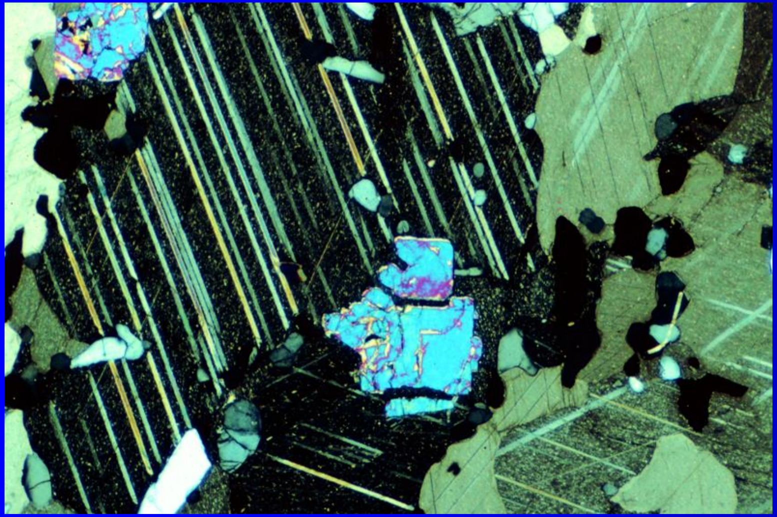
Minerals



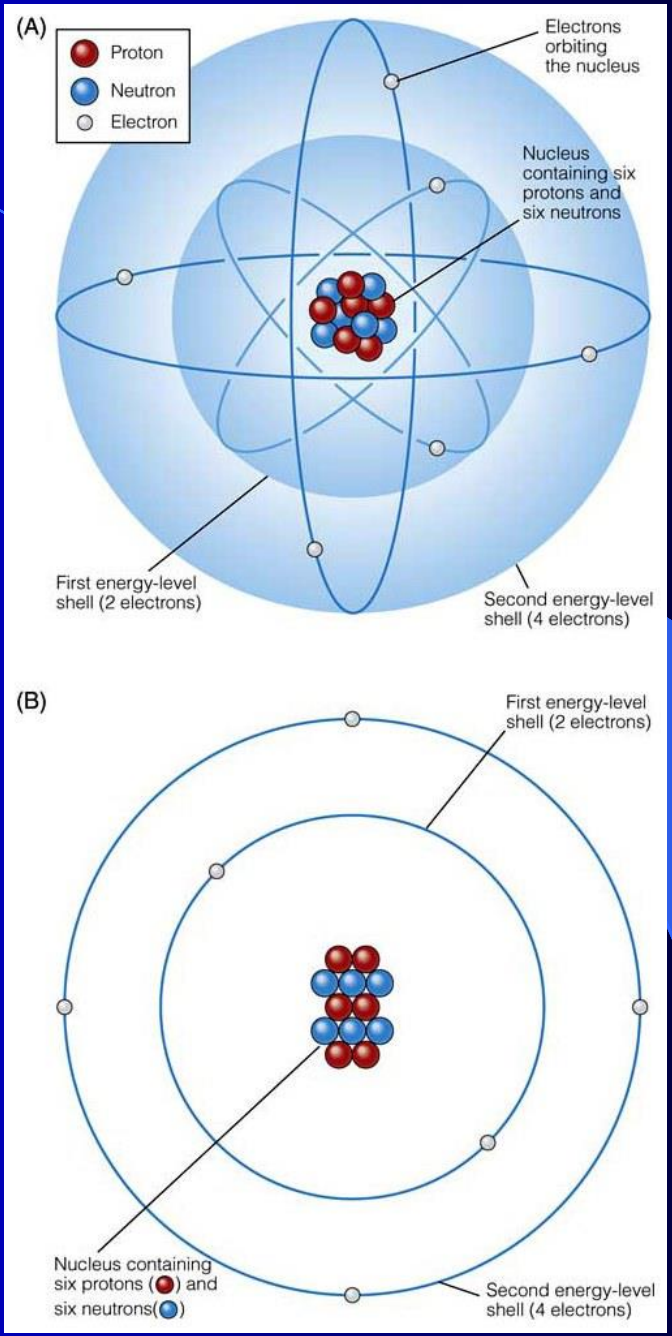

Atomic number

Atomic mass

Isotopes

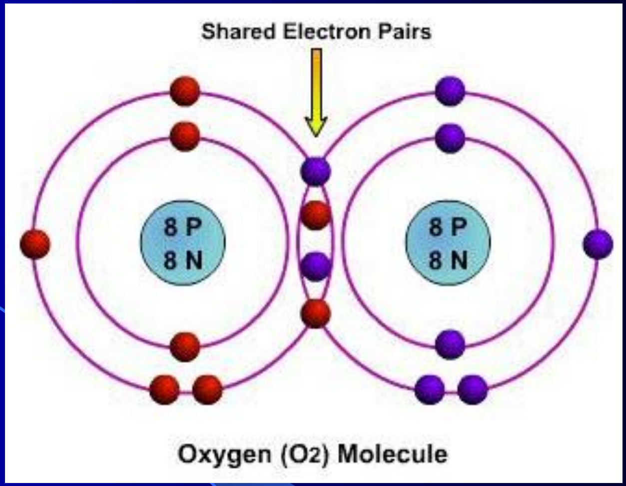
Neutral atom

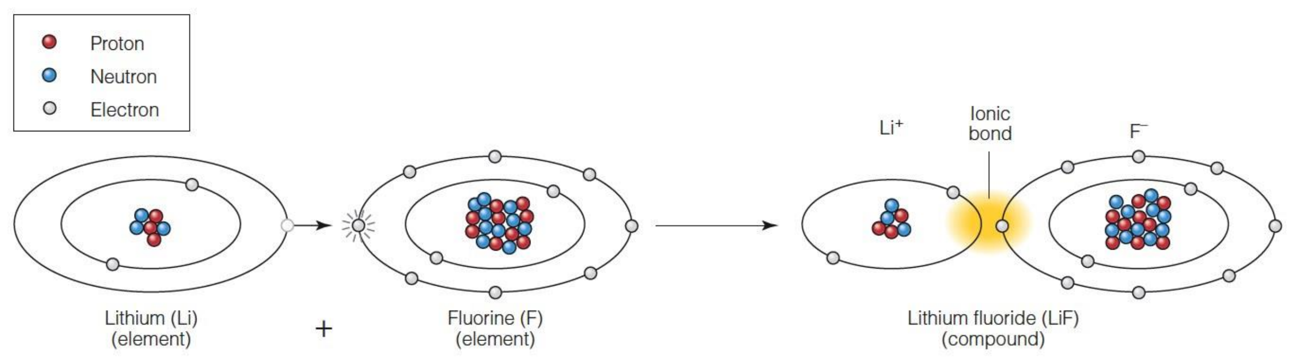
Ions

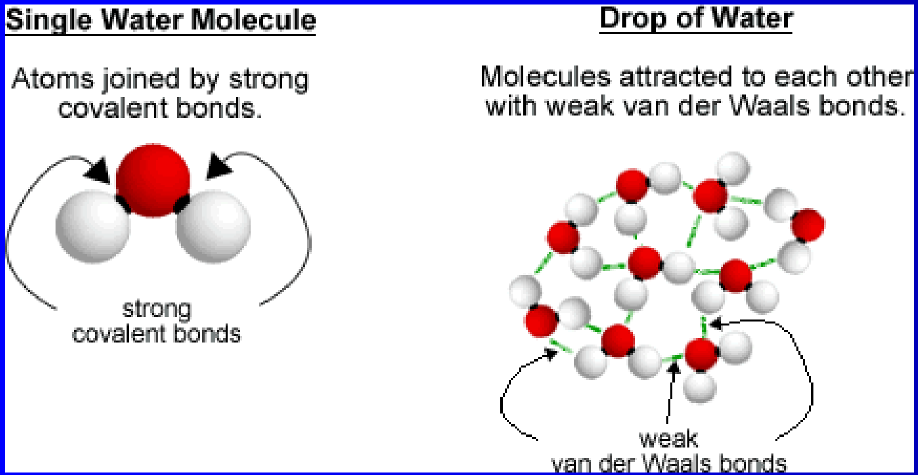


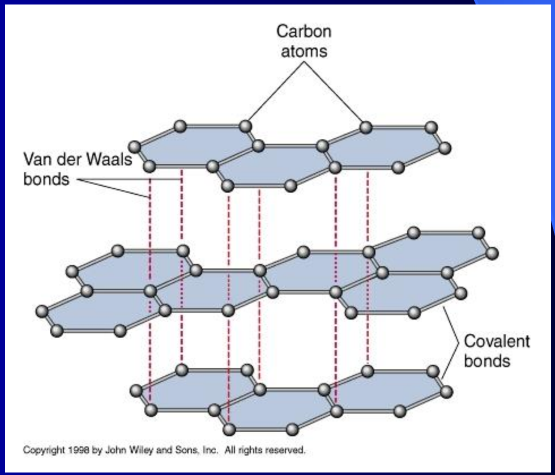
Types of Bonds

- Ionic
- Covalent
- van der Waals







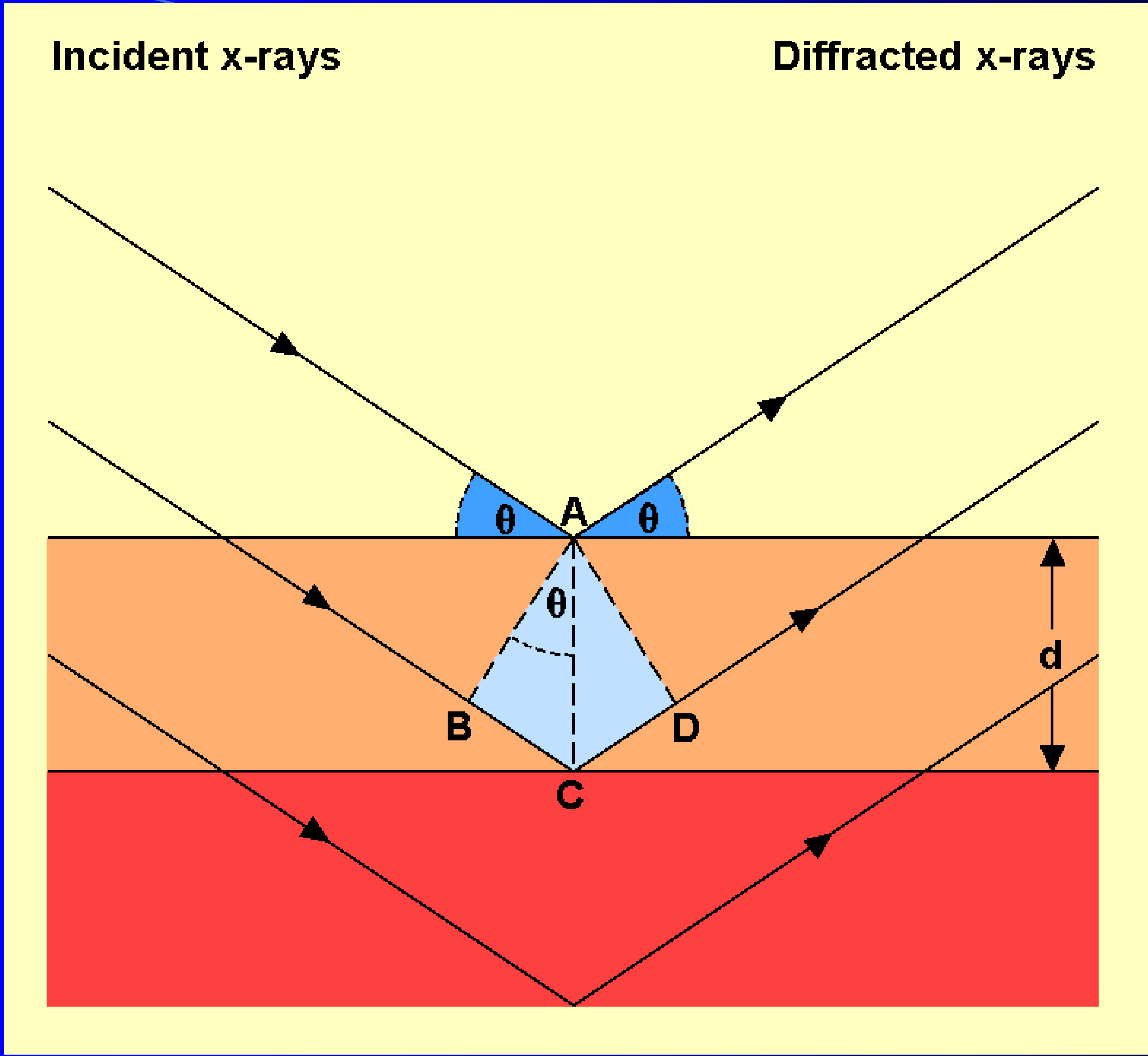


Mineral

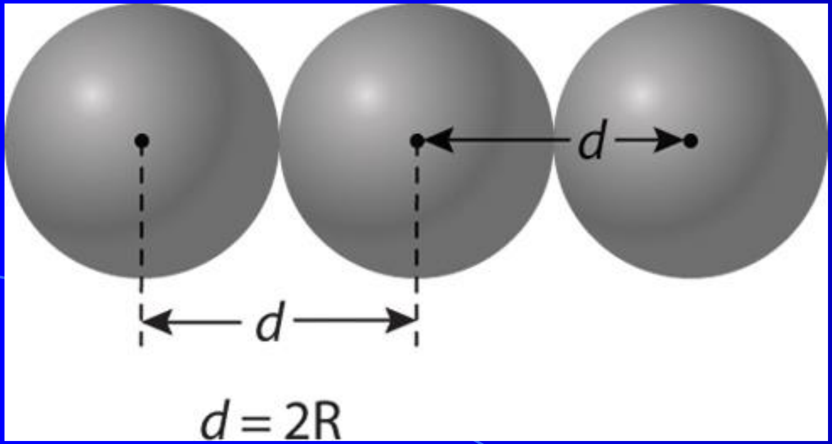
- Naturally formed
- Inorganic
- Solid
- Specific chemical composition
- Characteristic crystal structure

The two characteristics that best allow the study of minerals are

1. Crystal structure: the way the atoms of the elements are packed together
2. Composition: the major chemical elements that are present and their proportions



Bragg’s law: $\lambda = 2d \sin\theta$ and $d = \lambda/(2d \sin\theta)$. θ = angle of incidence and diffraction when Bragg’s law conditions are met. d = interplanar spacing.



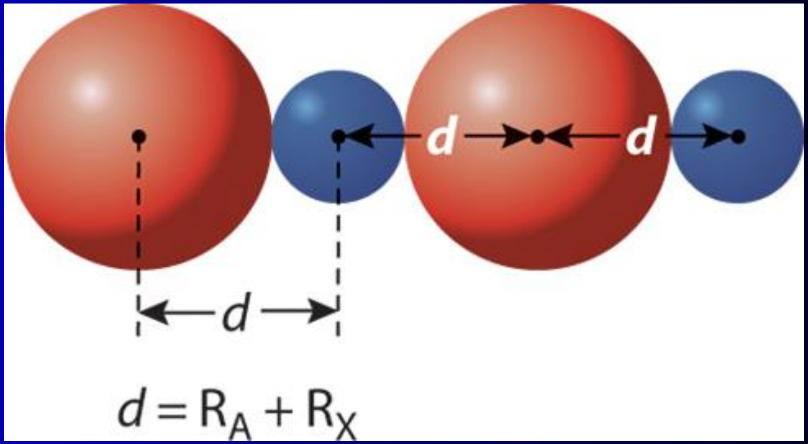


Table 4.3 Atomic radii in Ångstroms for 12-fold coordination.

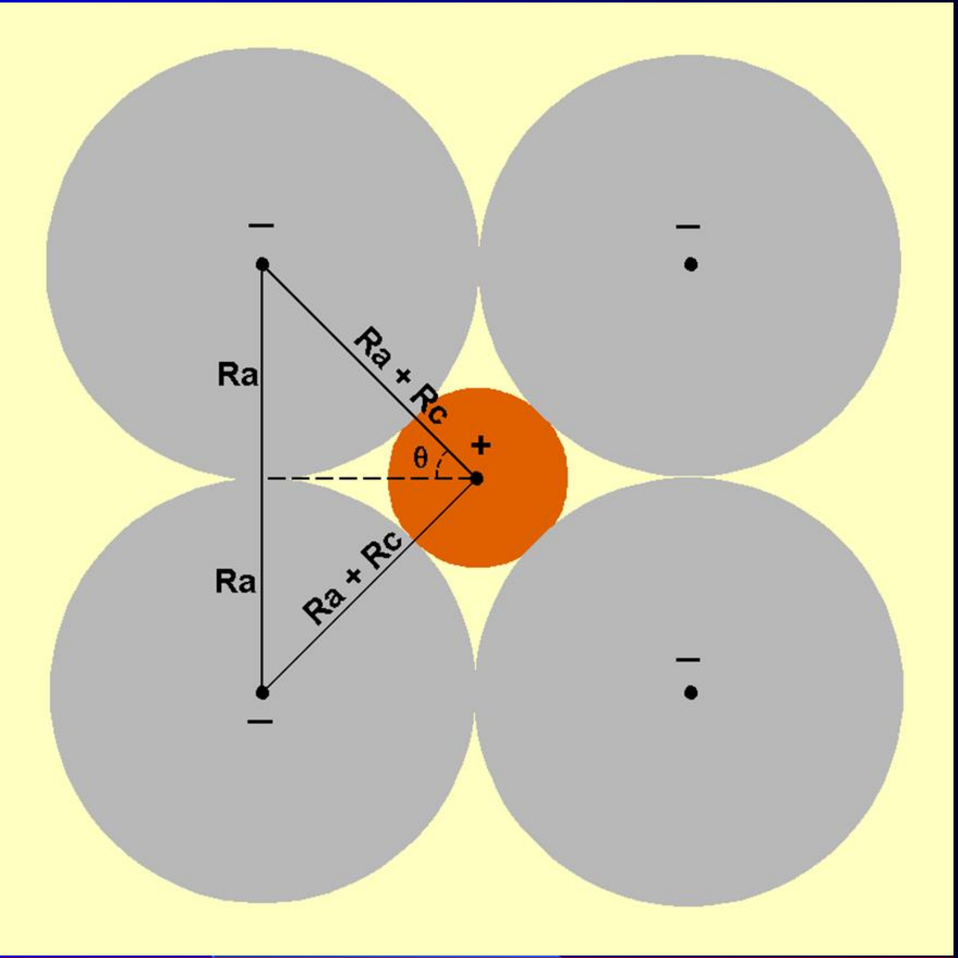
Atom	Radius	Atom	Radius
Li	1.57	Cr	1.29
Be	1.12	Mn	1.37
Na	1.91	Fe	1.26
Mg	1.60	Cu	1.28
Al	1.43	Ag	1.44
K	2.35	Sn	1.58
Ca	1.97	Pt	1.39
Ti	1.47	Au	1.44

Source: Wells (1991)

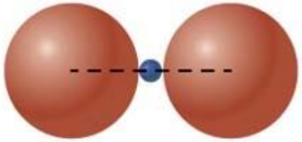
Coordination Principle

Radius Ratio = Radius cation/Radius Anion

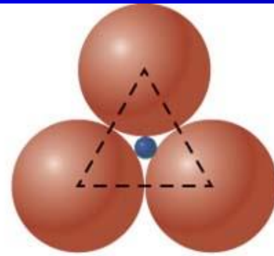
This ratio determines how many anions can be packed around a cation.



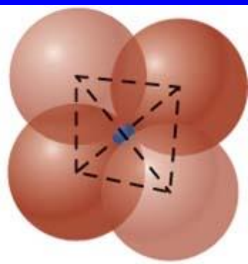
Packing of anions around a cation for a coordination number of 4. The minimum radius ratio can be calculated from the geometry of the packing. R_a and R_c are the radii of the anion and cation, respectively. In this case, $\theta = 45^o$.



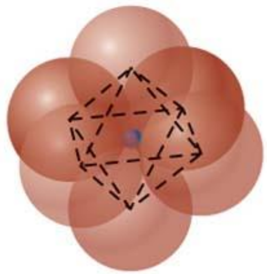
(A) Linear <0.155



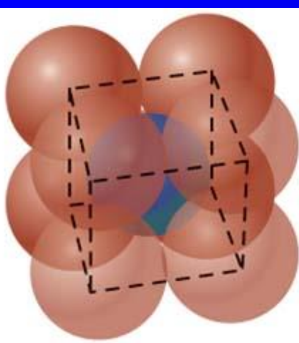
(B) Triangular 0.155–0.225



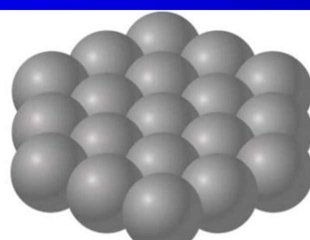
(C) Tetrahedral 0.225–0.414



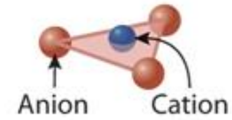
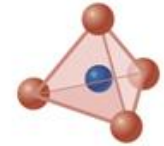
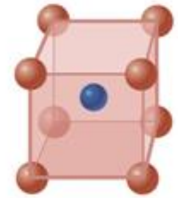
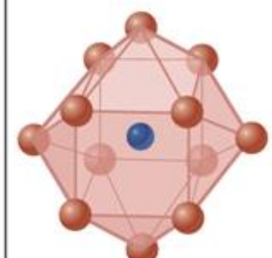
(D) Octahedral 0.414–0.732



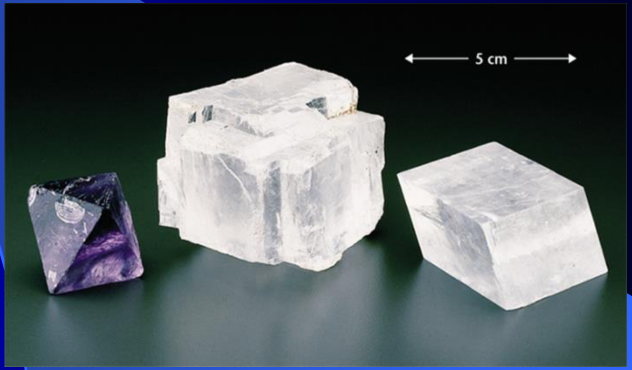
(E) Cubic 0.732–1.0



(F) 1.0

Radius ratio R_A/R_X limits	C.N.	Geometric shape	
0.155 to 0.225	III		Corners of an equilateral triangle (triangular coordination)
0.225 to 0.414	IV		Corners of a tetrahedron (tetrahedral coordination)
0.414 to 0.732	VI		Corners of an octahedron (octahedral coordination)
0.732 to 1.0	VIII		Corners of a cube (cubic coordination)
1.0	XII		Corners of a cuboctahedron (close packing)

Mineral Identification



Physical Properties:

- Habit
- State of aggregation
- Color
- Luster
- Cleavage
- Hardness
- Specific gravity (density)
- Fluorescence
- Magnetism

Habit – visible external shape of a mineral

A. Prismatic – elongate with the bounding faces forming a prism-like shape

B. Columnar – rounded columns

C. Acicular – “needle-like”

D. Tabular – flat like a board

E. Bladed – elongate and flat

F. Fibrous – threadlike masses

G. Dendritic – leaflike branching

H. Foliated – stack of thin leaves or plates

I. Capillary – hairlike or threadlike thin crystals

J. Massive – specimen totally devoid of crystal faces

Color and Luster

Luster – interaction of white light with the surface of a mineral

- Metallic – most of the light is reflected or scattered from the surface of the mineral. The mineral is opaque.

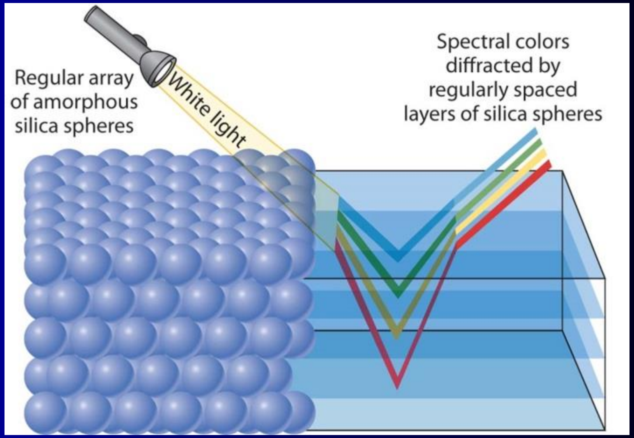


- Nonmetallic – most of the light passes through the mineral. The mineral is translucent.
  - Vitreous – luster of glass
  - Resinous – luster of resin

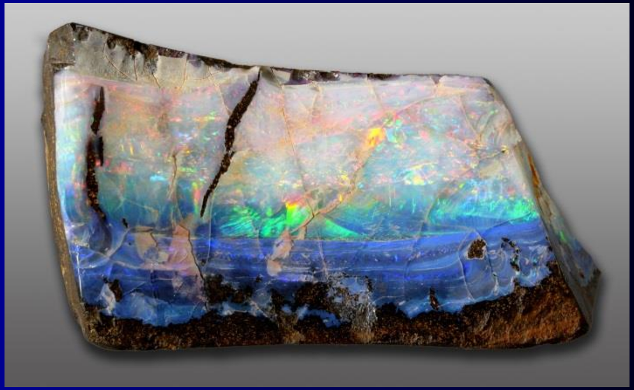
Vitreous

Resinous

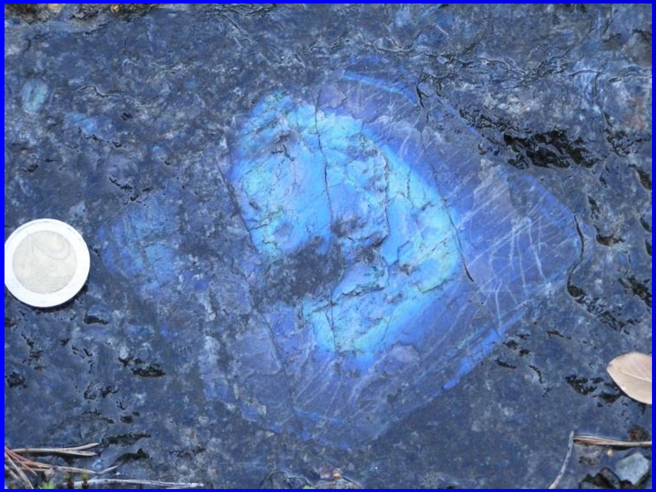
Play of color – example Opal ($SiO_2 \cdot nH_2O$) - stacked 3000 Å amorphous silica spheres causes diffraction. This leads to the display of colors.



Chatoyancy – as the mineral is tilted light moves from side to side. This is due to the presence of closely spaced fibers, inclusions or cavities.



Labradorescence – presence of closely spaced, parallel planar lamellae (exsolution lamellae). Scattered light diffracts from the microstructures producing colors.



Spectrolite

Asterism – six-rayed optical phenomenon due to the alignment of inclusions along crystallographic directions. Seen in star rubies and star sapphires when cut perpendicular to *c*. The inclusions are fine needles of rutile (TiO_2).

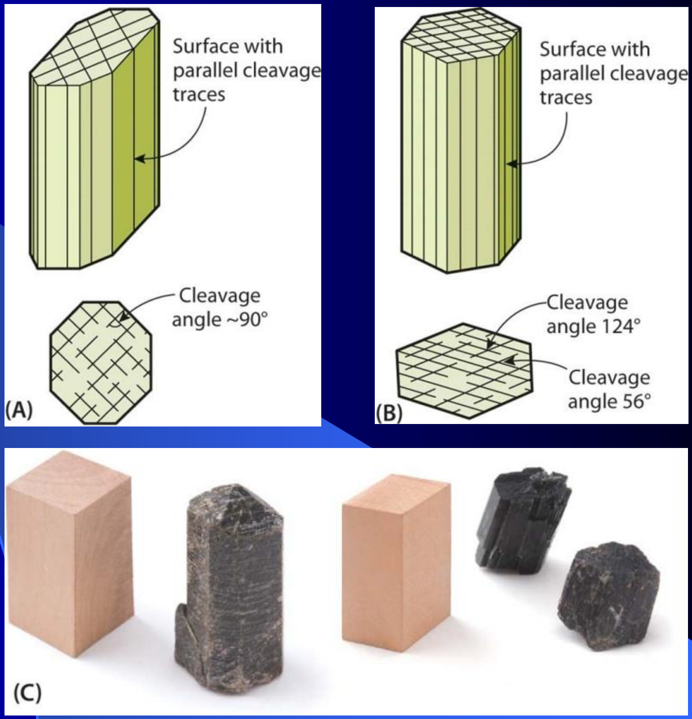
Fluorescence – occurs when UV light promotes electrons to higher energy levels. When the electrons return to an intermediate energy level the emitted photon is in the visible region of the spectrum.

Streak – color of powdered mineral. The color is usually more consistent. Most useful for metallic minerals.

Cleavage – breaking of minerals long planes of weakness. These planes are crystallographic planes. The cleavage planes are controlled by weak bonds or large interplanar spacings across atomic planes in a crystal structure.

Types of cleavage:

- Planar – cleavage along a single planar direction
- Prismatic – two different cleavage directions whose lines of intersection are commonly parallel to a specific crystallographic direction. In hand specimen, the distinction between an amphibole and a pyroxene is largely based on the intersection of the cleavage planes ($\sim 90^{o}$ for pyroxene, 56^{o} and 124^{o} for amphibole). Feldspars also show approximately right-angle cleavage intersections.



- Cubic – three cleavages at right angles. Isometric minerals such as halite and galena.
- Rhombohedral – three cleavage directions not at right angles. Example calcite
- Octahedral – breaking along four different directions. Example fluorite
- Conchoidal fracture – no specific directions. Irregular fracture pattern. Quartz and glasses show this type of fracture.

Cubic

Rhombohedral

Conchoidal

Octahedral

Hardness – resistance to abrasion or indentation.

Absolute hardness – weight in grams required to produce a standard scratch. This is done using an instrument known as a sclerometer. Note that grams are a unit of mass, not force. The correct measurement would be in dynes cm^{-2}. On the scale to the right the values should be multiplied by 980 to get the force in dynes cm^{-2}.

The Turner-sclerometer test consists of microscopically measuring the width of a scratch made by a diamond under a fixed load, and drawn across the face of the specimen under fixed conditions.

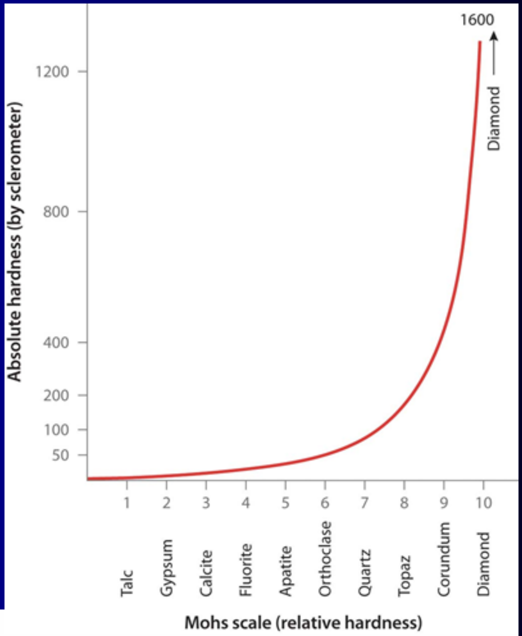


Table 3.1 Mohs hardness scale minerals.

Hardness number (**H**)	Mineral name	Chemical formula	Remarks
1	Talc	$Mg_3Si_4O_{10}(OH)_2$	Soft, greasy feel; flakes are left on the fingers
2	Gypsum	$CaSO_4 \cdot 2H_2O$	Can be easily scratched by the fingernail *fingernail hardness ~2.2*
3	Calcite	$CaCO_3$	Can be easily scratched with a knife and just scratched by a copper penny *copper penny hardness ~3.2*
4	Fluorite	CaF_2	Less easily scratched by a knife than calcite
5	Apatite	$Ca_5(PO_4)_3(F, Cl, OH)$	Is scratched by a knife with difficulty *pocket knife hardness ~5.1* *glass plate hardness ~5.5*
6	Orthoclase	$KAlSi_3O_8$	Not scratched by a knife and will scratch ordinary glass
7	Quartz	SiO_2	Scratches glass easily *porcelain streak plate hardness ~7*
8	Topaz	$Al_2SiO_4(F, OH)_2$	Scratches glass very easily[a]
9	Corundum	Al_2O_3	Cuts glass[a]
10	Diamond	C	Used as a glass cutter[a]

[a] There are few minerals that are as hard as, or harder than, quartz, and these include several of the highly prized gems.

Specific Gravity – the density of a mineral compared to the density of water. Specific gravity is non-dimensional.

Specific gravity for minerals is determined by

- The atomic weight of the elements that comprise the mineral
- Atomic packing - the way in which the atoms are packed in the crystal structure

Other Physical Properties:

- Magnetism – magnetite (Fe_3O_4) and pyrrhotite ($Fe_{1-x}S$)
- Solubility in acid – carbonates – aragonite and calcite ($CaCO_3$) versus dolomite [$CaMg(CO_3)_2$] , magnesite ($MgCO_3$), siderite ($FeCO_3$) , and rhodochrosite ($MnCO_3$) .
- Radioactivity – Uraninite (UO_2), Carnotite [$K_2(UO_2)_2(VO_4)_2$- 1-3H_2O], Thorite [$(Th, U)SiO_4$]

Silica and oxygen are the two most abundant elements in the Earth's crust (and mantle). They combine to form the silica tetrahedron which is the basic building block of the silicate minerals. The silicate minerals comprise 92% of the Earth's crust.

Table 7.1 The eight most common elements in the Earth's crust.

	Weight[a] percentage	Atom[b] percentage	Ionic radius[c] (Å)	Volume[d] percentage
O	46.60	62.55	1.26	~86
Si	27.72	21.22	0.40[IV]	
Al	8.13	6.47	0.53[IV]	
Fe	5.00	1.92	0.92[VI]	~14
Ca	3.63	1.94	1.14[VI]	in total
Na	2.83	2.64	1.32[VIII]	
K	2.59	1.42	1.65[VIII]	
Mg	2.09	1.84	0.86[VI]	
	98.59	100.00		

[a] Data from Mason and Moore, 1982.
[b] Values obtained by dividing the numbers in the first column by the appropriate atomic weights, then normalized to 100.
[c] Radii taken from Table 4.4.
[d] These values fluctuate somewhat depending on the radii used in the calculation of the ionic volume ($V = \frac{4}{3}\pi r^3$).

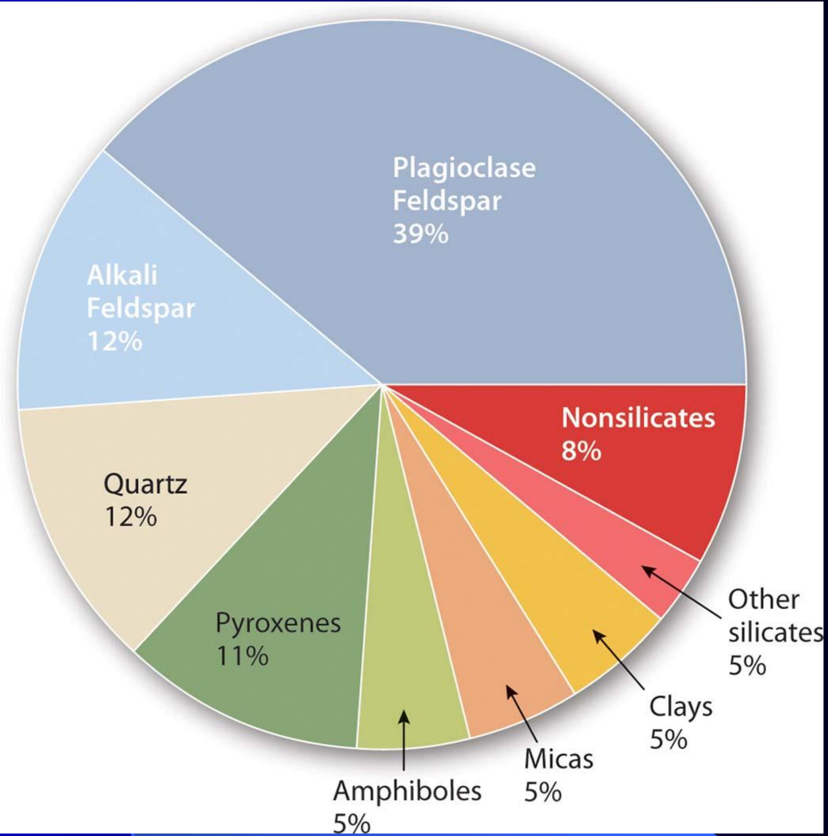


Table 7-4. Properties of the silicate crystal classes

Class	Tetrahedral arrangement	# shared corners	Chemical unit	Si:O	Example
Nesosilicate	Independent tetrahedra	0	SiO_4^{4-}	1:4	Olivine
Sorosilicate	Two tetrahedra sharing a corner	1	$Si_2O_7^{6-}$	1:3.5	Melilite
Cyclosilicate	Three or more tetrahedra sharing two corners, forming a ring	2	SiO_3^{3-}	1:3	Beryl
Inosilicate	Single chain of tetrahedra sharing two corners	2	SiO_3^{3-}	1:3	Augite
	Double chain of tetrahedra alternately sharing two or three corners	2.5	$Si_4O_{11}^{6-}$	1:2.75	Hornblende
Phyllosilicate	Sheet of tetrahedra sharing three corners	3	$Si_2O_5^{2-}$	1:2.5	Kaolinite
Tektosilicate	Framework of tetrahedra sharing all four corners	4	SiO_2	1:2	K-feldspar