Introduction to Earth Science (ES1101)

(Crystallography)

Instructor: Gaurav Shukla

Field Photo (Rock Study)

Group photo of 18MS batch with the instructors, in front of a rock exposure in the Singhbhum shear zone

Minerals and Rocks

Silver and copper mineralization in the Talkeetna Mountains. Green color is the copper mineral malachite. Photo credit: Evan Twelker, DGGS, taken 2014.

[Rocks & Minerals - Utah Geological Survey]

What are minerals?

- Minerals are building blocks of rocks.
- Rock is a solid aggregate or mass of minerals.
- Understanding the behavior of minerals in response to changes in physical and chemical environment help us decipher the records of geological history.

What are minerals?

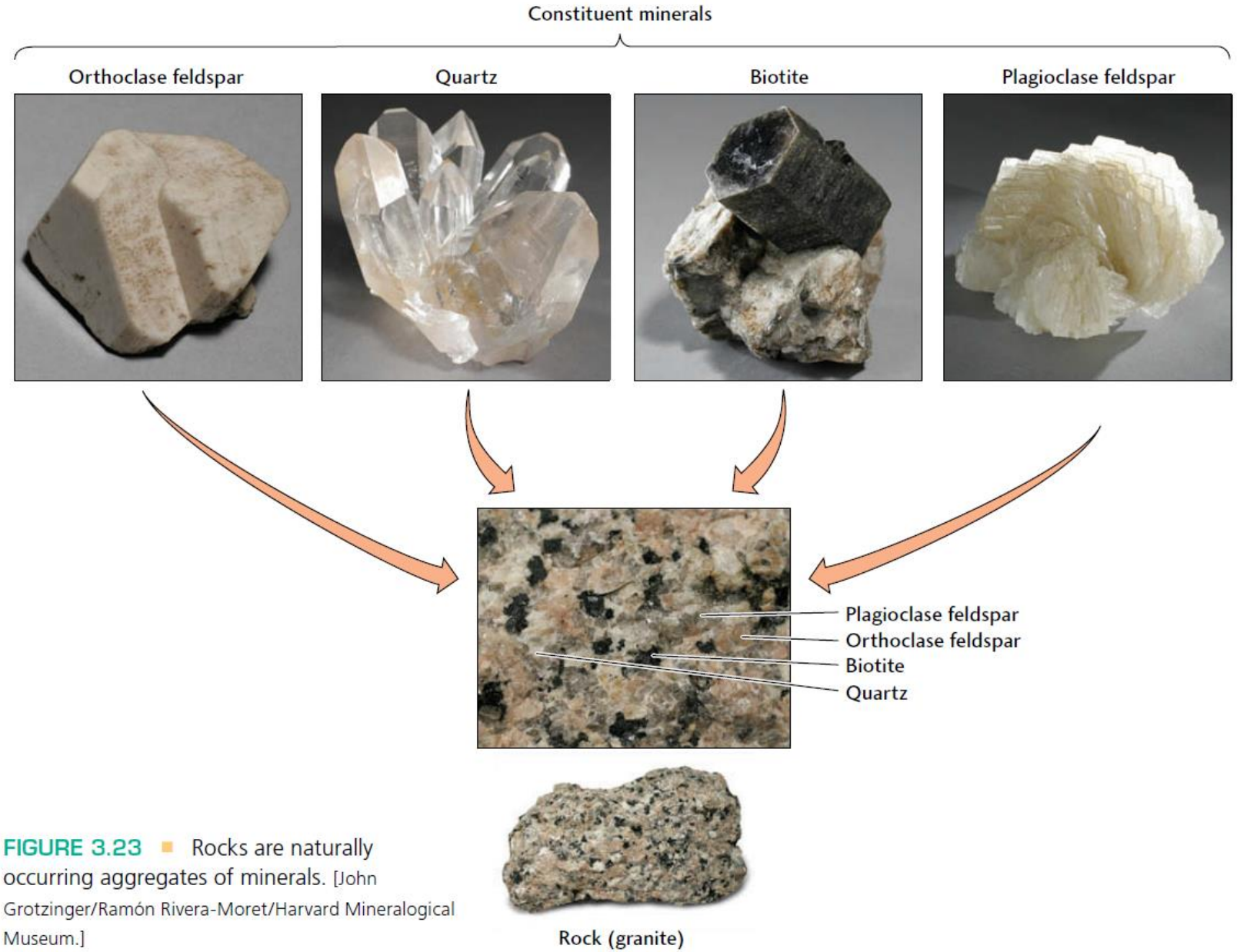


FIGURE 3.23 ■ Rocks are naturally occurring aggregates of minerals. [John Grotzinger/Ramón Rivera-Moret/Harvard Mineralogical Museum.]

Structure of Minerals

Most abundant elements in the crust

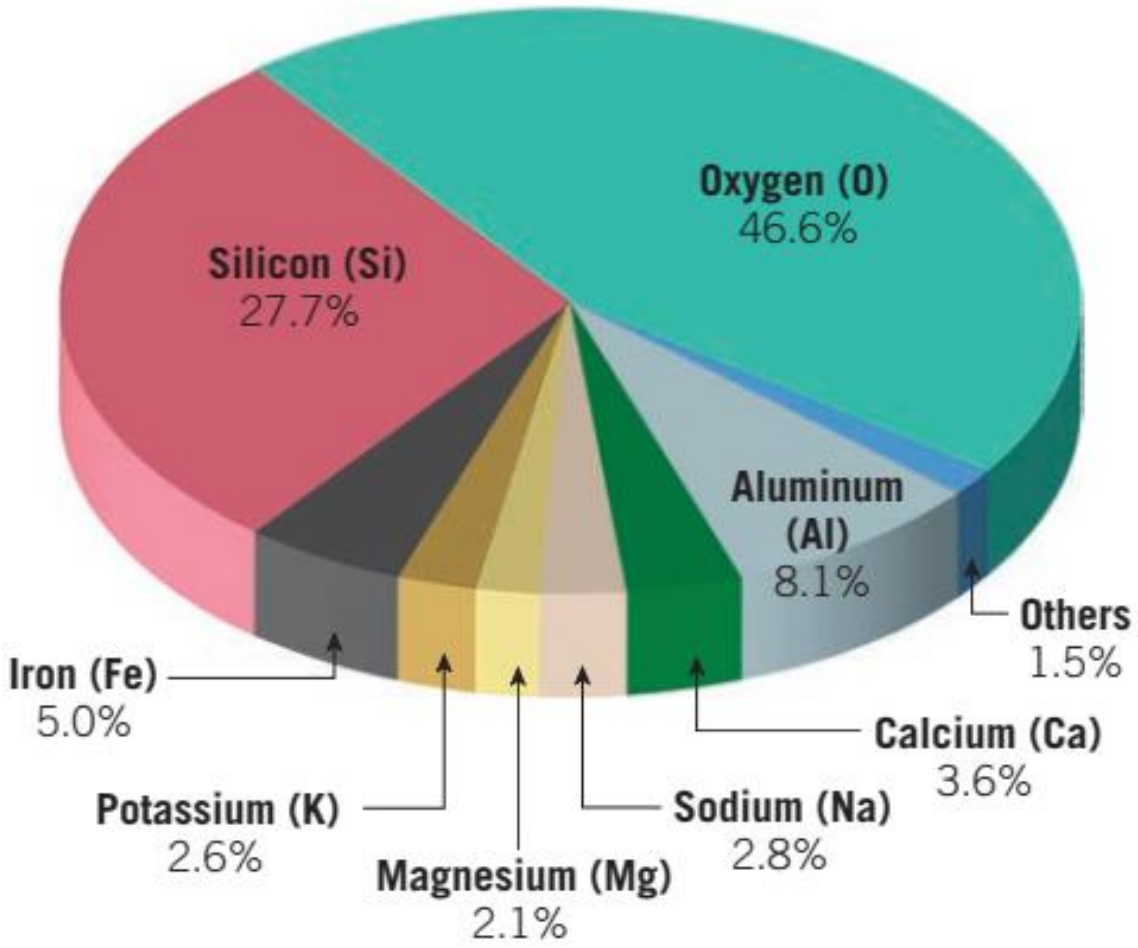


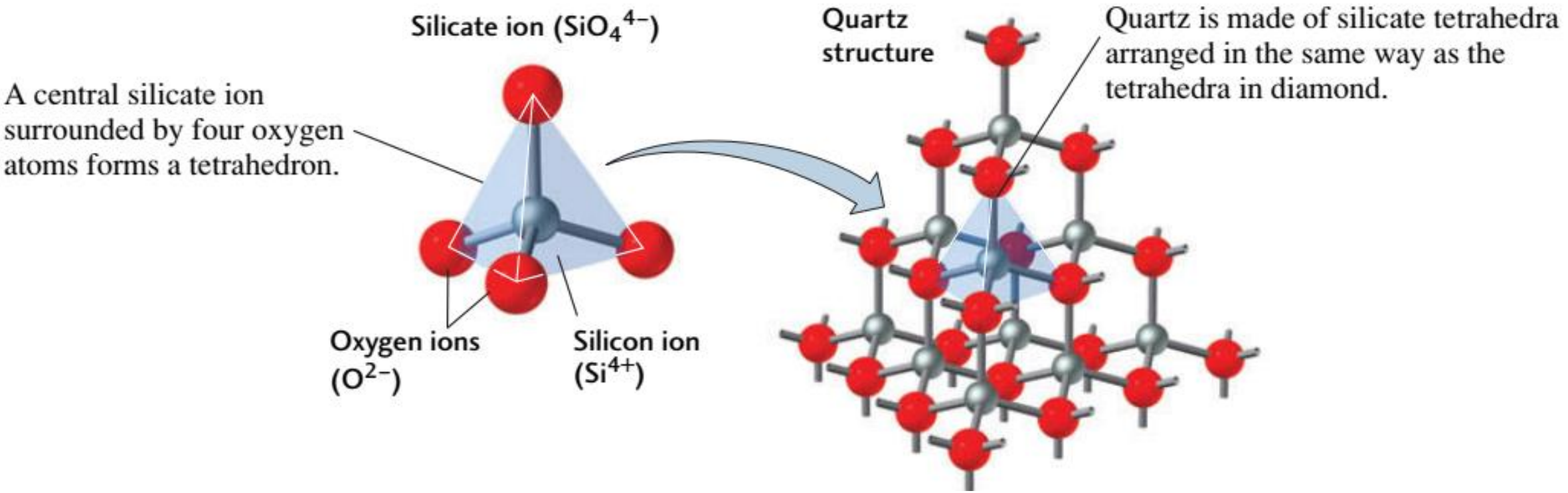
Figure 3.30
The eight most abundant elements in the continental crust

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.
- 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.

Definition of Minerals:

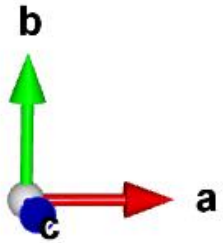
A mineral is a naturally occurring crystalline (inorganic) solid with a definite, but not necessarily a fixed, chemical composition.

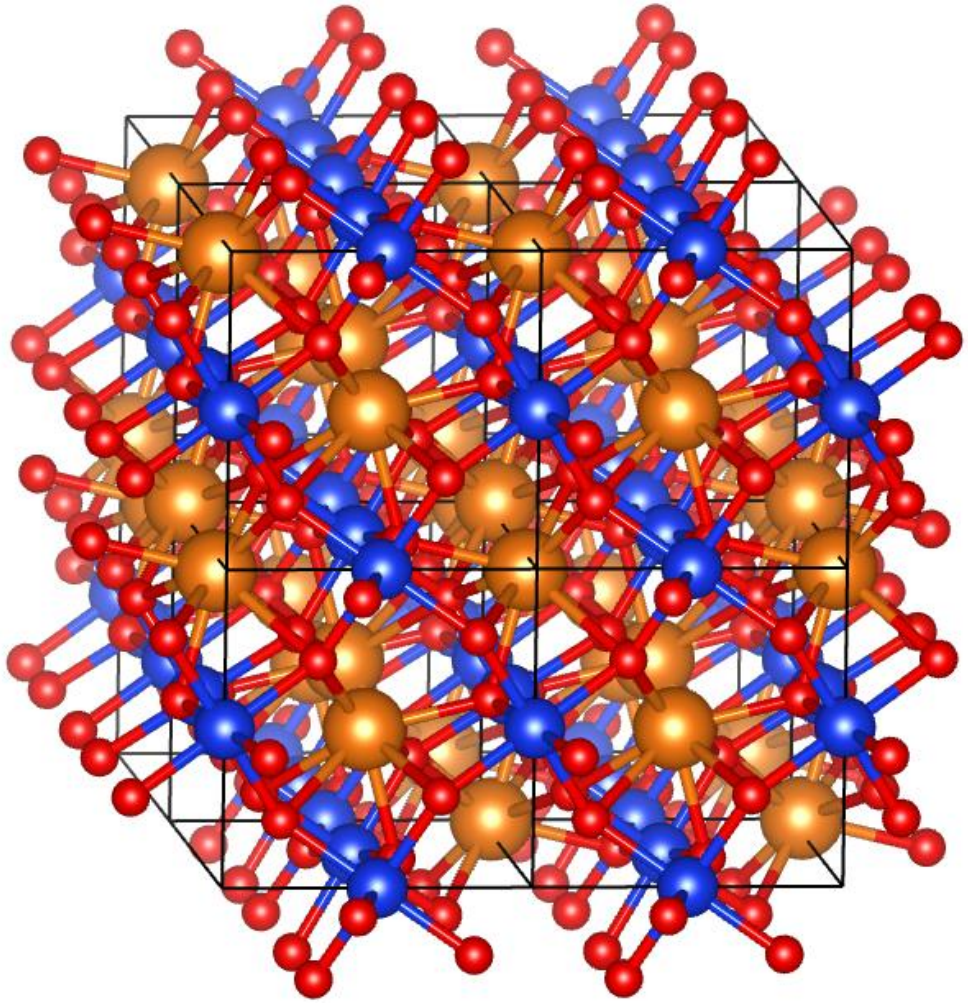


Definition of Minerals:

Crystalline (periodic) solid:

$MgSiO_3$





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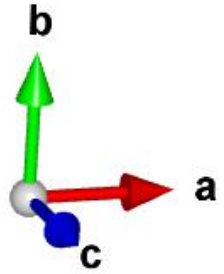
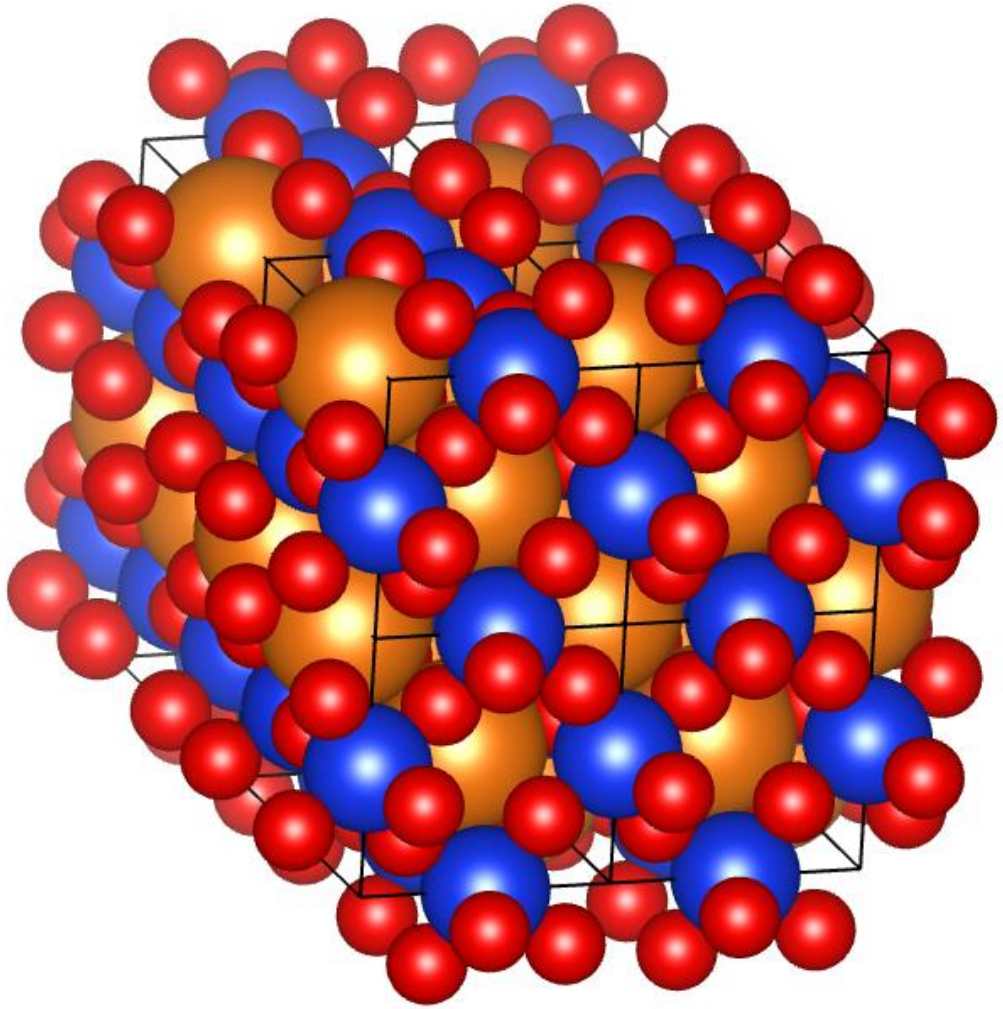
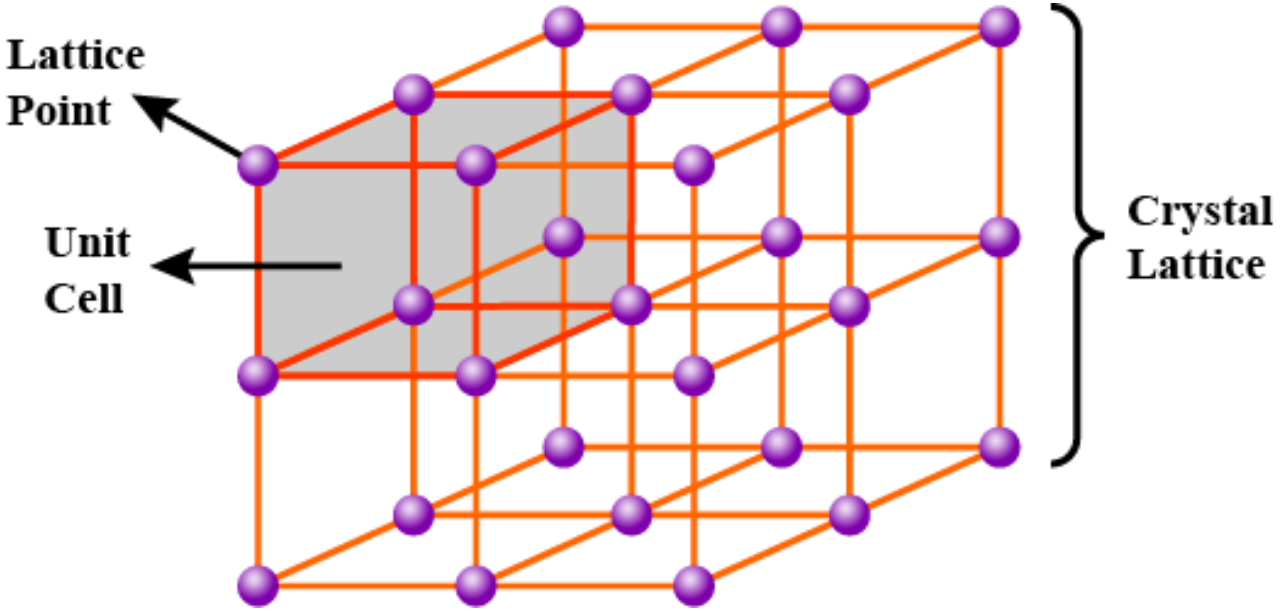
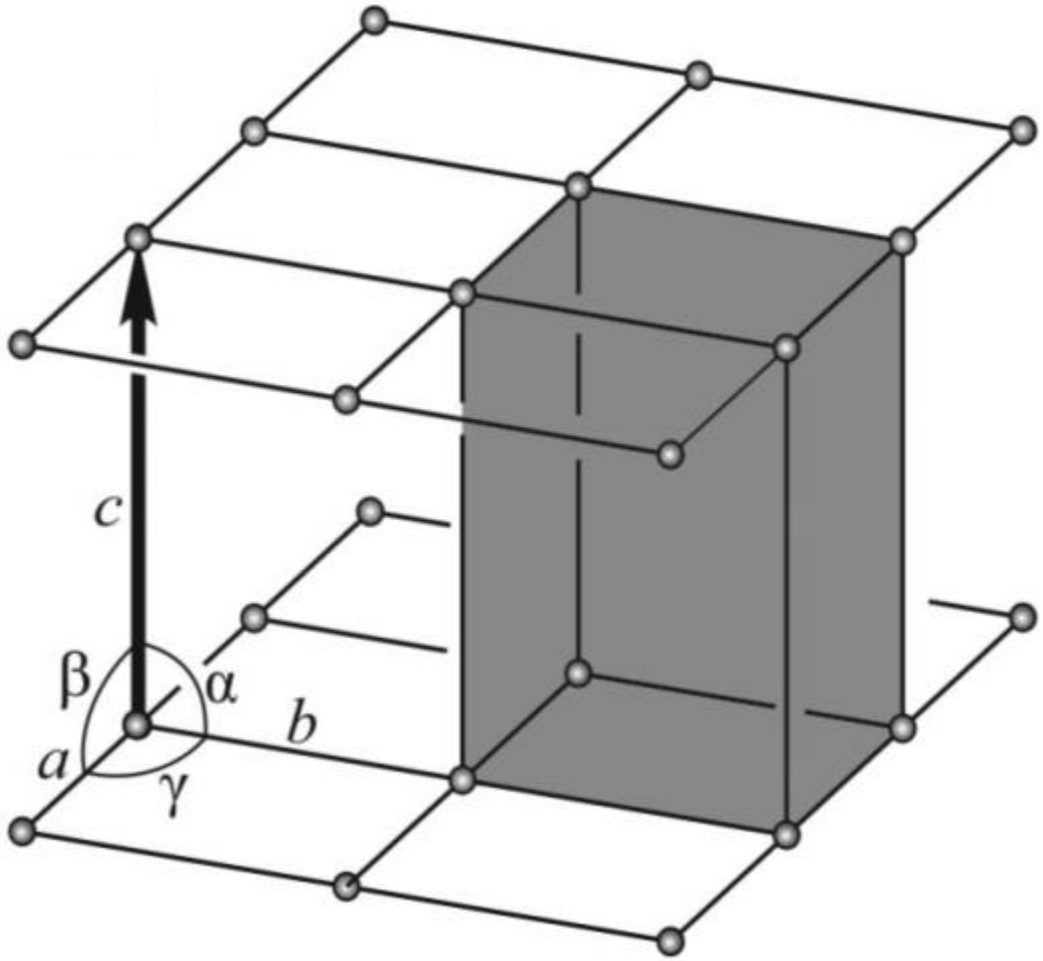




Crystallography of Minerals





Lattice Parameter: a, b, c & α, β, γ

Symmetry in Nature

Symmetry

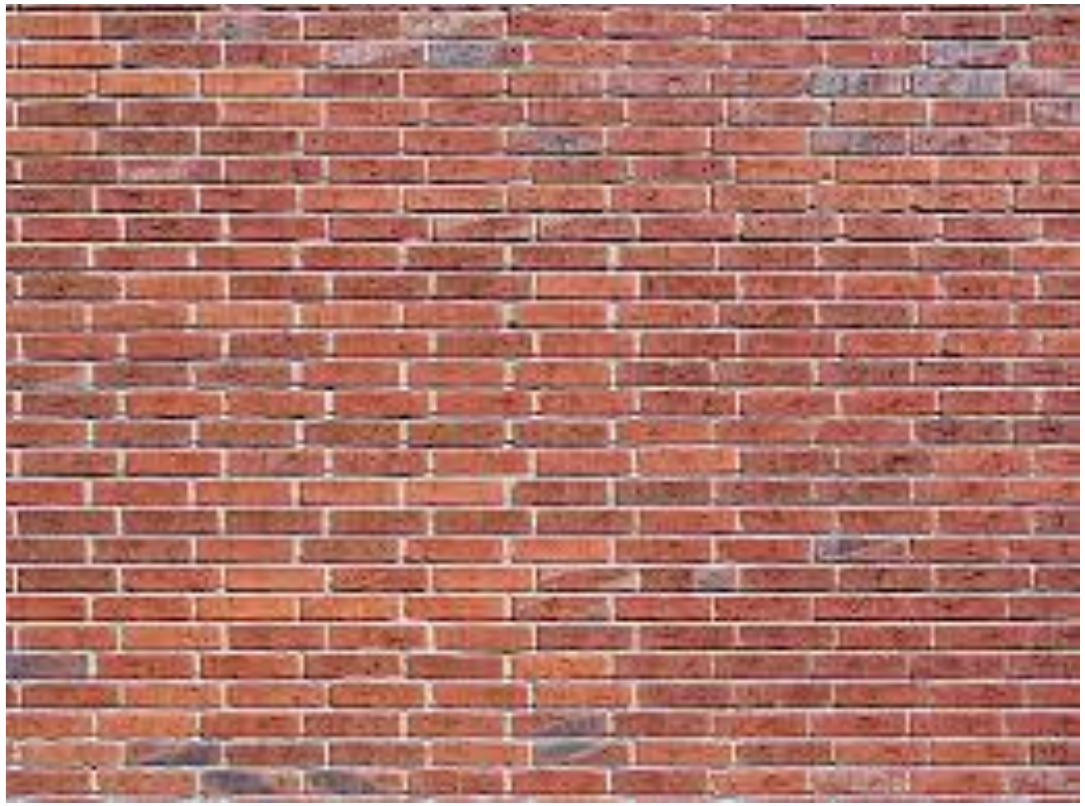
Translational Symmetry

Point group symmetry

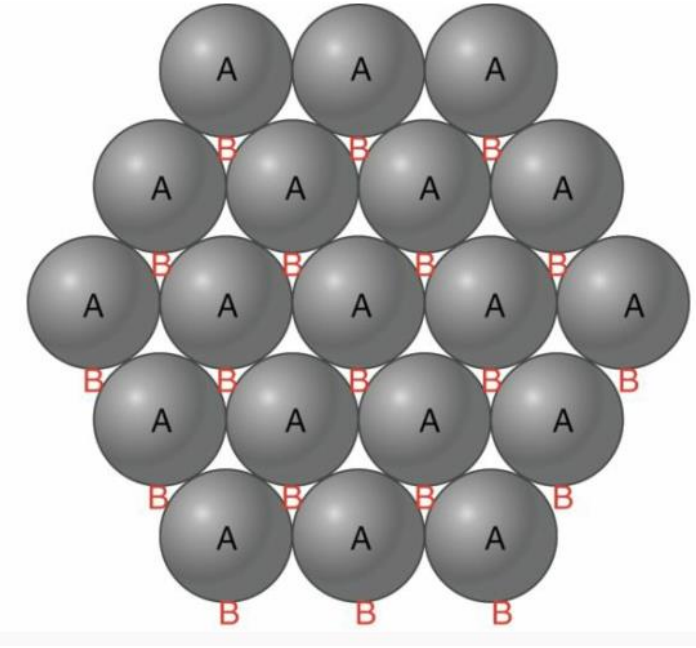
Translational symmetry +Point symmetry = Space group symmetry

Symmetry

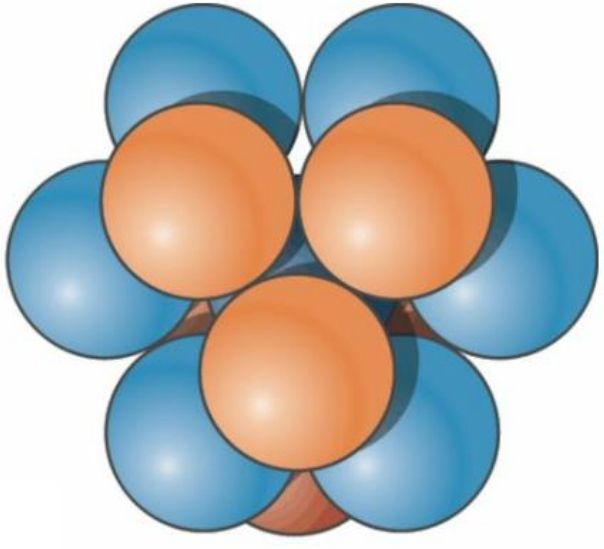
Translational Symmetry

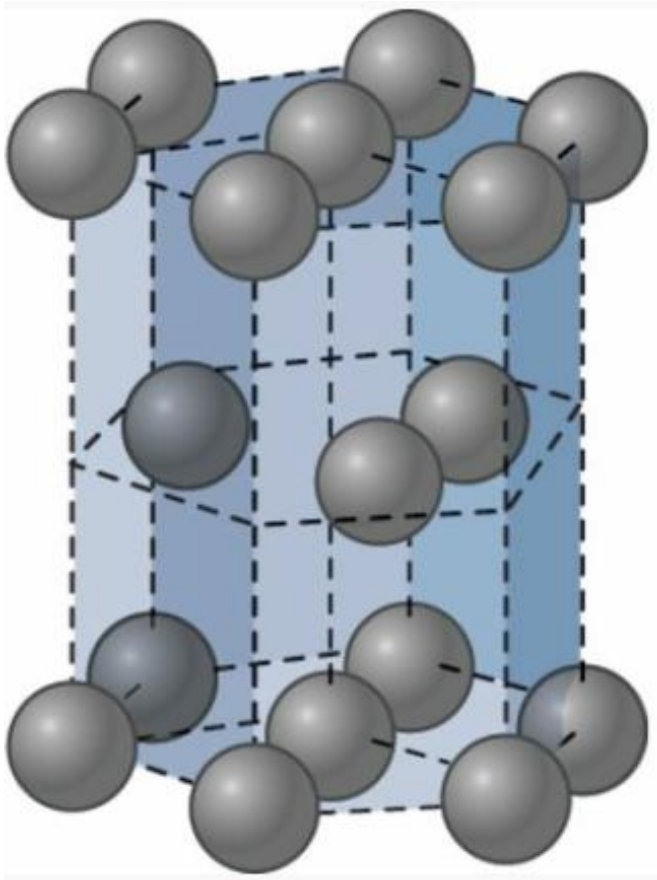


Coordination Number and Cation to Anion Radius Ratio



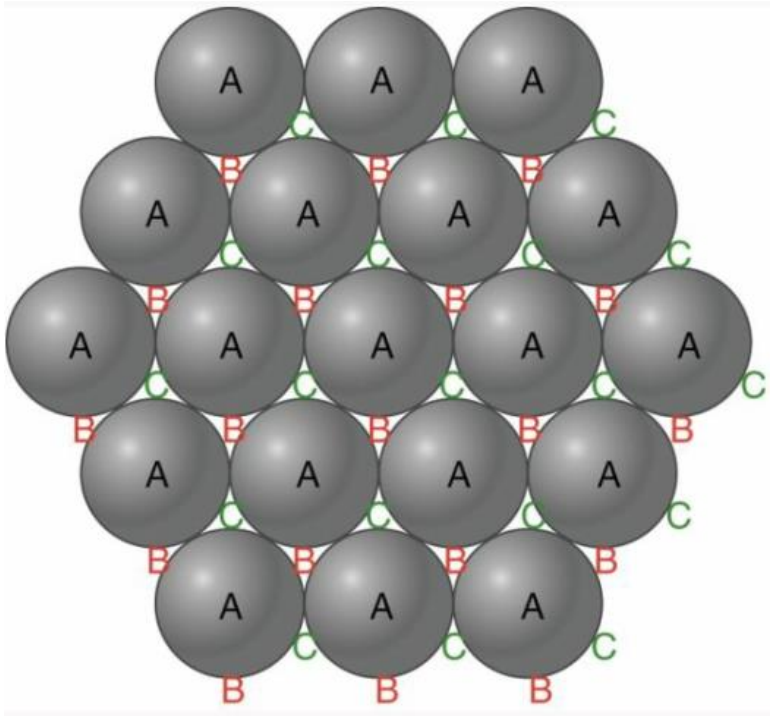
AB AB AB Sequence



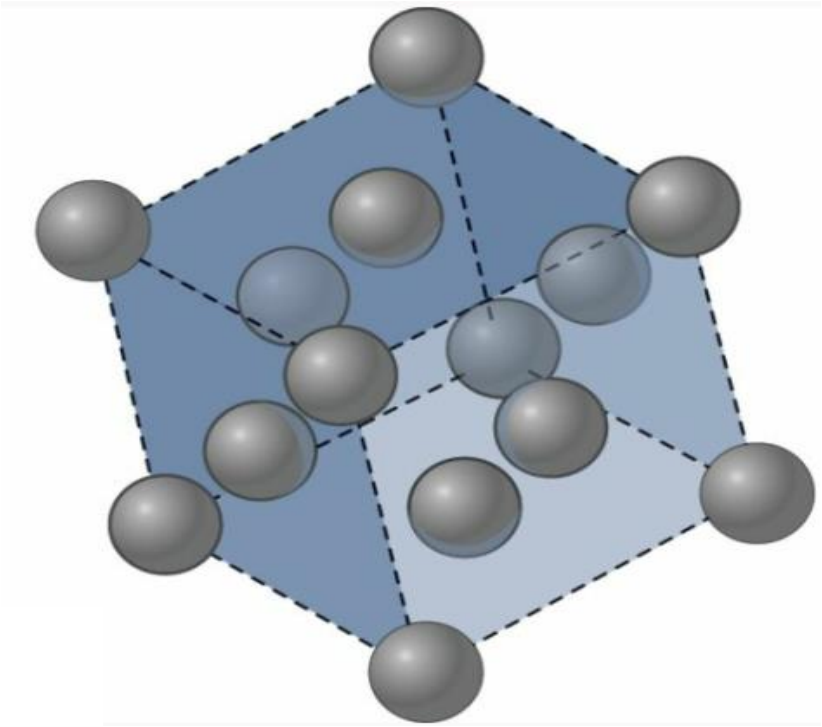


HCP Structure

Coordination Number and Cation to Anion Radius Ratio



ABC ABC Sequence



CCP Structure

Structure of Minerals

Radii of the most relevant cations and anions

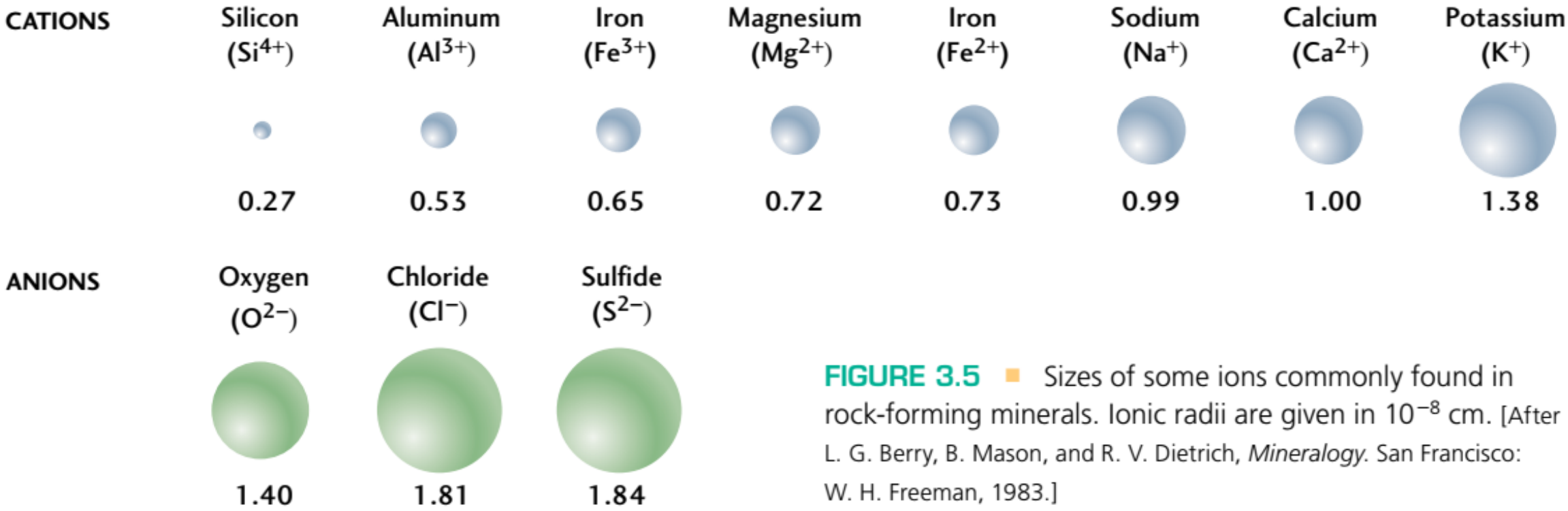
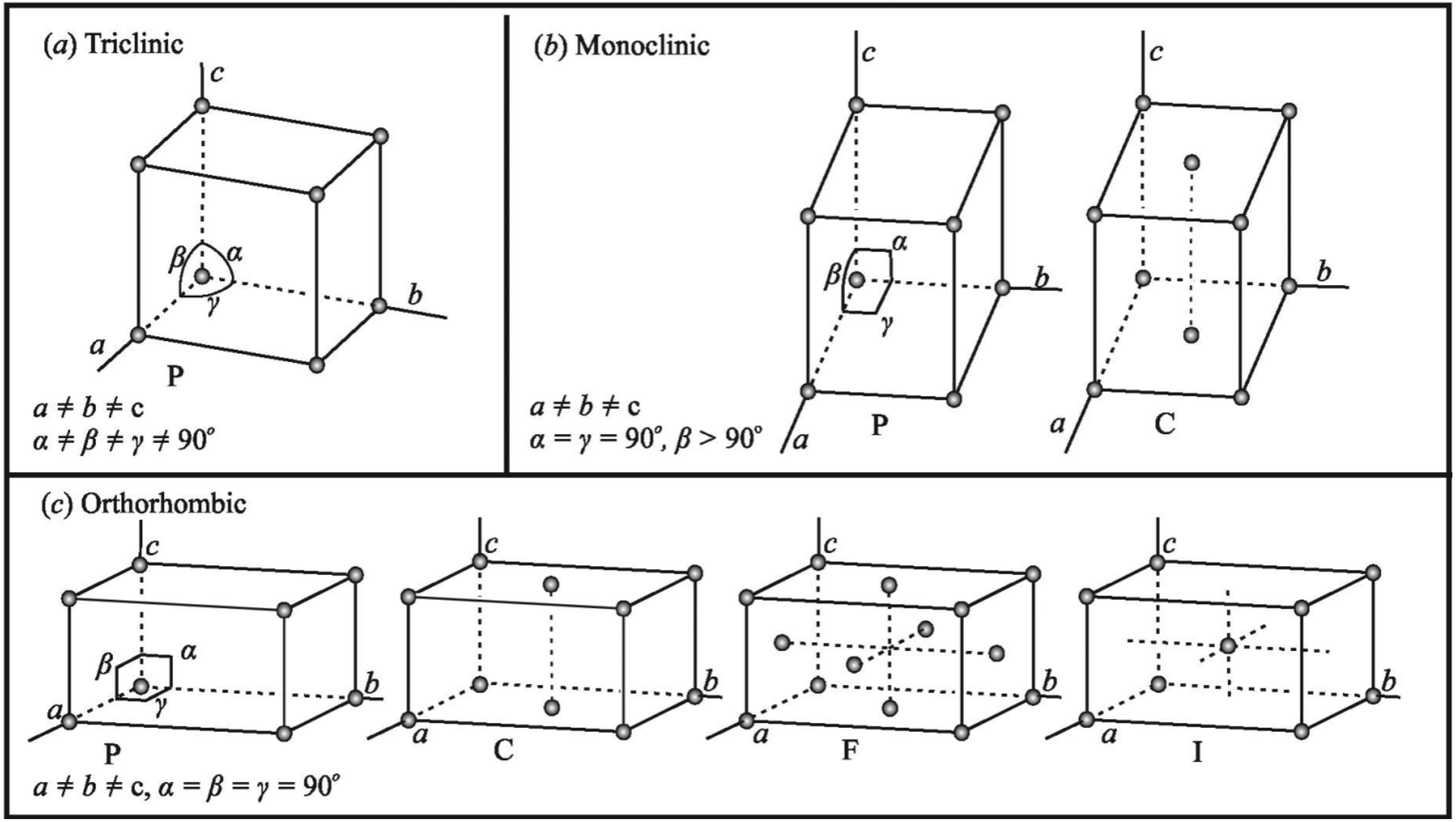


FIGURE 3.5 ■ Sizes of some ions commonly found in rock-forming minerals. Ionic radii are given in 10^{-8} cm. [After L. G. Berry, B. Mason, and R. V. Dietrich, *Mineralogy*. San Francisco: W. H. Freeman, 1983.]

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

Crystallography of Minerals

(14 Bravais Lattice from translational Symmetry)



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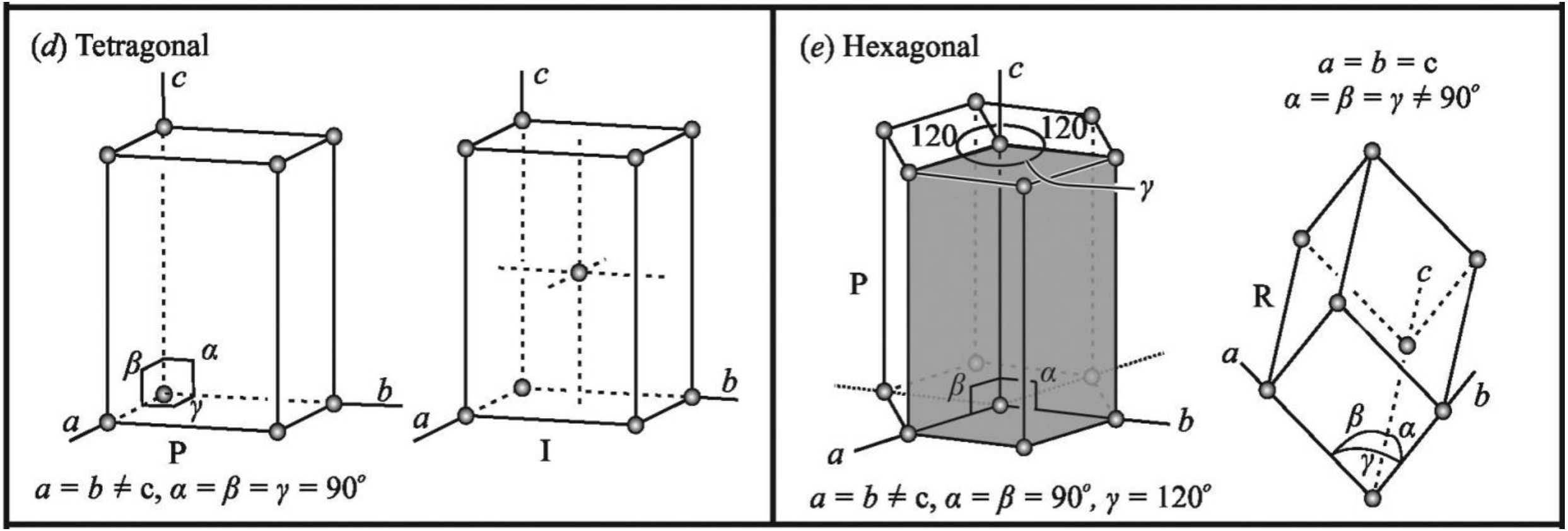

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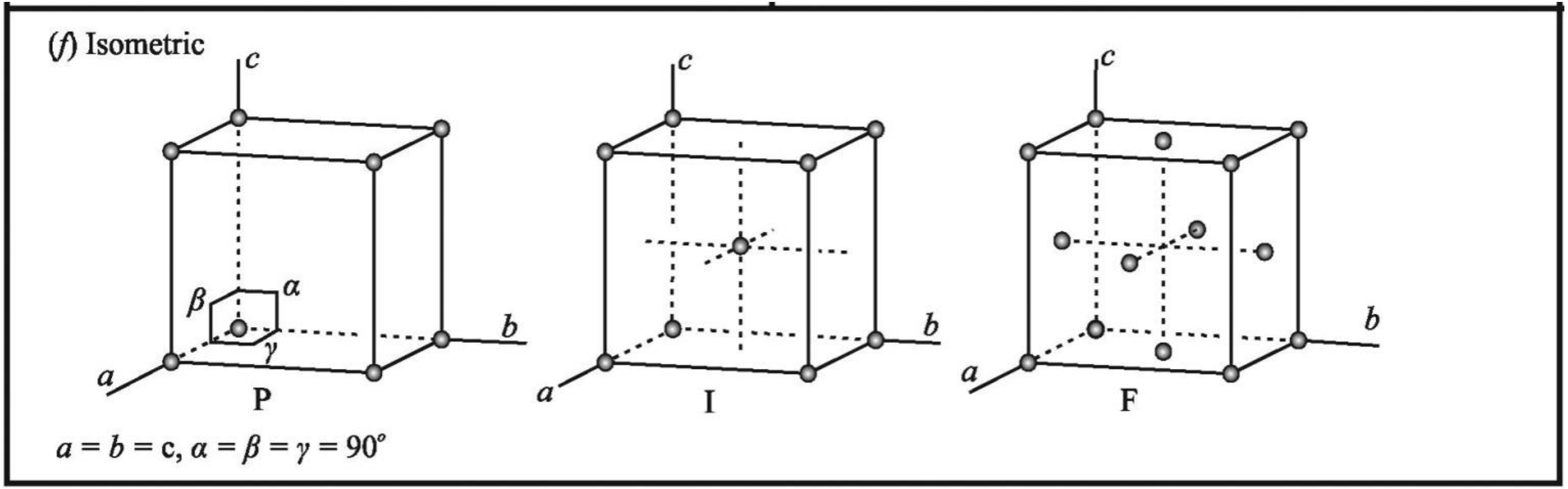


Figure 2.10 The 14 Bravais lattices define six different three-dimensional volumes (*a*–*f*) that correspond to the unit cells of the six crystal systems. The lengths of the three unit cell axes are *a*, *b*, and *c*, and the angles between them are α, β, and γ. In the notations, the $\neq$ sign indicates 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.

Point Symmetry

Point Symmetry

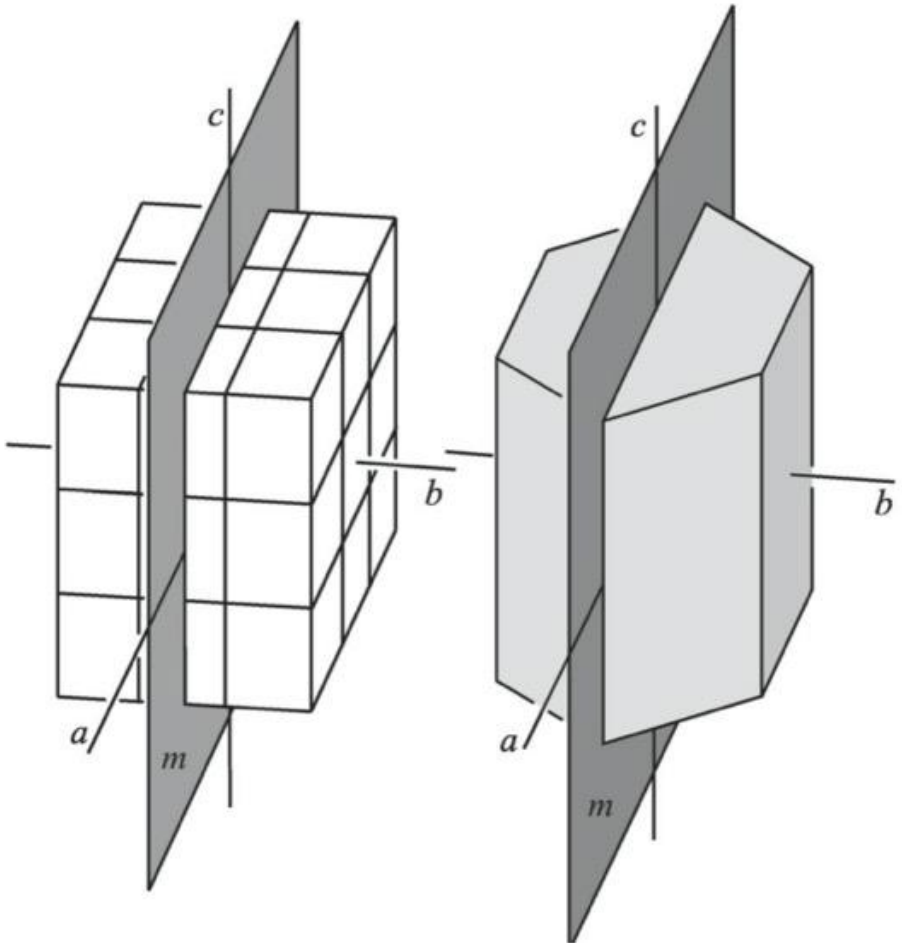
- **An object that consists of a systematic repetition of identical features is said to have“symmetry”.**
- **Three main external symmetry are recognized : (1) symmetry with respect to a plane; (2) symmetry with respect to a a line.; (3) symmetry with respect to a point.**
- **It is possible for an object to possess more than one type of symmetry.**

Point Symmetry

- **Mirror (reflection) Symmetry with respect to a plane.**
- **Rotational symmetry with respect to an axis.**
- **Inversion symmetry with respect to a point.**
- **Roto-inversion (A combination of rotation with a center of inversion) Symmetry**

Point Symmetry

Mirror Symmetry



- Symmetry by a mirror “m” plane of reflection.
- Monoclinic minerals will have only one mirror plane.
- Triclinic minerals will have no mirror plane.
- A cubic mineral may have as many as 9 mirror planes.

Point Symmetry

Rotational Symmetry

Vertically oriented symmetry axis

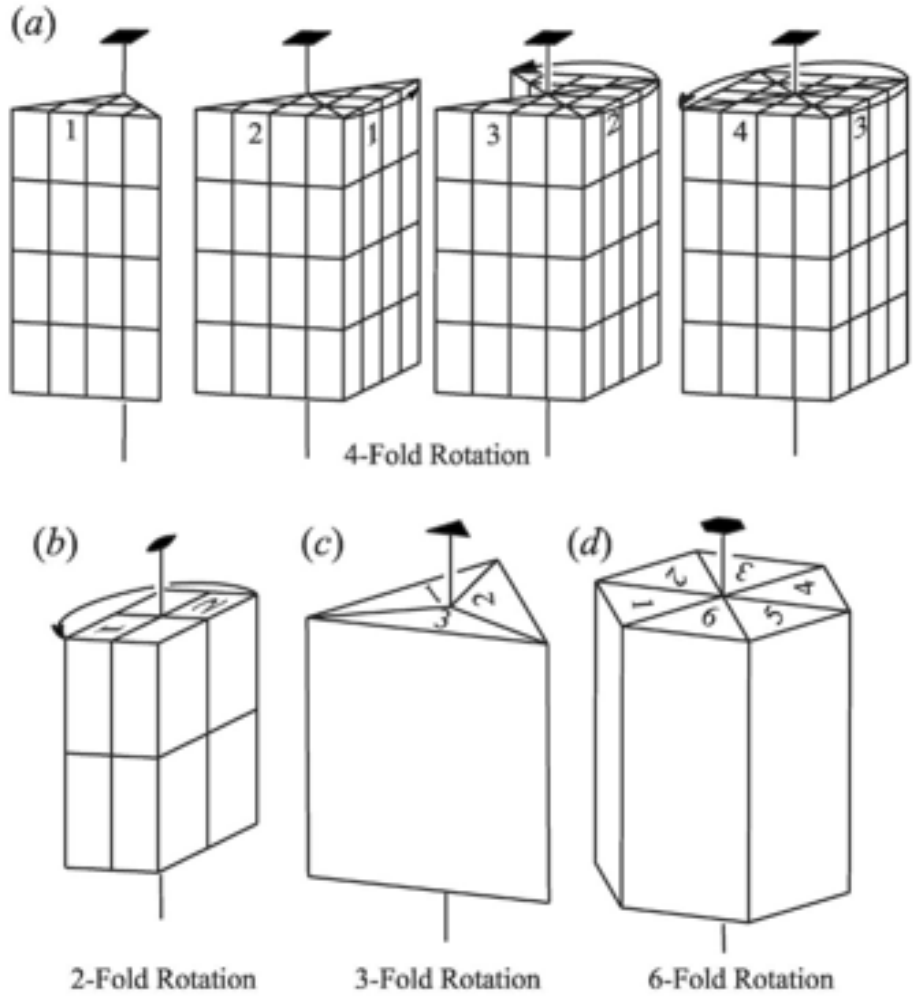
4 (α = 90 deg) 5 (α =72 deg) 6 (α = 60 deg)

If "$\boldsymbol{\alpha}$" symbolizes the repeat angle for an "X"-fold axis of symmetry – that is, the angle of rotation about this axis necessary to "repeat the scene"– then,

$$\boldsymbol{\alpha} = \frac{\mathbf{360}}{\boldsymbol{X}}$$

Point Symmetry

Rotational Symmetry

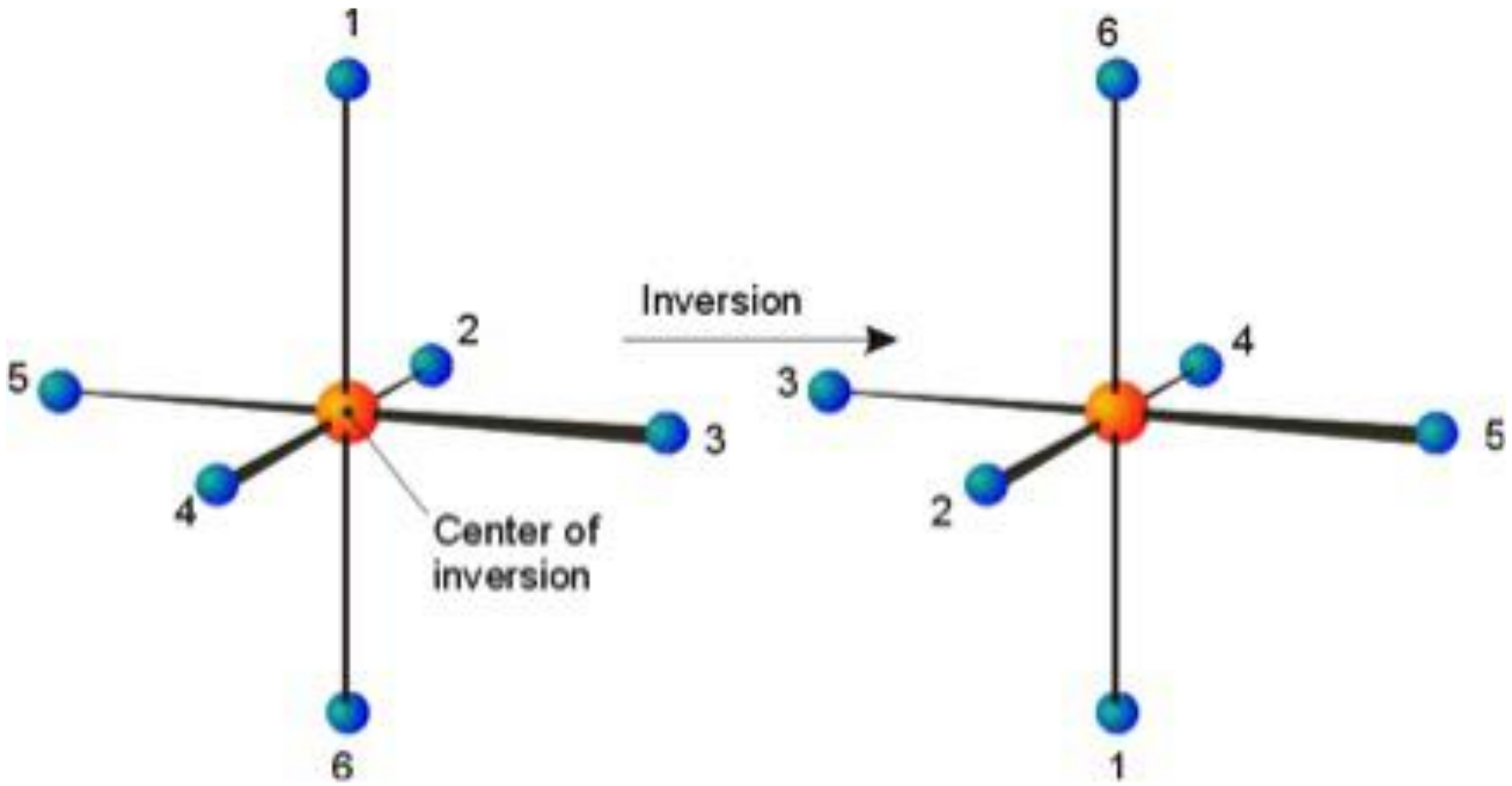


Point Symmetry

Inversion Symmetry:

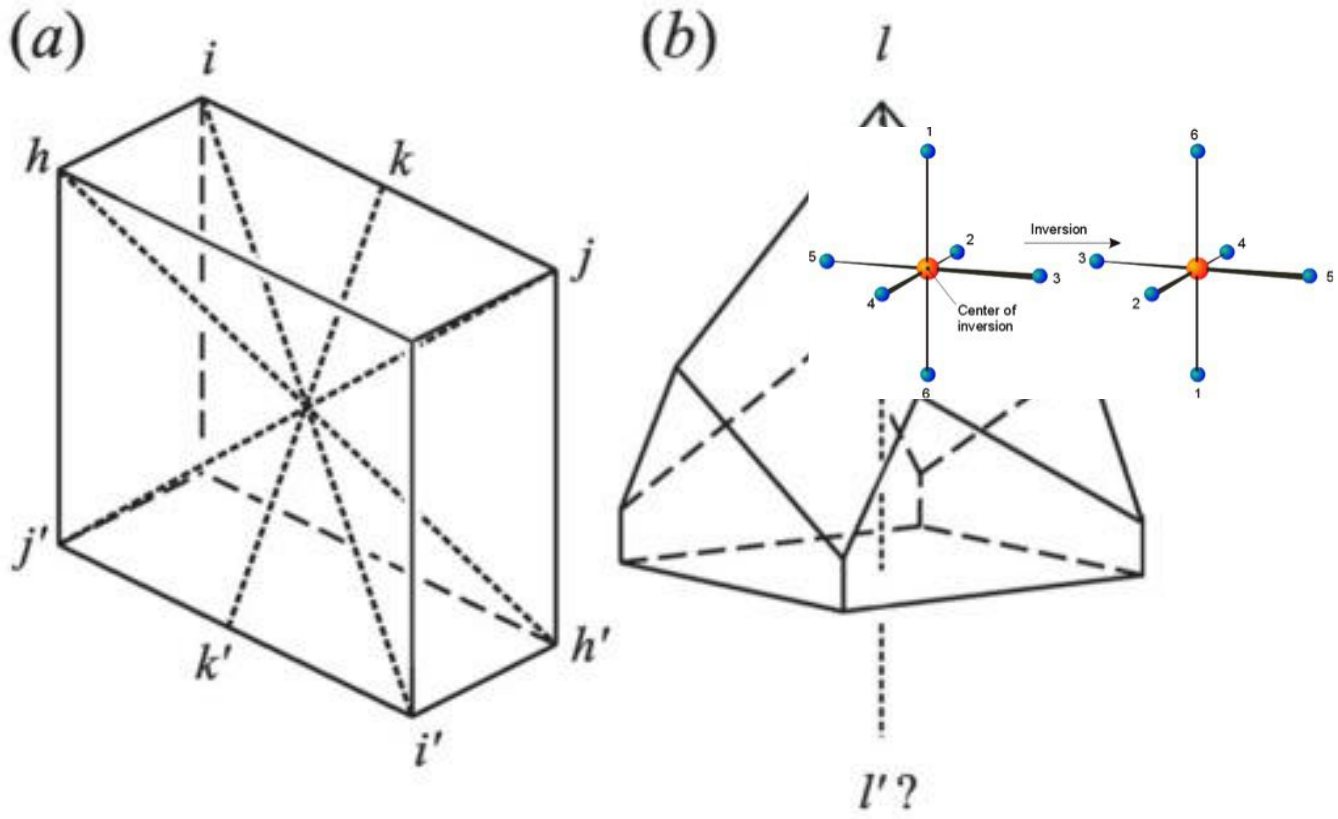
- **Inversion relative to the origin (centre of inversion):**

$$X, Y, Z \leftrightarrow -X, -Y, -Z$$



Point Symmetry

Inversion Symmetry

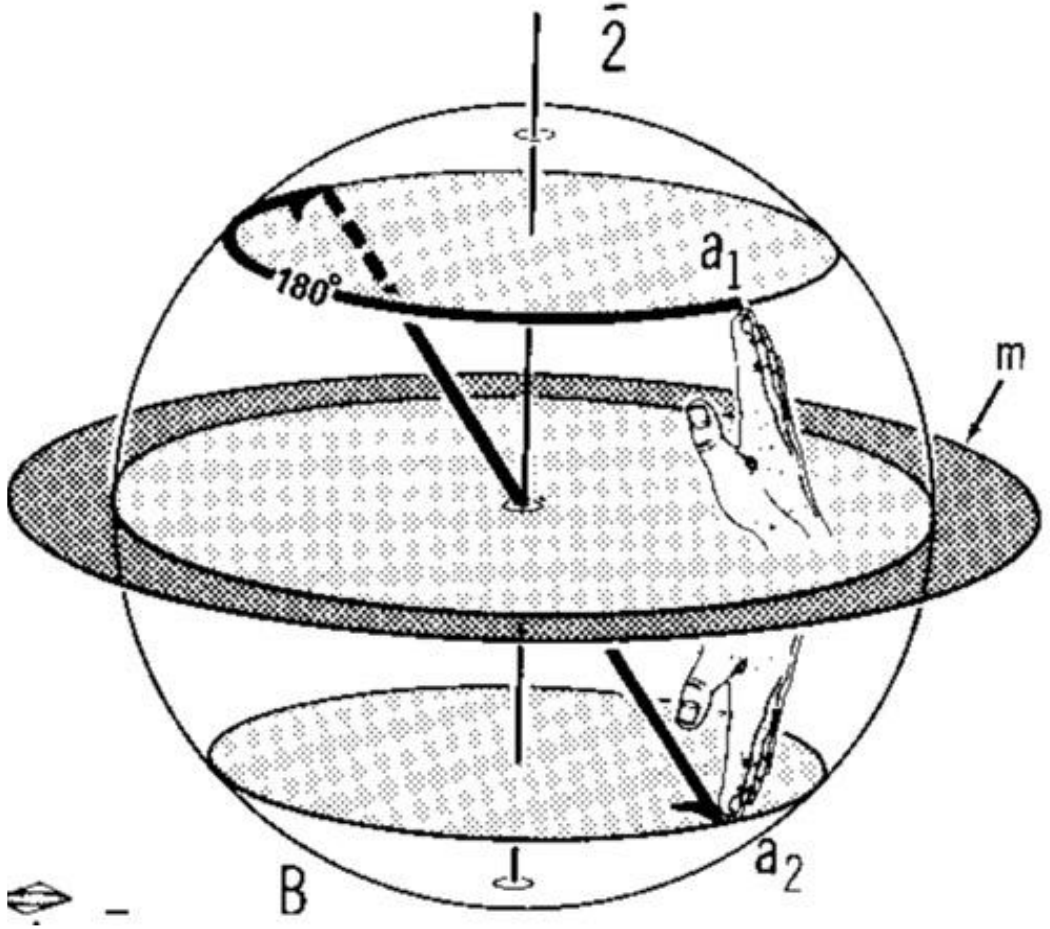


- If a crystal has inversion or center of symmetry, any line drawn through the origin will find identical features equidistant from the origin on opposite sides of the crystal.

- Inversion symmetry is identified with the letter ”i”.

Point Symmetry

Roto-inversion Symmetry: A combination of rotation with respect to an axis and inversion with respect to a point.



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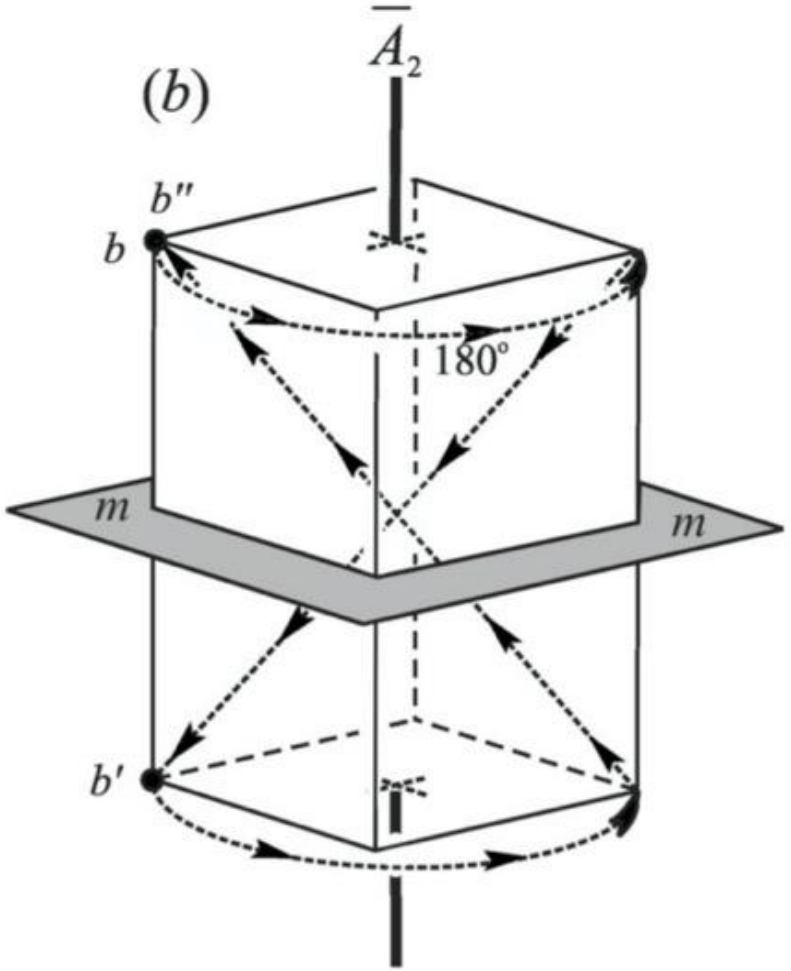

Point “b” upon rotation by 180 degree followed by inversion through the centre produces b’.