Good afternoon!

STRUCTURE OF MATTER PHYSICAL, MECHANICAL AND CHEMICAL PROPERTIES

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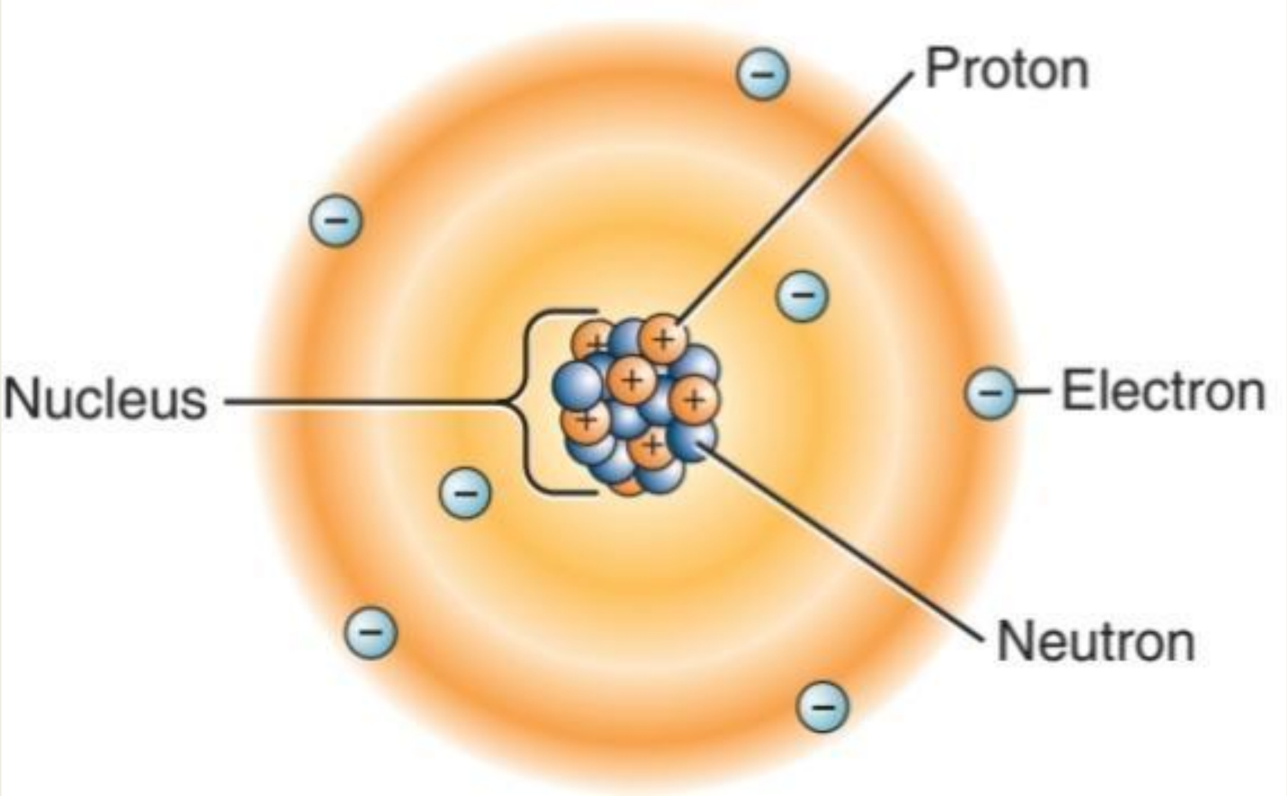
ATOMS

- An atom is a basic unit of matter which consists of Protons, Electrons and Neutrons.

Atom
Loses an electron
Positive ion

Atom
Gains an electron
Negative ion

- The number of Protons and Neutrons give mass to the nucleus of the atom and also its atomic weight.



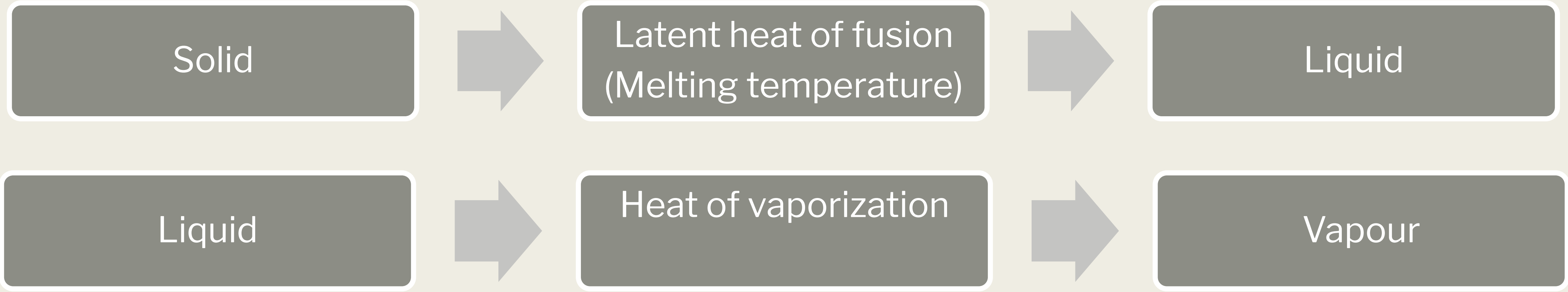
MOLECULES

- Two or more atoms can form an electrically neutral entity called a molecule. The state of attraction between adjacent molecules influences the state of matter of the material they form.

- Let’s consider a water molecule as an example.

- If each molecule attains a kinetic energy that is higher than the attraction between these molecules, they appear in the vapor form.
- As the surrounding temperature decreases, the level of kinetic energy within individual molecules decreases and the attraction between them becomes more prominent, so that they condense to a liquid form.
- Further cooling yields a solid, where the kinetic energy is so low that the molecules are immobilized by the attraction between them.

- The transformation between different states of matter is called as a change of state



Solid

Latent heat of fusion (Melting temperature)

Liquid

Liquid

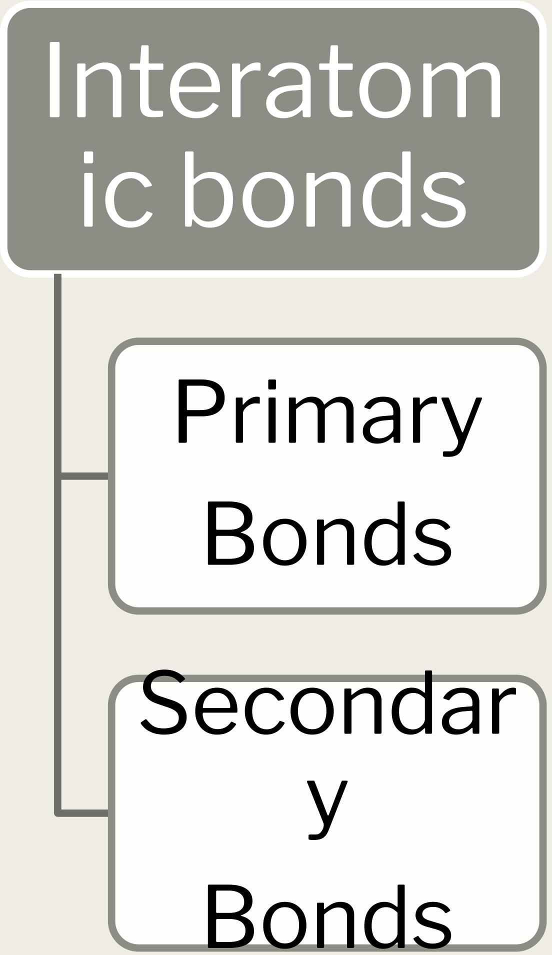
Heat of vaporization

Vapour

- In some materials such as in dry ice, solids are directly converted to vapor form by a process called **sublimation.**

INTERATOMIC BONDS

- Atoms are held together by way of forces of attraction that are called interatomic forces.
- The formation of primary bonds depends on the atomic structures and their tendency to assume a stable configuration. Primary atomic bonds, also called chemical bonds, may be of three different types: (1) ionic, (2) covalent, and (3) metallic.
- In contrast with primary bonds, secondary bonds do not share electrons. Instead, charge variations among atomic groups of the molecule induce dipole forces that attract adjacent molecules or parts of a large molecule.


Interatomic bonds

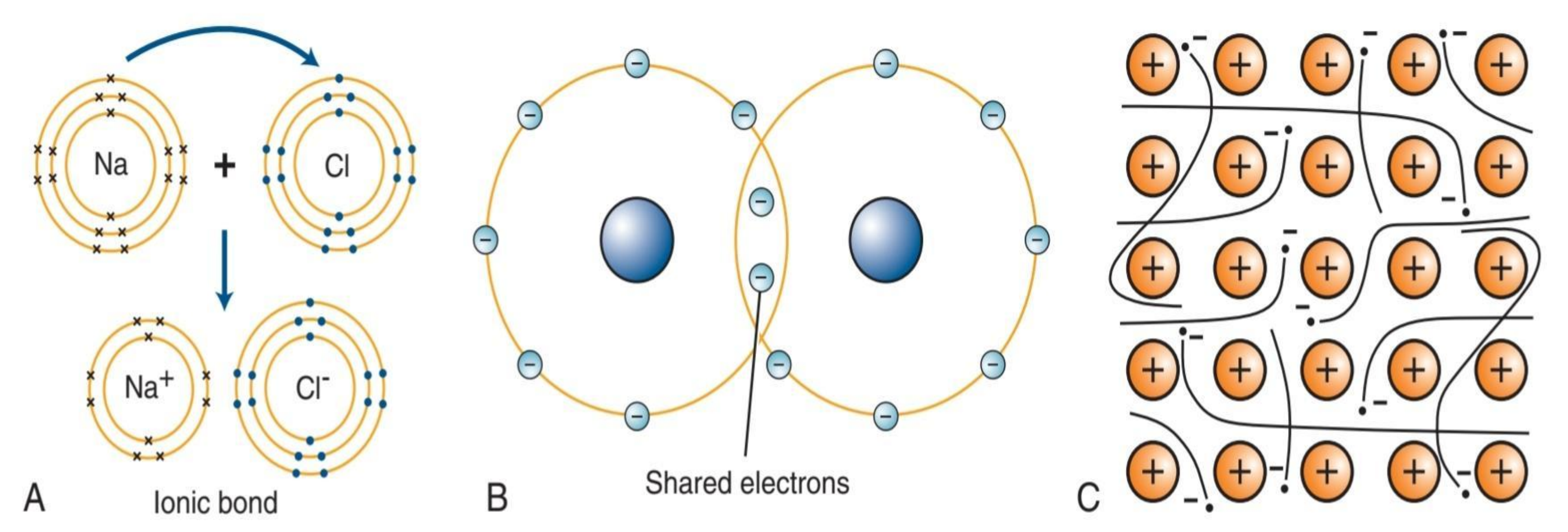
Primary Bonds

Secondary Bonds

PRIMARY BONDS

- The classic example of **ionic bonding** is the bond between the Na and CI of sodium chloride. Because the sodium atom contains one valence electron in its outer shell and the chlorine atom has seven electrons in its outer shell, the transfer of the sodium valence electron to the chlorine atom results in the stable compound NaCI In dentistry

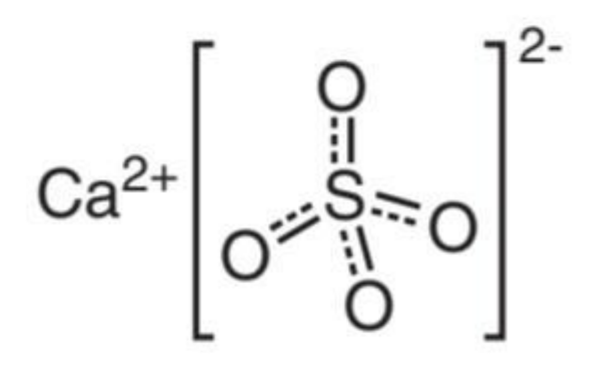
- In many chemical compounds, two valence electrons are shared by adjacent atoms. The two atoms are held together by **covalent bonds** to form a molecule that is sufficiently stable, and electrically neutral. The hydrogen molecule exemplifies covalent bonding. The single valence electron in each hydrogen atom is shared with that of the other combining atom, and the valence shells become stable.



1. Fig A shows ionic bonding
2. Fig B shows covalent bonding
3. Fig C shows metallic bonding

- The third type of primary atomic interaction is the metallic bond. The outer shell valence electrons can be removed easily from metallic atoms and form positive ions. The free valence electrons can move about in the metal space lattice to form what is sometimes described as an electron "cloud“.The electrostatic attraction between the electron cloud and the positive ions in the lattice provides the force that bonds the metal atoms together as a solid.

- The free electrons give the metal its characteristically high thermal and electrical conductivity. These electrons absorb light energy, so that all metals are opaque to transmitted light.
- Some compounds can also show more than one type of primary bonding such as I’m the case of Calcium sulphate



Here, there is presence of ionic bond between Calcium Ion and Sulphate. Additionally, there are covalent bonds present between Sulphur and Oxygen.
It is worth noting that Calcium sulphate is the main component of gypsum products which find extensive use in the field of dentistry.

SECONDARY BONDS

- In contrast with primary bonds, secondary bonds do not share electrons. Instead, charge variations among atomic groups of the molecule induce dipole forces that attract adjacent molecules or parts of a large molecule.

- The ‘van der Waals’ forces of attraction arise from dipole attractions. In the case of polar molecules, dipoles are induced by an unequal sharing of electrons. In the case of nonpolar molecules, random movement of electrons within the molecule creates fluctuating dipoles. Generated dipoles attract other similar dipoles.

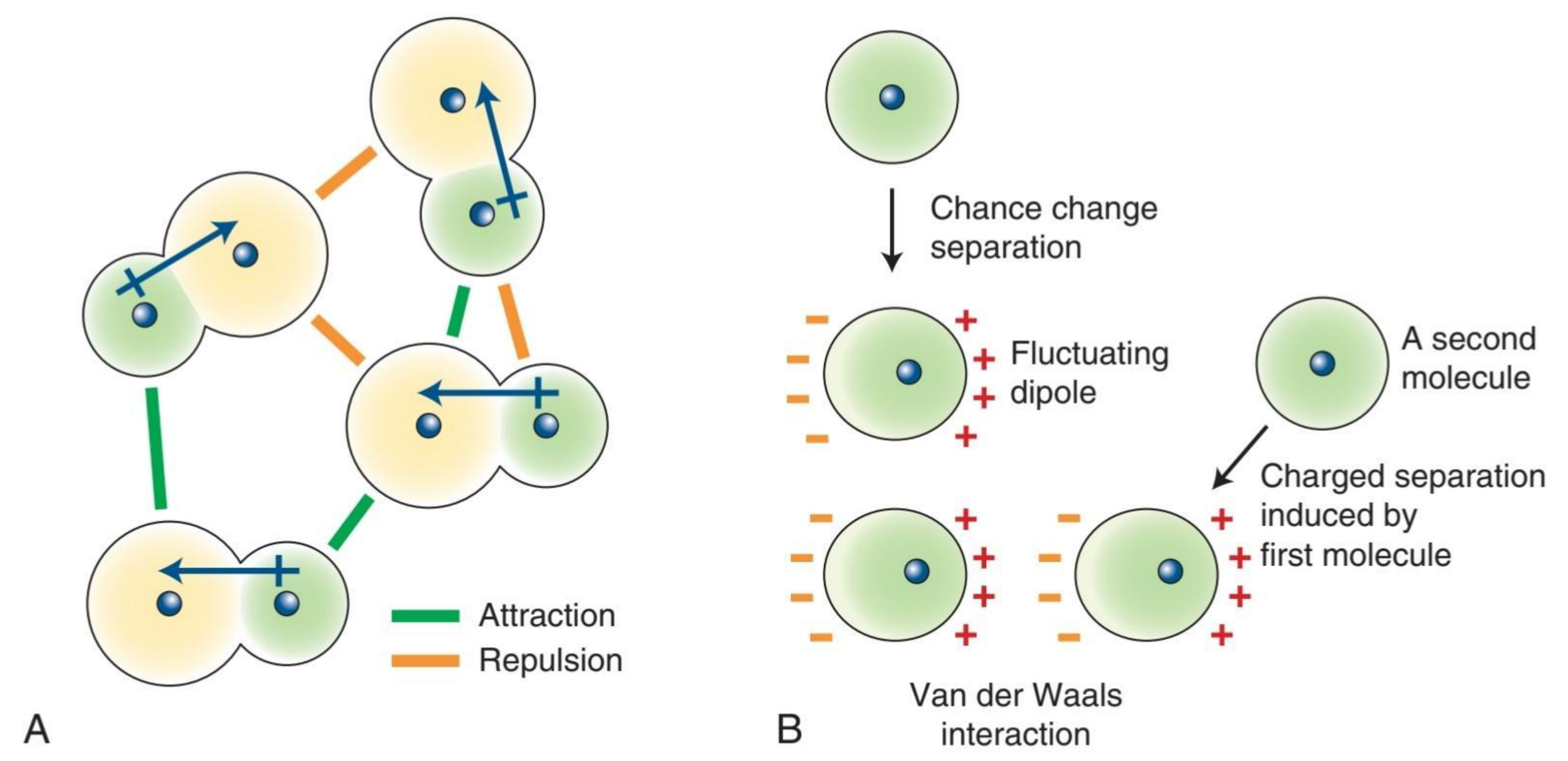
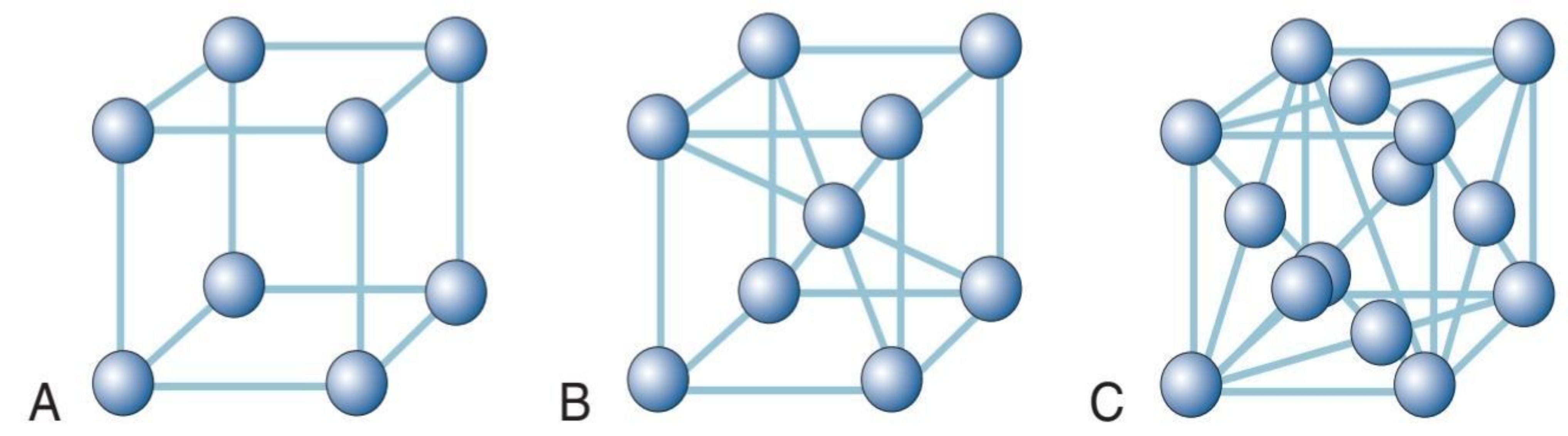


Fig A denotes a polar molecule
Fig B denotes a non polar molecule

CRYSTALLINE STRUCTURES

- These structures are composed mainly of lattice structures aka space lattice. A lattice structure refers to the orderly, regular and 3-D arrangement of atoms in a crystal.
- The simplest and most regular lattice is a cubic; it is characterized by axes that are all of equal length and meet at 90-degree angles, representing the smallest repetitive volume of a crystal, which is called a unit cell.



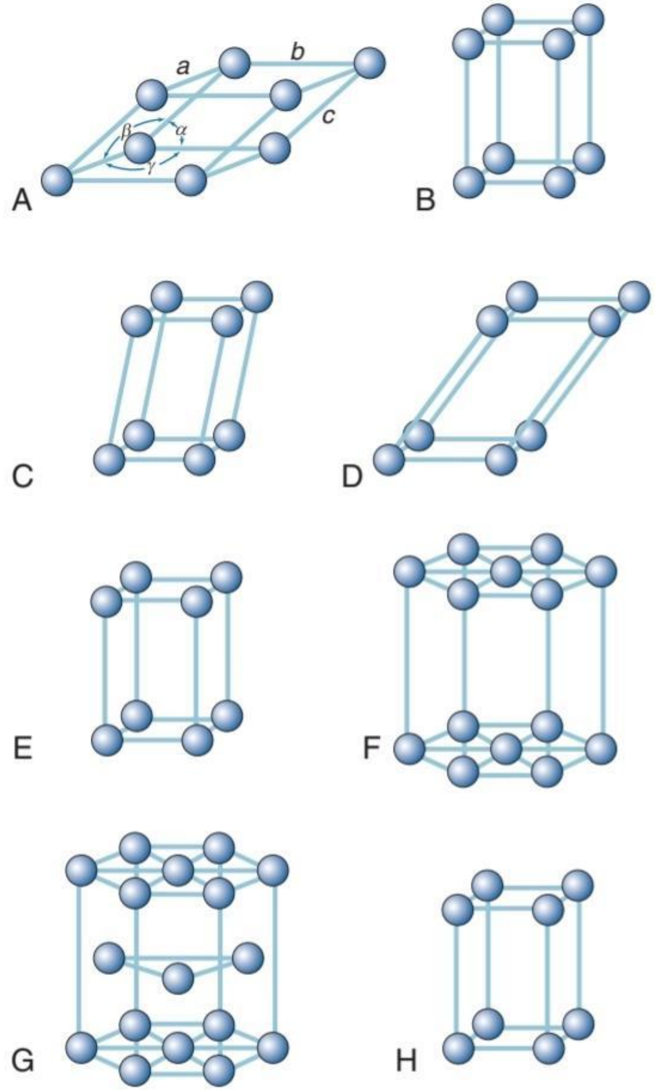


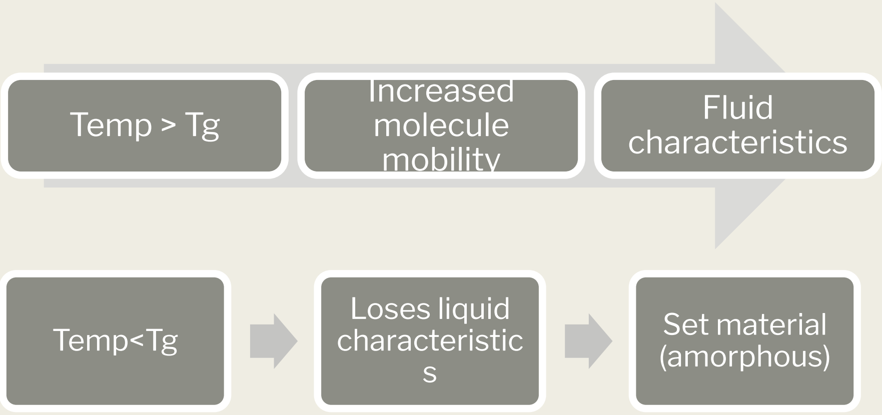
FIGURE 2-8 Other lattice types of dental interest. **A,** Rhombohedral; a = b = c; α = β = γ ≠ 90°. **B,** Orthorhombic; a ≠ b ≠ c; α = β = γ = 90°. **C,** Monoclinic; a ≠ b ≠ c; α ≠ β = γ = 90°. **D,** Triclinic; a ≠ b ≠ c; α ≠ β ≠ γ ≠ 90°. **E,** Tetragonal; a = b ≠ c; α = β = γ = 90°. **F,** Simple hexagonal; a = b ≠ c; α = β = 90°; γ = 120°. **G,** Close-packed hexagonal; a = b ≠ c; α = β = 90°; γ = 120°. H, Rhombic; a = b ≠ c; α = β = 90°; γ = 120°.

- A- rhombohedral
- B- orthorhombic
- C- Monoclinic
- D- Triclinic
- E- tetragonal
- F- simple hexagonal
- G- closely packed hexagonal
- H- rhombic

The hexagonal close-packed arrangement (G) observed in titanium, zinc, and zirconium has become an important crystalline structure in dentistry

NON CRYSTALLINE STRUCTURES

- Atoms tend to be arranged in non-repeating units. Hence the structure is unlikely that of the crystalline type where repeating units form the basis of the overall structure.
- Most polymer based materials used in dentistry are of the non crystalline which can be attributed to their tendencies to form long chain complex structures.
- They do not have a definite melting temperature but rather gradually soften as the temperature is raised.

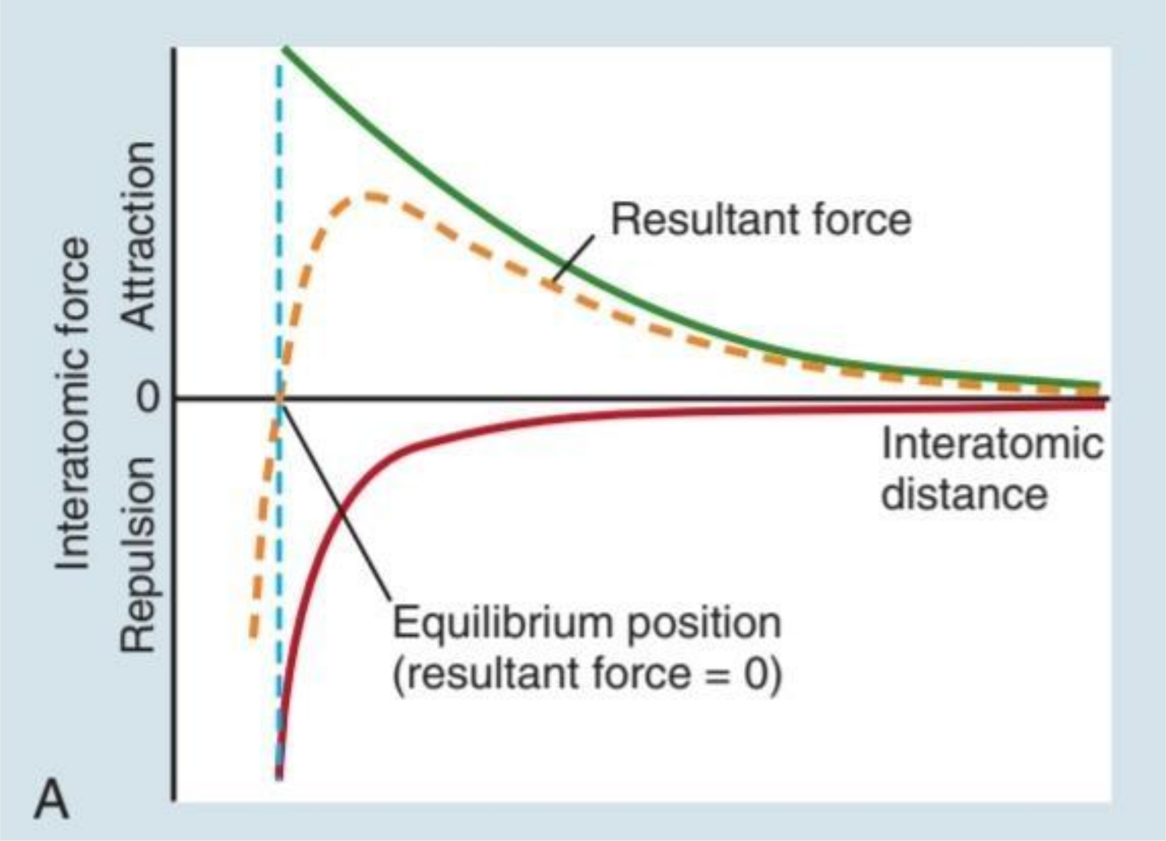

Temp > Tg
Increased molecule mobility
Fluid characteristics

Temp<Tg
Loses liquid characteristics
Set material (amorphous)

Tg- glass transition temperature

INTERATOMIC BOND DISTANCE

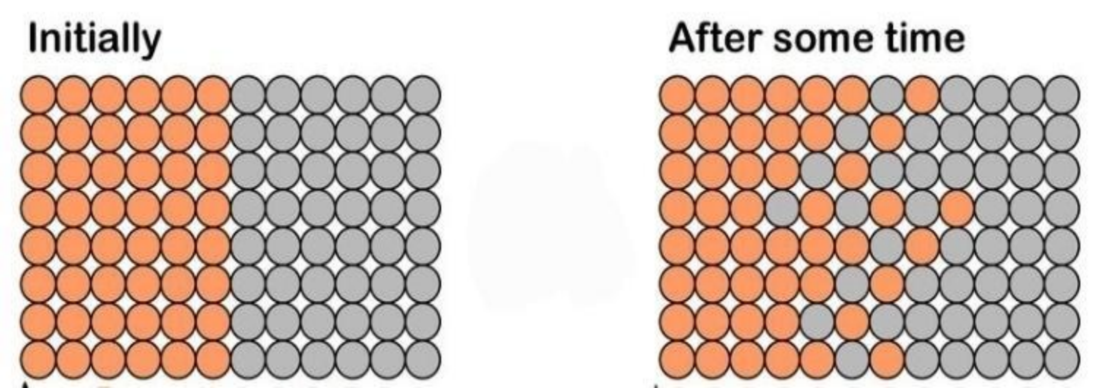
- Between any two atoms, there are forces of **attraction** drawing them together and forces of **repulsion** pushing them apart.
- The force of repulsion increases much more than the force of attraction as the atoms get closer.
- The balance between these two forces is essentially attractive when the two atoms are far apart, and becomes repulsive only when the atoms are much closer.



DIFFUSION

- Diffusion occurs not just in liquids but in solids as well – albeit at a much slower rate.
- Diffusion occurs as a consequence of atoms in a structure trying to achieve a state of equilibrium.
- Factors that influence diffusion are

1. Heat
2. Vibrations of individuals atoms vs Bond strength
3. Imperfections (vacancies) in lattice

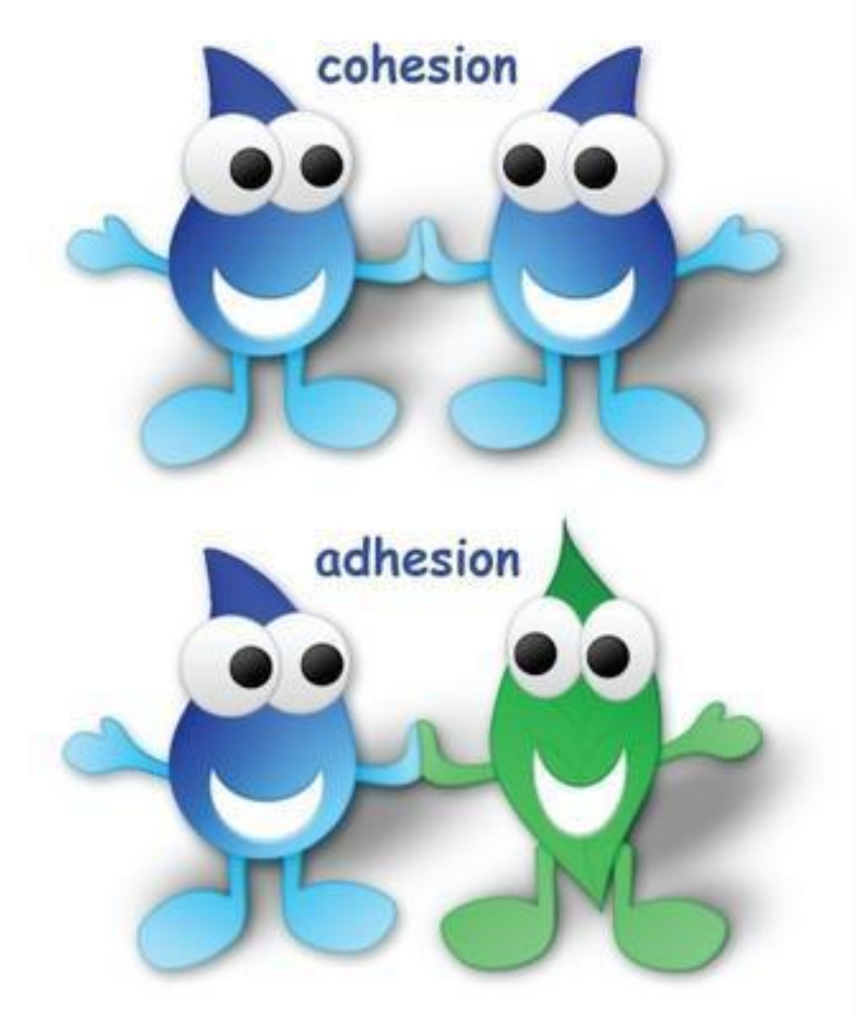


ADHESION & BONDING

- When the molecules of one substrate adhere or are attracted to molecules of the other substrate, the force of attraction is called **adhesion** when unlike molecules are attracted

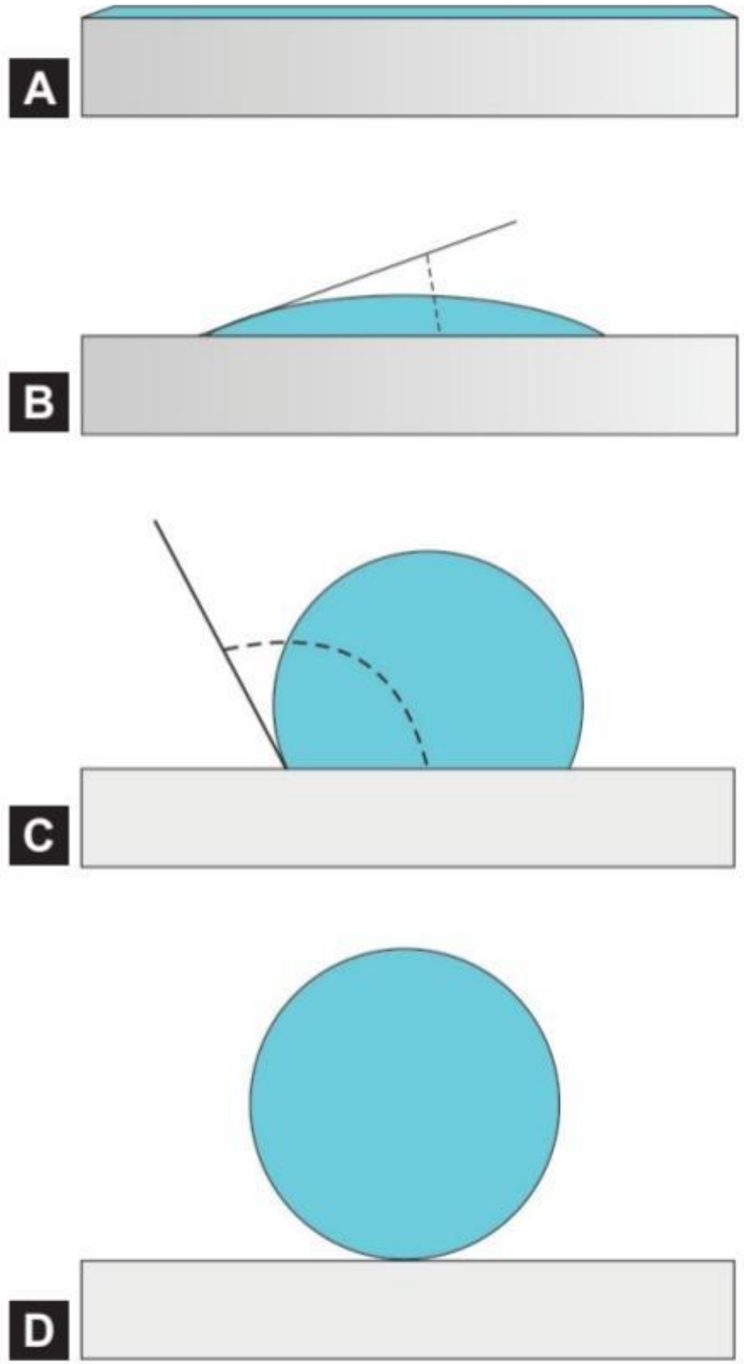
- **Cohesion** occurs when the molecules involved are of the same kind.

- The material that is used to cause bonding is known as the **adhesive** and the material to which it is applied is called the **adherend**.



WETTING

- To produce adhesion in this manned the liquid must flow easily over the entire surface and adhere to the solid. This characteristic is referred to as **wetting**.
- The degree of wetting is indicated by the contact angle of the adhesive to the adherend.
- A fluid that will flow into irregularities and thus provide contact over a great part of the surface of the solid. For example, when two glass plates are placed one on top of the other, they do not usually adhere. However, if a film of water is placed in between them, it becomes difficult to separate the two plates.



The **contact angle** is the angle formed by the adhesive (e.g. water) and the adherend (e.g. glass) at their interface. The extent to which an adhesive will wet the surface of an adherend may be determined by measuring the contact angle between the adhesive and the adherend.

A- Perfect Wetting (The contact angle is 0 degrees)

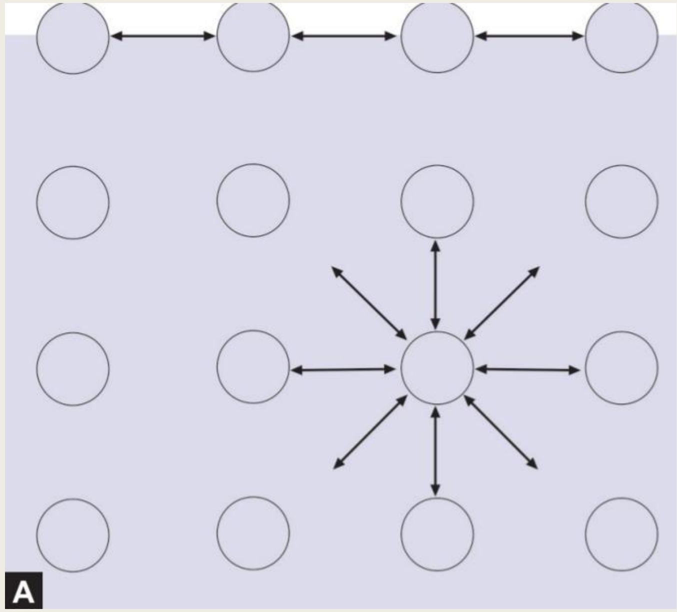
B- High Wettability (The contact angle is << 90)

C- Low wettability (The contact angle is 90<<180)

D- Perfect Non Wetting (The contact angle is 180 degrees)

SURFACE TENSION

- Surface tension is defined as a measurement of the cohesive energy present at an interface; in the case of a liquid, it is the liquid/air interface. This energy is the result of molecules on the surface of a liquid experiencing an imbalance of attraction between molecules.



MECHANICAL PROPERTIES

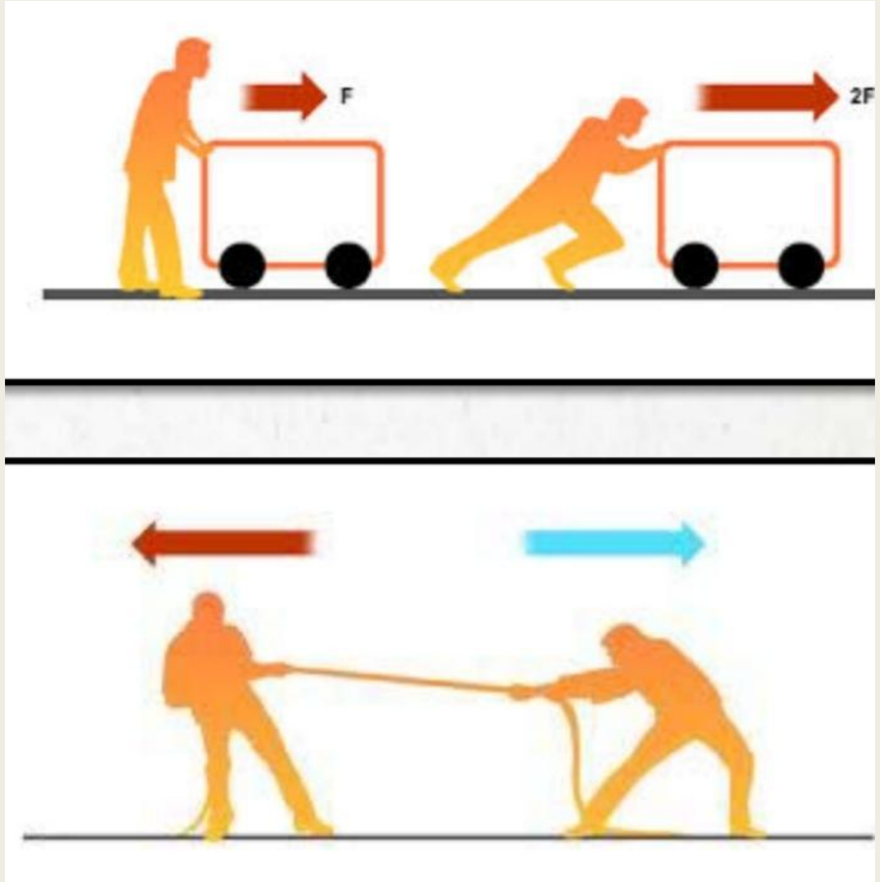
FORCE

- In physics, a force is any influence that causes an object to undergo a certain change, either concerning its movement, direction, or geometrical construction

- A force is defined by 3 characteristics:

1. Point of application
2. Magnitude
3. Direction of application

- The SI unit of force is Newton (N).



OCCLUSAL FORCES

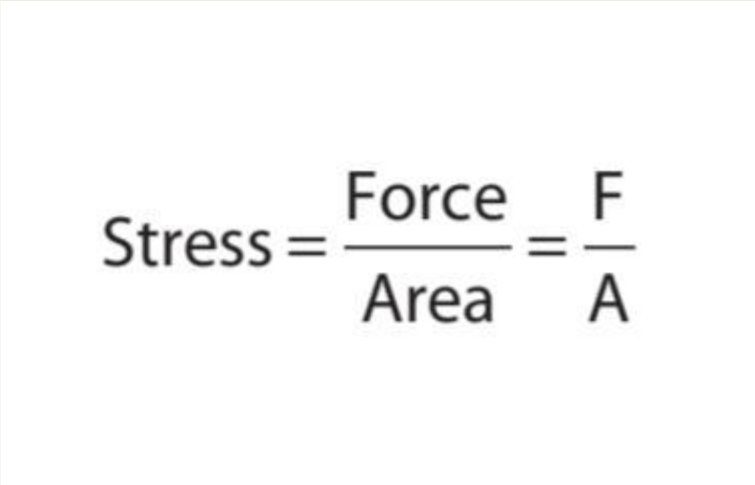
- Max. occlusal forces: 200 – 3500N
- Occlusal forces between adult teeth are highest in the posterior region and decrease from the molar to the incisors.
- Forces on first and second molars vary from 400 to 800N.
- Average on bicuspids, cuspids and incisors is about 300, 200 and 150N.
- Increase in force from 235 – 494N in growing children with an average yearly increase of about 22N.

STRESS

- When a force acts on the body, tending to produce deformation, a resistance is developed within the body to this external force. The internal resistance of the body to the external force is called stress.

- Stress is equal and opposite in direction to the force (external) applied. This external force is also known as load.

- The stress in a structure is designated as a force per unit area.



$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

Megapascal (Mpa)

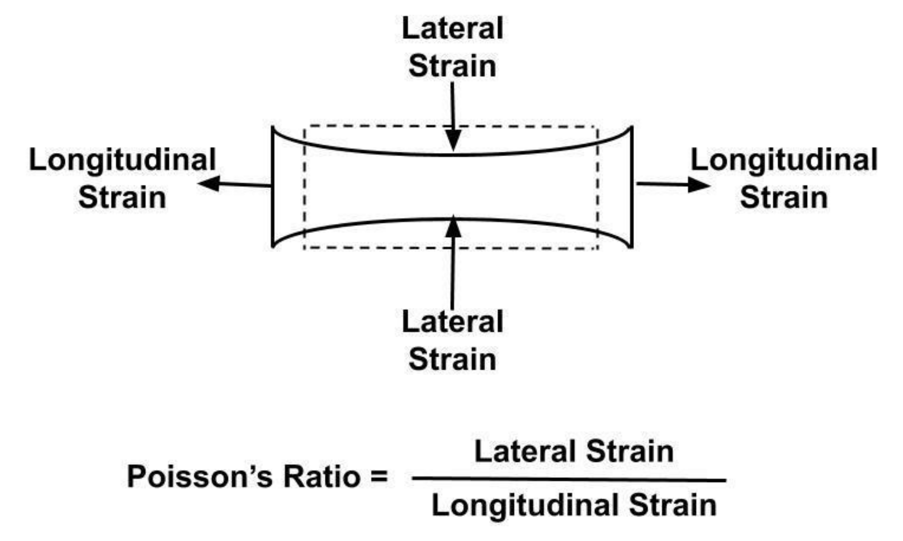
- STRESS
  - Tensile
  - Compressive
  - Shear

STRAIN

- If the stress (internal resistance) produced is not sufficient to withstand the external force (load) the body undergoes a change in shape (deformation).
- Strain is expressed as change in length per unit length of the body when a stress is applied.
- It is a dimensionless quantity and may be elastic or plastic or a combination ofthe two.

$$\text{Strain} = \frac{\text{Deformation or change in length}}{\text{Original length}} = \frac{E}{L}$$

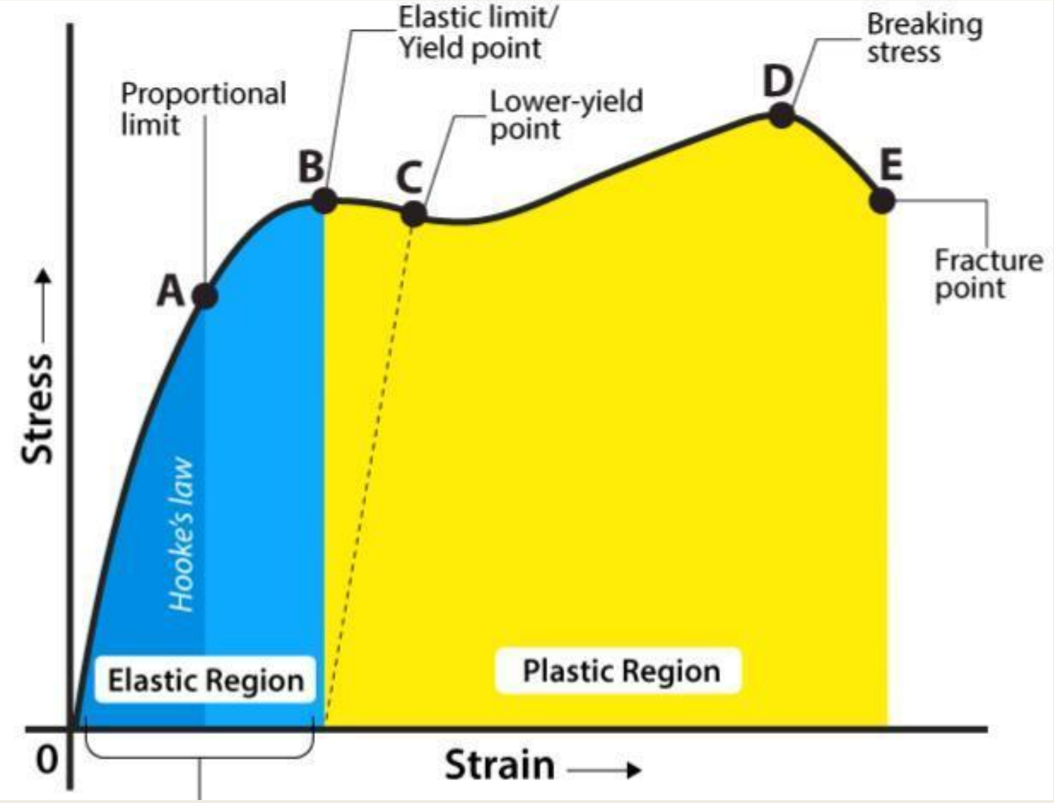
- It is difficult to induce just a single type of stress in a body. Whenever force is applied over a body, complex or multiple stresses are produced. These may be a combination of tensile, shear or compressive stresses. These multiple stresses are called **complex stresses**.



- If we take a cylinder and subject it to a tensile stress or compressive stress, there is simultaneous axial and lateral strain. Within the elastic range, the ratio of the lateral to the axial strain is called **Poisson's ratio**.

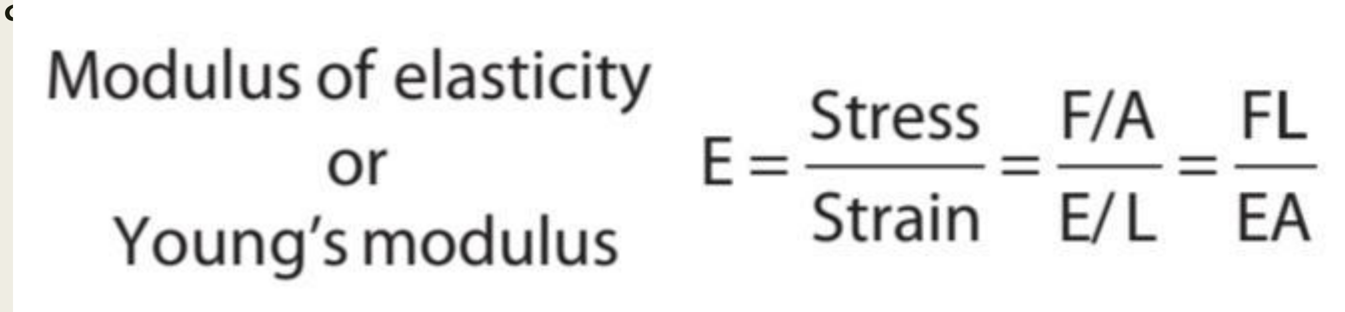
STRESS STRAIN CURVE

- If each stress is plotted on a vertical coordinate and the corresponding strain is plotted on the horizontal coordinate, a curve is obtained. This is known as stress-strain curve.
- The stress-strain curve is a straight line up to point 'P'. The point 'P ' is the proportional limit, i.e., up to point 'P ' the stress is proportional to strain (Hooke's Law).
- Thus proportional stress can be defined as the greatest stress that may be produced in a material such that the stress is directly proportional to strain.



YOUNG’S MODULUS

- It is also referred to as 'elastic modulus’ or 'Young's modulus’ it represents the relative stiffness or rigidity of the material within the elastic range.
- Young's modulus is the ratio of stress to strain. Since stress is proportional to strain (up to the proportional limit), the stress to strain ratio would be constant.
- Therefore, follows that the less the strain for a given stress, the greater will be the stiffness. Such a material would possess a comparatively high modulus ofelasticity.



Modulus of elasticity
or
Young’s modulus

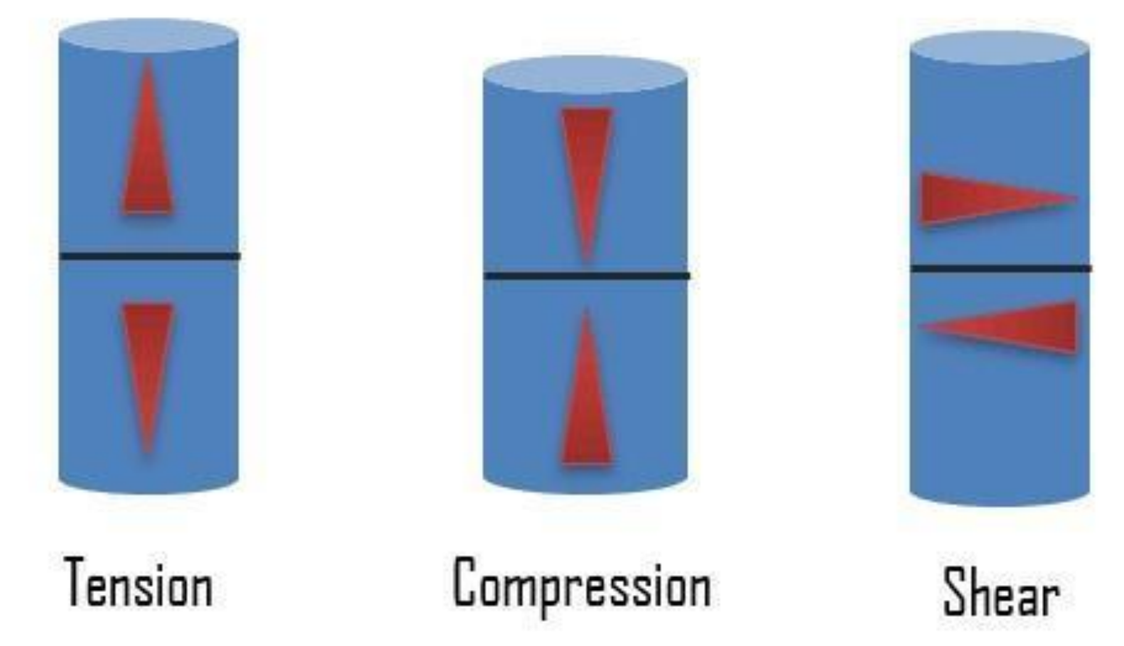
$$E = \frac{\text{Stress}}{\text{Strain}} = \frac{F/A}{E/L} = \frac{FL}{EA}$$

STRENGTH

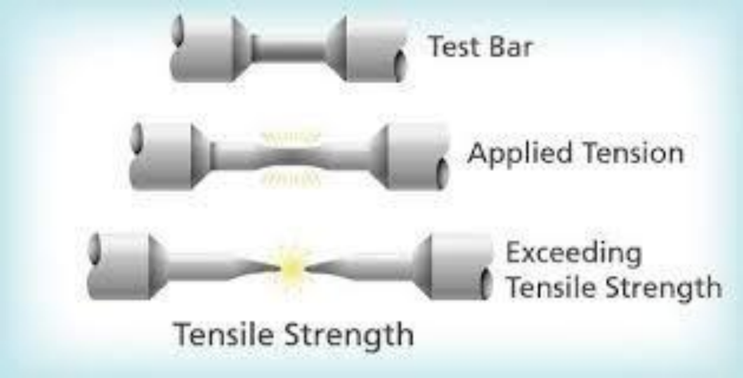
- Strength of a material is its resistance to fracture. It is measured by measuring the maximal stress required to fracture a structure.

- The three types of strength are

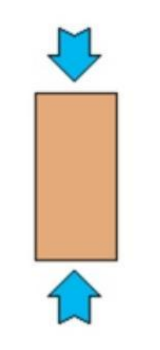
1. Tensile strength
2. Compressive strength
3. Shear strength



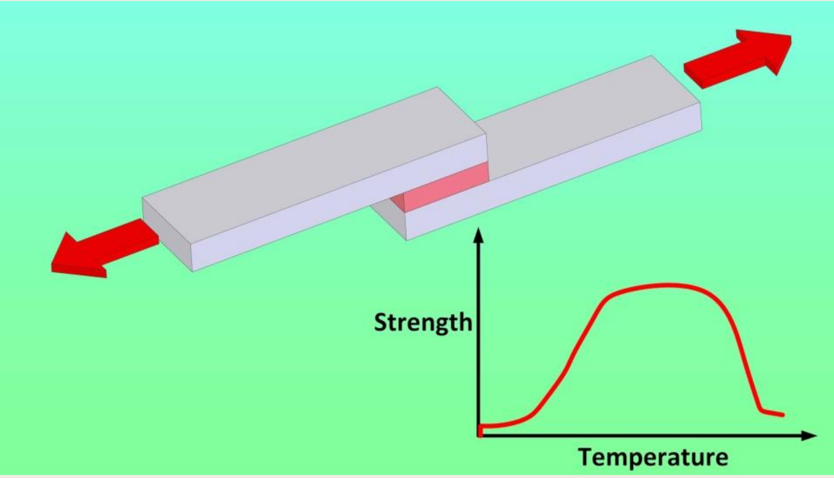
- Tensile strength is determined by subjecting a rod, wire or dumbbell shaped specimen to a tensile loading (a unilateral tension test).Tensile strength is defined as the maximal stress the structure will withstand before rupture.



- Compressive strength or 'crushing strength ' is determined by subjecting a cylindrical specimen to a compressive load.The strength value is obtained from the cross-sectional area and force applied.



- Shear strength is the maximum stress that a material can withstand before failure in a shear mode of loading. It is tested using the punch or pushout method.



STRESS CONCENTRATION

- A stress concentration is a location in an object where stress is concentrated. Causes of stress concentration.

- Knowledge ofthe causes and effects of stress concentration is important in dental restorations to prevent early failure.

- Stress concentrations occur due to

1. Structural defects
2. Improper design

- **Structural defects** - An object is strongest when force is evenly distributed over its area, so a reduction in area, e.g. caused by a crack, results in a localized increase in stress. A material can fail, via a propagating crack, when a concentrated stress exceeds the material's theoretical cohesive strength.The real fracture strength of a material is always lowerthan the theoretical value because most materials contain small cracks or contaminants (especially foreign particles) that concentrate stress.

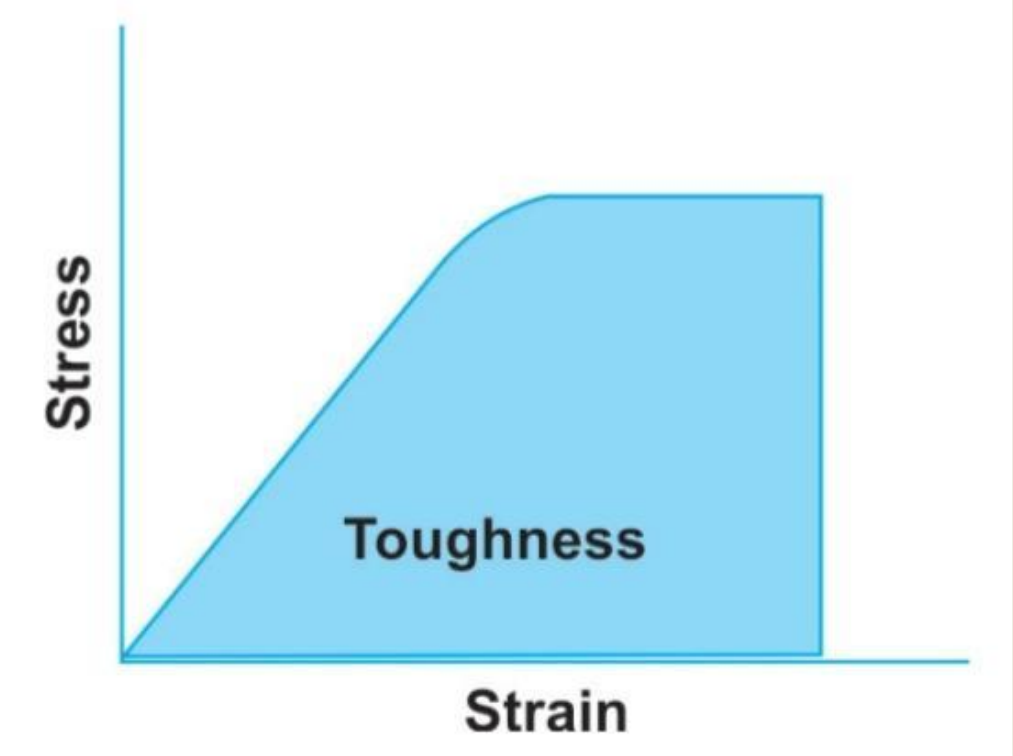
- **Design defects -** A structure should be designed in such a way that stress is evenly distributed. An example of a stress concentration design is a narrow post with supporting a large core. The weakest point of this structure is at the junction of the post and core. When occlusal forces are applied stress concentration at this point can lead to a fracture. Slight alteration of design can reduce stress concentration. In this case increasing the diameter ofthe post and increasing the bulk of the metal at the junction of the post to the core so that the transition is gradual rather than abrupt.

FATIGUE

- A structure subjected to repeated or cyclic stresses below its proportional limit can produce abrupt failure of the structure. This type of failure is called fatigue.
- Fatigue behavior is determined by subjecting a material to a cycles of a known value and determining the number of cycles that are required to produce failure.
- The stresses used in fatigue testing are usually very low. However) the repeated application causes failure.
- Restorations in the mouth are often subjected to cyclic forces of mastication. In order to last, these

TOUGHNESS

- It is defined as the energy required to fracture a material.
- It is a property of the material which describes how difficult the material would be to break.
- Toughness is also measured as the total area under the stress-strain curve.

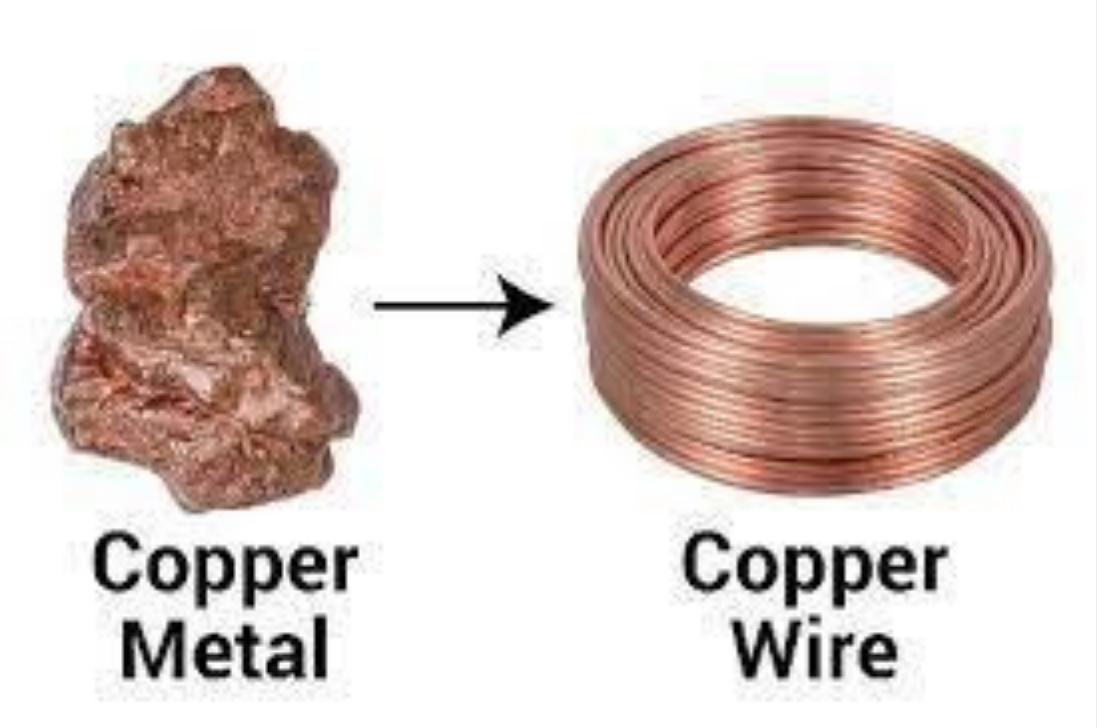


BRITTLENESS

- A brittle material fractures at or near its proportional limit.
- Brittleness is the opposite of toughness
- It is wrong to assume a brittle material does not have strength.

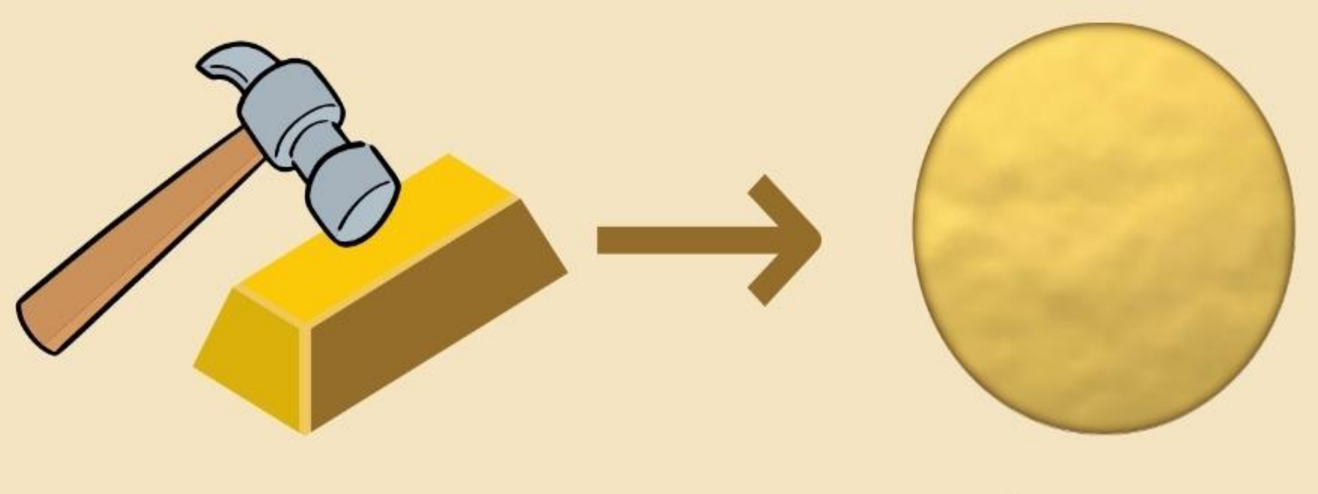
DUCTILITY

- It is the ability of a material to withstand permanent deformation under a tensile load without rupture.
- A metal that can be drawn readily into a wire is said to be ductile.
- Ductility is dependent on tensile strength.
- Ductility decreases as the temperature raised.



MALLEABILITY

- It is the ability of the material to withstand rupture under compression, as in hammering ans rolling into a sheet.
- It is not dependent on strength as is ductility.
- Malleability increases with rise in temperature.

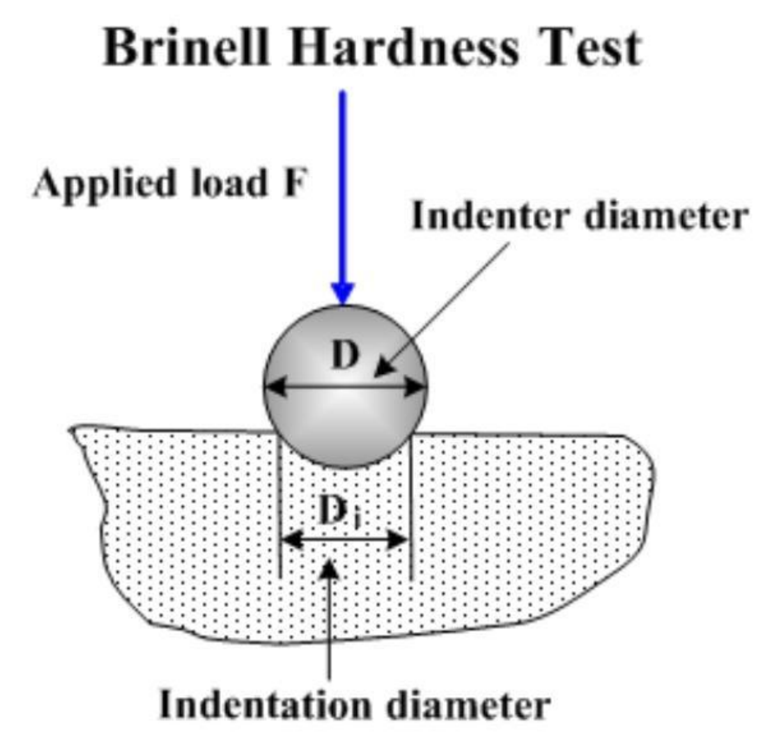


Gold is the most malleable metal.

HARDNESS

- Hardness is difficult to define specifically.
- In mineralogy the hardness is described as the ability of a material to resist scratching whereas in metallurgy and in most other fields, the resistance to indentation is taken as the measure of hardness.
- There are many surface hardness tests used to test materials

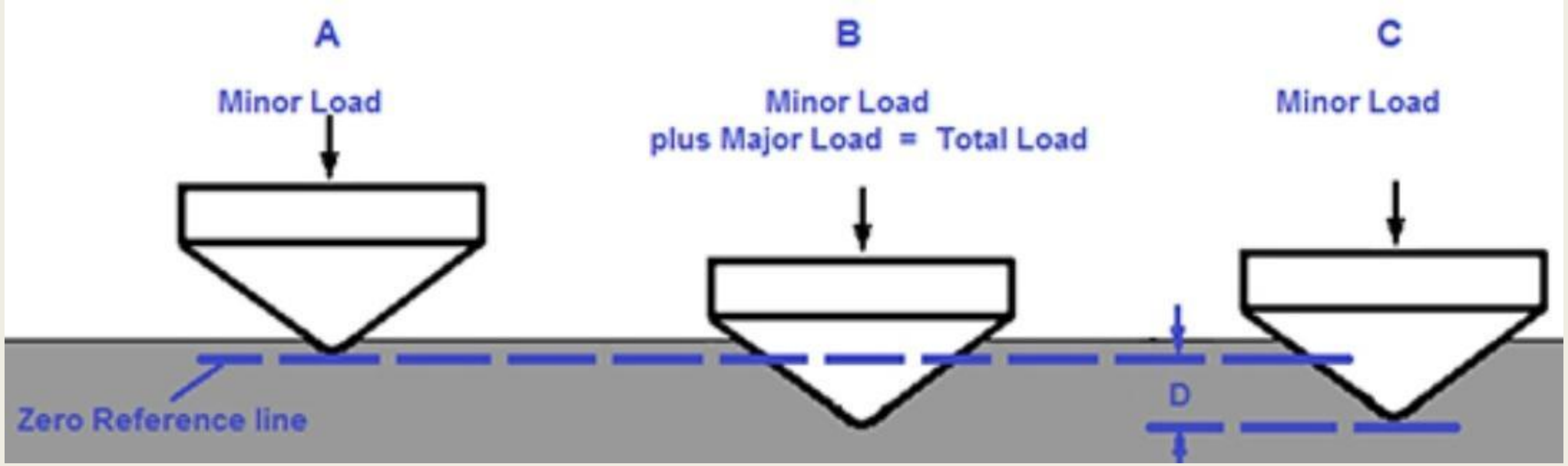
- The **Brinell test** utilizes a 10 mm diameter steel ball as an indenter, applying a uniform 3000 kgf (29 kN) force
- The diameter of the indentation left in the test material is measured with a low powered microscope. The load is divided by the area of the surface of the indentation and the quotient is referred to as Brinell Hardness Number (BHN).
- Used for measuring hardness of metals and metallic materials.



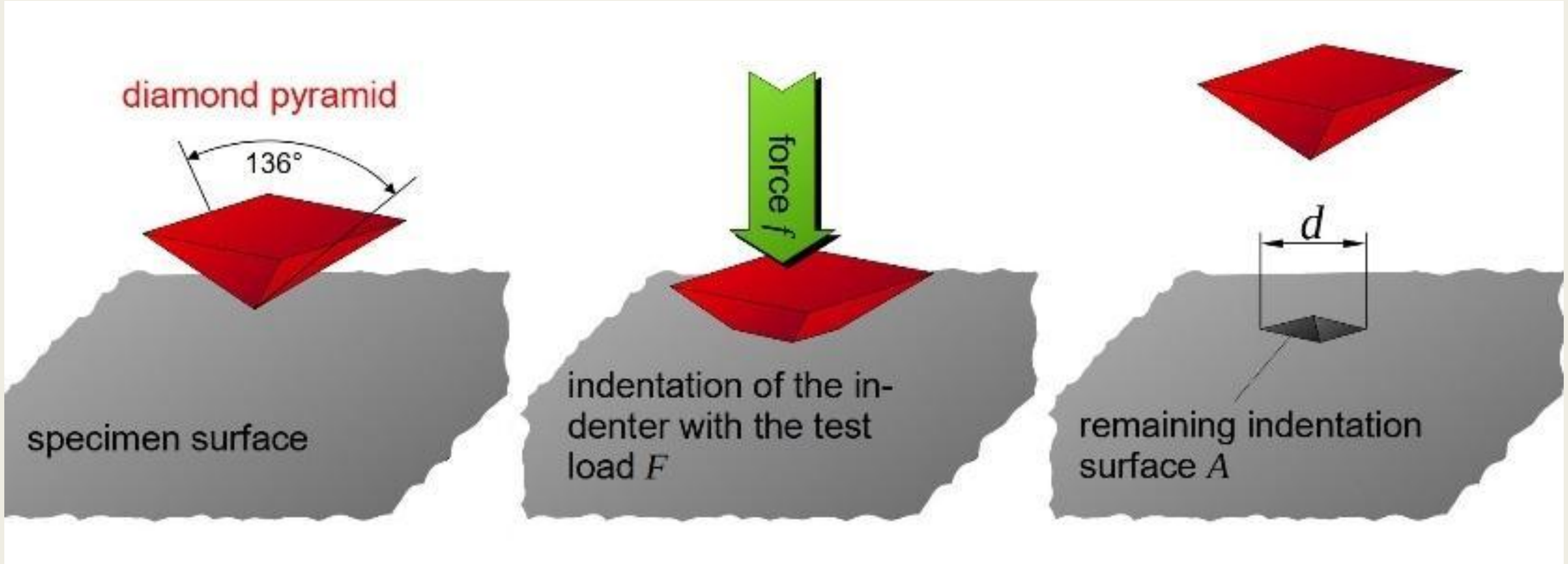
- In the Rockwell Hardness test, like the BH test, a steel ball or a conical diamond point is used. However, instead of measuring the diameter of the impression, the depth is measured directly by a dial gauge on the instrument.

- The Rockwell test has a wider application for materials, since Brinell test is unsuitable for brittle materials as well as plastic materials.

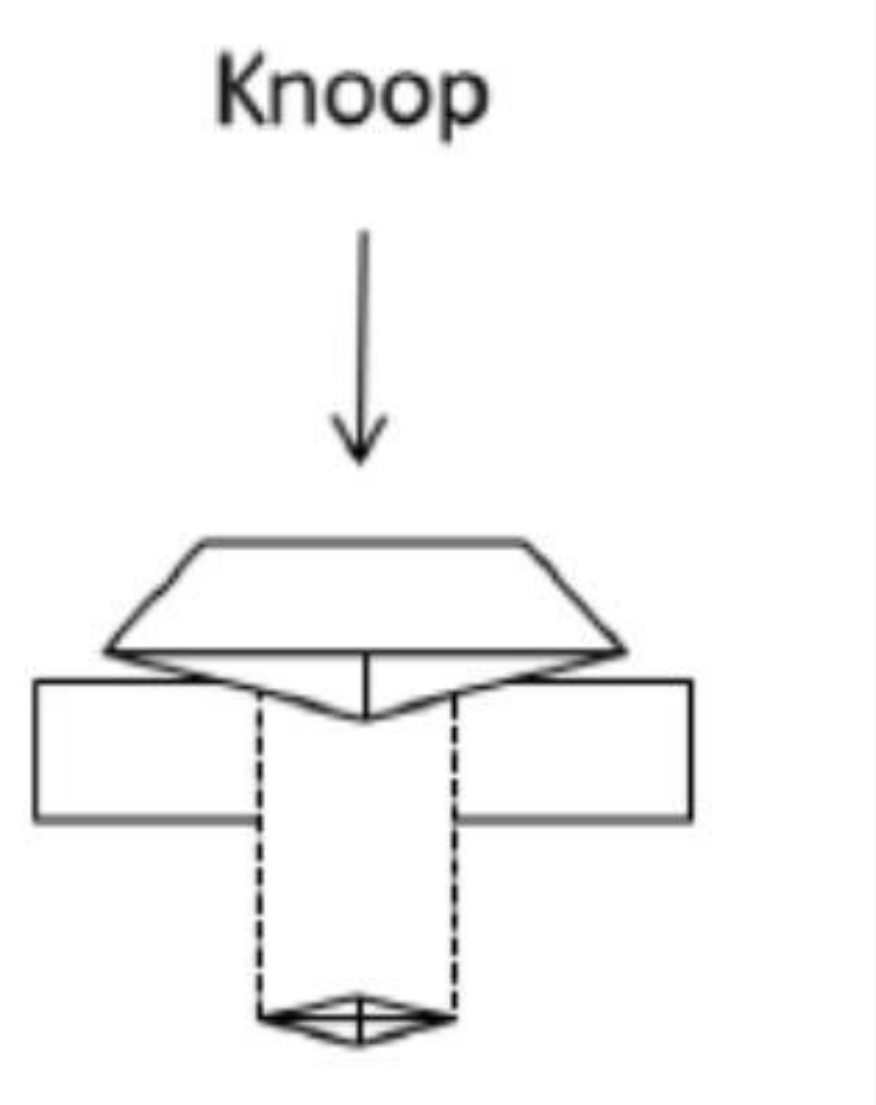
- Represented by Rockwell Hardness Number (RHN)

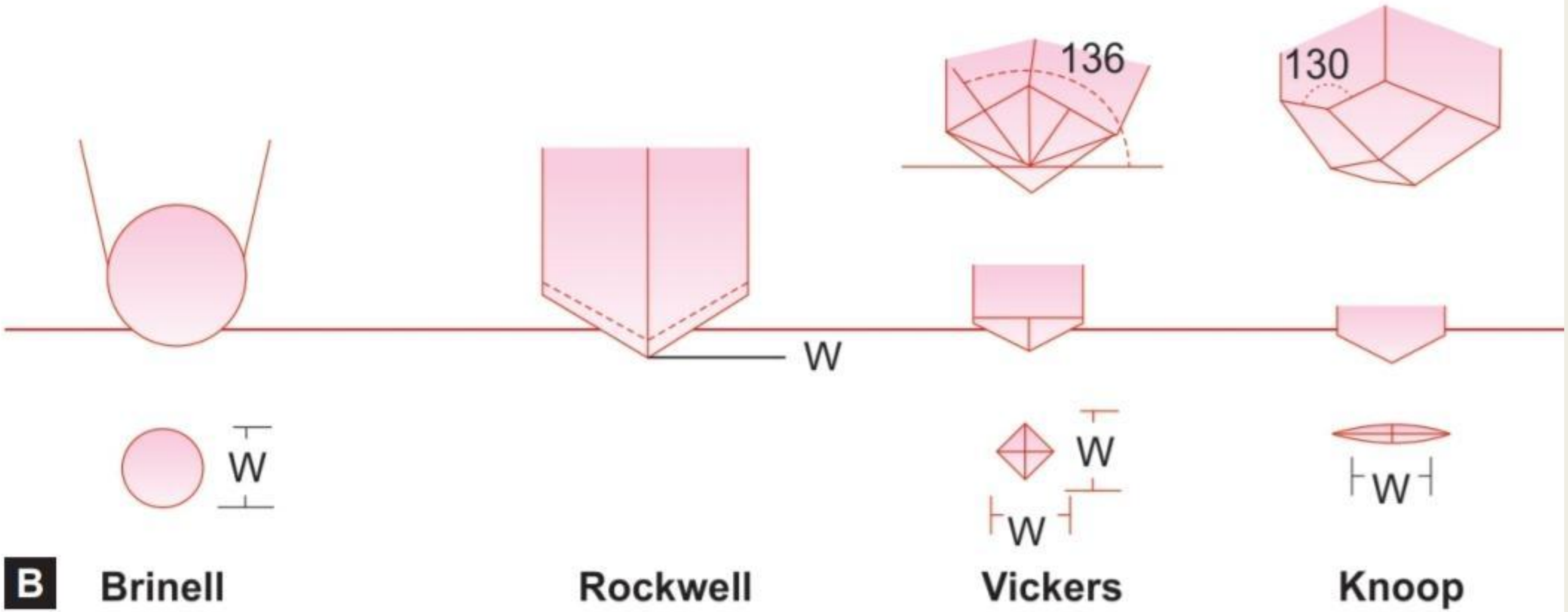


- **Vickers test** is also similar to the Brinell test, however, instead of a steel ball, a diamond in the shape of a square pyramid is used. The impression is square instead of round.
- The load is divided by the area of indentation. The length of the diagonals of the indentation (sides of the diamond) are measured and averaged.
- Vickers test is used in the ADA for dental casting golds. This test is suitable for brittle materials and so is used for measuring hardness of tooth structure.



- A diamond indenting tool is used of a different shape from that of Vickers.
- The indentation is more narrower and elongated.
- Knoop hardness value is independent of the ductility of the material and values for both exceedingly hard and soft materials can be obtained from this test



136
130
W
W
W
W
W
B
Brinell
Rockwell
Vickers
Knoop

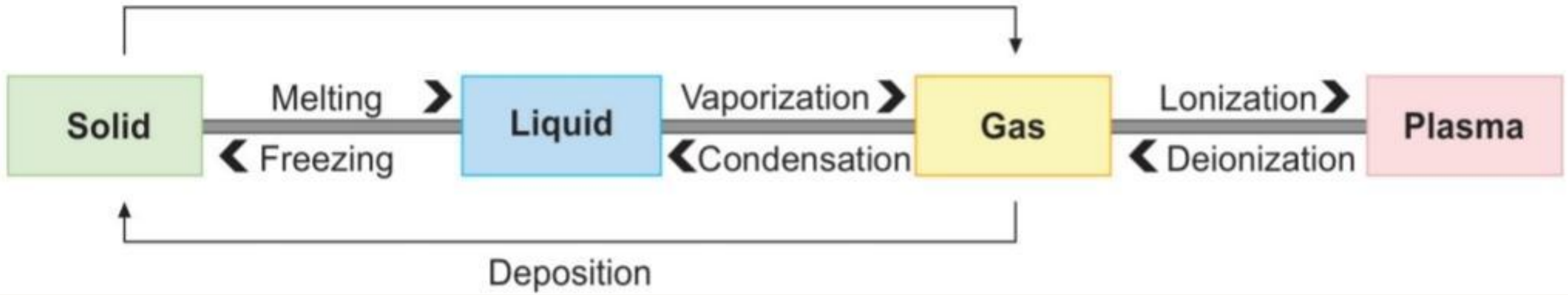
FLEXIBILITY

- Defined as the flexural strain that occurs when the material is stressed to its proportional limit.
- Materials used to fabricate dental appliances and restorations, a high value for the elastic limit is a necessary requirement. This is because the structure is expected to return to its original shape after it has been stressed and the force removed.
- Maximum flexibility - flexural strain that occurs when the material is stressed to its proportional limit

RESILIENCY

- It is the amount of energy per unit volume that is sustained on loading and released upon unloading of a test specimen.
- Term resilience is associated with springiness of a material but it means precisely the amount of energy absorbed within a unitvolume of a structure when it is stressed to its proportional limit.

PHYSICAL PROPERTIES



Solid

Melting

Freezing

Liquid

Vaporization

Condensation

Gas

Lonization

Deionization

Plasma

Deposition

MELTING AND BOILING POINT

- The **melting point** (or liquefaction point) of a solid is the temperature at which it changes state from solid to liquid at atmospheric pressure. At the melting point the solid and liquid phase exist in equilibrium.

- The **boiling point** of a substance is the temperature at which the vapor pressure of the liquid equals the pressure surrounding the liquid and the liquid changes into a vapor. The boiling point of a liquid varies depending upon the surrounding environmental pressure.

DENSITY

- The density, or more precisely, the volumetric mass density, of a substance is its mass per unit volume.
- The symbol most often used for density is ρ (the lower case Greek letter rho)
- The density of a material varies with temperature and pressure.
- Increasing the pressure on an object decreases the volume of the object and thus increases its density. Increasing the temperature of a substance decreases its density by increasing its volume.

$$\rho = \frac{m}{V}$$

GLASS TRANSITION TEMPERATURE

- The glass transition temperature (Tg) is the temperature at which an amorphous solid becomes soft upon heating or brittle upon cooling
- It is the temperature region where a polymer transitions from a hard,glassy material to a soft and rubbery state
- Tg gives us information about how a material behaves under ambient conditions, for eg, If a polymer’s glass transition temperature is well above ambient room temperature, the material behaves like a brittle glassy polymer. Conversely if it is well below the room temperature it is rubbery and is soft and can be elongated.

SOLUBILITY

- Solubility is the property of a solid, liquid, or gaseous chemical substance called solute to dissolve in a solid, liquid, or gaseous solvent to form a homogeneous solution of the solute in the solvent.
- Restorations placed in the oral cavity require to be insoluble in oral fluids. The tendency of cements to dissolve in the oral fluids can lead to marginal ditching, microleakage, recurrent caries, and ultimately failure of the restoration.

ELECTROCHEMICAL PROPERTIES

TARNISH

- Tarnish is a surface discoloration on a metal or even a slight loss or alteration of the surface finish or lustre.

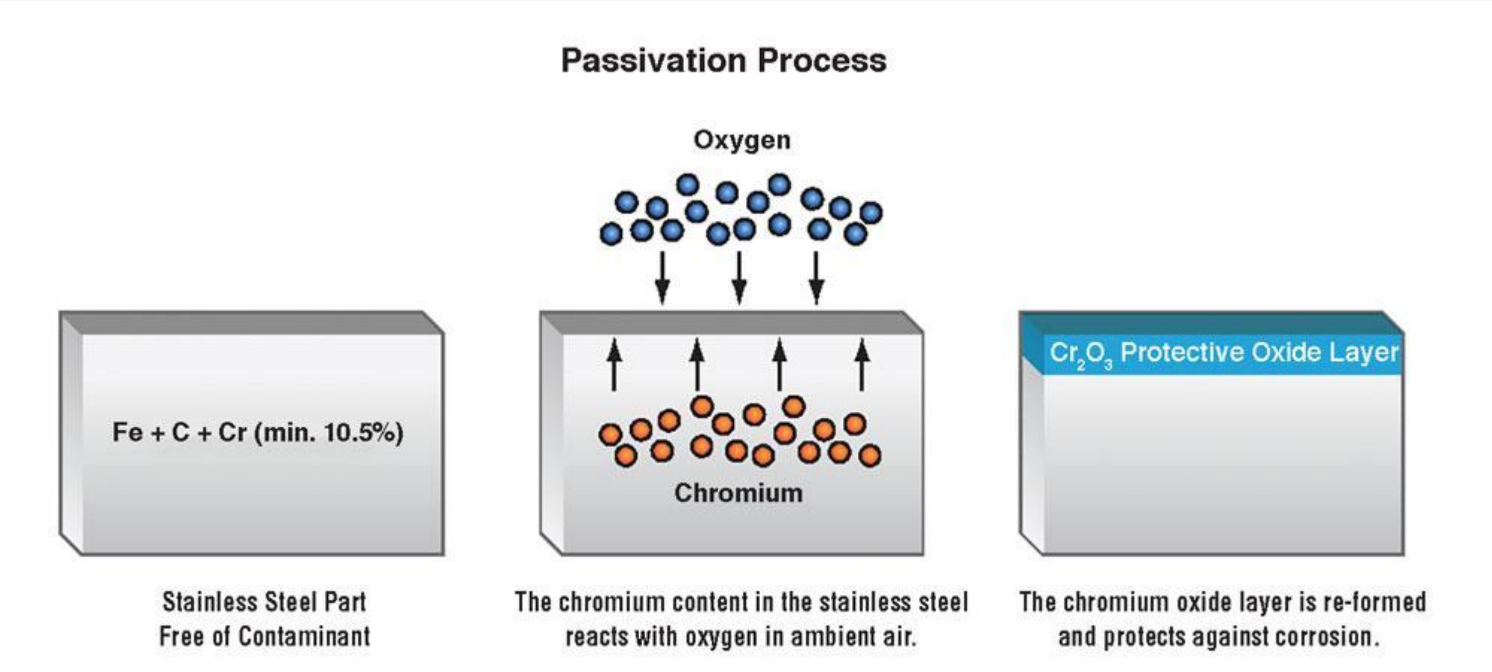
- Tarnish generally occurs in the oral cavity due to,

1. Formation of hard and soft deposits on the surface of the restoration, e.g. calculus, mucin and plaque.
2. Pigment producing bacteria, produce stains.
3. Formation of thin films of oxides, sulfides or chlorides.

- Tarnish is often the forerunner of corrosion.

PASSIVATION

- In certain cases, the oxide film can also be protective in nature. For example, chromium alloys (used in dental castings) are protected from corrosion by the formation of an oxide layer on its surface which protects the metal against any further corrosion. This is known as passivation.
- Another example is titanium



CORROSION

- It is not a surface discoloration but actual deterioration of a metal by reaction with the environment. It can be defined as the deterioration of metals by chemical interaction with their environment.

- Corrosion is a natural process, which converts refine metal to their more stable forms.

- In the most common use of the word, this means electrochemical oxidation of metal in reaction with a oxidant such as oxygen.

- However elements other than oxygen also can cause corrosion particularly in the oral environment. Water, oxygen, chloride ions, sulfides like hydrogen sulfide or ammonium sulfide contribute to corrosion attack in the oral cavity

- Corrosion degrades the useful properties of materials and structures including strength and appearance. In due course, it may lead to rapid mechanical failure of the structure.

- Corrosion
  - Chemical/dry

  - Electrolytic/Electrochemical/Wet

- **Chemical or Dry Corrosion**

The metal reacts to form oxides and sulfides in the absence of electrolytes.

For example, formation of Silver Sulfides in dental alloys containing silver.

Oxidation of alloy particles in dental amalgam.

- **Electrochemical or Wet Corrosion**

This requires the presence of water or other fluid electrolytes. There is formation of free

electrons and the electrolyte provides the pathway for the transport of electrons.

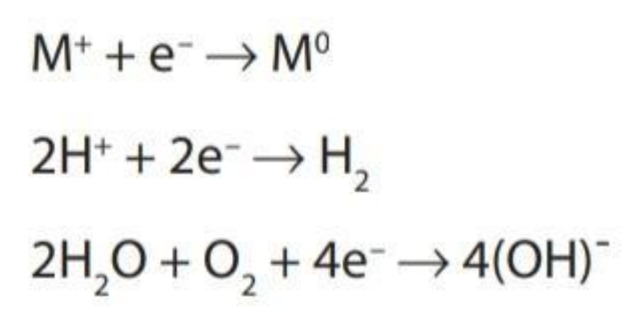
e anode generates free electrons. This reaction is called an

idization reaction. These electrons and consumed by the

thode which becomes stable leaving the anode surface

free

for corrosion due to loss of electrons (reduction)



$M^+ + e^- \rightarrow M^0$

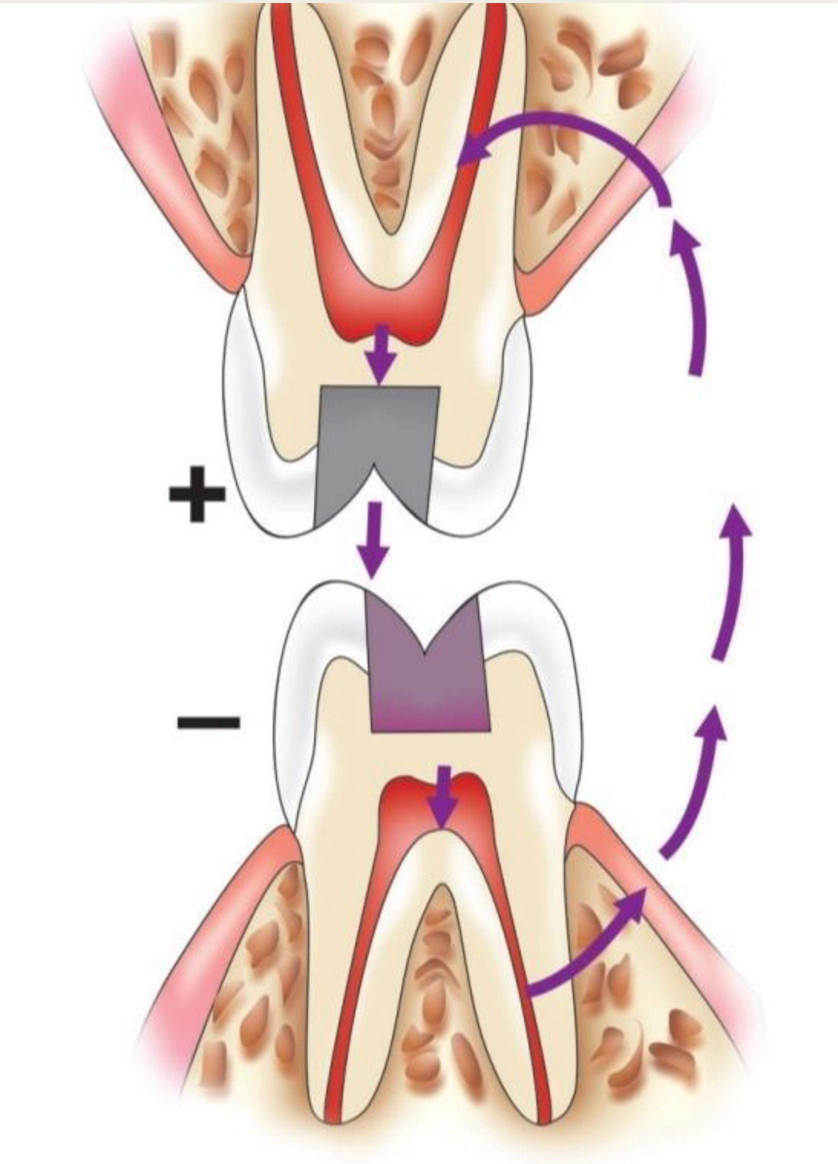
$2H^+ + 2e^- \rightarrow H_2$

$2H_2O + O_2 + 4e^- \rightarrow 4(OH)^-$

- The types of electrolytic corrosion are

1. Galvanic cell corrosion
2. Heterogenous composition corrosion
3. Stress corrosion
4. Concentration cell corrosion / Crevice corrosion

- **Galvanic cell corrosion** occurs when dissimilar metals lie in direct physical contact with each other and saliva due to the presence of various naturally occuring salts acts as an electrolyte.
- If a gold restoration comes in contact with an amalgam restoration, the amalgam forms the anode and starts corroding.
- The electric couple (500 millivolts) created when the two restorations touch, causes sharp pain called ‘galvanic shock’. It usually occursimmediately after insertion and can be minimized by painting a varnish on the surface of the amalgam restoration. However, the best precaution is to avoid dissimilar



- A metal which has been stressed by cold working, becomes more reactive at the site of maximum stress.
- If stressed and unstressed metals are in contact in an electrolyte, the stressed metal will become the anode of a galvanic cell and will corrode. This is known as **STRESS CORROSION**.
- For example, if an orthodontic wire has been cold worked, stress corrosion may occur and cause the wire to break.

- Concentration
- cell corrosion
  - Electrolyte concentration
  - Oxygen concentration

In a metallic restoration which is partly covered by food debris, the composition of the electrolyte under the debris will differ from that of saliva and this can contribute to the corrosion of the restoration.

Differences in oxygen tension in between parts of the same restoration causes corrosion of the restoration. Greater corrosion occurs in the part of the restoration having a lower concentration of oxygen.

PROTECTION AGAINST CORROSION

- Certain metals readily form strong adherent oxide films on their surface which protects them from corrosion. Adding more than 12% Cr to iron or cobalt produces a layer of Cr oxide on the surface of stainless steel or CoCr alloys which is highly corrosion resistant (Passivation)
- Alloys with at least 50 percent of their atoms present as a noble metal (gold, platinum or palladium) show reduced occurrence of corrosion. This is because noble metals have positive EMF with regard to the common reduction reactions found in the oral environment.
- Polishing metallic restorations to a high lustre reduces the chances of corrrosion.
- Avoid dissimiliar metal restorations

Thank you.