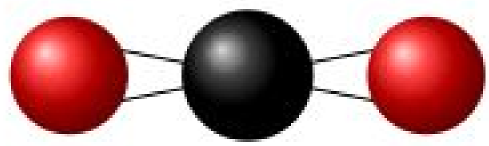
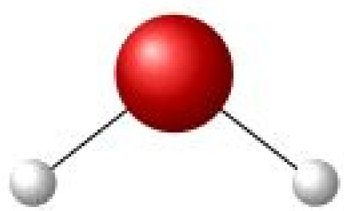
Molecular Geometry

1. Below are some pictures of common molecules and their molecular formula. For each one, find all symmetries of the molecule (it may be helpful, in order to visualize, to build each with a molecular model kit or use the pictures and assign numbers to the different atoms). Dotted lines indicate that the atoms are "behind" the page while the bold larger line indicates that the atom is in "front" of the page. Regular lines mean that the atoms lie in the same plane as the page. Make sure to explain why your list of symmetries is complete.

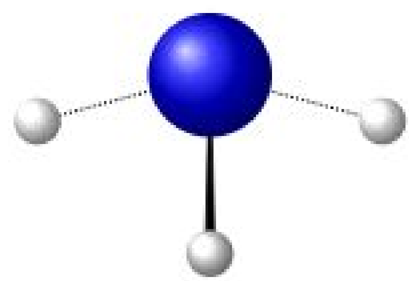
a. Carbon Dioxide, CO_2



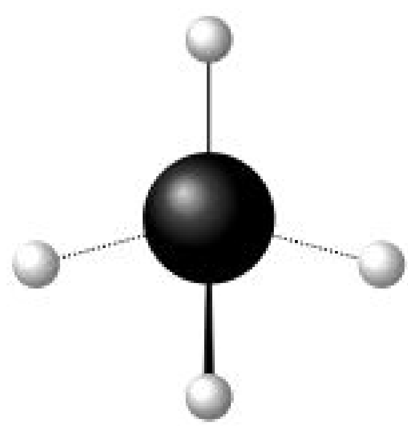
b. Water, H_2O



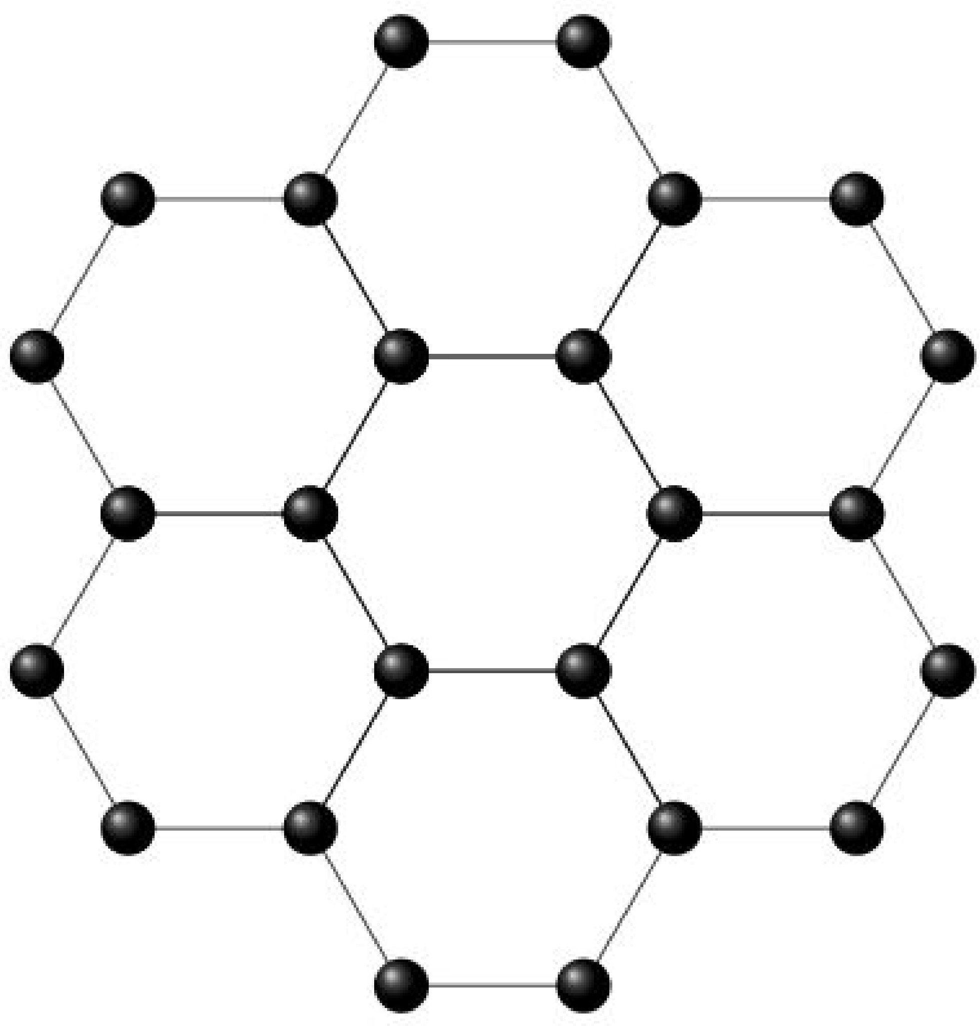
c. Ammonia, NH_3



d. Methane, CH_4



2. The most stable form of pure carbon is shown here



Molecular Geometry

The carbon atoms grow out in all directions in the same hexagonal pattern.

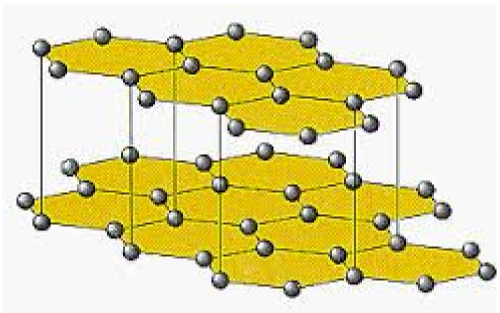
a. What are the rotational symmetries of this pattern (assuming it continues indefinitely)? Make sure to identify both the centers of rotation and the number of degrees.

b. What are the lines of reflective symmetry for this pattern?

c. Graphite is composed of sheets of carbon atoms. The bonds that hold each sheet of carbon atoms together are far stronger than the bonds between each layer. Based on this, what may happen when pressure is applied to graphite? Can you guess what uses graphite may have?

Molecular Geometry

Here is a picture of two sheets of graphite:

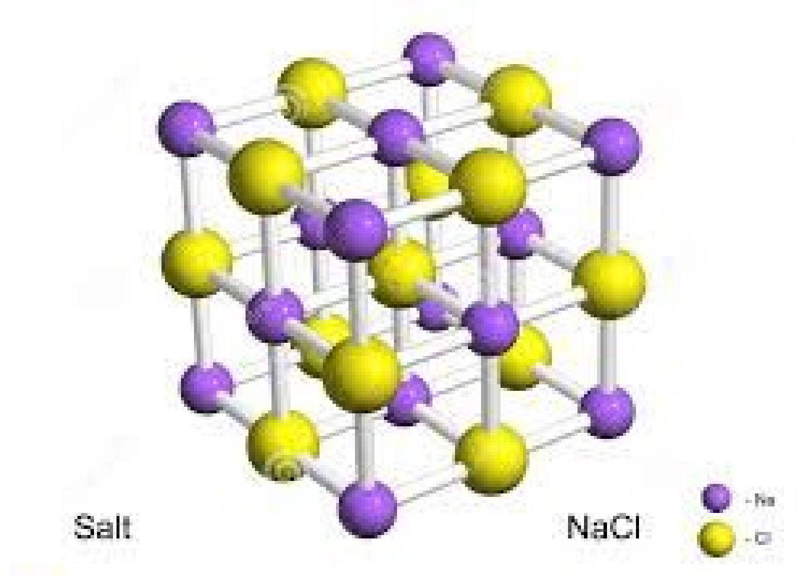


d. There is another very well known form of pure carbon shown here

What properties would you expect of this substance? Can you guess what it is?

Molecular Geometry

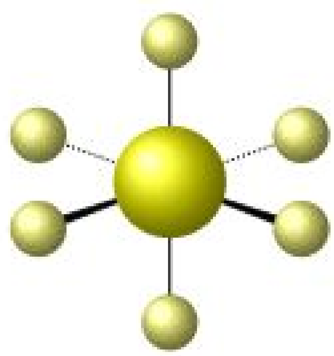
3. Salt, NaCl, has a simple molecular structure pictured here:



a. How many immediate neighbors does each sodium atom have? What about each chlorine atom? Remember that the picture continues on in all directions.

b. In the picture above, imagine the central chlorine atom is at located at (0,0,0) in 3 dimensional coordinates. Suppose that, in these coordinates, all atoms that touch (in the sense of being 'bonded') are one unit apart. What atom will be centered at the point (0,0,1)? What about (1,1,1)? (3,2, -4)? (a,b,c)?

4. Here is a picture of the sulfur hexafluoride molecule.



a. What shape is this molecule?

b. What are some symmetries of the sulfur hexafluoride atom?

THE CURTIS CENTER Molecular Geometry

For the Professional

“Perhaps Looking glass milk is not good to drink” Lewis Carroll

1. This problem looks at symmetries of some simple plane figures.

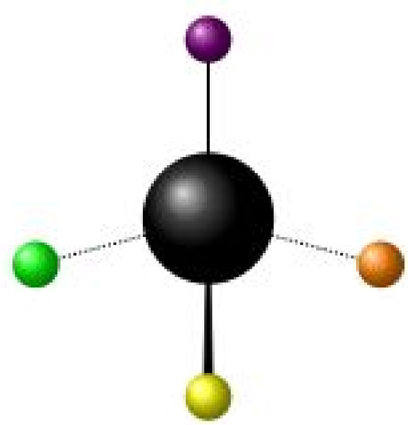
   a. What are the symmetries of an equilateral triangle? How many rotational symmetries does it have? How many reflections?

   b. What are the symmetries of a square? How many rotational symmetries does it have? How many reflections?

   c. Give an example of a quadrilateral with rotational symmetry (which is not a 360 degree rotation) but no reflectional symmetries.

d. If a polygon has *both* rotational and reflection symmetries, then the number of rotational symmetries is the same as the number of reflection symmetries. Explain why. Note: for the purposes of this problem, the 'identity symmetry' or symmetry that leaves every point on the figure unchanged is considered a rotation (through 0 degrees).

2. Here is a picture of the methane molecule with different colors to distinguish the four hydrogen atoms. Note, that in molecular chemistry kits, the color coding is usually as follows: violet represents iodine, green chlorine, orange bromine, and yellow fluorine.



a. Using the different colors to distinguish the four 'vertices' on this molecule, describe all of the rotational symmetries of the molecule: where do they send the different colored atoms? How many rotational symmetries are there for the regular tetrahedron?

b. Find and describe the planes of symmetry for the regular tetrahedron. How many planes of reflection does the regular tetrahedron have?

c. Is the number of rotational symmetries of the regular tetrahedron the same as the number of reflection symmetries?

d. How many total symmetries does the regular tetrahedron have? Are they all either rotations or reflections? Explain. If not, what are the 'missing' symmetries?

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Molecular Geometry

Common core standards illustrated in this work:

G-CO.2 Represent transformations in the plane using, e.g., transparencies and geometry software; describe transformations as functions that take points in the plane as inputs and give other points as outputs. Compare transformations that preserve distance and angle to those that do not (e.g., translation versus horizontal stretch).

G-CO.5 Given a geometric figure and a rotation, reflection, or translation, draw the transformed figure using, e.g., graph paper, tracing paper, or geometry software. Specify a sequence of transformations that will carry a given figure onto another.

G-CO.6 Use geometric descriptions of rigid motions to transform figures and to predict the effect of a given rigid motion on a given figure; given two figures, use the definition of congruence in terms of rigid motions to decide if they are congruent.