

Introduction to Crystallography

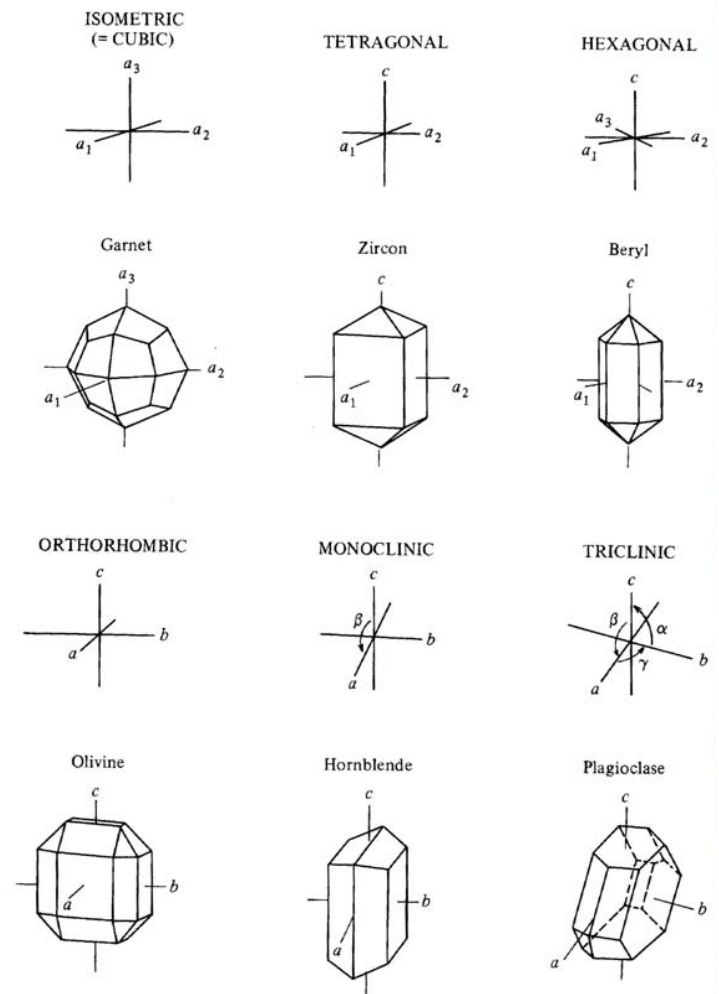
(This material has been slightly modified from a narrative by Dr John Grace, WMU faculty emeritus)

Since most naturally occurring solid substances have an orderly array of atoms they will often display (given enough time and space) planar faces typically grouped together in a shape referred to as a crystal. Since a given crystal shape is a reasonable diagnostic feature for any given mineral it will be worth our while to understand the science of crystallography.

It is one of nature's most amazing intrigues that no matter what sort of permutations, or numbers of atoms you put together as a regularly bonded aggregate you will have only six possible basic arrays! These are referred to as the six crystal systems. For convenience we illustrate the six systems below by using a notation called the crystallographic axes to illustrate the dimensionality of each system.

Figure 1 - The Six Crystallographic Systems

There are literally thousands of possible crystal shapes and combinations of shapes so the process of understanding crystallography is a little more complicated than just knowing the six systems. You should carefully study pages 16 through 21 in your field guide to understand some of the possible forms found within each of the six systems. A more extensive *Introduction to Crystallography and Mineral Crystal Systems* by Mike and Darcy Howard is provided as Appendix A of your *M&RCP*



Symmetry

One technique that can be useful in determining what system a particular crystal might belong to is the property of symmetry. Symmetry *elements* include planes of symmetry (2-D or mirror plane symmetry), axes of symmetry (1-D, linear or rotational symmetry), and points of inversion (dimension-less or roto-inversion symmetry) that, in combination, can help distinguish one crystal from another.

An axis of symmetry is an imaginary axis about which an object is rotated and if it appears symmetrical or the same at some point in one full rotation then it is said to have an axis of symmetry. The number of times it may repeat during one rotation gives the "foldedness" of a particular symmetry axis. In the crystalline world axis of symmetry of 2, 3, 4, or 6 fold are the only types of axis found

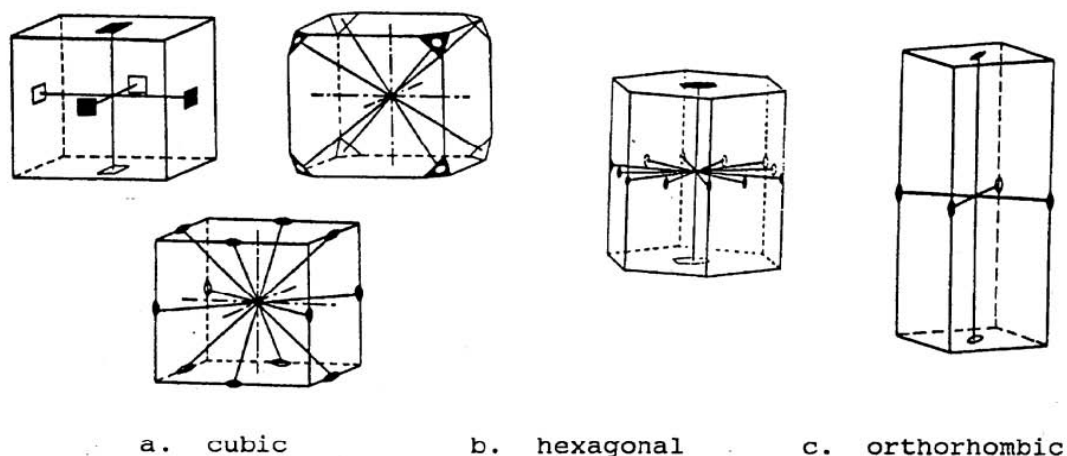


Figure 2

We can illustrate the concept by observing the figures shown above in Figure 2. The cube can be seen to have three 4 fold axes or symmetry corresponding to the crystallographic axes. In addition there are 3-fold axis of symmetry and many 2-fold axis of symmetry that do not correspond to the crystallographic axes. The cube represents one of nature's most symmetrical crystalline shapes.

If we observe the hexagonal prism in Figure 2b we see that it has a six fold symmetry axis corresponding to the C crystallographic axis and many two fold axis that are normal to the C axis and lie in the plane of the $a_1 a_2 a_3$ crystallographic axis. The orthorhombic crystal in Figure 2c has only 3 axis of 2 fold symmetry which correspond to the a, b, and c crystallographic axes.

It can be shown that the amount of symmetry is greatest for the cubic systems and is sequentially less as we consider each succeeding system until we reach the triclinic system that have very little symmetry. The following table lists the "characteristic" symmetry for each system and in our first laboratory we will use these concepts to develop our skills at placing unknown crystal into the appropriate crystal system.

TABLE 1

<i>Crystal System</i>	<i>Characteristic Symmetry</i>	<i>Symbology</i>
Cubic (isometric)	3 axes of 4 fold	(3A ₄)
Tetragonal	1 axis of 4 fold	(1A ₄)
Hexagonal	1 axis of 6 fold	(1A ₆)
Orthorhombic	3 axes of 2 fold*	(3A ₂)
Monoclinic	1 axis of 2 fold	(1A ₂)
Triclinic	1 fold symmetry only	

*Technically not always true but sufficient for our purposes.

Book references: *Simon and Schuster's Guide to Rocks and Minerals*; pp8-2

Darby; *Hands on Mineral Identification*: Ch7, slides 145 to 186

WWW sites for reference: Mike and Darcy Howard: *Crystallography and Mineral Crystal Systems* <http://www.rockhounds.com/rockshop/xtal/>

David Barthelmy: *Mineralogy Database; Crystallography*
<http://webmineral.com/crystall.shtml>

L.S. Fichter: *Crystal/Cleavage Models*
<http://csmres.jmu.edu/geollab/Fichter/Minerals/cleavage.PDF>

I. Determine the crystal system for each of the large wood models in the grey plastic trays.

<u>Sym.</u>	<u>System</u>	<u>Sym.</u>	<u>System</u>
1 _____		4 _____	
2 _____		5 _____	
3 _____		6 _____	

II. Do the same for the small models in the wood box set.

<u>Sym.</u>	<u>System</u>	<u>Sym.</u>	<u>System</u>
1 _____		7* _____	
2 _____		8 _____	
3 _____		9 _____	
4* _____		10 _____	
5 _____		11 _____	
6 _____			

*Nos. 4 and 7 are difficult and may have more symmetry than you might think initially.

III. Real crystals (in plastic tray) Real crystals are often distorted by accidents of growth so you must make allowances and assume the crystal is complete and perfect.

Quartz _____ Halite _____

Garnet _____ Feldspar _____

Apatite _____ Pyrite _____

IV. Museum Tour - do the best you can do observing the following from a distance.

Calcite _____ Fluorite _____

Tourmaline _____ Gypsum _____

1. List the axes and planes of symmetry for the following objects. (These are not mineral crystals so there is no limitation on the amount of symmetry they might possess)

- a. An egg _____
- b. A pair of scissors _____
- c. The human body _____
- d. Everett Tower _____
- e. A star fish _____
- f. A car _____

Construct the crystal/cleavage models and determine the symmetry elements for the first four models. Include mirror plane symmetry, rotational symmetry and *try* to determine roto-inversion symmetry. See :

L.S. Fichter: *Crystal/Cleavage Models*

<http://csmres.jmu.edu/geollab/Fichter/Minerals/cleavage.PDF>