## The Minerals:

Mineral is the inorganic substances (natural aggregate ) , it is naturally formed the rock , most rocks are composed of one or a few combinations of minerals(elements), all the minerals have physical , chemical , optical properties and formed by several different sources and are arranged by year , or. Minerals:

- "A mineral is an element or chemical compound that is normally crystalline and that has been formed as a result of geological processes"
- "Minerals are naturally-occurring inorganic substances with a definite and predictable chemical composition and physical properties."
- "A mineral is a naturally occurring homogeneous solid, inorganically formed, with a definite chemical composition and an ordered atomic arrangement"
- "These... minerals ...can be distinguished from one another by individual characteristics that arise directly from the kinds of atoms they contain and the arrangements these atoms make inside them"
- "A mineral is a body produced by the processes of inorganic nature, having usually a definite chemical composition and, if formed under favorable conditions, a certain characteristic atomic structure which is expressed in its crystalline form and other physical properties"
- "Every distinct chemical compound occurring in inorganic nature, having a definite molecular structure or system of crystallization and well-defined physical properties, constitutes a mineral species"

## FormationOfMinerals:

The minerals are formed by deferent ways:

1. Slowly cooling of the magma: the minerals are formed from crystallization from magma, crystallization is the transformation from liquid state to solid state due to cooling process and forming crystal.

2. Precipitation from the solutions : two kind of thermal solutions are formed the minerals, hydrothermal solutions of magma, and hydrothermal solution of water, from these solutions the minerals formed by:
   a. The minerals forms from decrease the temperature and pressure of the solutionby deferent methods according to the heat and depth of solutions:
      (1) Hypothermal Deposits- minerals precipitated with very high heat, from 300 to 500 C°, and very high pressure in highly depth, ex. Molibdenite, Casterite.
      (2) Mesothermal Deposits- minerals precipitated with intermediate heat from 200 to 300 C°, in medium depth ex. Galena, Calcite.
      (3) Epithermal Deposits-- minerals precipitated with low heat and pressure from 50 to 200 C°.
   B. Minerals formfrom evaporation of the Liquid solvent: When evaporation of salty water by very high heat the minerals begin crystallization ex. Calcium carbonate $CaCo_3$, sodium chlorideNacl.
   C. Minerals form from the evaporation of the solvent gas assistant- Groundwater and rain water contain carbonate dioxide , when the water and the gas reaction between each other weakly $H_2CO_3$ is formed , and when it passage on the lime s rocks, the reaction between each other, this reaction create unstable chemical components such as calcium bicarbonate because these components changed to calcium carbonate after evaporation of the carbonate dioxide immediately and forms many shape call (**Stalactite** and **Stalagmite**).
   D. Reaction the solutions with the solid substances: reaction the solutions with some materials and rocks by replacement which call Metasomatism such as saturated solution of silicon dioxide replacement the wood cells of the plants (Petrified Wood).
   E. Reaction the solutions between each other: many solutions reaction between each other to form deferent minerals such as

the reaction between calcium sulphates and bariumcarbonates to form calcium carbonates (Calcite) + barium sulphates (Barite).

F. Life effects on solutions: deferent oceanic plants and animals can extracted the soluble minerals from the solutions to build his hard skeletons , such as corals, and unions.

**3.** From the gases: beneath the surface, deferent gases escape fromhydrothermal solutionswhen it is penetrated through the fissures and fractures of the rocks, this gases reaction between each other to form new minerals such as castirite, and escape the gases from the lava flow when reach the surface of the earth and form deferent minerals , sulpher, halit.

## Classification of the minerals:

The scientists are classified the minerals into two groups depending on chemical composition:silicate minerals and non-silicate minerals, other scientists classify minerals in three groups in which clay minerals represent the third one for its importance.

**1.Silicate Minerals:** These are the main category representing rock formed minerals and subdivided into many groups according to their chemical composition(the ratio of silicon atoms and oxygen si/o), (Table 1).

**Table1**: Silicate minerals groups.

| Group | Silicon(si) | Oxygen (o) | Example |
|---|---|---|---|
| Quartz | 1 | 2 | Quartz |
| Feldspar | 3 | 8 | Orthocalse, Plagioclase |
| Amphibole | 4 | 11 | Hornblende |
| Pyroxene | 1 | 3 | Augite |
| Olivine | 1 | 4 | Olivine |
| Mica | 2 | 5 | Biotite, Muscovite |

**2.Non - silicate Minerals:** These minerals are subdivided into eight groups, Table 2:

**Table 2:** Non-silicate minerals.

| Group | Example |
|---|---|
| Native elements | Sulpher (S) ,Dimond(C), Gold(Au) |
| Oxides | Hematite($Fe_2O_3$),Magnetite($Fe_3O_4$) |
| Carbonates | Dolomite[Ca,Mg($co_3$)2], Calcite($CaCO_3$) |
| Sulphates | Gypsum($CaSO_4 2H_2O$),Anhydrite($CaSO_4$) |
| Slphides | Pyrite($FeS_2$), Galena(PbS) |
| Phosphates | Apatite[Ca,F($PO_4$)] |
| Fluorides | Fluorite($CaF_2$) |
| Chlorides | Halite(NaCl) |

4. **Clay Minerals**: They are hydrous alumina silicates originate as products of the chemical weathering of the other silicate minerals.Clay minerals are also important rock forming minerals since they constitute shales and make up a large percentage of the soil. Because of the importance of soil in agriculture and as a supporting material for buildings and many industries, clay minerals are extremely important for geologists and civil engineers and other specialists.

## Properties of minerals:

**1.Physical properties.**

### 2.chemical properties.

**3.optical properties.**

## Physical properties:

**1.Crystallography:**Many specimen of the minerals formed from crystals (single or cluster of crystals), it develops a regular pattern of faces and angles between the faces, which is characteristic of a particular mineral.

A crystal is defined as a polyhedral from bounded by plane surface (faces) that reflects the orderly internal arrangement of atoms with a specific crystal form and constant angles and ordered in special systems.

Crystals are classified into six systems according to their degree of symmetry and to geometrical relationships of their crystallographic axes (their relative lengths and the angles between them) Figure 5.

**(a)Cubic system**- This crystal is consisted three mutually perpendicular axes and the same equal length , such as galena(pbs),magnetite and halite and fluorite.

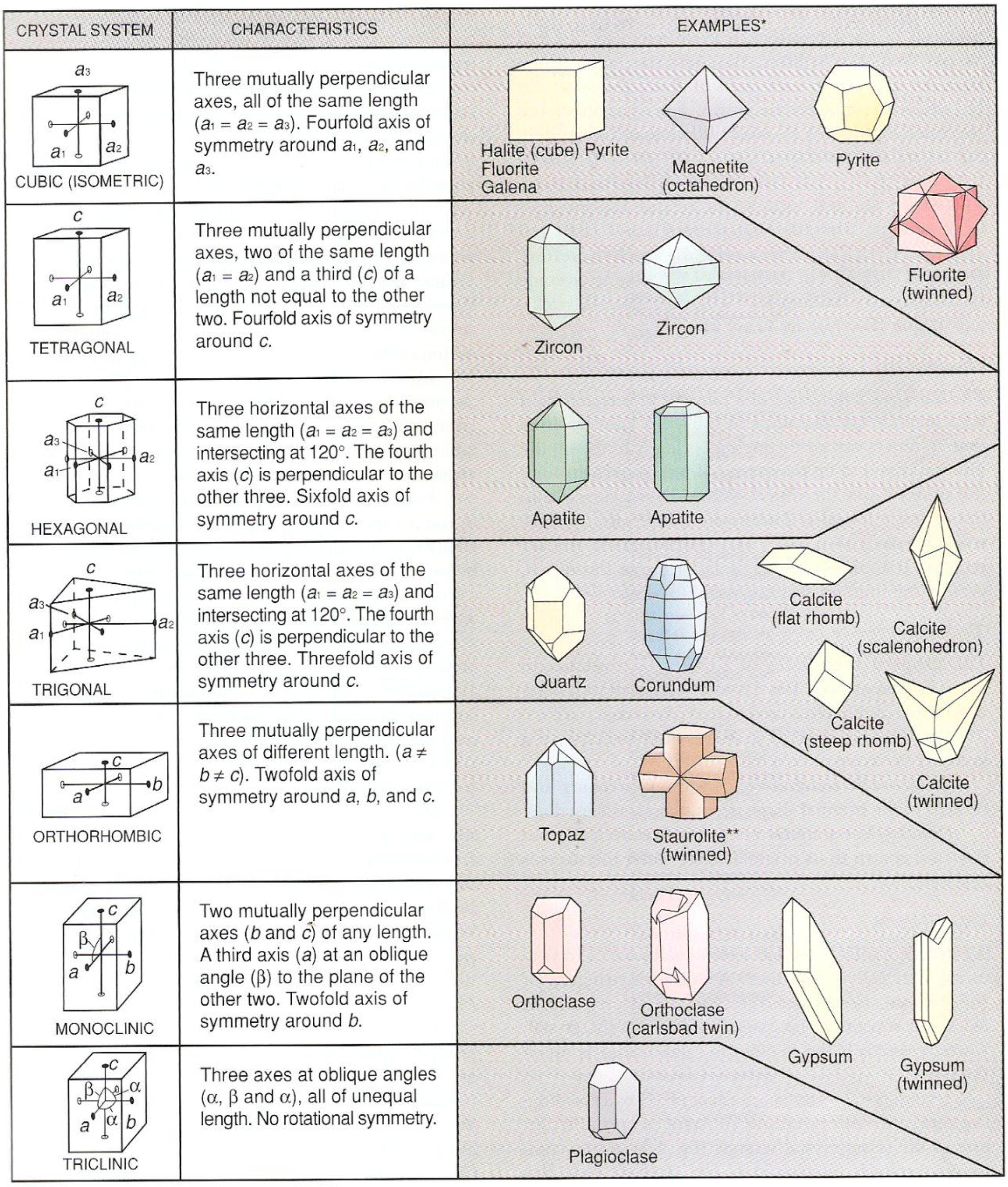
**(b)Tetragonal system** – It consists three mutually perpendicular axes, two of them the same length and the third not equal to them, zircon and cassterite example of this system.

**(c)Hexagonal system** –and Trigonal system - it consists four axes , three horizontal axes of the same length and intersecting at 120 degree, the fourth axis is perpendicular to the other three , the deferent between these two systems by the symmetry , examples of hexagonal system apatite ,examples of trigonalsystem,quartz,calcite,corundum.

**(d)Orthorhombic system –** It consists three mutually perpendicular axes and these axes not the same equal length, such as andalozite, hemomorphite, olivine.

**(e)Monoclinic system –**It consists three unequal axes , two of them perpendicular axes of any length and the third axis is oblique angle to the plane of the other two. Mineral example, azorite,malakite, manganite, gypsum, hornblend, orthoclase.

**(f)Triclinic system –** It consist three axes at deferent length and oblique angles, minerals example, kaolinite, microcline, albite, plagioclase, aligioclase, kinite.



| CRYSTAL SYSTEM | CHARACTERISTICS | EXAMPLES* |
|---|---|---|
| CUBIC (ISOMETRIC) | Three mutually perpendicular axes, all of the same length ($a_1 = a_2 = a_3$). Fourfold axis of symmetry around $a_1$, $a_2$, and $a_3$. | Halite (cube) Pyrite Fluorite Galena; Magnetite (octahedron); Pyrite; Fluorite (twinned) |
| TETRAGONAL | Three mutually perpendicular axes, two of the same length ($a_1 = a_2$) and a third ($c$) of a length not equal to the other two. Fourfold axis of symmetry around $c$. | Zircon; Zircon |
| HEXAGONAL | Three horizontal axes of the same length ($a_1 = a_2 = a_3$) and intersecting at 120°. The fourth axis ($c$) is perpendicular to the other three. Sixfold axis of symmetry around $c$. | Apatite; Apatite |
| TRIGONAL | Three horizontal axes of the same length ($a_1 = a_2 = a_3$) and intersecting at 120°. The fourth axis ($c$) is perpendicular to the other three. Threefold axis of symmetry around $c$. | Quartz; Corundum; Calcite (flat rhomb); Calcite (scalenohedron); Calcite (steep rhomb); Calcite (twinned) |
| ORTHORHOMBIC | Three mutually perpendicular axes of different length. ($a \neq b \neq c$). Twofold axis of symmetry around $a$, $b$, and $c$. | Topaz; Staurolite** (twinned) |
| MONOCLINIC | Two mutually perpendicular axes ($b$ and $c$) of any length. A third axis ($a$) at an oblique angle ($\beta$) to the plane of the other two. Twofold axis of symmetry around $b$. | Orthoclase; Orthoclase (carlsbad twin); Gypsum; Gypsum (twinned) |
| TRICLINIC | Three axes at oblique angles ($\alpha$, $\beta$ and $\alpha$), all of unequal length. No rotational symmetry. | Plagioclase |

**Figure 4: Crystallization systems.**

**2. Color**:Color is the first thing someone notices when they view a mineral. Color is also one of the big reasonsthat attract people to minerals. Generally speaking, color is not a good property to be used in the identification of minerals. It is usually the first property to confuse a novice collector into making anincorrect identification. Many minerals have different colors and some minerals' colors are identical toother minerals' colors**Figure 5**. It is important to understand what causes color in minerals in order to understandthis mineral property.Color in minerals is caused by the absorption, or lack of absorption, of various wavelengths of light.The color of light is determined by its wavelength. When pure white light, that is, containing allwavelengths of visible light, enters a crystal, some of the wavelengths might be absorbed while other wavelengths may be emitted. If this happens then the light that leaves the crystal will no longer bewhite but will have some color.
What absorbs and or emits these wavelengths? Atomic bonds are generally the culprit. Some elementshave electrons that absorb certain wavelengths or colors. These wavelengths provide energy to theelements that will often emit another wavelength to get rid of the extra energy. The energy state of theelectron is related to the wavelength that it absorbs. The bonding in this element affects the energy stateof these electrons. Therefore bonds to different elements produce different colors.Elements that produce colors through absorption and emittance of wavelengths are usually transitionmetals. They can cause a mineral to always be a certain color if they are part of the chemistry of themineral. However, if there is just a trace of these elements, they still can strongly influence the color ofthe mineral. Even tiny amounts of these elements can deeply color minerals.


**Figure 5: Color of minerals.**

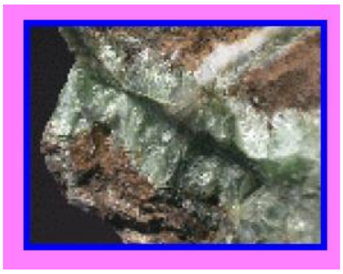
**3.Streak:**Streak is closely related to **color,** but is a different property because the color of the mineral may be different than the colorof the streak. Streak is actually the color of the powder of amineral. It is called streak because the proper way to test forstreak is to rub a mineral across a tile of white unglazed porcelainand to examine the color of the "streak" left behind. It has provento be a powerful property because it is generally very consistentfrom specimen to specimen for a given mineral.Two minerals that have similar outward color may have differentcolors when powdered. For instance, the minerals **hematite** and**galena** can be confused when both have a gray color. However,hematite's streak is blood-red, while galena's streak is lead gray.Hematite (pictured above) is probably the most well knownexample of streak with its completely surprising streak color.

**4.Hardness :** A good property in mineral identification is one that does notvary from specimen to specimen. In terms of reliability, hardnessis one of the better physical properties for minerals. Specimens ofthe same mineral may vary slightly from one to another, butgenerally they are quite consistent. Inconsistencies occur whenthe specimen is impure, poorly crystallized, or actually anaggregate and not an individual crystal.Hardness is one measure of the strength of the structure of themineral relative to the strength of its chemical bonds. It is not thesame as brittleness, which is another measure of strength, that ispurely related to the structure of the mineral. Minerals with smallatoms, packed tightly together with strong covalent bondsthroughout tend to be the hardest minerals. The softest mineralshave metallic bonds or even weaker bonds asimportant components of their structure. Hardness is generallyconsistent because the chemistry of minerals is generallyconsistent.Hardness can be tested through scratching. A scratch on amineral is actually a groove produced by microfractures on thesurface of the mineral. It requires either the breaking of bonds orthe displacement of atoms (as in the metallic bonded minerals). Amineral can only be scratched by a harder substance. A hardmineral can scratch a softer mineral, but a soft mineral can notscratch a harder mineral (no matter how hard you try). Therefore,a relative scale can be established to account for the differencesin hardness simply by seeing which mineral scratches another.That is exactly what French mineralogist Friedrich Mohsproposed almost one hundred and seventy years ago. The **MohsHardness Scale** starting with **talc** at 1 and ending with **diamond**at

10, is universally used around the world as a way ofdistinguishing minerals. Simply put; the higher the number, theharder the mineral.

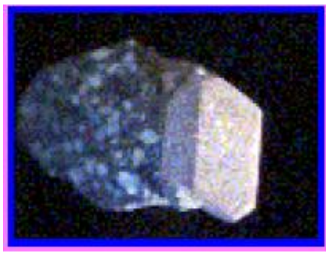
**Table 1 :Moho scale of hardness.**

| Hardness | Minerals |
|---|---|
| 1 | talc |
| 2 | Gypsum |
| 3 | Calcite |
| 4 | Fluorite |
| 5 | Apatite |
| 6 | Orthoclase |
| 7 | Quartz |
| 8 | Topaz |
| 9 | Corundum |
| 10 | Diamond |



1 Talc 2 Gypsum 3Calcite





4Fluorite5Apatite6Othoclase




7Quartz 8Topaz 9Corundum 10 Diamond

**5.Transparencey:** Transparency, also known technically as *diaphaneity*, is a function of the way light interacts with the surface of a substance. There are only three possible interactions. If the light enters and exits the surface of the substance in relatively undisturbed fashion, then the substance is referred to as **transparent**. If the light can enter and exit the surface of the substance, but in a disturbed and distorted fashion, then thesubstance is referred to as **translucent**. If the light can not even penetrate the surface of the substance, then the substance is referred to as **opaque**Figure 6.

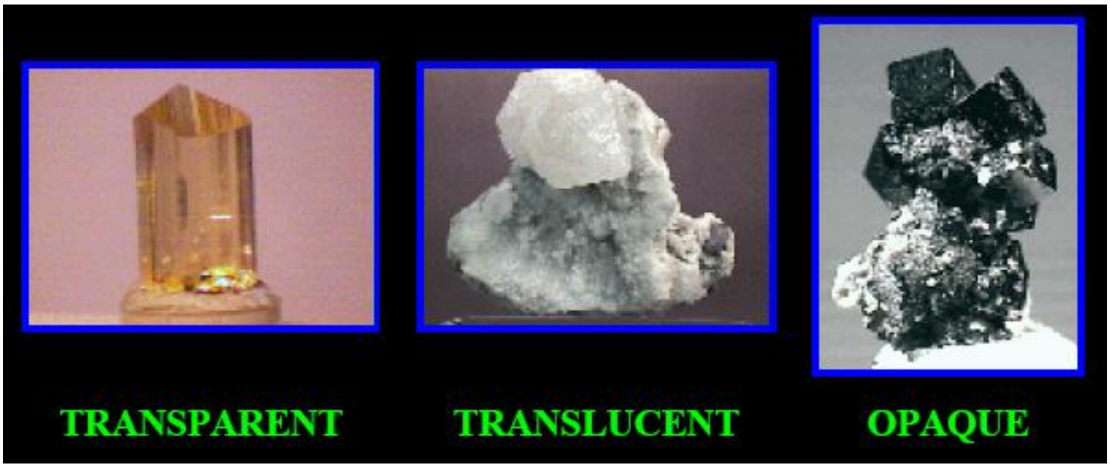
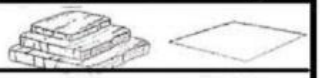
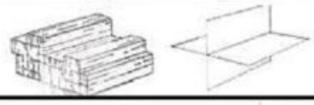
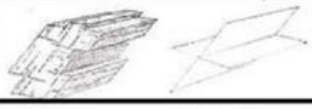
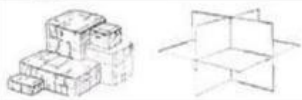
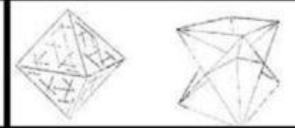
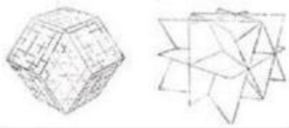
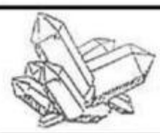



**Figure 6: Transparency of minerals.**

**6.Fracture :**Fracture is a description of the way a mineral tends to break. It is different from **cleavage** and **parting** which are generally clean flat breaks along specific directions. Fracture occurs in all minerals even ones with cleavage, although a lot of cleavage directions can diminish the appearance of fracture surfaces. Different minerals will break in different ways and leave a surface that can be described in a recognizable way. Is the broken area smooth? Irregular? Jagged? Splintery? These are some of the ways of describing fracture.

The most common fracture type is **conchoidal**. This is a smoothly curved fracture that is familiar to people who have examined broken glass. Sometimes described as a clam-shell fracture.**Quartz** has this fracture type and almost all specimens that have been broken, demonstrate this fracture type very well.Another common type is **subconchoidal**. Similar to conchoidal, just not as curved, but still smooth. **Andalusite**can show this type.**Uneven** is a type that is basically self explanatory. It is a common type that is found in **anhydrite**.**Splintery** is a fracture type that occurs in fibrous or finely acicular minerals and in minerals that have a relatively stronger structure in one direction than the other two.
**Chrysotile serpentine** is a typical mineral with splintery fracture and **kyanite**is an example of a non-fibrous mineral that has this fracture.
**Earthy** is a fracture that produces a texture similar tobroken children's clay. It is found in minerals that aregenerally massive and loosely consolidated such as**limonite.**

**7.Cleavage :**When a mineral breaks it does so either by ***fracturing*** or by ***cleaving*.** Crystal cleavage is a smooth break producing what appears to be a flat crystal face. Here are a few rules about cleavage. First cleavage is reproducible, meaning that a crystal can be broken along the same parallel plane over and over again. All cleavage must parallel a possible crystal face. This means that the crystal could have a crystal face parallel to its cleavage, but these faces are not always formed. All cleavage planes of a mineral must match that mineral's **symmetry.** And finally, the same mineral will always, always have the same cleavage. The tendency for minerals to cleave or not and in which directions, is very characteristic and therefore important to the identification of minerals. Cleavage is described in terms of how easy the cleavage is produced. From easiest to hardest to produce the terms are: ***perfect, imperfect, good, distinct, indistinct,*** and ***poor.*** Cleavage is said to be *basal* when it occurs perpendicular to the major axis of the mineral and *prismatic* when it occurs parallel to the major axis. Multiple cleavages that produce geometric polygons are referred to using the name of the geometric polygon, such as ***octahedral*** cleavage in the mineral **fluorite,** ***cubic*** cleavage in the mineral **halite** or ***rhombohedral*** cleavage in **calcite** (pictured). Cleavage occurs in minerals that have specific planes of weakness. These planes or directions are inherent in the structure of the mineral and form from a variety of factors. Cleavage, being related to structure, is important at times in the correct identification of a mineral's **symmetry.** Remember, cleavage must obey the symmetry of the mineral and must be parallel to a possible crystal face. A mineral of the **isometric** symmetry class can either have no cleavage or at least three directions of identical cleavage that form a closed three dimensional polygon. A mineral of a uniaxial class (**trigonal**,**tetragonal** or **hexagonal**) will potentially have a cleavage perpendicular to the dominant axis and/or prismatic cleavage of either 3, 4 or 6 directions respectively, running parallel to the axis. Other cleavage directions are possible, but will always be controlled by the symmetry of the crystal. A biaxial mineral, those belonging to **orthorhombic, monoclinic** or **triclinic** classes, can not have more than two *identical* cleavage directions. The angle between cleavages is also important to note and maybe diagnostic. The **pyroxene** and **amphibole** groups of minerals aredistinguished primarily by cleavage angle with the pyroxenes having a more acute angle. The angle may also help identify the type of cleavage. Three identical directions of cleavage in one mineral can only be either cubic cleavage, rhombic cleavage or prismatic (forming six sided prisms). If the angle between cleavage faces is 90 degrees, then the cleavage is cubic. If the angle is 60 degrees, then the cleavage is prismatic. Also, if the angle is something else and there are *three identical cleavages*,then the cleavage is rhombic. The **phyllosilicates**are a group of minerals whose structure is based upon stacked layers. A natural cleavage plane is produced between these layers. Other minerals may have cleavage planesthat are more related to bond strength. Weak bonds that all lie in a plane will produce a cleavage direction. To identify cleavage in a mineral remember that it is always parallel to a possible crystal face, it is reproducible over and over again and that it may be seen as internal reflection planes. Cleavage can be observed without the specimen being cleaved all the way through as pictured above. Minerals with perfectcleavage will sometimes have a stairstep look around a broken section. **Twinning** may break a minerals cleavage at the twinplane and this should be kept in mind. Knowledge of a mineral'scleavage can be important in determining if a given specimen hasbeen broken or not (a key characteristic in a mineral specimen'svalue). The related property of **parting** is thought by many tojust be an example of poor cleavage. Many minerals lack anycleavage at all and will only show **fractures.**

| Mineral | Direction of Cleavage | Shape of Cleavage |
|---|---|---|
| Mica | One direction |  |
| Gypsum and Feldspar Group | Two perpendcular direction |  |
| Amphybole Group | Two Direction with Oblique angle |  |
| Halite | Three perpendcular Direction |  |
| Calcite | Three Direction With Oblique angles |  |
| Diamond & Fluorite | Four directions |  |
| Sphalirite | Six directions |  |
| Quartz | No Cleavages |  |

**8.Luster–**Light is reflected from the surface of a mineral, the amount of light depending on physical qualities of the surface (such as its smoothness and transparency). This property is called the luster of the mineral, and is described according to the degree of brightness from splendent to dull. The terms to describe luster are given in table 2.

**Table 2:** The luster of minerals

| Luster | Subdivision | Mineral example |
|---|---|---|
| Metallic | - | Galena, Magnetite, Silver |
| Submetallic | - | Cinnabar |
| Nonmetallic | adamantine | diamond |
| | Vitreous | quartz |
| | resinous | amber |
| | silky | Asbestos |
| | pearly | mica |
| | greasy | Opal |
| | waxy | Gypsum |
| | earthy | kaolin |

**9.Specific Gravity-** The specific gravity or density of the minerals can be measured easily in a laboratory, provided the crystal is not too small. The specific gravity(sp.gr.)is given by the relation:

**Specific gravity =$W_1/(W_1 - W_2)$**
Where:
W1=the weight of the mineral in the air
W2= the weight of the mineral in the water

**Table 3**: Specific Gravity of Minerals.

| Specific gravity | Example | Range of sp.gr. |
|---|---|---|
| Low | Silicates,Carbonates,Sulphates Halides | 2.2 to 4.0 |
| Medium | Metallicores ex.oxides,sulphides | 4.5 to 7.5 |
| High | Native metallic elements | >7.5 |

**10.Fluorescence:** There are several ways that minerals can emit light, besides the light that is emitted from exposure to daylight or the light from normal light bulbs. Some of these ways involve special lamps that emit non-visible ultraviolet light (at least not visible to humans). The light from these ultraviolet lamps reacts with the chemicals of a mineral and causes the mineral to glow; this is called **fluorescence.** If the mineral continues to glow after the light has been removed, this is called **phosphorescence.**

## Chemical properties:

1. **Reaction with acids:** when a drop of dilute hydrochloric acid is put on the certain minerals , a reaction take place. Calcite bubbles of carbon dioxide make the acid froth, and in some sulphide ores, hydrogen sulphide is produced.
2. **Taste :** Taste is not the first or possibly even the last property someone would associate with minerals. And yet, taste is sometimes a very good characteristic and a key to identification in some cases. The most commonly "tasted" mineral is **halite** or *rock salt*, but there are several other minerals that have a distinctive taste. When tasting a mineral, do not lick the specimen. There are minerals that are poisonous and a lick can cause a considerable amount of unnecessary ingestion of the substance. It is recommended that the testing person first wet their finger, then place the wet finger on the specimen and finally taste the finger. This should provide enough of a taste without getting a tongue full of perhaps a badly tasting or worse yet poisonous mineral. Another technique is to just place the tip of the tongue to the mineral for a brief moment. Some minerals have a unique taste that can not be described except in general terms, but with practice can be identified readily. The list below is composed of **sulfates**, **halides** and **borates** because these minerals can be more **soluble** in water than other minerals in general and some solubility in water is required in order to have a taste in the first place. **These are some of the more common minerals that have a significantly distinct taste:**
   *Borax (sweet alkaline)
   * Chalcanthite (sweet metallic & slightly poisonous)
   * Halite (salty)
   *Hanksite (salty)
   . Ulexite (alkaline).

## The Rocks: