CONSTRUCTION OF CRYSTAL MODELS AND THEIR GRAPHIC EQUIVALENTS

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INTRODUCTION

This laboratory exercise involves construction of physical and computer models of crystals based on a description of their symmetry. The purpose of the exercise is to help you visualize symmetry in two and three dimensions, and to help you explore the relationships between the different crystal systems. It is a problem-solving exercise: the morphology of the crystal is described in simple terms, and both physical and computer models should meet the requirements of these descriptions. Because the physical models may be used in other laboratory exercises, they should be large enough and precise enough for measurement, and durable enough to take handling.

Materials

The physical models can be built from any reasonably durable material. Heavy paper (used manila folders, for example) works well for models up to about 5 cm edge length. A fast-setting glue that is compatible with the materials being used is necessary.

Computer models can be made with programs for making crystal drawings (*e.g.*, SHAPE). The only requirement is that the program be flexible enough to allow input based on crystal morphology (*i.e.*, the program should not require specification of the space group).

Assignment

1. For parts 1 and 2 of this assignment, you will work in groups. Each group is responsible for making <u>two</u> physical models of each of three crystals you are assigned. The two models may be identical, or may be different, if different geometries satisfy the requirements.

Leave one model of each pair blank; on the second, mark the locations of the symmetry elements (except symmetry centers), and label each face with its Miller index and the name of the form to which it belongs.

Your group number is in the top line of the following table; the models you will make are specified by the entries (columns) in the table.

Group No.	1	2	3	4	5	6
No. of Faces: **Crystal System:**	4 triclinic	4 monoclinic	4 orthorhombic	4 tetragonal	4 hexagonal	4 isometric
No. of Faces: **Crystal System:**	5 triclinic	5 monoclinic	5 orthorhombic	5 tetragonal	5 hexagonal	5 isometric
No. of Faces: **Crystal System:**	6 triclinic	6 monoclinic	6 orthorhombic	6 tetragonal	6 hexagonal	6 isometric

2. Using SHAPE, make computer models of each crystal you made in assignment 1. Print out appropriate graphics for each.

3. When you have completed 1 and 2, turn in your results, so that everybody has access to your models and crystal drawings. Then each of you will write and hand in an essay discussing the following:

How are objects of a specific crystal system, but having 4, 5 and 6 faces, related to each other?
How are objects having the same number of faces, but belonging to different crystal systems, related to each other?
Can you name minerals that have crystals shaped like the models?

In your essay, you should use proper crystallographic terminology, and illustrate the principles involved using stereographic projections of appropriate crystals. The text of your essay should be limited to one typewritten page for each question.

Grading
Each group will be assigned a grade for models and graphics. This group grade will be 50% of the grade for the exercise. Grades for the essay will be the other 50% of the grade.

NOTES TO THE INSTRUCTOR

This laboratory exercise is designed to achieve three objectives: **1.** to fix in students' minds the essential symmetry content of the six crystal systems; **2.** to help students visualize the relation between three-dimensional objects and their two-dimensional representations; and **3.** to help students understand the relationships between the six crystal systems. Students should see that lower symmetry objects can be visualized as distortions of higher symmetry objects; this is particularly obvious among the crystals with six faces.

There are four activities in this exercise. Some are best planned as group activities. The first is the construction of physical models that meet specific requirements and correspond to the symmetry of the six crystal systems. The second is the construction, using a computer program like SHAPE, of a two dimensional representation of the physical model that was built in step 1. The third is a writing activity that requires students to compare models of the different crystal systems using crystallographic terminology. The fourth is an optional activity that extends the first two by requiring students to identify, on their models, the symmetry elements that are present, the Miller indices of specific faces, the forms that are present, and to draw stereographic projections. I regard the first and third activities as essential to the exercise.

I can think of three ways of assigning groups. Pairs of students can be assigned to complete pairs of physical and computer models. Groups of students can be assigned to make all models for a single crystal system, or groups of students can be assigned to make all models meeting specific constraints, regardless of the crystal system to which they belong. Once the models are made, they become community property, to be used by all students for completing the third activity.

The background students require to complete this exercise is an introduction to symmetry and to the crystal systems. If the fourth activity is assigned, introduction to Miller indices, forms and stereographic projection is also needed. I have not tried this exercise exclusively as a "discovery" exercise in which students have no prior introduction to symmetry and crystal systems, although I think this approach might also be possible. Even after an introduction to crystal systems, there is a problem solving aspect to the exercise that frightens some students: the simple recipe describing the crystal morphology is difficult for most students to translate into a series of adjoining faces that have to be cut and folded, etc. Most students assemble the crystals from separate pieces, rather than planning out a strategy for making the model from a single, contiguous piece. It is helpful to point out that the students need to leave "tabs" along the edges of the crystal faces so that adjacent faces can be glued together.

One of the models that is assigned - an object with five faces and isometric symmetry - is, to the best of my knowledge, impossible to build. Students assigned this model will discover that it is impossible. Assigning this model is a useful teaching exercise because of its discovery aspect.

Left to their own devices, students generate a variety of products: some models will be less than an inch on a side, others will be the size of a basketball; some will be made of onionskin paper with no integrity of shape, others will be of balsa wood; some will be nondescript, others will have each face a different color; some will be very precisely made, others will hardly have parallel edges or regular angles. If all of the models are within an acceptable range of durability, these differences are useful for talking about shape and size in contrast to form and symmetry.

I schedule this exercise over three laboratory periods, involving an aggregate of 3 hrs of scheduled laboratory time. I assign it and introduce SHAPE on Tuesday (1.5 hr lab period), work and consult with students Thursday (1.5 hr lab period), collect models the following Tuesday, and collect essays Thursday. I expect the essays to be done outside of scheduled lab time, so that the second week, except for brief discussion of some of the models on Tuesday, is available for introduction of new material.

I found the assignment involving SHAPE to be difficult. When I assigned this, we had DOS version 2; I found it not to be user-friendly, and the distortion of crystal shapes in some of the perspectives was hard to explain to students. I use parts of this exercise as a take-home activity for K-6 science teachers in an introductory earth science course, with good results. The exercise is easily exportable to younger students, and teaches solid geometry in a simple, hands-on way.