KINETIC MOLECULAR MODEL AND INTERMOLECULAR FORCES

Kinetic Molecular Model of Liquids and Solids

Recalling the concept:

Matter in the gas state has indefinite shape and volume.

Matter in the liquid state has indefinite shape and definite volume.

Matter in the solid state has definite shape and volume.

Recalling the concept:

SOLID

ARRANGEMENT OF PARTICLES

-closely and orderly packed

KINETIC ENERGY OF PARTICLES

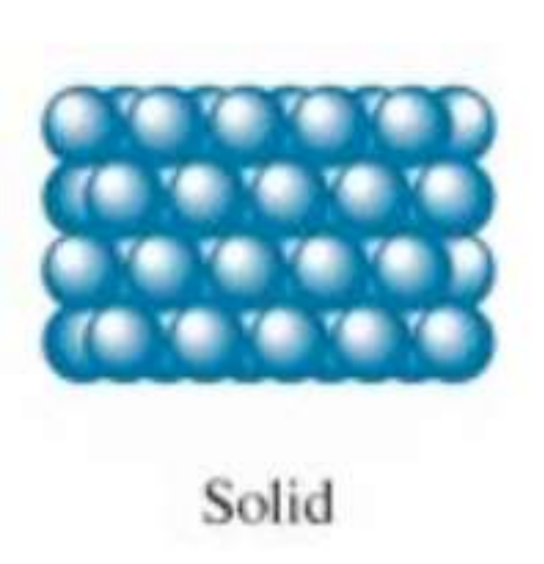
-vibrate and rotate about a fixed position

PARTICLE MOTION

-very low

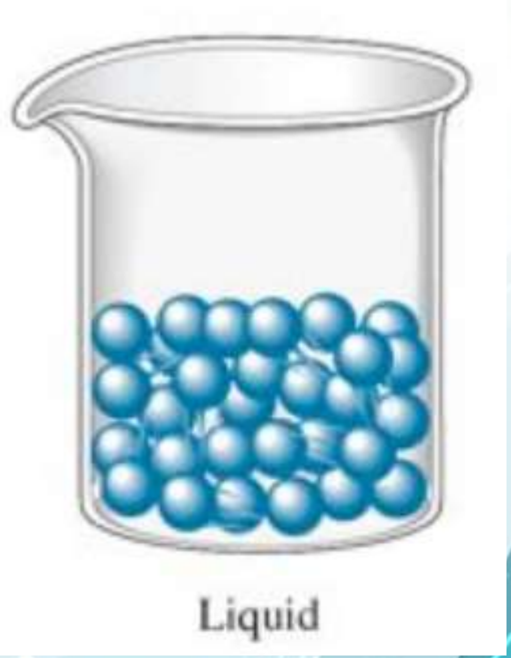
ATTRACTIVE FORCES

-very strong



Recalling the concept:

LIQUID



ARRANGEMENT OF PARTICLES

-less closely packed

KINETIC ENERGY OF PARTICLES

-particles slide over each other

PARTICLE MOTION

-low

ATTRACTIVE FORCES

-strong

Recalling the concept:

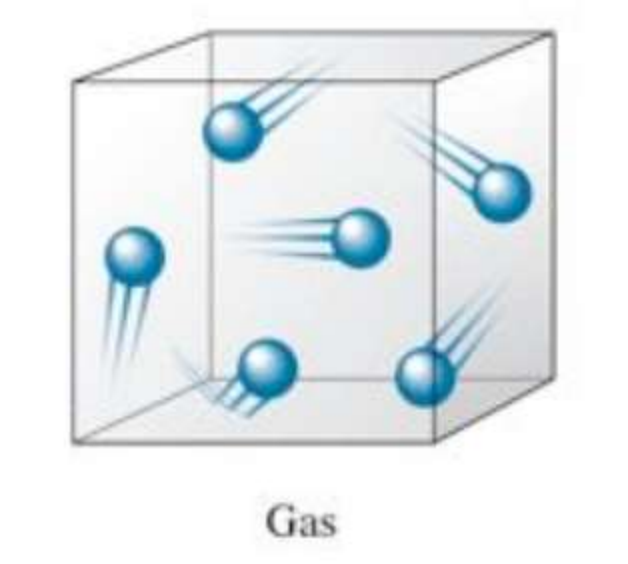
GAS

ARRANGEMENT OF PARTICLES
-very far apart

KINETIC ENERGY OF PARTICLE
-particles move at great speed

PARTICLE MOTION
-high

ATTRACTIVE FORCES
-low



Polar attraction as a universal law…

- **Molecules are held together by an electrostatic attraction:**
  a. Intramolecular attraction

IONIC

COVALENT

METALLIC

Polar attraction as a universal law…

- **Molecules are held together by an electrostatic attraction:**
  - **a. Intermolecular forces**

$$K^+ \leftrightarrow HCl$$

van der Waals forces:

- The term for all known Intermolecular forces.
- Named after a Dutch scientist: **Johannes van der Waals (1837 – 1932)**

Types of van der Waals forces:

Ion – dipole

- Results when an ion and the partial charge found at the end of the polar molecule attract each other.
- Positive ions are attracted to the negative end of a dipole and vice versa.

Example:

a. Salt (NaCl) Dissolved in Water (H_2O)
b. Potassim (K+) Dissolved in Hydrochloric Acid (HCl)

Types of van der Waals forces:

Ion – dipole

- Results when an ion and the partial charge found at the end of the polar molecule attract each other.

Example:

a. Salt (NaCl) Dissolved in Water (H_2O)
b. Potassim (K+) Dissolved in Hydrochloric Acid (HCl)

Types of van der Waals forces:

Dipole – dipole

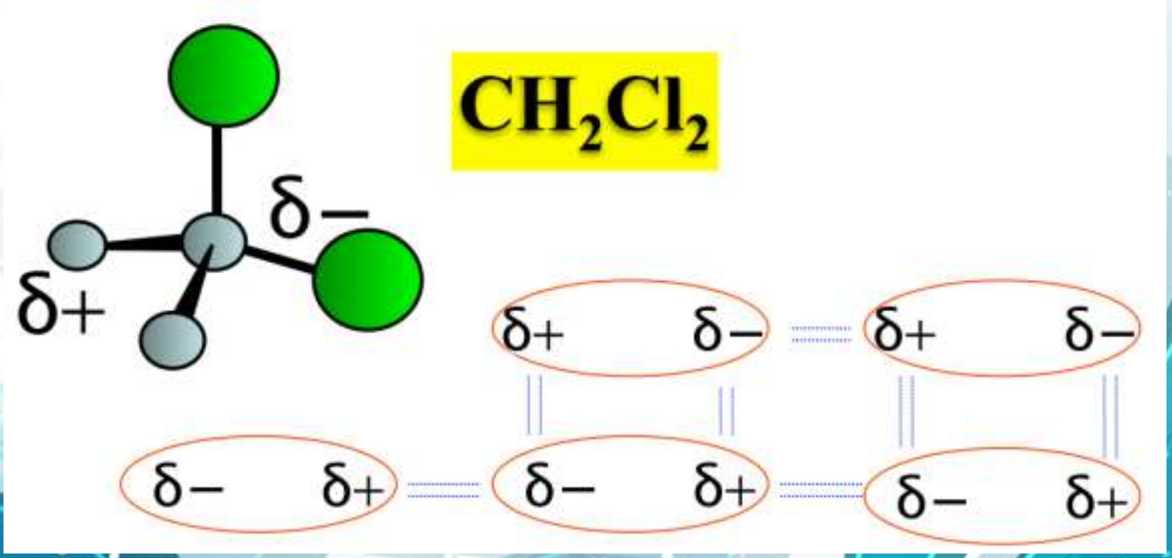
- Exists between neutral polar molecules
- Polar molecules attract each other when the positive end of one molecule is near the negative end of another.
- Weaker force compared to ion-dipole (depending on size)

Types of van der Waals forces:

Dipole – dipole

Example:

a. Dichloromethane
b. Hydrochloric Acid



Types of van der Waals forces:

London Dispersion Forces

- Force of attraction between nonpolar molecules or atoms (Cl_2 and CH_4)
- Originated from Fritz London (1900-1954), a German-American physicist

Types of van der Waals forces:

London Dispersion Forces

Instantaneous dipole

Induced dipoles

Types of van der Waals forces:

London Dispersion Forces

- Dipole can be induced more likely on molecules having larger molecular masses. (Polarizability)

-This also affects the melting and boiling points of the molecules.

Types of van der Waals forces:

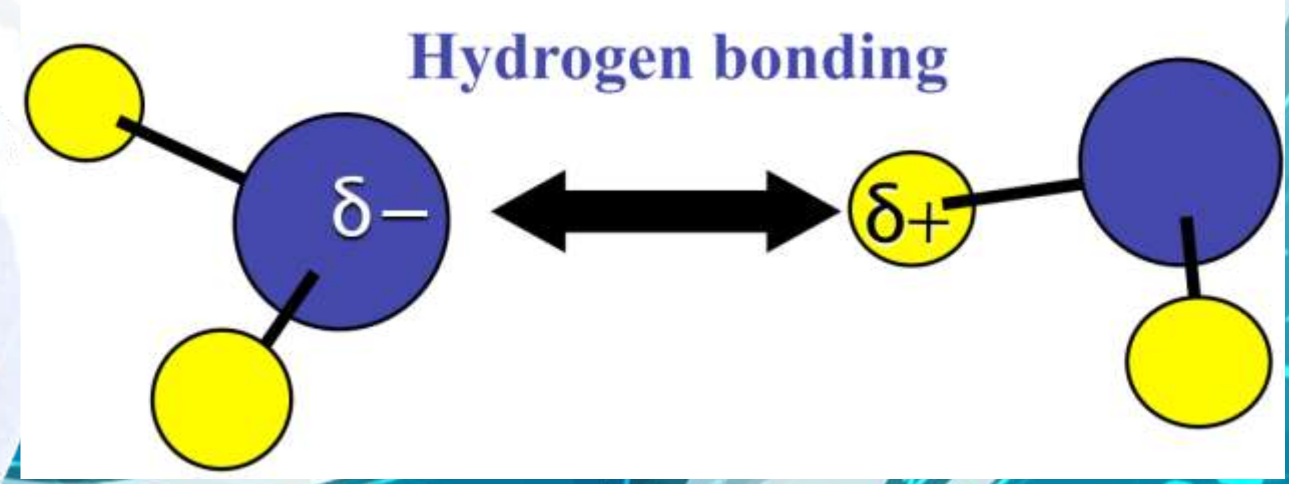
Hydrogen Bonds

- Plays an important role in life processes
- It can easily be broken and reformed
- Occurs in water, DNA molecules and protein

Types of van der Waals forces:

Hydrogen Bonds

- It is an attractive interaction between a hydrogen atom bonded to an electronegative Fluorine, Oxygen and Nitrogen atom and an unshared electron pair of another nearby electronegative atom.



Types of van der Waals forces:

Hydrogen Bonds

Example:

a. Water (H_2O)
b. Ammonia
c. Ammonia and Water (NH_3)
d. Hydrofluoric Acid (HF)

PROPERTIES OF LIQUIDS

What factors determine the physical properties of liquids?

POPERTIES OF LIQUIDS

A. VISCOSITY

- What is the difference between fluid and viscous liquids?
- VISCOSITY is the ability of a fluid to resist flowing.
- Viscosity of a liquid depends on intermolecular forces that is present.

POPERTIES OF LIQUIDS

A. VISCOSITY

- Non-polar molecules have low viscosities because of weak London Force. **Example: Benzene, pentane and carbon tetrachloride.**
- Polar molecules such as glycerol and aqueous sugar solution have high viscosities.

POPERTIES OF LIQUIDS

A. VISCOSITY

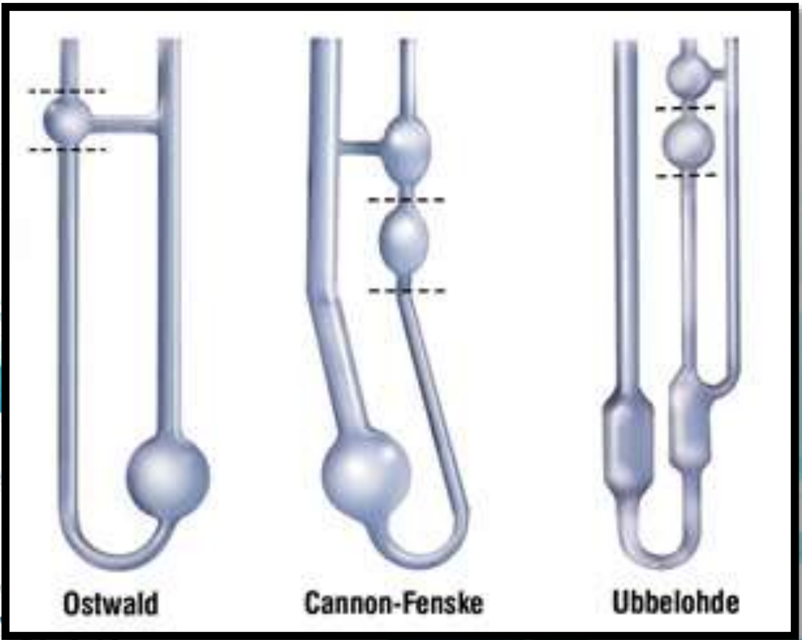
What do you think is the effect of an increasing temperature to the viscosity of a liquid?

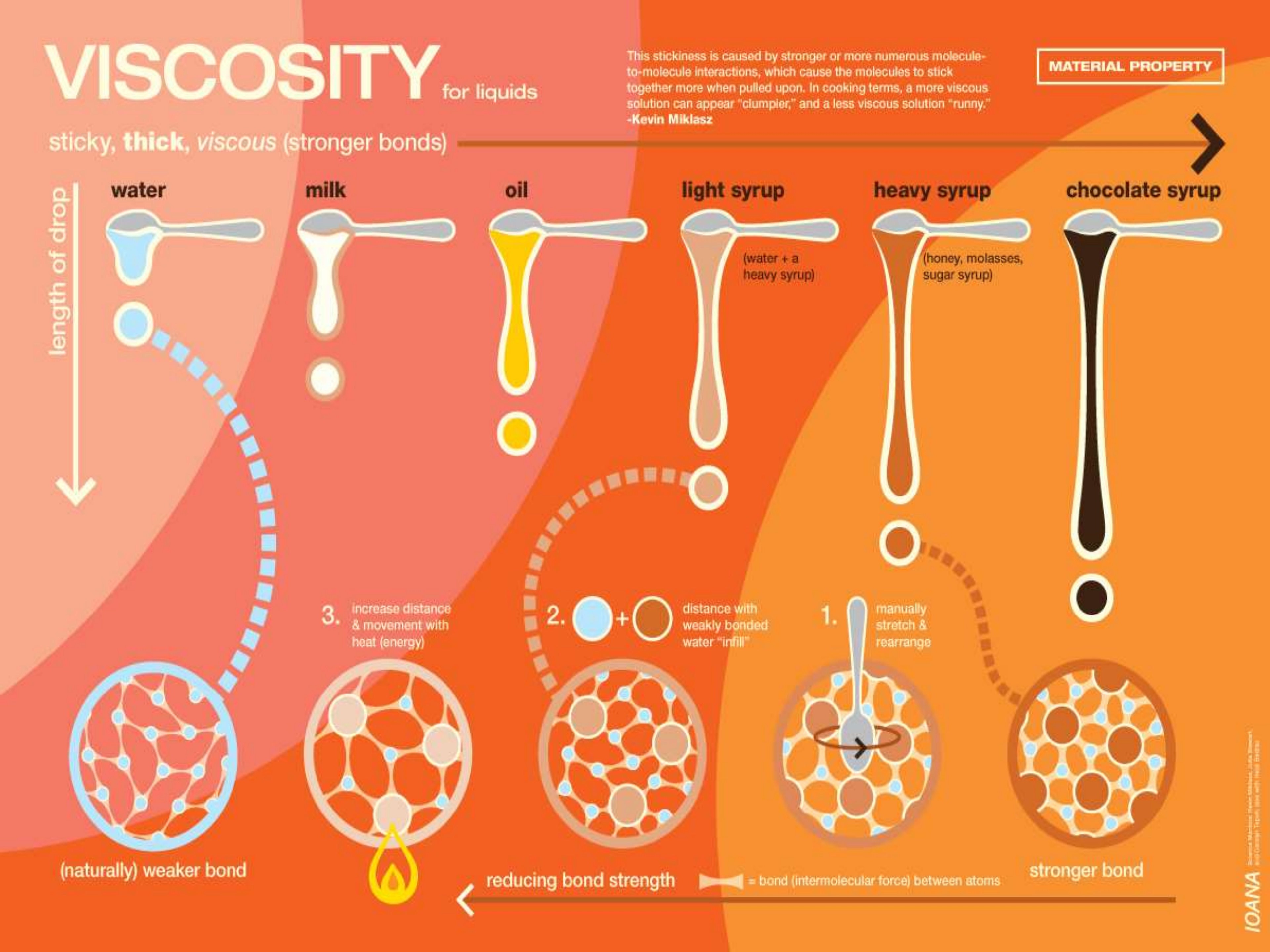
The viscosity decreases as the

Types of van der Waals forces:

A. VISCOSITY

- **VISCOMETER is a device used to measure viscosity.**

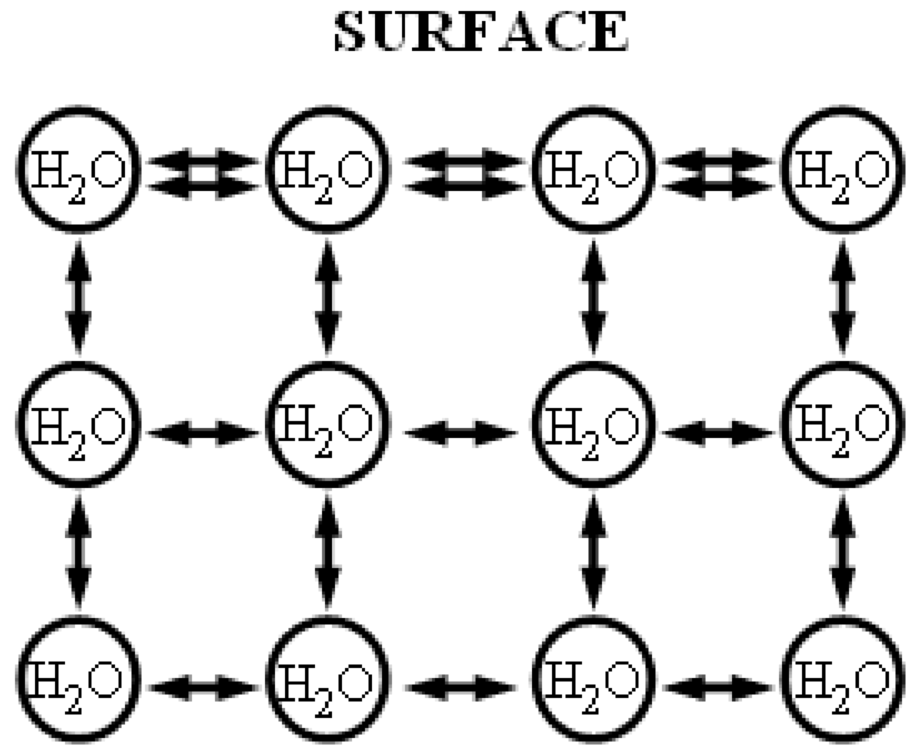




VISCOSITY for liquids
This stickiness is caused by stronger or more numerous molecule-to-molecule interactions, which cause the molecules to stick together more when pulled upon. In cooking terms, a more viscous solution can appear "clumpier," and a less viscous solution "runny."
-Kevin Miklasz
MATERIAL PROPERTY
sticky, thick, viscous (stronger bonds)
length of drop
water
milk
oil
light syrup
(water + a heavy syrup)
heavy syrup
(honey, molasses, sugar syrup)
chocolate syrup
3. increase distance & movement with heat (energy)
2. distance with weakly bonded water "infill"
1. manually stretch & rearrange
(naturally) weaker bond
reducing bond strength
= bond (intermolecular force) between atoms
stronger bond
IOANA

POPERTIES OF LIQUIDS

B. SURFACE TENSION



Surface tension—molecules at the surface form stronger bonds

POPERTIES OF LIQUIDS

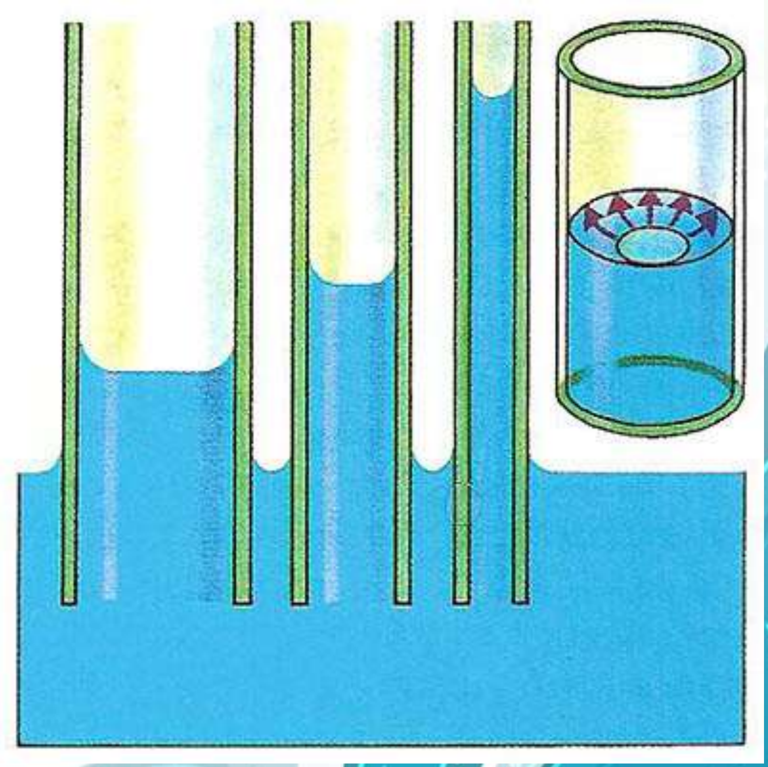
B. SURFACE TENSION

- The measure of the resistance of a liquid to spread out.
- The higher the temperature, the less the strength of the attractive force that holds the molecule together

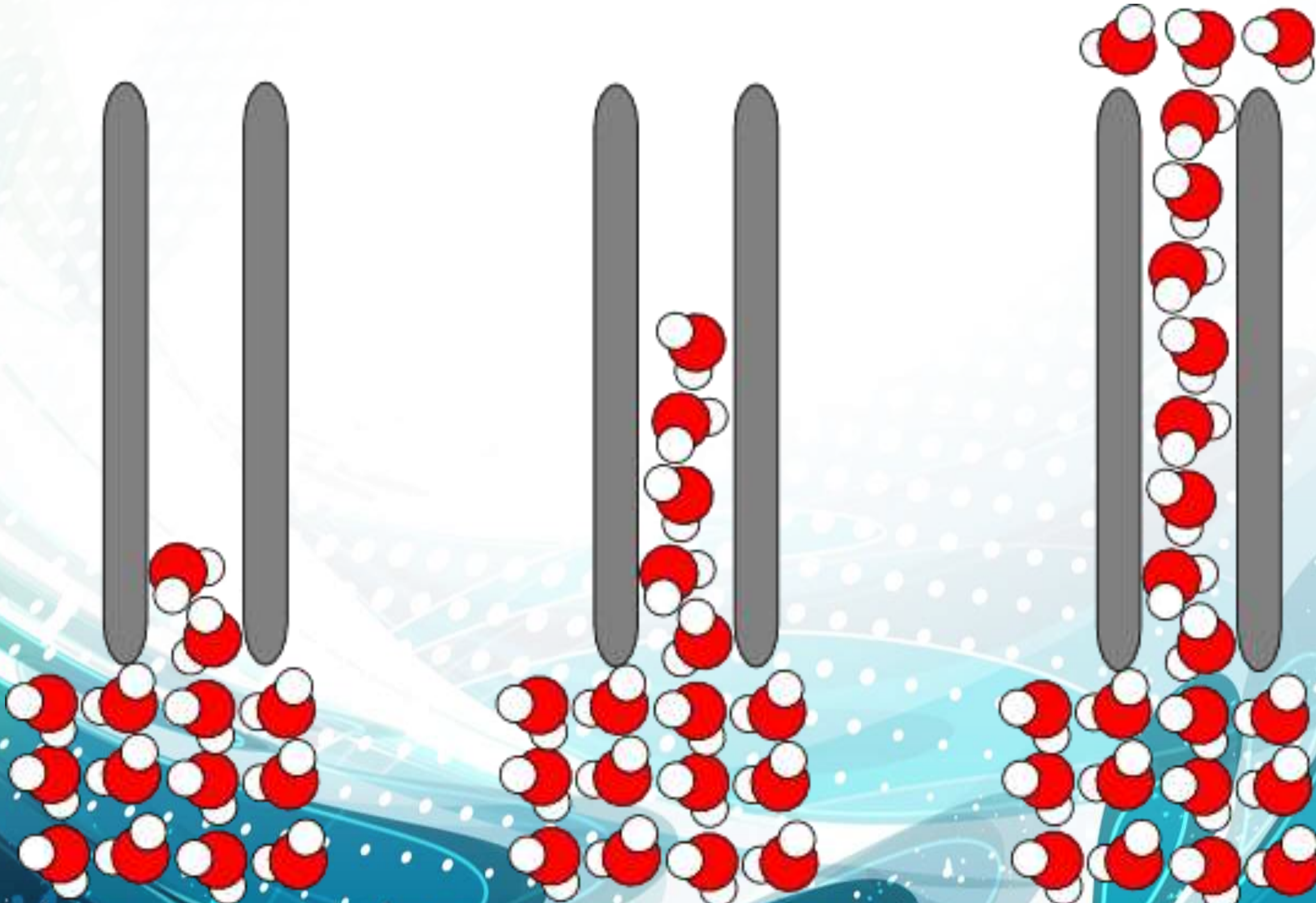
POPERTIES OF LIQUIDS

C. CAPILLARITY

- The rising of any liquid
- Results from competition between liquid’s intermolecular force and the walls of the tube.
- Capillarity is also observed in plants’ transport system.



POPERTIES OF LIQUIDS



POPERTIES OF LIQUIDS

D. EVAPORATION, VAPOR PRESSURE AND BOILING POINT

- **Molecules of liquids, when obtained enough kinetic energy liberates**
- **The escape of energetic molecules in liquid reduces the average kinetic energy of the remaining molecules**

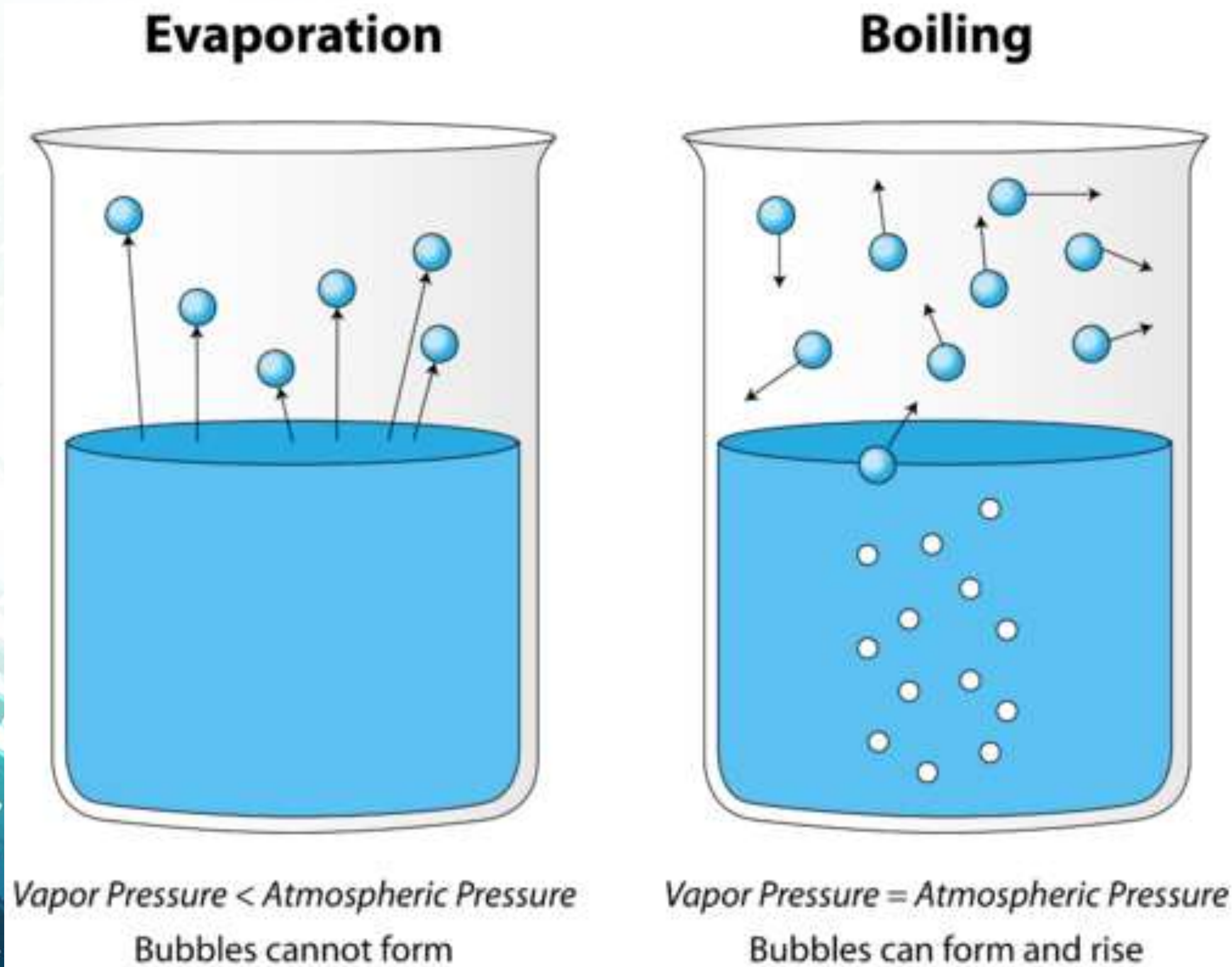
POPERTIES OF LIQUIDS

D. EVAPORATION, VAPOR PRESSURE AND BOILING POINT

POPERTIES OF LIQUIDS

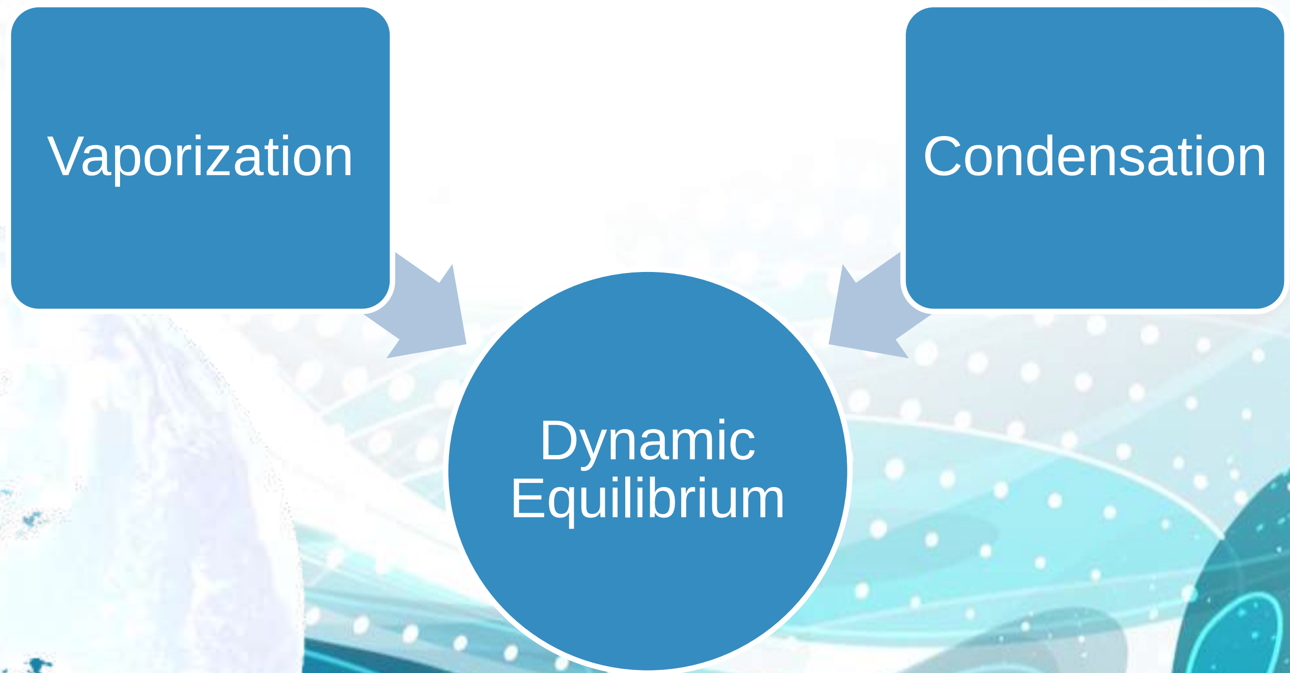
D. EVAPORATION, VAPOR PRESSURE AND BOILING POINT

- What do you think is the relationship of liquid evaporation to temperature and pressure?
- The escape of energetic molecules in liquid reduces the average kinetic energy of the remaining molecules


Evaporation
Boiling
Vapor Pressure < Atmospheric Pressure
Bubbles cannot form
Vapor Pressure = Atmospheric Pressure
Bubbles can form and rise

POPERTIES OF LIQUIDS

D. EVAPORATION, VAPOR PRESSURE AND BOILING POINT



POPERTIES OF LIQUIDS

ANALYSIS

- **Normal boiling point happens when a liquid reaches an internal temperature of 100^{O}C under 1 atm (atmospheric pressure)**

Which level with respect to sea level foods cooks faster and slower?

POPERTIES OF LIQUIDS

At higher altitude, atmospheric pressure is lesser.

Thus water boils faster at a lower temperature because less pressure is exerted on water molecules.

Inefficient delivery of heat to cook the food and it takes time for the food to be cooked.

Let's check your understanding.

Answer the following questions briefly in a ½ sheet of pad paper; copy and answer.

1. Why do droplets of water come in spherical shape on top of the leaves of the plants like gabi?
2. Boiling points varies with location.
3. Your arm feels cool when alcohol evaporates from your skin.
4. On a warm day, water droplets form on the outside of the bottle of a carbonated beverage.

PROPERTIES OF SOLIDS

How are the structures and properties of solids related?

POPERTIES OF SOLIDS

- A **SOLID** is formed when the <u>temperature of a liquid is low</u> and the <u>pressure is sufficiently high</u> causing the particles to come very close to one another.
- They are rigid
- Their particles hardly diffuse

POPERTIES OF SOLIDS

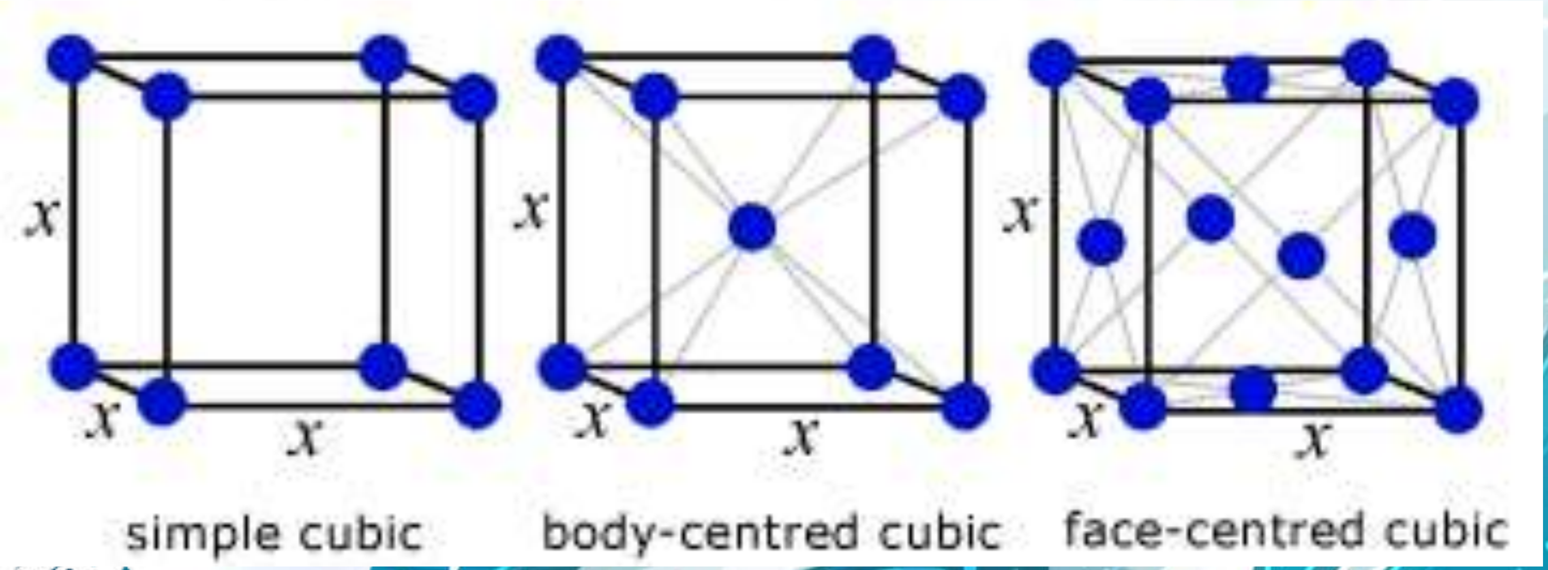
NATURE OF SOLIDS

- Crystalline Solids
- Amorphous Solids

POPERTIES OF SOLIDS

A. CRYSTALLINE

- Atoms, ions, or molecules are arranged in well defined arrangement
- Having flat surface and sharp edges
- Example: gems, salts, sugar and ice.



POPERTIES OF SOLIDS

TYPES OF CRYSTALLINE SOLIDS

- Ionic
- Molecular
- Covalent Network
- Metallic

POPERTIES OF SOLIDS

1. Ionic Crystalline Solids

- **Composed of (+) and (-) ions**
- **Held by electrostatic attractions**
- **They are hard, brittle and poor electrical and thermal conduction**
- **Example: NaCl**

POPERTIES OF SOLIDS

2. Molecular Crystalline Solids

- Composed of atoms and molecules
- Held together by: H-Bond, dipole-dipole, and London dispersion forces
- Soft, low to moderate melting point and poor thermal and electrical conductivity
- Examples: CH_4, $C_{12}H_{22}O_{11}$, CO_2, H_2O and Br_2

POPERTIES OF SOLIDS

3. Covalent Network Crystalline Solids

- **Atoms connected in a network of covalent molecules**
- **Held together by covalent bonds**
- **Very hard, very high melting point and often poor thermal and electrical conductivity.**
- **Examples: Plastics, Allotropes of carbon, silicon carbide**

POPERTIES OF SOLIDS

4. Metallic Crystalline Solids

- **Composed of atoms and molecules**
- **Held together by metallic bonds**
- **Soft to hard, low to high melting point, malleable, ductile and good thermal and electrical conduction**
- **All metallic elements: Cu, Na, Zn, Fe and Al**

POPERTIES OF SOLIDS

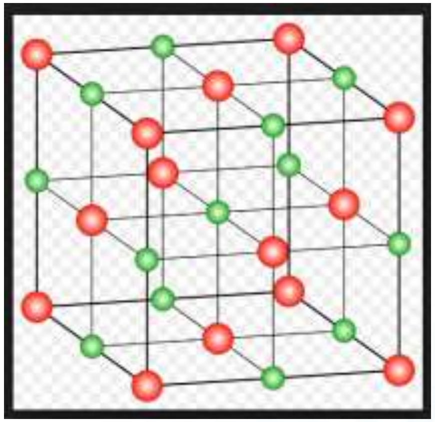
How are molecules being arranged in microscopic level?

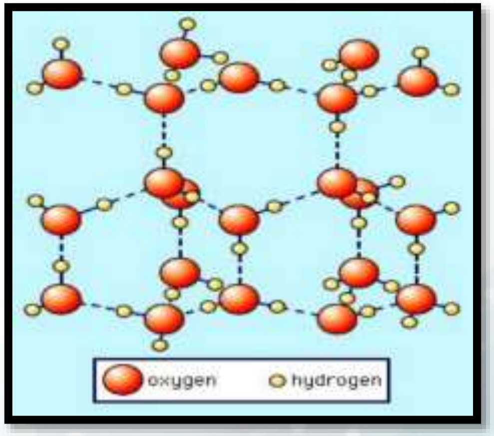
Unit Cell	The smallest portion of the crystal which shows the complete pattern of its particles
Crystal Lattice	The repetition of unit cells in all directions

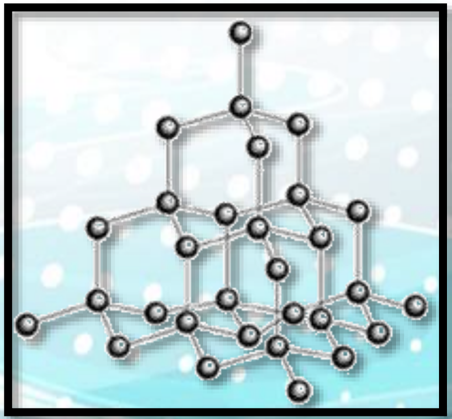
POPERTIES OF SOLIDS

Structural Representations of Molecules:

1. NaCl
2. Ice
3. Diamond
4. Metallic Bond in (Fe)







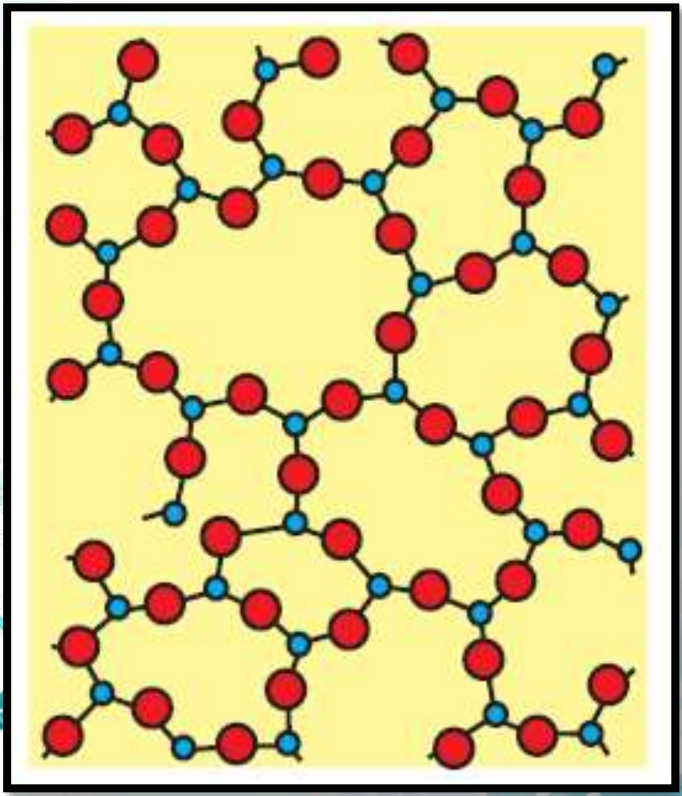
POPERTIES OF SOLIDS

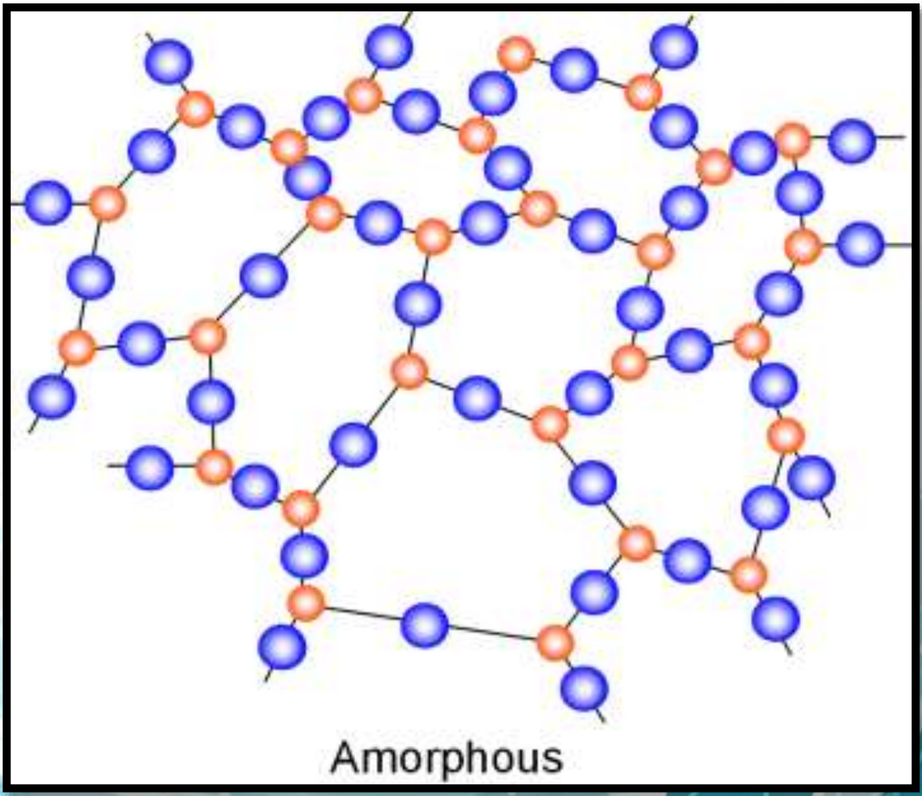
B. AMORPHOUS SOLIDS

- From the Greek word for “without form”
- Solid particles which do not have orderly structures.
- They have poorly defined shapes
- are rigid, but they lack repeated periodicity or long-range order in their structure.
- examples include thin film lubricants, metallic glasses, polymers, and gels

POPERTIES OF SOLIDS

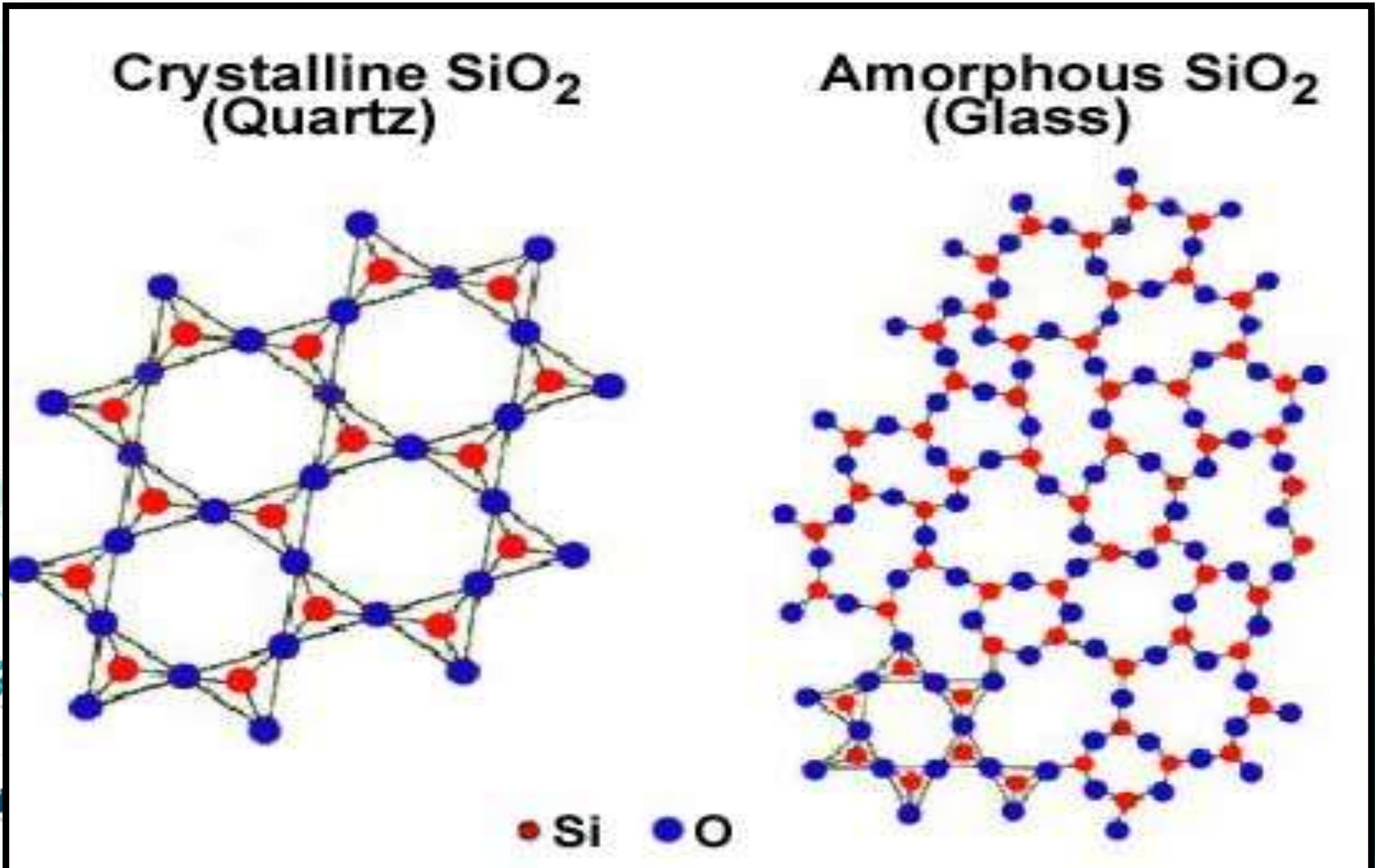
STRUCTURE OF AMORPHOUS SOLID:





POPERTIES OF SOLIDS

CRYSTALLINE VERSUS AMORPHOUS SOLIDS



POPERTIES OF SOLIDS

- It can be noted that as temperature of crystalline solid is increased, the particles vibrate back and forth about its lattice point.
- The crystal becomes less ordered.
- The heat added increases the kinetic motion of the particles.
- Until the crystalline structure is completely destroyed by the vibrations of the particles, melting is achieved.

POPERTIES OF LIQUIDS

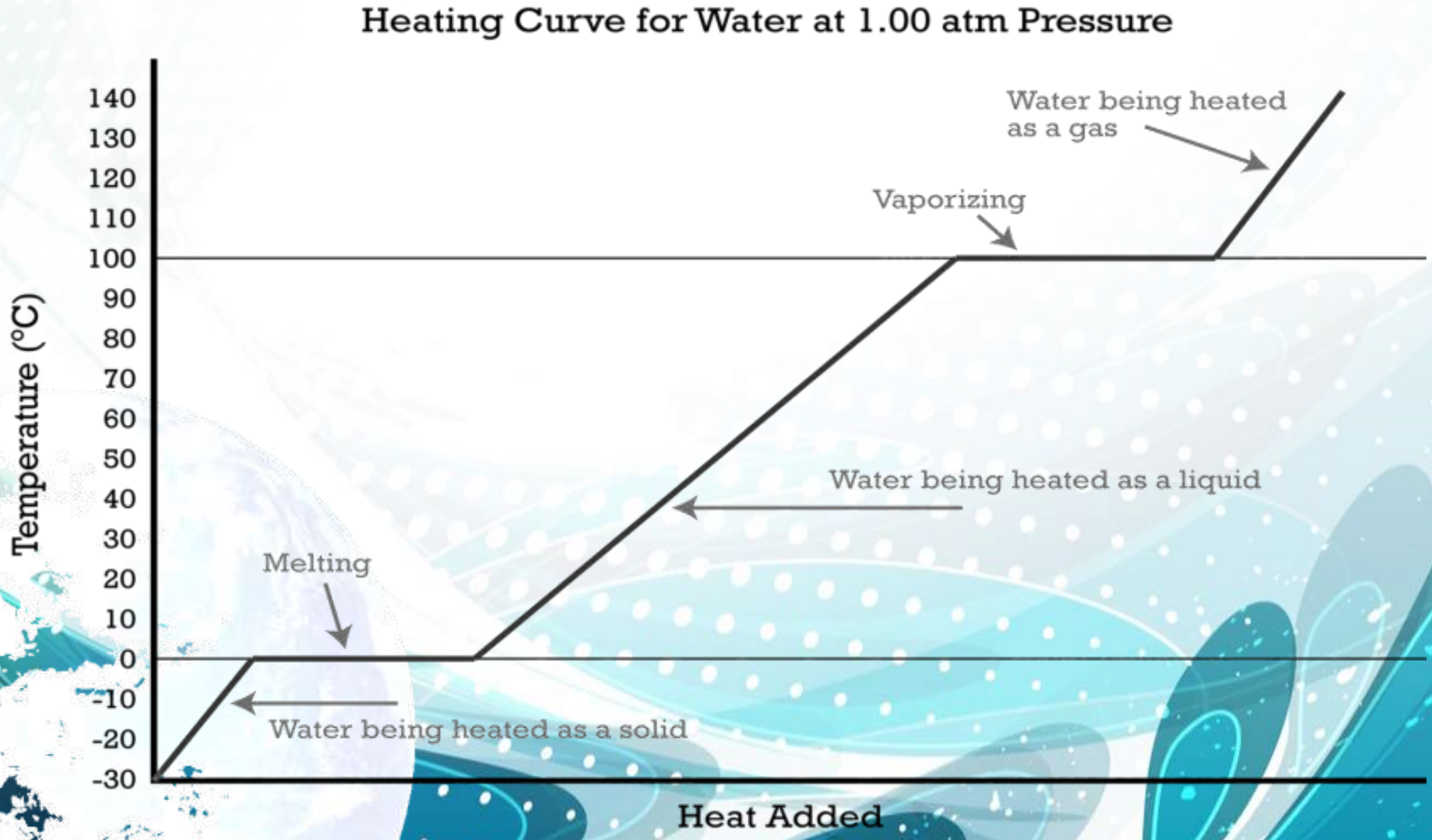
ANALYSIS

- **What will happen if heating stops and no heat is allowed to escape?**

Both solid and liquid phases are present in equilibrium.

PHASE CHANGE

Heating curve for the conversion of ice to gaseous water.



PHASE CHANGE

ANALYSIS

- **How does intermolecular force relates to the rate at which melting point of a substance is achieved?**

Forces of attraction are weak in substances with lower melting point and vice versa.

PHASE CHANGE

VOCABULARIES

- **HEAT FUSION- refers to the amount of energy required to overcome the intermolecular forces to convert a solid into a liquid**
- **HEAT VAPORIZATION- the amount of energy required to convert a liquid into a gas.**

PHASE CHANGE

SYNTHESIS

- **Ionic Compounds have very high melting point because of a very strong intermolecular force.**
- **Example:**
  - NaCl
  - $MgCl_2$
  - BeF
  - CaF_2

PHASE CHANGE

SYNTHESIS

- **Covalent compounds have low to moderate melting point because of weak intermolecular force.**
- **Example:**
  - Water
  - Glycerin
  - Hormones
  - Other Fats

QUANTITATIVE ASPECTS IN PHASE CHANGES

- **Different substances absorbs heat in varying amounts.**
- **SPECEFIC HEAT is defined as the amount of heat needed to raise the temperature of one gram of substance by one degree Celsius.**

$$Q = mc\Delta T$$

Q= heat
m= mass
c= specific heat capacity
ΔT= change in temperature

QUANTITATIVE ASPECTS IN PHASE CHANGES

NOTE:

- When materials with small specific heat value absorbs energy, its temperature rises rapidly.
- In contrast, materials with high specific heat values absorb a large amount of heat without much increase in temperature.
- Water has a specific heat capacity of 4.16 Joules.

QUANTITATIVE ASPECTS IN PHASE CHANGES

SAMPLE PROBLEM:

- Hot water at 100^oC can burn and damage the skin, but the effect of steam on the skin can be even more severe. Calculate the amount of heat absorbed by the skin from a 150-g steam burned at 100^oC.

ENERGY CHANGES IN CHEMICAL REACTIONS

Thermochemistry

THERMOCHEMISTRY

INTRODUCTION

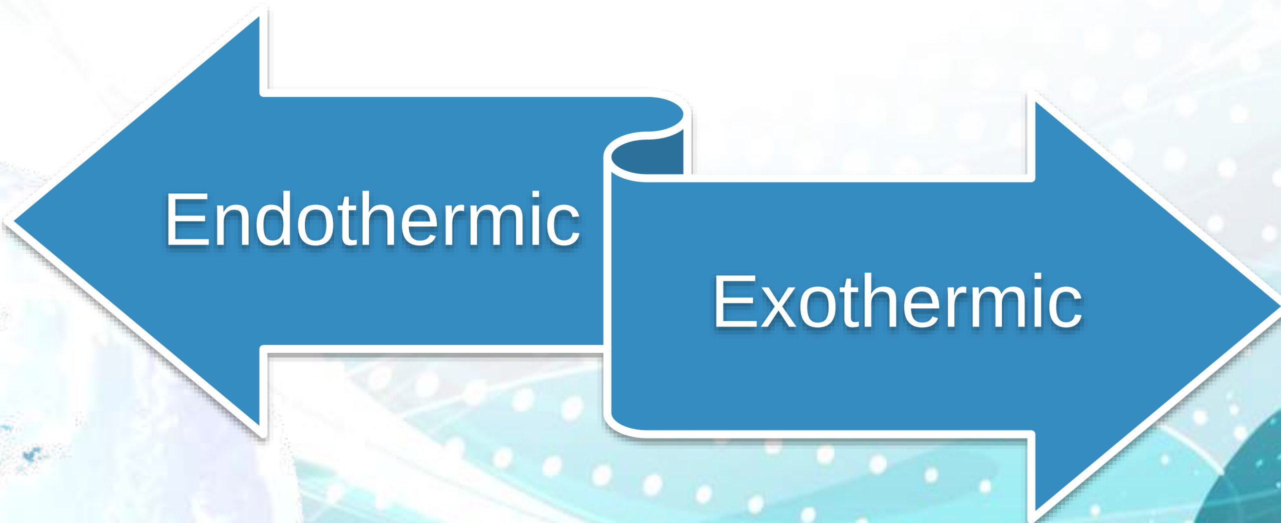
Energy is the foundation of the universe.

THERMOCHEMISTRY

- Energy transfer may be in the form of heat or work.
- **HEAT (Q) –** is the transfer or energy between a system and surroundings due to temperature difference.
- Heat may be absorbed or released by a system depending on which has a higher temperature between the system and the surroundings.

THERMOCHEMISTRY

- **During chemical reaction, there is an energy change between molecules.**
- **TWO TYPES OF REACTIONS:**



THERMOCHEMISTRY

THERMOCHEMISTRY

- **The study of energy changes that occur during chemical reactions and changes of state.**

THERMOCHEMISTRY

ANALYSIS

- **How does energy undergo change within a system or within a chemical reaction?**

Heat flows in and out of the system during chemical reactions.

THERMOCHEMISTRY

THE LAW OF CONSERVATION OF ENERGY:

- In any chemical or physical process, energy is neither created nor destroyed.
- In any chemical or physical process, energy in the universe remains unchanged.

$$\text{Energy}_{\text{univ}} = \text{constant}$$

THERMOCHEMISTRY

Recitation: Explain how energy is conserved in the following situations:

- **Burning of gasoline**
- **Hydroelectric powerplant**
- **Cellphone telecommunications**
- **Condensation of water vapor**
- **Induction cooking**

THERMOCHEMISTRY

THREE TYPES OF SYSTEMS:

- Open System
- Closed System
- Isolated System

THERMOCHEMISTRY

OPEN SYSTEM

- Matter and energy occurs between system and surrounding
- System interacts with the surrounding

THERMOCHEMISTRY

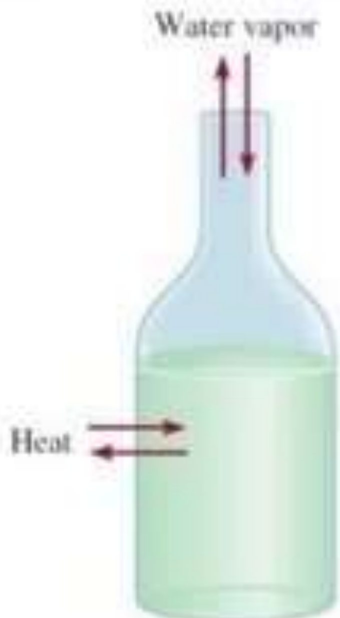
CLOSED SYSTEM

- Only energy can transfer between system and surroundings

ISOLATED SYSTEM

- Matter and energy cannot transfer between the system and its surroundings.
- ***Example: contents of adiabatic bomb calorimeter.***

- There are generally 3 types of systems.

Open system	Closed system	Isolated system
		
An ***open system*** *can exchange mass and energy, usually in the form of heat with its surroundings*	***closed system***, which *allows the transfer of energy (heat) but not mass.*	***isolated system***, which *does not allow the transfer of either mass or energy.*

THERMOCHEMISTRY

The magnitude of heat can be computed using the following equation

$$Q = mc\ T$$

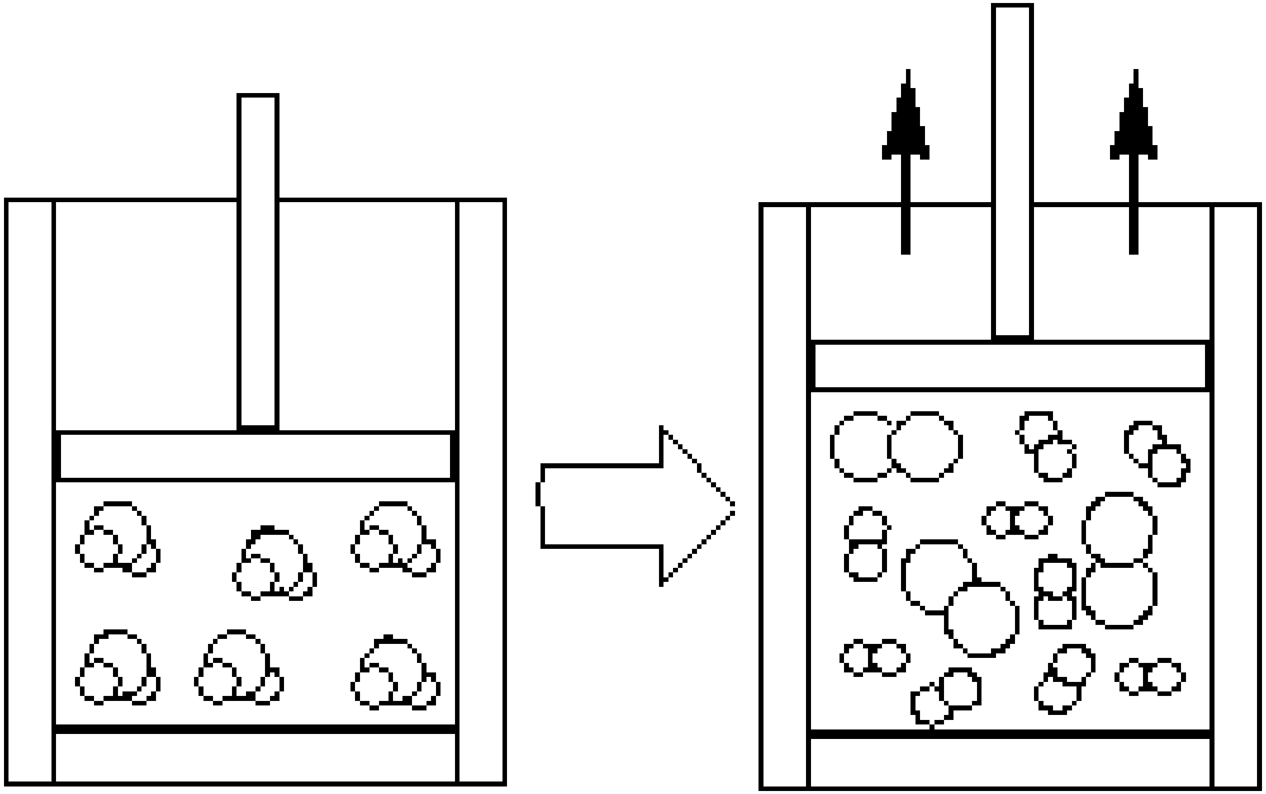
Q= heat
m= mass
c= specific heat capacity
T= change in temperature

THERMOCHEMISTRY

WORK (*w*)

- Force applied over a given distance
- Energy transfer between a system and the surrounding due to a force acting through a distance

$$2\ NH_3(g) \rightarrow N_2(g) + 3\ H_2(g)$$



THERMOCHEMISTRY

TABLE 3.2: Assigned Convention for Work, w		
System does work on the surroundings	-w	Expansion
Surroundings does work on the system	+w	Compression

THERMOCHEMISTRY

SAMPLE PROBLEM:

- How much work is needed in a system to expand from 25 to 50 liters against a pressure of 5 atm? Is work done by the system or on the system?

THERMOCHEMISTRY

SAMPLE PROBLEM:

- How much work is needed in a system to compress a carbon dioxide gas inside a fire extinguisher from the volume of 500 liter to 275 liter at 3.5 atm? Is work done by the system or on the sytem?

THERMOCHEMISTRY

ENTHALPY

- In a chemical reaction, there is an energy change from the beginning up to the end of the reaction.
- Change in energy: ENDOTHERMIC OR EXOTHERMIC REACTION
- Represented by ΔH

THERMOCHEMISTRY

ENTHALPY

- Energy change in the reaction or the sum of all the energy stored in the bonds of the product minus the energy stored in the bond of the reactant

- If there is more energy in the product than the reactant, the value of H is positive = **ENDOTHERMIC REACTION**

THERMOCHEMISTRY

THERMOCHEMICAL EQUATIONS

- **If there is less energy in the product than the reactant, the value of H is negative = EXOTHERMIC REACTION**

THERMOCHEMISTRY

WRITING THERMOCHEMICAL EQUATIONS:

I. When heat is lost, the H value is negative. (Exothermic reaction)

$$CH_4(g) + 2O_2 \text{ ------ } CO_2(g) + 2H_2O(l)$$

$$\Delta H = -890 \text{ kJ}$$

THERMOCHEMISTRY

WRITING THERMOCHEMICAL EQUATIONS:

I. When heat is gained, the H value is positive. (Endothermic reaction)

$CO_2(g) + 2H_2O(l)$ ------ $CH_4(g) + 2O_2$

$\Delta H = 890$ kJ

THERMOCHEMISTRY

WRITING THERMOCHEMICAL EQUATIONS:

II. HEAT IS A STATE FUNCTION, thus energy changes or ΔH value for the same equation may be different if it occurs in different physical state.

THERMOCHEMISTRY

WRITING THERMOCHEMICAL EQUATIONS:

III. If a reaction is reversed, then the enthalpy ΔH value will also be reversed. Hence +a becomes –a and vice versa

THERMOCHEMISTRY

WRITING THERMOCHEMICAL EQUATIONS:

III. If we change the stoichiometric coefficients in the reaction, we also change the enthalpy ΔH value proportionally!

THERMOCHEMISTRY

WRITING THERMOCHEMICAL EQUATIONS:

a. If coefficient is doubled enthalpy must be doubled also
b. If we triple the coefficient, enthalpy must also be tripled
c. Same with when we half the coefficient.
d. If we double the equation and reverse, we must also double the enthalpy and reverse the sign

THERMOCHEMISTRY

Sample Problem:

a. Manipulate the thermochemical equation below as endothermic reaction:

$$CH_{4(g)} + 2O_2 \text{ ------ } CO_{2(g)} + 2H_2O_{(l)}$$

$$\Delta H = -890 \text{ kJ}$$

THERMOCHEMISTRY

HESS LAW

- States that the enthalpy change of an overall reaction is the sum of the enthalpy changes of its individual steps.

EXAMPLE: we can burn carbon directly to carbon dioxide

C(s) + O2(g) ------------- CO2(g) H= -393.509 kJ

OR

THERMOCHEMISTRY

HESS LAW

- Carbon to carbon monoxide, then carbon monoxide to carbon dioxide

C(s) + ½ O2(g) ------------ ~~CO~~(G) H= -110.524 kJ

~~CO~~(g) + ½ O2(g) ---------- CO2(g) H= -282.958 kJ

C(s) + O2(g) -------------- CO2(g) H= -393.509 kJ

THERMOCHEMISTRY

STEPS IN GETTING THE HEAT SUMMATION:

1. **Identify the net equation whose ΔH is unknown. Make sure that the reaction is balanced.**

2. **Manipulate the equations where ΔH is known so that the correct moles of the reactants and the products are on correct sides.**

THERMOCHEMISTRY

STEPS IN GETTING THE HEAT SUMMATION:

1. **Add these individual reactions to get the net reaction. The value of the unknown ΔH is the sum of the individual manipulated ΔH.**

THERMOCHEMISTRY

STEPS IN GETTING THE HEAT SUMMATION:

1. **Add these individual reactions to get the net reaction. The value of the unknown ∆H is the sum of the individual manipulated ∆H.**

REACTION RATES

Chemical Kinetics

Chemical Kinetics

Reaction Rate

- How fast the reaction takes place
- Some reactions proceed at very fast rate while others proceed very slowly
- Fractions of the reactants are changed into product until all the substances are converted fully.

(R)Rate= M(molar mass)/s(second)

Chemical Kinetics

Examples of Reaction

- Burning of Rocket Fuel
- Spoiling of food outside the refrigerator
- Rusting of Iron

Factors Affecting Rates of Reactions

A. Nature of Reactants:

- Reaction depends on the particular reactants and the number of bonds that have to be broken.
- Reactions are rapid between oppositely-charged particles
- Reactions involving covalent substances are slow at room temperature.
- Gasses proceed quick reactions than solid and liquid.
- The reactions between heterogeneous reactions are slower than homogeneous reactions

Factors Affecting Rates of Reactions

B. Concentration:

- An increase in concentration of the reactant indirectly means an increase in collision theory, thus increasing the reaction rate.

Factors Affecting Rates of Reactions

C. Surface Area:

- **The smaller the size of particles, the larger the surface area exposed.**

A larger surface area increases the frequency of collisions

Factors Affecting Rates of Reactions

C. Effects of Catalyst:

- Provides an alternative pathway of lower activation energy.
- Representation of a chemical equation with the presence of catalyst:

$$2H_2O_2 \xrightarrow{MnO_4} O_2 + 2H_2O$$

Factors Affecting Rates of Reactions

C. Effects of Temperature

- Food spoilage at room temperature on warm summer days
- Most plants grow faster in warm than in cold weather.
- Animals living at moderate pressure under the deep sea are fatty than those fishes living in the shallow portion of the sea/freshwater.

Identify the factors that influence reaction rates and explain:

1. **A brush (grass fire) spreads more rapidly on a sunny day than on an overcast day.**
2. **Sodium reacts more rapidly with water than iron does.**
3. **Powdered zinc reacts more rapidly with sulfuric acid than a large piece of zinc of equal weight does.**
4. **It is more dangerous to drop a lighted match into a gasoline tank that has just been emptied than into one which is completely full.**
5. **Cake batter will cook only when heated.**

QUIZ

Identify the factors that influence reaction rates and explain:

PROGRESS OF CHEMICAL REACTION

Chemical Reaction

THERMOCHEMISTRY

RATE LAW

- The concentration of reactants influences the rate of chemical reactions.
- The effect of concentration of reactants on the rate of reaction can be seen quantitatively using the rate law for the reaction.
- An expression that gives a mathematical relationship of the rate of a reaction and the concentration of reactants.

$$\text{Rate} = k[A]^m[B]^n$$

THERMOCHEMISTRY

Consider the equation between oxygen and nitric oxide in the formation of acid rain:

$$O_{2(g)} + 2NO_{(g)} \rightarrow 2NO_{2(g)}$$

$$\text{Rate} = k[O_2]^m[NO]^n$$

THERMOCHEMISTRY

$$\text{Rate} = k[O_2]^m[NO]^n$$

- Brackets represent the concentration of the reactants given in moles per liter
- k= the fixed value for rate constant
- m and n represent the order of the reaction
- In getting the experimental value for m and n, the concentration of one of the reactants is changed while the other is kept constant.

THERMOCHEMISTRY

$$2N_2O_5 \rightarrow 2N_2 + 5O_2$$

	$[N_2O_5]_{initial}$	$\Delta[N_2O_5]/\Delta t$
Trial 1	1.0 M	-0.00048 M/s
Trial 2	2.0 M	-0.00096 M/s

$$2N_2O_5 \rightarrow 2N_2 + 5O_2$$

	$[N_2O_5]_{initial}$	$\Delta[N_2O_5]/\Delta t$
Trial 1	1.0 M	-0.00048 M/s
Trial 2	2.0 M	-0.00096 M/s

The reaction is FIRST ORDER WITH RESPECT TO N_2O_5

- Doubling the initial concentration of the reactants, the rate of the reaction is also doubled

THERMOCHEMISTRY

When we double a concentration, what happens to the rate?

if rate is multiplied by	reaction order
1	0
2	1
4	2
½	-1

THERMOCHEMISTRY

	$[NO]_{initial}$ (M)	$[O_2]_{initial}$ (M)	rate (M/s)
Trial 1	0.100	0.250	0.04
Trial 2	0.200	0.250	0.16
Trial 3	0.100	0.500	0.08

THERMOCHEMISTRY

Example Problem:

$$R = k[O_2][NO]^2$$

THERMOCHEMISTRY

	$[NO]_{initial}$ (M)	$[O_2]_{initial}$ (M)	rate (M/s)
Trial 1	0.100	0.250	0.04
Trial 2	0.200	0.250	0.16
Trial 3	0.100	0.500	0.08

$R = k[O_2][NO]^2$ $\quad k = 1.6\ M/s$

$0.04 M/s = k(0.250 M)(0.100 M)$

Given reaction rate data for: $F_2 + 2ClO_2 \rightarrow 2FClO_2$

Trial	$[F_2]$(M)	$[ClO_2]$(M)	Initial Rate (M/s)
1	0.10	0.010	0.0012
2	0.10	0.040	0.0048
3	0.20	0.010	0.0024

What is the order with respect to each reactant and the overall reaction order?

What is the rate law for this reaction?

Calculate the rate constant, k.

12. For the reaction $2A + B \rightarrow A_2B$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•s)
1	0.420 M	0.530 M	0.420
2	0.420 M	1.590 M	3.780
3	0.140 M	0.530 M	0.140

a) Determine the order with respect to each reactant
b) Determine the overall order of reaction
c) Write the rate expression for the reaction.
d) Find the value of the rate constant, k.

13. For the reaction $A + B \rightarrow AB$, the following data were obtained.

Trial	Initial [A]	Initial [B]	Initial Rate (mol/L•min)
1	0.480 M	0.190 M	0.350
2	0.480 M	0.380 M	0.350
3	0.240 M	0.190 M	0.087

a) Determine the order with respect to each reactant
b) Determine the overall order of reaction
c) Write the rate expression for the reaction.
d) Find the value of the rate constant, k.

Rate of Chemical Reaction

The following data were obtained for the reaction:

$$A_2 + B_2 + 3C \rightarrow D$$

Experiment No.	Reactant Concentrations			Rate of Reaction (M/s)
	[A]	[B]	[C]	
1	0.10	0.20	0.20	0.0090
2	0.20	0.20	0.30	0.0360
3	0.20	0.60	0.30	0.0720
4	0.20	0.20	0.60	0.2880

BALANCING REDOX REACTIONS

Review:

- Electrons makes it possible for one atom bind with another atom.
- In acid-base reactions, transfer of proton (H+) is involved.

BALANCING REDOX REACTIONS

What is a REDOX reaction?

- RED(Reduction): Substance gain an electron
- Antoine Lavosier may leave or goes in into a substance, thus changing its mass.
- OX(Oxidation): Tendency of a substance to loose an electron.

BALANCING REDOX REACTIONS

REDOX IN NATURE:

- Cellular Respiration
- Photosynthesis
- Battery charging
- Burning process

BALANCING REDOX REACTIONS

In electron transfer,

- We track electrons like a banking transactions.

$$Fe_{(s)} + CuSO_{4(aq)} \longrightarrow FeSO_{4(aq)} + Cu_{(s)}$$

$$Fe_{(s)} + Cu^{2+}_{(aq)} + \cancel{SO_4^{2-}}_{(aq)} \longrightarrow Fe^{2+}_{(aq)} + \cancel{SO_4^{2-}}_{(aq)} + Cu_{(s)}$$

Oxidizing Agent

Reducing Agent

$$Fe_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Fe^{2+}_{(aq)} + Cu_{(s)}$$

Lost of e- (oxidized)

Gain of e- (reduced)

BALANCING REDOX REACTIONS

Oxidation number in tracking electrons:

- Hypothetical value for each atom in a molecule (not actual)
- ELEMENT: zero (0) oxidation# (He, O_2, Fe)
- MONOATOMIC ION: the same with its ionic charge (Oxygen -2, Fe +2)
- NEUTRAL MOLECULE: ox. Numbers add up to get zero [CO_2 (+4 -4)]

BALANCING REDOX REACTIONS

Assigning Oxidation Number:

$$4Fe_{(s)} + 3O_2 \rightarrow 2Fe_2O_3$$

$4Fe_{(s)}$	$3O_2$	$2Fe_2O_3$ (Fe)	$2Fe_2O_3$ (O)
0	0	+3	-2

Fe: 0 → +3: Loss of –e [oxidized] — Reducing Agent

O: 0 → -2: Gain of –e [reduced] — Oxidizing Agent

BALANCING REDOX REACTIONS

Practice

$$PbO_2$$

$$MnO_4$$

$$S$$

$$NH_3$$

BALANCING REDOX REACTIONS

Balancing a Redox Reaction

0 0 +3 -2

Fe: 0 → +3: Loss of –e [oxidized] Reducing Agent

O: 0 → -2: Gain of –e [reduced] Oxidizing Agent

BALANCING REDOX REACTIONS

Consider the aqueous solution iron (II) ion (Fe3+) with dichromate ion ($Cr_2O_7^{-2}$):

$$4Fe^{2+} + Cr_2O_7^{-2} \rightarrow 4Fe^{3+}\ Cr^{3+}$$

STEPS:

Separate the unbalanced reaction into half-reactions. A half reaction is an oxidation/reduction that occurs as part of overall redox reaction.

Oxidation: $Fe^{2+} \rightarrow Fe^{3+}$

Reduction: $Cr_2O_7^{-2} \rightarrow Cr^{3+}$

BALANCING REDOX REACTIONS

$$4Fe^{2+} + Cr_2O_7^{-2} \rightarrow 4Fe^{3+}\ Cr^{3+}$$

STEPS:

Balance each of the half-reactions with regard to atoms other than O and H. In this case, no change is required for the oxidation half-reaction. We adjust the coefficient of the chromium (III) ion to balance the reduction half reaction.

Oxidation: $Fe^{2+} \rightarrow Fe^{3+}$

Reduction: $Cr_2O_7^{-2} \rightarrow 2Cr^{3+}$

BALANCING REDOX REACTIONS

$$4Fe^{2+} + Cr_2O_7^{-2} \rightarrow 4Fe^{3+} Cr^{3+}$$

STEPS:

Balance both half-reactions for H by adding H^+ . Once again, the oxidation in this case requires no change, but we must add 14 hydrogen ions to the product side of the reaction.

Oxidation: $Fe^{2+} \rightarrow Fe^{3+}$

Reduction: $Cr_2O_7^{-2} \rightarrow 2Cr^{3+} + 7H_2O$

BALANCING REDOX REACTIONS

$$4Fe^{2+} + Cr_2O_7^{-2} \rightarrow 4Fe^{3+} Cr^{3+}$$

STEPS:

Balance both half-reactions for H by adding H^{+} Once again, the oxidation in this case requires no change but we must add 14 hydrogen ions to the reactant side of the reaction

Oxidation: $Fe^{2+} \rightarrow Fe^{3+}$

Reduction: $14H^{+} + Cr_2O_7^{-2} \rightarrow 2Cr^{3+} + 7H_2O$

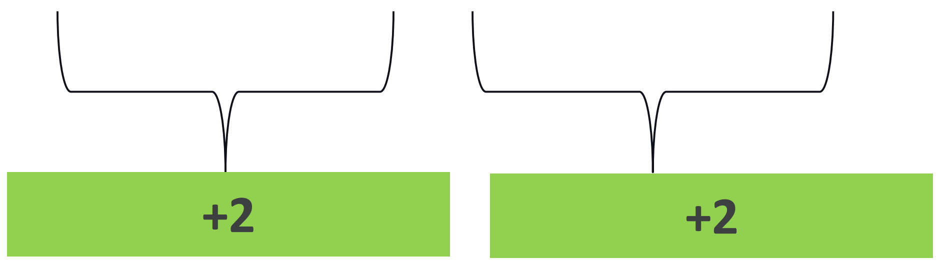
BALANCING REDOX REACTIONS

$$4Fe^{2+} + Cr_2O_7^{-2} \rightarrow 4Fe^{3+}\ Cr^{3+}$$

STEPS:

Balance both half-reactions for charge by adding electrons. To do this, we determine the total charge on each side and add electrons to make total charges equal.

Oxidation: $Fe^{2+} \rightarrow Fe^{3+} + e^-$



BALANCING REDOX REACTIONS

$$4Fe^{2+} + Cr_2O_7^{-2} \rightarrow 4Fe^{3+}\ Cr^{3+}$$

STEPS:

In case of reduction, there is total charge of [(14)(+1) + (2)(-)] = +12 on the reactant side and a total charge of [(2)(+3)] = +6 on the product side. Adding six electrons to the reactant side makes the charges equal

Reduction: $6e^- + 14H^+ + Cr_2O_7^{-2} \rightarrow 2Cr^{3+} + 7H_2O$

+6   +6

BALANCING REDOX REACTIONS

$$4Fe^{2+} + Cr_2O_7^{-2} \rightarrow 4Fe^{3+}\ Cr^{3+}$$

STEPS:

If the number of electrons in the balanced oxidation half-reaction is not the same as the number of electrons in the balanced reduction half-reaction, multiply one or both of the half-reactions by the number(s) req. to make it balanced.

Oxidation: $6(Fe^{2+} \rightarrow Fe^{3+}\ e^-)$

$6Fe^{2+} \rightarrow 6Fe^{3+}\ 6e^-$

Reduction: $6e^- + 14H^+ + Cr_2O_7^{-2} \rightarrow 2Cr^{3+} + 7H_2O$

BALANCING REDOX REACTIONS

$$4Fe^{2+} + Cr_2O_7^{-2} \rightarrow 4Fe^{3+}\ Cr^{3+}$$

STEPS:

Finally, add the balanced half-reactions back together and cancel the electrons, in addition to any other identical terms that appear on both sides.

$$6Fe^{2+} \rightarrow 6Fe^{3+}\ 6e^-$$

$$6e^- + 14H^+ + Cr_2O_7^{-2} \rightarrow 2Cr^{3+} + 7H_2O$$

$$6Fe^{2+} + 14H^+ + Cr_2O_7^{-2} \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$$