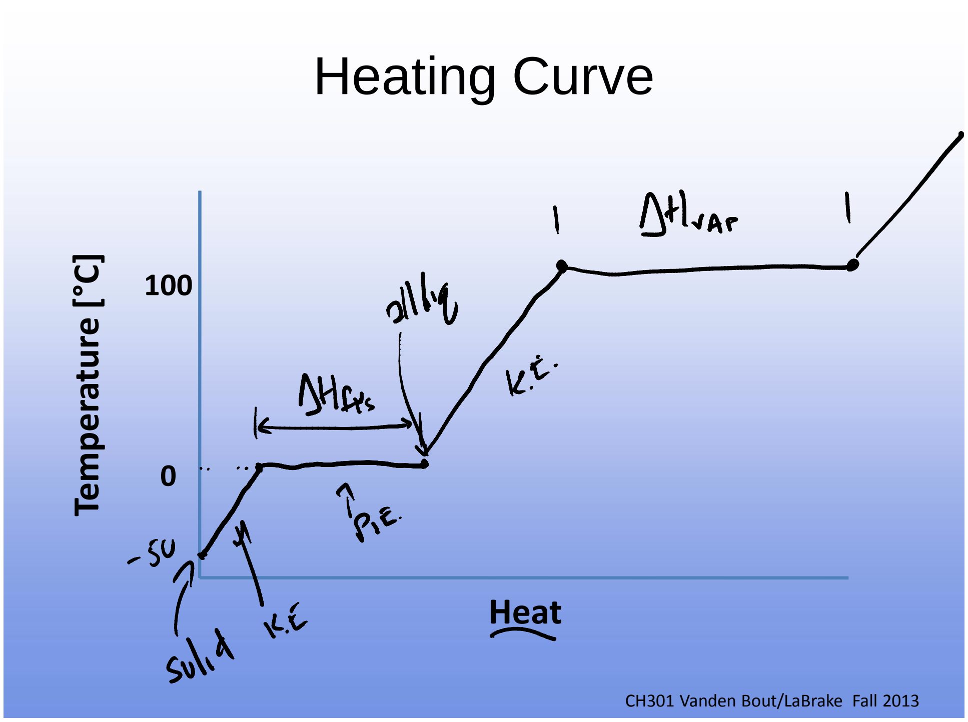
Heating Curve
Temperature [°C]
100
0
-50
Heat
ΔHfus
ΔHvap
K.E.
P.E.
K.E
solid
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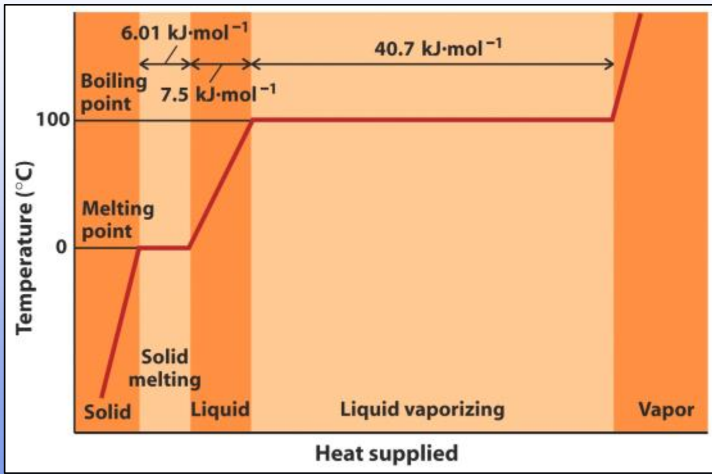
Heating Curve



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POLL: iClicker Question 8

The molar heat of fusion of Na is 2.6 kJ mol^{-1} at its melting point, 97.5 °C. How much heat must be absorbed by 5.0 g of solid Na at 97.5 °C to go through a phase change? Answer in Joules

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POLL: iClicker Question 9

How many "q" calculation steps are needed in order to determine the amount of heat that must be absorbed by 50.0 g of ice at -12.0°C to convert it to steam at 120 °C.

a) 1 step
b) 3 steps
c) 4 steps
d) 5 steps
e) 6 steps

Quantify Energy on the Move

We use a *calorimeter* to measure the heat flow in or out of a system.

Demonstration

Dissolve $CaCl_2$ in water

POLL: iClicker Question 10

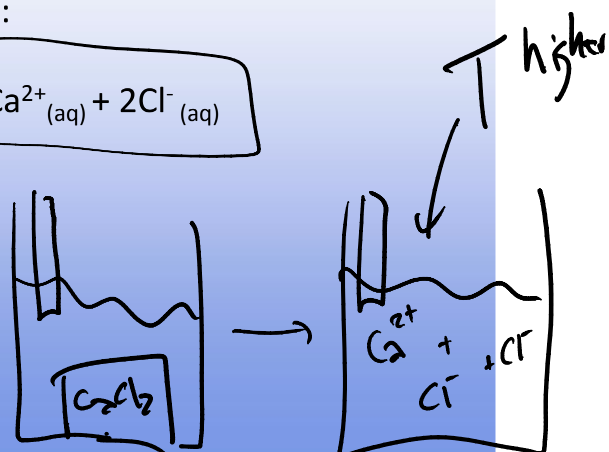
Look at the following physical change observed in the calorimeter demonstration:

$$H_2O + CaCl_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2Cl^-_{(aq)}$$

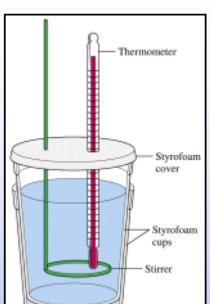
Which is lower in energy?

a) Products

b) Reactants



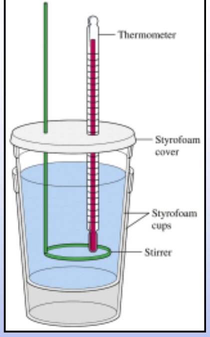
Calorimetry



A Coffee Cup calorimeter measures the transfer of heat at constant pressure. ($q_p = \Delta H$)

measure

Calorimetry



A Coffee Cup calorimeter measures the transfer of heat at constant pressure. ($q_p = \Delta H$)

measure

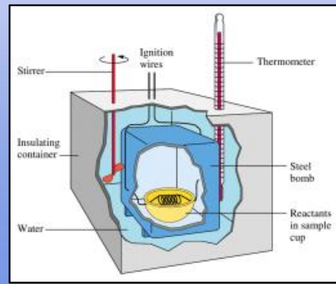
$\Delta H = q_p = C\Delta T$

ΔH

A Bomb calorimeter measures the transfer of heat at constant volume. ($q_v = \Delta U$)

$\Delta U = q + w$
$\Delta U = q - P\Delta V$
$\Delta U = q_v$

$\Delta V = 0$



ΔU

Enthalpy and Internal Energy

Enthalpy is also proportional to the combination of internal energy and work

Enthalpy and Internal Energy

Enthalpy is also proportional to the combination of internal energy and work

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

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

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

Enthalpy and Internal Energy

Enthalpy is also proportional to the combination of internal energy and work

Enthalpy and Internal Energy

Enthalpy is also proportional to the combination of internal energy and work

$\Delta U = q + w$

Constant Volume

$\Delta U = q_v + w$

Constant Pressure

$\Delta U = q_p + w$

$\Delta U = \Delta H + w$

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

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

What have we learned today?

Heat vs Thermal Energy

Quantify heat transfer

New Thermodynamic State Function $\Delta H = q_p$

Calorimetry – Tool used to experimentally determine heat flowing into or out of a system

Learning Outcomes

Calculate change in enthalpy for physical change in T and Phase Change

Understand the concept of heat capacity, specific heat capacity and molar heat capacity

Explain the difference between coffee cup calorimeter and bomb type calorimeter

Understand the concept of change in enthalpy

Calculate change in enthalpy, ΔH, and change in internal energy, ΔU, based on raw calorimeter data

Calculate q for various processes