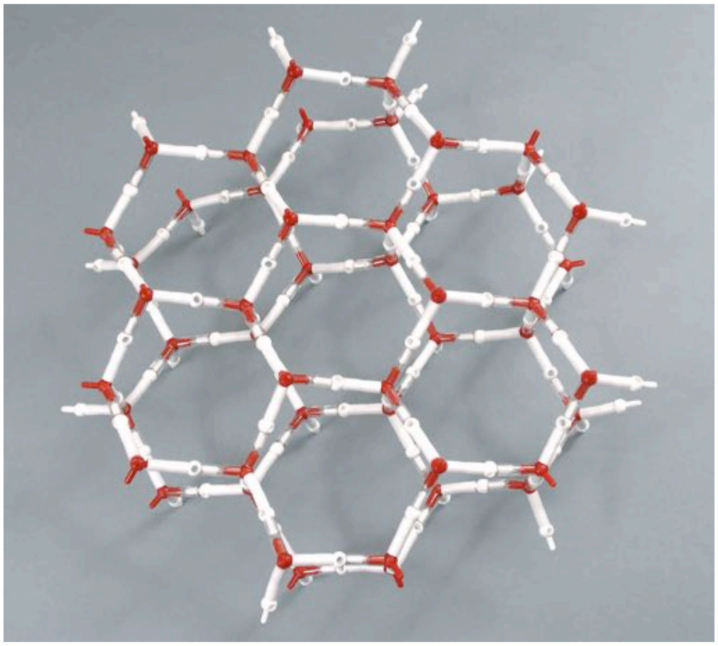
Super Models



Ice Molecular Model Kit

Recommended for ages 10-adult

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

Kit Contents:

50 red 4-peg oxygen atom centers (2 spares)
100 white hydrogen 2-peg atom centers (2 spares)
74 clear, .87″hydrogen bonds (2 spares)
100 white, .87″ covalent bonds (2 spares)

Related Kits Available:
Chemistry of Water

Phone: 806-438-6865
E-mail: etishler@rylerenterprises.com
Website: www.rylerenterprises.com
Address: 5701 1st Street, Lubbock, TX 79416

General Information

Ice, of course, ordinarily refers to water in the solid phase. In the terminology of astronomy, an ice can be the solid form of any element or compound which is usually a liquid or gas. This kit is designed to investigate the structure of ice formed by water.

Water ice is very common throughout the universe. According to NASA, within our solar system ice is found in comets, asteroids, and several moons of the outer planets, and it has been located in interstellar space as well.

There are about 18 different ice crystalline phases (regularly organized structures) and three phases that have no regular organization. The latter are called amorphous or glassy ices. The glass we come in contact with every day has no regular molecular framework, and since amorphous ice resembles this characteristic of glass, the term "glassy" is applied to amorphous ice. The form that ice takes depends on the temperature and pressure conditions present when the ice forms. Most of the names for the crystalline types are very simple, e.g. Ice-one (or Ice I), Ice-two (or Ice II), Ice-three (or Ice III), etc. See the following for more information about ice phases and naming conventions.
http://www.idc-online.com/technical_references/pdfs/chemical_engineering/Ice_phases.pdf

The most common type of earthbound ice is ice I_h. The subscript "h" on the I means hexagonal. When you build your model, you will see water

molecules forming hexagons. Glassy ice (ice I_c), When can be found in the earth's upper atmosphere. The subscript "c" on the I means cubic.

The other forms of crystalline ice are made in laboratories.

A water molecule consists of a tetrahedral, central oxygen atom with two lone pairs of electrons. Each oxygen is also covalently bonded to two hydrogen atoms. Hydrogen atoms of nearby water molecules form hydrogen bonds with the lone pairs of electrons on an oxygen of a water molecule. See Fig. 1 below.

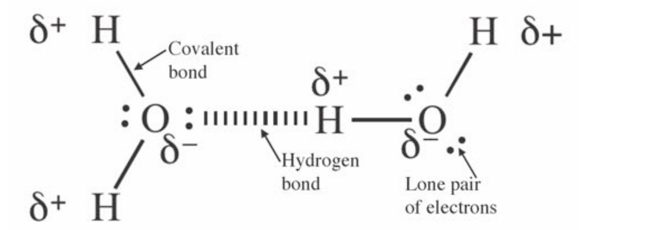


Fig. 1 Two water molecules bonded by a hydrogen bond.

The symbol δ means partial, so when a plus sign is added, the combination means partial positive charge. The opposite obtains when a negative sign is added to the δ.

In ice I, the bonding of six neighboring water molecules produces an open hexagonal ring thereby decreasing the density of the solid. In the ring, the molecules are further apart than they are in the liquid state. This is why ice floats. See Fig. 2.

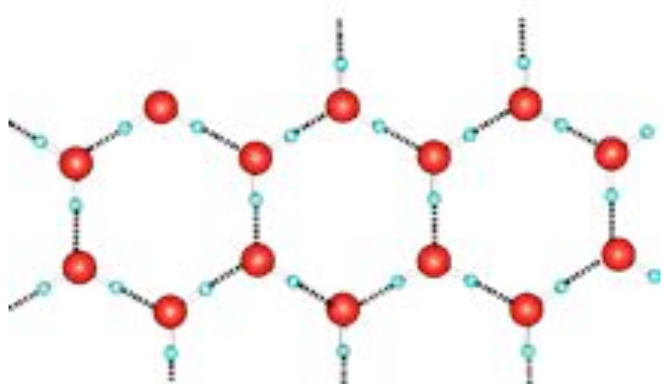


Fig. 2 A portion of an ice crystal showing hexagonal arrangement of six water molecules.

An interesting project using ice was proposed by the British during World War II. An English inventor by the name of Geoffrey Pike convinced the Royal Navy to build an aircraft carrier out of sawdust and ice. The material, which became known as pykrete, was used to build a small test version of a ship that was launched into a lake in Canada. Due to the fast approaching end of the war, the project was cancelled. To read more about this interesting use of ice go to:
https://en.wikipedia.org/wiki/Pykrete

For more general information about iced, see
http://www1.lsbu.ac.uk/water/ice_phases.html

Ice Assembly Instructions

1. Connect two of the white 2-peg hydrogen atom centers to a red 4-peg oxygen atom center using the short, white tubes. This represents a covalently bonded water molecule. See Fig. 3. Repeat this process with all the red (oxygen) and white (hydrogen) atom centers. See Fig. 4.

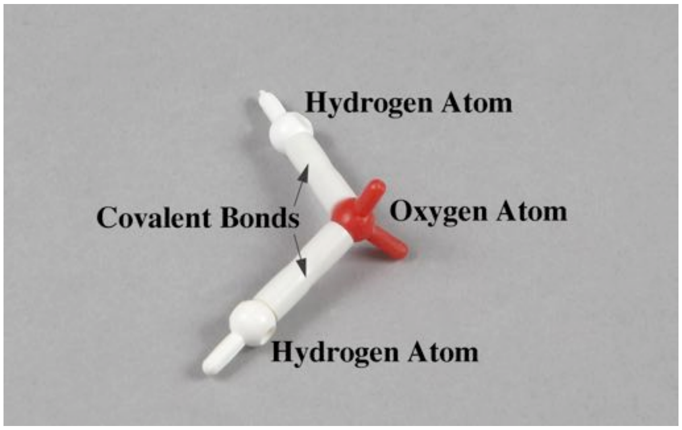


Fig. 3 A single water molecule.

Fig. 4 Forty-eight completed water molecules.

2. You will start building the ice model by constructing a hexagon made of six water molecules. It will be helpful to see what the finished hexagon looks like and to see patterns in the placement of the individual water molecules and bonds in the closed ring.

   Notice that going clock-wise from any red, oxygen atom to a hydrogen atom the bond is covalent. The bond between each hydrogen atom and the next clock-wise oxygen is a clear H bond. See Fig. 5.

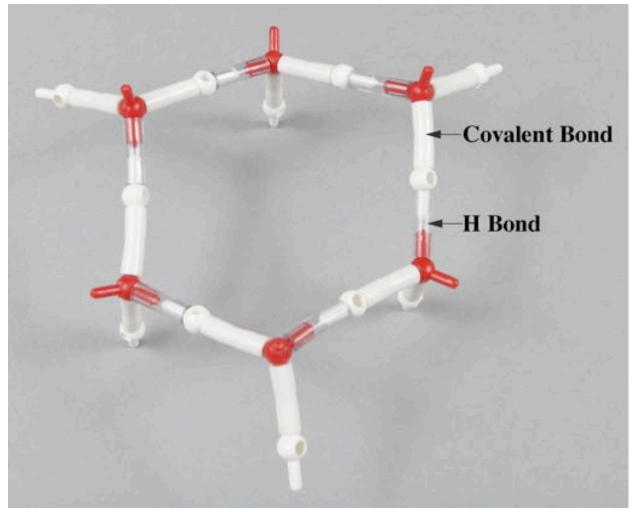


Fig. 5 A hexagonal ring of six water molecules.

Fig. 6 provides an additional method to assure the proper alignment of atoms and bonds in the hexagon. First observe that the ring should not be flat (planar). Due to bond strain within the ring, the ring becomes naturally bent into a chair conformation. As a result of ring bending, three of the oxygen atoms have lone pairs of electrons in an axial (vertical) position and three lone pairs in an equatorial (horizontal) alignment. Axial and equatorial placements alternate with each other.

In a similar way, three of the hydrogen atoms not participating in H bonds are axial and three are equatorial.

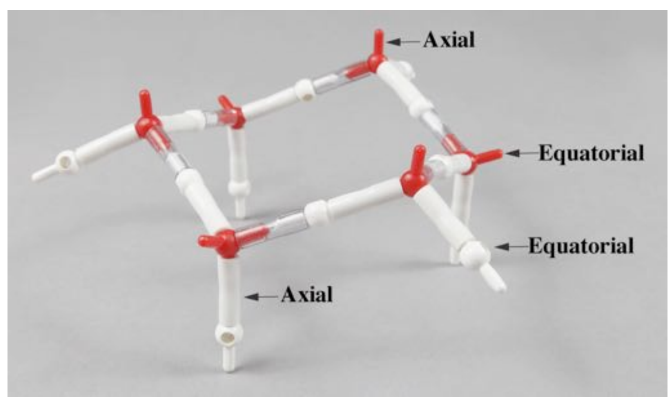


Fig. 6 Six water molecules in a chair conformation.

Take six water molecules and six clear H bonds in order to make the hexagonal ice structure. See Fig. 7.

Fig. 7 Readying six water molecules and six H bonds to make a hexagonal ring.

A handy method which you can use to ensure proper alignment of any two consecutive water molecules is to look down an oxygen atom covering another oxygen atom behind it as shown in Fig. 8.

You are looking for a staggered conformation. Fig. 9.

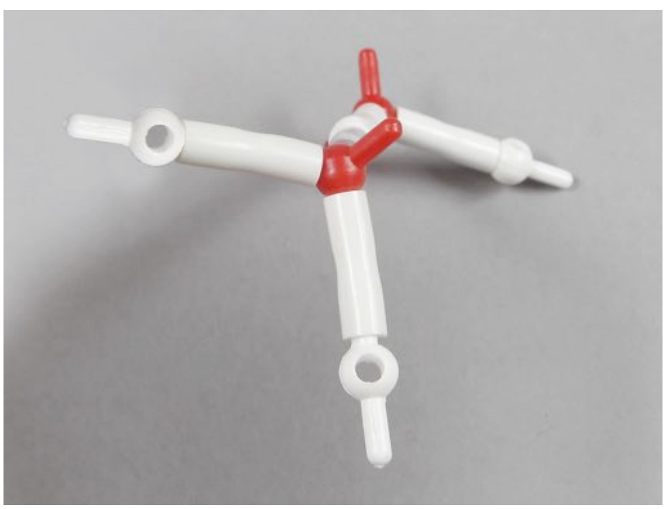


Fig. 8 Staggered bonds on oxygen atoms.

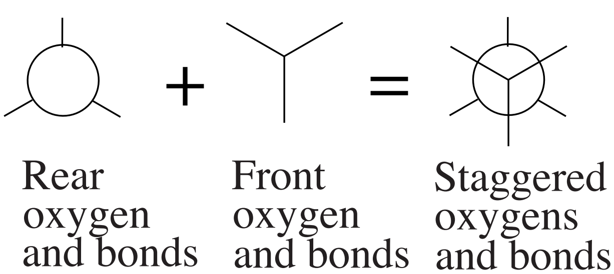


Fig. 9 Simplified diagram of staggered oxygen atoms.

3. Layer number 1 can now be completed to form the general shape shown in Fig. 10.

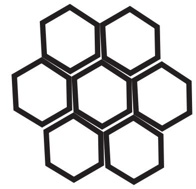


Fig. 10 The generalized shape of one layer of ice.

When adding more water molecules and hydrogen bonds to the hexagonal ring you just completed, you will use the principle of alternating axial and equatorial nonbonding pairs of electrons on the oxygen atoms you connect. Ignore the pattern of clock-wise, alternating covalent bonds and H bonds you used to make your first hexagonal ring.

Look back to Fig. 6 to refresh your memory with regard to axial and equatorial oxygen lone electron pair placements.

Arrange Ring #1 as shown below in Fig. 11 and set aside four water molecules and five H bonds.

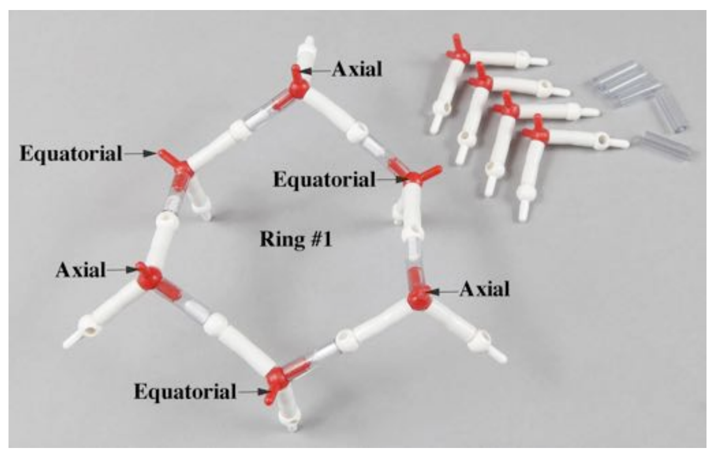


Fig. 11 Getting Ring #1 ready for adding four more water molecules.

Attach a new H bond to the equatorial hydrogen atom furthest away from you, and place the oxygen of a water molecule onto the H bond. The new oxygen nonbonding electrons should be equatorial. See Fig. 12.

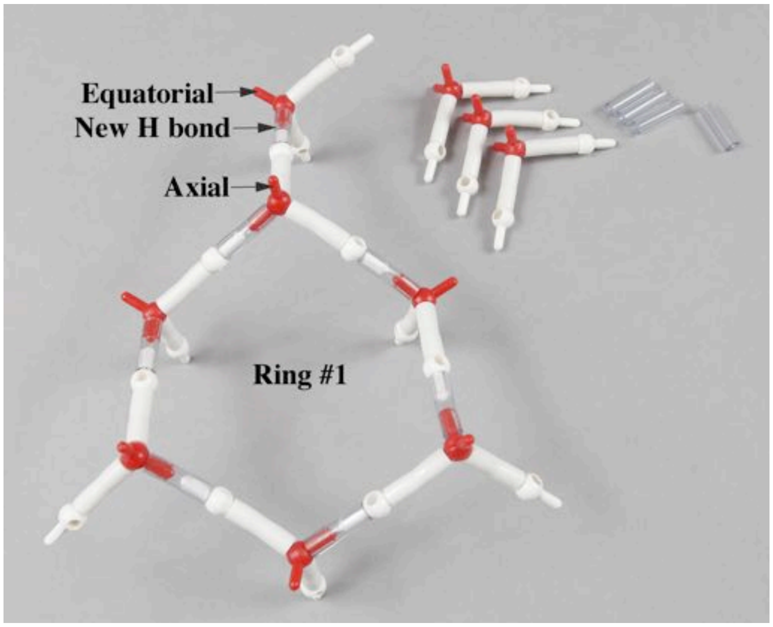


Fig. 12 Beginning a new ring attached to Ring #1.

Now add a second H bond and water molecule to Ring #1, making sure that the nonbonding electrons on oxygen are in an axial position. See Fig. 13.

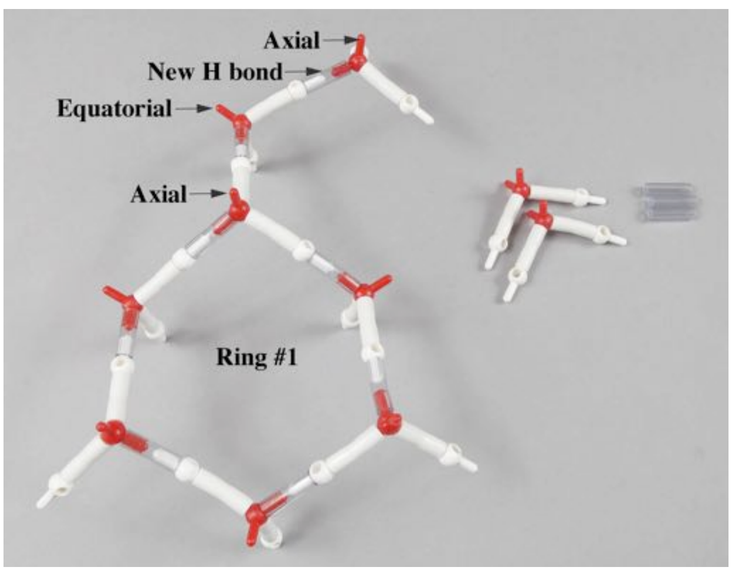


Fig. 13 Ring #1 with two new water molecules attached.

Add a third H bond and water molecule to Ring #1, making sure that the nonbonding electrons on oxygen are in an equatorial position. See Fig. 14.

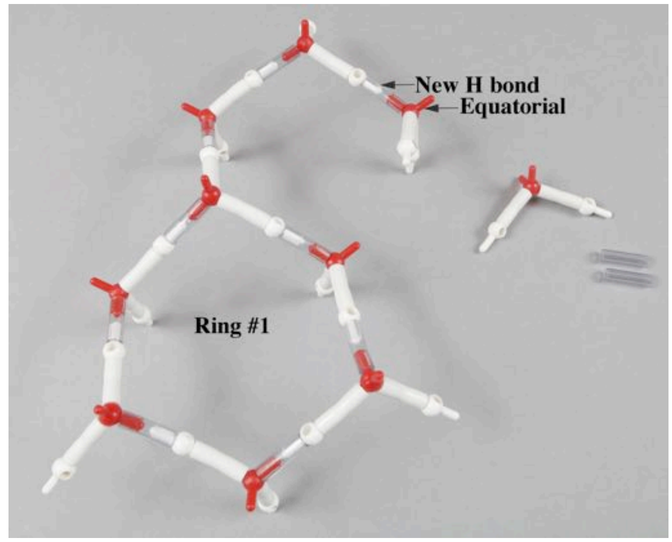
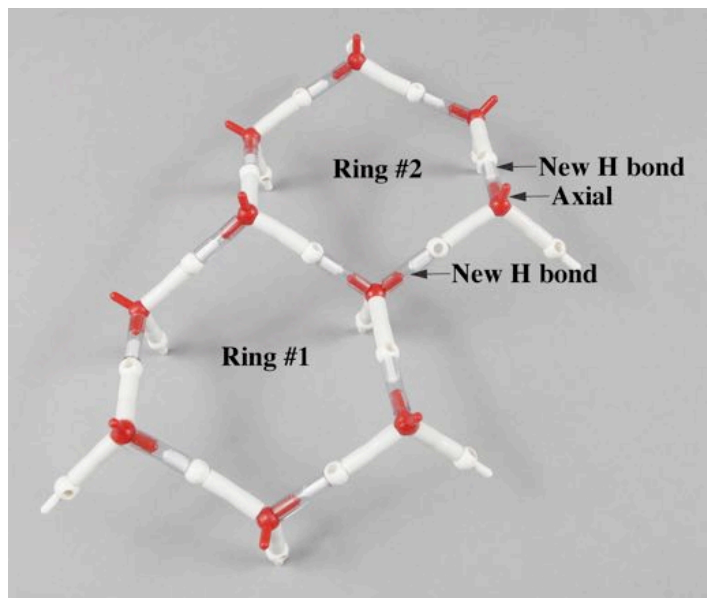
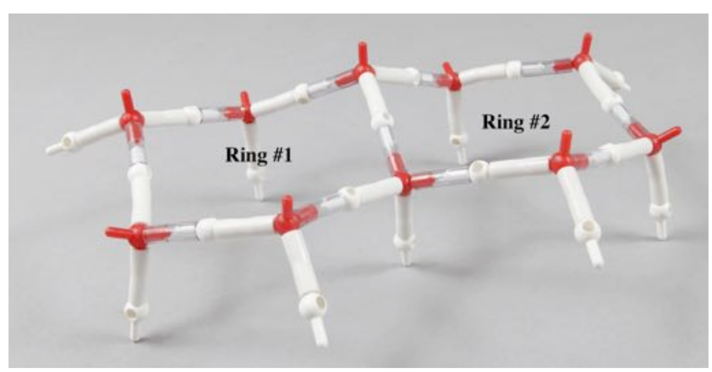


Fig. 14 Ring #1 with three new water molecules attached.

Connect the last water molecule and two H bonds to finish Ring #2. See Figs. 15 and 16. Pay close attention to the alternating axial and equatorial oxygen lone pairs of electrons.



Figs. 15 The completed second ring (Ring #2).



Figs. 16 A side view of Rings #1 and #2.

In order to finish a layer of ice, you will have to add water molecules to the five remaining sides of the central ring (Ring #1). Fig. 17 shows Ring #1 and Ring #2, the three water molecules and four H bonds needed to make Ring #3.

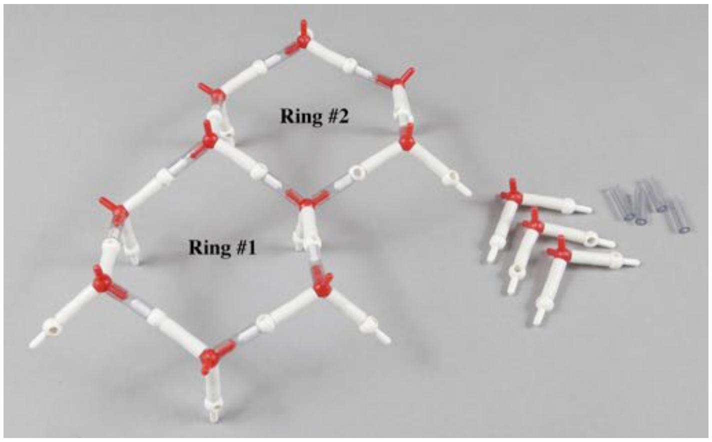


Fig. 17 Preparing to add Ring #3.

Connect one water molecule and one H bond to Ring #2 as you can se in Fig. 18.

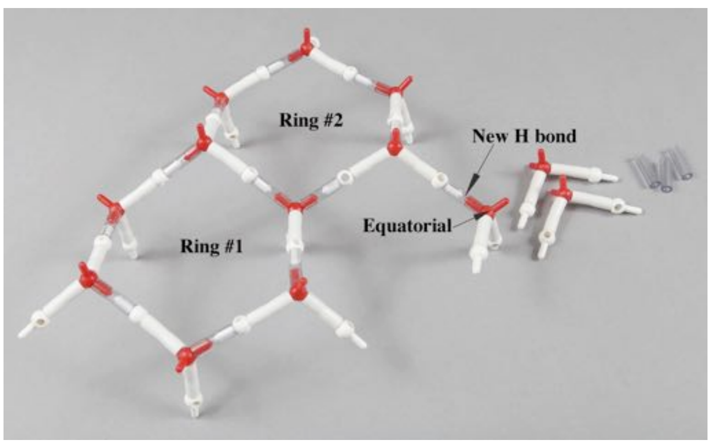


Fig. 18 Adding one H bond and one water molecule to Ring #2.

After placing another water molecule and one H bond in place, your model should look like Fig. 19. Note the axial position of the electrons.

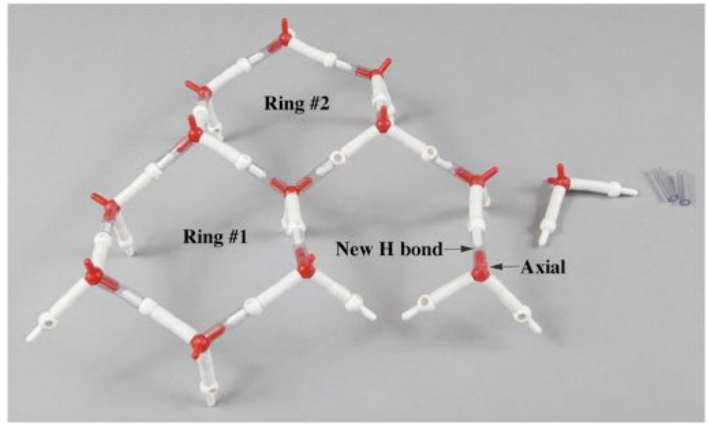


Fig. 19 Almost completed Ring #3.

After adding the last water molecule and two H bonds, your ice model should look like Fig. 20. Notice that the three rings have been labeled. The six sides of the original hexagon have been labeled as well; S 1, S 2, etc.. The subsequent four rings which you will attach are to be added to sides S 3 through S 6.

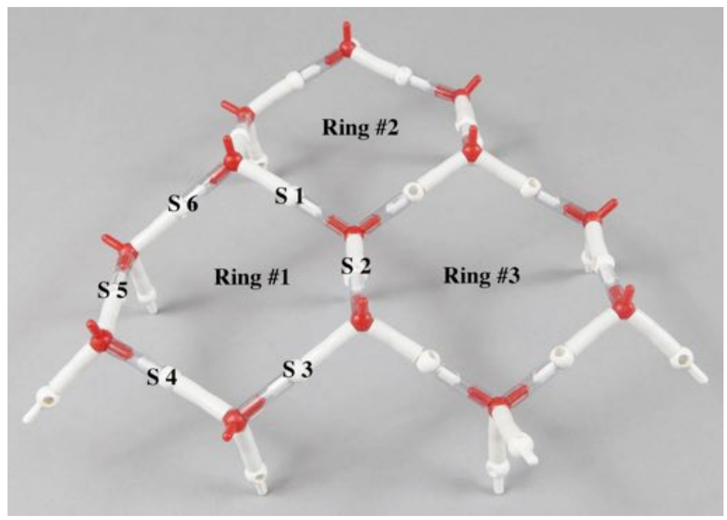


Fig. 20 Three completed rings.

Obtain three more water molecules and four H bonds in order to make Ring #4. See Fig. 21 on the next page.

Make sure you follow the axial, equatorial pattern for each new ring you make.

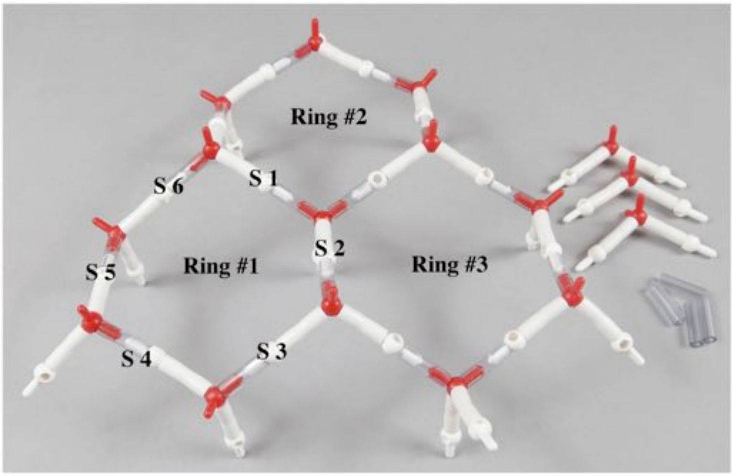


Fig. 21 Preparing to make Ring #4 on S 3.

In Fig. 22, you will see four completed rings.

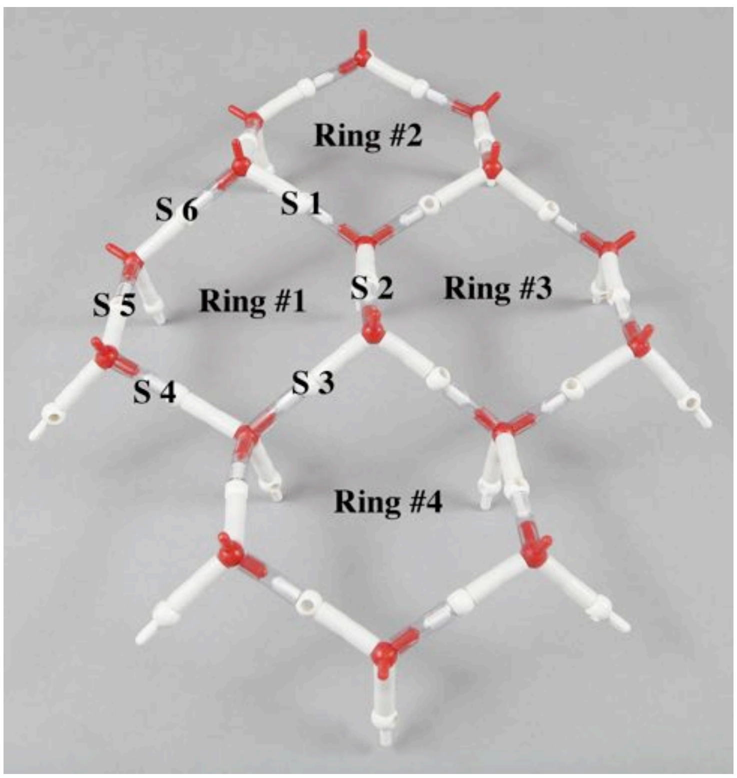


Fig. 22 An ice model with four rings.

Using three more water molecules and four H bonds, extend Ring #5 on S 4 and compare with Fig. 23 below.

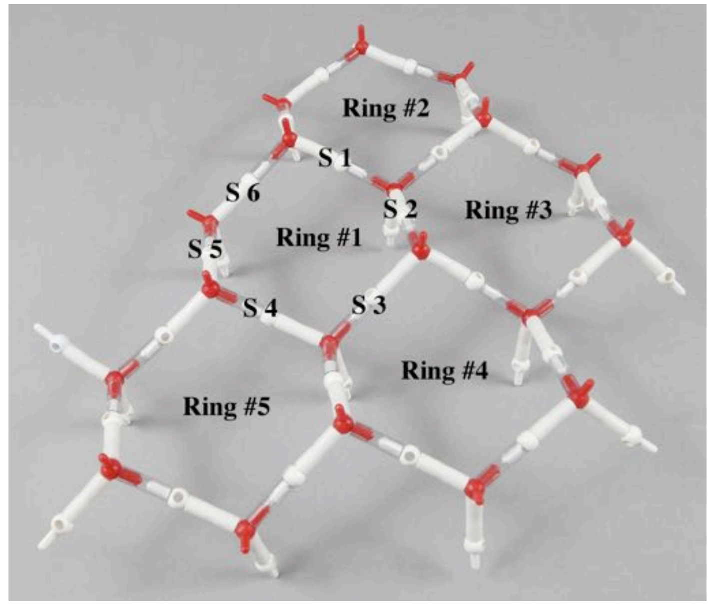


Fig. 23 An ice model with five rings.

Using three more water molecules and four H bonds, extend Ring #6 on S 5 and compare with Fig. 24 below.

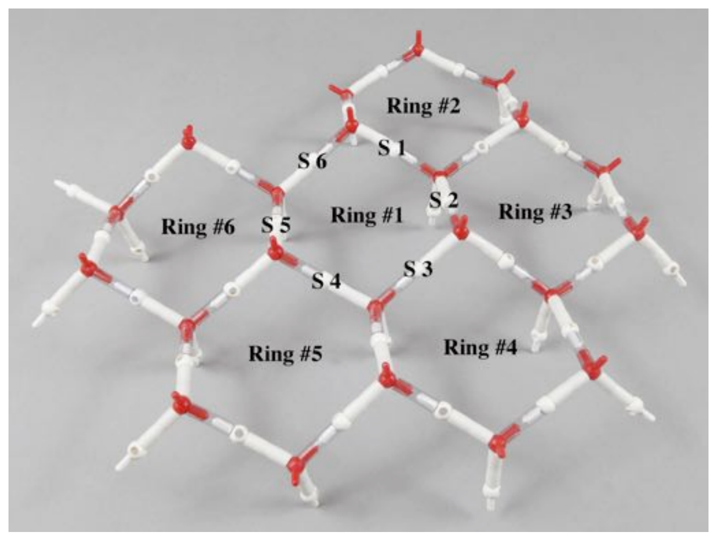


Fig. 24 An ice model with six rings.

For making the final ring to complete the ice layer, find two water molecules and three H bonds, and then attach them at S 6.

Compare your model to Fig. 25. Make sure that you have alternated axial and equatorial oxygen lone pairs of electrons.

It may also be helpful to turn the model over in order to see that the free hydrogen atoms are also alternating axially and equatorially as is Fig. 26.

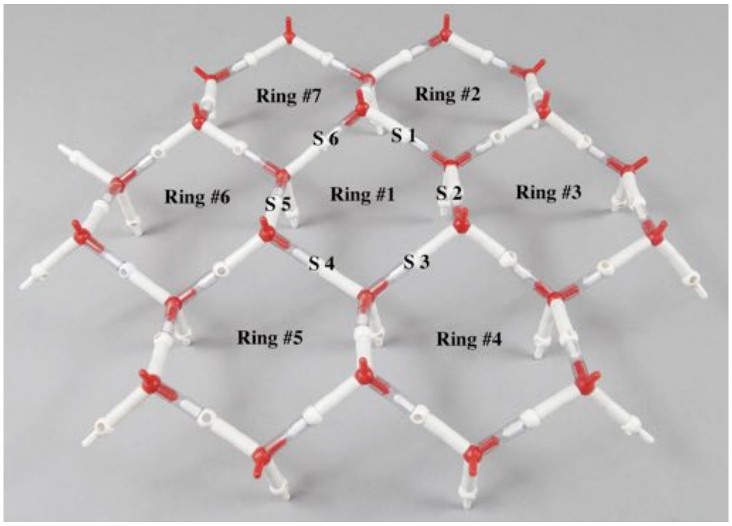


Fig. 25 A completed layer of the ice model with seven rings.

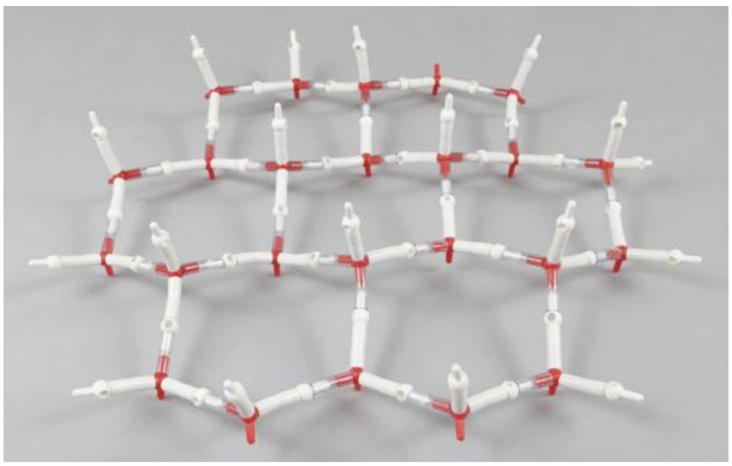


Fig. 26 Alternating axial and equatorial free hydrogen atoms.

5. Repeat the steps to construct another layer. Attach the two layers with axial hydrogens bonded to axial oxygens.

Teaching Activities for the Ice Model

Activity 1: Making ice crystals

Give one kit to a team of two students. Modify the instructions for assembly by using the following rules:

1. Each oxygen must have two hydrogens covalently bonded to it.
2. Each oxygen may have up to two hydrogen bonds also.
3. Water molecules arrange in rings of six molecules
4. Assemble your own ice crystal

Allow the students about 15 minutes to assemble their own miniature snowflakes. Evaluate their results based on if they followed rules 1-4 above. Compare each groups final product and discuss why there is such diversity in the shapes of snowflakes. Ask the question: Do you think every snowflake is unique? If a single snowflake is made of a small drop of water with a mass of about 0.01g, then there would be about 3×10^{20} water Molecules in one snowflake. The odds of two being exactly the same would be astronomically small.

Activity 2: Expansion of water when it freezes

Fill a small paper cup to the brim with water and Put it into the freezer. Take it out the next day and observe. Have students assemble water molecules by connecting two hydrogens (white) to one oxygen (red). Place the assembled water molecules in a pile and make a note of how much space (volume) they occupy. Assemble the ice structure by connecting the water molecules. Note and describe the amount of space (volume) the structure now occupies. Compare this with the space occupied by the water molecules when they were in a pile. What are some observations in nature of this phenomenon? Answers: ice floats on water (ice cubes, lakes), ice expands in water pipes and can cause them to break, one inch of rain is approximately 10 inches of snow.

Activity 3: 6 Sided Symmetry

Weather permitting: Go outside on a day when it is snowing and observe snowflakes. Leave some glass plates outside to use for catching snowflakes. Count the number of sides on typical snowflakes. Assemble the ice model. The water molecules form rings with how many sides? Answer: six. Turn the model and look at it from different angles. Rings of six atoms are apparent.