Kinetics/Thermo Notes

Lesson 1 : What is Energy? How can you calculate the specific heat or heat of a reaction?

Essential Question: What happens in a molecule to increase kinetic energy? Do all metals heat up at the same rate?

Questions/ Vocab/etc.	Notes:
	(see below)

Energy in Chemical & Physical Processes

Energy

- ❖ Energy is defined as the ability to do _______________ or transfer ______________ energy.
- ❖ There are 2 forms of energy. Chemical systems contain both Potential Energy & Kinetic Energy.

1. Potential Energy (PE): Energy at rest due to the _______________ of an object; chemical potential energy is the energy stored in a substance's _______________________.
2. Kinetic energy (KE): Energy of the _____________ of particles in a substance and is DIRECTLY proportional to KELVIN temperature. As temperature increases, KE also _________________.

- ❖ Law of Conservation of Energy states that energy is neither _______________ nor destroyed, just changed in form

$$C_8H_{18} + O_2 \longrightarrow H_2O + CO_2 + \text{Energy}$$

Stored PE converts to 25% work and 75% heat

Kinetics

- ✔ Kinetics is defined as:
- ✔ We can measure how fast or slow a reaction takes place by looking at its Reaction rate

$$\text{Rate} = \frac{\text{Change in amount of substance}}{\text{Change in time}}$$

Collision theory: Defines 3 conditions that MUST be met for a reaction to occur.

- Reactants must _____________________.
- Collisions must be at the correct ______________________.
- Collisions must meet a minimum energy called ___________________________for the reaction to occur.

Factors that Affect Reaction Rate

1. *Nature of Reactant:* Some substances are just more reactive than others.
2. *Surface area*: As surface area increases, more effective collisions happen & the reaction rate__________________.

(Reactant particles must collide. Larger surface means more contact with each other. Greater collision frequency!)

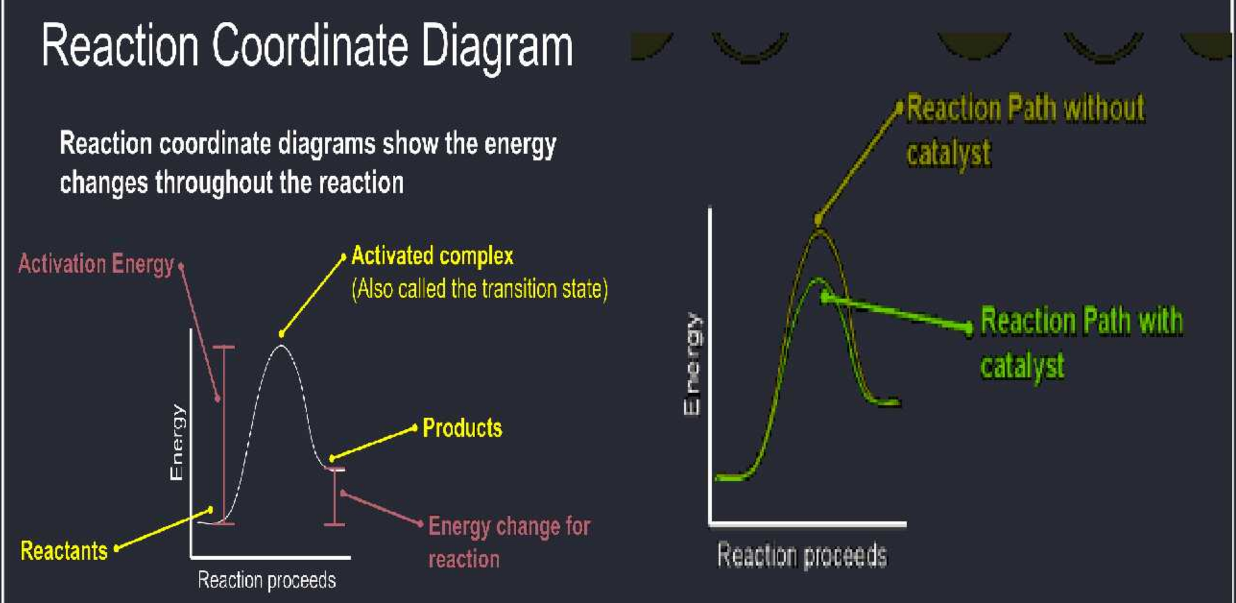
3. Concentrations of the Reactants: As reaction concentration increases, more effective collisions happen & the reaction rate ____________________. (More reactants mean greater collision frequency !)
   - ✔ 1M HCl is less concentrated than 3M HCl
4. Temperature: Molecules at a higher temperature have higher average ___________________ so they move faster with greater collision frequency. ALSO, reactants must have minimal energy (activation energy) to collide. At higher temperatures, the particles collide with more energy which helps contribute to the required activation energy.
   - ✔ Temperature increases NOT ONLY the collision frequency BUT IT ALSO helps the reaction meet its activation energy more effectively.
5. Catalyst: substance that speeds up the rate of reaction without being used up.

✔ ____________________ are catalysts in the body.

✔ Catalysts ____________________ the activation energy by letting it proceed in a different way.

✔ Lower E_a = faster reaction

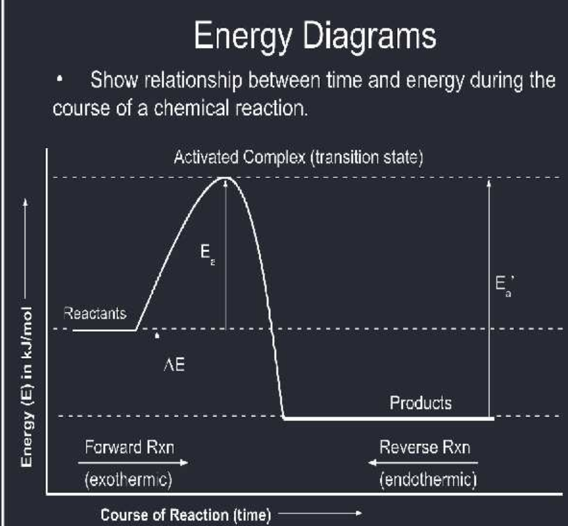
Reaction Pathways



✔ Activated complex (transition state): **temporary state of the molecule at the top of the hill**

Activation Energy(E_a): the minimum energy needed to get the reaction to occur

To calculate E_a: **Forward direction: E_a = $E_{\text{transition state}}$ - E_{reactant}**



Heat of Reaction ΔE (ΔH): Enthalpy Change; can be

1. Endothermic: ΔE (ΔH) is positive; products have higher energy than the reactants
2. Exothermic: ΔE (ΔH) is negative; products have lower energy than the reactants

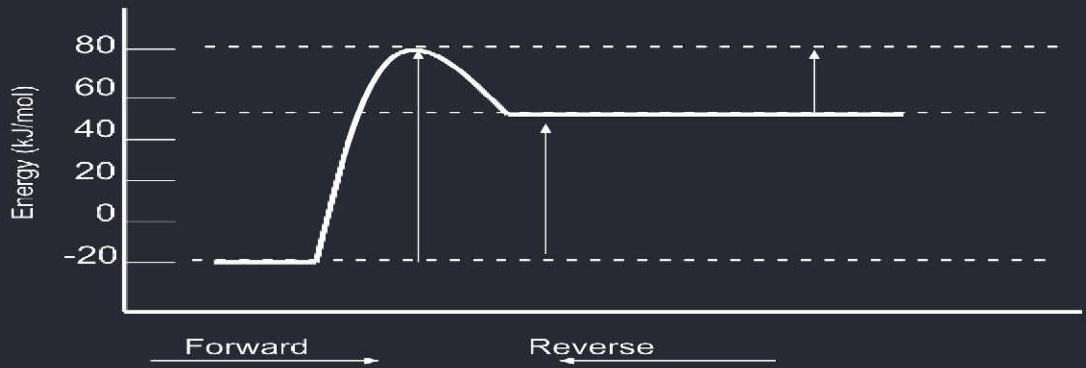
To calculate ΔH (Heat of the Reaction or Change in Enthalpy): Subtract the final - initial energies; Dependent on which direction you are looking at

Forward direction:

(ΔH_{rxn}) ΔE_{rxn} = E_{products} - $E_{\text{reactants}}$

Practice:

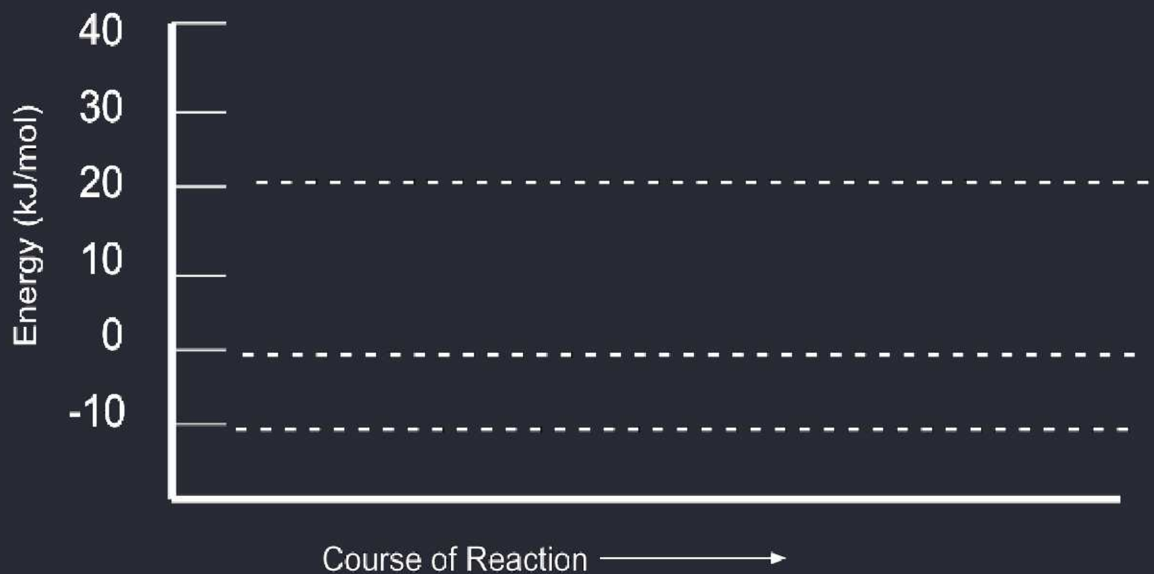
1. For the energy diagram provided, label the reactants, products, and activated complex (transition state). identify the Energy of the Reactants, Activated Complex (transition state) and Products. Calculate the heat of reaction ΔE(ΔH), and the activation energy (E_a) of the reaction. Is the reaction Endo or exothermic?



E_p = E_{ts} = E_r =

ΔH = E_a = Type of Reaction :

2. Draw and label an energy diagram that depicts the following forward reaction. Place the reactants at an energy level of 0 kJ/mol. **$\Delta E_{forward}$ = -10 kJ/mol and E_a = 20 kj/mol** Is the reaction Endothermic or Exothermic?



Energy in chemical Reactions

- ✔ Thermochemical Equation: Balanced chemical equations that show the enthalpy released or absorbed in a chemical reaction
- ✔ **Enthalpy** (ΔH) **: heat released or absorbed during a chemical reaction; classified as positive or negative**

HOT PACK

- ❖ An exothermic reaction is when the system ___________________ energy; heat flows OUT of the reaction and the surroundings get WARMER !
- ❖ ΔH will be ___________________

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$ ***ΔH = - 1625 kJ*** *or* *$4Fe + 3O_2 \rightarrow 2Fe_2O_3$* ***+ 1625 kJ***

COLD PACK

- ❖ An endothermic reaction is when the system ___________________ energy; heat flows INTO a reaction and the surroundings get COLDER.
- ❖ ΔH will be _________________

$H_2 + Br_2$ ⍰ $2HBr$ *ΔH= +72.8 kJ* *or* $H_2 + Br_2$ + 72.8 kJ ⍰ 2HBr

Stoichiometry & Enthalpy

- Once the ΔH_{rxn} is determined or given, it can be used in stoichiometric calculations.
- Use moles (coefficients) of reactants or products and the ΔH_{rxn} as a conversion factor.

If you are solving for ΔH, you must use the sign. If you are solving for how much energy is absorbed or released, you don't have to put the sign.

Example:

How much heat will be released when 6.5 moles of sulfur reacts with excess oxygen according to the following equation? Also, tell whether it will be exothermic or endothermic! $2S + 3O_2 \rightarrow 2SO_3$ $\Delta H = -791.4$ kJ/1mol rxn

Example:

A commercial heat pack reaction: $4\ Fe\ (s) + 3\ O_2\ (g) \Rightarrow 2\ Fe_2O_3\ (s)$ $\Delta H = -1652$ kJ/1 mol rxn

a. Exothermic or Endothermic?

b. How much heat is released when 4.00 mol iron reacts with excess O_2 ?

c. How much heat is released when 1.00 g iron reacts with excess oxygen?

Example:

Determine the heat involved in reacting 200 mL of 0.50 M HCl with excess Zn in the following reaction. $Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$ $\Delta H_{rxn} = -165$ kJ/1mol rxn

What is the difference between **"Heat" and "Temperature"?**

	Temperature	**Heat**
Instrument used to measure this		
Unit used to measure this		
Definition	A measure of the average KINETIC ENERGY of the molecules in a substance. A measure of how hot or cold something is.	The total amount of energy in a substance. It is transferred between objects of different temperatures. Heat always transfers from hot to cold. It depends on 3 things:

		A measure of how fast or slow particles are moving	1. ______________________________ 2. ______________________________ 3.______________________________

Units of Heat Energy

- ❖ A calorie is defined as the amount of heat needed to raise the temperature of 1 g of water by 1 °C (***1 cal= 4.184 J***)
- ❖ Most common units are joules (J) or kilojoules (kJ)

Specific Heat

- Amount of heat required to raise the ______________________________ of 1 g of a substance by 1 °C

$$\text{Specific Heat [c]} = \frac{\text{Heat in Joules [q]}}{\text{Mass [m]} \times \text{Change in Temp } [\triangle T]}$$

Change in Temp = final temp - initial temp

- Different substances have different specific heats.
- Water has a specific heat of ____________________. Iron (Fe) has a specific heat of .449 J/g°C. Gold (Au) has a specific heat of .129 J/g°C.
- The higher the ________________________, the more energy it takes to change its temperature.

Example: If the same amount of energy is applied to the same size sample of Fe & Au, which substance will change its temperature the most?

Lesson 2 : Heat Calculations & Properties of Solids and Liquids

Essential Question: Do all metals heat up at the same rate? Why or why not? What happens to a substance's physical state and/or temperature when heat is added or removed?

Questions/ Vocab, etc.	Notes
q = heat (joules "J") **(**if given kJ you must convert to J)** **m = mass (g)** **c = specific heat ($\frac{J}{g\ °C}$)** **$\triangle$T = change in temp (°C)**	**Calculating Heat** $$q = m \times c \times \triangle T$$ **Example:** A 155.0 g sample of an unknown substance was heated from 25.0 °C to 40.0 °C. The substance absorbed 5696 J of energy. What is the specific heat? **Example:** How much heat is needed to change the temperature of 12.0 g of silver with a specific heat of 0.057 cal/g°C from 25.0°C to 83.0 °C?

Example:

A sample of metal absorbs 355 J of heat when its temperature changes by 4.56°C. Its specific heat capacity is 1.23 J/g°C. What is the mass of the sample?

Properties of a Liquid

1.

2.

3.

4.

5.

Properties of a Solid

1.

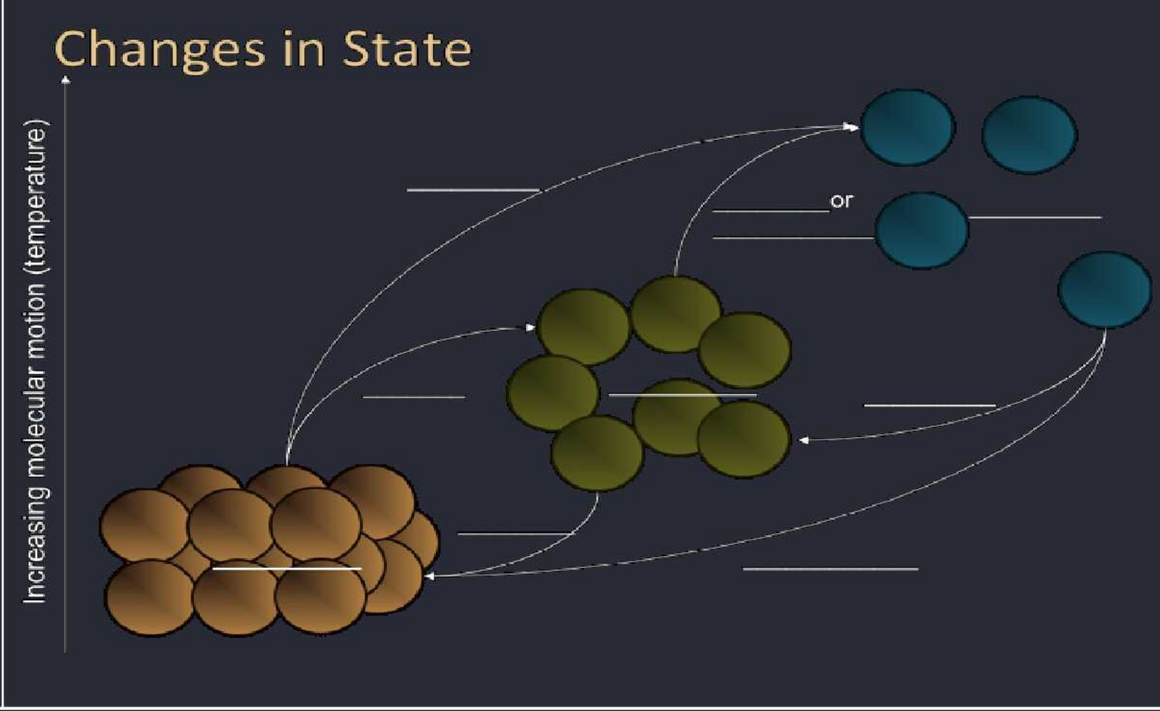
2.

3.

4.

5.

Changes in State



	Endothermic physical changes of state o **_Kinetic Energy must be put INTO the substance_** in order to increase the ____________________of the molecules so as to break the ___________________________ forces holding the particles together ✔ Melting: change of state from a solid to a ________________________ ✔ Vaporization (Boiling or Evaporation): change of state from a __________ to a gas ✔ Sublimation: direct change of state from a __________________________ to a gas *Exothermic physical changes of state* o **Kinetic Energy must be taken OUT (removed) the substance** in order for the molecules to _____________ down so that the ___________________________ forces can begin to hold the particles together ✔ Freezing: change of state from a _____________________ to a solid ✔ Condensation: change of state from a gas to a ____________________ ✔ Deposition: direct change of state from a __________________ to a solid **Temperature of State Changes** ✔ Freezing point (fp) is the temperature at which the liquid turns into a solid ✔ Melting point (mp) is the temperature at which the solid turns into a liquid ✔ Freezing Point = Melting Point Example: Water has a mp and a fp of 0 °C ✔ Boiling point (bp) is the temperature at which the liquid turns into a gas ✔ Condensation point (cp) is the temperature at which a gas turns into a liquid ✔ Boiling Point = Condensation Point Example: Water has a bp and a cp of 100 °C *******All substances have their own specific freezing and boiling point, which makes this physical property a great way to identify an unknown substance. *******

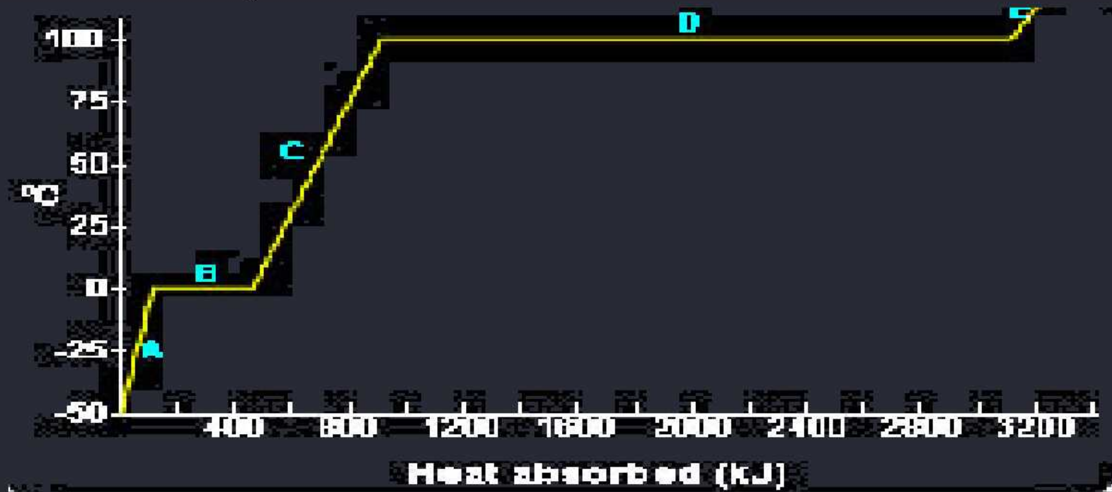
Lesson 3: Heating & Cooling Curves & Phase Diagrams

Essential Question: What information can be determined from heating and cooling curves? What information can be determined from phase diagrams?

Questions/ Vocab, etc.	Notes
	Heating & Cooling Curves ✔ *A diagram that shows how solids, liquids & gasses change state when TEMPERATURE is changed* ✔ Plateaus represent the changes of state (freezing, melting, vaporizing & condensing) ✔ Freezing Point & Melting Point are at the temperature or at the same plateau ✔ Boiling Point /Condensation Point are at the same temperature or at the same plateau ✔ Slopes represent the pure states (solid, liquid or gas) ✔ At the ***plateaus***, **KINETIC ENERGY remains constant** because temperature remains constant while **potential energy changes**

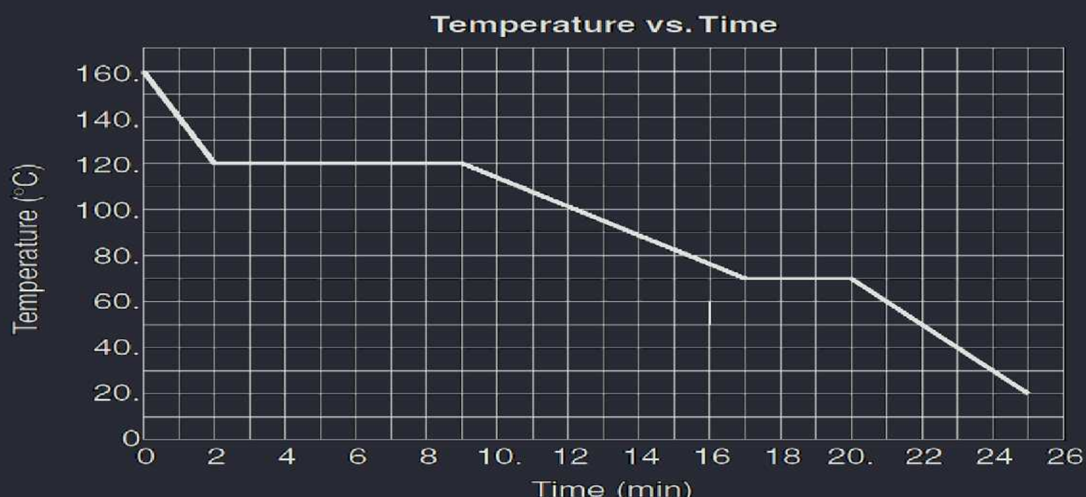
✔ At the ***slopes***, **KINETIC ENERGY changes** because temperature changes while **potential energy remains constant**

SELF CHECK: Heating Curve



1. What is the boiling point of the substance?
2. What letter represents the solid state only?
3. What letter represents the melting process?

SELF CHECK: Cooling Curve



1. While the substance is cooling during the liquid phase, the average kinetic energy of the molecules of the substance wil: Increase Decrease Stay the Same
2. What is the freezing point of this substance?
3. How long does it take for the gas to completely liquefy?

Phase Diagram

✔ *A diagram that shows how solids, liquids & gases change state AS BOTH TEMPERATURE & PRESSURE are changed*

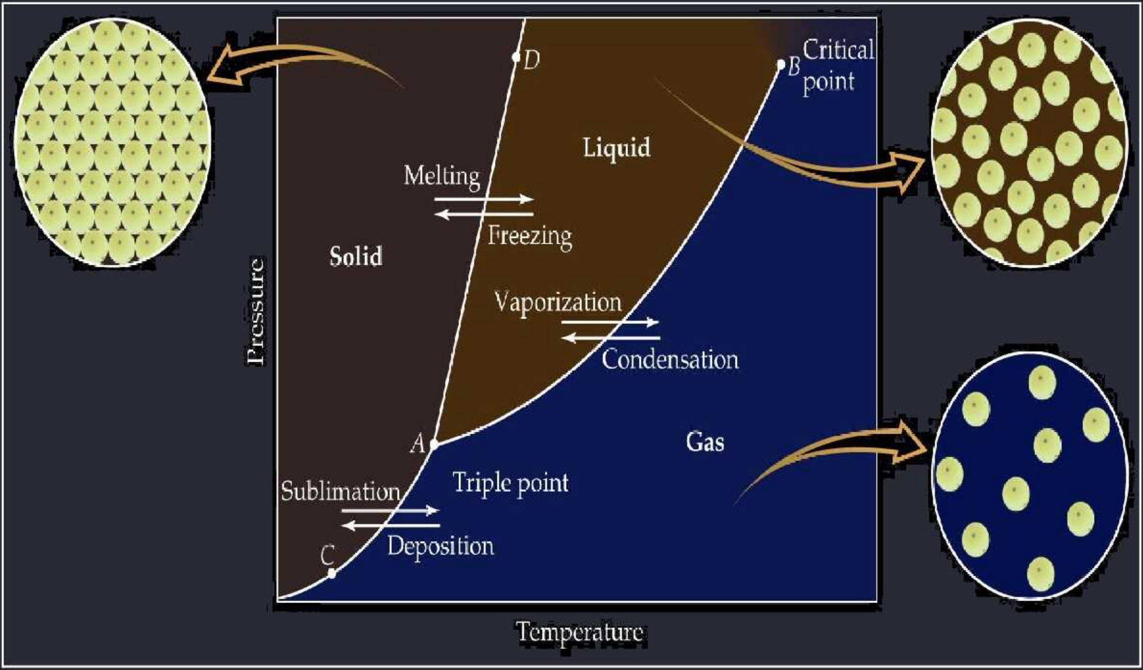
✔ Crossing a line between states determines the change of state (boiling, melting, etc)

✔ A point directly on a line will identify the pressure and temperature (boiling point, melting point, etc.) of the phase change

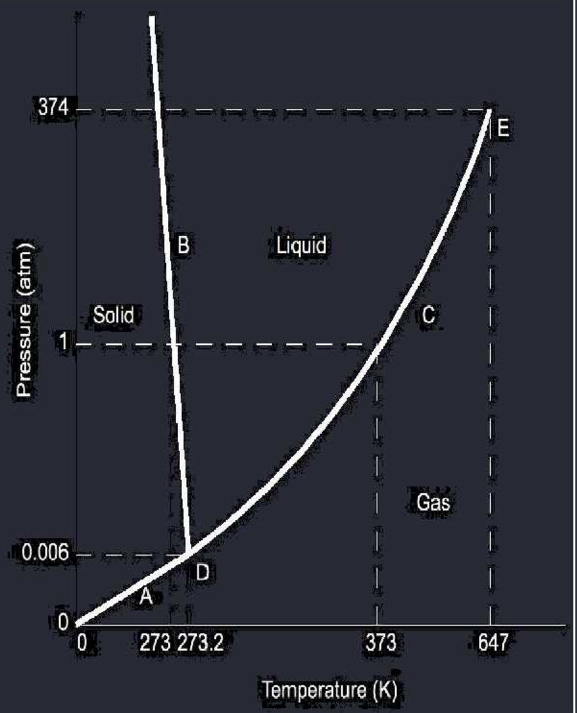
✔ _______________is the temperature and pressure in which all 3 of the states coexist

✔ _______________is the temperature & pressure at which a gas can no longer liquefy

Important information regarding the Phase Diagram of Water:



SELF CHECK: See diagram



[1] What is the temperature (freezing point) of line B at 1 atm?

[2] What is the temperature (boiling point) of line C at 1 atm?

[3] What is point D?

[4] What is point E?

[5] What change of state happens when you cross line B at a constant pressure of 10 atm and increase temperature?

[6] What change of state occurs when you cross line A at constant pressure of .001 atm?

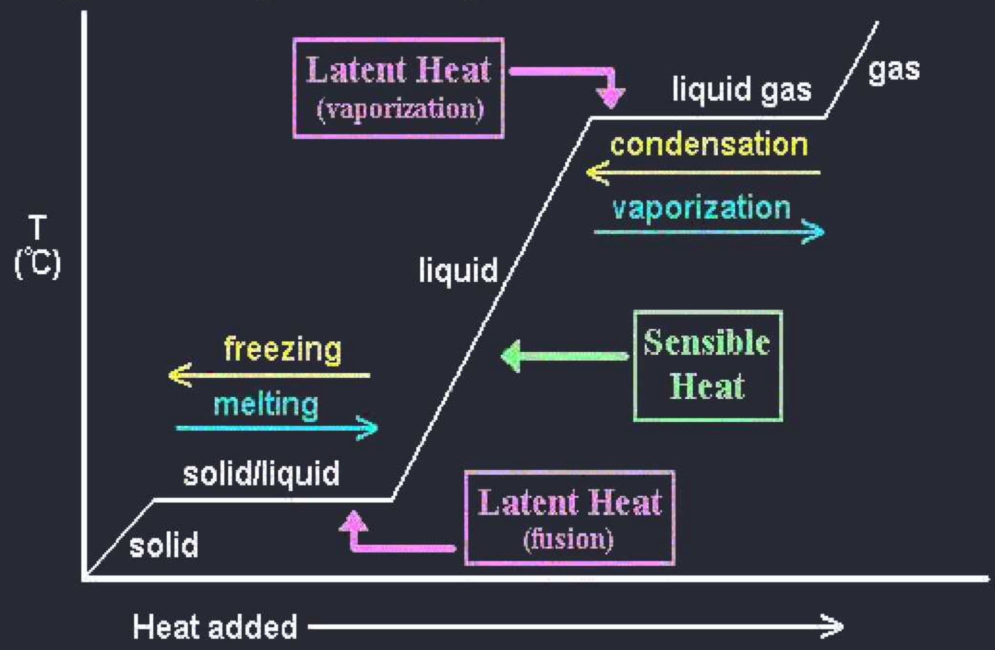
[7] What change of state happens when you cross line C at 400 K to 300 k at approximately 5 atm?

Lesson 4 : Heat Calculations of Phase Changes

Essential Question: How much energy is absorbed or released when a substance changes its physical state?

Questions/ Vocab, etc.	Notes

Measuring Heat during Phase Changes



Heat of Fusion/Solidification

→ Latent Heat of fusion (ΔH_{fus}) is the heat energy required to melt one gram of a solid at its melting point

$$q = \Delta H_{fus} \text{ x mass}$$

→ For water, ΔH_{fus} = 334 J/g ***On reference sheet***

→ Latent Heat of solidification (ΔH_{solid}) is the heat energy lost when one gram of a liquid freezes to a solid at its freezing point

$$q = \Delta H_{solid} \text{ x mass}$$

→ For water, ΔH_{solid} = -334 J/g

Heat of Vaporization/Condensation

→ Latent Heat of vaporization (ΔH_{vap}) is the heat to vaporize one gram of a liquid at its normal boiling point

$$q = \Delta H_{vap} \text{ x mass}$$

→ For water, ΔH_{vap}= 2260 J/g ***On reference sheet***

→ Latent Heat of condensation (ΔH_{cond}) is the heat energy released when one gram of a liquid forms from its vapor

$$q = \Delta H_{cond} \text{ x mass}$$

→ For water, ΔH_{cond} = -2260 J/g

Examples

1. How much heat is needed to melt 500.0 g of ice at 0 °C?

2. How much heat is evolved when 1255 g of water condenses to a liquid at 100°C?

3. How much heat is evolved when 50.0 g of ice changes from -30.0 °C to a gas at 110°C?
   This is a multi step problem.

Visual of
what to do:

1.

2.

3.

4.

5.