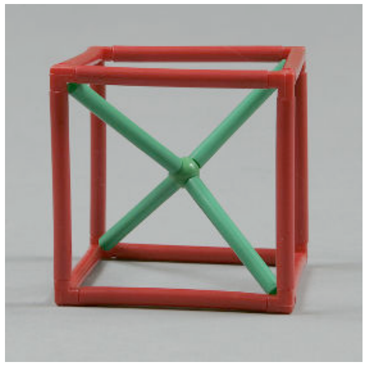
Super Models



Tetrahedral Bond Angle Determination
Molecular Model Kit

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Recommended for ages 10-adult

⚠ **Caution:** Atom centers and vinyl tubing are a choking hazard. Do not eat or chew model parts.

Kit Contents:
9 Cube Corner Vertices
2 green, 4-peg Atom Centers
4 Red, 21 cm Tubes
4 green, 21 cm Tubes

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Tetrahedral Bond Angle Determination Kit

INTRODUCTION:

The tetrahedron is a very common shape among molecules found in nature. A central atom with four identical atoms surrounding it will have a 109.5° angle between the bonded atoms.

This tetrahedral angle results from the mutual repulsions of the electron pairs in the bonds (according to VSEPR theory).

Other common shapes, such as trigonal pyramidal and bent triatomic, found in many molecules are variations of the tetrahedral angle. The goal of this activity is to determine the tetrahedral angle to six significant digits using mathematics and a plastic model kit.

The activity can be presented to students as a puzzle, a lab, or an extra-credit activity. The teacher may wish to provide some hints to students who are having difficulty with the assignment. The teacher may also want to cover basic geometric and trigonometric concepts useful in this activity.

Instructions to the teacher prior to the first time use of the kit:

1. Cut the red, 21 cm tubes into pieces that are exactly 5.0 cm long. You will need 12 of these 5.0 cm pieces. You will have some spare tubing in case of a mistake in cutting. See Fig. 1.

Fig. 1 Red tubing cut to size.

2. Cut the green, 21 cm long tubes into pieces which are exactly 4.2 cm long. You will need four of the 4.2 cm long pieces. Again, you will have some spare tubing in case of a mistake. Fig. 2.

Fig. 2 Green tubing cut to size.

The kit is now ready to be used by the student.

INSTRUCTIONS TO THE STUDENT:

1. Construct a cube using 12 red tubes and eight red corner vertices. You will assume this to be a perfect cube. Set the cube aside. See Fig. 3 and Fig. 4.

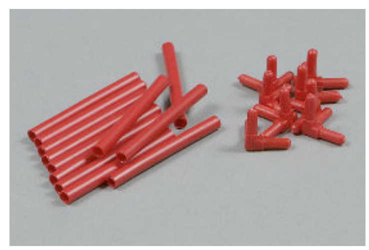

Fig. 3 Unassembled tubes and vertices.

Fig. 4 An assembled cube.

2. Connect the four green tubes to the green tetrahedral atom center (one tube on each peg). See Fig. 5.

Fig. 5 A green tetrahedral atom center with four green, 4.2 cm tube attached.

3. Place the green tetrahedral atom center with the attached green tubes inside the cube, and adjust the tetrahedron so that it stays in place in the interior of the cube as in Fig. 6.

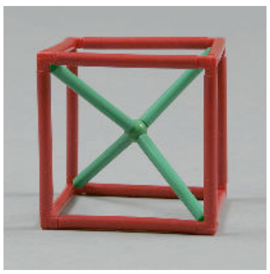

Fig. 6 The cube with an inserted tetrahedron.

4. Assume that the green tetrahedral atom is exactly in the center of the cube.

5. Using geometry and trigonometry, determine the angle between any two green tubes (the tetrahedral angle) to six significant digits.

METHOD OF DETERMINATION:

Here we present one of the several possible solutions to the problem.

1. Assume the length of one side of the cube to be one unit. All sides will be one unit, since we are assuming this to be a perfect cube. See Fig. 7.

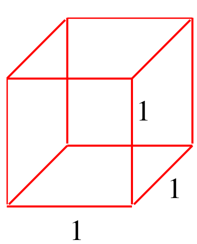

Fig. 7 A cube with arbitrary sides of 1 unit.

2. The diagonal across the cube has a length equal to the square root of 2 (1.41421) using the Pythagorean theorem. See Fig. 8.

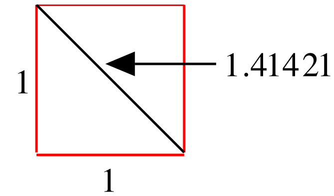

Fig. 8 Calculating a diagonal of the cube.

3. The diagonal is opposite the tetrahedral angle ϕ. See Fig. 9 and Fig. 10.

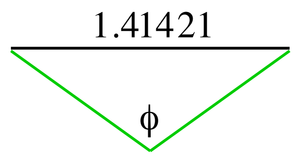

Fig. 9 A drawing of the angle below the diagonal.

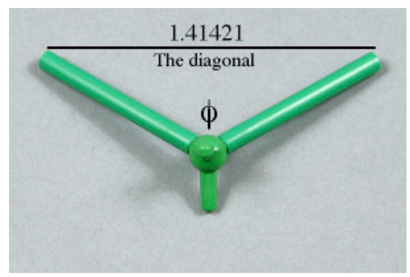

Fig. 10 A photo showing the angle ϕ.

4. Splitting the angle ϕ in half creates a right triangle with sides ½ and (1.41421)/2. See Fig. 11.

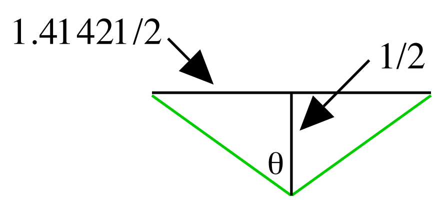

Fig. 11 Making the angle θ.

5. Now $\tan\theta = [(1.41421)/2]/(1/2) = 1.41421$, and the inverse tangent of $1.41421 = 54.7355^0$, which is half of the tetrahedral angle ϕ. The tetrahedral angle, therefore, is $54.7355^0 \times 2$, or 109.471^0 to six significant digits.