Chapter 11

Thermochemistry: Heat & Chemical Change

The Flow of Energy

Thermochemistry:

- Study of heat changes that occur during physical processes and chemical reactions

Energy

- Energy is the capacity to do work or supply heat.
- Unlike matter, energy is:
  - Weightless
  - Odorless
  - Tasteless
- Energy is only detected because of its effects

Potential Energy

- Energy stored within the structural units of chemical compounds is called chemical potential energy
- Different substances store different amounts of potential energy
  - Gasoline is an example of a substance that has a significant amount of chemical potential energy

Heat energy

- Heat: represented by “q” or “ΔH”
- Energy that transfers from one object to another
- Transferred because of temperature differences
- Always flows from warm to cool

Endothermic vs Exothermic

Law of Conservation of Energy

- The law of conservation of energy states that in any chemical process energy is neither created nor destroyed
- All the energy in a chemical process can be accounted for as work, stored energy or heat.

Flow of heat in a system:

- Takes into consideration the direction heat flows in a chemical reaction
  - From the system to the surroundings or
  - From the surroundings to the system

Heat Change Sign Convention		
Direction of heat flow	**Sign**	**Reaction type**
Heat flows out of system	Negative	Exothermic
Heat flows into system	Positive	Endothermic

Endothermic Process

- Heat Flow is represented by the symbols ΔH or q, and is positive for an endothermic process
- Heat flows from the surroundings to the system, so the energy of the system increases and ΔH is +
- An endothermic process absorbs energy

Exothermic Process

- Heat Flow is negative for an exothermic process
- Heat flows from the system to the surroundings, so the energy of the system decreases and ΔH is -
- An exothermic process releases energy ($\Delta H = q = -$)

Heat Capacity & Specific Heat

Heat Capacity:

- The amount of heat needed to raise the temperature of an object exactly 1^0C

Specific Heat Capacity:

- The amount of heat required to raise ***1 gram*** of a substance $\mathbf{1^0C}$
- Simply referred to as specific heat

Heat energy units

A calorie is the amount of heat required to raise the temperature of 1 gram of water by 1 degree C

- 1 cal = 4.184 joules (J)
- Named after the English physicist James Prescott Joule
- 1 joule = 0.2390 cal

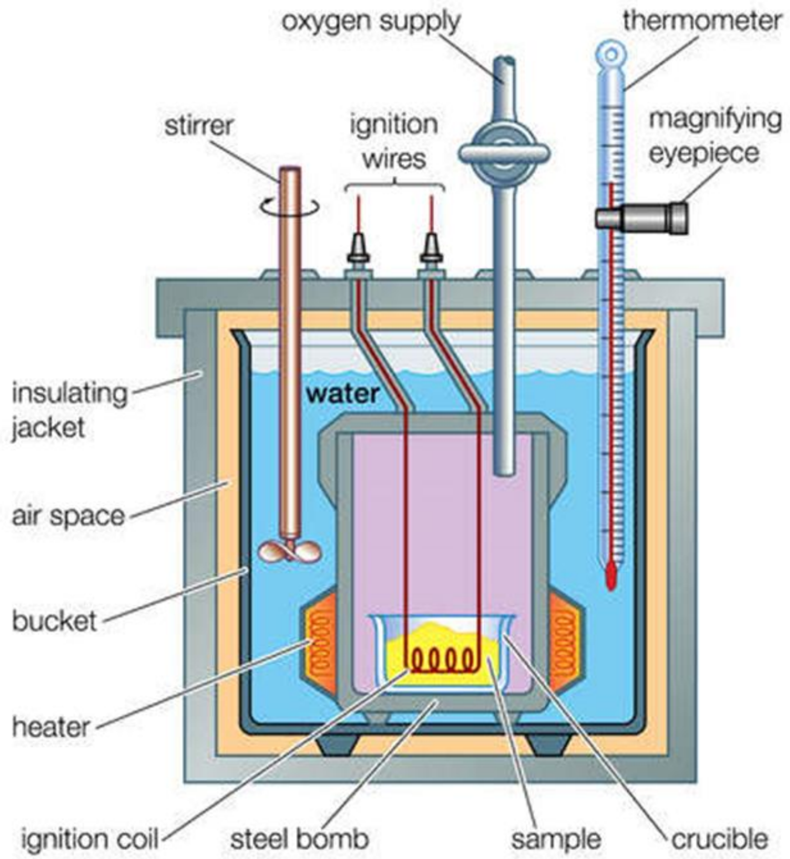
Heat Capacity:

Depends on two things:

- Mass of object
- Chemical composition of object

Solving for Specific Heat

- **Calorimeter**: device used to determine the specific heat of a substance through energy transfer



Calorimetry:

- The accurate and precise measurement of heat change for chemical and physical processes
- The heat released by the system is equal to the heat absorbed by its surroundings

Calorimeter:

- An insulated device used to measure the absorption or release of heat in chemical or physical processes
- Calorimeters may be simple- such as Styrofoam cups or soda cans
- Or, very complex- such as a Bomb calorimeter

Specific Heats of Water

- Constants
  - Water: 4.184 J/g·°C
  - Ice: 2.03 J/g·°C
  - Steam: 2.01 J/g·°C

Calculating Specific Heat:

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

- C = specific heat
- m = mass
- q = heat (J's or cal)
- ΔT = temperature (T_2-T_1) ^{0}C

Specific Heat

- Two forms of the equation:

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

Or

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

Enthalpy: (H)

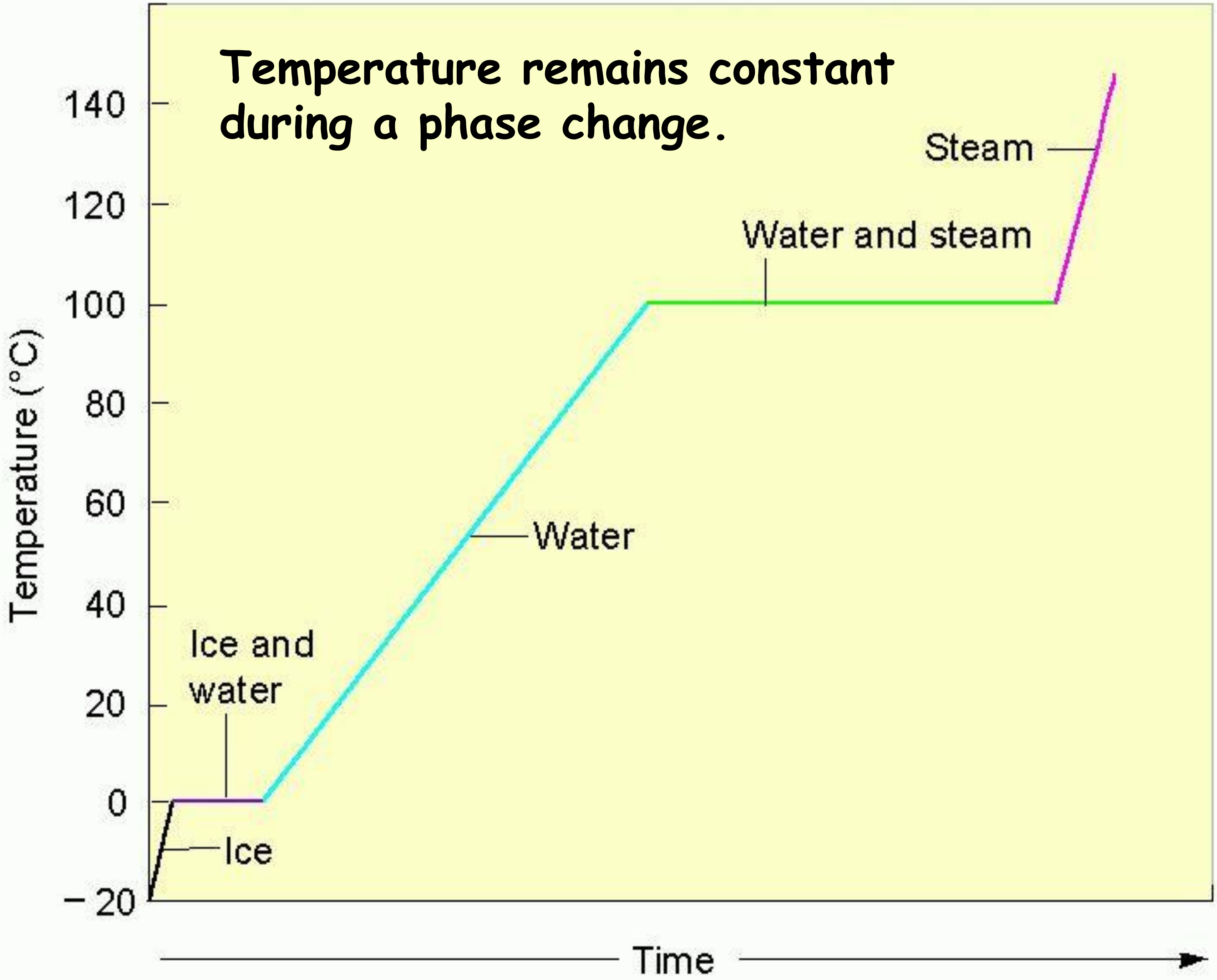
- Enthalpy is another term used to describe heat change at a constant pressure
- The terms "heat" and "enthalpy" are used interchangeably

$$\text{Enthalpy} = \Delta H = q$$

$$\text{so } \Delta H = m \times c \times \Delta T$$

Heat in changes of state:

Temperature remains constant during a phase change.



Heat of fusion:

- Molar heat of fusion
- ΔH_{fus} is the heat absorbed when one mole of a substance moves from solid to liquid state at a constant temperature
- the phase change called "melting"

Heat of Fusion

ΔH_{fus} = molar heat of solidification

- the heat lost when one mole of a liquid solidifies at a constant temperature
- The phase change of "freezing"

Heats of Vaporization

- Water absorbs heat as it turns to a vapor
- Heat flows from surroundings to the liquid
- The amount of heat necessary to vaporize one mole of water is its *molar heat of vaporization*

Heat of Vaporization

- For water = ΔH_{vap} = 40.7kJ/mol
- To vaporize 1 mole of water you need 40.7kJ of energy

Heat of Vaporization

- Condensation is the opposite of vaporization
- Amount of heat released when 1 mole of a vapor condenses is the *molar heat of condensation*

$$\Delta H_{cond}$$

Phase Change Calculations

For melting/freezing:

$$q = m \cdot \Delta H_{fus}$$

q = heat in joules or calories

m = mass

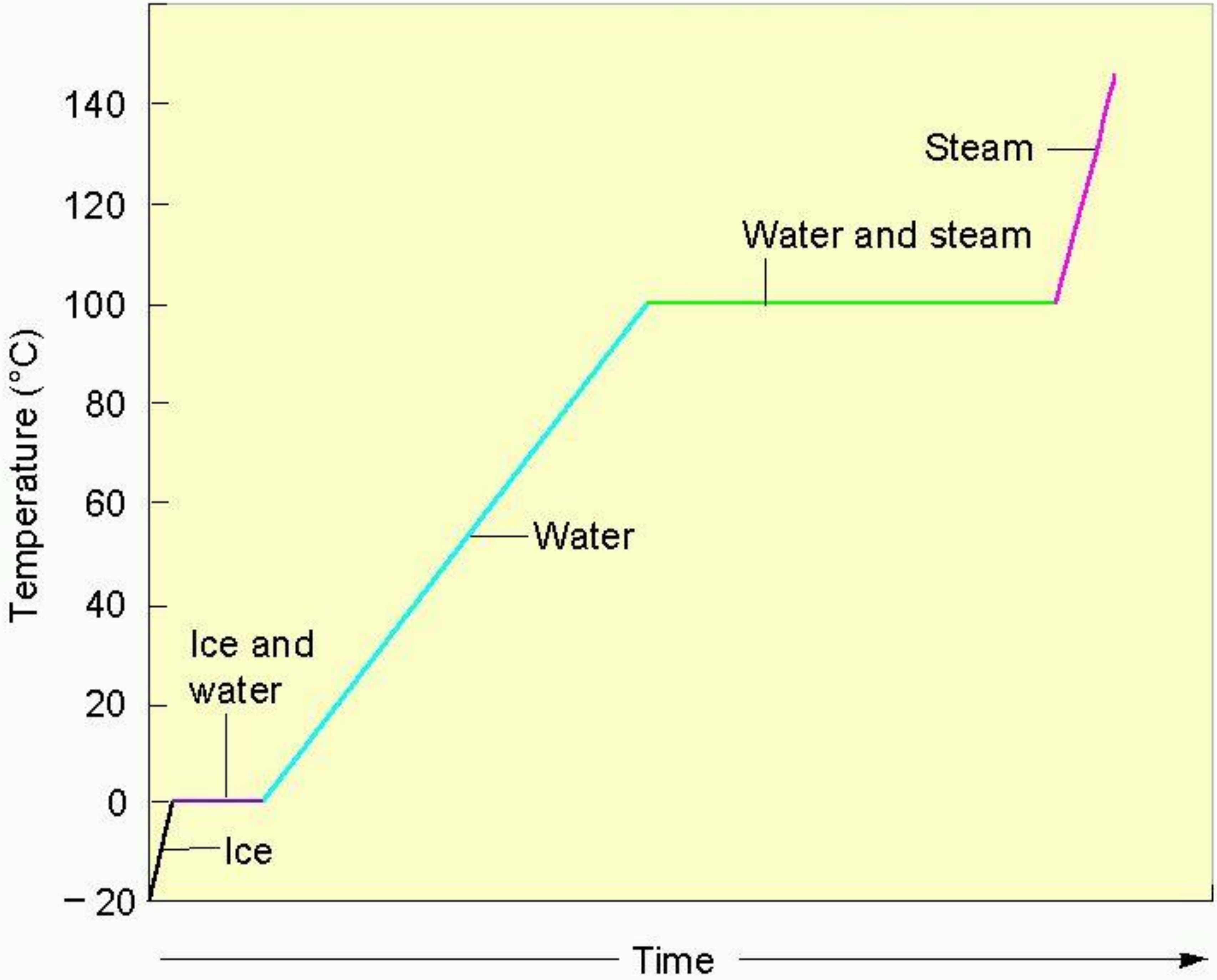
Phase Change Calculations

For vaporizing/condensation:

$$q = m \cdot \Delta H_{vap}$$

q = heat in joules or calories

m = mass



Temperature (°C)
140
120
100
80
60
40
20
0
−20
Steam
Water and steam
Water
Ice and
water
Ice
Time

Constants

ΔH_{fus} = 333 J/g	Specific heat of water: 4.184 J/g^{0}C
ΔH_{vap} = 2260 J/g	Specific heat of ice: 2.10 J/g^{0}C
	Specific heat of steam: 2.00 J/g^{0}C
$q = m \bullet c \bullet \Delta T$	
$q = \Delta H_{fus} \bullet m$	$q = \Delta H_{vap} \bullet m$