Matter and Minerals (Part 1)

- Properties of Atoms
- Isotopes
- Electron Shells
- Ions
- Bonding of Atoms
- Definition of a Mineral
- Crystal Structures
- Polymorphs
- Crystal Faces

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Matter And Minerals

The cave of crystals, Chihuahua, Mexico

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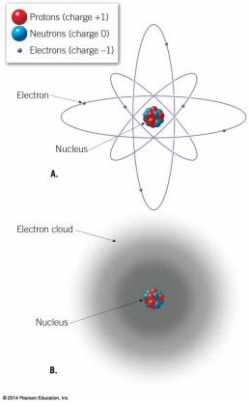
Atoms

An atom is the smallest unit of an element that retains the physical and chemical properties of that element



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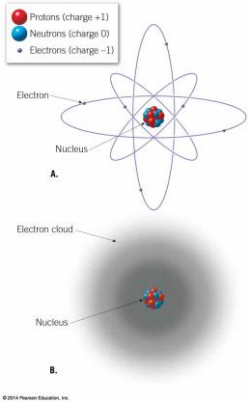
The Structure of Atoms

- An atom consists of different particles:
  - Proton: positively charged, atomic mass = 1
  - Neutron: no charge (neutral), atomic mass = 1
  - Electron: negative charge, atomic mass = 0
- Protons and neutrons comprise the nucleus of an atom while electrons orbit around the nucleus



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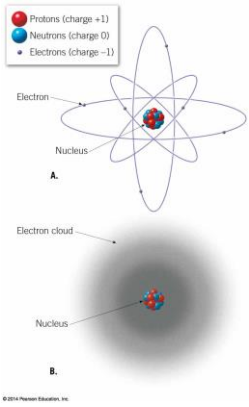
Properties of an Atom

- In an electrically neutral atom, the number protons = number electrons
- The number of protons an element contains is known as its atomic number
- The sum of the masses of all the protons and neutrons in the nucleus of an atom = atomic mass or weight



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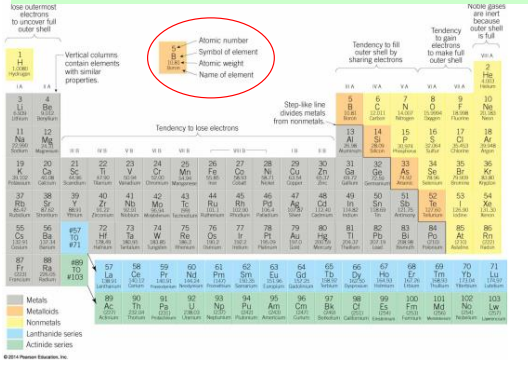
Elements Are Arranged In Order Of Increasing Atomic Numbers



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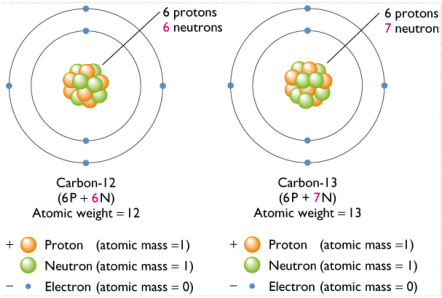
Isotopes Of An Element Have The Same Number Of Protons But Differ In The Number Of Neutrons



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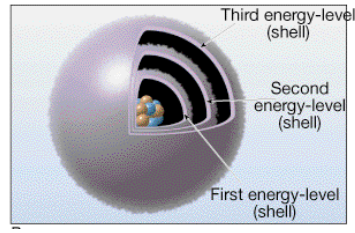
Electron Shells



- Electrons occur in electron shells (energy levels) around the nucleus
- Valence electrons are those in the outermost shell

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Table 2.1 Atomic Number and Distribution of Electrons

Element	Symbol	Atomic Number	Number of Electrons in Each Shell 1st	2nd	3rd	4th
Hydrogen	H	1	1			
Helium	He	2	2			
Lithium	Li	3	2	1		
Beryllium	Be	4	2	2		
Boron	B	5	2	3		
Carbon	C	6	2	4		
Nitrogen	N	7	2	5		
Oxygen	O	8	2	6		
Fluorine	F	9	2	7		
Neon	Ne	10	2	8		
Sodium	Na	11	2	8	1	
Magnesium	Mg	12	2	8	2	
Aluminum	Al	13	2	8	3	
Silicon	Si	14	2	8	4	
Phosphorus	P	15	2	8	5	
Sulfur	S	16	2	8	6	
Chlorine	Cl	17	2	8	7	
Argon	Ar	18	2	8	8	
Potassium	K	19	2	8	8	1
Calcium	Ca	20	2	8	8	2

Maximum two electrons in 1st electron shell

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Nitrogen	N	7	2	5		
Oxygen	O	8	2	6		
Fluorine	F	9	2	7		
Neon	Ne	10	2	8		
Sodium	Na	11	2	8	1	
Magnesium	Mg	12	2	8	2	
Aluminum	Al	13	2	8	3	
Silicon	Si	14	2	8	4	
Phosphorus	P	15	2	8	5	
Sulfur	S	16	2	8	6	
Chlorine	Cl	17	2	8	7	
Argon	Ar	18	2	8	8	
Potassium	K	19	2	8	8	1
Calcium	Ca	20	2	8	8	2

Maximum eight electrons in 2nd and 3rd electron shells

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Helium	He	2	2			
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Boron	B	5	2	3		
Carbon	C	6	2	4		
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Oxygen	O	8	2	6		
Fluorine	F	9	2	7		
Neon	Ne	10	2	8		
Sodium	Na	11	2	8	1	
Magnesium	Mg	12	2	8	2	
Aluminum	Al	13	2	8	3	
Silicon	Si	14	2	8	4	
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Argon	Ar	18	2	8	8	
Potassium	K	19	2	8	8	1
Calcium	Ca	20	2	8	8	2

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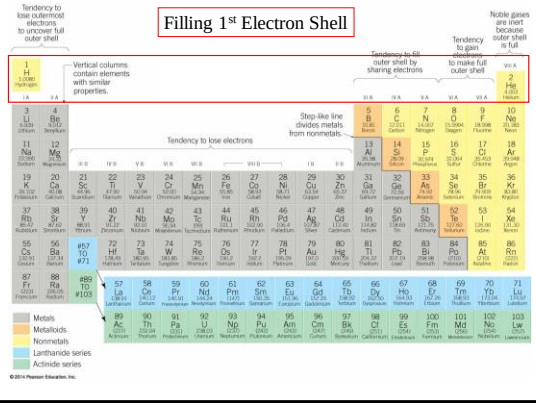
Filling 1st Electron Shell



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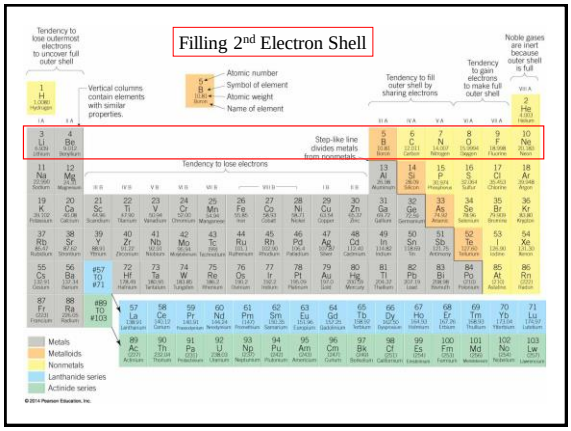

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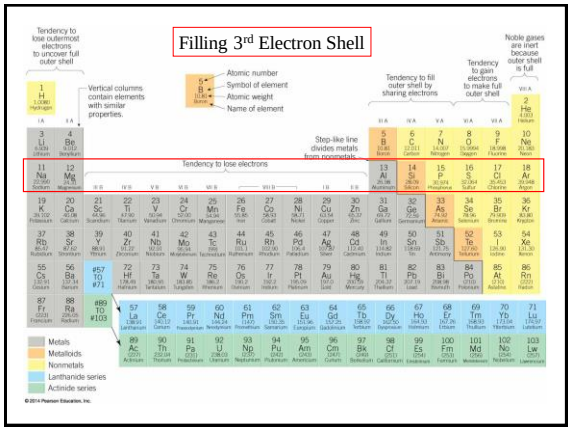

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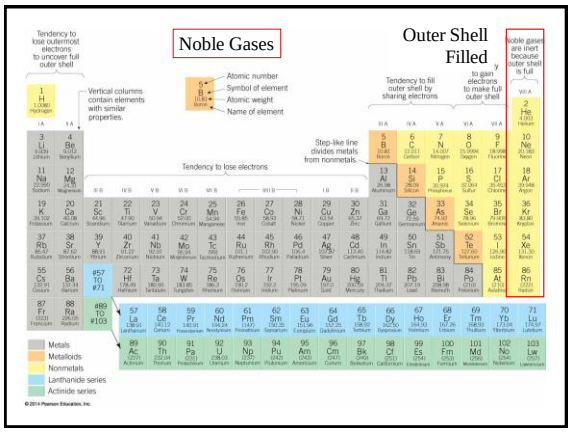

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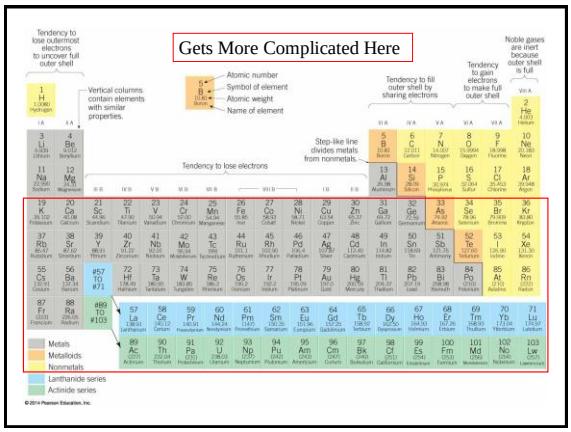

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Gaining and Losing Electrons

- **For an electrically neutral atom, the number of electrons = number of protons**
- **After gain or loss of an electron, the atom is no longer electrically neutral and is therefore called an ion**

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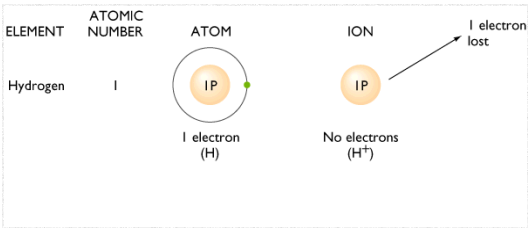
When a neutral atom loses an electron, it acquires a positive charge and is called a cation (e.g. H+, K+, Na+)



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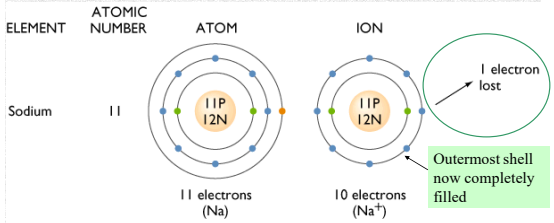
The Most Stable Configuration For An Atom Is To Have The Outermost Shell Completely Filled With Electrons



Sodium does this by getting rid of it's outermost lone electron, acquiring a positive charge

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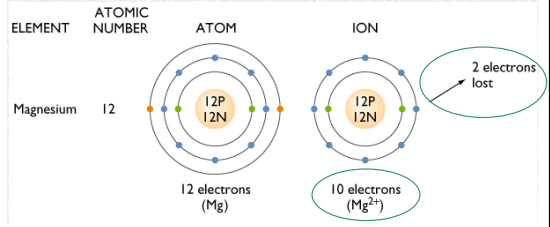
Some elements can lose more than one electron (e.g. Ca^{2+}, Mg^{2+})



Magnesium thus acquires a 2+ charge

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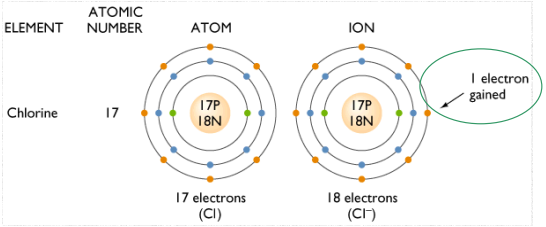
If a neutral atom gains an electron, it acquires a negative charge and is called an anion (e.g. Cl^-, Br^-)



Gaining one electron fills the outermost shell of chlorine

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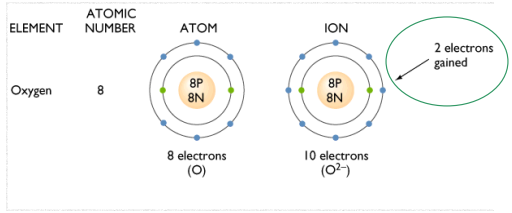
Some elements can gain more than one electron (e.g. O^{2-})



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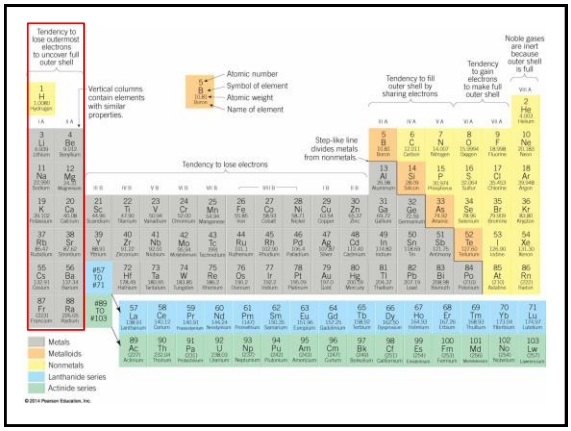

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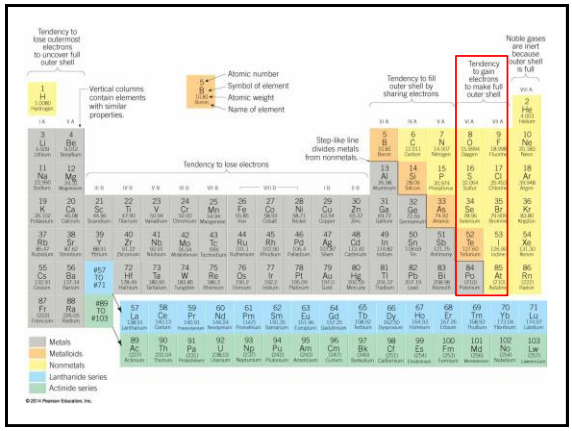

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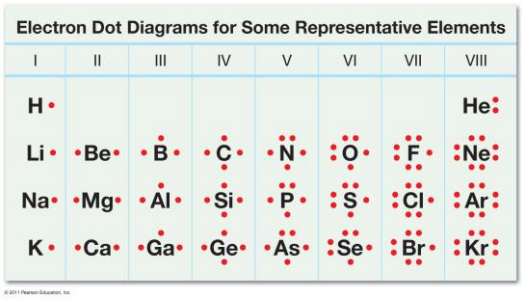

Each dot represents a valence electron in the outermost shell

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Chemical Reactions

- Elements can combine with other elements to form compounds:
  $Ca^{2+} + 2Cl^- = CaCl_2$
- Compounds can also react to form other compounds:
  $CaCO_3 + 2HCl = H_2CO_3 + CaCl_2$
  $H_2CO_3 = CO_2 + H_2O$

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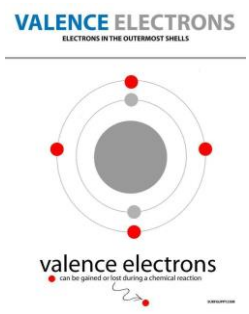
Chemical Reactions and Bonds

- In chemical reactions of most elements, only the valence electrons in the outermost shells interact
- Elements form chemical bonds in order to fill their outermost shells with electrons:
  - Ionic bonds
  - Covalent bonds
  - Metallic bonds



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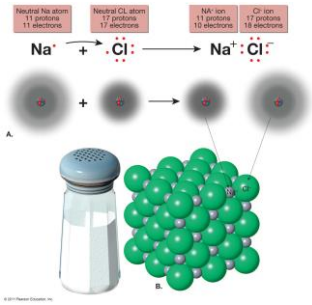
Ionic Bonds

- In ionic bonds, one element loses an electron to become positively charged
- Another element acquires the electron to become negatively charged
- The oppositely charged ions are attracted and bond



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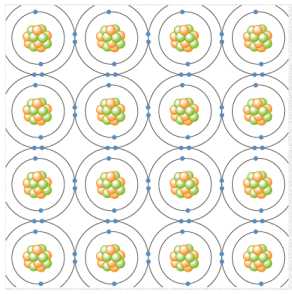
Covalent Bonds

- In covalent bonds, electron orbits (shells) of elements can overlap with those of adjacent elements
- Electrons are therefore shared
- Complex ions like CO_3^{2-}, SO_4^{2-}, and NO_3^- form through a combination of ionic bonding and electron sharing



Carbon atoms sharing electrons in diamond

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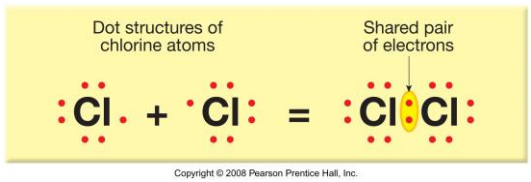
Covalent Bonding Between Two Chlorine Atoms To Form Cl_2 Gas



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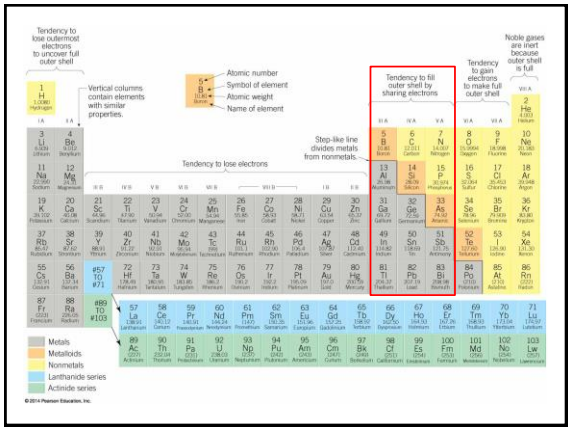

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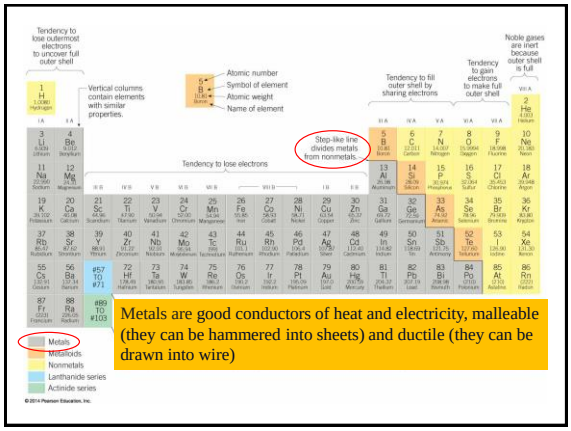

Metals are good conductors of heat and electricity, malleable (they can be hammered into sheets) and ductile (they can be drawn into wire)

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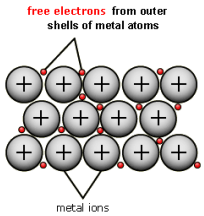
Metallic Bonds

- Metallic atoms pack together as cations
- Electrons are mobile and move about freely
- Electrons are dispersed and shared among the cations
- Occurs among a small number of minerals like copper and some sulfides



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Definition of a Mineral

- Naturally occurring and therefore generally found in nature
- Solid within temperature range normally found at Earth's surface
- Orderly crystalline structure where atoms are arranged in an orderly, repetitive manner
- Well-defined chemical composition
- Generally inorganic even though some may contain carbon

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Minerals

- A mineral constitutes an orderly arrangement of atoms
- Different minerals can have different atomic arrangements (crystal structures)

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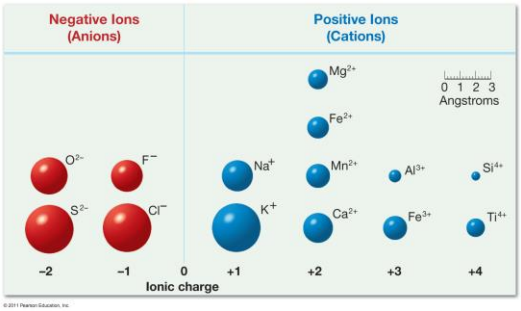
Atoms are of different sizes and charges, which can affect the type of crystal structure formed when they bond together



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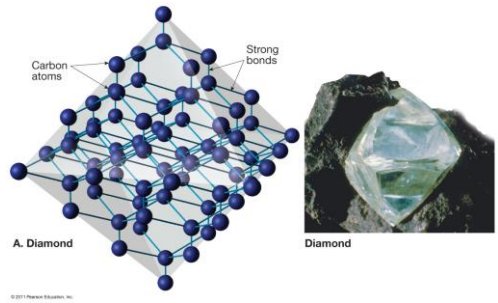
In diamond, each carbon atom shares electrons with four adjacent carbon atoms (covalent bonds) in a tetrahedral arrangement



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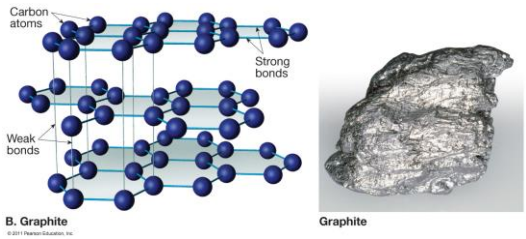
The arrangement of carbon atoms in graphite is different from that of diamonds, resulting in very different properties for the two minerals



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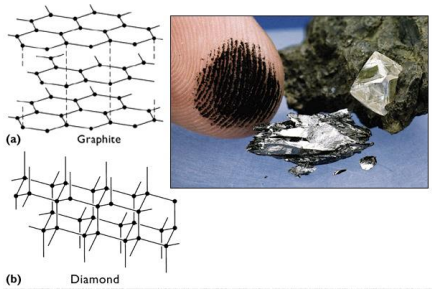
Graphite And Diamond Are Both Composed Entirely Of Carbon Atoms But Have Different Crystal Structures



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Polymorphs

- **Two minerals that have the same chemical composition but differ in crystal structure are termed 'polymorphs'**
- **Examples:**
  - **Graphite/diamond**
  - **Calcite/aragonite**
  - **Low temperature quartz/cristobalite (high temperature)**

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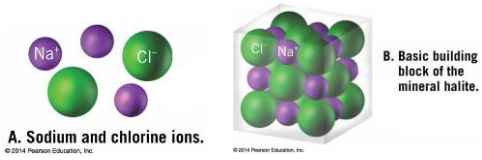

- In Halite (NaCl), sodium and chlorine form ionic bonds
- Each sodium atom is bonded to six chlorine atoms and each chlorine atom is bonded to six sodium atoms.
- This arrangement results in the atomic structure of a cube

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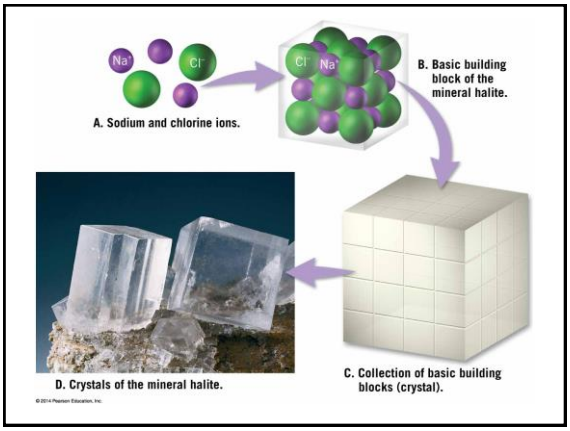

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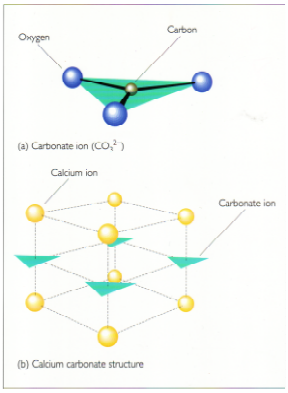
The Crystal Structure of Calcite ($CaCO_3$)



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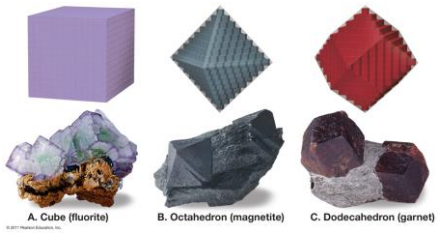
Crystals of Minerals



- Different minerals have different crystal forms due to differences in the internal arrangement of atoms
- We cannot see the atomic arrangement of a mineral directly, but we can view the overall shape of the crystal

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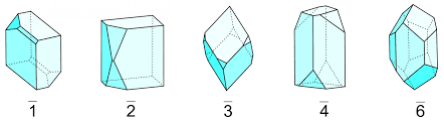
Crystal Faces



- Crystal faces are relatively flat surfaces formed by the natural growth of minerals
- Faces are produced naturally during the process of crystal growth
- Faces intersect at well-defined angles that depend on the internal arrangement of atoms

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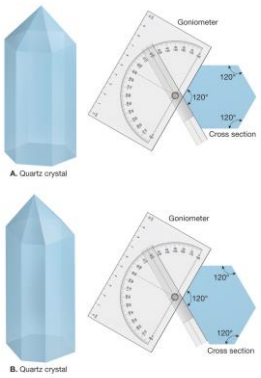
Crystal Faces and Angles

Although some faces of a crystal may grow larger than others, the angles between equivalent faces are constant for a given mineral



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Crystal Faces Of Quartz

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