Earth and Planetary Sciences (ES1101)

(Minerals: Building Blocks of Rocks)
(Autumn 2021 by Gaurav Shukla)

Book: 1) Understanding Earth by Grotzinger & Jordan (Text Book)
2) Earth: An introduction to Physical Geology by Tarbuck & Lutgens
3) The Solid Earth: An introduction to global geophysics by Fowler

Minerals Classification

- **More than 4000 minerals have been identified, and several new ones are identified each year.**

- **Common minerals that make up most of the Earth's crust are only a few dozens and known as rock-forming minerals.**

Structure of Minerals

Most abundant elements in the crust

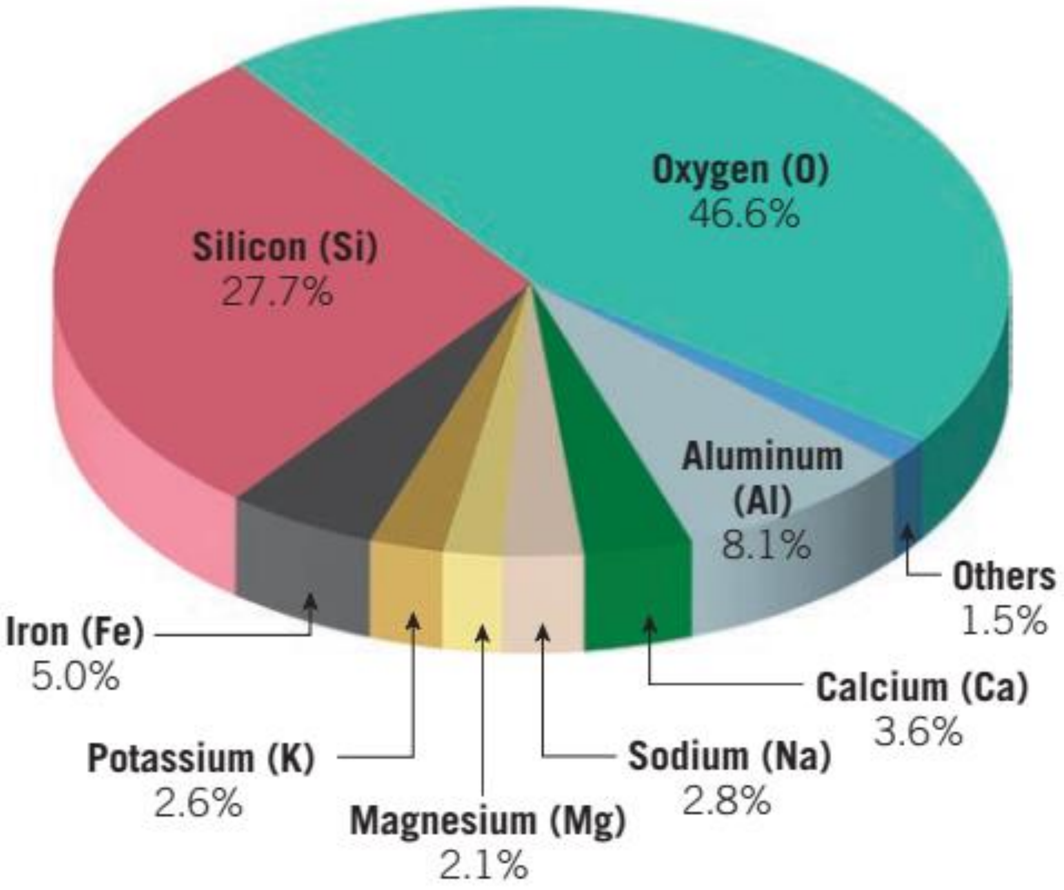


Figure 3.30
The eight most abundant elements in the continental crust

Structure of Minerals

Radii of the most relevant cations and anions

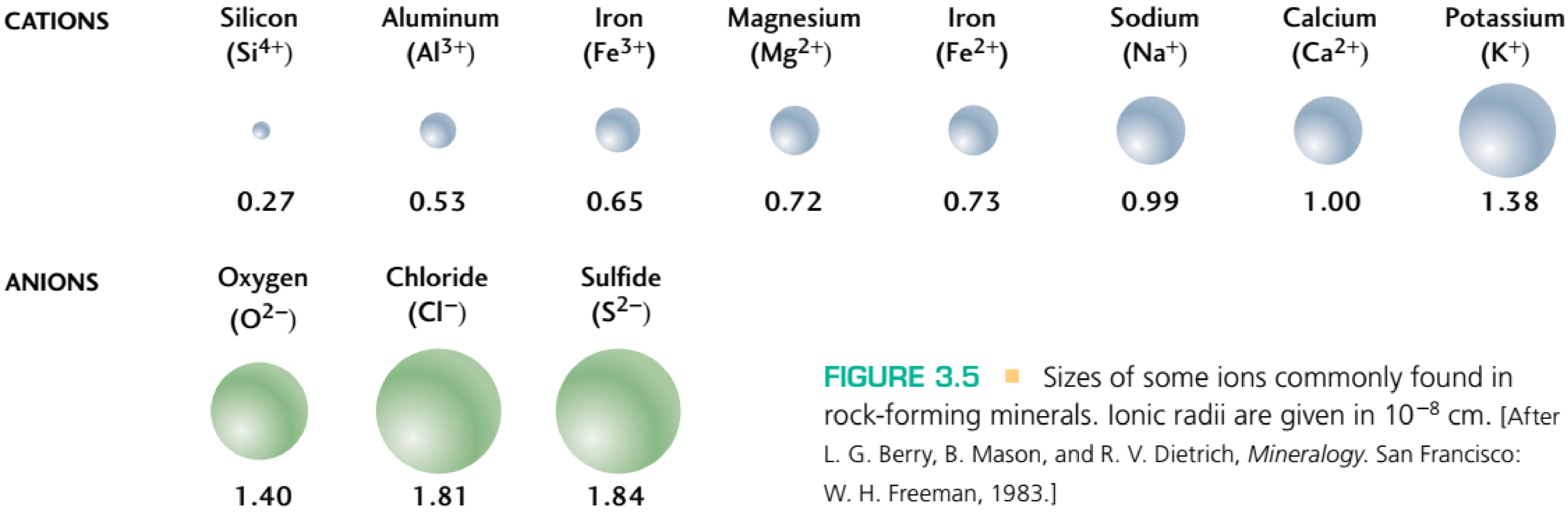


FIGURE 3.5 ■ Sizes of some ions commonly found in rock-forming minerals. Ionic radii are given in 10^{-8} cm. [After L. G. Berry, B. Mason, and R. V. Dietrich, *Mineralogy*. San Francisco: W. H. Freeman, 1983.]

These radii shown here are averaged out rough estimates. You may follow the link for the expected values of radii: http://abulafia.mt.ic.ac.uk/shannon/ptable.php

Structure of Minerals

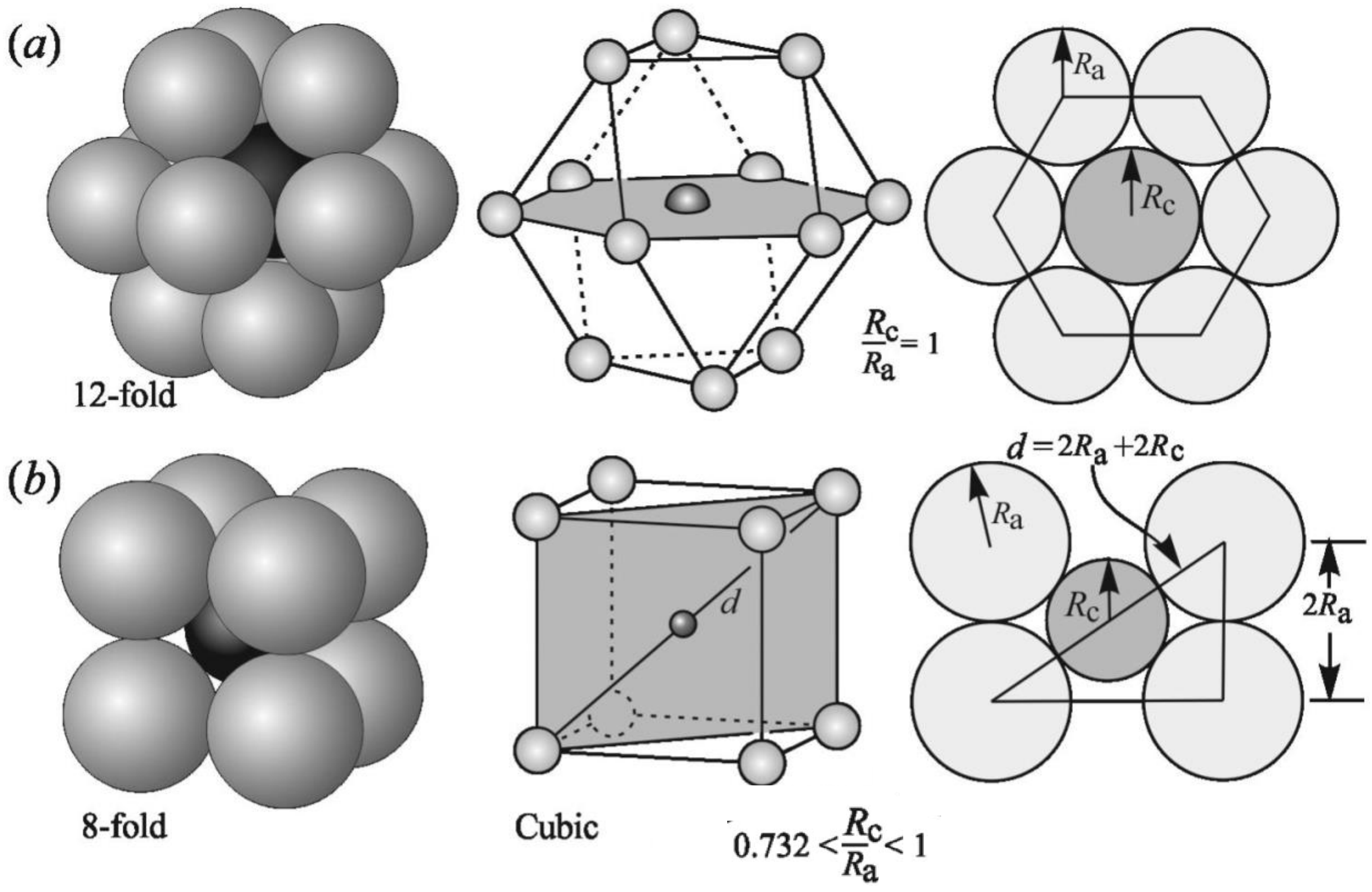
Radii of the most relevant cations and anions

Table 4.2 Cation Sizes Appropriate for Regular Coordination Polyhedra When Coordinating with O^{2-} (~1.26 Å)

Coordination	Radius Ratio	Minimum Radius (Å)	~Maximum Radius (Å)	Common Cations
12	~1.00	1.26	N/A	K^+, Ca^{2+}, Na^+
8	0.732–1.00	0.92	1.26	Fe^{2+}, Ca^{2+}, Na^+, Mg^{2+}
6	0.414–0.732	0.52	0.92	Al^{3+}, Fe^{2+}, Fe^{3+}, Mg^{2+}
4	0.225–0.414	0.28	0.52	Si^{4+}, Al^{3+}, S^{6+}, P^{5+}
3	0.155–0.225	0.20	0.28	C^{4+} [a]
2	<0.155	N/A	0.20	None

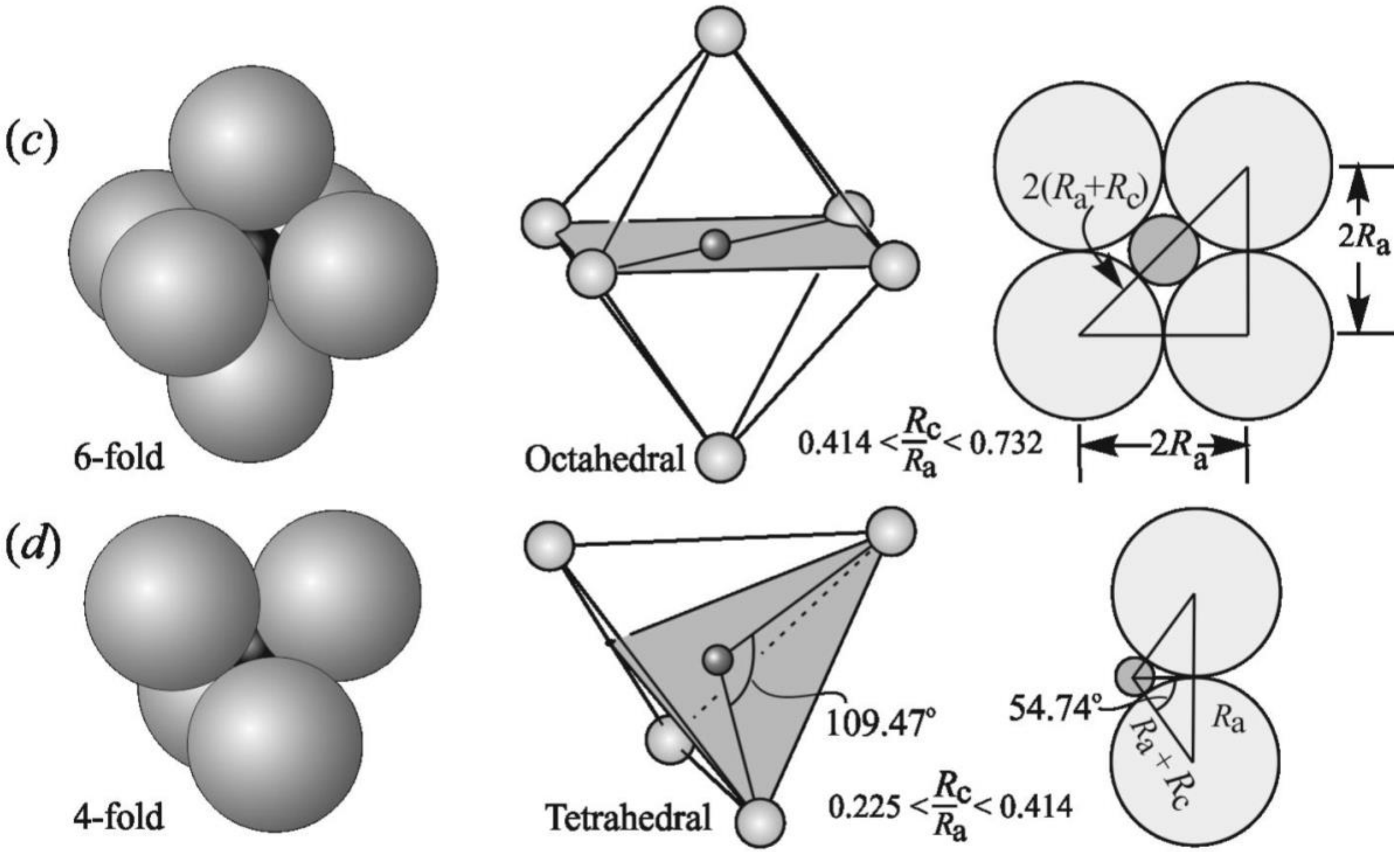
Structure of Minerals

Radius ratio and coordination number (contd)



Structure of Minerals

Radius ratio and coordination number (contd)



Structure of Minerals

Radius ratio and coordination number

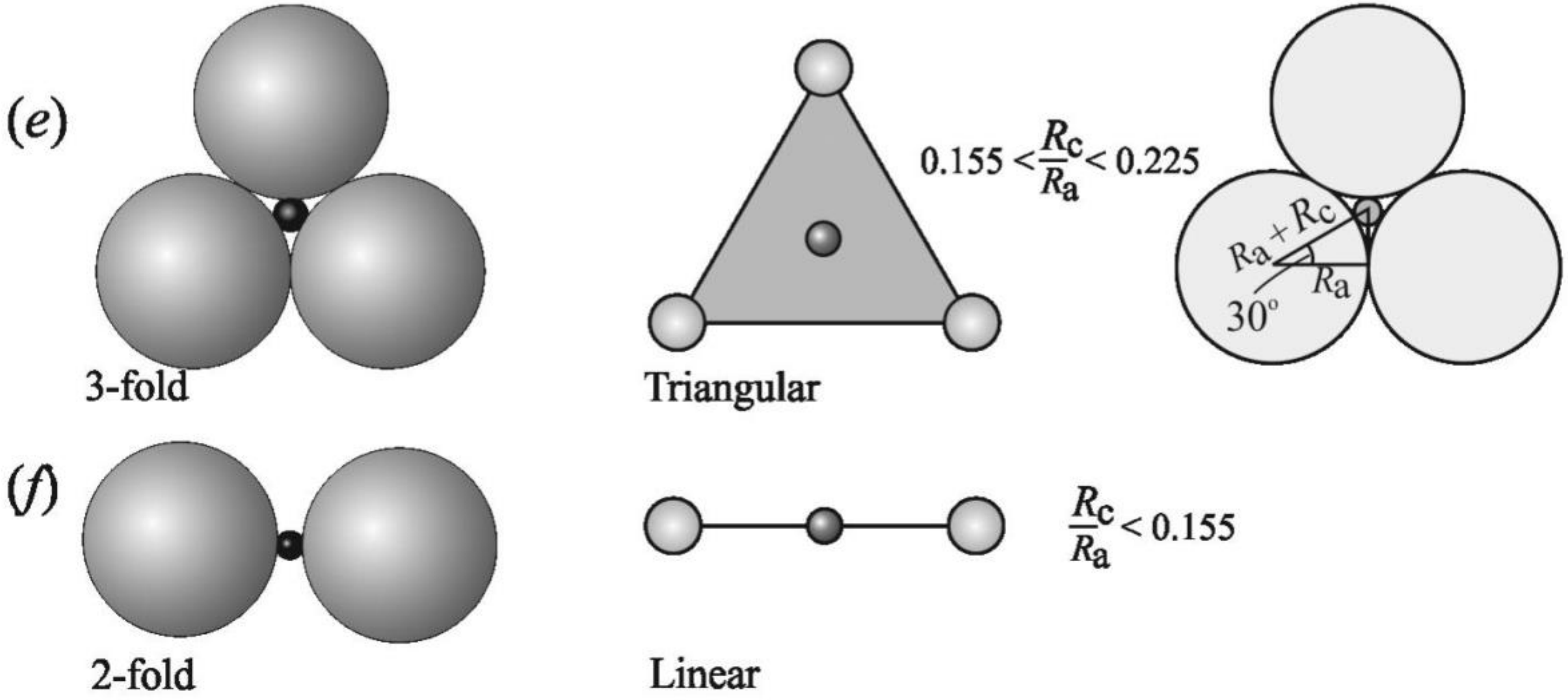
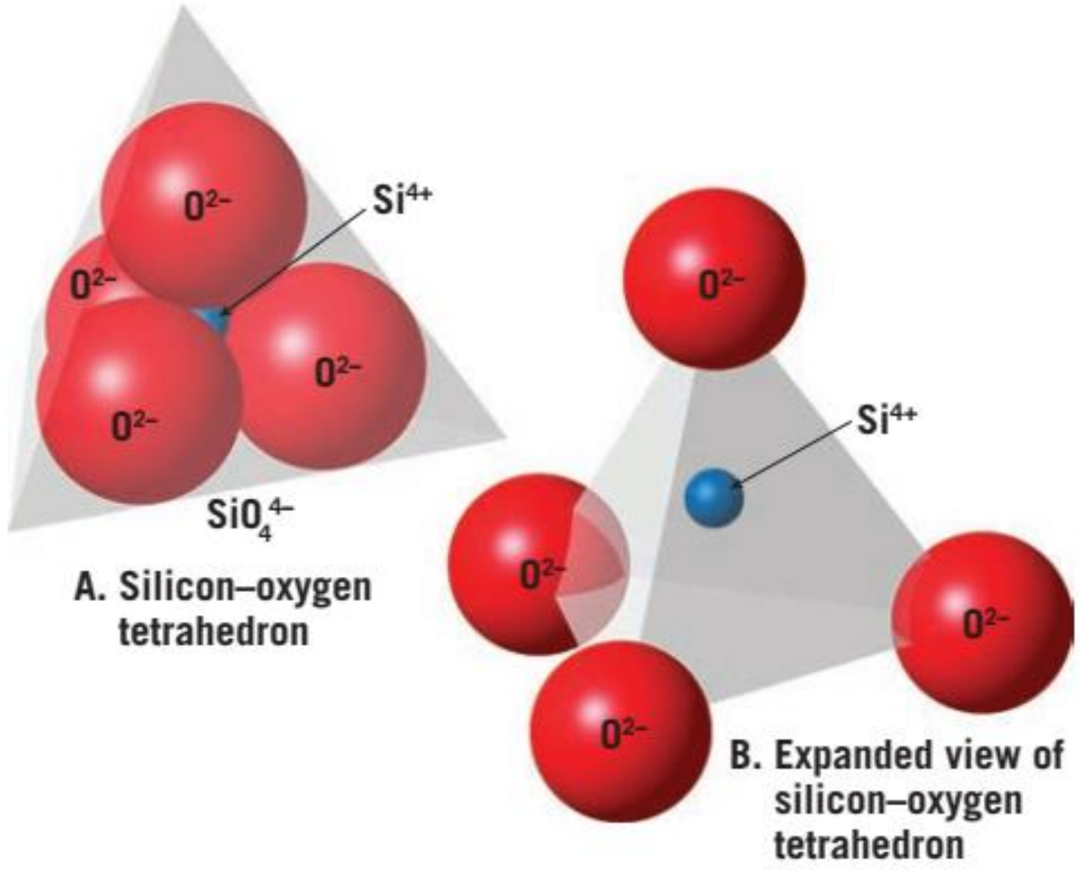
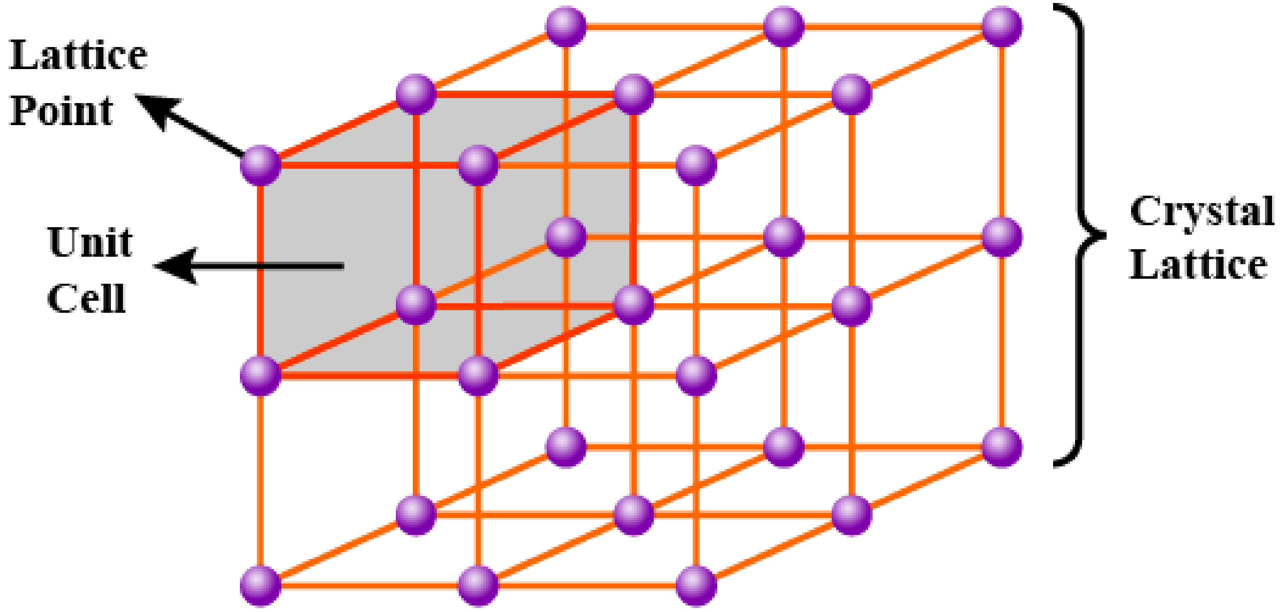


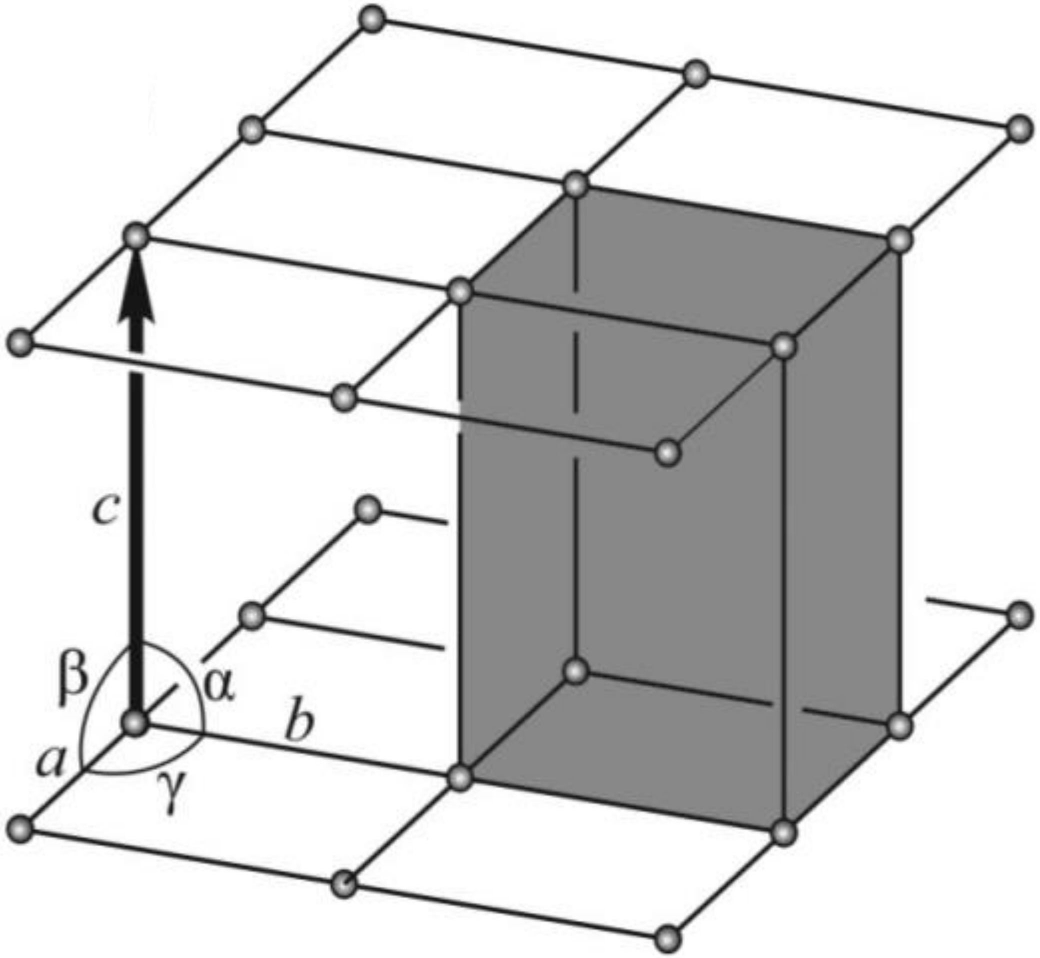
Figure 4.4 Coordination polyhedra. Anions with radius R_a are shown with light shading, cations with radius R_c with dark. Left view shows cation and anions drawn to scale. Center view shows the coordination polyhedra. Right view shows the plane through the polyhedron (shaded in center view) from which the radius ratio is calculated. See text for additional discussion. (*a*) 12-fold coordination (based on cubic closest packing). The coordination polyhedron is not a regular shape. (*b*) 8-fold, or cubic, coordination. (*c*) 6-fold, or octahedral, coordination. (*d*) 4-fold, or tetrahedral, coordination. (*e*) 3-fold, or triangular, coordination. (*f*) 2-fold, or linear, coordination.

Silicon-Oxygen Tetrahedra

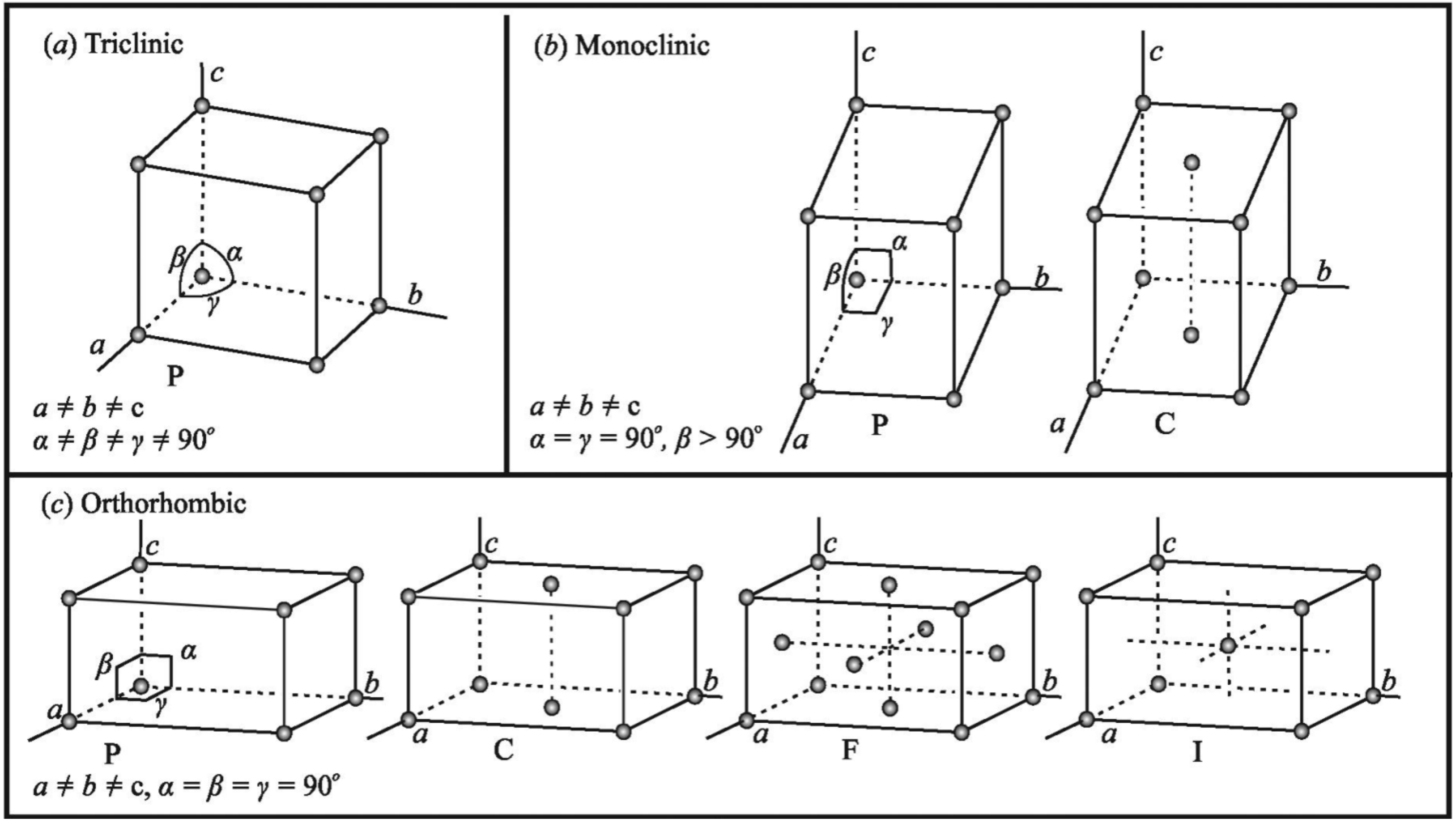


Crystallography of Minerals

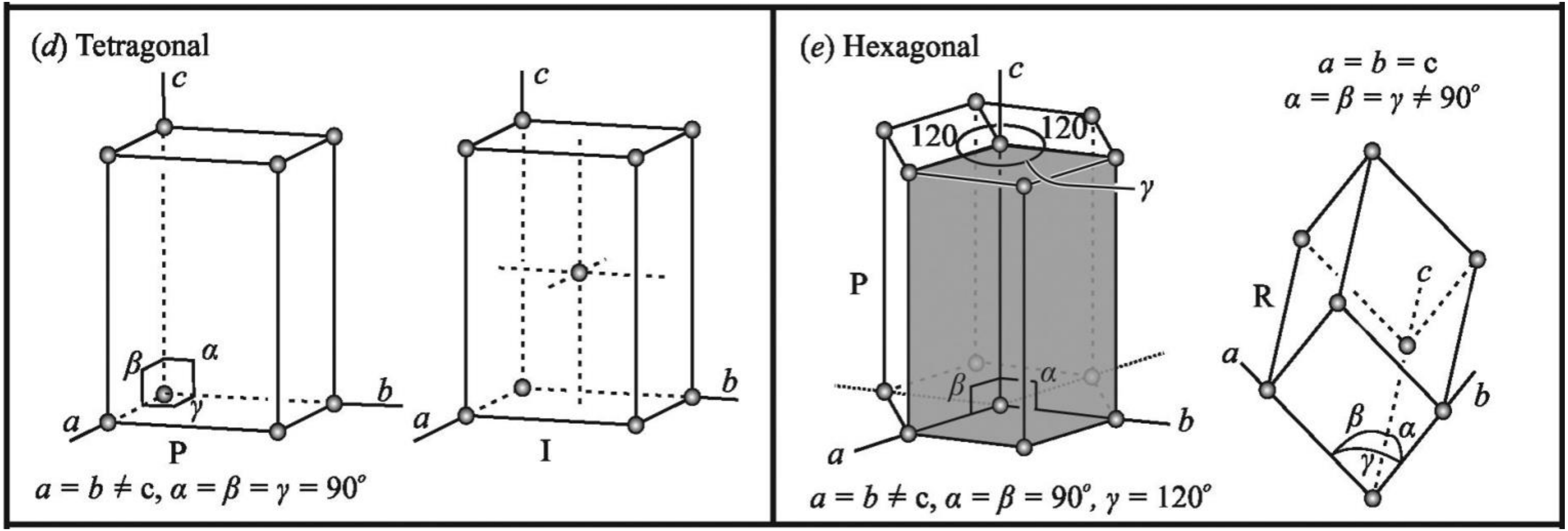




Crystallography of Minerals



Crystallography of Minerals



Crystallography of Minerals

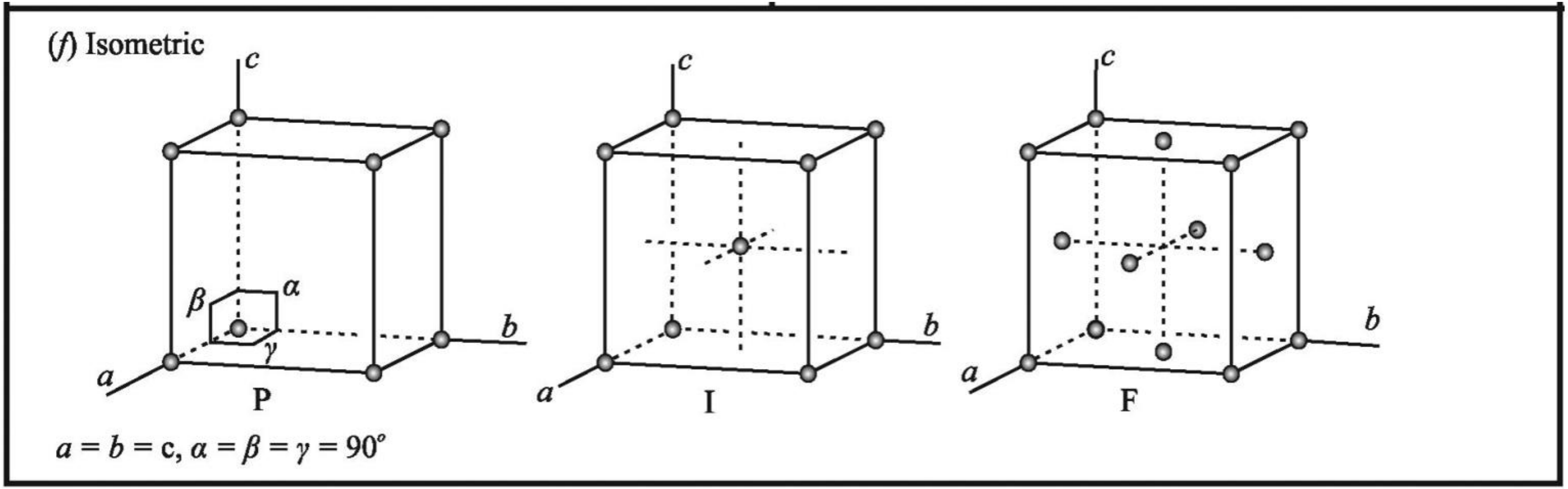


Figure 2.10 The 14 Bravais lattices define six different three-dimensional volumes (*a*–*f*) that correspond to the unit cells of the six crystal systems. The lengths of the three unit cell axes are a, b, and c, and the angles between them are α, β, and γ. In the notations, the ≠ sign indicates that equality of the axis lengths or angles is not required, although occasionally equality may occur by chance. The hexagonal (R) lattice shown in (*e*) is based on the rhombohedral axes shown in Figure 2.8c. A unit cell with the same geometry as the hexagonal (P) lattice shown in Figure 2.8a is far more commonly used.

Minerals Classification

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- **Common minerals that make up most of the Earth's crust are only a few dozens and known as rock-forming minerals.**

- **As we have seen that the oxygen and silicon are the most common elements in the Earth's crust, so the silicate minerals account for more than 90% of the crust.**

Minerals Classification

TABLE 3-1 Some Chemical Classes of Minerals

Class	Defining Anions	Example
Native elements	None: no charged ions	Copper metal (Cu)
Oxides	Oxygen ion (O^{2-})	Hematite (Fe_2O_3)
Halides	Chloride (Cl^-), fluoride (F^-), bromide (Br^-), iodide (I^-)	Halite (NaCl)
Carbonates	Carbonate ion ($CO_3{}^{2-}$)	Calcite ($CaCO_3$)
Sulfates	Sulfate ion ($SO_4{}^{2-}$)	Anhydrite ($CaSO_4$)
Silicates	Silicate ion ($SiO_4{}^{4-}$)	Olivine $(Mg,Fe)_2SiO_4$
Sulfides	Sulfide ion (S^{2-})	Pyrite (FeS^2)

Minerals Classification

Nonsilicate Minerals

Common Nonsilicate Mineral Groups				
Mineral Group (key ion(s) or element(s))	**Mineral Name**	**Chemical Formula**	**Economic Use**	**Examples**
Carbonates (CO_3^{2-})	Calcite Dolomite	$CaCO_3$ $CaMg(CO_3)_2$	Portland cement, lime Portland cement, lime	 A. Calcite B. Dolomite
Halides (Cl^{1-}, F^{1-}, Br^{1-})	Halite Fluorite Sylvite	$NaCl$ CaF_2 KCl	Common salt Used in steelmaking Used as fertilizer	 C. Halite D. Fluorite
Oxides (O^{2-})	Hematite Magnetite Corundum Ice	Fe_2O_3 Fe_3O_4 Al_2O_3 H_2O	Ore of iron, pigment Ore of iron Gemstone, abrasive Solid form of water	 E. Hematite F. Magnetite
Sulfides (S^{2-})	Galena Sphalerite Pyrite Chalcopyrite Cinnabar	PbS ZnS FeS_2 $CuFeS_2$ HgS	Ore of lead Ore of zinc Sulfuric acid production Ore of copper Ore of mercury	 G. Galena H. Chalcopyrite
Sulfates (SO_4^{2-})	Gypsum Anhydrite Barite	$CaSO_4 \cdot 2H_2O$ $CaSO_4$ $BaSO_4$	Plaster Plaster Drilling mud	 I. Gypsum J. Anhydrite
Native elements (single elements)	Gold Copper Diamond Graphite Sulfur Silver	Au Cu C C S Ag	Trade, jewelry Electrical conductor Gemstone, abrasive Pencil lead Sulfadrugs,chemicals Jewelry, photography	 K. Copper L. Sulfur

Minerals Classification

Nonsilicate Minerals: Calcite

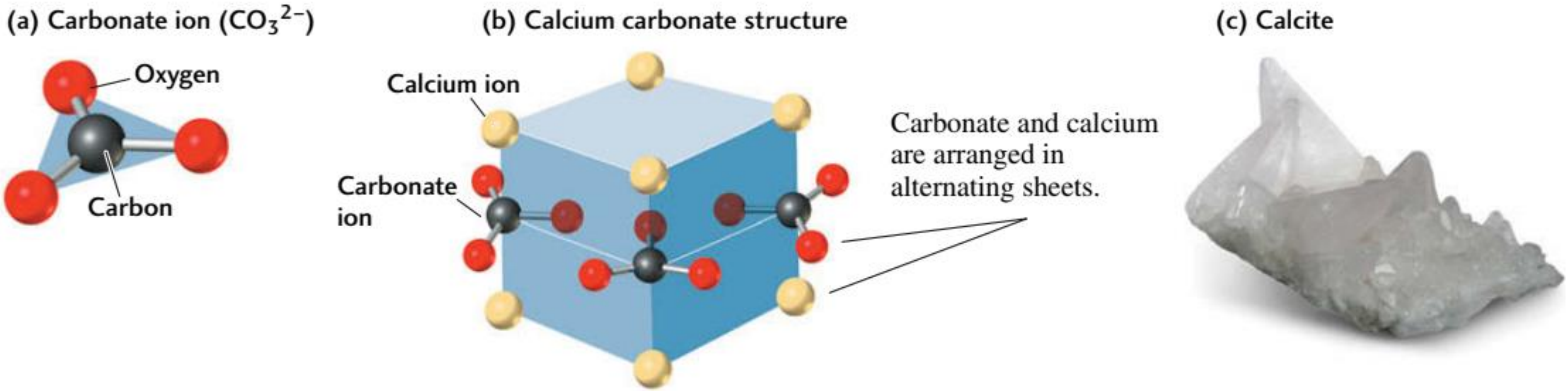

FIGURE 3.12 ■ Carbonate minerals, such as calcite (calcium carbonate, $CaCO_3$), have a layered structure. (a) Top view of the carbonate ion, composed of a carbon ion surrounded by three oxygen ions in a triangle. (b) View of the alternating layers of calcium and carbonate ions in calcite. (c) Calcite. [Photo by John Grotzinger/Ramón Rivera-Moret/Harvard Mineralogical Museum.]

Minerals Classification

Nonsilicate Minerals: Pyrite

FIGURE 3.14 ■ Pyrite, a sulfide mineral, is also known as "fool's gold." [John Grotzinger/Ramón Rivera-Moret/Harvard Mineralogical Museum.]