MSE200
Lecture 18 (CH. 11.1, 11.3)
Ceramics

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Objectives/outcomes: You will learn the following:

- Ceramic crystal structures.
- Diamond and graphite.
- Structure of AX compounds:
- Structure of AX_2 compounds,
- The Perovskite ($BaTiO_3$) structure.
- Silicate structures. The SiO_4 tetrahedron.

Ceramic articles








http://video.google.com/videosearch?gbv=2&hl=en&q=ceramic&ie=UTF-8&sa=N&tab=iv

Introduction on Ceramics

- **Bounding: ionic or covalent**
- **Physical properties:**
  - electrical and heat insulation
  - Magnetic, piezoelectric (special ceramics)
- **Mechanical Properties: Brittle**
- **Chemical properties: stabile and high melting temperature.**
- **Traditional Ceramics: Basic components (Clay and Silica).**
- **Engineering Ceramics: Pure compounds (Al_2O3, SiC, etc).**

Ionic and Covalent Bonding in Simple Ceramics

- **Mixture of Ionic and Covalent Types.**
- **Depends on electronegativity difference.**

Table 10.2

Ceramic compound	Bonding atoms	Electronegativity difference	% ionic character	% covalent character
Zirconium dioxide, ZrO_2	Zr–O	2.3	73	27
Magnesium oxide, MgO	Mg–O	2.2	69	31
Aluminum oxide, Al_2O_3	Al–O	2.0	63	37
Silicon dioxide, SiO_2	Si–O	1.7	51	49
Silicon nitride, Si_3N_4	Si–N	1.3	34.5	65.5
Silicon carbide, SiC	Si–C	0.7	11	89

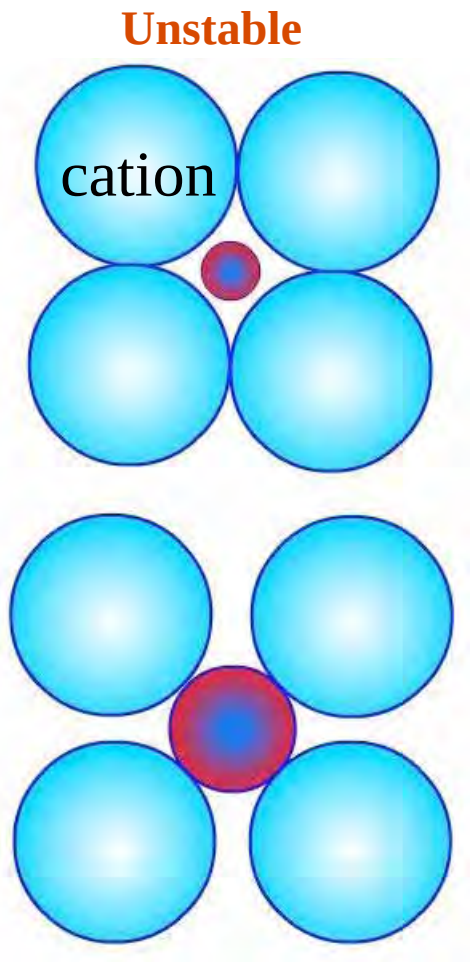
$$\%\ \text{ionic character} = \left[1 - e^{-(X_A - X_B)^2/4}\right] 100\%$$

Simple Ionic Arrangements

- **Packing of Ions depends upon**
  - **Size:**
  - **Charge:**

- **Radius ratio = r_{cation}/r_{anion}**
- **Critical radius ratio for stability**

  for coordination numbers 8, 6 and 3 are >0.732, >0.414 and > 0.155 respectively.



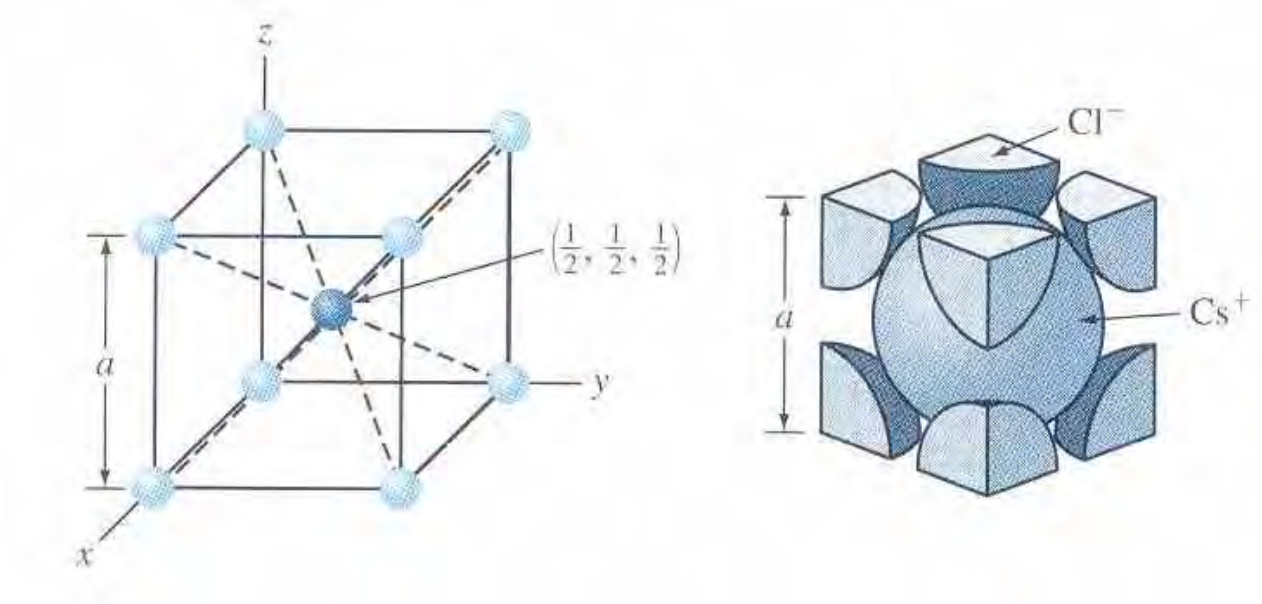
Critical radius ratio

Disposition of ions about central ion	CN	Range of cation radius ratio to anion radius
Corners of cube	8	≥0.732
Corners of octahedron	6	≥0.414
Corners of tetrahedron	4	≥0.225
Corners of triangle	3	≥0.155

CN = Coordination number

Cesium Chloride Crystal Structure

- **CsCl is ionically bonded with radius ratio = 0.94 and CN = 8.**



Sodium Chloride Crystal Structure

- **Highly Ionically bonded with Na^+ ions occupying interstitial sites between FCC and Cl^- ions.**
- **Radius ratio = 0.56, CN = 6.**
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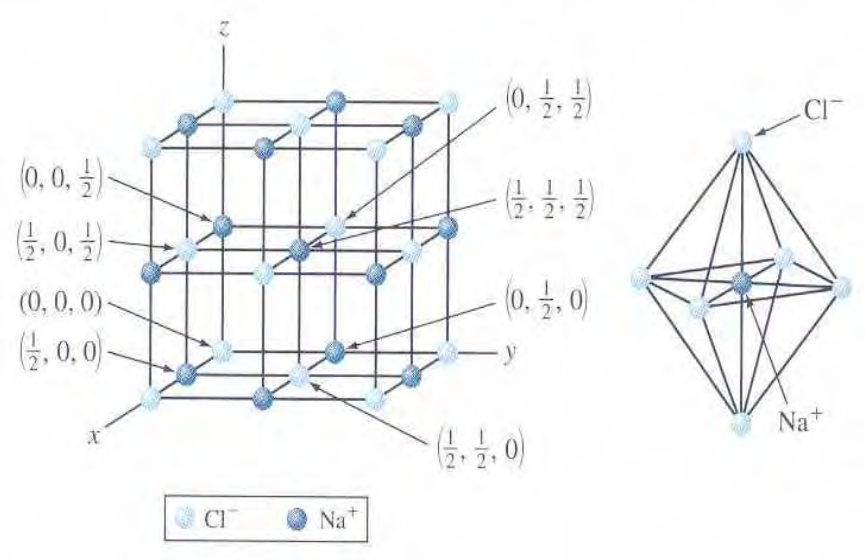
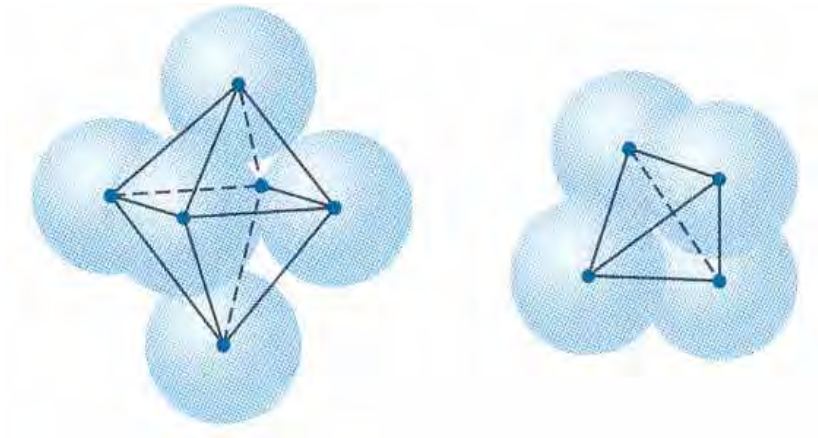
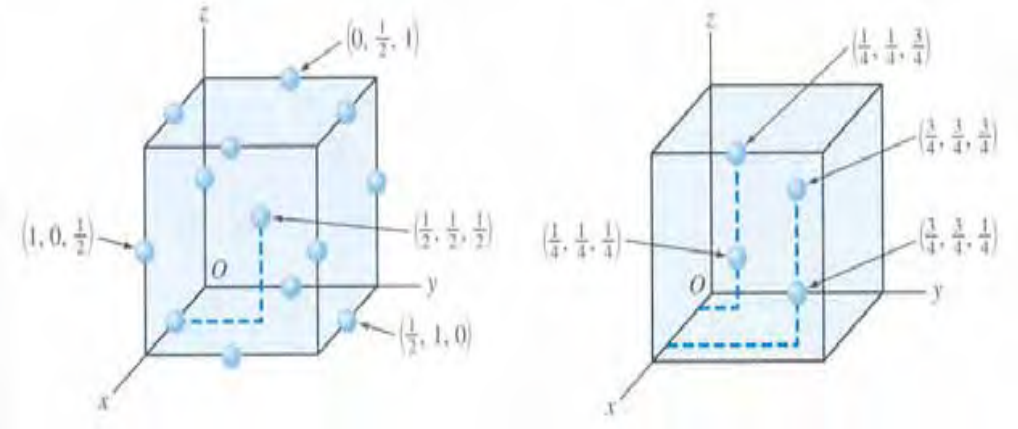


Interstitial Sites in FCC Crystal Lattices

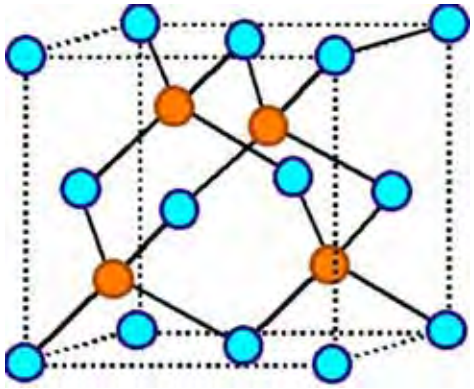
- **Octahedral interstitial sites: Six nearest atoms or ions equidistant from central void.**
- **Tetrahedral Interstitial Sites: Four nearest atoms or ions equidistant from central void.**
- **There are four octahedral sites and eight tetrahedral sites per unit cell of FCC.**

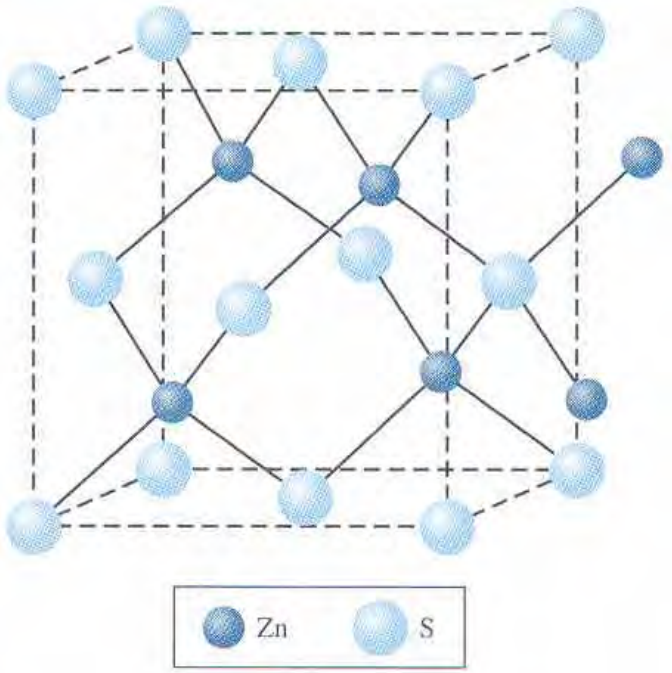




Zinc Blende (ZnS) Crystal Structue

- **One type (Zn or S) occupies lattice points and another occupies half (4) of interstitial sites of FCC unit cell.**
- **Tetrahedrally covalently bonded**
- **CN = 4**





Calcium Fluorite (CaF2) Crystal Structure

- **Ca^{2+} ions occupy the FCC lattice sites while the F^- ions are located at eight tetrahedral sites.**
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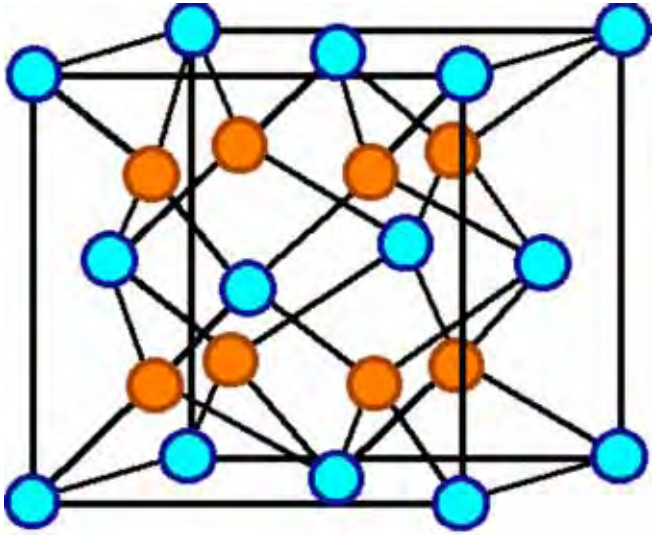
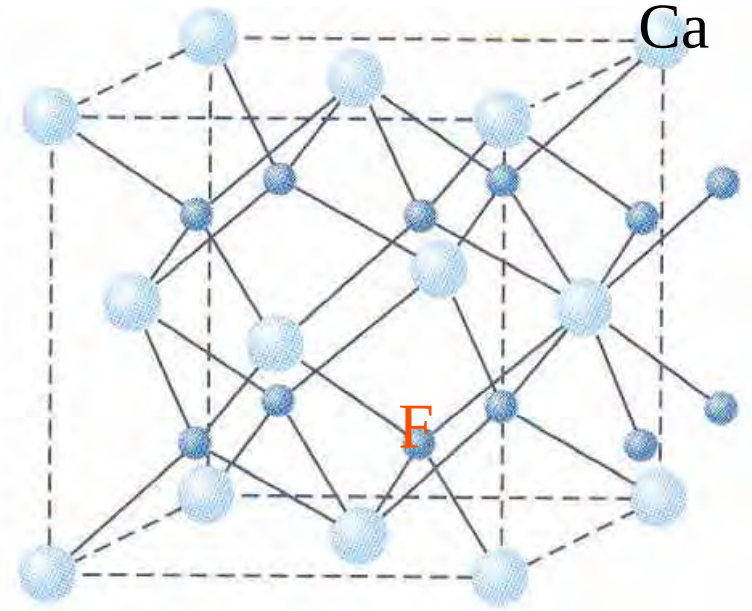
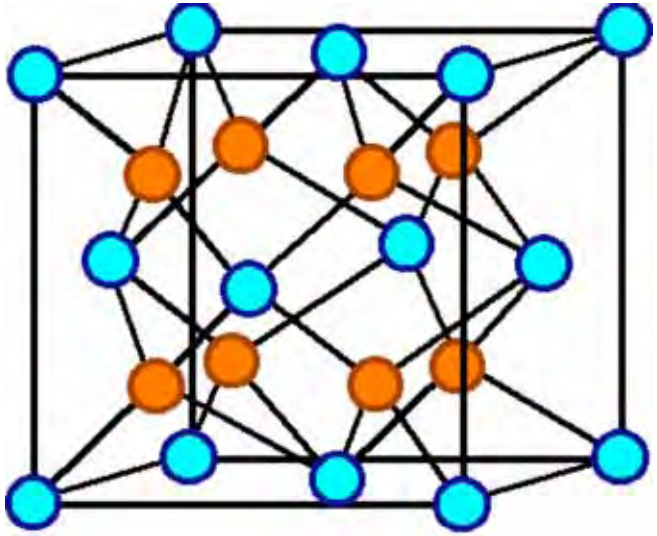


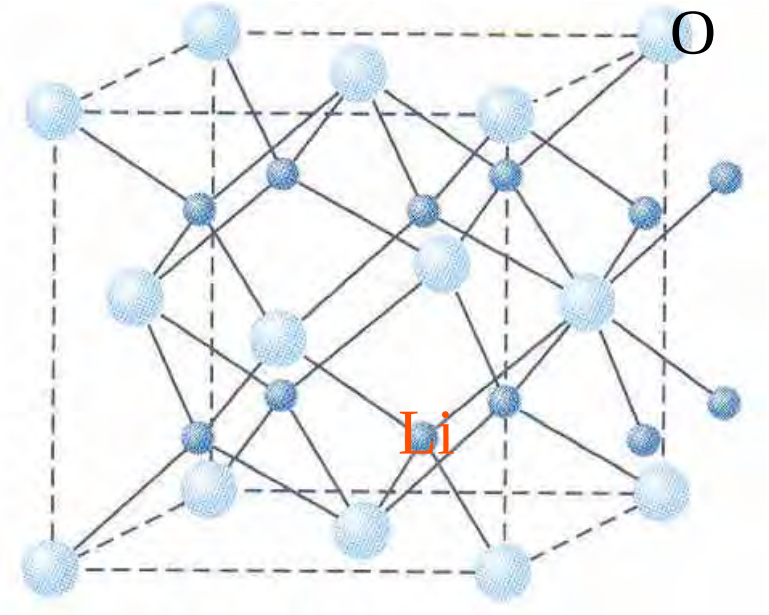


Other Crystal Structures

- **Antifluorite: Anions occupy lattice points and cations occupy eight tetrahedral sites of FCC.**

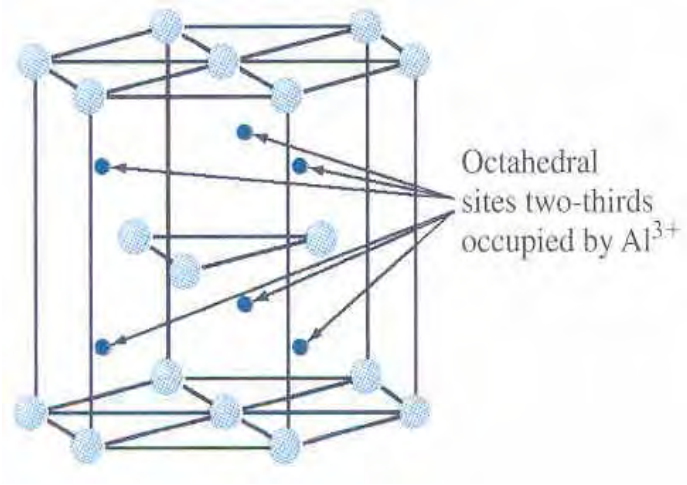
  Examples: Li_2O, Na_2O





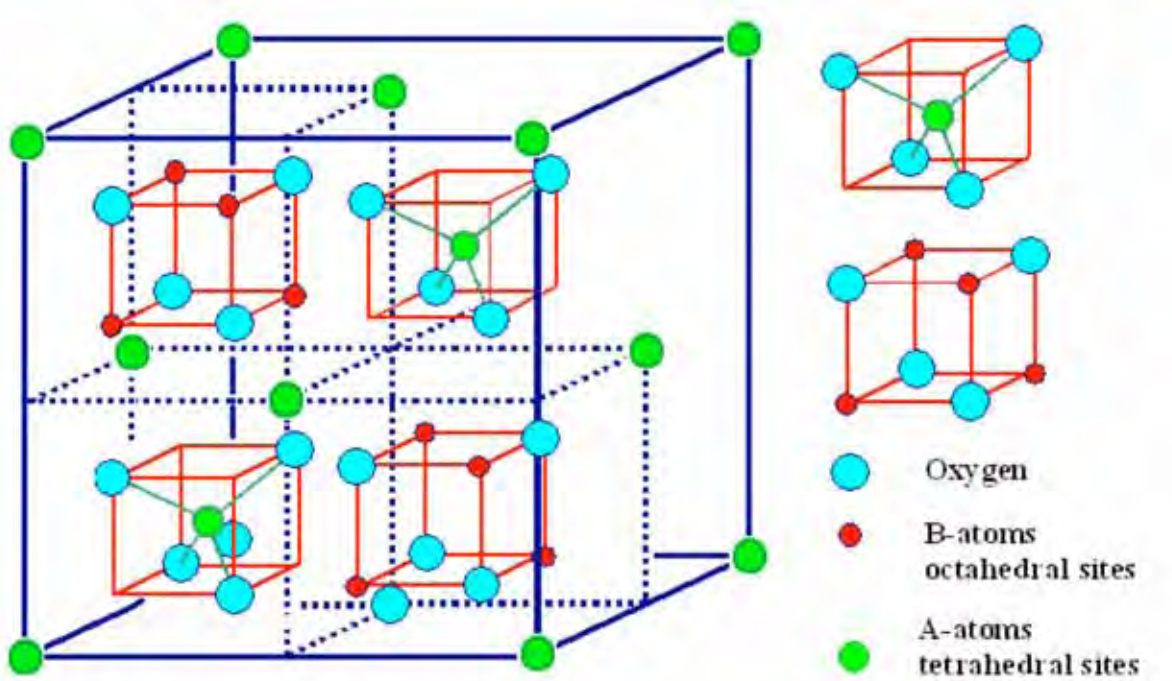
Corundum

- **Oxygen ions in lattice points of HCP unit cell.**
  - **Two Al^{3+} ions in octahedral sites for every three O^- ions**
    - **Al^{3+} occupy 2/3 of the octahedral sites**
    - **distortion of structure.**

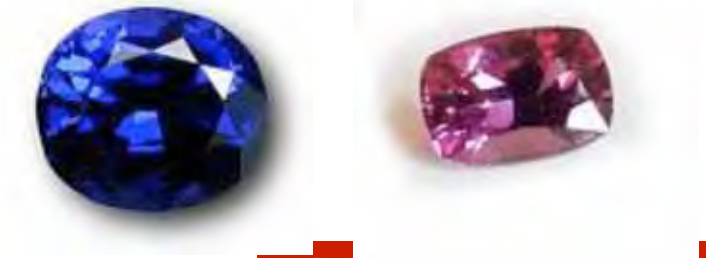


Spinel ($MgAl_2O_4$) or (AB_2O_4)

- **Oxygen ions form FCC lattice and Mg and Ml ions occupy interstitial sites**



AB_2O_4 **spinel** The red cubes are also contained in the back half of the unit cell

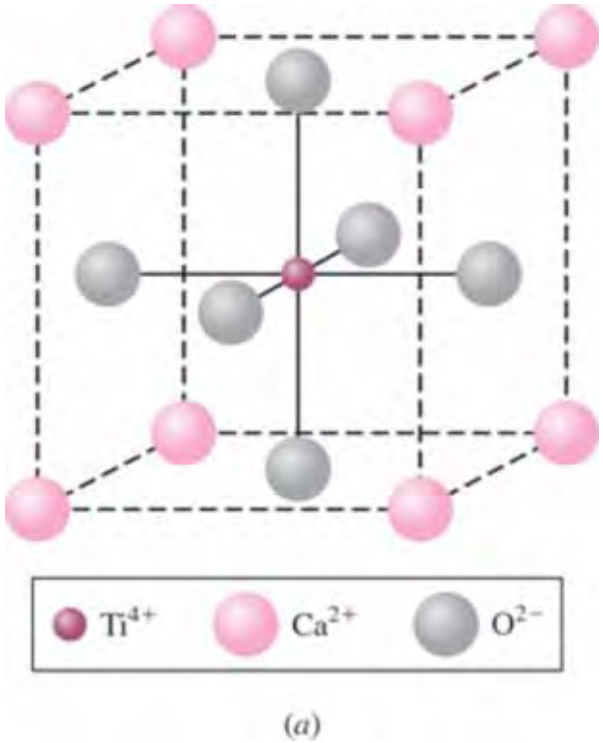


http://images.google.com/images?hl=en&q=spinel&btnG=Search+Images&gbv=2

http://video.google.com/videosearch?q=spinel&hl=en&emb=0&aq=f#

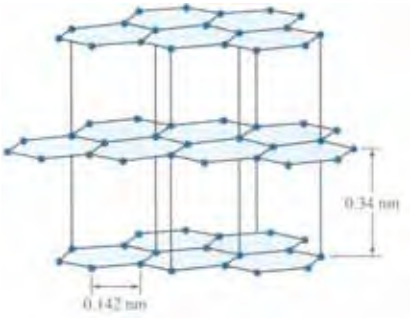
Other Crystal Structures

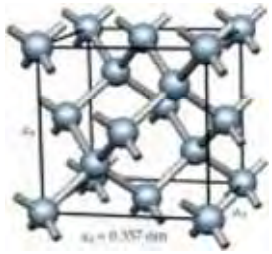
- **Perovskite ($CaTiO_3$) : Ca^{2+} and O^{2-} ions form FCC unit cell.**
  - **Ca^{2+} Ions occupy corners**
  - **O^{2-} Ions occupy face centers.**
  - **Ti4+ ions are at octahedral sites.**

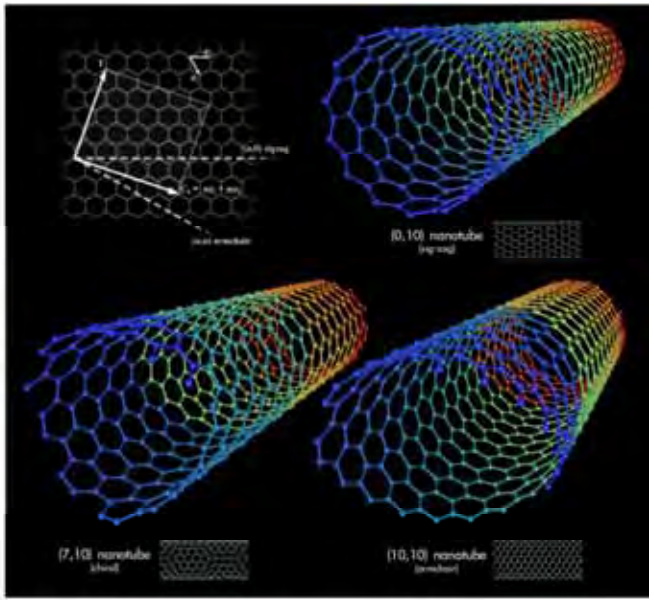


Carbon structures

- **Graphite : Polymorphic form of compound.**
- **Layered structure with carbon atoms in hexagonal arrays.**
- **Good lubricating properties**
- **Diamond:**
- **Carbon Nanotubes**
- **C60 (buckyball)**

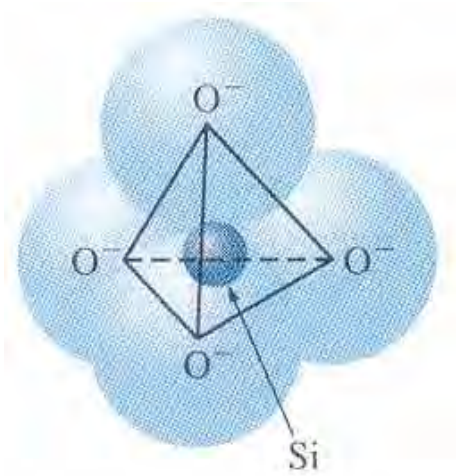


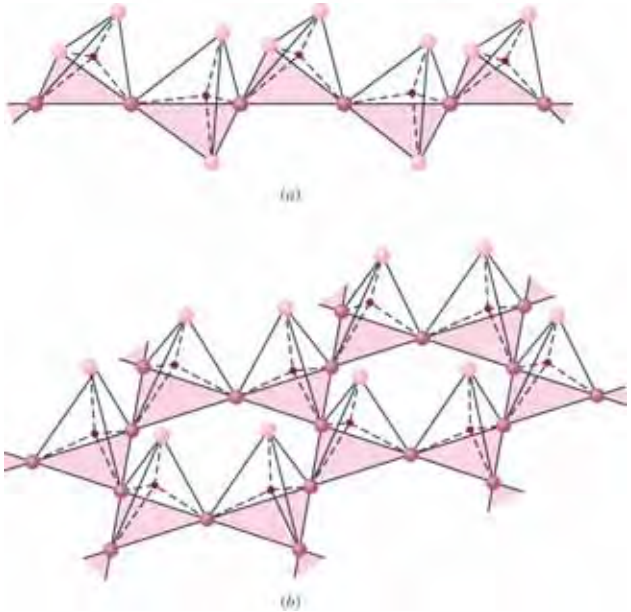




Silicate Structures

- **Silicate (SiO_4^{4-}) is building block of silicates.**
- **Chain/ring structure: Two corners of each SiO_4^{4-} tetrahedron bonds with corners of other tetrahedron.**



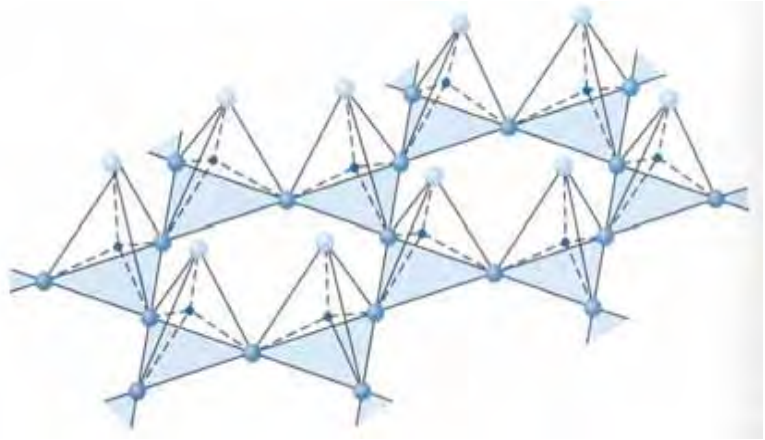


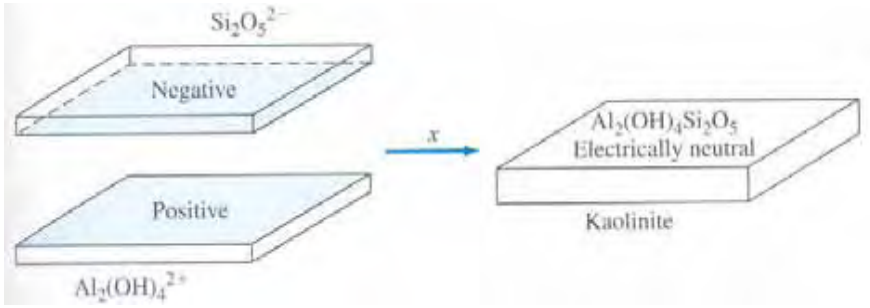
Sheet Structures of Silicates

- **Sheet structure: Three corners of same planes of silicate tetrahedron bonded to the corners of three other silicate tetrahedra.**
- **If the bondings are weak,**

  sheets slide over each other

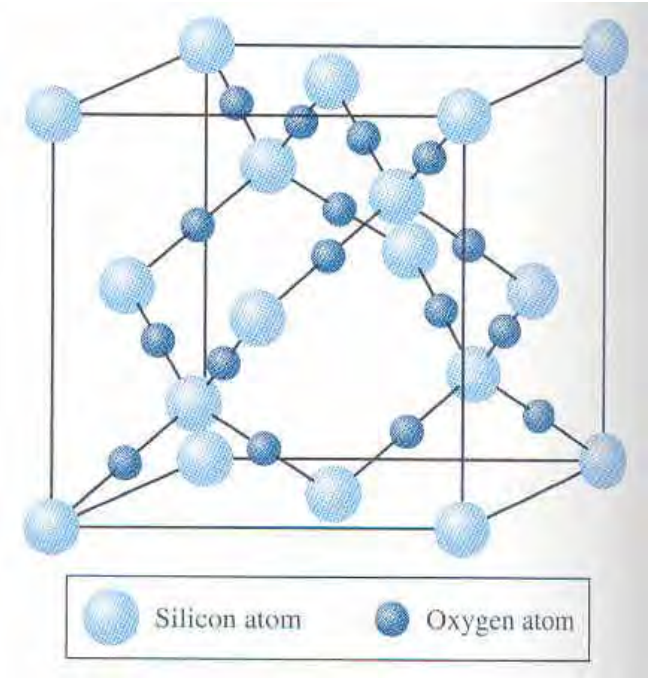
  easily.





Silicate Networks

- **Silica: All four corners of the SiO_4^{4-} tetrahedra share oxygen atoms.**
- **Basic structures: Quartz, tridynute and cristobarlite.**
- **Important compound of many ceramic and glasses.**
- **Feldspars: Infinite 3D networks.**
- **Some Al3+ Ions replace Si4+ Ions: Net negative charge.**
- **Alkaline and alkaline fit into interst**



Homework

- **Chapter 11:** 11.5, 11.7, 11.8, 11.9. 11.10,
- Example problems: 11.1, 11.2, 11.3, 11.4, 11.7, 11.8,
- Reading assignment: Sections 11.6, 11.8