Intermolecular Forces (IMF) Lab Name: ____________________

NETWORK COVALENT BONDING

1. Examine the model that shows a bunch of beads epoxied together.
Think of this as representing a diamond crystal. What would the beads represent? ___________________

And what would the epoxy represent? __________________

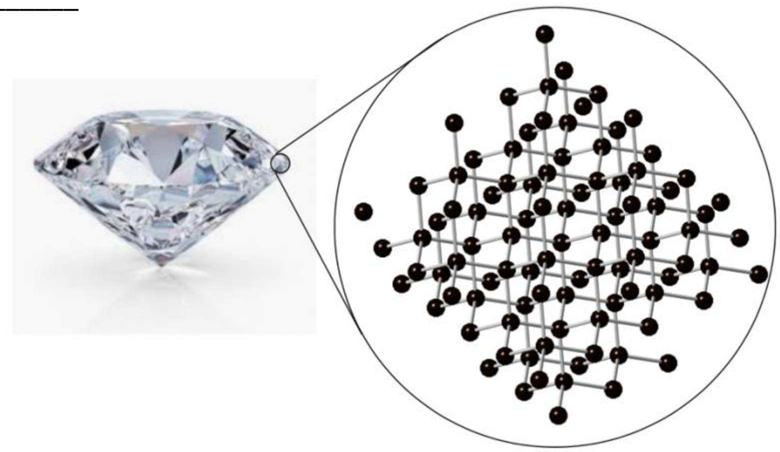
How difficult is it to pull the beads apart? ________________

What two properties of diamond result from this extreme bond strength? ________________ _______________

Look up the Mohs scale. What is it a measure of? _____________

What are the high and low numbers of this scale and what substances do they correspond with?

Some chemists argue that a diamond is actually one l arge single molecule. In what way is this true?



IONIC BONDING

2. Examine the model of the ionic compound: sodium chloride ($NaCl$). The small blue spheres represent the Na^{1+} ions; the larger green ones represent the Cl^{1-} ions. Their arrangement shows how the ions bond together in a very specific pattern to form a crystal. Draw this crystal in the space at right (labeling the smaller ones + and the larger ones -). The crystal you have is only 3 x 3 x 4 ions. The tiniest visible crystal of sodium chloride would actually be more like 3 million x 3 million x 4 million ions! If our model contained that many ions, it would cover most of Kirkwood!!

3. Each positive ion is in contact with only negative ions (and vise-versa).

Why do you think this is the most stable arrangement? __________________________________

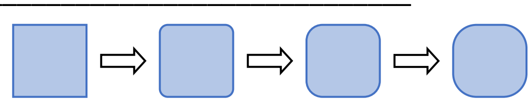
4. Pick an ion that is in a corner position: a) how many other ions are in contact with that ion? ___

b) Now pick an ion that is along one of the edges, how many other ions are in contact with it? ____

c) How about an ion that is on one of the sides (faces)? ____

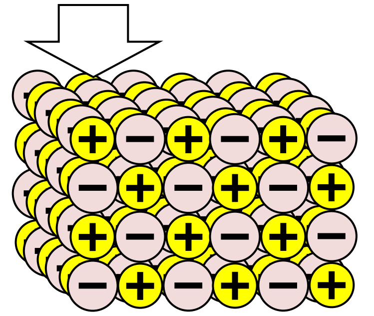
d) How about one in the center? ___

5. Which do you think would be easiest to remove: a corner ion, an edge ion, a face ion or an ion from the center? __________________ Try pulling them off and see if your prediction was right. (Careful when pulling this model apart: the ions tend to pop off and roll across the floor. Working over the plastic tray should keep you from having to chase runaway ions all over the room.)
Why was this ion the easiest to remove? ____



6. When an ionic substance dissolves, it's nice sharp cubic crystals tend to turn into more rounded off shapes.
Based on what you observed above, why do you think this happens? ____

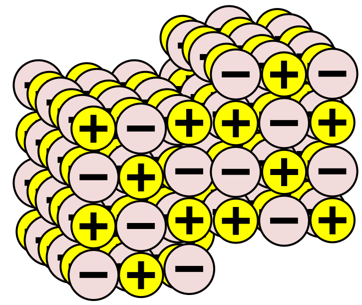
7. Pull off two ions of the same charge, and try putting them together magnet to magnet.



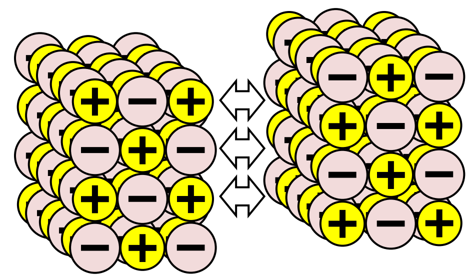
What do they do? ________________ Why? ________________________________

The model is not perfect. If you put the magnet of one ion next to the plastic of the other, you'll find they actually attract. What would two real ions of the same charge do to one another no matter what their orientation? _____________

8. One property of ionic compounds is that they are brittle (not malleable). If you try to hammer them out into a thin sheet, they break up into smaller little crystals. As they do so, they break apart along planes known as "cleavage planes." (To "cleave" means to split into small pieces.) This happens because as the crystal has a stress applied and a block of ions all shift down one notch, they all go from being next to oppositely charged ions to being next to ions of the same charge (as shown at right). Thus every attractive force turns into a repulsive force and the block of ions doesn't just fall off, it flies off! Reassemble the 3 x 3 x 4 crystal block you started with and see if you can use it to demonstrate how ionic substances break apart along distinct cleavage planes.



9. Look at the crystal. It can be used to represent NaCl or KBr, but it would not work as a model for other ionic substances such as MgF_2 or Li_3N.



Why not? ____

METALLIC BONDING

10. The instructor will come by with three different models for metallic bonding.

In model #1, what is being used to represent the metal atoms? _________________ And what is being used to represent the sea of electrons? _________________

In model #2, what is being used to represent the metal atoms? _________________ And what is being used to represent the sea of electrons? _________________

In model #3, what is being used to represent the metal atoms? _________________ And what is being used to represent the sea of electrons? _________________

DISPERSION FORCES

11. The bag of large paper clips (and one nail) represents a bunch of nonpolar molecules (such as F_2 or CO_2). Place one on the table, and bring the nail up alongside it to see if there is any kind of attraction. Is there? _________

Remember that nonpolar molecules generally have an even distribution of electrons, so you may not see much of an attraction at all. It's only when, by chance, the electrons are gathered to one side of the molecule that we get a temporary dipole and we then can see an attraction. To help create a "temporary dipole" in the nail, rub one end against a very strong magnet - the trapezoid-shaped magnet on the ring stand. Now bring this polarized (actually magnetized) nail up to a paper clip on the table.

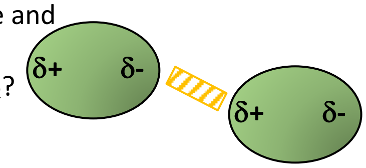
Do you see an attraction now? ______ If not, try rubbing it again. HARDER! If so, how strong is it? ________

Now knock the polarized end of the nail the table. This should knock out the dipole (put the electrons back in an even distribution). Now bring it back up to the paper clip on the table.

Is it still attracted? ______ If it is, try knocking it again. If not, then this shows you just how short-lasting and weak these dispersion forces are.

DIPOLE-DIPOLE ATTRACTIONS

12. The bag of magnetic marbles is supposed to represent a bunch of polar molecules like CO or OF_2. Place one marble on the table and bring another marble up to it. What does it do?



______________________ The attraction between the partial positive end of one molecule and the partial negative end of another is called a dipole-dipole attraction. Do you think a polar compound like OF_2 would have stronger or weaker IMF's than a nonpolar compound like CO_2?

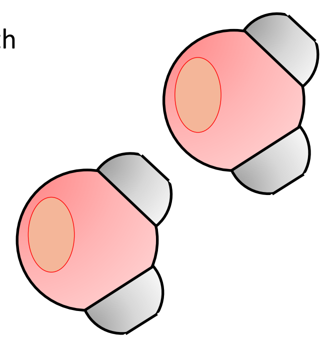
__________ Why do you think that? ____

Take the marble in your hand and turn it 180°. Now what happens when you bring it up to the other molecule? ____

* Note that magnets are being used in place of electric charges. Magnetic forces of attraction are quite similar to electric ones -- "North" & "South" are used to designate the two poles rather than "+" & "-" -- but it is important to note that the two forces are not quite the same.

HYDROGEN BONDING

13. The bag of red and white "Mickey Mouse" models represents a compound with H-bonding -- specifically H_2O. On the two diagrams at right, label the H's and the O's. (Hint: think about the formula: H_2O). Also on the diagram at right, indicate which atom is δ+ and which is δ- (Hint: O has the higher electronegativity.) Now, place one of the molecules on the table. Bring the O-end of a second molecule slowly up next to it.



What happens? ___________________________________

Repeat this step, but this time, bring the H-end of the molecule slowly up next to it.

What happens? ____

14. You may have notices that the H-atom is attracted not just to the O-atom, but specifically to the flat regions on the O-atom.

What do these flat regions represent? ___________________________________

H_2O has many unusual properties, and almost all of them are the result of its extensive H-bonding. For example, H_2O is a liquid at room temperature when almost every other substance with a molar mass less than 50 is a gas.* Also recall that water has a very high specific heat capacity. It also has an extremely high surface tension. Surface tension refers to a property in which the surface of a liquid behaves almost as though it had a skin on it! Surface tension is what allows something that is more dense than water (like a paper clip) to be floated on the water's surface.

*CH_4 (16), NH_3 (17), HF (20), C_2H_2 (26), N_2 (28), CO (28), NO (30), C_2H_6 (30), O_2 (32), H_2S (34), F_2 (38), C_3H_8 (44), CO_2 (44), N_2O (44), NO_2 (46), O_3 (48) are all gases!

Another unusual property of water is that it is very good at dissolving ionic substances like NaCl or KNO_3. At first this might seem surprising because ionic bonds are generally much stronger than H-bonds. But what the water molecules lack in strength, they make up for in numbers. As the ions break off, water molecules attach onto them on all sides to create what is called a hydrated ion. Recall that the blue balls in the ionic crystal model represent Na^{1+} ions.

Which end of the water molecule -- the H-atom or the O-atom -- will be attracted to the Na^{1+} ion? ________

Why? ____

15. Place a water molecule on the table, then pull an Na^{1+} ion off the model and slowly bring it up to the water molecule.

Was your prediction correct?_______

Now predict which part of the water molecule would be attracted to a green (Cl^{1-}) ion: ________

Why? ____

Go ahead and pull of a Cl^{1-} ion, and bring it up to the water molecule on the table. Was your prediction correct?_______

Take the Na^{1+} ion and place some water molecules on it (either 2,4 or 6) and on the positive ion at right, draw what they look like. Also take the Cl^{1-} ion and place 2, 4 or 6 water molecules on it and on the negative ion at right draw what they look like.

Note: As for the models, you can fit up to six water molecules around each ion. In reality, the water molecules do tend to crowd each other, and how many water molecules actually do attach themselves onto an ion depends on the size and the charge on that ion.

One other very unusual property of water is that it ***expands*** when it freezes. Most substances *contract* when they

freeze. Explain why contracting while freezing makes sense: ____

16. As the molecules slow down, the IMFs tend to take over and lock the particles into a rigid tightly packed crystal structure. You would think that with its strong H-bonding, water would contract the most as it freezes. So why does it do just the opposite? Why is solid H_2O (ice) more spread apart than liquid H_2O (water)? Go take a look at the group of water molecules on the front table that has been arranged to show ice's structure. What do you notice about the structure that could account for this unusual property?

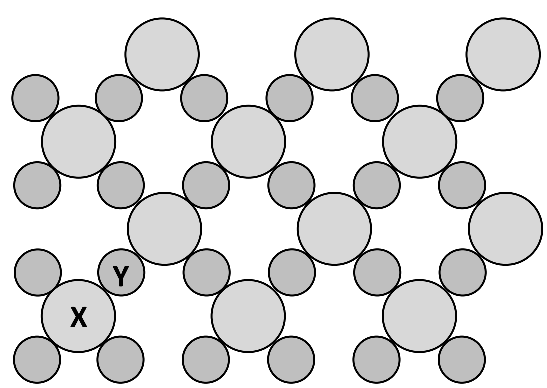
____

If time permits, your group can try arranging its molecules into the ice structure similar to the one on the front table.

Follow-up questions: (these do not match up with the follow-up ones on quia, but you are welcome to consider them!)

1. Think back to what you learned earlier this year about metals and nonmetals how strongly they attract their outermost electrons.
Why does Na tend to acquire a 1+ charge? And why does Cl tend to acquire a 1- charge?

2. So why are Na^{1+} ions and Cl^{1-} ions attracted to each other?



3. The diagram at right shows an ionic compound. But it's not NaCl this time. How can you tell?

4. Which of the following compounds might the diagram represent: a) CsBr b) Li_2S c) Al_2O_3 d) FeF_3

5. If the answer to question #4 above is correct, what element is X? ____ and what element is Y? ____

6. If nonpolar molecules don't have any charges on them, how are they attracted to one another?
(Use diagrams and sentences to show you fully understand how dispersion forces work.)

7. Where would there be stronger dispersion forces: between two F_2 molecules or between two H_2 molecules?
________________ Why?

8. Dipole-dipole attractions involve positive and negative charges attracting each other, just like ionic bonds. So why are dipole-dipole forces so much weaker?

9. Kevin knows that NH_3 has three very positive H atoms per molecule, and H_2O only has two. So he figures NH_3 would have more H-bonding going on that H_2O. Sylvia realizes that Kevin is wrong. What should Sylvia say to explain to Kevin why H_2O has more H-bonding than NH_3?

10. Several unusual properties of water are mentioned in lab. List three of them:

______________________ _____________________ _________________________

11. There is nothing unusual about the way that benzene behaves. So would a chunk of solid benzene float or sink in a beaker full of liquid benzene? __________ Why?

What substance behaves the opposite way? _________ Why?

12. Pot-holes are an on-going problem on our streets. They always occur in the winter after there's been ice or snow and a series of cold and warm days. How is the formation of pot-holes the result of water and its unusual properties?