

## Crystal Symmetry

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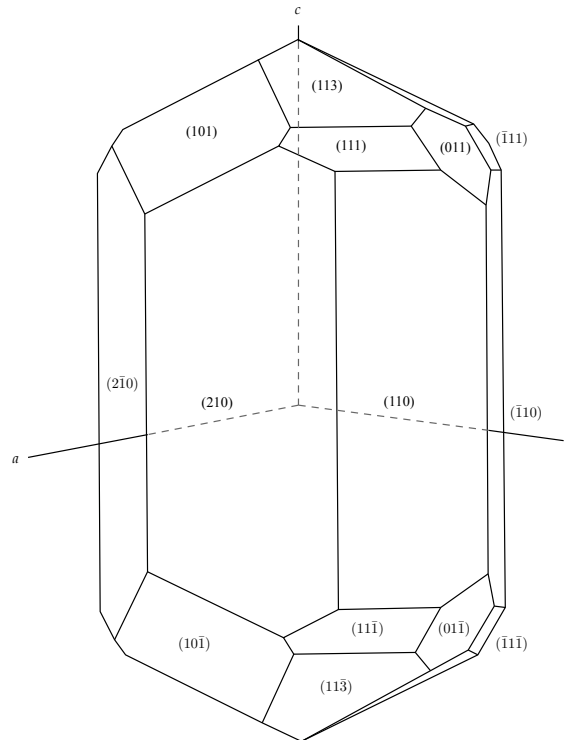
Crystals have faces that represent externally some facets of the internal structure of minerals. Quartz has a six-sided shape and a pointed end, called a termination, which represents the hexagonal arrangement of the  $\text{SiO}_2$  in the crystal structure. Pyrite commonly occurs as cubes, reflecting its cubic structure. The study of the relation between the crystal shapes and the crystal structure is called CRYSTALLOGRAPHY.

Crystallographers have several tools to peer into the crystal structure. A primary tool is x-ray diffraction. We will look at x-ray diffraction in a couple of weeks. We will start by making some simple observations about crystals, primarily the symmetry of crystals.

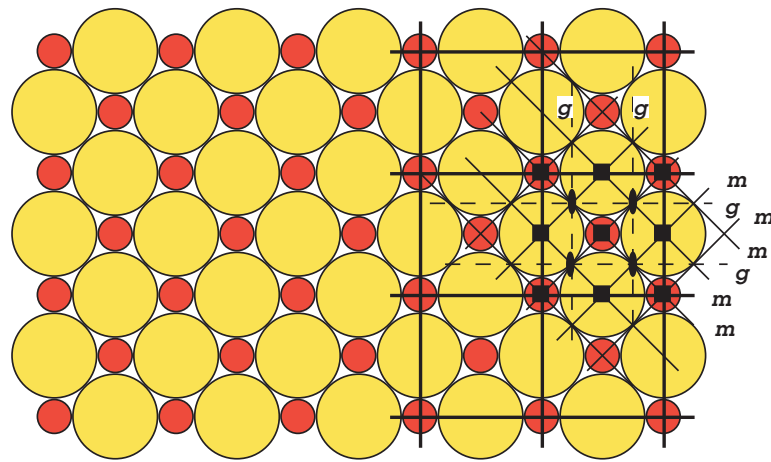
Symmetry occurs in two forms: translation and point symmetry. We won't be able to observe directly the translation symmetry because it can only be seen at the scale of a unit cell. We can, however, see the point symmetry easily in crystals.

For all intents and purposes we can consider the point-symmetry elements to be rotation axes, mirror planes, and centers of symmetry. Crystals can possess one of 32 possible combinations of these symmetry elements. Each combination is called a point group, and though there are 32 groups, only six or seven are important for the rock-forming minerals. A list of all 32 groups is attached and includes common minerals that form in the groups and their symmetry elements. The letter *i* stands for a center, The letter *A* stands for a rotation axis and has a subscript indicating its multiplicity, *p* stands for a mirror plane, and a bar over the number indicates rotation and inversion through the center. The groups are gathered into seven crystal systems with the most important in each highlighted.

1. Examine one of the clear plastic models of crystals. Make a sketch of the crystal in your notebook. Examine the crystal and notice the symmetry that the crystal possesses. Rotate the crystal about several axes and note whether the crystal form has two-fold or four-fold axes of symmetry. That is, the crystal appears to have the same form when rotated  $180^\circ$  (two-fold) or  $90^\circ$  (four-fold). Are there any mirror planes present? List the symmetry content using the scheme described above and mark on your sketch the locations of the various symmetry elements.

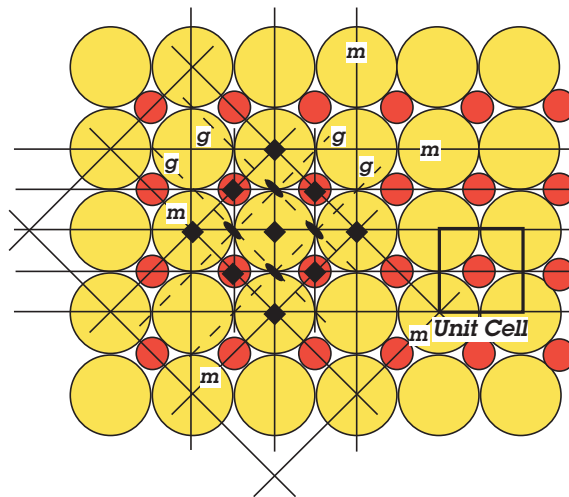


2. Look at the pearwood models 108 and 65. These represent the crystal forms of the most common point groups in the orthorhombic and monoclinic systems. Make a list of the symmetry content of these two models.
3. Look at some real crystals. They rarely have the nice “faces” shown in the plastic or wooden models. Try to determine from the symmetry present which systems they belong to. You should have quartz, pyrite, garnet, tourmaline, and a few others.
4. Use the Mineralogy Tutorial on the computers in the computer lab as a guide to the possible point-symmetry operations. You can navigate to the section by clicking on the first item, Crystallography. In this section you can find examples of the elementary operations and descriptions of the 32 possible combinations of symmetry operations. Refer to the tutorial as necessary for visual clues to symmetry concepts.
5. Translation symmetry can be determined with the use of a technique such as x-ray diffraction, which can indicate the positions of atoms in the crystal structure. To illustrate the concepts of translation symmetry, we will look at a two-dimensional representation of the NaCl structure. The structure, consisting of alternating large and small atoms, has the symmetry operations shown on the right side of the figure.



**Centered Square Lattice**

$Z = 2$



**Primitive Square Lattice**

$Z = 1$

The heavier lines outline a centered square lattice. The primitive lattice is oriented at  $45^\circ$  to the centered one (see your homework assignment).

There is one operation present in this structure that is a combination of point and translation symmetry—the glide plane, shown as dashed lines. Glide planes represent reflection of the motif across a mirror plane and translation a distance of  $1/2$  the unit-cell distance parallel to the plane. Another feature of note is that the intersection of two mirror planes automatically generates a two-fold or a four-fold rotation axis.

Look at the following pattern and determine the symmetry operations present, the lattice type, the unit cell, the motif, and the space group (refer to the handouts from class).

