GEM 106
Minerals

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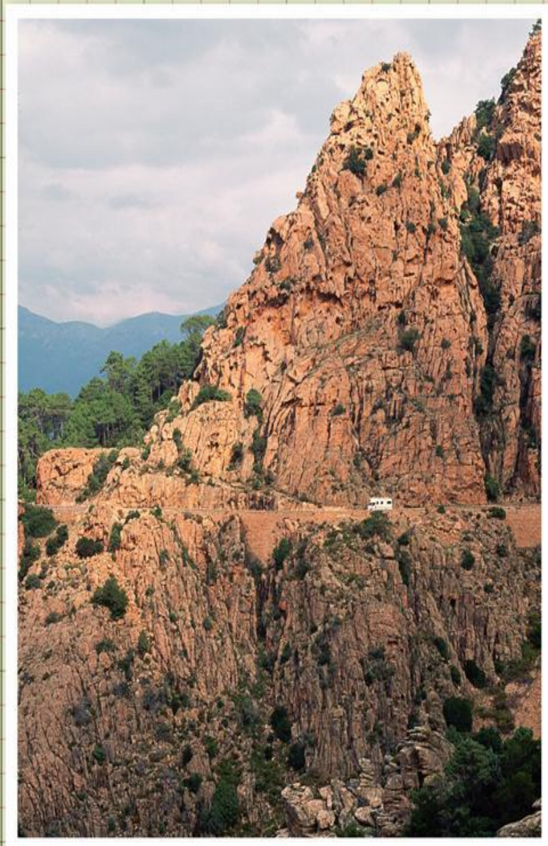
Introduction

- The Earth is composed of rocks.
- Rocks are aggregates of minerals.
- So minerals are the basic building blocks of the Earth. Currently there are over 4,000 different minerals known and dozens of new minerals are discovered each year.
- Our society depends on minerals as sources of metals, like Iron (Fe), Copper (Cu), Gold (Au), Silver (Ag), Zinc (Zn), Nickel (Ni), and Aluminum (Al), etc., and non-metals such as gypsum, limestone, halite, clay, and talc.

Introduction...........Cont.

- Many minerals of great economic importance and their distribution, extraction, and availability have played an important role in history.
- Minerals are composed of atoms.
- We'll start our discussion with the geological definition of a Mineral.

Field observations on mountain hike

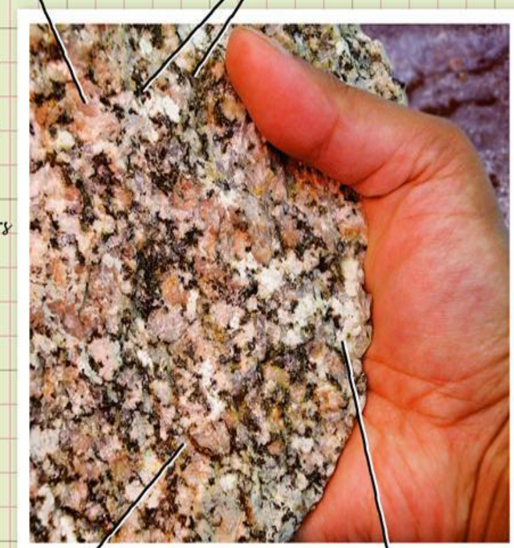


A. Lots of bare rock exposed on mountain cliffs. The rock is called granite, and looks very uniform in color from a distance.

Lots of pink, box-shaped mineral grains

Black mineral in thin sheets

B. Close up, the rock consists of many smaller ingredients, called minerals. The minerals have many different colors and shapes.



Gray. translucent, sort of glassy-looking mineral

White mineral

Definition of a Mineral

A **mineral** is:

- Naturally formed - it forms in nature on its own (some say without the aid of humans]
- Solid (it cannot be a liquid or a gas)
- With a definite chemical composition (every time we see the same mineral it has the same chemical composition that can be expressed by a chemical formula).
- and a characteristic crystalline structure (atoms are arranged within the mineral in a specific ordered manner).

Definition of a Mineral……..Cont.

- usually inorganic, although a mineral can be formed by an organic process.
- A **mineraloid** is a substance that satisfies some, but not all of the parts of the definition.
- For example, opal, does not have a characteristic crystalline structure, so it is considered a mineraloid.

Note also that the "minerals" as used in the nutritional sense are not minerals as defined *geologically*.

Examples of mineraloid

- **Glass** - can be naturally formed (volcanic glass called obsidian), is a solid, its chemical composition, however, is not always the same, and it does not have a crystalline structure. Thus, glass is not a mineral.
- **Ice** - is naturally formed, is solid, does have a definite chemical composition that can be expressed by the formula H2O, and does have a definite crystalline structure when solid. Thus, ice is a mineral, but liquid water is not (since it is not solid).

Atoms

- Since minerals (in fact all matter) are made up of atoms, we must first review atoms.
- Atoms make up the chemical elements. Each chemical element has nearly identical atoms. An atom is composed of three different particles:
- ✓ ***Protons --*** *positively charged, reside in the center of the atom called the nucleus*
- ✓ ***Electrons --*** *negatively charged, orbit in a cloud around nucleus*
- ✓ ***Neutrons --*** *no charge, reside in the nucleus.*

Atoms………..Cont.

- Each element has the same number of protons and the same number of electrons.
- ✓ Number of protons = Number of electrons.
- ✓ Number of protons = ***atomic number.***
- ✓ Number of protons + Number of neutrons = ***atomic weight.***

Isotopes

- ***Isotopes*** are atoms of the same element with differing numbers of neutrons. i.e. the number of neutrons may vary within atoms of the same element.
- Some isotopes are unstable which results in radioactivity.

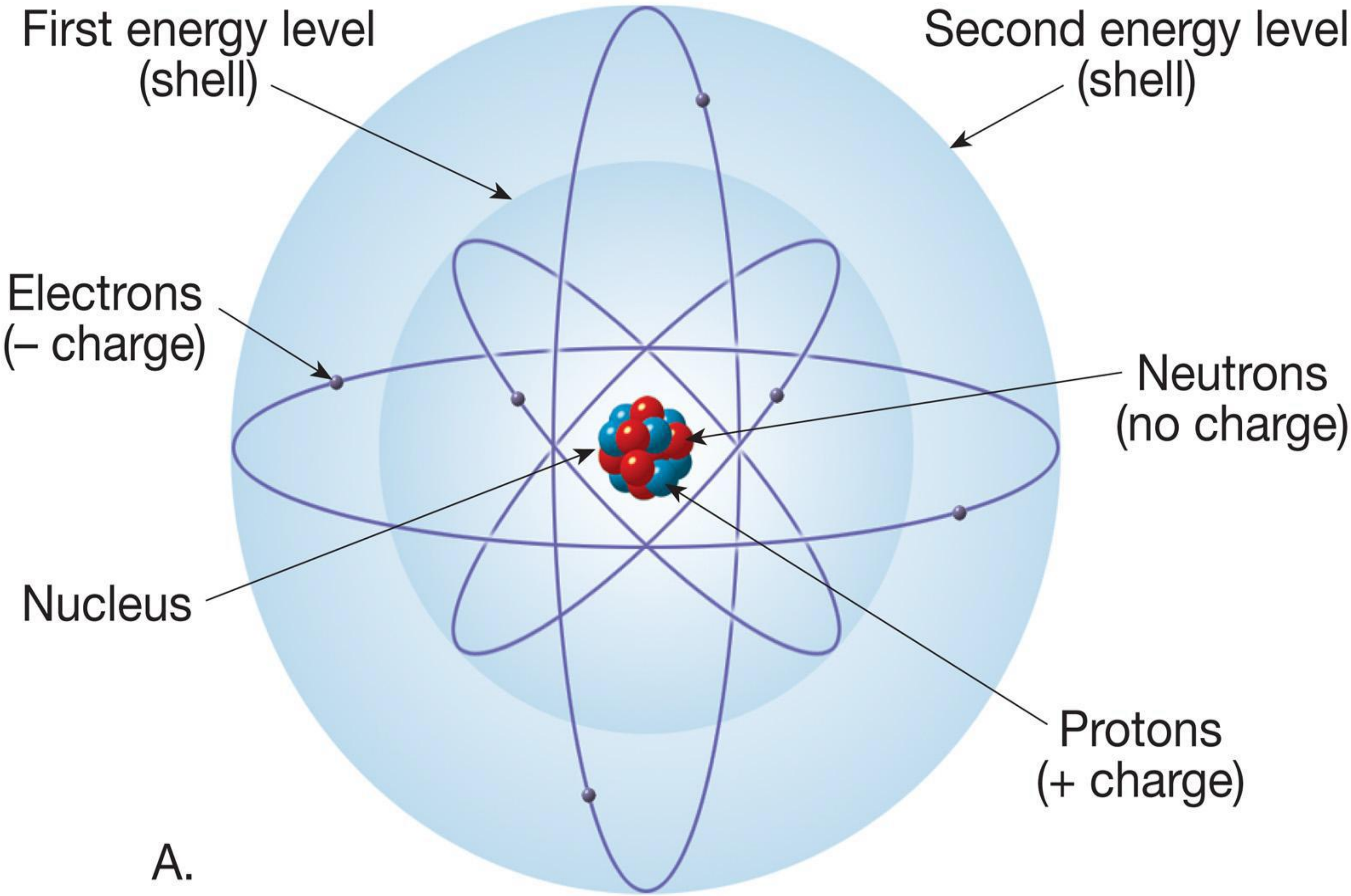
Example:

- ✓ K (potassium) has 19 protons. Every atom of K has 19 protons. Atomic number of K = 19. Some atoms of K have 20 neutrons, others have 21, and others have 22.
- ✓ Thus atomic weight of K can be 39, 40, or 41. 40K is radioactive and decays to 40Ar and 40Ca.

Structure of Atoms

- Electrons orbit around the nucleus in different shells (first, second, third levels).
- A Stable electronic configuration for an atom is one 8 electrons in outer shell Thus, atoms often loose electrons or gain electrons to obtain stable configuration.
- Noble gases have completely filled outer shells, so they are stable. Examples He, Ne, Ar, Kr, Xe, Rn.
- Others like Na, K loose an electron. This causes the charge balance to become unequal and produce charged atoms called ***ions.***

Atomic structure



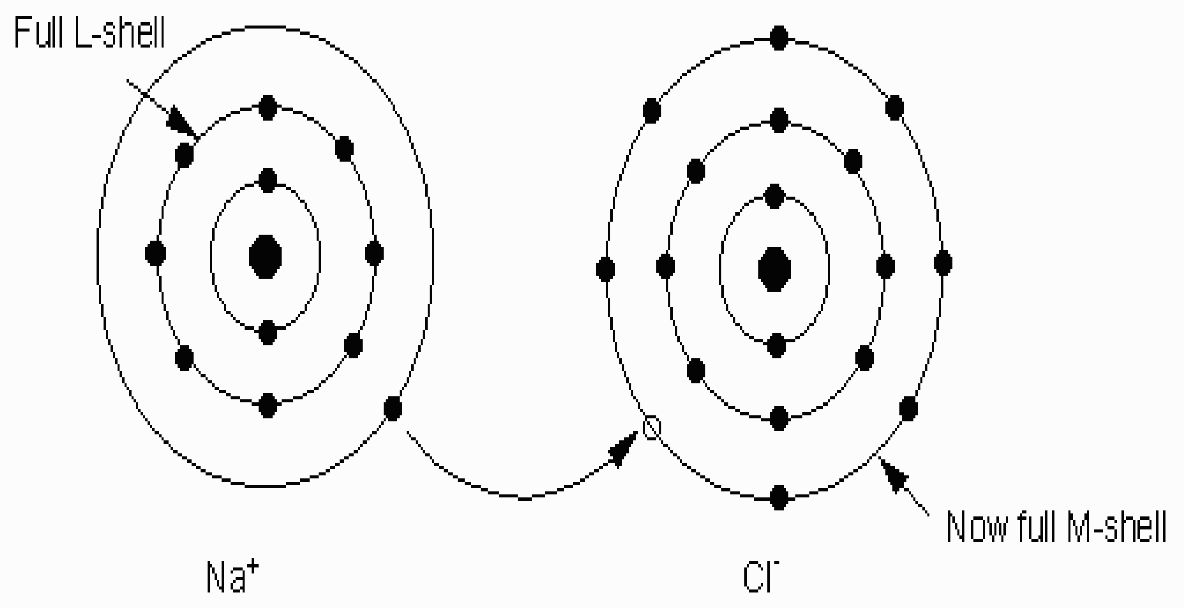
Structure of Atoms………Cont.

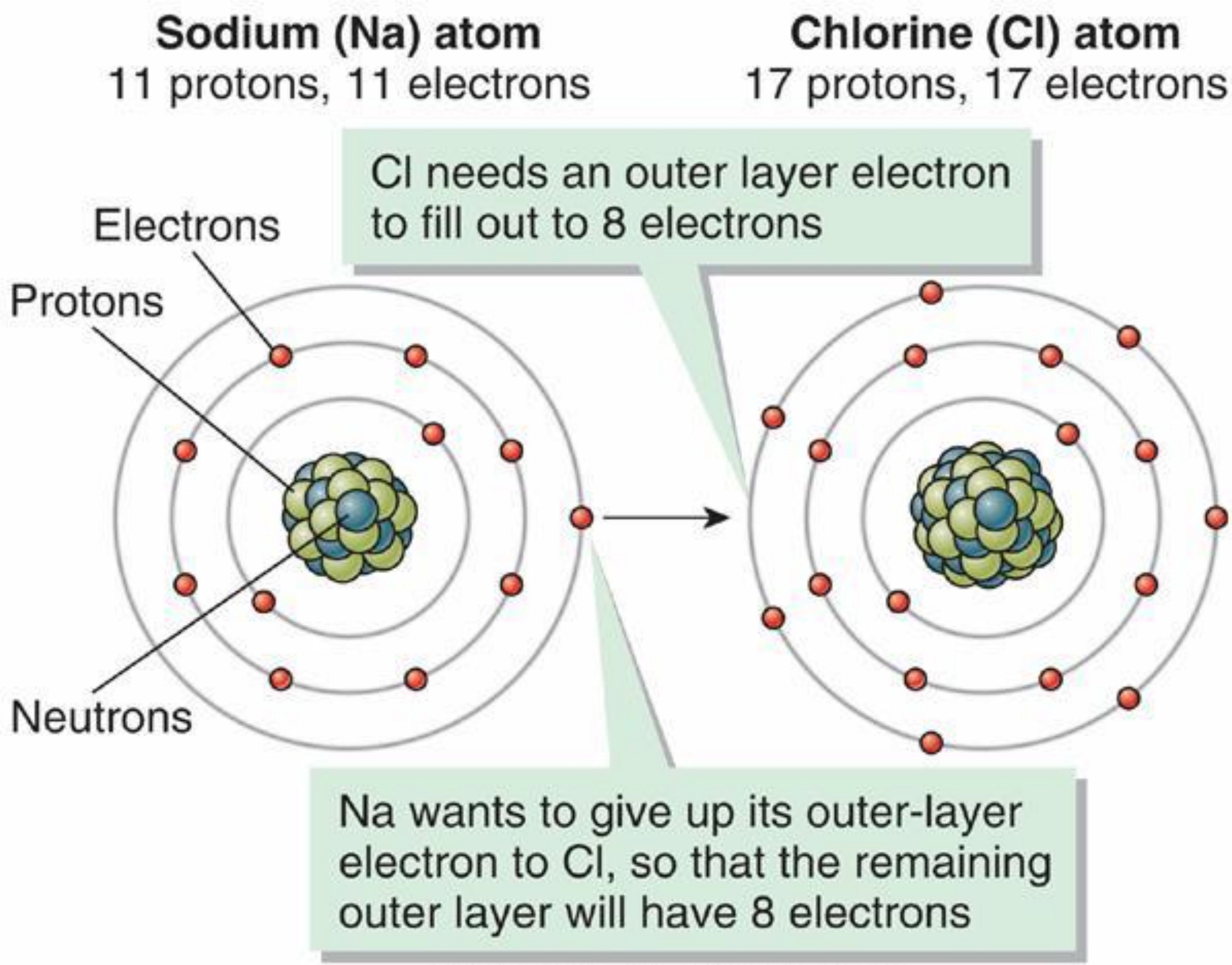
- Positively charged atoms are called ***cations.*** Elements like F, Cl, O gain electrons to become negatively charged.
- Negatively charged ions are called ***anions.***

- The drive to attain a stable electronic configuration in the outermost shell along with the fact that this sometimes produces oppositely charged ions, results in the binding of atoms together.
- When atoms become attached to one another, we say that they are **bonded** together.

Types of bonding:

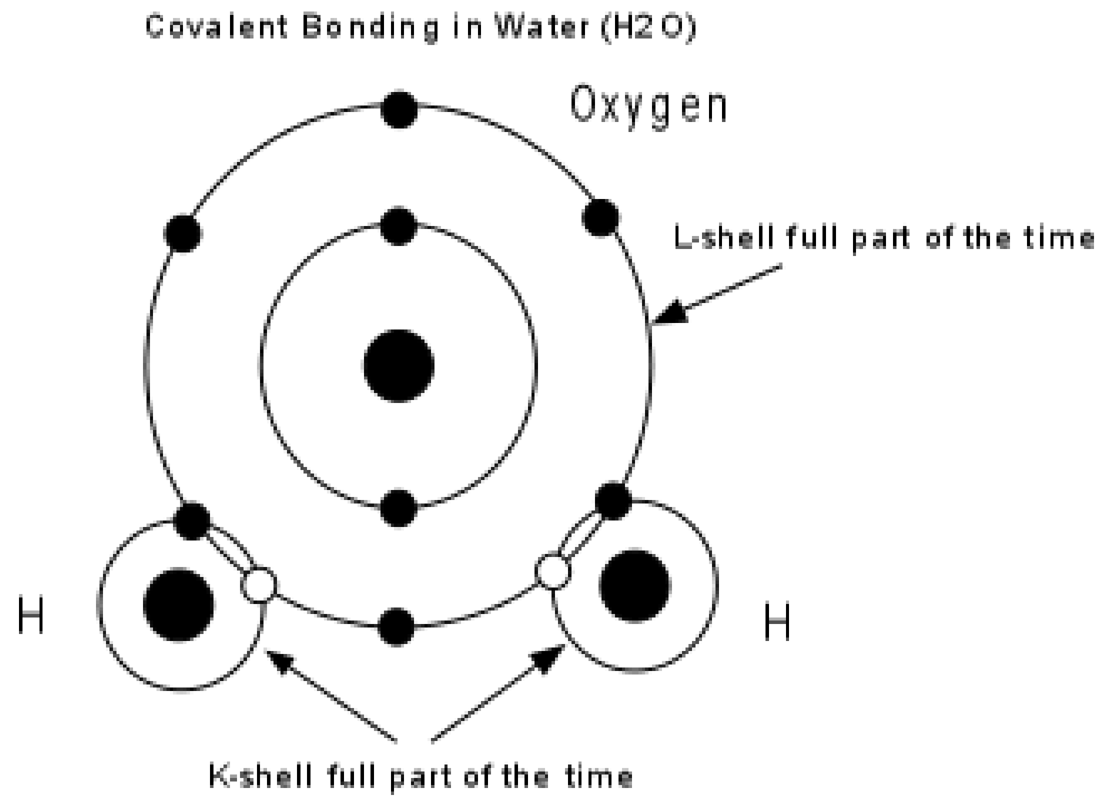
- ***Ionic Bonds -*** caused by the force of attraction between ions of opposite charge.
- Example Na+1 and Cl-1. Bond to form NaCl (halite or salt).
- **Ionic bonds are moderately strong.**




Sodium (Na) atom
11 protons, 11 electrons
Chlorine (Cl) atom
17 protons, 17 electrons
Cl needs an outer layer electron to fill out to 8 electrons
Electrons
Protons
Neutrons
Na wants to give up its outer-layer electron to Cl, so that the remaining outer layer will have 8 electrons

Covalent Bonds

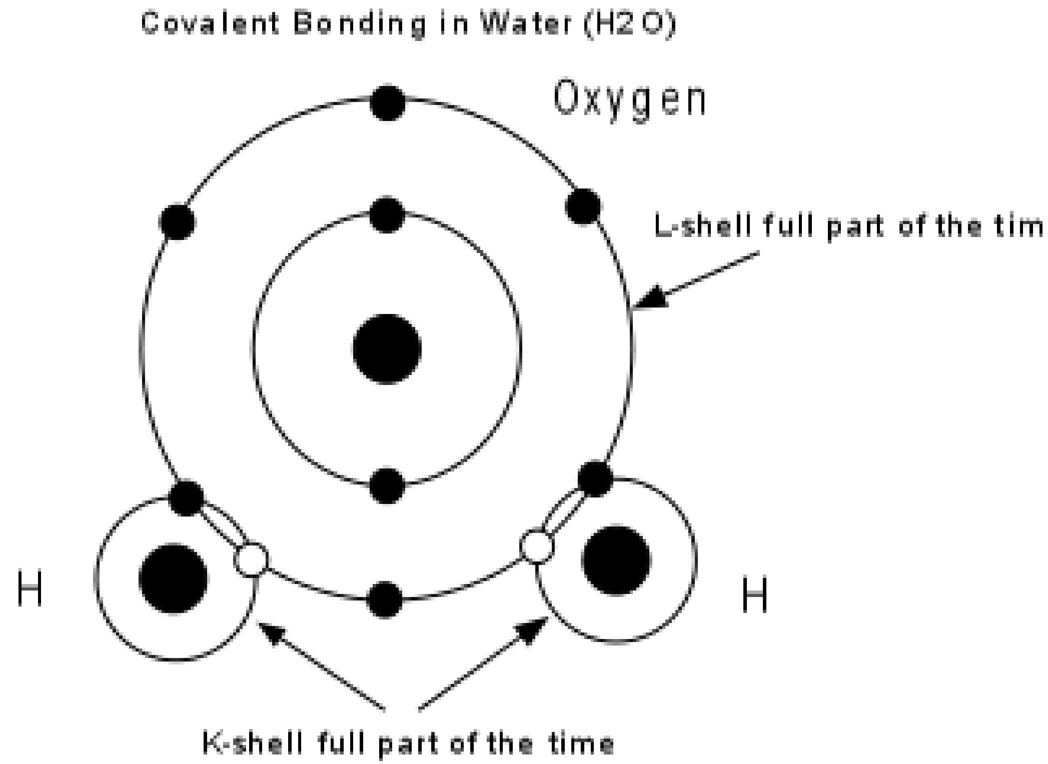
- Electrons are shared between two or more atoms so that each atom has a stable electronic configuration (completely filled outermost shell) part of the time. **Covalent bonds are very strong bonds.**



Covalent Bonds…………..Cont.

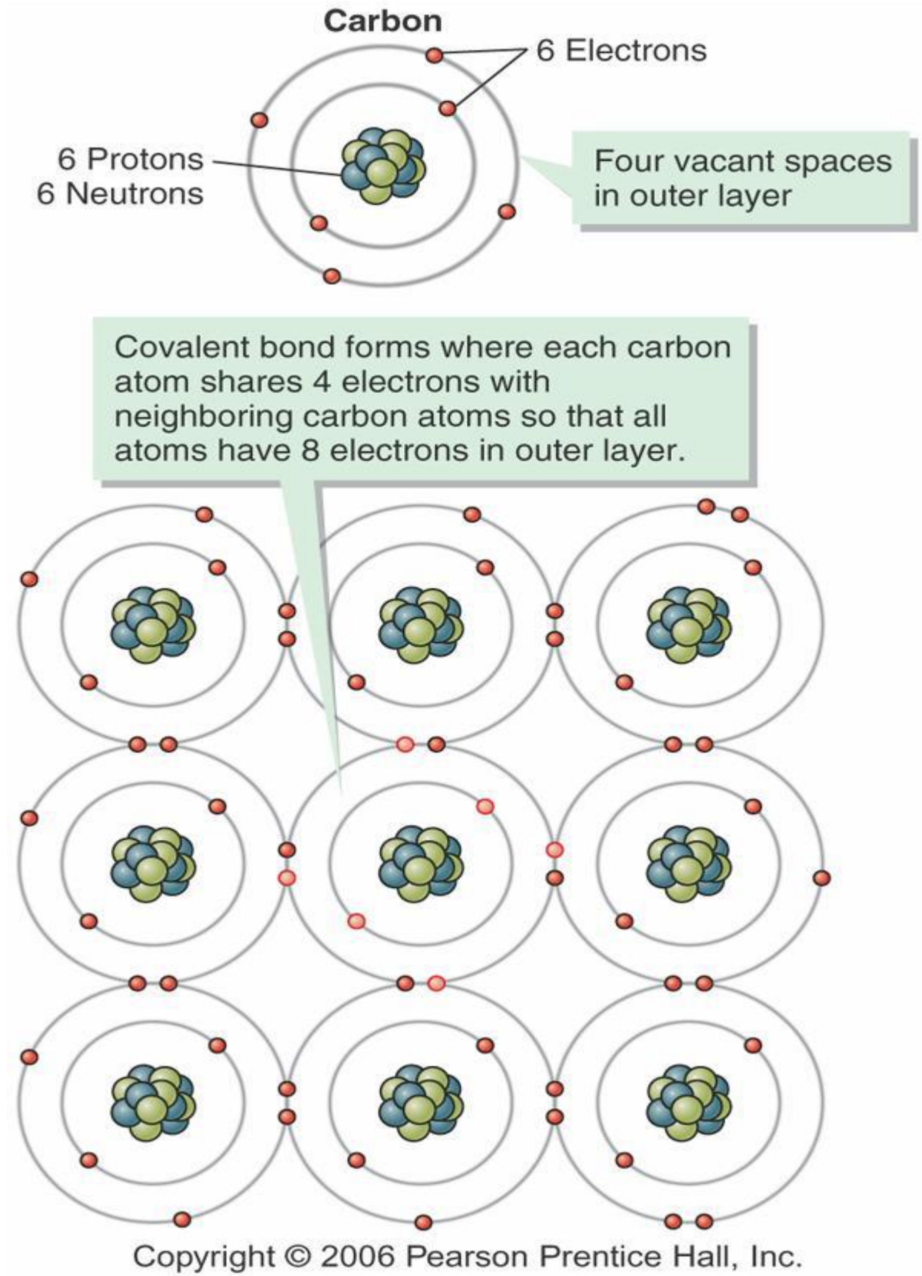
Example:

- H has one electron, needs to 2 to be stable. O has 6 electrons in its outer shell, needs 2 to be stable.
- So, 2 H atoms bond to 1 O to form H2O, with all atoms sharing electrons, and each atom having a stable electronic configuration part of the time.



Covalent Bonds...Cont.

- Covalent bonds
  - Atoms share valence electrons
  - This effectively fills all unfilled layers
  - Covalent bonds are strong

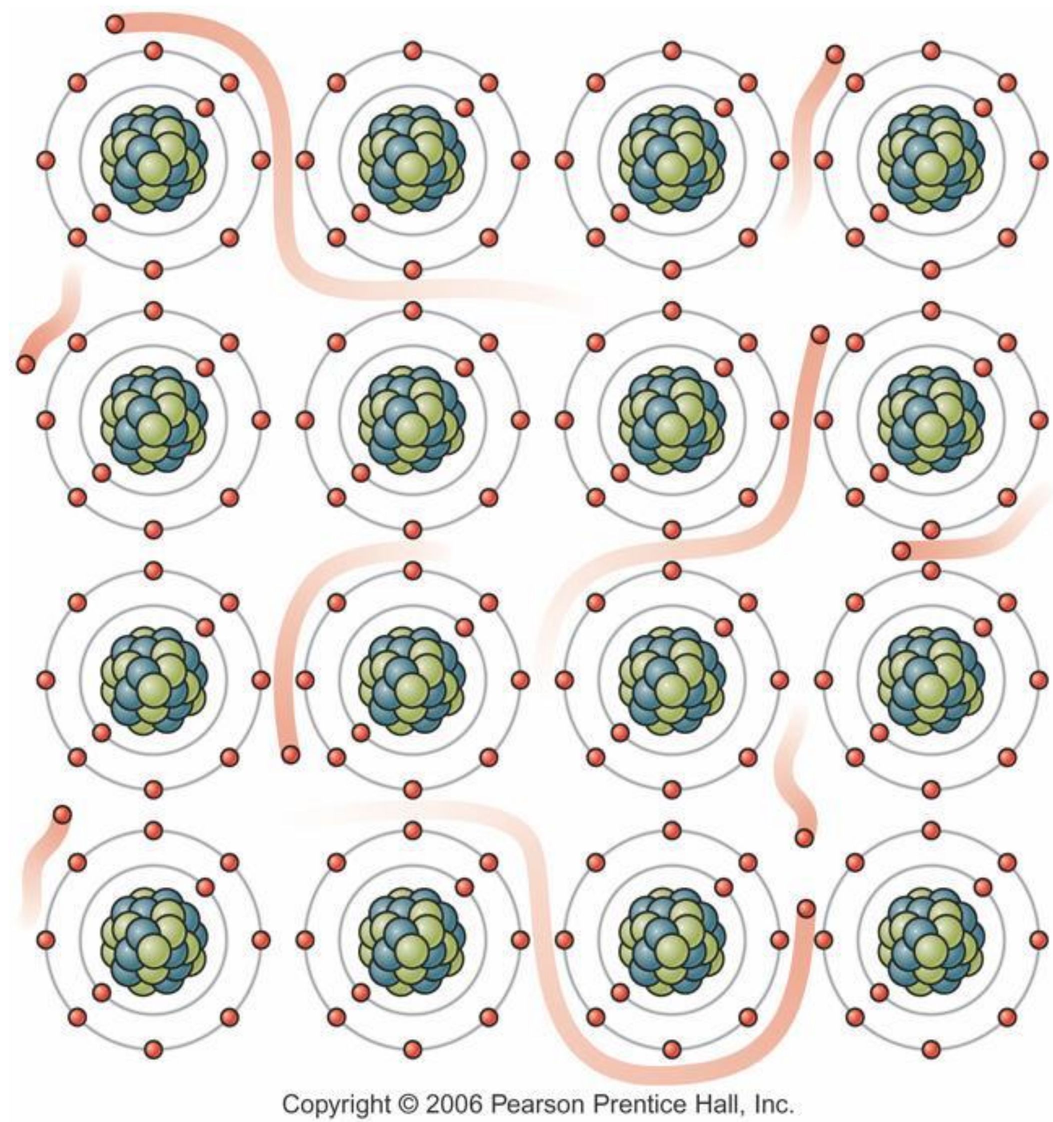


Metallic Bonds

- Similar to covalent bonding, except innermost electrons are also shared.
- In materials that bond this way, electrons move freely from atom to atom and are constantly being shared.
- Materials bonded with metallic bonds are excellent conductors of electricity because the electrons can move freely through the material.

Metallic Bonds

– Looks like covalent
– However, electrons are not shared with adjacent atoms
– Electrons are free to “roam” (delocalized)
– Gives metals their electrical conductivity



Van der Waals Bonds

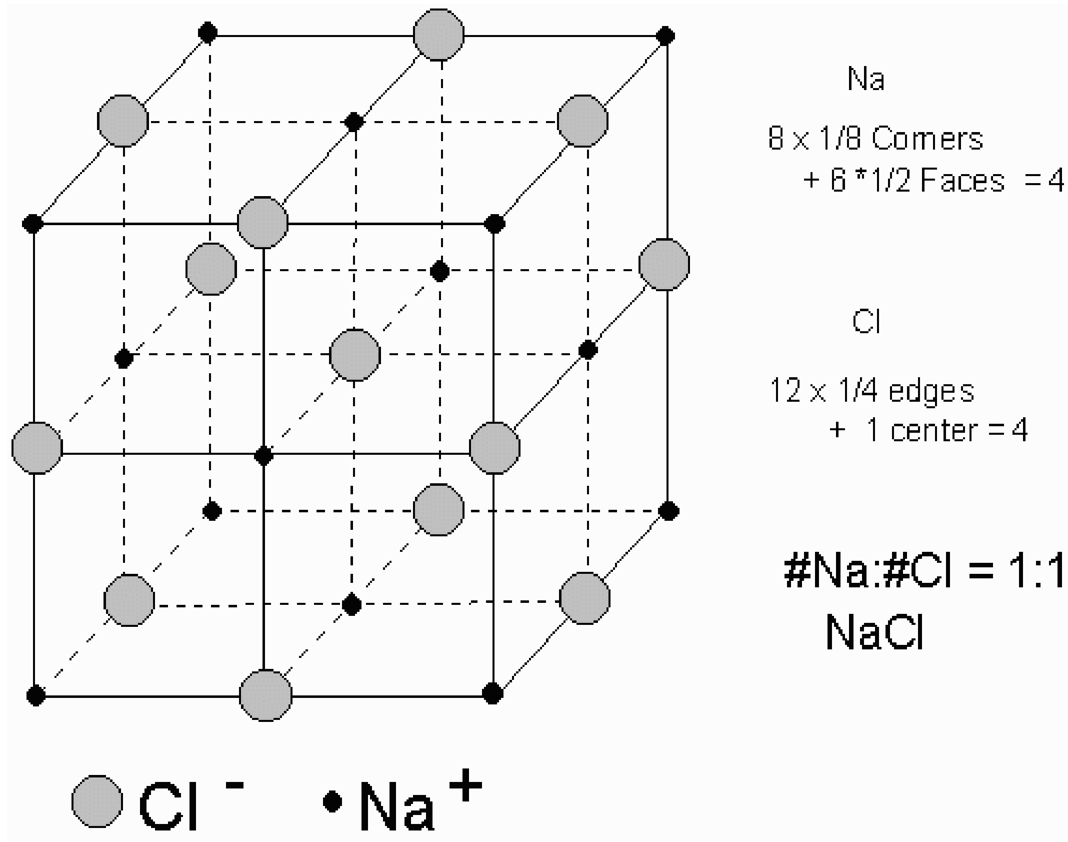
- A weak type of bond that does not share or transfer electrons.
- Usually results in a zone along which the material breaks easily (***cleavage).***
- Good examples's graphite and micas like biotite and muscovite.
- Several different bond types can be present in a mineral, and these determine the physical properties of the mineral.

Crystal Structure

- All minerals, by definition are also crystals. Packing of atoms in a crystal structure requires an orderly and repeated atomic arrangement.
- Such an orderly arrangement needs to fill space efficiently and keep a charge balance.
- Since the size of atoms depends largely on the number of electrons, atoms of different elements have different sizes.

Crystal Structure; Example of NaCl

- For each Na atom there is one Cl atom. Each Na is surrounded by Cl and each Cl is surrounded by Na.
- The charge on each Cl is -1 and the charge on each Na is +1 to give a charged balanced crystal.



Law Of Constancy Of Interfacial Angles

- Angles between the same faces on crystals of the same substance are equal.
- This is a reflection of ordered crystal structure.
- The structure of minerals is often seen in the shape of crystals.
- Crystal structure can be determined by the use of X-rays.

Law Of Constancy Of Interfacial Angles……Cont.

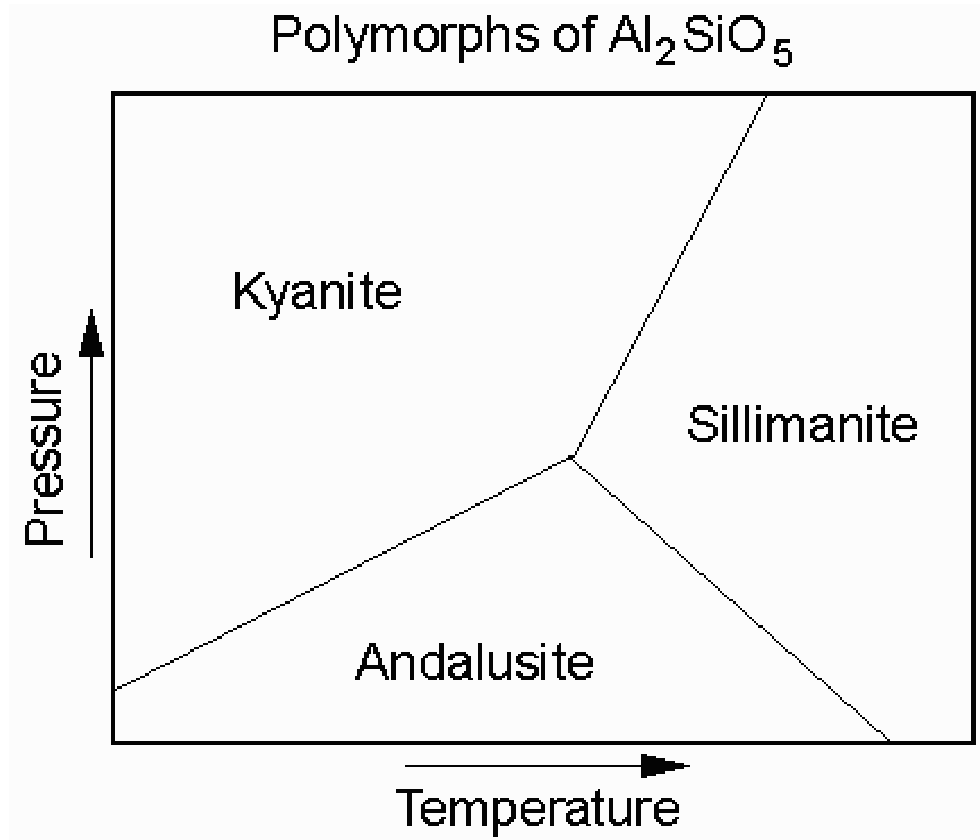
- A beam of X-rays can penetrate crystals but is deflected by the atoms that make up the crystals.
- The image produced and collected on film, can be used to determine the structure.
- The method is know as **X-ray diffraction**.
- Crystal structure depends on the conditions under which the mineral forms.

Polymorphs

- Are minerals with the same chemical composition but different crystal structures.
- The conditions are such things as temperature (T) and pressure (P), because these effect ionic radii.
- At high T atoms vibrate more, and thus distances between them get larger.
- Crystal structure changes to accommodate the larger atoms.
- At even higher T substances changes to liquid and eventually to gas.
- Liquids and gases do not have an ordered crystal structure and are not minerals.
- Increase in P pushes atoms closer together. This makes for a more densely packed crystal structure.

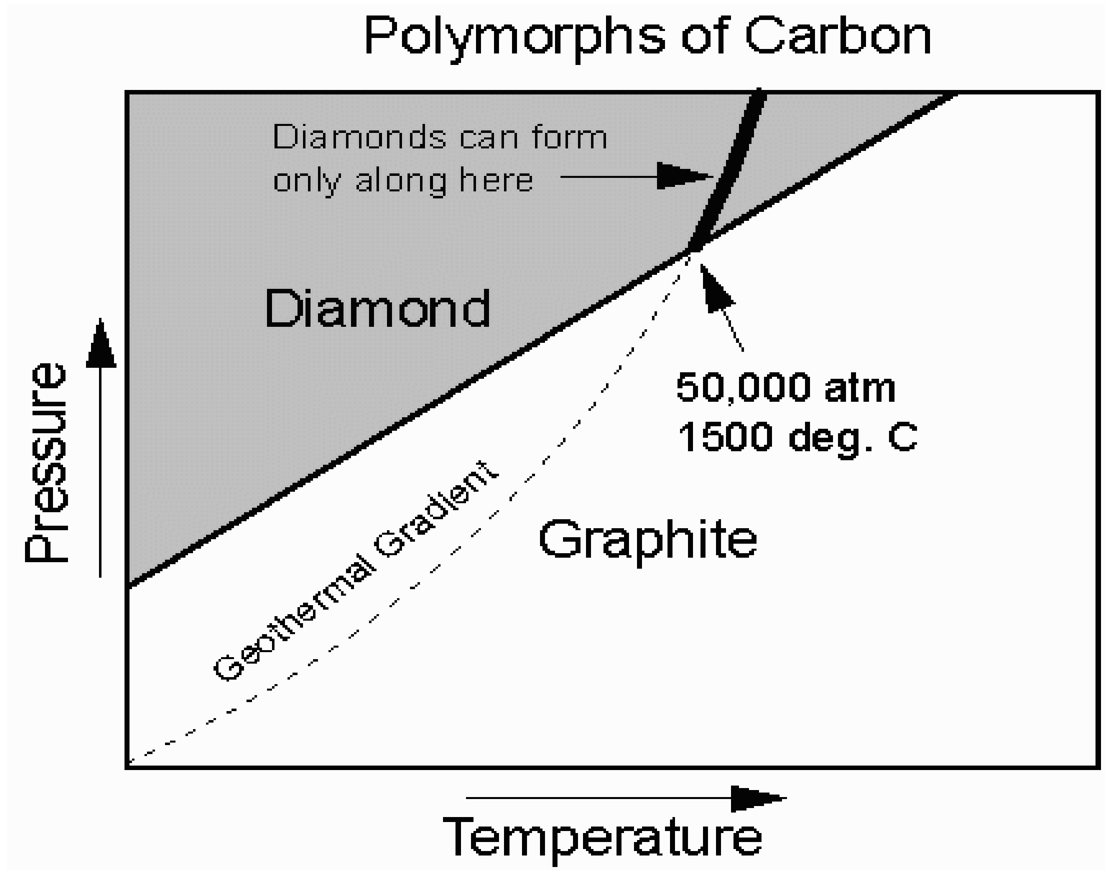
Examples of Polymorphs

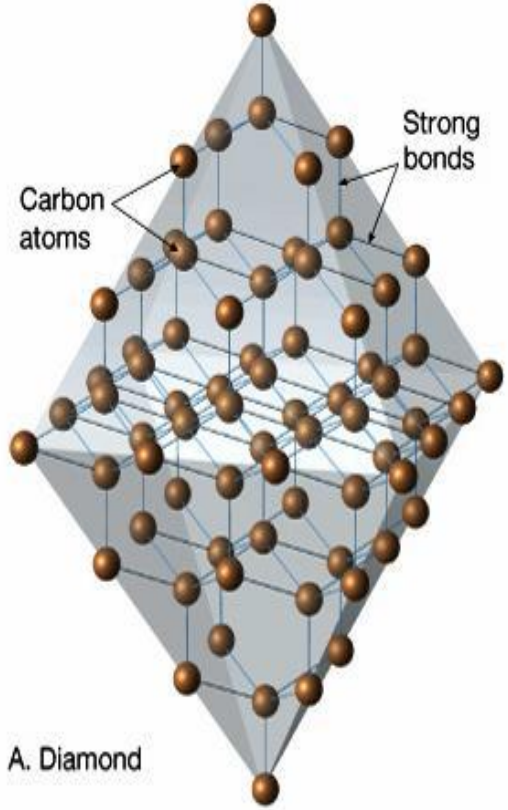
- The compound Al2SiO5 has three different ***polymorphs*** that depend on the temperature and pressure at which the mineral forms.
- At high P the stable form of Al2SiO5 is **kyanite**,
- At low P the stable from is **andalusite**, and
- At high T it is **sillimanite**.



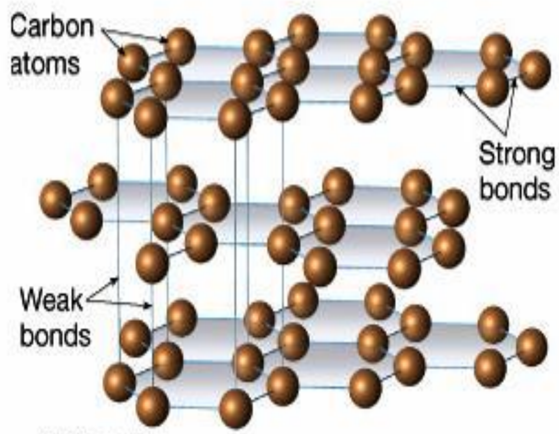
Examples of Polymorphs

- Carbon (C) has two different polymorphs. At low T and P pure carbon is the mineral graphite, (pencil lead), a very soft mineral.
- At higher T and P the stable form is diamond, the hardest natural substance known.





A. Diamond



B. Graphite


A. Diamond


B. Graphite

References:

Lecture Notes: Stephen A. Nelson
https://www.tulane.edu/~sanelson/

Minerals: Building Blocks of the Planet, Lutgens and Tarbuck, Lecture 2, 2006 Pearson Prentice Hall, Inc.