# 2. Matter and Minerals

Mineral - naturally occurring crystalline solid substance, generally inorganic, with a specific chemical composition.

1) naturally occurring - cannot be formed in the laboratory.

2) crystalline substance- an internal structural framework of atoms (or ions) arranged in a regular geometric pattern. e.g. glass not a mineral.

3) solid - single solid phase. ice is a mineral; water is not.

4) inorganically formed - e.g. shell, although aragonite, is at times not considered a mineral because it is organic. Coal is not a mineral.

5) definite chemical composition - mineral is a chemical compound.

Mineralogy and chemistry are closely related because minerals are made of elements. Most minerals are a combination of two or more elements joined to form a chemically stable compound.

Atom-smallest part of matter that still retains the characteristic of an element.

## Atomic Structure

Nucleus - central region with very dense positively charged protons and neutral particles called neutrons.

Orbiting the nucleus are negatively charged particles called electrons.

Electrical Charge:

P = +1 N = 0 E = -1

Atomic weight:

P = 1 N = 1 E = 0

Atomic number - number of protons.
- determines name of element.

Atomic number = 8; oxygen

Atomic mass number - number of protons and neutrons

O = 16; 8 protons and 8 neutrons.

Electrically neutral atoms:

Protons = Electrons

## Bonding

Combining of two or more elements into a compound.

Forces bonding elements are electrical in nature.

The outermost electrons are generally involved.

First shell - 2 electrons maximum; H, He.
Each successive shell - 8 electrons maximum.

Every atom seeks a full outer shell to become inert or stable by gaining, losing, or sharing electrons.

Two major types of bonds:

Ions - atoms with an electrical charge because of unequal number of electrons and protons.
Due to the gain or loss of electrons.
Positive ion - cation Negative ion - anion

Ionic bond is one in which oppositely charged ions attract one another to produce a neutral chemical compound.

Ionic bonds - dominant chemical bond - 90%

e.g. NaCl One atom becomes stable by giving up its valence electrons and the other uses it to complete its outer shell.

| | | |
|---|---|---|
| $^{11}Na$ | 2-8-1 | looks to lose 1 electron. |
| $^{17}Cl$ | 2-8-7 | looks to gain 1 electron. |

Covalent Bonds - produced by sharing of electrons to acquire the complete outer electron shell.

## Structure of Minerals

Minerals are formed by the process of crystallization - the growth of a solid from molten material whose constituent atoms can come together in a proper chemical proportions and crystalline arrangements.

Orderly stacking of atoms is reflected in regularly shaped objects we call crystals.

Controls of crystalline structure

1) number and size of specific ions entering into the composition, and
2) the charge on the ions.

Each positively charged ion (cation) is surrounded by the largest number of negative ions that will fit, while maintaining neutrality.

Geometrical stability implies the ions must be packed in a way to keep them tight and rigid.

Electrical stability implies that the charges must be balanced.

Many of the cations are relatively small; the anions are larger.

## Polymorphs

Polymorphs - minerals with the same chemical composition but different atomic arrangement and properties.

The same atoms or ions in the same proportion may be built into several structures.

Different polymorphs of the same substance are formed under different physical conditions:
Pressure and Temperature

e.g. diamond and graphite      Carbon

## Physical Properties of Minerals

-minerals-have unique physical properties.

Crystal form: external expression of a mineral that reflects the internal arrangement of atoms.

Crystal is a solid body bounded by plane natural surfaces

Crystal form develops best when mineral has space to grow.
Interference results in an intergrown crystal mass.

Crystals are classified by their symmetry.

Color - obvious and useful diagnostic property. Causes varied and complex.

Impurities can give mineral different colors.
Exotic Coloration - displaying a variety of colors (quartz);
Inherent Coloration - single color (sulfur).

Iron tends to color strongly.

Streak - color of a finely powdered mineral.

Streak plate; crushing, filing, or powdering.

Hardness - resistance of mineral to scratching.
Resistance of the crystal structure to mechanical deformation.
Strong bonds (covalent) give high hardness.

*Mohs* scale of hardness - relative scale with numerical value from 1-10:

| | |
|---|---|
| 1) talc | 6) orthoclase |
| 2) gypsum | 7) quartz |
| 3) calcite | 8) topaz |
| 4) fluorite | 9) corundum |
| 5) apatite | 10) diamond |

fingernail - 2.5
copper penny - 3
>6 not scratched by a knife.

Cleavage - tendency of minerals to break along planes of weak bonding within the crystalline structure.

Usually parallel to a crystal face.

Minerals possess cleavage because the strength of bonding within the structure is different in different directions.

Covalent bonds give poor or no cleavage; ionic bonds (weak) give excellent cleavage.

e.g. micas have excellent cleavage in one direction. Bonding within layers is strong, whereas bonding between layers is weak.

Not all minerals have cleavage.

Fracture - irregular breakage in minerals which lack cleavage.

Specific gravity - number representing the ratio of the weight of a mineral to the weight of an equal volume of water. Most rocks ~3.

Luster - is produced by light reflected from the surface of a mineral.

Metallic vs. Submetallic vs. Nonmetallic

Other properties - taste (halite), magnetism (magnetite), smell, chemical reaction to HCl, Luminescence - emission of light.

Fluorescence - emission of light at the same time as the irradiation.
Absorption of energy by the ions and release in the form of light.
e.g. Franklin Marble - Franklin, NJ

## Mineral Groups

Silicates -most common mineral group.
Crust ~95% silicate minerals
60% are feldspar and 12% quartz.
All silicates contain oxygen and silicon.

Eight elements compose the bulk of the rock forming minerals and earth's crust: oxygen (47%), silicon (28%), aluminum (8%), iron (5%), calcium, sodium, potassium, magnesium.

## Structure of Silicates

Silicon-oxygen tetrahedron

Four oxygen atoms surrounding a much smaller silicon atom.

$Si^{4+}$ $4O^{2-}$

Results in an ion with a charge of -4.

Can be balanced by adding cations or sharing oxygen with other tetrahedra.

The tetrahedra themselves can be linked to form a variety of configurations: single chain, double chain, and sheet structures

The joining of tetrahedra in these configurations results from the sharing of oxygen atoms between silicon atoms in adjacent tetrahedra.

The ratio of oxygen atoms to silicon atoms differs in each of the structures.

There is a relationship between the internal structure of a mineral and the cleavage it exhibits.

Silicates tend to cleave between the silicon - oxygen bonds (rather than across them) because the silicon-oxygen bonds are extremely strong.

Silicate structures (except for quartz) are neutralized by the inclusion of metallic ions that bind them together into a variety of crystalline configurations.

Common ions include Fe, Mg, K, Na, Al, and Ca.

Ions of the same size are usually free to substitute for each other. Expressed by parentheses in formula:

e.g. Olivine $(Fe,Mg)_2 SiO_4$

*Silicate Minerals*

Most silicates form when molten rock cools. The rock produced is a function of the chemical composition of the magma and the environment it forms at.

Ferromagnesian silicates - contain iron or magnesium in their structures and are usually dark in color, and higher specific gravity.

1. olivine - $(Mg,Fe)_2SiO_4$ -
    high temperature silicate
    black to olive green
    small rounded crystals
    single tetrahedron
    no cleavage

2. pyroxene - $(Fe,Mg)SiO_3$ - important component of the mantle.
augite- black opaque mineral with two directions of cleavage that meet at ~90 degrees.
    single chains silicate.
    Dominant mineral in basalt - common rock of the oceanic crust.

3. Amphibole Group - $(Ca_2Mg_5)Si_8O_{22}(OH)_2$
hornblende
    Double chain silicate
    Dark green to black
    cleavage at 60 and 120 degrees

4. biotite - dark iron rich member of the mica family.
    Sheet structure with excellent cleavage in one direction.

Nonferromagnesian silicates
    light in color; lower specific gravity

1. muscovite - member of the mica family.
    light in color with a pearly luster.
    cleavage in one direction.
    sheets are clear.

2. feldspar -
    the most common mineral group
    formed in a wide variety of environments
    two planes of cleavage that meet at 90 degrees;
    hardness of 6, pearly to glassy luster.
    three dimensional framework.
    silicon atoms replaced by aluminum.
Difference in charges of aluminum versus silicon made up with K, Na, or Ca.
    Two different structures exist-
orthoclase feldspar-with K; $KAlSi_3O_8$; and

light cream to salmon pink in color.
plagioclase feldspar-($CaAl_2Si_2O_8$ - $NaAlSi_3O_8$)
plagioclase-white to medium gray, striations - fine parallel lines

3, quartz - silicon: $SiO_2$
three dimensional framework is developed through the complete sharing of oxygen by the adjacent silicon.
Strong bonds - hard mineral, no cleavage.
Hexagonal crystals

NONSILICATE MINERALS

carbonate minerals - Limestones
carbonate ion ($CO_3^{2-}$).
calcite - $CaCO_3$

Halite - NaCl -
evaporite deposits - salt.