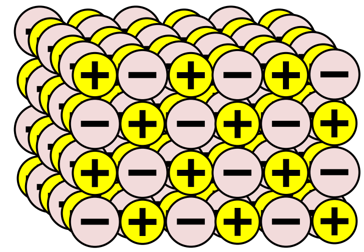
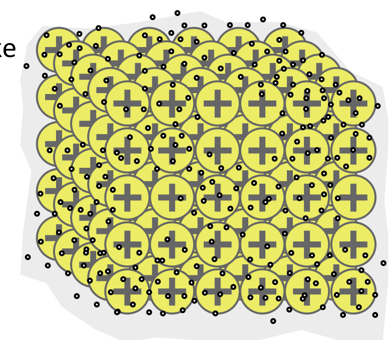
Intermolecular Forces Info sheet Name: ________________________

Why is it that some substances like salt (NaCl) and zinc (Zn) are solids at room temperature, other substances like water (H_2O) are liquids, and other substances like NF_3 and CO_2 are gases? It all has to do with what kind of particles (ions, atoms or molecules) these substances are made up of, and how *attracted* these particles are to one another.

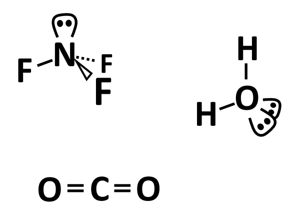


For example, NaCl is made up of ions which have full charges (1+ and 1-) on them. Since opposite charges attract one another, ionic substances (those made up of metals bonded to nonmetals) have strong attractions holding them together into big crystals, like the one shown at right: Because of these strong attractions, all ionic substance are solids at room temperature. They generally have to be heated up quite a bit (to several hundred degrees Celsius) before these forces are overcome and the substance can melt into a liquid or vaporize into a gas. [If you are comparing substances within this group, greater charges make stronger attractions so 2+/2- is stronger than 1+/1-, and smaller ions can get closer together and therefore have stronger attractions, so NaBr has a stronger ionic bond than KBr or NaI.]



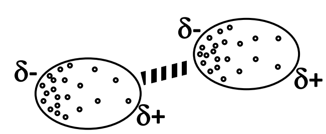
Metallic substances are not really compounds; they are either elements like Zn or mixtures like brass (a copper-zinc alloy). Since metals generally have a very loose hold on their electrons, metal atoms give up their electrons to form positive ions and the electrons are given up to a delocalized "sea of electrons." This delocalized negatively charged sea of electrons acts as a sort of flexible glue to hold these positively charged ions together into a flexible crystal type arrangement. This is known as "metallic bonding" and it is generally weaker than ionic bonding – which is why metals generally have lower melting points than ionic substances. [Comparing within this group is similar to comparing within the group of ionic substances: larger charges and smaller atoms both make for stronger attractions. Thus Mg has stronger metallic bonding Na. Mg also has stronger metallic bonding than Ca.]

Most substances that are not ionically or metallically bonded into big crystals are covalently bonded into small molecules. Take H_2O, NF_3 and CO_2 for example. (These are the things you have been drawing Lewis structures and three-dimensional drawings of for the past few months!).

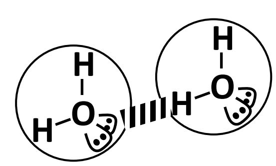


Note how these compounds are made up entirely of nonmetal atoms sharing electrons (covalent bonds) to make molecules. Though the atoms in the molecules are held together by very strong covalent bonds, the molecules are not held to one another by very much at all. That is why most molecular substances turn out to be gases or liquids or perhaps low-melting solids.

The forces that do act between molecules are called "intermolecular forces" or "IMF's," and there are three types. Before we get to those three types, recall that there are two types of molecules: Some molecules are polar. That means they have some off-centered electron hogs that pull the electrons toward one end of the molecule – like the F's in NF_3 above. Other molecules are nonpolar; that means they are symmetrical and have no lopsidedness in their electron distribution – like CO_2 above. So here are the three types of intermolecular forces:

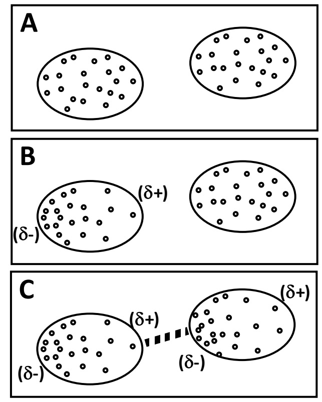


a) Dipole-dipole attractions These are the attractions between two *polar* molecules. Quite simply, the partial positive (δ+) end of one molecule is attracted to the partial negative (δ -) end of another. Since these molecules have permanent dipoles (δ + and δ - ends), these attractions are moderately strong.



b) Hydrogen bonding These forces are like dipole-dipole attractions on steroids! It occurs when an H atom is bonded directly to a very electronegative atom (namely N, O or F). N, O and F are such electron hogs that the H atom is left with a strong positive charge. Because it is so small, this positively charged H atom can get very close to the negatively charged nonbonding electron pair (ghost) on a neighboring molecule. The dipole-dipole attraction that results is so much stronger than any other dipole-dipole attraction that it has been given its own name: "hydrogen bonding," and it is by far the strongest of the three types of intermolecular forces. Even still, it is nowhere near as strong as ionic bonding. [If you are comparing within this group, the molecules with more extensive H-bonding with have stronger attractions. H_2O has stronger IMFs than either HF or NH_3. (See the H-bonding worksheet for more examples.)]

c) Dispersion forces (AKA: London forces). These are the attractions that occur between any nonpolar molecules. Since these molecules are nonpolar, (with their electrons pretty evenly distributed), you might think that there would no attraction between them (A), but since the electrons do move around a bit, they do have times when they are by chance unevenly distributed, and this creates a temporary δ + and δ - end to the molecule (B). This can cause an uneven distribution in a neighboring molecule (C) and thus a quick, momentary attraction occurs between them. As you might imagine, these dispersion forces are much weaker than the two others. [If you are comparing within this group, the more total electrons there are, the more likely there is to be a significant temporary dipole, the stronger the dispersion forces.]



Intermolecular Forces worksheet Name: ___________________________

1. Ionic bonds are easy to spot. They are always between _____________ and ______________.
The metals _________ electrons and become ______________ charged and the nonmetals _______ electrons and become _______________ charged. The full positive charge and full negative charge _____________ one another a lot, and so these ionic bonds are quite _____________. Because of this, ionic substances all tend to be ________ at room temperature. That is, they are compounds with rather ________ melting points.

2. Metallic bonding is also rather easy to spot. It always involves ___________ atoms bonded to each other. These atoms tend to ________ their valence _____________ and become positively charged. These lost ______________ form a sort of _________ which acts like a sort of _________ to hold the _________________ charged _________ ions together. Substances with _________________ bonding tend to have _________________ melting points

3. H-bonding is also easy to spot. It always involves a(n) ____ atom bonded directly to a very electronegative ___, ___ or ___ atom. These highly electronegative atoms ______ the electrons and give the H atom a partial ___________ charge. Because the H atom is so _______, it can get very close to the ___________ charged nonbonding electron pair of another molecule and form a very _________ dipole-dipole attraction. Substances with H-bonding tend to be __________ (like H_2O) or low melting ________.

4. Dipole-dipole attractions occur between any two molecules that are ___________. A molecule is _________ when it has ________ bonds (ones in which the __________ difference is 0.5 or greater), and has a(n) ________________ shape. This gives the molecule a permanent lopsidedness in terms of its ______________ distribution. The sides of the molecule that has the higher concentration of electrons becomes partial ______________, and the side that has the lower concentration of ______________ becomes partial ______________. Dipole-dipole refers to the attraction between the partial ____________ end of one molecule and the partial ___________ end of another.

5. Dispersion forces occur between _______________ molecules. Because of ____________ movement, sometimes the ______________ end up more on one side of a molecule than the other, and this creates a _____________ dipole. This _____________ dipole can then cause a neighboring molecule to do the same thing, and a brief attraction (like dipole-dipole) occurs. Dispersion forces are very ___________, and that's why many nonpolar substances are ______ at room temperature.

Ans:
H O N F
asymmetrical
attracts
electron
electrons
electrons
electrons
electrons
electronegativity
gain glue gases
high hog
intermediate
liquids
lose
lose
metal
metal
metallic
metals
nonmetals
nonpolar
negative
negative
negatively
negatively
polar polar polar
positive
positive
positive
positively
positively
random
sea
small
solids
solids
strong
strong
temporary
temporary
weak