Mineralogy

Course of Mineralogy G102
Second Semester (February-June, 2014)
Department of Geology
College of Science /University of Basrah
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What is mineral?

- In general term “a mineral is component element or chemical that is normally crystalline and what has been formed as a result of geological processes”.

- *Note/ the use of word “normal” permits the classification of some amorphous and para-amorphous substances as minerals.*

- *Note/ most minerals are inorganic. Organic crystals forming from organic matter in the geologic environment are also considered minerals.*

- What is crystal? “ A crystal is any solid with an essentially discrete diffraction pattern”.

CMMN

- **C**ommission on **N**ew **M**inerals and **M**ineral **N**ames.
- There are:
- **1758** accepted mineral species names.
- **331** names not accepted by CMMN but possibly valid.
- **111** that have been renamed by the CMMN, for a total of 4189.
- **128** an additional polytypes listed that are not considered species.
- Source: Aleph Enterprises http://www.alephent.com

Inorganic Chemistry

Low-temperature aqueous geochemistry

$CaCO_3$? Why calcite form?

- What are the environments that are conducive to crystallization?

- 1- the elements Ca, C, O need to be ionized for entry into bonded relationship.

- 2-because of variability in ionic size and electrical charge of the chemical elements controlling their bonding configurations.

- 3- natural environment.

Electrochemical properties of element

The formation of minerals is a bonding process, fundamentally an electrical process, and because bonding results from interaction between the electrons of atoms, it is fundamentally an electrical process.

Bonding parameters

- Bonding parameters are:
  1. Bond strength
  2. Bond length
  3. Bond direction

❖ *Bonding parameters are important in understanding many physical and chemical properties of minerals.*

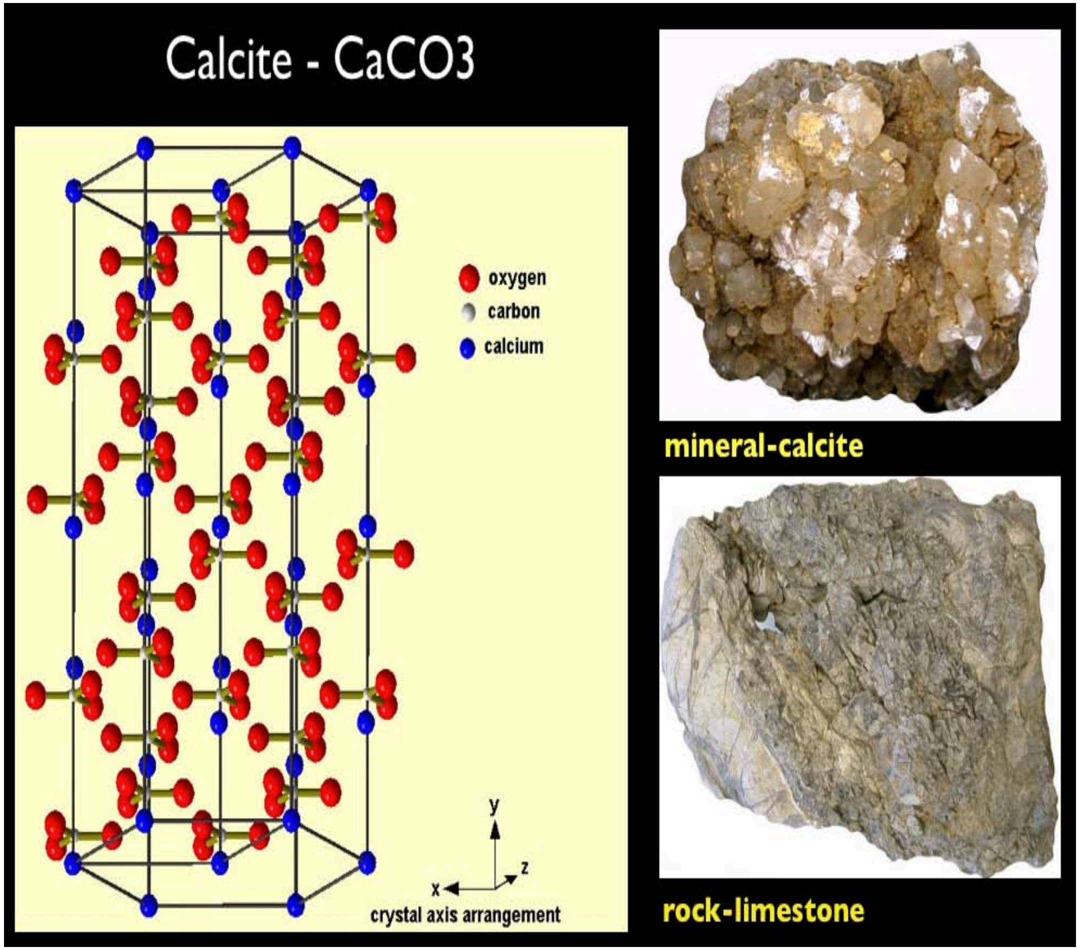
Bond strength

- Quantified as lattice energy (or crystal energy or total lattice potential energy) of crystal and as the bond energy of a molecule.
- ❖ the lattice energy values are an indication of the relative amounts of energy required to break the bonds of crystal, relative to melting point and hardness.
- ❖ *Note/ elements that are divalent tend to form stranger bonds in crystal structures than those that are monovalent.*

Bond Length

- Is the measured between the centers of one atom to the center of another atom to which is bonded.

- Ex: the distance between a bonded carbon and oxygen atom in calcite is the sum of the bounded radius of carbon (0.40 Å) and the oxygen (0.88 Å) for a bond length 1.28 Å.



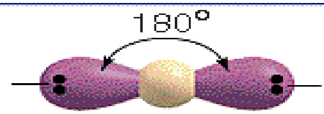
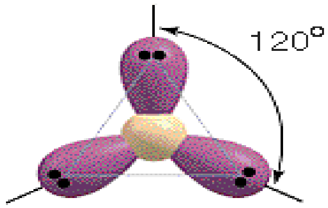
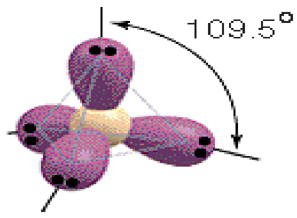
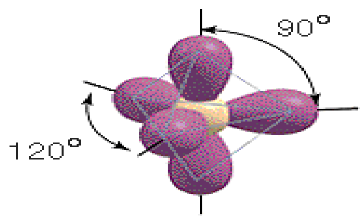
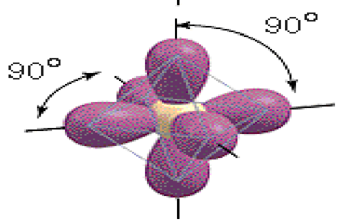
www.geologycafe.com

The bond length between the oxygen and one of the calcium ions is 2.36 A°, which is the sum of the bonded radii of oxygen (1.18 A°) in the direction of the calcium ion, and the bonded radii of the calcium (1.18 A°) along that same direction.

Bond Angeles

- Bond angles in simple geometrical arrangements of atoms are:
- - Linear (180°)
- - Trigonal planar (120°)
- - Tetrahedral (109.5°)
- - Trigonal bipyramidal (120°, 90°)
- - Octahedral (90°)
- *Bond angles can be many others in more complex molecular and crystal structural arrangements.*

ELECTRON-PAIR GEOMETRIES AS A FUNCTION OF THE NUMBER OF ELECTRON PAIRS

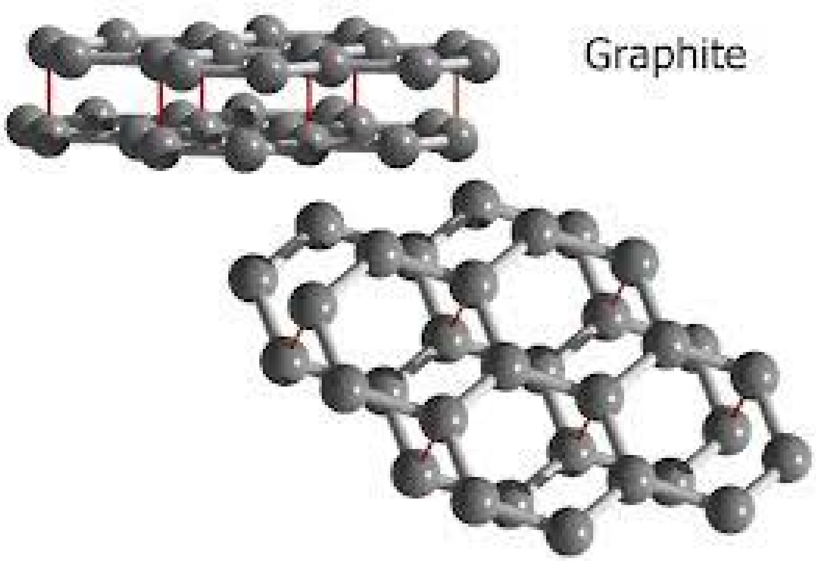
Number of Electron Pairs	Arrangement of Electron Pairs	Electron-Pair Geometry	Predicted Bond Angles
2		Linear	180°
3		Trigonal planar	120°
4		Tetrahedral	109.5°
5		Trigonal bipyramidal	120° 90°
6		Octahedral	90° 180°

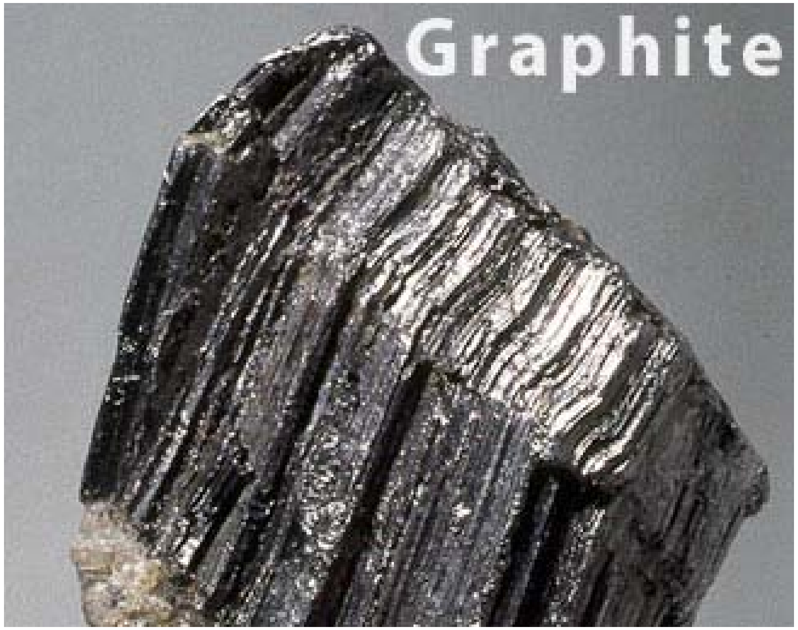
www.chem.ufl.edu

Types of chemical bonds and their bond strengths

1- Van der Waals' Forces or London Attraction

- Van der Waals' force is the weak bonding between clusters of atoms and between molecules. Breakage of s typical van der Waals' force bond requires less than 1kcal/mol.
- Ex: bonding between layers of carbon atoms in the mineral graphite and between rings of sulfur in the mineral sulfur.



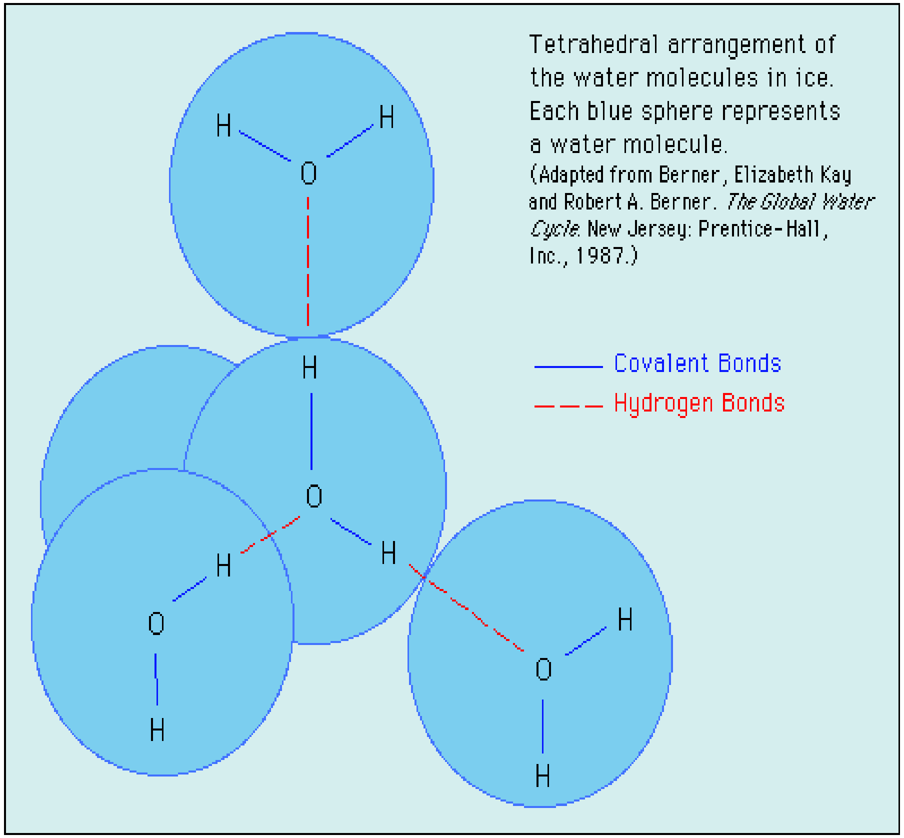


facweb.bhc.edu

www.mineralogy4kids.org

- **Hydrogen bounding**: is weak bonding involving hydrogen.

- Ex:
- Bonding between the positive end of one dipole water molecule to the negative end of another.



- The relatively low melting point of ice (0˚C) and the boiling point of water (100˚C) are linked to weak boning between H2O molecules.
- Breakage of a typical hydrogen bond requires about 5 kcal/mol whereas a typical covalent bond requires about 100 kcal/mol to be broken.

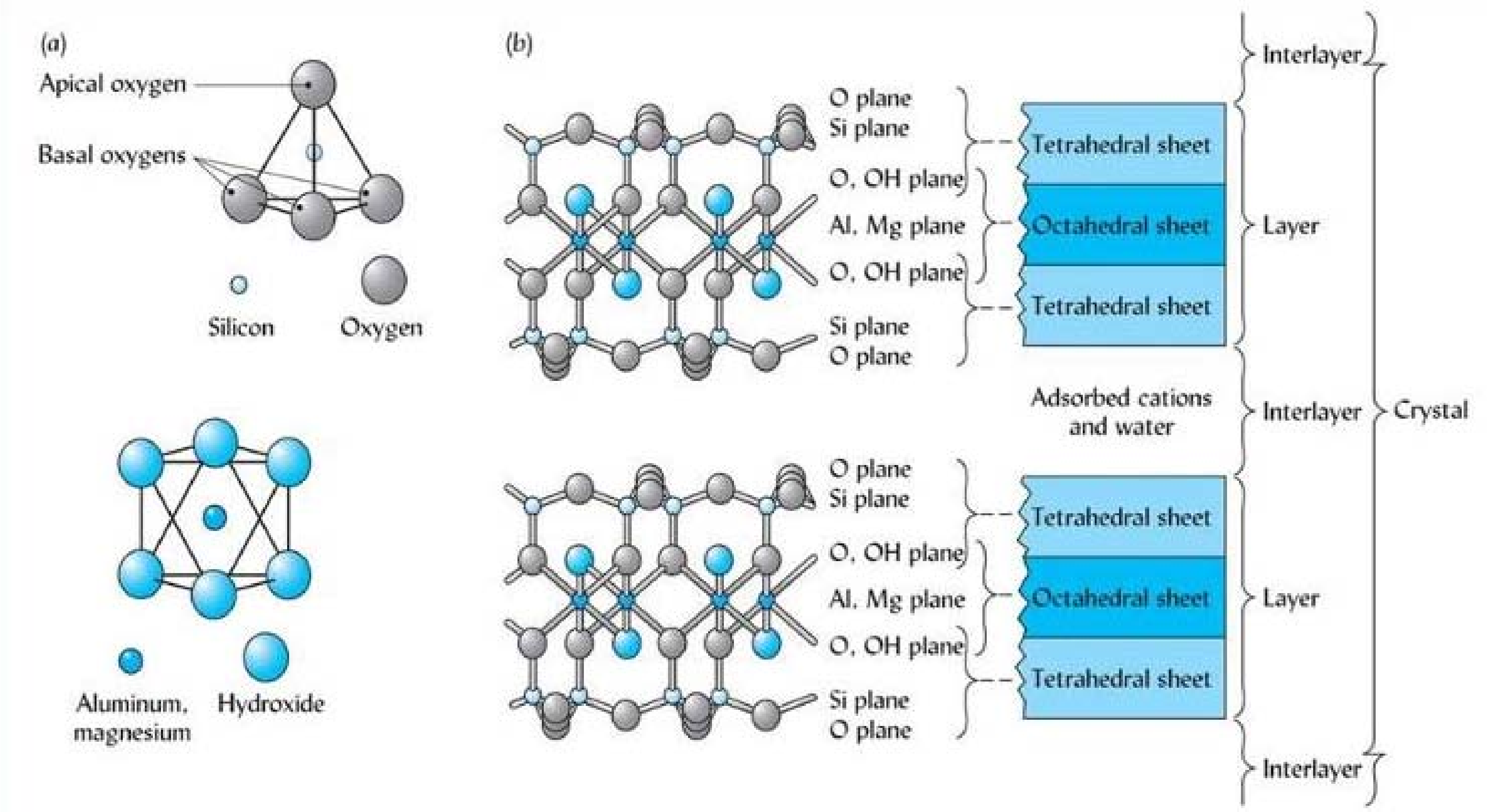
- The water of hydrated minerals is another example of hydrogen bonding.

- **Clay minerals** are hydrates, some of which lose their water of hydration as they dry, and gain water (and swell) as they are wetted. These are well-known ***shrink-swell clays*** that raise havoc with building foundations.

- *Note/ Hydrate minerals such as clays and zeolites are very common in low-temperature, aqueous surface environments.*

Ex: Montmorillionite

- (2:1) one octahedral sheet sandwiched between two tetrahedral sheets.
- Very active shrink/ swell behavior



http://faculty.yc.edu/ycfaculty/ags105/week08/soil_colloids/soil_colloids_print.html

Covalent bonding

- Covalent bonding is a sharing of electrons as an overlap of electron positions in participating atoms.
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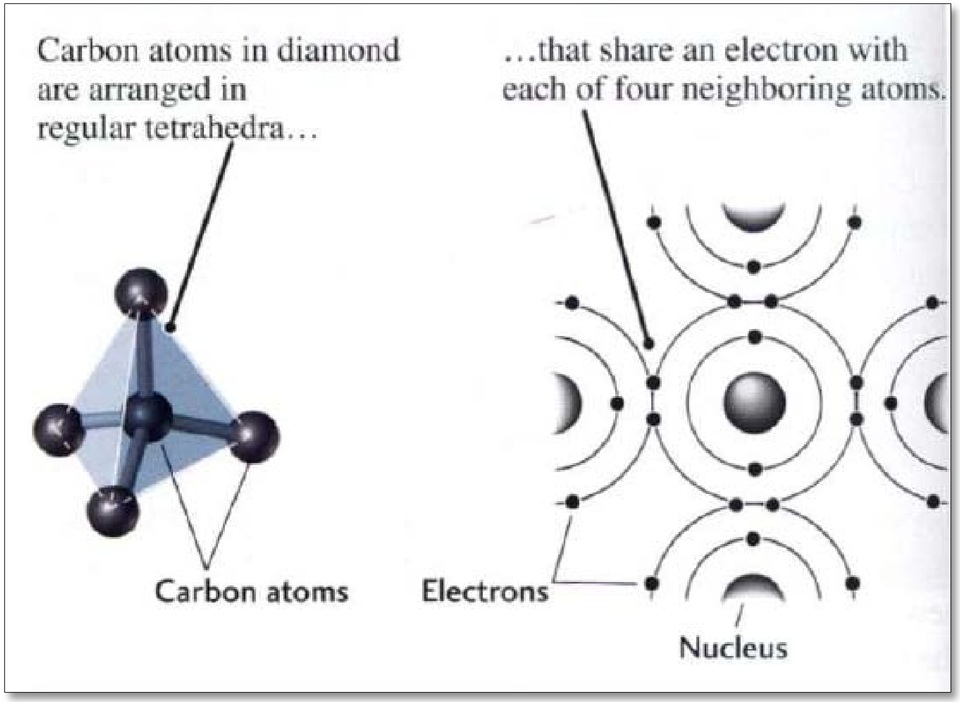
- Ex: the bonding between O_2, $C+O_2= CO_2$
- Strong Si+O bond in silicate minerals
- Diamond
- Sheets of graphite

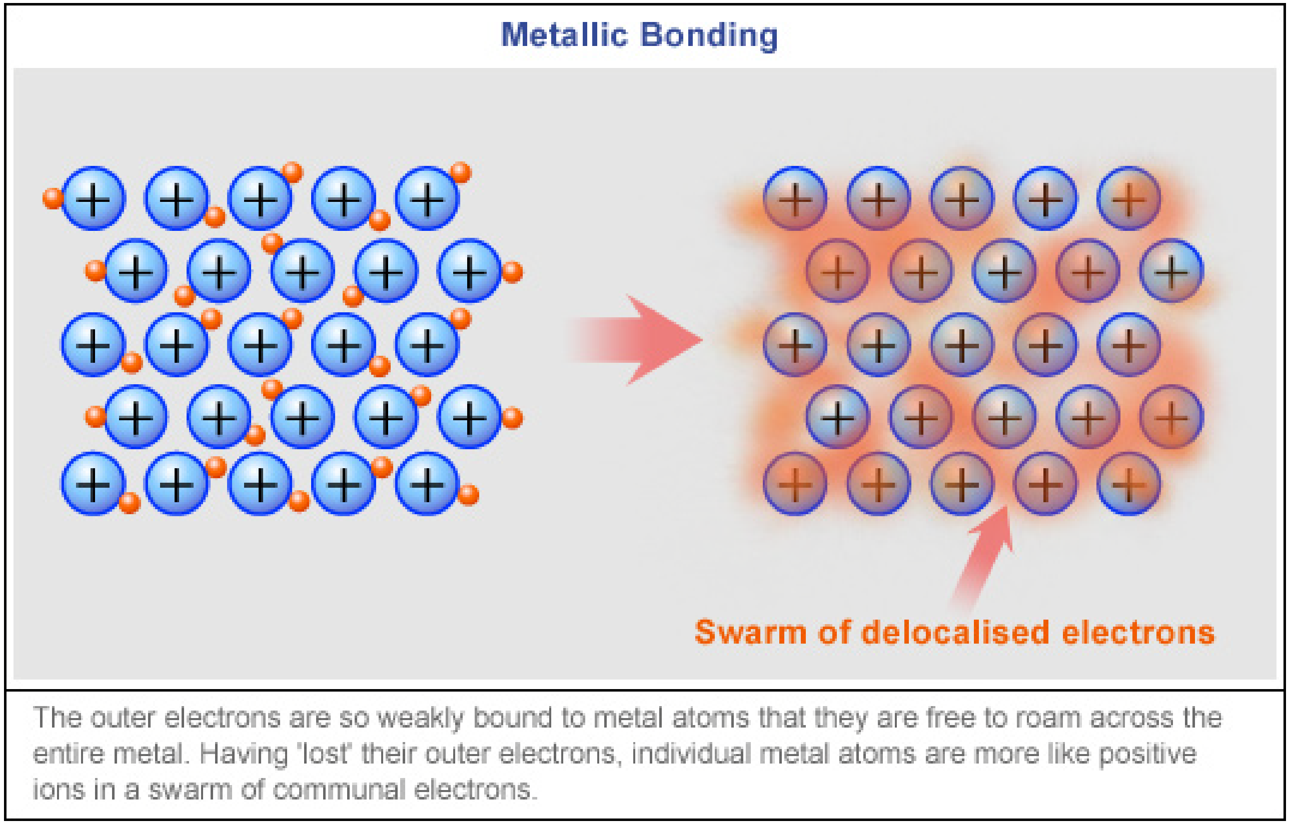


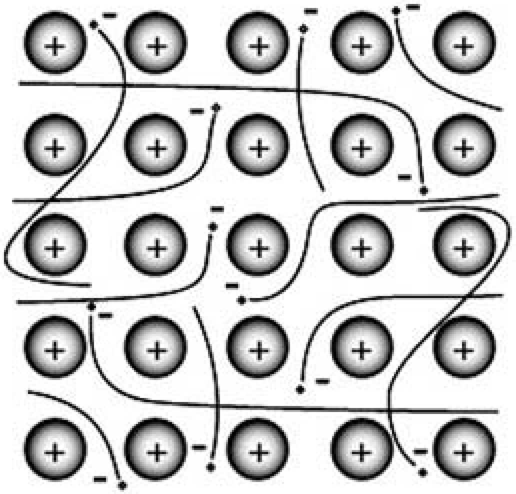
Covalent bonding (Grotzinger and Jordan, 2006)

Metallic bonding

- The overlaps of electrons from many atoms resulting in more-or-less free movement, or "wandering", of electrons.
- There is no ionization as such, meaning that there is no loss, gain, or specific sharing of these electrons.
- Ex: native gold, native copper, natural alloy electrum (AuAg) and the rare mineral moschellandsbergite (Ag_2Hg_3).
- Note/ the physical expression of metallic bonding is plastic behavior when stressed, high electrical conductivity, and metallic luster.

Metallic bonding





The black dots represents the possible positions of electrons as they move about the atomic structure, supplying the necessary charge balance wherever it is needed.

(http://mtweb.mtsu.edu/cribb/1030minerals.html)

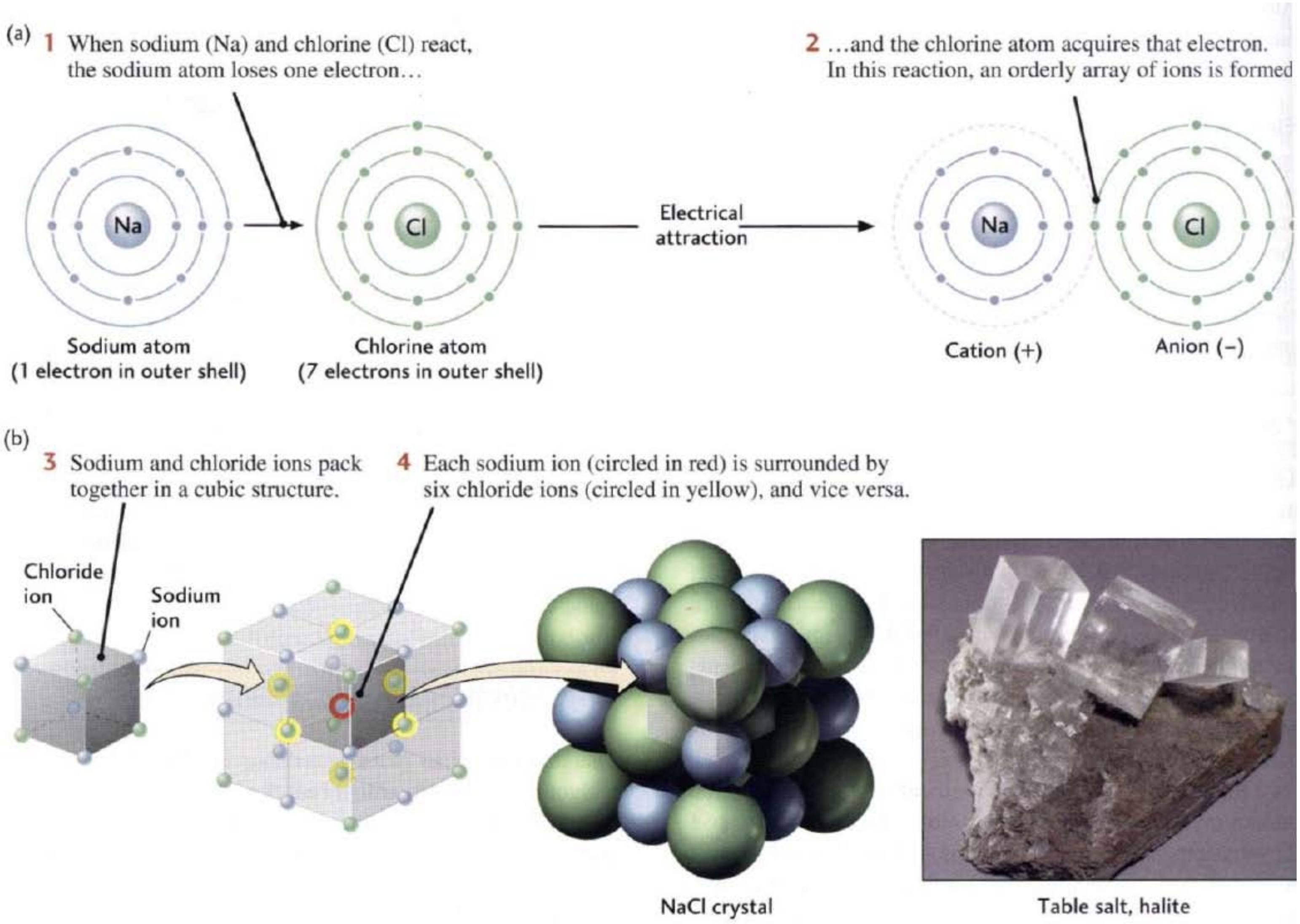
Ionic bonding

- Transfer of electrons from one atom to another.
- Ionization is the removal of one or more electrons from an atom or ion if there has already been some ionization.

- Most minerals have bonding that has characteristics of both ionic and covalent bounding.

- *Ex: the bonding between copper and oxygen in the mineral cuprite is about 57% ionic and 43% covalent.*

- *For quartz, there is considerable disagreement on the proportion of ionic and covalent bounding.*



Ionic bonding (Grotzinger and Jordan, 2006)

Electrochemical Factors in Chemical Bonding

- Electron Configuration: the number of electrons in bonding with other atoms (valence electron) and the type of bonding they participate in are both closely linked to the electron configuration about the atomic nuclei.

- Electron Affinity (E): one measure of an element's ionization and bonding attributes is the energy change that occurs when an electron is added to a gaseous atom or ion.

- Ex: Mg+e= Mg- (+240 kj/mol). This means that it takes 240 kj/mol of energy to form the negatively charged magnesium ion.

- Ionization Potential (I): is the energy acquired by a particle carrying a charge equal to that of one electron through a potential of 1volt.

- Note/ the charge on one electron is 1.6022*10-19 C (coulombs). If this is multiplied by 1 volt, 1.6022*10-19 joules is obtained.

- Electronegativity (e): is a measure of an element's ability to gain electrons to form negative ions.

Notes//

- Remember that/ *electron affinity (E)* is a measure of the energy change involved in adding an electron to any atom or ion.
- *Ionization potential is a measure of the energy required to remove electrons.*
- In the case of *electronegative*, a dimentionless scale has been established that ranges from 1to 4. Low numbers indicate little or no tendency to gain electrons; high values indicate a propensity to form anion.

Notes/ /

- The most practical use of e number is in estimating the type of bonding an element is likely to be involved in. Low values and high values are an indication of ionic bonding. Intermediate values, as the 2.5 that applies to carbon and sulfur, indicate that these elements have no strong tendency to gain or lose electrons.

- Ex: sulfur can form negative ions (S2-) as well as positive ions (S2+, S4+ and S6+) as well as negative ions (S2-) depending on natural environmental conditions. Not surprisingly, these intermediate e values are also an indication that the native occurrence of carbon and sulfur is possible if environmental conditions are just right.

References

- This lectures is prepared from the following books:

- - Hibbard, M.J., 2002. Mineralogy: a geologist's point of view. Mc Graw Hill. 562P.

- - Grotzinger, and Jordan, 2006. Understanding Earth. W.H. Freeman & Company. 637P>