Changes and Properties of Matter

Physical Properties of Matter

- **Physical Changes**: Changes that change only the appearance of a substance, not its chemical identity.
- Physical Properties: Properties that can be observed through physical change

Physical Change

- **Melting**
- **Boiling**
- **Dissolving**
- **Evaporating**
- **Crushing**
- **Stretching**

Physical Property

- **Melting point** (the temperature at which a substance turns from a solid to a liquid)
- **Boiling point** (the temperature at which a substance turns from a liquid to a gas)
- **Solubility** (the amount of solute that can be dissolved in a solvent)
- **Vapor pressure** (the pressure exerted by a vapor at vapor-liquid equilibrium)
- **Malleability** (the ability to be hammered or rolled into thin sheets)
- **Ductility** (the ability to be stretched into a wire)
- **Density** (the mass of a substance per unit volume)
- **Electrical & Heat Conductivity** (the ability to pass heat or electricity through a substance

Chemical Properties and Changes

- **Chemical Changes**: Changes that result in changing the chemical composition of a substance. Can be reversed only by another chemical change.
- Chemical Properties: Properties that can only be observed through chemical change.

Chemical Change

- **Corrosion of metals**, flammability
- **Chemical decomposition** e.g. hydrogen peroxide decomposes to form water and oxygen, but water does not decompose spontaneously
- **Combustion releases heat** (exothermic) Rarely do chemical changes absorb heat (endothermic)

Chemical Property

- **Reactivity** (the likelihood of one substance to undergo a chemical reaction with another substance)
- **Stability** (the likelihood that a substance will no decompose)
- **Heat of Reaction** (the energy absorbed or released by a chemical reaction)

Indications of a chemical reaction:

- Energy absorbed or released (heat and/or light)
- Color change
- Gas production (bubbling, fizzing, or odor change)
- formation of a precipitate- a solid that separates from solution (won't dissolve)
- Irreversibility- not easily reversed
- new substances produced, old substances destroyed.




Checking for understanding

Explain why are these processes physical changes:

- Boiling
- Condensation
- Shredding paper

- Explain why are these processes chemical changes:
- Burning paper
- Rusting bicycle
- Frying eggs

Change in Energy

Energy

Different types of energy exist (heat, potential, kinetic, chemical, nuclear etc.)

Heat - the energy transferred between objects that are at different temperatures. Unit of heat is joules J.

According to the Law of Conservation of Energy, energy cannot be created or destroyed. It can only by transferred or transformed. The total amount of energy in a system remains constant.

- Add a potential energy diagram
- To draw from scratch
- Do more calculations on enthalpy/energies

Potential Energy Diagram

http://www.kentchemistry.com/links/Kinetics/PEDiagrams.htm

Potential Energy Diagram

- Potential Energy Diagrams show changes in energy during chemical reactions.
- CHEMICAL EQUATIONS

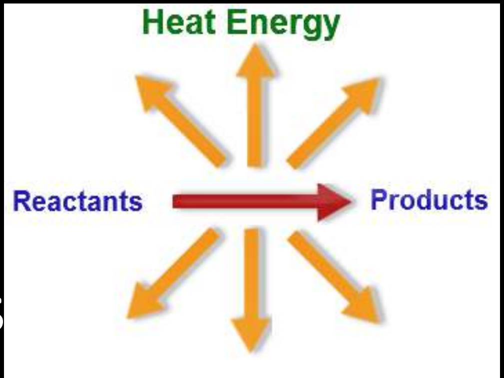
A + B ---> C + D

Reactant   Products

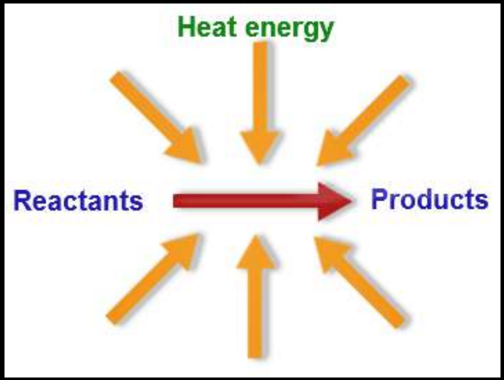
- In chemical reactions, reactants react to form products with an associated release or absorption of energy.

Change in Heat Energy

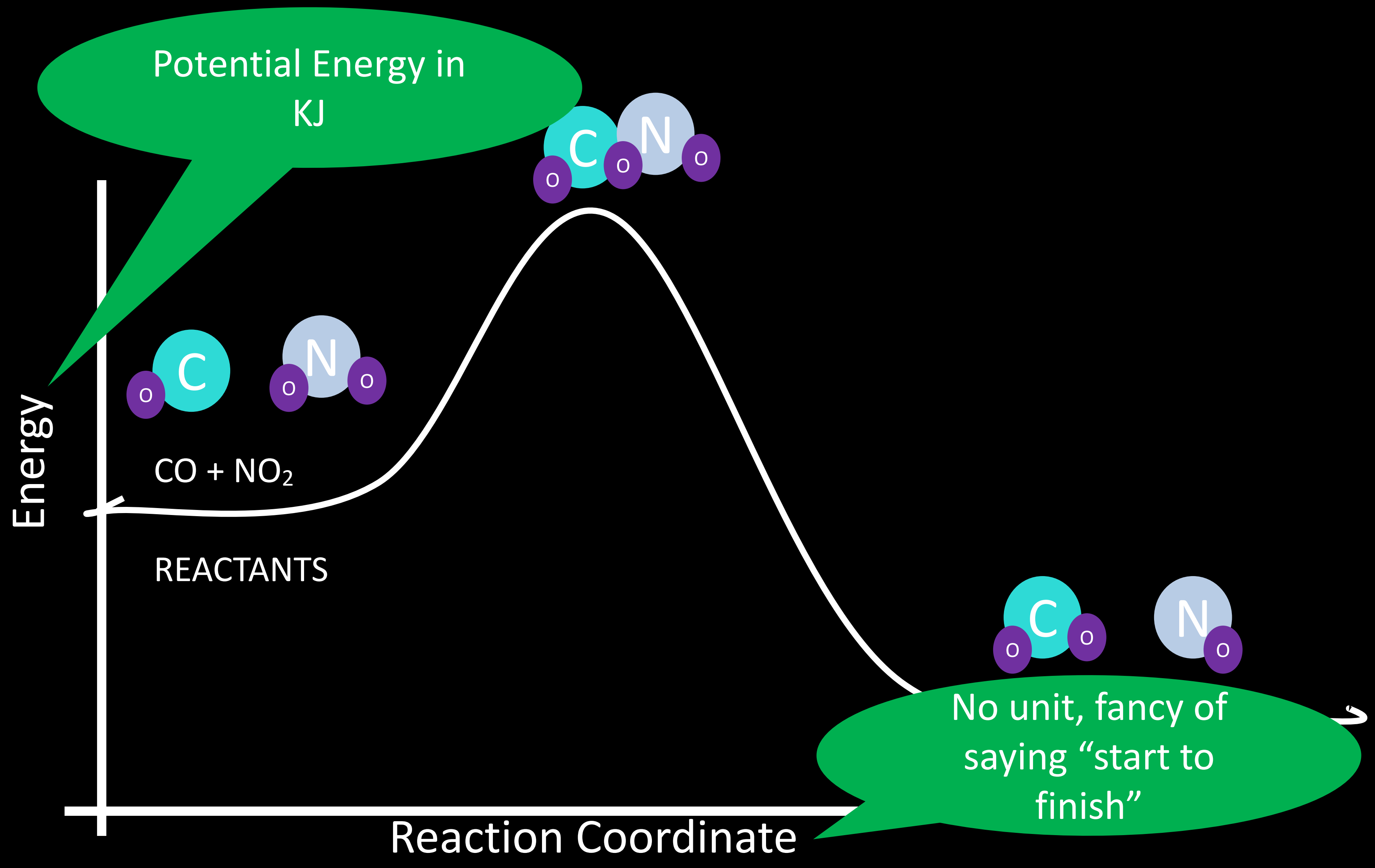
1. **Exothermic Reaction**
   - The change in heat (ΔH) is NEGATIVE.
   - Heat is released into the surroundings



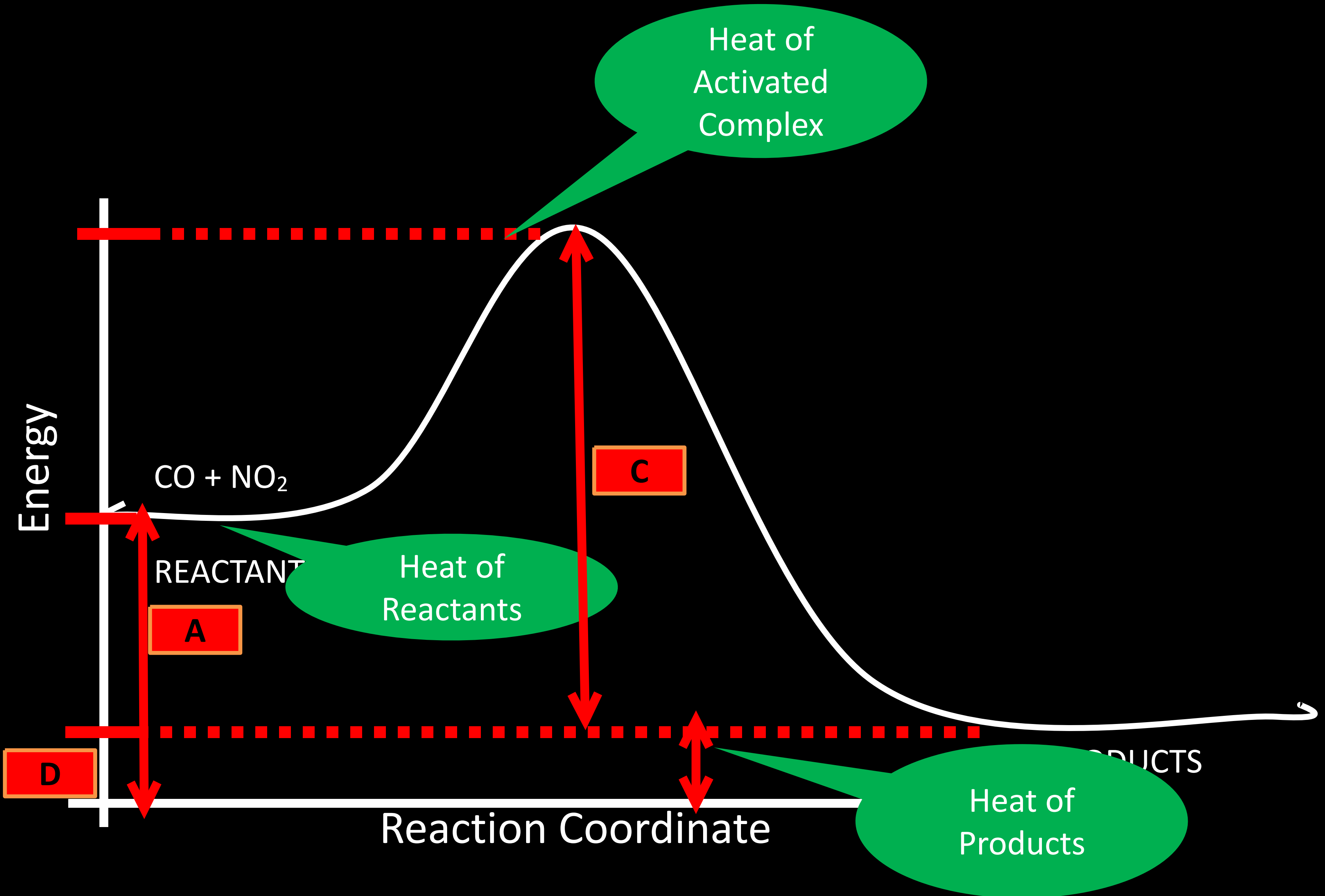
2. **Endothermic Reaction**
   - The change in heat (ΔH) is POSITIVE.
   - Heat is absorbed by the system



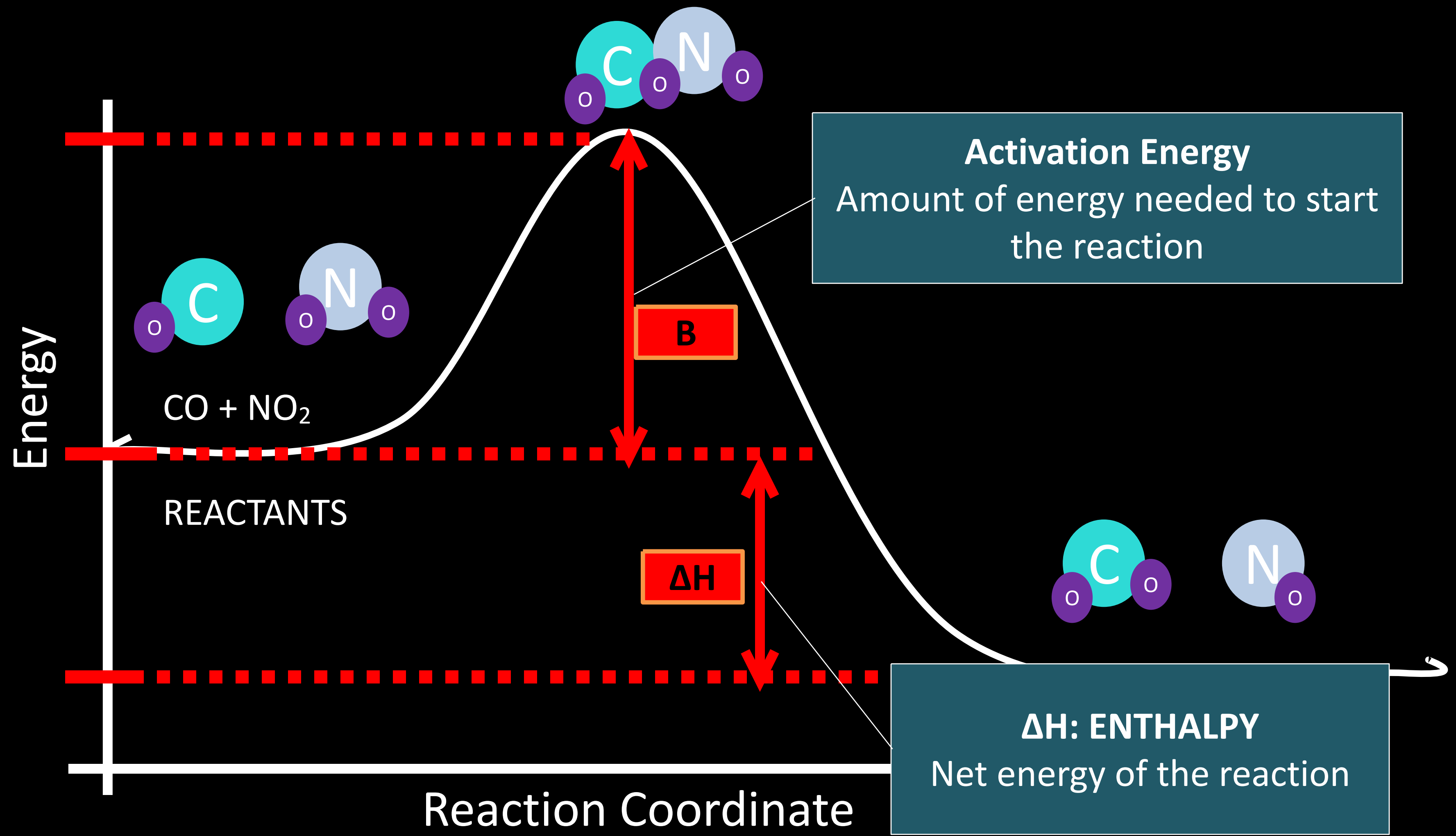
Potential Energy Diagram



Potential Energy Diagram



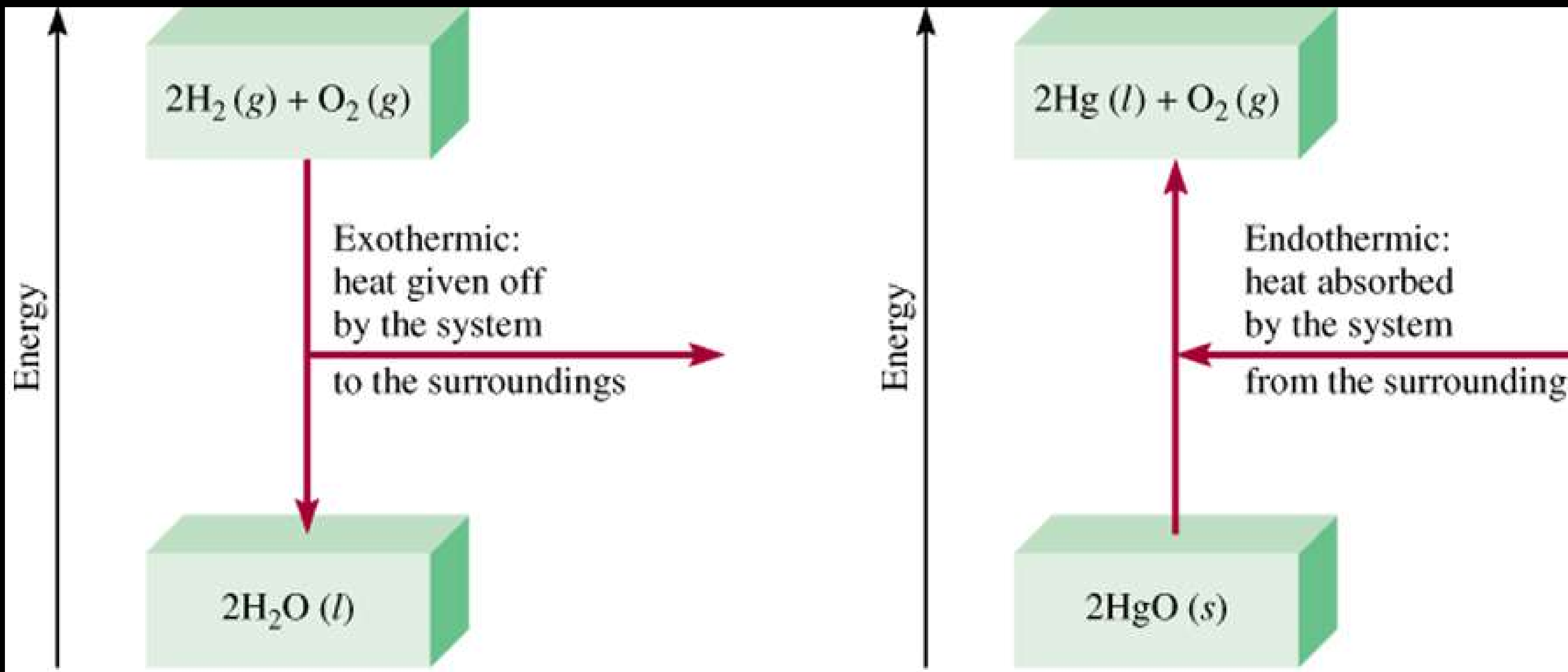
Potential Energy Diagram



Enthalpy (H) is used to quantify the heat flow into or out of a system in a process that occurs at constant pressure.

$$\Delta H = H\text{ (products)} - H\text{ (reactants)}$$

ΔH = heat given off or absorbed during a reaction **at constant pressure**



$H_{\text{products}} < H_{\text{reactants}}$

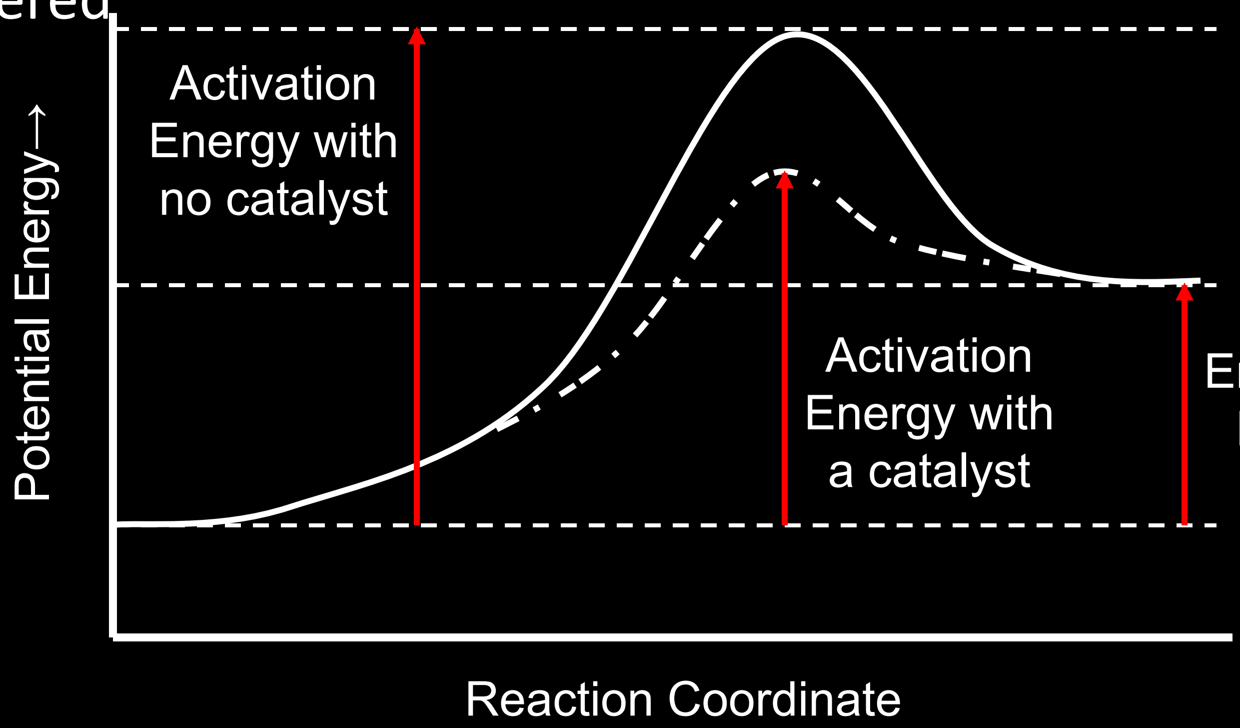
$\Delta H < 0$

$H_{\text{products}} > H_{\text{reactants}}$

$\Delta H > 0$

Potential Energy Diagrams

- A ***catalyst*** is a substance that changes the speed of reactions by changing the **activation energy**.
- ***Catalysts*** speed up chemical reaction by **lowering** the activation energy
- **Catalysts** are not consumed during the reaction and can be recovered

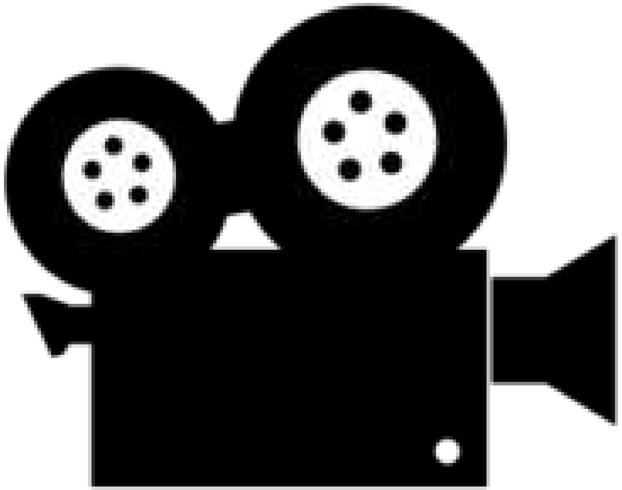


Click Below for the Video Lectures

Activation Energy

Reaction Coordinate

Catalyst



Exothermic and Endothermic

Exothermic Reaction

A + B → C + D + **ENERGY**

a) **Heat is released as a product.**
b) This heat is released into the environment surrounding the reaction, causing the temperature of the surroundings to increase.
c) The products have less energy than the reactants after release.
d) Since the products have less energy stored in their chemical bonds, they are more stable than the reactants were. Burning paper is exothermic. The ash formed by the burning is not flammable and will not burn.

General Exothermic Reaction

A + B → C + 70 kJ

ΔH_A = **60 kJ**

ΔH_B = **40 kJ**

ΔH_c = **30 kJ**

\+ 100 KJ

Energy **Released** as product **Exothermic**

Law of conservation of energy states that the total energy of an isolated system cannot change.

Exothermic Reaction

$C\ (g) + O_2\ (g) \rightarrow CO_2\ (g)$ **$\Delta H = -393.5\ kJ$**

- The minus sign in front of the enthalpy
  393.5 kJ indicates that this reaction is exothermic, that energy was released.
- This energy can be placed on the products side, as follows:

$C\ (g) + O_2\ (g) \rightarrow CO_2\ (g)$ **+ 393.5 kJ**

Synthesis →

$C\ (g) + O_2\ (g) \rightarrow CO_2\ (g)$ **$\Delta H = -393.5\ kJ$**

← Decomposition

1 mol of CO_2

- If we were to synthesize **2.3 moles of CO_2, how many kJ would be released?**

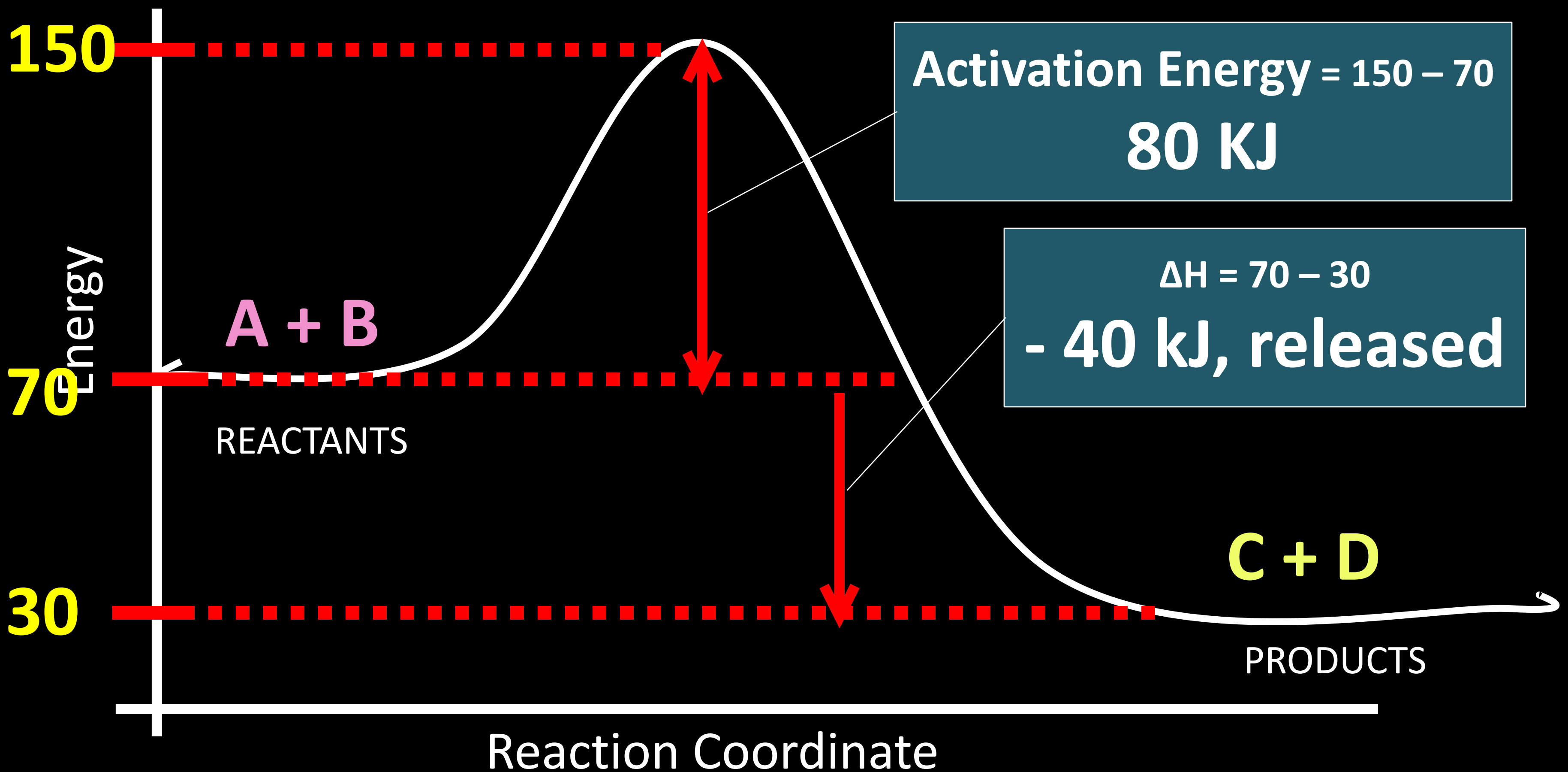
$$\frac{2.3\ \text{mol}\ CO_2 \;\big|\; 393.5\ kJ}{\;\big|\; 1\ \text{mol}\ CO_2} = -\ \mathbf{910\ kJ}$$

If $\Delta H_{synthesis}$ = - 393.5 kJ/mole,

then $\Delta H_{decomposition}$ = +393.5 kJ/mole

Potential Energy Diagram - **Exothermic**

A + B → C + D + **40 kJ**



Endothermic Reaction

A + B + ENERGY → C + D

a) **Heat is absorbed by the reactants.**
b) This heat is absorbed from the environment surrounding the reaction, and the temperature of the surroundings decreases.
c) The products have more energy than the reactants after absorption.
d) This energy is stored in the chemical bonds of the products

General Endothermic Reaction

A + B + **50 kJ** → C

ΔH_A = **40 kJ**

ΔH_B = **20 kJ**

ΔH_C = **110 kJ**

\+

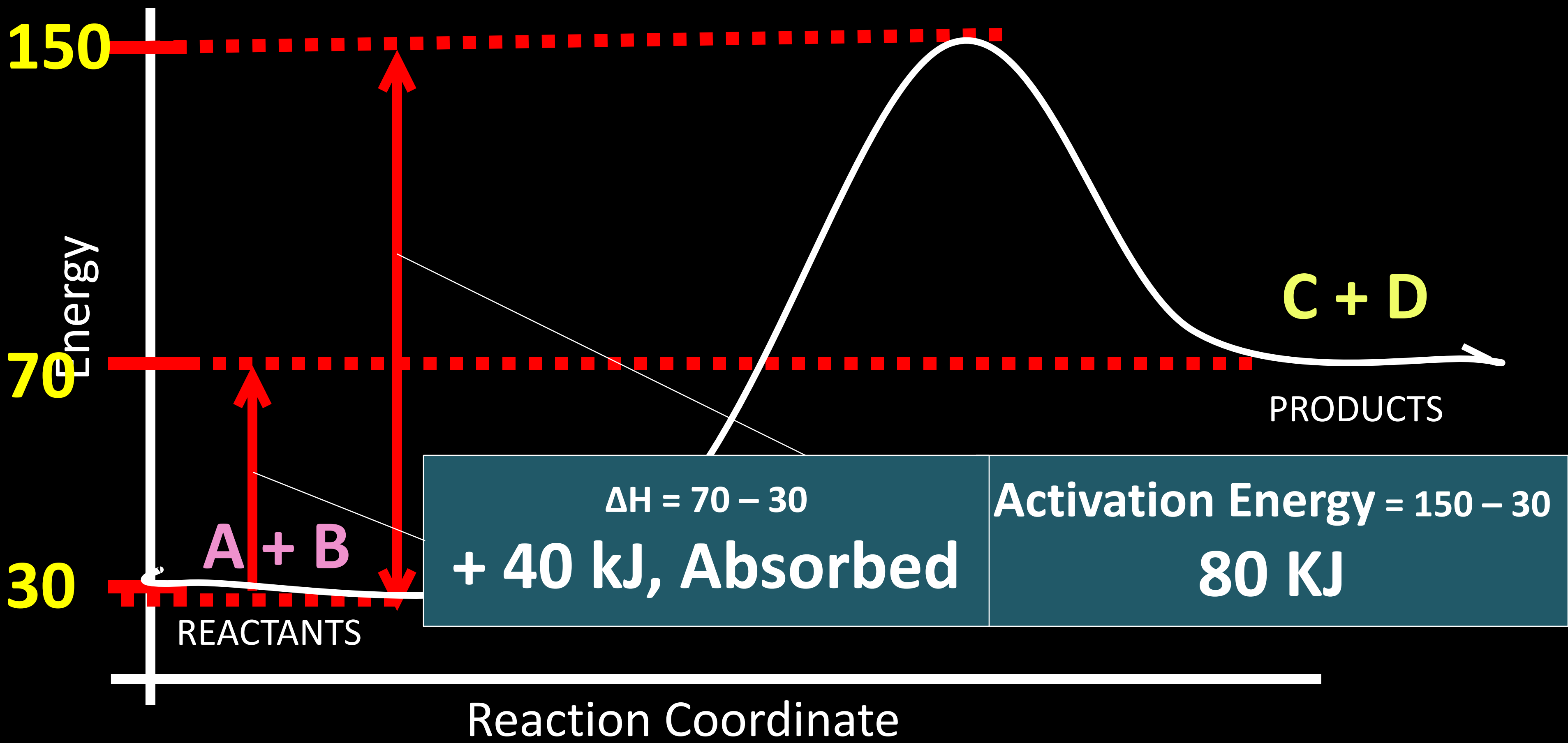
60 KJ

Energy **absorbed** as product **Endothermic**

Law of conservation of energy states that the total energy of an isolated system cannot change.

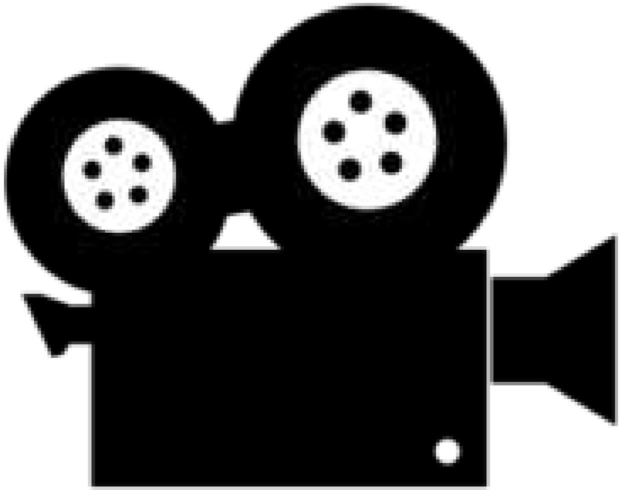
tential Energy Diagram - **Endothermic**

A + B + **40 kJ** → C + D



Click Below for the Video Lectures

Exothermic and Endothermic



Calorimetry

Calorimetry

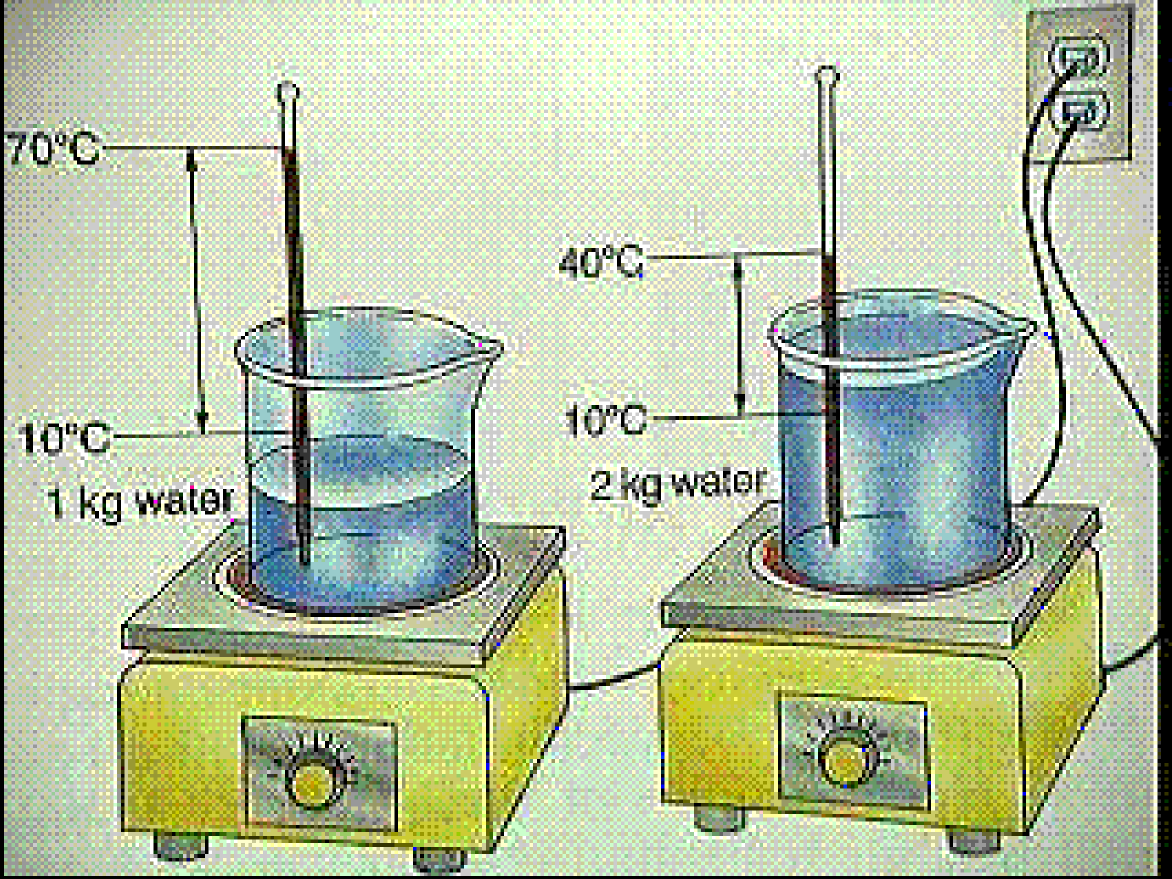
$$q = m\,C\,\Delta T$$

	q	m	C	ΔT
units	Joules (J)	Grams (g)	J/g°C	°C
What Each Variable Means	q is the quantity of heat that is absorbed or released by a physical or chemical change	m is the mass of water in the calorimeter cup that absorbs heat from the change or releases heat to the change.	C is the specific heat of water, the rate at which water gains or loses heat if energy is absorbed or removed from it.	ΔT is the Temperature change of the water in the calorimeter cup as a result of the physical or chemical change.

C

Specific Heat

The amount of heat required to raise the temperature of one gram of substance by one degree Celsius.



	cal/g°C	J/g°C (or J/gK)
water	1.00	4.18
aluminum	0.22	0.90
copper	0.093	0.39
silver	0.057	0.24
gold	0.031	0.13

Calorimetric Formulas –

No Phase Change: $Q = m(\Delta T)C_p$

Latent Heat of Fusion: $Q = m\Delta H_{fus}$

Latent Heat of Vaporization: $Q = m\Delta H_{vap}$

Use this equation on the back of periodic table

Specific Heat of water. Use the one for correct unit! They are NOT equations!!!

Specific Heat of Water: $C_p(H_2O) = 1.00 \frac{cal}{(g\ °C)} = 4.18 \frac{J}{(g\ °C)}$

Latent Heat of Fusion of Water: $\Delta H_{fus}(H_2O) = 80 \frac{cal}{g} = 334 \frac{J}{g}$

Latent Heat of Vaporization of Water: $\Delta H_{vap}(H_2O) = 540 \frac{cal}{g} = 2260 \frac{J}{g}$

1. Circle the numbers, underline what you are looking for.
2. Make a list of number you circled using variables.
3. Write down the formula
4. Derive the formula to isolate the variable you are looking for.
5. Plug in the numbers

- How many joules are absorbed by 100.0 grams of water if the temperature is increased from 35.0°C to 50.0°C?

m = 100.0 g

T i= 35.0°C

T f= 50.0°C

q= ?

C= 4.18 j/g°C

$$q = mc\Delta T$$

$$q = (100.0\ g)(4.18\ j/g°C)(50.0°C - 35.0°C)$$

q = 6270 J

1. Circle the numbers, underline what you are looking for.
2. Make a list of number you circled using variables.
3. Write down the formula
4. Derive the formula to isolate the variable you are looking for.
5. Plug in the numbers

- 300. J of energy is absorbed by a 50. g sample of water in a calorimeter. How much will the temperature change by?

$q = 300\ J$

$m = 50g$

$\Delta T = ?$

$C = 4.18\ j/g^{o}C$

$$q = mc\Delta T$$

$$\Delta T = q / mc$$

$$\Delta T = 300\ J / (50g)(4.18\ j/g^{o}C)$$

$$\Delta T = = 1.4354066\ ^{o}C$$

$$\Delta T = = 1.4^{o}C$$

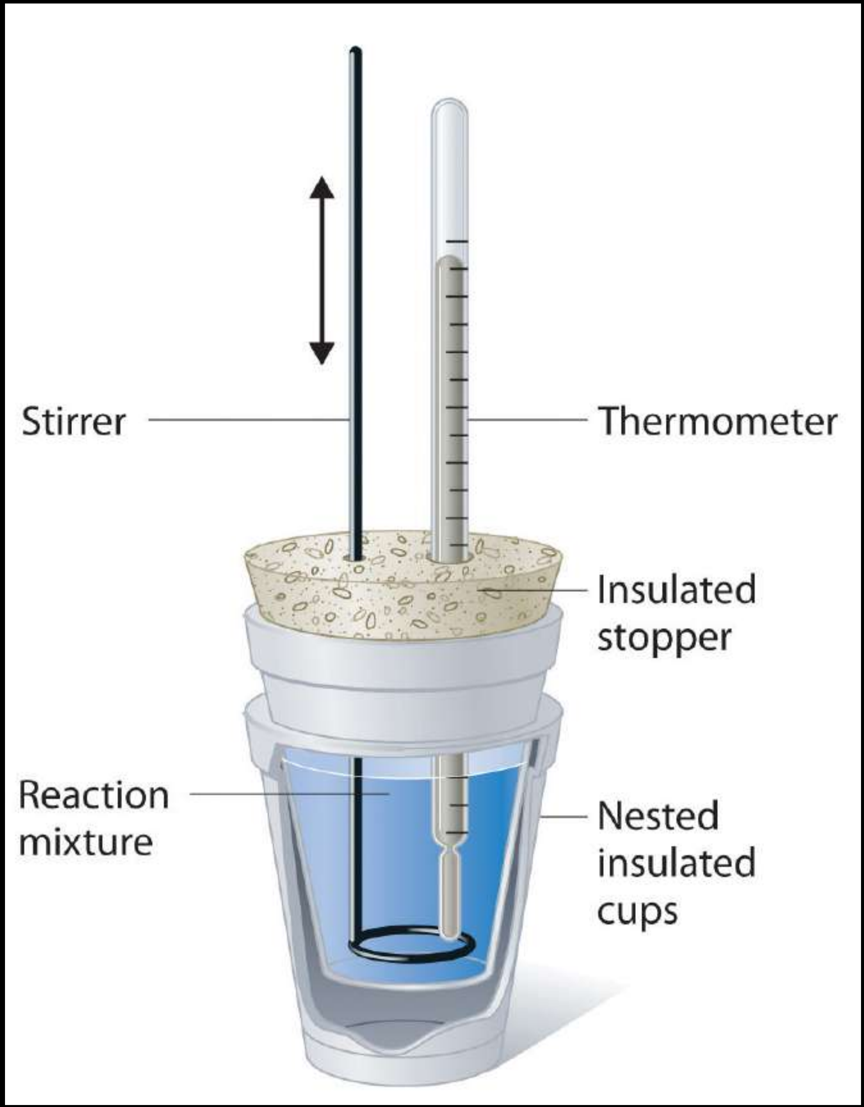
Checking for understanding

1. How many joules are required to raise the temperature of 100. grams of water from 20.0°C to 30.0°C ?

2. How many grams of water can be heated from 20.0°C to 75.0°C using 2500. J?

Calorimetry

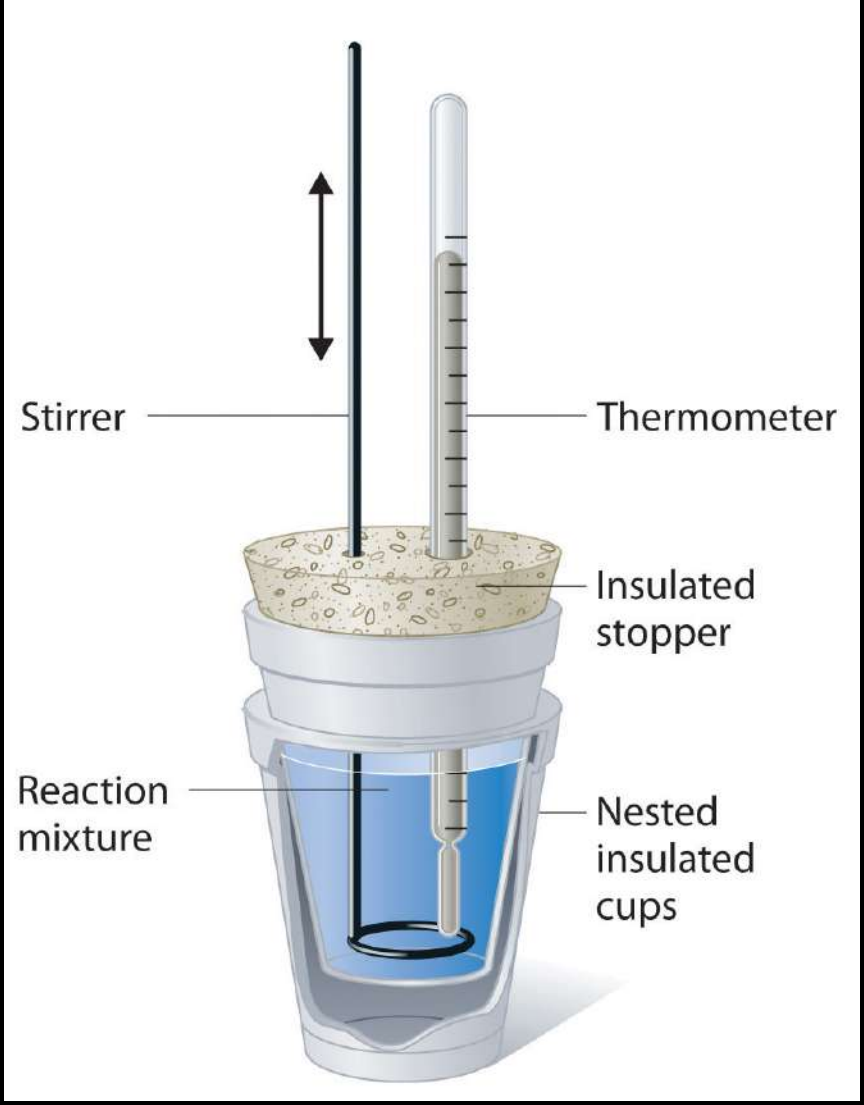
- We use an insulated device called a calorimeter to measure this heat transfer.
- A typical device is a "coffee cup calorimeter."



Calorimetry

To measure ΔH for a reaction

1. dissolve the reacting chemicals in known volumes of water
2. measure the initial temperatures of the solutions
3. mix the solutions
4. measure the final temperature of the mixed solution



Calorimetry

- The heat generated by the reactants is absorbed by the water.
- We know the mass of the water, m_{water}.
- We know the change in temperature, ΔT_{water}.
- We also know that water has a specific heat of C_{water} = 4.18 J/°C-g.
- We can calculate the heat of reaction by:
- $q_{sys} = \Delta H = -q_{surr} = -m_{water} \times C_{water} \times \Delta T_{water}$

When 25.0 mL of water containing 0.025 mol of HCl at 25.0˚C is added to 25.0 mL of water containing 0.025 mol of NaOH at 25.0˚C in a coffee cup calorimeter, a reaction occurs. Calculate ΔH (in kJ) during this reaction if the highest temperature observed is 32.0˚C. Assume the densities of the solutions are 1.00 g/mL.

Knowns: $V_{final} = V_{HCl} + V_{NaOH} = (25.0 + 25.0)\ mL = 50.0\ mL$

$D_{water} = 1.00\ g/mL$

$\Delta T_{water} = T_{final} - T_{initial} = 32.0°C - 25.0°C = +7.0°C$

$C_{water} = 4.18\ J/°C\text{-}g$

Calculation: $m_{water} = 50.0\ g$

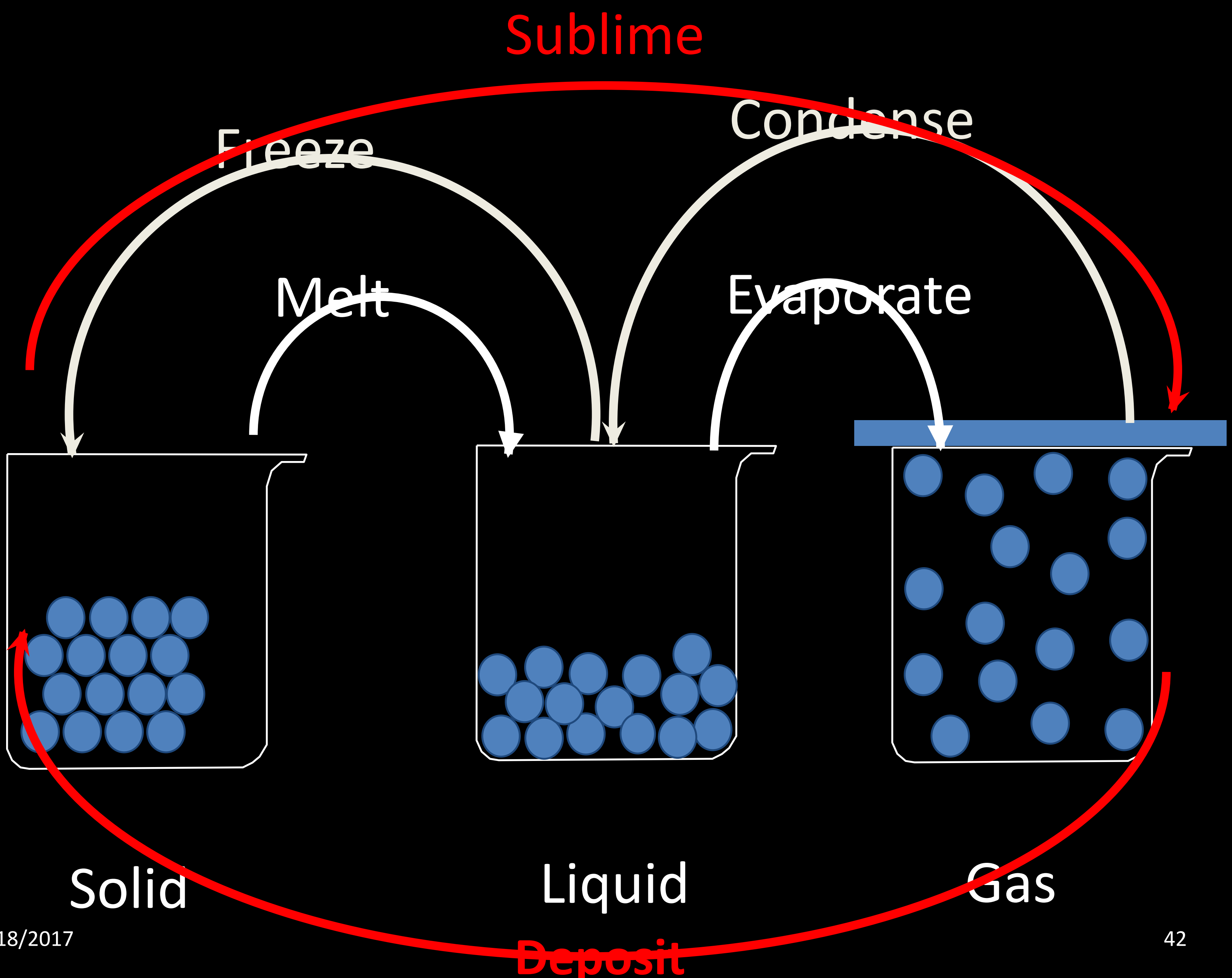
$\Delta H = -m \times C \times \Delta T$

$= -(50.0\ g)(4.18\ J/˚C\text{-}g)(7.0˚C)$

$= -1463\ J$

$= -1.5 \times 10^3\ J$

Phase Change Heating and Cooling Curve


Sublime
Freeze
Condense
Melt
Evaporate
Solid
Liquid
Gas
Deposit

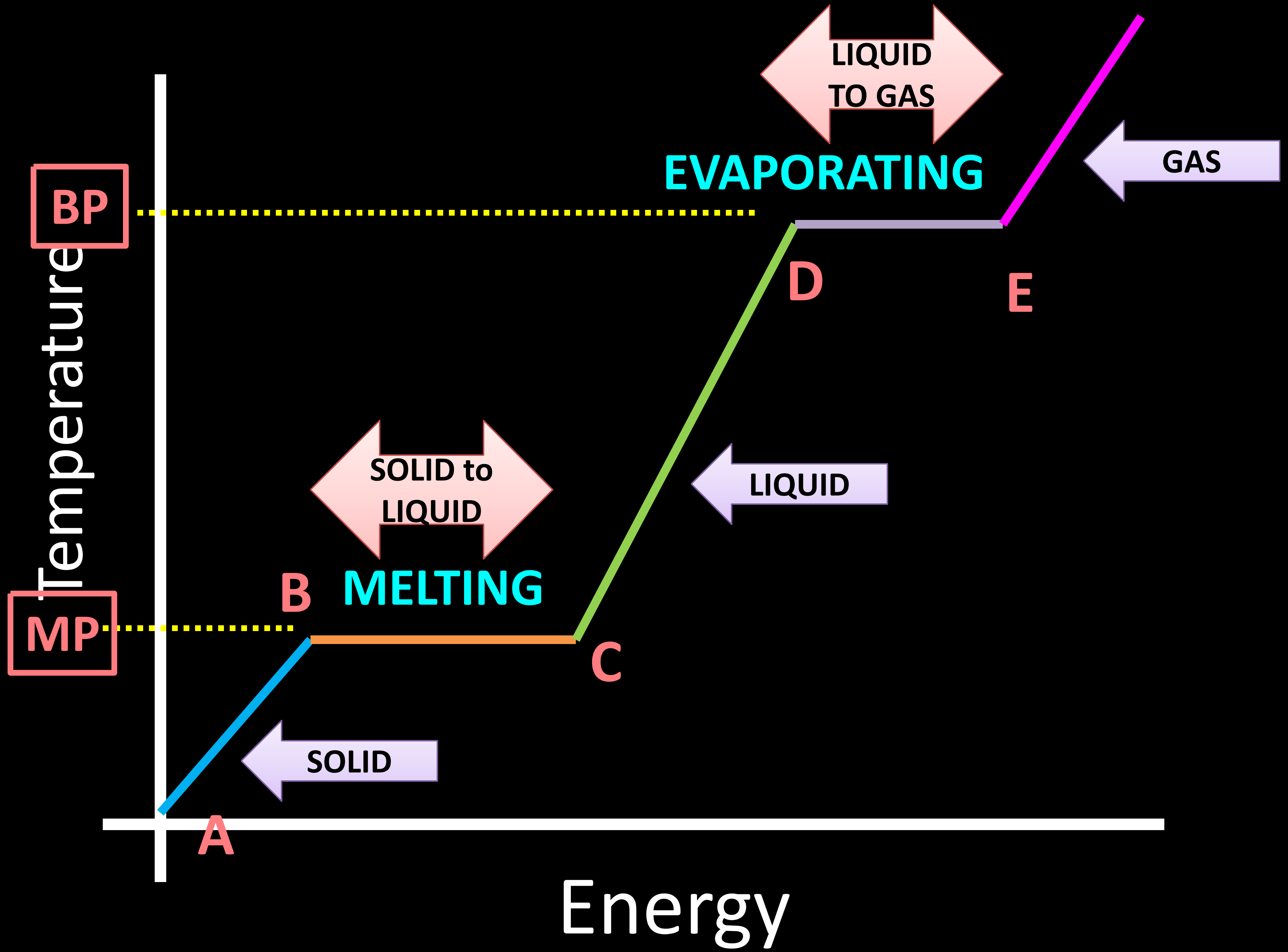
Phase Change

- During a phase change, there is a change in heat energy but no change in temperature.

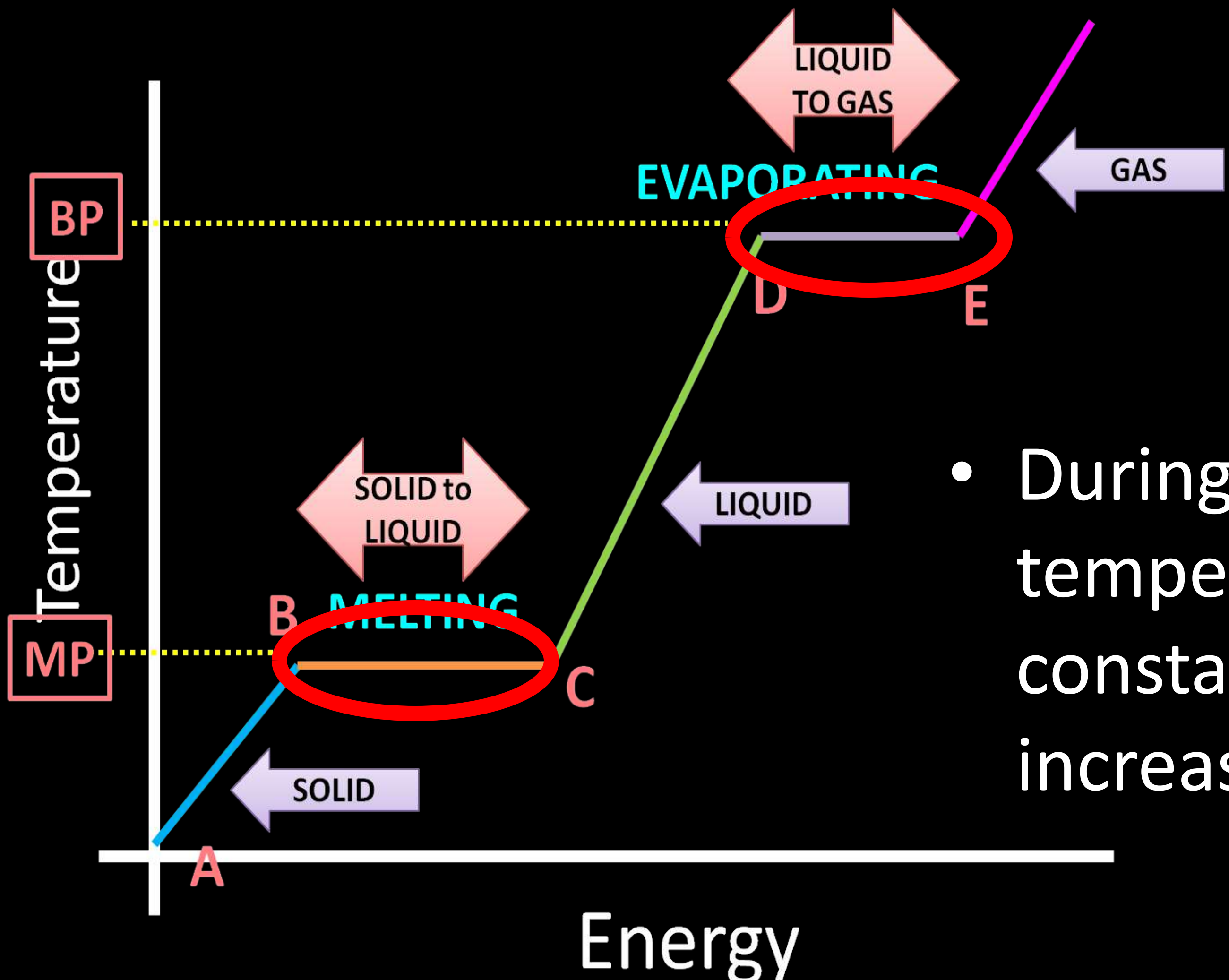
At the melting point, heat energy is being used to break down the crystalline lattice.

At the boiling point, heat energy is being used to convert the liquid to a gas.

During a phase change, heat is being used to change phase, not increase the kinetic energy of the particles. It is for this reason that Temperature remains constant in a phase change while heat energy changes.

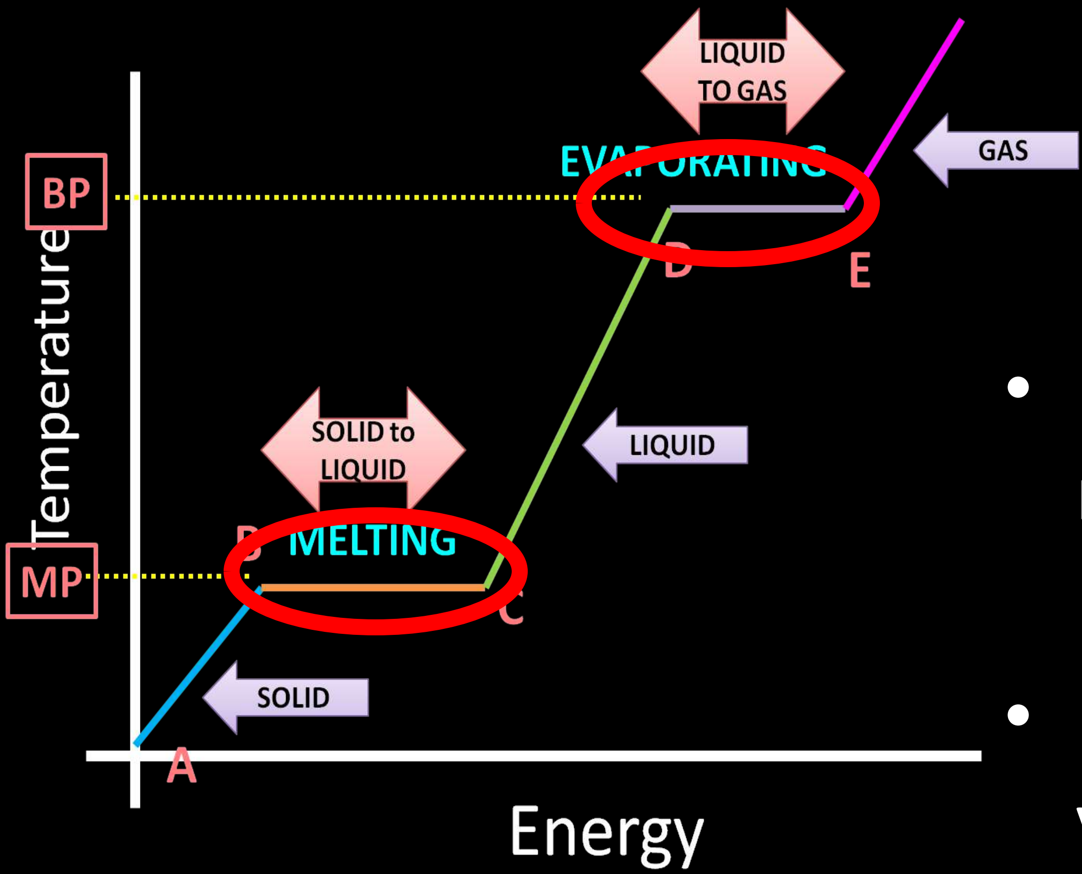

LIQUID
TO GAS
GAS
EVAPORATING
BP
D
E
Temperature
SOLID to
LIQUID
LIQUID
MELTING
B
MP
C
SOLID
A
Energy

Phase Change



- During phase change, temperature stays constant but energy increases.

Phase Change



- Energy needed to melt is called Latent Heat of Fusion (ΔH_{fus})
- Energy need to vaporize is called Latent Heat of Vaporization ($\Delta H_{vaporization}$)

Constants

Volume of Ideal Gas at STP: $22.4\ \frac{\text{L}}{\text{mol}}$

Speed of Light in a Vacuum: $c = 3.00 \times 10^8\ \frac{\text{m}}{\text{s}}$

Specific Heat of Water: $C_p(H_2O) = 1.00\ \frac{\text{cal}}{(\text{g}\ °\text{C})} = 4.18\ \frac{\text{J}}{(\text{g}\ °\text{C})}$

Latent Heat of Fusion of Water: $\Delta H_{fus}(H_2O) = 80\ \frac{\text{cal}}{\text{g}} = 334\ \frac{\text{J}}{\text{g}}$

Latent Heat of Vaporization of Water: $\Delta H_{vap}(H_2O) = 540\ \frac{\text{cal}}{\text{g}} = 2260\ \frac{\text{J}}{\text{g}}$

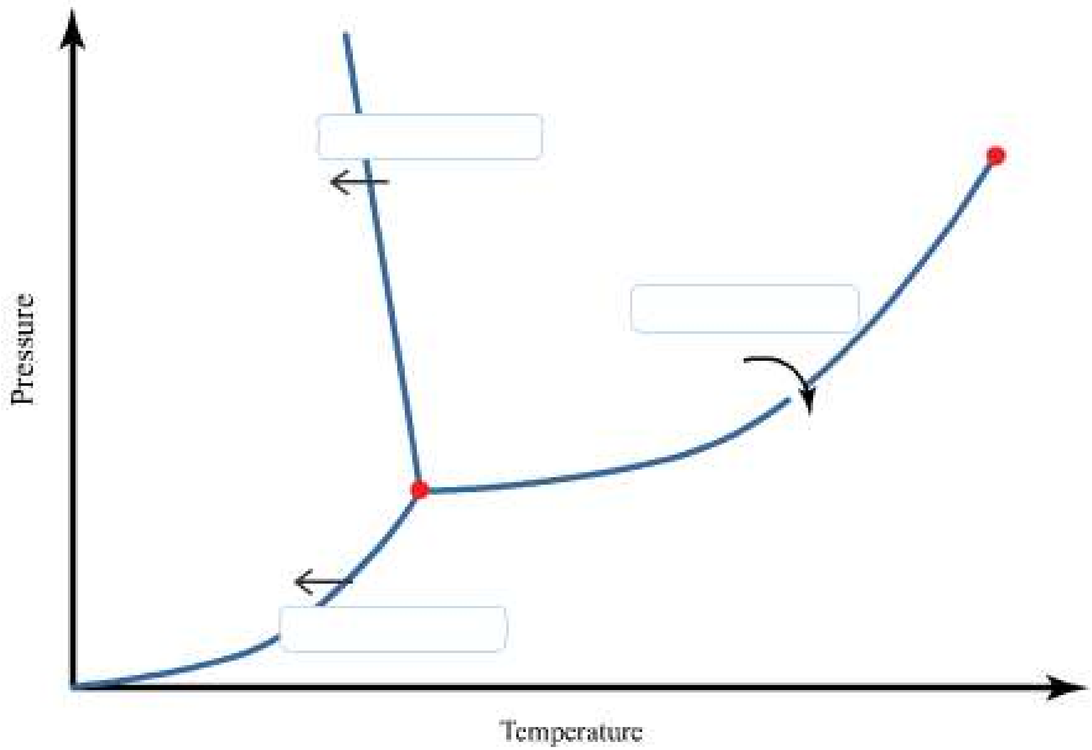
Calorimetric Formulas –

No Phase Change: $Q = m(\Delta T)C_p$

Latent Heat of Fusion: $Q = m\Delta H_{fus}$

Latent Heat of Vaporization: $Q = m\Delta H_{vap}$

Identify the three phase changes indicated by each arrow below in the phase diagram of water.



deposition

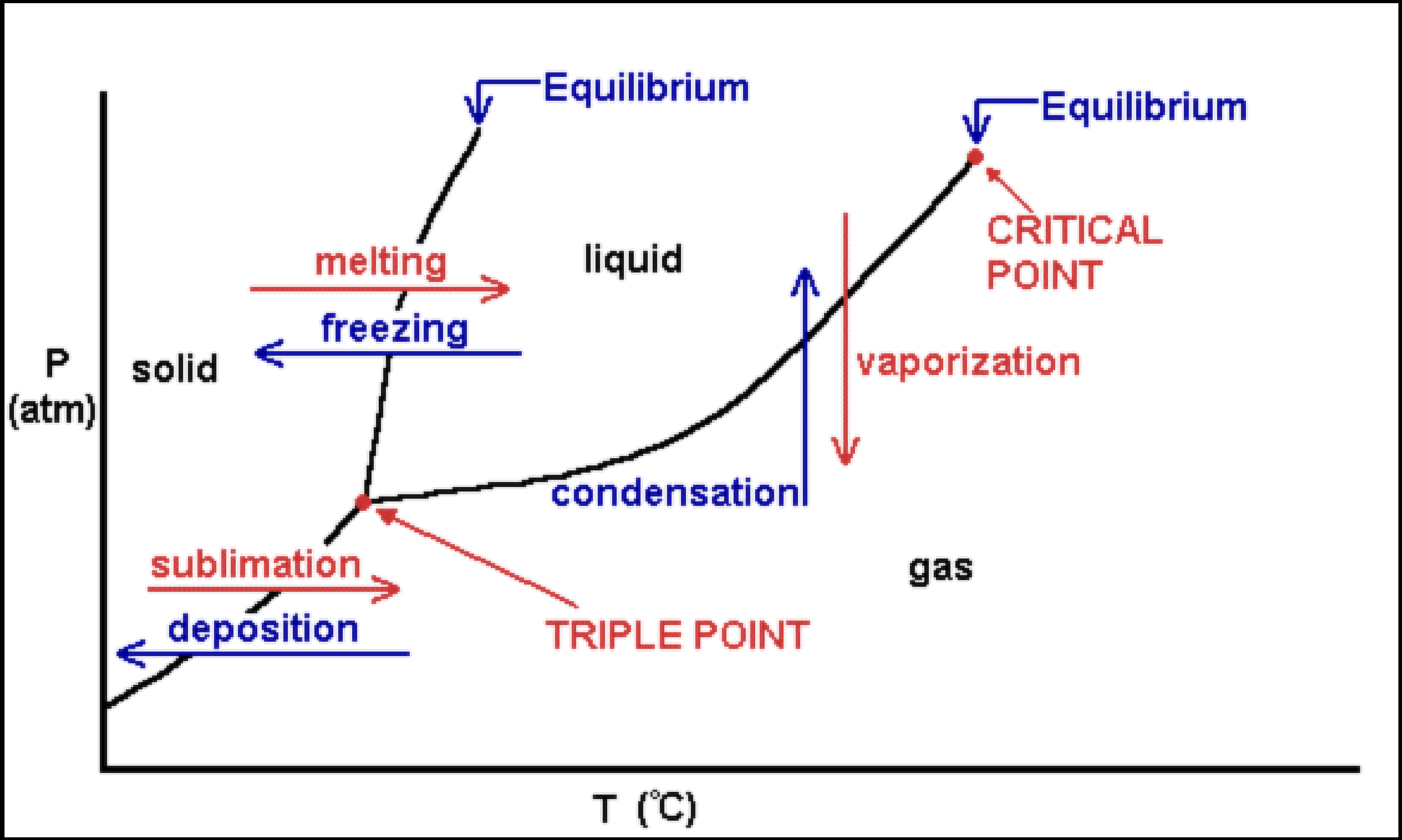
freezing

vaporization

sublimation

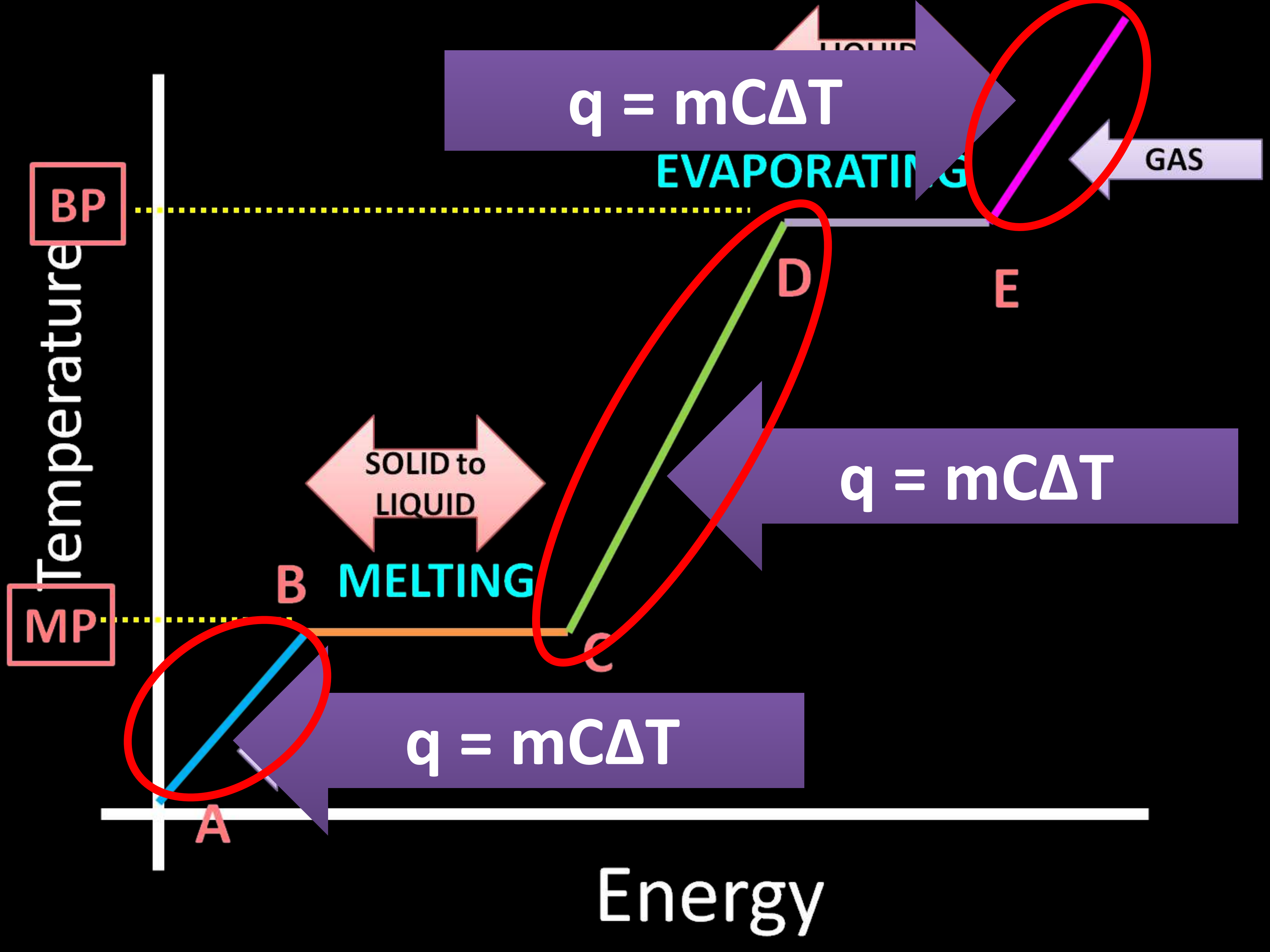
condensation

melting

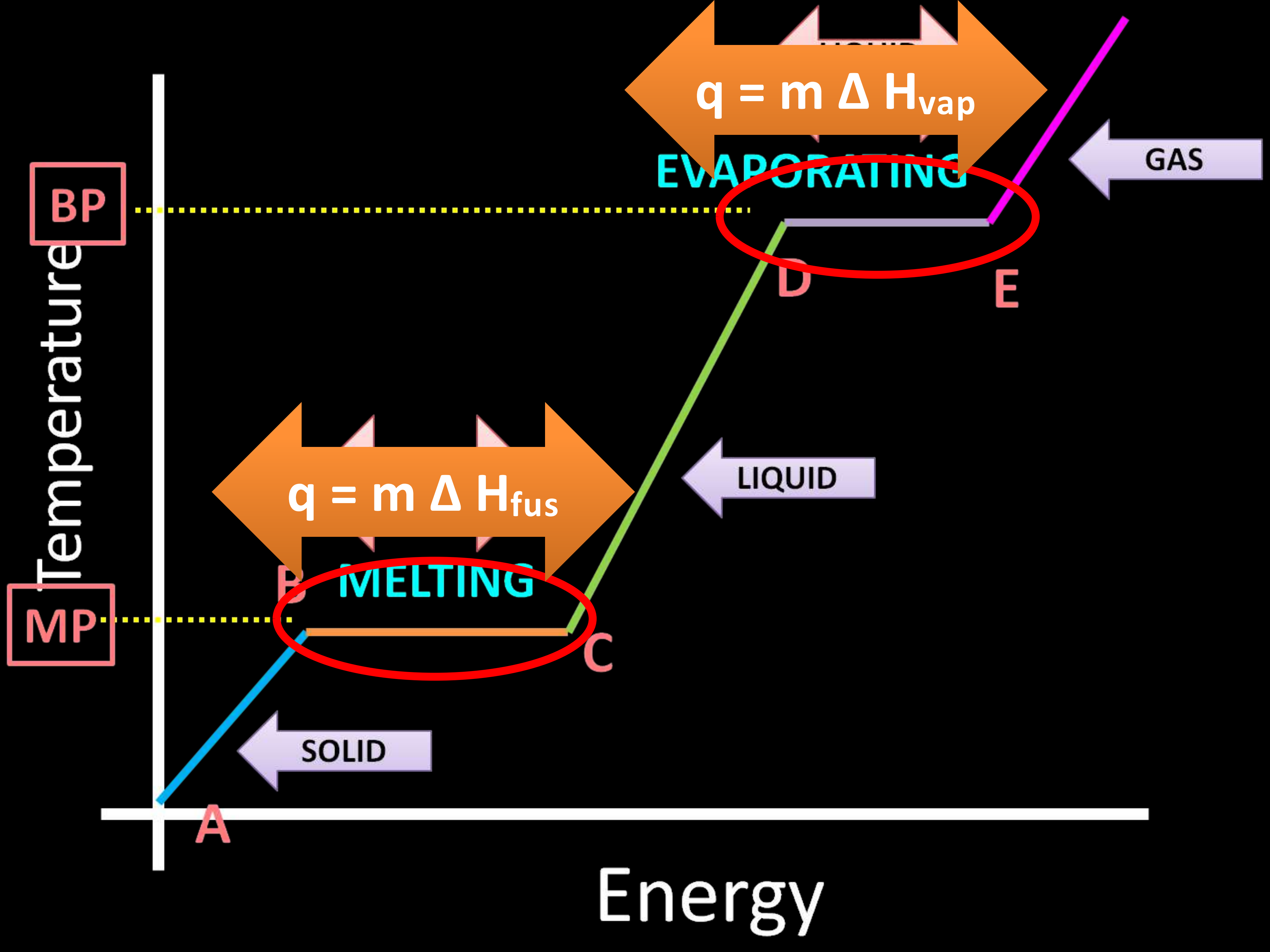


Triple point – the point on a phase diagram at which the three states of matter: gas, liquid, and solid coexist

Critical point – the point on a phase diagram at which the substance is indistinguishable between liquid and gaseous states



q = mCΔT
EVAPORATING
GAS
BP
D
E
Temperature
SOLID to
LIQUID
q = mCΔT
B
MELTING
MP
C
q = mCΔT
A
Energy



q = m Δ Hvap
GAS
EVAPORATING
BP
D
E
LIQUID
q = m Δ Hfus
MELTING
B
MP
C
SOLID
A
Temperature
Energy

How many joules does it take to melt 100. grams of water at its melting point?

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

$= 100.$ grams X 334 J/gram

$= 33400$ Joules

Constants

Volume of Ideal Gas at STP: $22.4\ \frac{L}{mol}$

Speed of Light in a Vacuum: $c = 3.00 \times 10^{8}\ \frac{m}{s}$

Specific Heat of Water: $C_p(H_2O) = 1.00\ \frac{cal}{(g\ °C)} = 4.18\ \frac{J}{(g\ °C)}$

Latent Heat of Fusion of Water: $\Delta H_{fus}(H_2O) = 80\ \frac{cal}{g} = 334\ \frac{J}{g}$

Latent Heat of Vaporization of Water: $\Delta H_{vap}(H_2O) = 540\ \frac{cal}{g} = 2260\ \frac{J}{g}$

How many joules does it take to condense 50.0 grams of water at its boiling point?

$q = \mathbf{m \, \Delta \, H_{vap}}$

$= 50.0$ grams X 2260 J/gram

$= 113\,000$ Joules

Constants

Volume of Ideal Gas at STP: $22.4 \frac{\text{L}}{\text{mol}}$

Speed of Light in a Vacuum: $c = 3.00 \times 10^{8} \frac{\text{m}}{\text{s}}$

Specific Heat of Water: $C_p(H_2O) = 1.00 \frac{\text{cal}}{(\text{g °C})} = 4.18 \frac{\text{J}}{(\text{g °C})}$

Latent Heat of Fusion of Water: $\Delta H_{fus}(H_2O) = 80 \frac{\text{cal}}{\text{g}} = 334 \frac{\text{J}}{\text{g}}$

Latent Heat of Vaporization of Water: $\Delta H_{vap}(H_2O) = 540 \frac{\text{cal}}{\text{g}} = 2260 \frac{\text{J}}{\text{g}}$