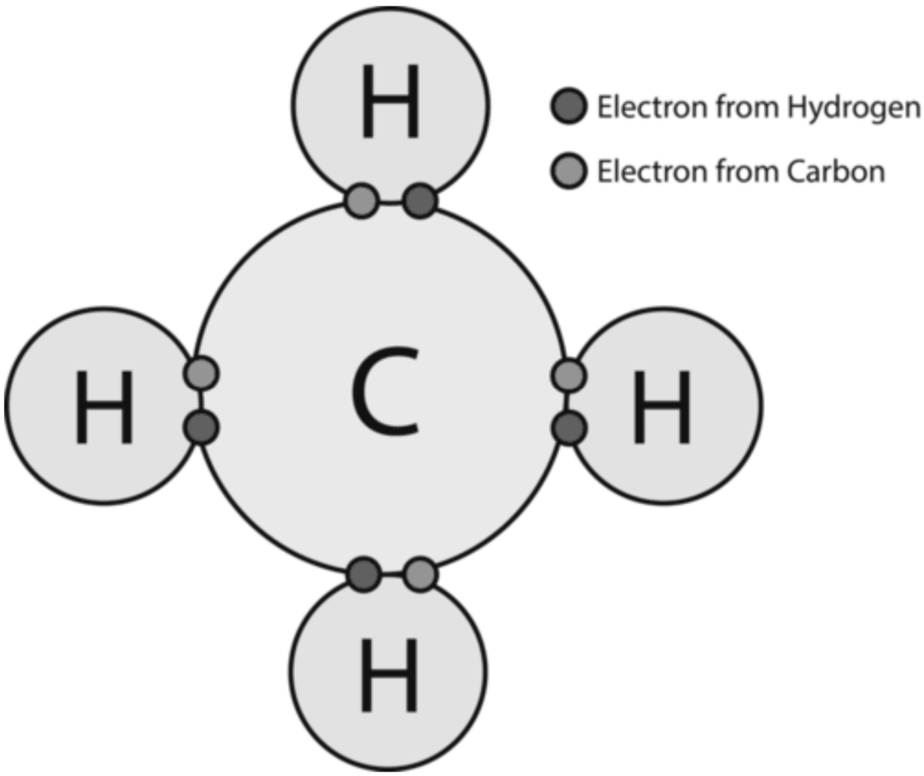
NAME: ________________________________ class period:_____

Bonding Chemistry



I understand that this booklet will be graded by my teacher while I take the Bonding Celebration.

I will hand it in during the Celebration, or lose 5 points for being late.

1 point per page, and if a single blank exists, it's a –1 for the page.

This booklet has 18 pages of notes and 5 HW pages, = 23 total points.

Signed ____________________

Covalent bonds share electrons between nonmetals only. They can be single, double, or triple, and they can be polar or nonpolar. Most compounds follow the octet rule, but there are exceptions.

Ionic bonds transfer electrons between metals and nonmetals.

Metallic bonds explain how metals can remain "stuck together" and explain their important properties.

Intermolecular bonds are really intermolecular attractions: the attraction between molecules, not the bonds INSIDE the molecules. There are 3 kinds of these, and they are much weaker than the "real" bonds above. These attractions have a small but real affect on substances.

Lewis Dot diagrams are drawings to show the transfer, or sharing of electrons in compounds.

Structural diagrams use "dashes" to show the sharing of electrons in covalent bonds, they are easier.

There are several kinds of unusual, or exceptional bonds, which include: coordinate covalent bonds and resonating bonds.

Bonding is especially important. You should plan to do all of the homework assignments, every single electron counts and is needed.

If found, please return to room 262.

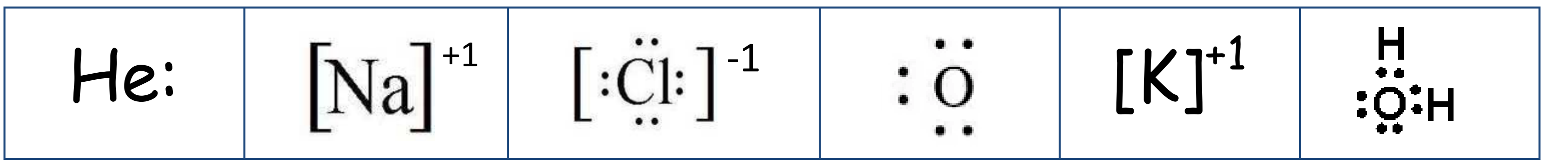
Bonding Basics

Chemistry is the study of the stuff of the universe, and importantly, how it forms into new substances by bonding in certain ways (or un-bonding to become simpler). There are several ways atoms can bond together in high school chemistry. We will look over each type, learning the particular ways they work, and understand their differences.

Most of the bonds we will see are inside compounds, bonding hydrogen to oxygen when water forms, or sodium ions to chloride ions when sodium chloride forms. There are some types of bonds between particles as well. Finally, there are bonds that hold metals together as solids, and help us to understand how metals exist with their special properties of electrical conduction, and their ability to bend and not shatter.

LEWIS DOT DIAGRAMS

In order to help "see" how bonding works, a chemist named Dr. Lewis developed a diagram method for atoms, ions, and compounds. We will draw many in class. The diagrams look like these below.
Which species (what are the specific chemistry names?) are each of these?



Helium atom, sodium cation, chloride anion, oxygen atom, potassium cation, and water molecule.

Atoms like helium, and oxygen show all valence electrons, and electrons will tend to PAIR UP, which is part of the suborbital system of chemistry that we don't spend any time on, just remember that. The potassium cation has lost it's outermost electron, and the whole valence orbital at the same time. It ends up with $19p^+$ and only $18\ e^-$, making it have an overall charge of +1. The chloride anion started out as a chlorine atom. It started with a 2-8-7 electron configuration, but gained one electron into it's third, or valence orbital. It becomes a -1 anion with 8 valence electrons, all drawn in here.

Lewis dot diagrams for atoms show all valence electrons. Cations show the new, "empty" valence orbital in brackets with a charge to show you KNOW what's going on. Anions end up with FULL VALENCE orbitals, which show ALL dots, and have brackets and charges as well.

PRACTICE QUESTIONS Set 1 (answers on the last page)

1. What are the electron configurations for the phosphorous atom and the phosphorous anion? and for magnesium?

2. What are the electron configurations for the magnesium atom and the magnesium cation?

3. Which electrons are drawn in Lewis dot diagrams?
   A. all of them B. inner electrons C. outermost electrons D. no electrons

4. Draw Lewis Dot Diagrams for the lithium atom, boron atom, calcium cation, and the oxide anion.

5. Will an atom of aluminum ever normally lose 1 or 4 electrons? Why not?

IONIC BONDING

This type of bonding is the simplest to understand for the new students of chemistry. Whenever metals and nonmetals bond together it's this way: Metals will lose electrons and form into positive CATIONS. They TRANSFER these valence electrons to nonmetals, which form into negative ANIONS. This transfer of electrons is always perfect", the amount of electrons lost by the metals are picked up by the nonmetals. No extra electrons, or left over electrons are allowed ever. The most common ionic compound is sodium chloride, table salt, the formula is NaCl.

To quickly review what we learned earlier in the year, metals will lose enough electrons to become ISOELECTRIC to a noble gas. They lose enough electrons to get a noble gas electron configuration.

A sodium atom has a 2-8-1 electron configuration. It will become a Na^{+1} cation with a 2-8 configuration, it loses one electron (it transfers this electron to a nonmetal, possibly chlorine, it doesn't actually LOSE it!)

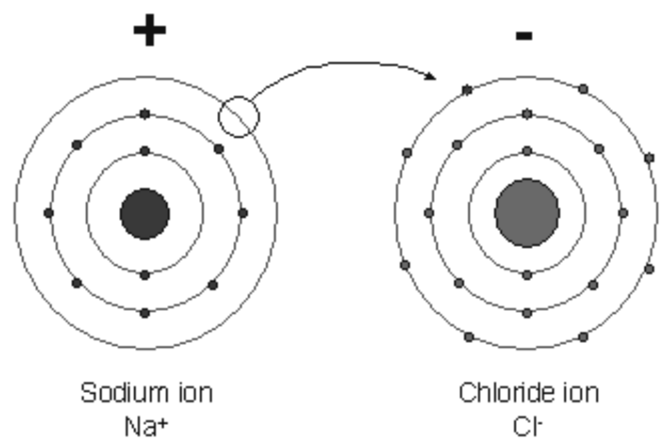
An atom of Aluminum has a 2-8-3 electron configuration. It must "lose" 3 electrons to become isoelectric to neon. $Al \rightarrow Al^{+3}$ with a 2-8 cation electron configuration.

Nonmetals, like chlorine, gain electrons to form into negative anions. Chlorine atoms start with 17 electrons in a 2-8-7 configuration. When $Cl \rightarrow Cl^{-1}$, it's electron configuration changes to 2-8-8, which is isoelectric to argon.

Cations can only form simultaneously with anions. The transfer of electrons is always perfectly balanced, & that keeps all ionic compounds that form electrically neutral (the positive charges = the negative charges). You can't have a jar of cations, nor can you have a test tube of anions, they only exist at the same time.

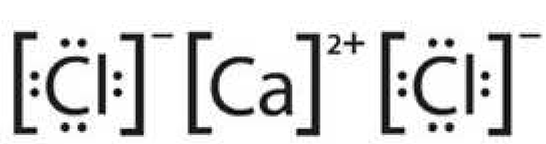
To draw atoms and ions (and compounds) in ways to help us understand this electron transfer we use LEWIS DOT DIAGRAMS. These show the VALENCE ELECTRONS only, which are the electrons in the outermost orbital of the atom, NOT all of the electrons, just the outside electrons.

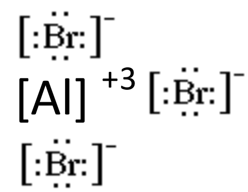
At right is a model of the sodium cation
that has already "lost" an electron
(and it's WHOLE VALENCE ORBITAL),
and the chloride anion which gained that electron.
The ions opposite charge makes them very attracted
together, which is called an ionic bond.
The electron has been TRANSFERRED from Na → Cl



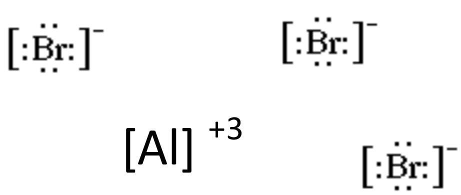
When ionic compounds form, we can draw Lewis dot diagrams for them as well. They are not exactly "pretty" but they are obvious. Just push the cation diagram close to the anion diagram together to indicate that they are making a compound. This is KCl...

If the compound has more than two ions (say $CaCl_2$ or even $AlBr_3$) just push the ion diagrams close. There is no "correct" way to do this, literally, just make them close.





The differences here should be noted. The chloride ions are both labeled with the (-) sign but not (-1). That is fine. The Calcium cation has a 2+ instead of +2, another difference not worth worrying about. The bromides at right all show with a (-) sign, not (-1) too. Different texts interchange some of these minor points.



This arrangement at left <u>DOES NOT</u> show ionic bonding, it's more like four random Lewis dot diagrams that are drawn near each other. Ionic bonding diagrams are CLOSE together, like the two shown above.

PRACTICE QUESTIONS Set 2

1. Draw the Lewis dot diagrams for Li^{+1}, P^{-3}, and for Neon.
2. Draw Lewis Dot diagrams for magnesium oxide and for potassium nitride.
3. Define ISOELECTRIC.

<u>COVALENT BONDING</u>

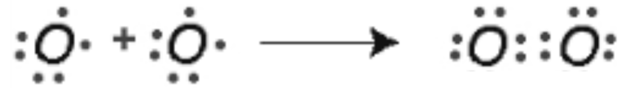
When metals and nonmetals bond, they form ions first, then are attracted together by opposite charge. When 2 or more nonmetals bond together (no metals allowed, ever), they DO NOT FORM IONS. The atoms still try to become ISOELCTRIC to the noble gases, but they do not transfer electrons to do this. Instead, when two atoms make a covalent bond they SHARE valence electrons. By sharing, both atoms can share full orbitals.

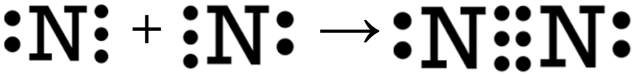
This SHARING of ELECTRONS can be a perfectly even sharing (like best friends) or be uneven sharing (like me and you and one piece of cherry pie ala mode!).

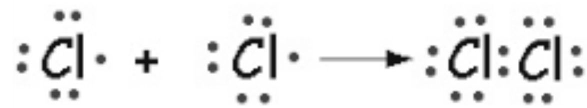
Nonmetals share enough electrons to get FULL ORBITALS, usually that means 8 electrons, but it's only 2 electrons for the smallest atoms. Rarely there are exceptions.

Water, carbon dioxide, and nitrogen gas all make types of covalent bonds. We will examine them now.

We will start with the HONClBrIF twins, they all show covalent bonding. The Lewis dot diagrams for them are here as atoms, and then as molecules. The simplest are H, Cl, Br, I and F, all making the smallest bonds.







The rest of the "twins", Br_2, I_2, and F_2 all follow the exact dot structure as Cl_2 does just above. All have 7 valence electrons, and the diatomic molecule ends up sharing one pair of electrons, like Cl_2 does.

To show these bonds without all of the dots, we use little lines to indicate a bond. Each shared pair of electrons is replaced by a dash. Hydrogen molecules share 1 pair of electrons, so H_2 have a single dash to indicate that.

Oxygen molecules share 2 pairs of electrons, they make a double bond, hence the 2 lines between the O's.

Nitrogen molecules share 3 pairs of electrons, they make a triple bond, hence the 3 lines between the N's.

The rest of the HONClBrIF Twins all share one pair of electrons, they all get the single dash to show that.

H—H   O==O   N≡N   Cl—Cl   Br—Br   I—I   F—F

These are important things to notice, and not get mixed up about.

The HONClBrIF twin molecules exhibit a variety of covalent bonds. H_2, Cl_2, Br_2, I_2 and F_2 all share one pair of electrons. This is called a single covalent bond. Since these atoms have the same exact electronegativity value, these bonds are also nonpolar. We call them: SINGLE NONPOLAR COVALENT bonds.

Oxygen must share two pairs of electrons. The electronegativity difference is also zero, so these are DOUBLE NONPOLAR COVALENT bonds.

Nitrogen must share three pairs of electrons. The electronegativity difference is again zero, so these are TRIPLE NONPOLAR COVALENT bonds.

Bonds can be IONIC when formed from ions.

Bonds can be COVALENT when two or more nonmetals share electrons.

Covalent Bonds can be POLAR or NONPOLAR bonds.

Covalent Bonds can be SINGLE, DOUBLE, or TRIPLE bonds.

molecules	Share this many pairs of electrons	Share this many electrons	Name of the bond
F_2	1	2	single nonpolar covalent
H_2	1	2	single nonpolar covalent
O_2	2	4	double nonpolar covalent
N_2	3	6	triple nonpolar covalent
HCl	1	2	single polar covalent
NaCl	0	0	ionic
MgO	0	0	ionic
CH_4	1	2 for each of the 4 bonds	4 individual single polar covalent bonds

Electronegativity means tendency to gain electrons in a bond. The higher electronegativity "gets" electrons more of the time than the lower value. So, atoms with higher electronegativity will tend to get the electron and "be" negative more of the time. The atom that gets the electron LESS of the time tends to be the more positive side of the bond. The POLAR BOND has a positive and a negative pole (most of the time).

We can SHOW this polarity with a DIPOLE ARROW. This arrow shows the DIRECTION that the electrons go - to what side of the bond. The arrow ALSO shows what side is left "MORE POSITIVE" because the electrons moved to the other side of the bond. A dipole arrow looks like this:

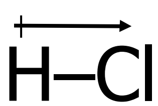
This side is more positive

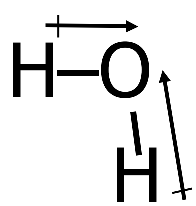
The electron exits this atom

This side is more negative

The electron moves over here most of the time

A couple of examples of molecules with dipole arrows are:





The hydrogen becomes more positive than the Cl, and the H become more positive in water as well.

In both examples, hydrogen has a LOWER electronegativity value, so the arrow heads point to the atom with the higher electronegativity value. The Cl in HCl becomes negative most of the time because chlorine "gains" that electron most of the time. The two atoms DO NOT SHARE EVENLY. In water, the oxygen makes two different bonds with the two hydrogen atoms, each one is sharing unevenly.

All of these three bonds are SINGLE POLAR COVALENT, because there are NO METALS bonding it must be covalent; they share one pair of electrons, and they share them unevenly.

TRICKY Questions

A common trick on the regents is to catch you on ionic bonds and sharing electrons. IONIC BONDS are about transferring electrons - NOT SHARING. Trick questions like:

A. In sodium chloride, NaCl, how many pairs of electrons are being shared? **(none!)**

B. In magnesium oxide, do these ions share two pairs of electrons? **(no, they don't share!)**

C. In calcium chloride, $CaCl_2$, are there two single polar bonds, or two single nonpolar bonds?) **(neither! The bonds are IONIC. Ionic bonds CAN'T BE single, double or triple either!)**

E. In sodium hydroxide, NaOH, are the bonds ionic or covalent? **BOTH! The Na^{+1} bonds ionically to the OH^{-1}, but INSIDE THE hydroxide, the O-H bond is polar covalent!**

F. How many electron pairs are shared between aluminum phosphide in AlP? **(NONE! It's ionic and there are no electrons shared, they are transferred!)**

PRACTICE Questions set 3

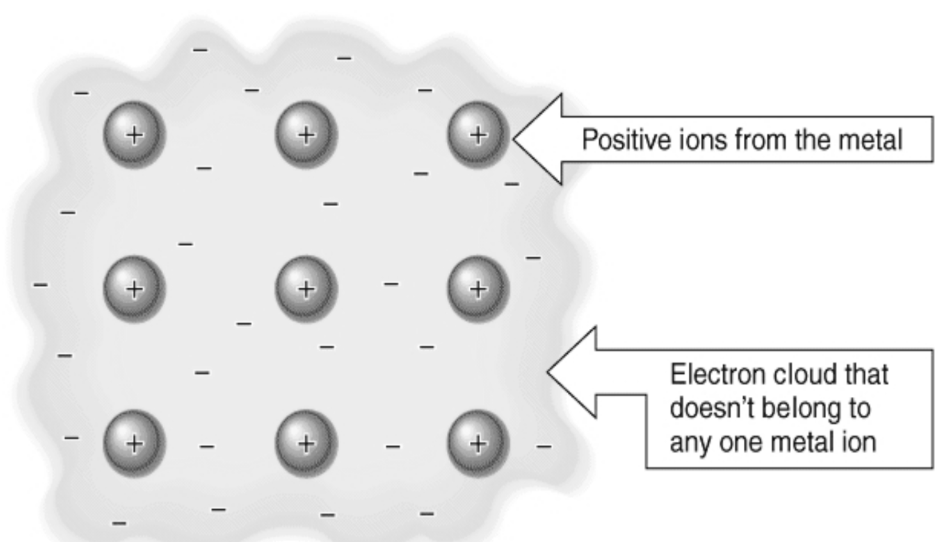
1. Draw larger sized structural diagrams for KCl, for boron trifluoride, carbon tetra bromide.
2. Carbon dioxide makes two double bonds this way: O=C=O in a straight line. Name the type of bond between one atom of oxygen and one atom of carbon.
3. Name the bond types in oxygen difluoride.
4. Name the bond types in ammonium chloride.

METALLIC BONDING

When a frying pan is made, or if you take one out of your kitchen drawer, that hunk of metal displays many interesting properties. It's been stuck in that position for a long time, and it will likely hold it's shape indefinitely. It conducts heat well. It will also conduct electricity (as do all metals). It's been smashed into a shape and it didn't crack. If you bash it on a big rock, it might bend but it won't shatter like glass. The reason scientists believe metals do these things, instead of not conducting electricity, or not being malleable, is because of how they describe how metals bond together.

Metals are described not as packed atoms, rather as PACKED CATIONS with their valence electrons LOOSE and (literally) mobile in the metal. Like the picture below.

If the metal cations are crushed together, say by banging the pan on a rock, the positive cations would get closer, and would want to repel, even to crack apart. This DOES NOT HAPPEN, the metal is able to change form, because the loose electrons moving at near the speed of light, move towards these closer cations, and they offset that overly positive charge with some negative charge, keeping the metal electrically neutral, and the meal bends instead of cracking.



Electricity is described as moving electrons. If you run electricity into one side of a metal wire, electrons move into the metal, immediately disrupting the neutrality of the metal. Out the other side flows an equal number of electrons to complete the current. The electrons that flow into the metal are NOT NECESSARILY the ones flowing out the other side. The electrons are almost like water flowing through a pipe, although this pipe is a wire and it's a solid.

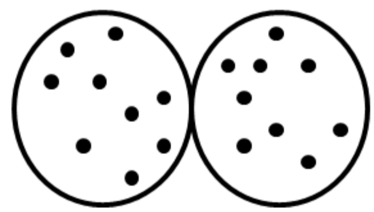
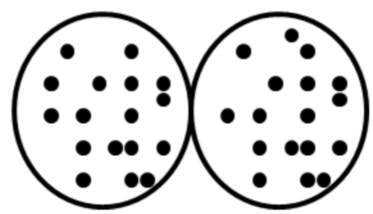
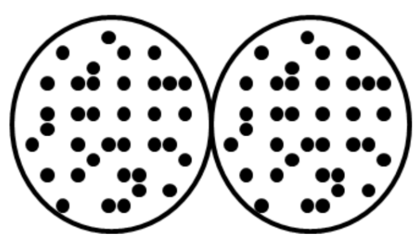
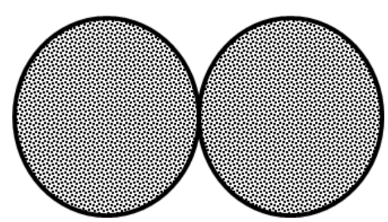
Loose valence electrons, in a packed cation solid, explain most of the metallic properties.

INTERMOLECULAR BONDING

Bonding INSIDE compounds or inside metals are clearly covered with ionic bonds, covalent bonds, and with metallic bonding. There is also bonding between particles of a gas, particles of a liquid, or particles of a solid. These are called inter-molecular bonds. Of all bonds, these are the weakest types, but they are still important and help determine phases of substances.

The three we will cover, from weakest to strongest are called: ELECTRON DISPERSION, DIPOLE ATTRACTION, and HYDROGEN BONDING.

Electron Dispersion Attraction or electron dispersion forces are due to the electrons of any atom or compound. Let's look at the atoms of group 17, the halogens to describe this intermolecular attraction.

Atom	Formula	Number of e^- in an atom	Number of e^- in a molecule	diagram
F	F_2	9	18	
Cl	Cl_2	17	34	
Br	Br_2	35	70	
I	I_2	53	106	

In every atom and every compound, the electrons are moving very fast, and not in any exact orderly way (like the planets going around the Sun). The electrons are in orbitals, or ZONES, where they are most likely to be found, but they are not limited to any special exact spots.

At any instant of time, the electrons are somewhere. They might be completely spaced out evenly, and the whole molecule would be balanced or neutral. If the electrons were all slightly off to one side, for that instant that one side would be MORE NEGATIVE and the other side would be MORE POSITIVE, then it would change.

Over time, these instant points of negative or positive in the electron clouds have some attraction and some repulsions for other atoms or molecules. If you have few electrons, it's hard for this to amount to much positive or negative, and the force is terribly weak (real, but nearly insignificant).

At STP, both F_2 and Cl_2 are gases. The REASON they are gases is that the only attractive force pulling them together is ELECTRON DISPERSION forces. As the electrons are instantaneously dispersed, creating instantaneous positive and negative spots on their orbital clouds, this force even with 34 electrons in Cl2 cannot overcome the kinetic energy of STP. These two elements are gases at normal temperature and pressure.

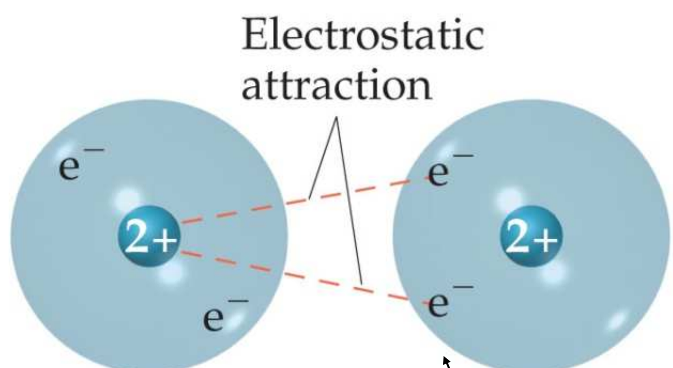
Bromine, Br_2, has 70 total electrons, and that many electrons dispersing at any point in time make MORE points of temporary positive and negative than fluorine or chlorine. Br_2 at STP is a liquid, because the electron dispersion attraction with this many electrons is enough attraction to hold the molecules together as a liquid (but not solid).

Iodine, I_2, has 106 total electrons, and a greater amount of electrons dispersing. When that many electrons are moving about, they create more moments of positive and negative, enough of them to pull this halogen into a solid at STP.

The three phases, gas, liquid, and solid are present in one group on the table; and these phases are caused only by the motion of the electrons in time, which create the weak but real electron dispersion force of attraction.

This is sometimes called London Dispersion Force, but that's a bit old fashioned.

All atoms, and all compounds have electron dispersion attraction, but usually it doesn't impact the particles as much as other forces. Mostly it cannot compete with the temperature (kinetic energy) of substances.
It's the weakest attraction of them all.



In this atom of helium at left:
the electrons are dispersed evenly
in this moment.

On the right, the electrons in helium atom #2
are off to the left, creating a TEMPORARY,
but real negative spot on the orbital cloud.
That negative point is attracted to the
positive nucleus of the left side helium atom.
This lasts for A MOMENT, but new ones constantly
appear as the electrons keep dispersing, or moving.

DIPOLE ATTRACTION

When atoms bond in covalent bonds they can share electrons perfectly together, if their electronegativity values are equal. Electronegativity means tendency to gain an electron in a bonding situation. If two atoms of fluorine bond, each has an EN Value of 4.0 which means that the difference in their EN Values is zero.

Neither atom of F gets the electrons they share more of the time. The bond is single NONPOLAR covalent.

Same with H_2, or Br_2. Both have single NONPOLAR covalent bonds.

And it's the same with O_2 although that is a double NONPOLAR covalent bond.

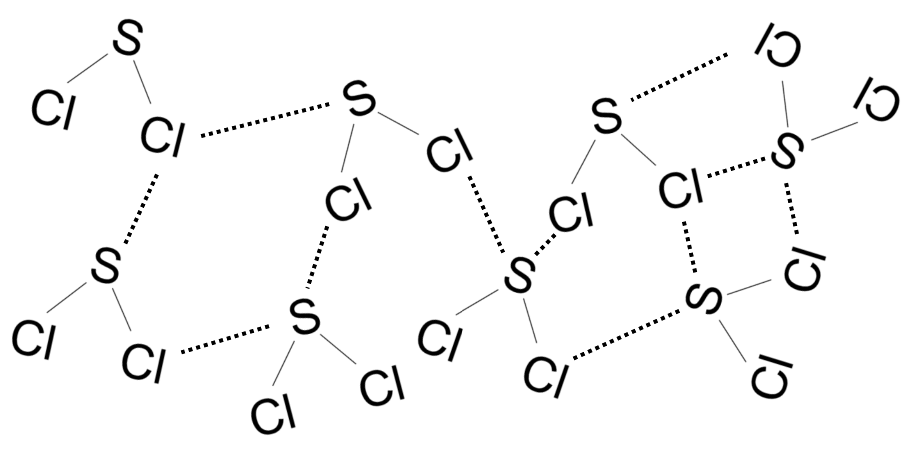
N_2 has a triple NONPOLAR covalent, but again NO DIFFERENCE in EN VALUES.

When bonds form and the bond is POLAR, because there IS A DIFFERENCE in EN Value, the atom with the higher electronegativity "gets" the electrons of the bond more often. That side of the bond is said to be more negative, the other side would be more positive.

These polar covalent bonds are sharing electrons, just not sharing equally. This unequal sharing will make the bonds almost always uneven, or POLAR.

When a whole bunch of sulfur dichloride molecules (SCl_2) are together, since the bonds between sulfur and chlorine have an EN Value difference (3.2 - 2.6 = 0.6 which is a polar bond), these bonds are almost always skewed so that the chlorine side is negative and the sulfur side is positive. Not a lot of positive or negative, actually just a little, but most of the time this polarity exists.

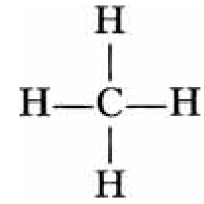
When these molecules are close together, they act like weak magnets. Chlorines (-) of one molecule are attracted to the sulfur (+) of other molecules, this near constant attraction is called DIPOLE ATTRACTION.



Above are eight molecules of SCl_2, randomly dispersed. Remember, all the sulfur atoms are usually positively charge because of the EN Value differential with chlorine. The chlorine atoms are all usually negatively charged. This ALMOST CONSTANT POLARITY creates dipole attraction. This is also somewhat weak, but will make these molecules stick together better than molecules without it (see next page).

This DIPOLE ATTRACTION is indicated with the dotted lines.

With molecules of methane you need to see that the C-H bonds are polar, but…



The shape of this molecule is very important. The molecule has a balanced shape. Even though the hydrogen atoms are all mostly positive because the carbon in the center attracts their electrons most of the time, the positive charges sort of cancel each other out, because of the shape.

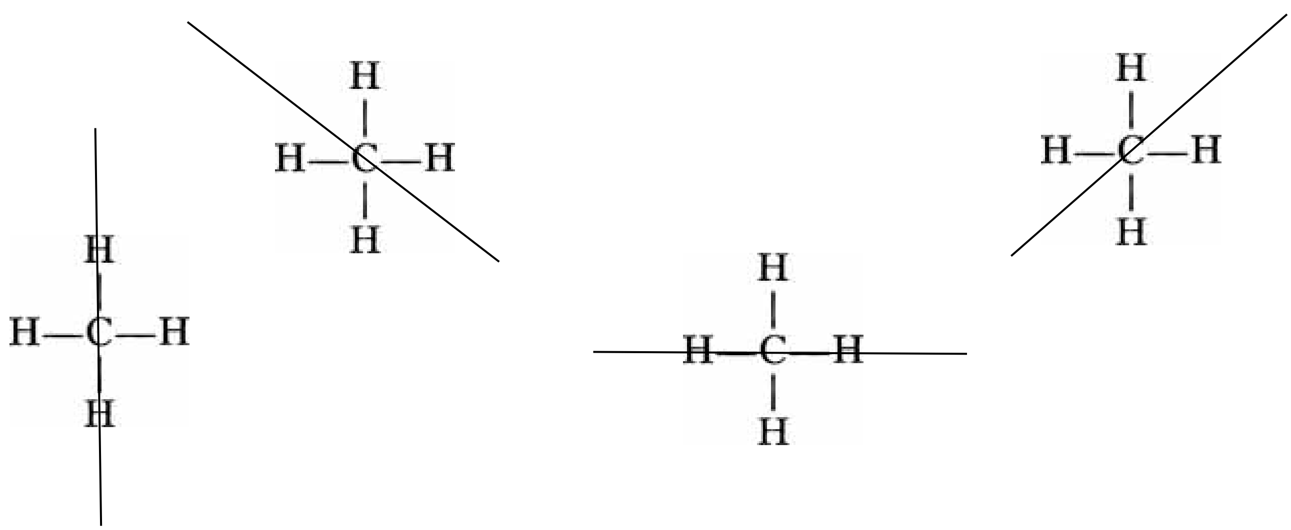
This molecule has RADIAL SYMMETRY. That is the same sort of balance as a pizza pie.

No matter how you cut a pizza pie (or cherry pie, or circle). If you go through the middle point, you get two equal halves. NO MATTER WHAT. If a molecule exhibits radial symmetry, it's balanced in shape, and the polar bond charges cancel each other out. This whole methane molecule has a positive outside, a negative inside. When you put a bunch of methane together, all of the outside to all of the molecules are positively charged (most of the time), there is NO DIPOLE ATTRACTION.

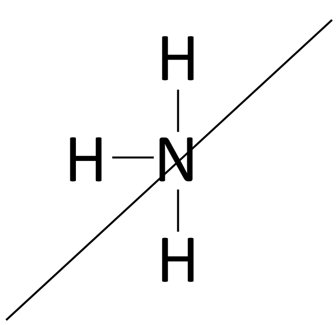
To get dipole attraction, you need polar bonds IN polar molecules. The shape of a molecule that determines if if is polar or non-polar.

Radial symmetry is the only symmetry we care about in chemistry.

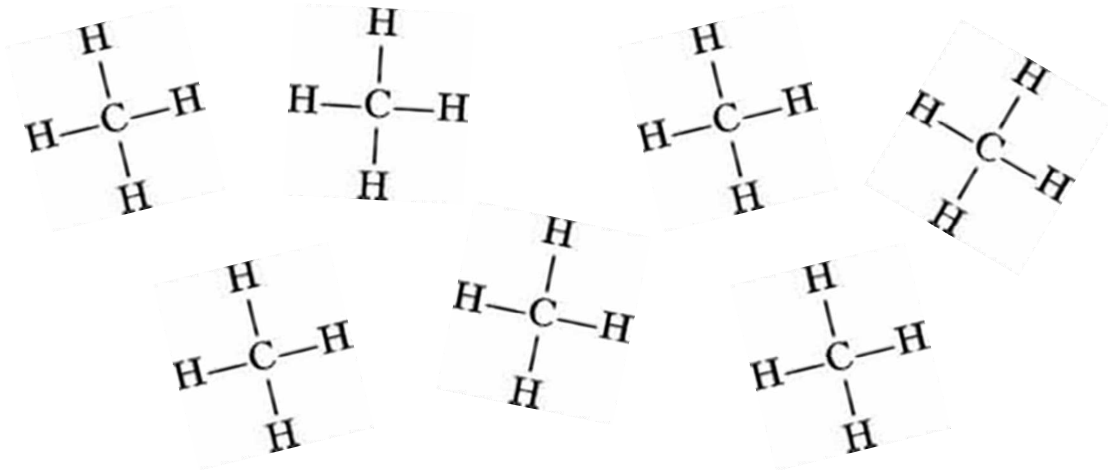
Humans (and gingerbread men) have bilateral symmetry. So does a water molecule. They have only one plane of symmetry. Water molecules are POLAR, the polarity of the bonds just can't cancel out.



Any cut, though the center of the molecule gives you two EQUAL sides. This is radial symmetry, the bond polarity can cancel out.



In ammonia, the bonds between N-H are polar. Since there are three hydrogen atoms bonded to the ammonia, when you cut it this way, you get one side with 2 H and one side with one H and two extra electrons that nitrogen is not bonding with. This is NOT radial symmetry, this is a polar molecule.



All of these molecules of methane have radial symmetry. They have polar bonds, but the molecules are balanced and NONPOLAR. They have almost no intermolecular attraction, except for electron dispersion forces. Unlike HCl or NH_3 or other polar molecules, they are most likely going to be gases at STP. BONDS can be polar, MOLECULES can be polar.

- Bonds are polar when there is a difference in EN Values.
- Molecules are polar when no radial symmetry exists.

HYDROGEN BONDING

When molecules that are polar and the bonds contain hydrogen, molecules like water and ammonia, not only are the bonds polar, but they are EXTRA POLAR because hydrogen has such a low EN VALUE. For example:

SCl_2 has an EN Value difference of 0.6 between S and Cl. In water, the difference between oxygen and hydrogen EN Value is 3.4 - 2.2 = 1.2 which is a much greater polarity in the bond.

With Ammonia, nitrogen and hydrogen make an EN Value differential of 3.0 - 2.2 = 0.8, again much greater than the 0.6 differential in SCl2, these dipole attractions are so much greater, they have a different name.

This is sort of silly. Dipole attraction + super-duper dipole attraction would be fine with me, but not with NYS!

So, there are dipole attractions when polar bonds exist in polar molecules. But if these polar bonds contain hydrogen, they are called HYDROGEN BONDS.

These intermolecular attractions are not really bonds either, they are super-duper dipole attractions.

In order of weakest to strongest, the intermolecular bonds are:

- electron dispersion
- dipole attraction
- hydrogen bonding

UNUSUAL BONDING, exceptions, weirdo bonds that are important to us as people, etc.

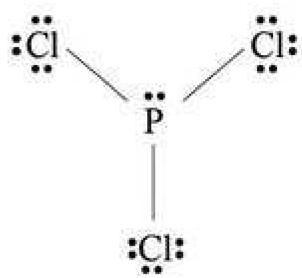
There are several bonds that we need to learn about that do not follow the "rules" of bonding, but somehow they exist, and they are worth looking at.

Rules include the octet rule, meaning only 8 electrons fit into the valence orbital unless it's too small.
This rule is broken with the compound PCl_5

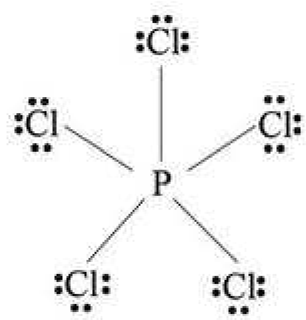
In this, phosphorous has 5 valence electrons, and they break apart, allowing 5 chlorine atoms to bond in.
That gives the P atom 10 electrons. This is not normal, but possible.

PCl_3 and PCl_5 are shown here. They have 3 or 5 polar covalent bonds. In the first, there are one pair of UNSHARED electrons shown at top. This molecule does not have radial symmetry, it's polar. So is PCl_5

PCl_3



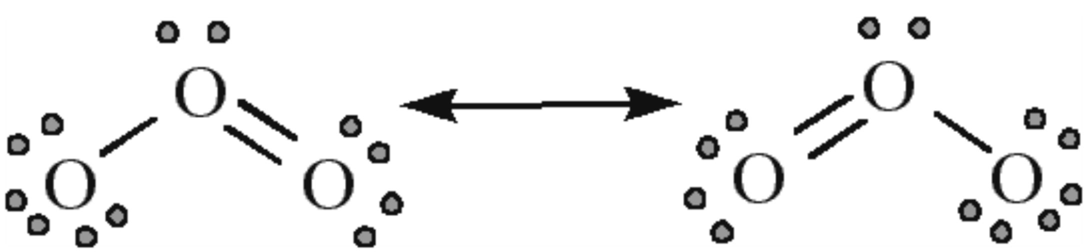
PCl_5



This diagram shows a combo design of structural with the nonbonding unshared pairs of electrons. At left, P has 2 electrons that are not involved in bonding, and paired for their stability. The chlorine atoms at right have three pairs each of unshared electrons. The P atom at right seems to have 10 electrons, and it does!

It breaks the octet rule.

As you might remember, I am from a place in Queens called <u>Ozone</u> Park. Ozone is a type of pure oxygen, but it's got a different formula, and different bonding. You can't stay alive if you breathe ozone, and pure O_2 won't protect you from harmful rays of the Sun. They're both pure oxygen but with different structures, different bonding, and different properties. These are ALLOTROPES. Ozone is O_3. But it won't bond in a stable way, the only way to keep it bonded is to make a single bond, and a double bond as below left. This switches around in an instant to the other side, which is also not stable. These bonding styles are both a bit unstable, so ozone RESONATES the bonds back and forth quickly. This shows <u>RESONTATING BONDS</u>.



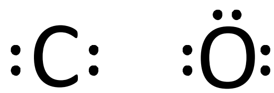
Neither side is "stable" and what ends up happening is that it forms as the left shows, realizes it's not stable so it reverts to the right side, but then realizes it's unstable that way too, so it reverts back to the first way (and over and over). This ozone exists, and the bonding makes no sense, unless you "agree" that this can flip back and forth. It ends up forming an approximate 1½ sized bond on both sides rather than a double/single as shown. That's because this resonance is FAST.

COORDINATE COVALENT BONDS

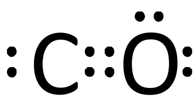
CO2 makes two double polar covalent bonds. Since the molecule has radial symmetry (balance) the molecule is nonpolar. When CO, carbon monoxide forms, there is NO WAY that you can get the electrons to balance unless you know a tricky bond called coordinate covalent.

This is a common substance in your life, so you need to learn this, but it's not common bonding.

Carbon has 4 valence electrons, or 2 pairs. Oxygen has 3 pairs of valence electrons. There is possible combination where carbon shares 2 electrons with oxygen so oxygen gets an octet. This leaves carbon with just six, not an octet. SO, now oxygen will "loan" two of it's nonbonding electrons (the top 2 electrons) so carbon can have an octet as well. Since they are sharing just 2 pairs (double polar covalent bond) and oxygen "loans" one pair (a coordinate covalent bond) this is the only way both get an octet. It's also the only way to explain how these 2 atoms could bond. Start here:



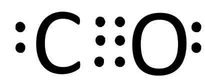
So what happens, strangely, is that CO makes a double polar covalent bond this way (first)



This "satisfies the oxygen with an octet, but not carbon (and carbon is not happy without an octet). It's got to do more!

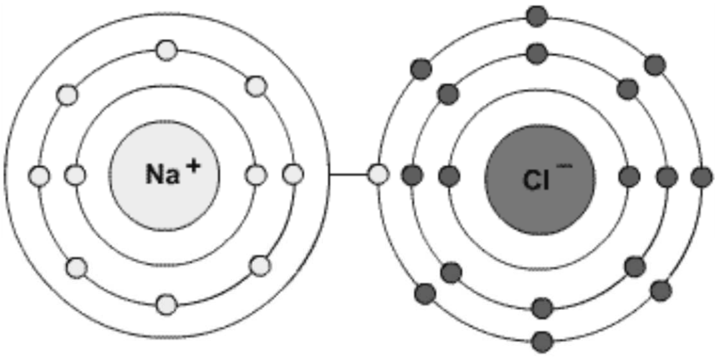
A coordinate covalent bond can be described as oxygen coordinating an octet for carbon by "lending" 2 of it's (top) unshared electrons to the double bond, making what LOOKS LIKE a triple bond, but is really a double polar covalent bond, PLUS a coordinate covalent bond. It looks like this:

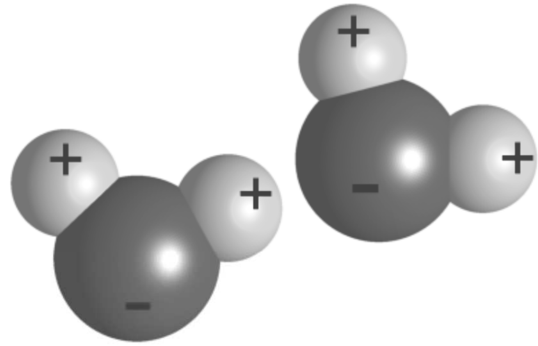
This "appears" to be a triple bond, but notice that carbon has 2 unshared electrons at left, and only has 2 more of it's electrons in the center. The extra electron carbon seems to "have" is from the oxygen atom.

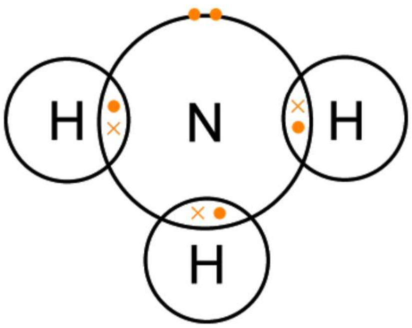


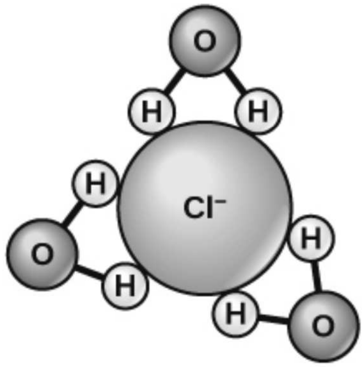
This is a double polar covalent bond PLUS two electrons just being put into the middle so carbon "feels" like it gets an octet too. Not normal, but CO exists in our life, we need to keep track of this bond.

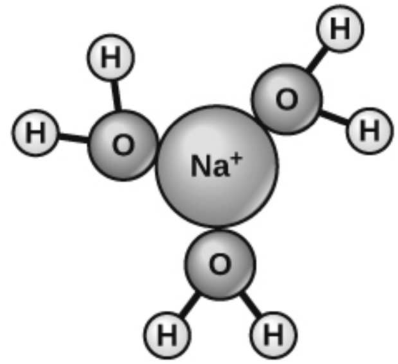
There are many ways to show bonding, many are here. These are not used often, but you should be able to figure them out if you care to. NaCl forms when Na transfers an electron to Cl. Two water molecules with polar bonds (hydrogen are +). One H is attracted to the neighboring oxygen, via hydrogen bonding.



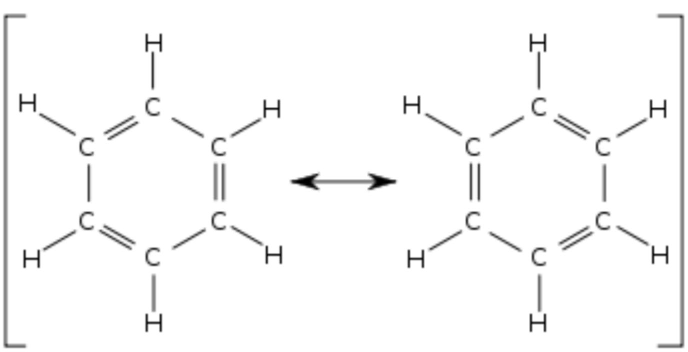








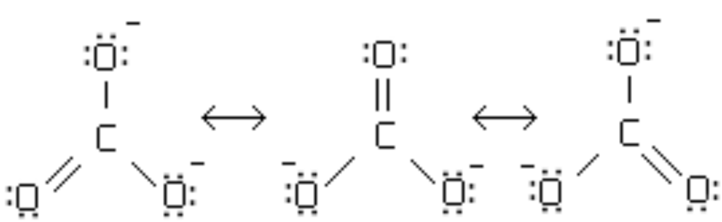
Ammonia forms when three H atoms bond to one N atom. The nitrogen has one unshared pair of electrons at top. Next is water molecules that surround sodium and chlorine ions ($NaCl_{(AQ)}$) Note the orientation of the water molecules, their polarity "point" them at the ions in a particular way.

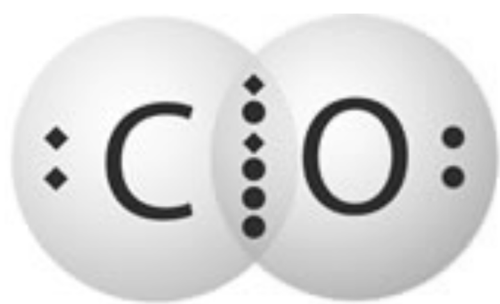


C_6H_6 resonates with 3 triple bonds and 3 single bonds between the carbon atoms. Neither is more stable than the other, so they will resonate back and forth.

At bottom left is the carbonate anion CO_3^{-1} It too has no stable form, and the extra electron making it charged moves about, shifting the bonding to the oxygen atoms around.

At bottom right is CO, showing the carbon electrons as diamonds, and the oxygen electrons as dots. Count them up. There are 6 in the center, 2 carbon diamonds, and 4 oxygen dots. Both atoms end up with an octet, only because oxygen coordinates this with the coordinate covalent bond.





Alloys

Alloys are mixtures of elements that contain at least one metal, often 2 or more metals. The elements are usually melted together, stirred up, and then let to chill to a solid. The new solid that forms is a mixture of the metals and together they have "better" properties than the original metals alone.

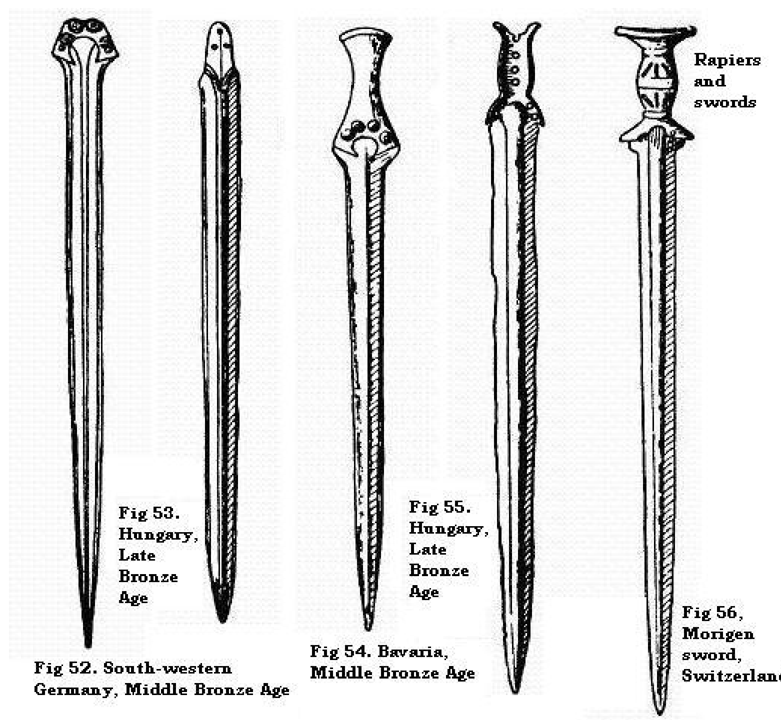
Common alloys include sterling silver (used in forks and knives) made from silver and copper melted together, stainless steel (for scalpels and tools) made from iron and chromium mixed together. Brass (trumpets, tubas, and French horns) is made from melting together zinc and copper.

Some alloys are made from metals plus nonmetals as well, such as: cast iron (used in plumbing pipes) made from iron and carbon.

These elements get mixed and when allowed to solidify, the atoms pack differently and often give stronger, more durable metallic mixtures with properties that make them better suited for certain uses.

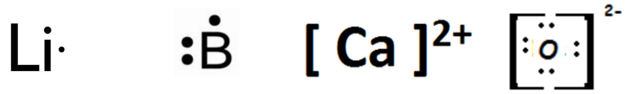
It's important to note again: these are mixtures, the metals, or metal-nonmetal mixtures are not compounds. These alloys have no set formulas, but certain quantities of each element make for somewhat stronger, or more lustrous, or increase some quality. They can be melted apart and the elements should separate by density.

The Bronze Age started about 5000 years ago. During that time humans learned to melt together the metals copper and tin. Together the tools they made were much stronger, and golden in color. Below are drawings of weapons from that period from all over Europe. Wooden handles, or even spears were attached to the metal points.

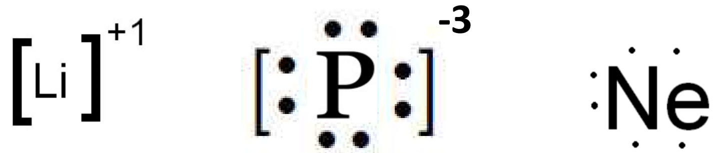


PRACTICE QUESTIONS Set 1 (answers on the last page)

1. What are the electron configurations for phosphorous and for magnesium? What are their ion electron configurations?
   P has a 2-8-5 electron configuration, the Mg has a 2-8-2. The P^{-3} anion is 2-8-8, the Mg^{+2} cation is 2-8.
2. Which electrons are drawn in Lewis dot diagrams? ONLY the outermost ones, the VALENCE ELECTRONS
3. Draw Lewis Dot Diagrams for the lithium atom, boron atom, calcium cation, and the oxide anion.
   The lithium atom has 1 valence electron, the boron atom has 3 valence electrons. The calcium cation transfers 2 electrons and ends up with an empty outermost orbital, oxygen gains 2 electrons to get its octet

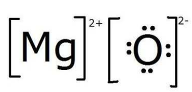


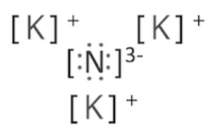
4. Will an atom of aluminum ever normally lose 1 or 4 electrons? Why not? No, aluminum is a metal, it loses enough electrons to become isoelectric to a noble gas. Al start as 2-8-3, when it loses 3 electrons to become Al^{+3} that changes to 2-8 (like neon)

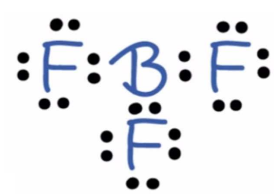


PRACTICE QUESTIONS Set 2

1. Draw the Lewis dot diagrams for Li^{+1}, P^{-3}, and for Neon.
2. Draw Lewis Dot diagrams for magnesium oxide and for potassium nitride.



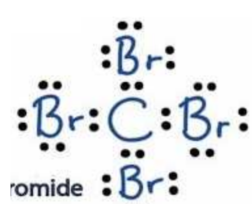


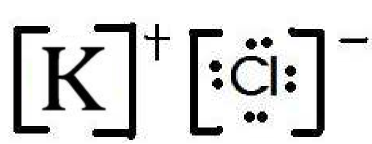


3. Define ISOELECTRIC. Isoelectric means obtaining the same electron configuration as a noble gas. This happens when metals lose exactly enough electrons to match up their electron configuration with a noble gas, or when a non-metals gain enough electrons to do this same thing. They DON'T become noble gases, they get similar electron configurations.

PRACTICE Questions set 3

1. Draw larger sized structural diagrams for KCl, for boron trifluoride, carbon tetra bromide.
2. Carbon dioxide... Have double polar covalent bond.
3. Name the bond types in oxygen difluoride. This has 2 single polar covalent
4. Name the bond types in ammonium chloride. IONIC!





Bonding Notes

Types of bonds we will see:

1. Ionic

2. Covalent

3. Metallic

4. Intermolecular

5. The outermost electrons are the ____________________ electrons

6. The outermost electron orbital is the _______________________ _____________________________.

7. Bonds always form when atoms or ions end up with ______________________________, like the noble gases.

To draw LEWIS DOT DIAGRAMS

8. Dots represent ____________________________

9. Lewis Dot diagrams show only ____

10. Electron orbitals: the first orbital is ______________________ and holds only ___________ electrons

11. The second orbital is larger, and holds up to __________electrons.

12. Fill in this chart (and keep going)

Atom number	Atom symbol	Lewis Dot (atom)	Ion Symbol	Lewis Dot (ion)
1	H		H^{+1}	
2	He		X	X
3	Li			
4	Be			

Atom number	Atom symbol	Lewis Dot (atom)	Ion Symbol	Lewis Dot (ion)
5			X	X
6			X	X
7				
8				
9				
10			X	X
11				
12				
13				

Atom number	Atom symbol	Lewis Dot (atom)	Ion Symbol	Lewis Dot (ion)
14			X	X
15				
16				
17				
18			X	X
19				
20				

20. When sodium chloride forms from sodium metal and chlorine non-metal, the atoms form ions first. To do this, the sodium ________________________ an electron to a chlorine atom .

21. The sodium becomes a sodium cation with a ____________ charge

22. The chlorine becomes a chloride anion, with a _______________ charge

23. Let's draw the Lewis dot diagrams for the atoms, the ions, and then the compound.

Atom	Ion	Compound

24. It's important to note here, the sodium atom at 2-8-1 electron configuration becomes _______________ as it loses one electron, becoming isoelectric to neon.

25. It loses enough electrons to get a perfect outer orbital, as defined by noble gases having the most perfect, or
____________________________________ electron orbitals of all.

26. The chlorine atom has a 2-8-7 configuration, gains one electron, and becomes _________________, making it isoelectric to the noble gas ________________.

27. Both ions end up with perfect outer orbitals, both end up
____.

28. Almost all ions follow the _________________ rule.

29. This is described as:

30. This is a rule, not the law. An exception is ________ which is too ________________...

31. Fill in this chart.

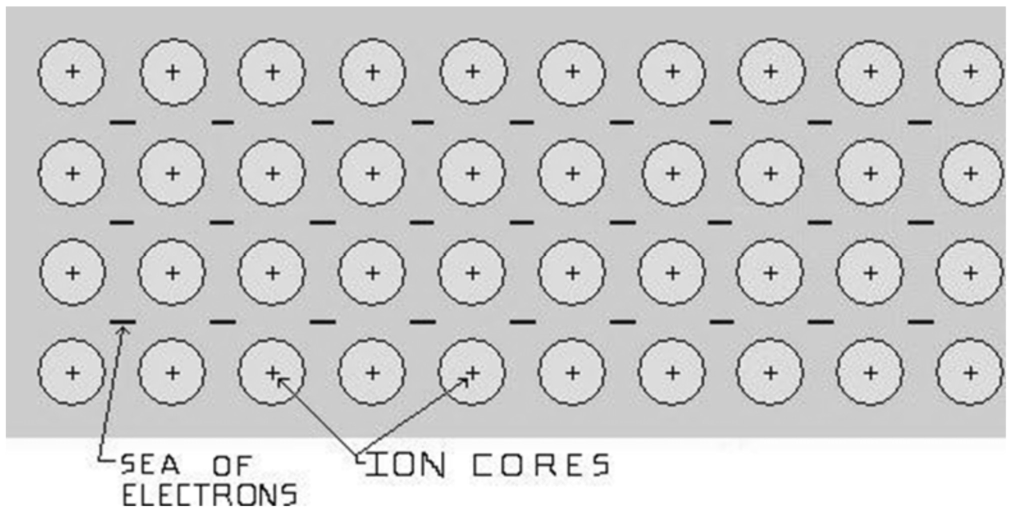
Compound name	Compound	Cation	Anion	Lewis Dot Diagram
Magnesium oxide	MgO	Mg^{+2}	O^{-2}	
	LiF			
	$CaCl_2$			
Sodium…			S^{-2}	
Cesium oxide				

32. Why is the formula for aluminum oxide Al_2O_3 and not some other ratio?

33. Draw the (ugly) Lewis Dot diagrams for Magnesium Nitride and Aluminum Oxide

34. Metallic Properties that you should remember include…

35. Metals are understood to be…



36. Metals are made up of…

37. Smashing a piece of metal with a hammer:

38. The flow of electrons…

39. In metals, the…

40. Covalent Bonding:

41. They do not…

42. With Ionic Bonding, there is a

43. In Covalent Bonding..

44. No…

45. Covalent Bonds…

46. Molecules form with…

47. Draw Lewis Dot diagrams for H_2 and F_2

48. In covalent bonds, all atoms get ____.

49. These bonds for H_2 and F_2 are all ___________________________________ BONDS because they only

    share ___________________________ AND ____

50. $F_2 + H_2$ have ____ bonds.

51. Draw Lewis Dot Diagram for HCl, and name the bond present.

52. Draw the Lewis Dot Diagram for H_2O, and name the bond present (there are 2 identical bonds in water)

53. Draw STRUCTURAL diagrams for HCl & water.
(1 dash = 1 pair of electrons being shared in a bond) →

54. Draw the Lewis Dot Diagram, and the Structural diagram →
for AMMONIA, NH_3.

55. Draw the Lewis Dot Diagram, and the Structural diagram for →
METHANE, CH_4.

56. The greater the difference in electronegativity values between two atoms, the greater the polarity of the bond. Polarities can be stronger (greater EN difference) or weaker (less EN difference).

Fill in this chart

Molecule formula	EN #1	EN #2	EN diff	Polarity rank	Structural diagrams
H_2 diatomic hydrogen	2.2	2.2	0		H—H
PCl_3					
OF_2					
HBr					
HI					

57. Draw 2 Lewis Dot Diagrams of atoms of oxygen. →

58. How many electrons does EACH atom of oxygen need to complete the octet? ___________
Can they do this for each other? ______

59. Draw the Lewis Dot Diagram for the Molecule of oxygen in the box
MEMORIZE THIS ONE.

The O_2 molecule. Makes a ____________________________________ bond. Why is it nonpolar?

60. Draw structural diagrams and name the types of bonds in these HONClBrIF twins (leave N_2 for last)

H_2	O_2	F_2
Cl_2	Br_2	I_2

61. Draw a Lewis Dot Diagram for a nitrogen atom	How many electrons does each atom need to meet the octet rule?	Draw a Lewis Dot Diagram for another nitrogen atom

62. Draw a nitrogen molecule in the box
Memorize this one also!

63. Nitrogen molecules have a triple nonpolar covalent bond because...

	Dot diagram	Structural diagram	name all bonds present
64 C_2H_6			
65 C_2H_4			
66 C_2H_2			
67 C_3H_8			
68 CO_2			
69 $AsCl_3$			
70 C_4H_{10}			
71 OBr_2			
72 CCl_4			

73. Draw a Lewis Dot diagram for CaO calcium oxide, and tell what sort of bond or bonds are present.

74. Define ALLOY:

75. Alloy examples:

76. In this NaCl model, each Na^{+1} is surrounded by 6 Cl^{-1} anions.

The ___________________________________ number for sodium cations is __________

The ___________________________________ number for chloride anions is __________

77. With this ______ coordination number ratio, the shape of NaCl crystals is ______________

78. With a __________ coordination number, $CaCO_3$ ends up with a very different ________________

79. Coordination number is…

80. What's the big deal about a coordination number?

----

81. Draw the Lewis dot diagram for a carbon atom	Draw the Lewis dot diagram for an oxygen atom	Draw the Lewis dot diagram for carbon monoxide, CO

82. CO forms a…

83. Shorthand notation for this looks like: _______________ no atoms make this bond alone.
There is always a "real bond" forming first, then this exceptional bond allows both atoms to get an octet.

84. Phosphorous Pentachloride (PCl_5) is another weirdo compound. It breaks the octet rule also. Attempt it here:

Lewis dot diagram	Structural diagram

85. How does this break the octet rule?

86. Oxygen + Ozone are both PURE FORMS of oxygen. Their formulas are: _________ + ______________

87. Ozone is an ___________________________________ of oxygen.

88. Allotropes are:

89. Let's bond 3 oxygen atoms here

90. These bonds ___________________________, they are not stable one way or the other, but they are stable "both ways at the same time"!

Another name for this is a __________________________ bond

91. Because they literally resonate back and forth all of the time, each bond is really: ______________

92. Intermolecular bonds are:

93. Ionic bonds form between a ______________________________ and a ________________________________

These bonds ________________________ electrons. Examples include: _____________________

94. Covalent bonds form between a ______________________________ and a ________________________________

These bonds do not transfer electrons, they _________________ electrons. Examples include: ________________

94. Metallic Bonds…

95. All of these bonds (ionic, covalent, and metallic) are …

96. There are ____ kinds of intermolecular attractions (or bonds). All are __________ _____________ than ionic, or covalent or metallic bonds.

97. Weakest to strongest, these intermolecular bonds are named:

98. The weakest intermolecular bond is _____________________________________ which is caused by

99. Example 1: Fluorine F_2

100. When all of fluorine's _____ electrons move…

101. Example 1: Chlorine Cl_2

102. When all of chlorine's _____ electrons move…

103. Example 3: Bromine Br_2

104. When all of Bromine's _____ electrons move…

105. Example 4: Iodine I_2

106. When all of Iodine's _____ electrons move…

107. At STP, the halogens exhibit…

108. Which is ONLY due to the differences in their

____

109. Dipole Attraction:
(draw 2 molecules)

110. The dipole arrows
DO NOT

111. Molecular polarity is based upon a molecule's ______________

112. If the molecule has ______________________________ then it is nonpolar.

113. The only symmetry (or balance) that matters in chem is called ____________________ symmetry.

114. There are other forms of symmetry, but they don't matter in chem. Humans and gingerbread men have

symmetry called _____________________________. It's a type of symmetry, but not important concerning molecules.

115. Draw SCl_2 It does not have radial symmetry. The bonds are…

116. Draw CH_4 It DOES have radial symmetry. The bonds are…

117. Radial symmetry offsets that polarity, and the molecule is nonpolar. SCl_2 will be liquid at room temperature, while CH_4 would be a gas. Why???

118. Draw 5 molecules of SCl_2 Use DOTS to show dipole attraction (intermolecular attraction)

119. Draw 4 molecules of methane, there are NO dipole attractions here.

120. Hydrogen bonding is EXACTLY LIKE ____ but the difference is that atoms of ______________________________ must be present.

121. This matters because H has a much _________________ _____________________, making the bonds much more _______________________

122. Draw a molecule of SCl_2 and of water.

Electronegativity values & differences: S___ Cl ___ difference ______ H___ O ___ difference ______

Since _____ has a greater electronegativity difference, it has a _____________ __________ bond.

This super duper dipole that forms is so strong instead of strong dipole attraction, we call it

____

123. Draw 6 water molecules, include DOTS that show

124. Bond type	example formulas
Ionic	
Single nonpolar covalent	
Single polar covalent	
Double nonpolar covalent	
Double polar covalent	
Triple non polar covalent	
Triple polar covalent	
Coordinate covalent	
Resonant	
Ionic + Covalent at the same time	
Breaks the octet rule (more than $8e^-$)	
Breaks the octet rule (less than $8e^-$)	

125. Oxidation numbers are:

126. Show all of the oxidation numbers for H and O, use the t-chart properly

127. What are the relative oxidation numbers for

HCl

CO_2

$AsCl_3$

☺	Sulfur dioxide	SO_2	S^{+4} O^{-2} O^{-2} (0 overall charge)
☺	Chromate ion	CrO_4^{-2}	Cr^{+6} O^{-2} O^{-2} O^{-2} O^{-2} (-2 overall charge)
129	Permanganate ion		
130		NH_3	
131		NaOH	
132		$KClO_3$	
133	Carbon monoxide		
134	Carbon dioxide		
135	Dihydrogen sulfate		
136	Nitrate ion		
137	Nitrogen dioxide		
138	Phosphorus trichloride		

Intermolecular bonding system Jeopardy!

139. It keeps ammonia NH_3 together as a liquid, what is…

140. It keeps Br_2 bromine a liquid, but iodine I_2 a solid, what is…

141. It keeps phosphorus trichloride PCl_3 together as a liquid, what is…

142. What is the difference between bond polarity and molecular polarity?

143. The bonds in ozone…

144. Draw the CO, carbon monoxide molecule properly (dots and structurally). Name the <u>bond or bonds</u>

145. True or False?

Ionic bonds can be double or single bonds

Covalent bonds cannot be nonpolar bonds

Oxygen molecules have double polar covalent bonds

Nitrogen molecules have double nonpolar covalent bonds

Hydrogen atoms can make single or double covalent bonds

Oxygen atoms must make double bonds ONLY

Water is sometimes a straight line molecule by shape

Molecules with polar bonds can never be non polar molecules

Molecules with nonpolar bonds only can never be polar molecules

The weakest intermolecular bond is the dipole force of attraction

100 Bonding Questions—answers are online at arbuiso.com   click on BONDING page.

1. Based on electronegativity values, which type of elements tends to have the greatest attraction for electrons in a bond?
   1. metals 2. metalloids 3. nonmetals 4. noble gases

2. Draw a Lewis electron-dot diagram for a chlorine atom in the ground state.

3. Which element has atoms with the greatest attraction for electrons in a chemical bond? 1. Be 2. F 3. Li 4. O

4. Draw a Lewis electron-dot diagram of a aluminum atom in the ground state.

5. Which of the following atoms has the greatest tendency to attract electrons? 1. Ba 2. Be 3. B 4. Br

6. Which of the following elements has the highest electronegativity? 1. H 2. K 3. Al 4. Ca

7. The strength of an atom's attraction for the electrons in a chemical bond is the atom's
   1. electronegativity 2. ionization energy 3. heat of reaction 4. heat of formation

8. What is represented by the dots in a Lewis electron-dot diagram of an atom of an element in Period 2 of the Periodic Table?
   1. the number of neutrons in the atom 2. the number of protons in the atom
   3. the number of valence electrons in the atom 4. the total number of electrons in the atom

9. As a neutral sulfur atom gains two electrons, what happens to the radius of the atom?

10. As two chlorine atoms combine to form a molecule, energy is 1. absorbed 2. released 3. created 4. destroyed

11. What occurs when an atom of chlorine forms a chloride ion? The chlorine atom…
   1. gains an electron, and its radius becomes smaller. 2. gains an electron, and its radius becomes larger.
   3. loses an electron, and its radius becomes smaller. 4. loses an electron, and its radius becomes larger.

12. What occurs when an atom of chlorine and an atom of hydrogen become a molecule of hydrogen monochloride?
   1. A chemical bond is broken and energy is released. 2. A chemical bond is formed and energy is released.
   3. A chemical bond is broken and energy is absorbed. 4. A chemical bond is formed and energy is absorbed.

13. When an atom of phosphorus becomes a phosphide ion (P^{3-}), the radius 1. decreases 2. increases 3. remains the same

14. Which of these elements has the least attraction for electrons in a chemical bond? 1. O 2. F 3. N 4. Cl

15. Which change occurs when a barium atom loses two electrons?
   1. It becomes a negative ion and its radius decreases. 2. It becomes a positive ion and its radius decreases.
   3. It becomes a negative ion and its radius increases. 4. It becomes a positive ion and its radius increases.

16. Which Lewis electron-dot diagram represents a boron atom in the ground state?

17. Based on Reference Table S, which of these elements have the strongest attraction for electrons in a chemical bond?
   1. Nitrogen 2. Sodium 3. Phosphorous 4. Platinum

18. Draw the electron-dot (Lewis) structure of calcium chloride.

19. Draw the Lewis dot diagram for carbon dioxide.

20. Draw the Lewis dot diagram for water.

21. Draw the Lewis dot diagram for aluminum phosphide.

22. Which compound contains ionic bonds? 1. NO 2. NO_2 3. CaO 4. CO_2

23. Which formula represents an ionic compound? 1. NaCl 2. N_2O 3. HCl 4. H_2O

24. What is the total number of pairs of electrons shared in a molecule of N_2? 1. one 2. two 3. three 4. four

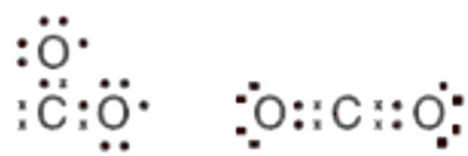
25. What is the total number of electrons shared in a molecule of N_2? 1. one 2. two 3. three 4. six

26. Which type of bond results when one or more valence electrons are transferred from one atom to another?
1. a hydrogen bond 2. an ionic bond 3. a nonpolar covalent bond 4. a polar covalent bond

27. What is the total number of electrons shared in the bonds between the two carbon atoms in a molecule of C_2H_2?
1. 6 2. 2 3. 3 4. 8

28. A metal, M, forms an oxide compound with the general formula of M_2O. In which group on the Periodic Table could metal M be found? 1. Group 1 2. Group 2 3. Group 16 4. Group 17

29. The two diagrams at right *should* make you remember…
1. CO_2 is bent and is a polar molecule
2. CO_2 is straight and is a polar molecule
3. CO_2 is bent and is a nonpolar molecule
4. CO_2 is straight and is a nonpolar molecule.



30. Draw an electron-dot diagram for calcium oxide, CaO

31. Draw an electron-dot diagram for hydrogen monobromide, HBr

32. Draw an electron-dot diagram for ethane, C_2H_2

33. Which molecule contains a triple covalent bond? 1. H_2 2. N_2 3. O_2 4. Cl_2

34. Which of these formulas contains the most polar bond? 1. H-Br 2. H-Cl 3. H-F 4. H-I

35. Which element has atoms that can form single, double, and triple covalent bonds with other atoms of the same element?
1. hydrogen 2. oxygen 3. fluorine 4. carbon

36. Which type of chemical bond is formed between two atoms of bromine? 1. metallic 2. hydrogen 3. ionic 4. covalent

37. Which type of bond is formed when electrons are transferred from one atom to another?
1. metallic 2. hydrogen 3. ionic 4. covalent

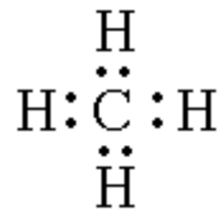
38. The bond between Br atoms in a Br_2
1. ionic and is formed by the sharing of 2 valence electrons 2. covalent and is formed by the sharing of 2 valence electrons
3. ionic and is formed by the transfer of 2 valence electrons 4. covalent and is formed by the transfer of 2 valence electrons

39. Covalent bonds are formed when electrons are
1. transferred from one atom to another 2. captured by the nucleus
3. mobile within a metal 4. shared between two atoms

40. The bonds between hydrogen and oxygen in a water molecule are classified as
1. polar covalent 2. nonpolar covalent 3. ionic 4. metallic

41. Which compound contains only covalent bonds? 1. NaOH 2. $Ba(OH)_2$ 3. $Ca(OH)_2$ 4. CH_3OH

42. In the diagram at right, which electrons are represented by all of the dots?
1. only carbon valence electrons 2. only hydrogen valence electrons
3. the carbon + hydrogen valence electrons 4. all of the carbon + hydrogen electrons



43. Which substance is correctly paired with its type of bonding?
1. NaBr - nonpolar covalent 2. HCl - nonpolar covalent
3. NH_3 - polar covalent 4. Br_2 - polar covalent

44. Which compound contains both ionic and covalent bonds? 1. $CaCO_3$ 2. PCl 3. MgF_2 4. CH_2O

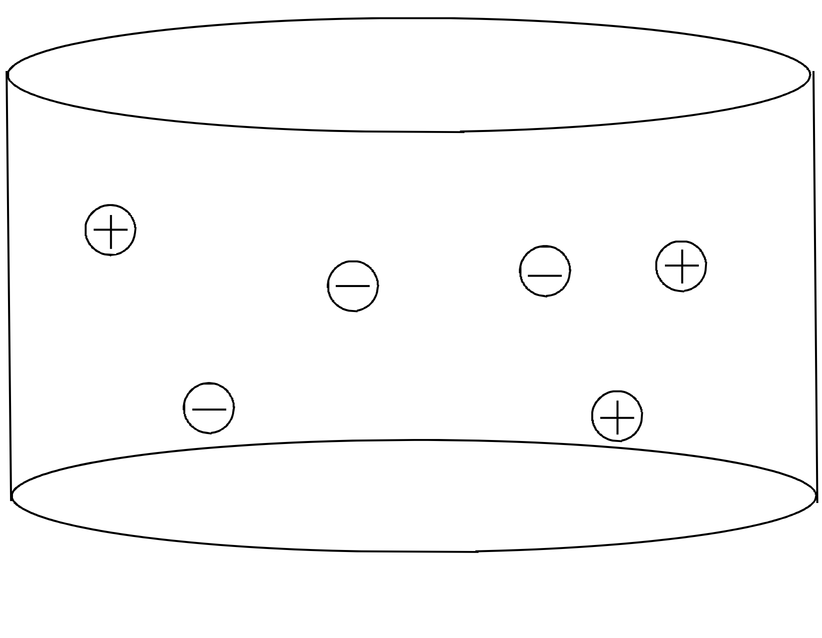
45. Which formula represents a nonpolar molecule containing polar covalent bonds? 1. H_2O 2. CCl_4 3. NH_3 4. H_2

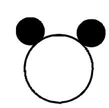
46. The degree of polarity of a chemical bond in a molecule of a compound can be predicted by determining the difference in the
1. melting points of the elements in the compound
2. densities of the elements in the compound
3. electronegativities of the bonded atoms in a molecule of the compound
4. atomic masses of the bonded atoms in a molecule of the compound

47. Which formula represents a nonpolar molecule? 1. CH_4 2. HCl 3. H_2O 4. NH_3

48. The strongest forces of attraction occur between molecules of 1. HCl 2. HF 3. HBr 4. HI

49. Using the symbols in the key at right, draw at least 12 water molecules with proper orientation to the potassium nitrate ions.



KEY	
water	
potassium cation	+
nitrate anion	−

50. Explain why CCl_4 is classified as a nonpolar molecule.

51. Explain why NH_3 has stronger intermolecular forces of attraction than Cl_2.

52. Draw the electron-dot (Lewis) structure for the ammonia molecule.

53. Explain why the bonding in KCl is different than the compounds in questions 50, 51, and 52.

54. Which molecule is nonpolar? 1. H_2O 2. NH_3 3. CO 4. CO_2

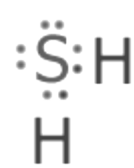
55. Which of the following compounds has the highest boiling point? 1. H_2O 2. H_2S 3. H_2Se 4. H_2Te

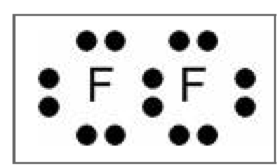
56. Which type of molecule is CF_4?
    1. polar, with a symmetrical distribution of charge
    2. nonpolar, with a symmetrical distribution of charge
    3. polar, with an asymmetrical distribution of charge
    4. nonpolar, with an asymmetrical distribution of charge

57. Molecules in a sample of $NH_{3(L)}$ are held closely together by intermolecular forces
    1. existing between ions
    2. existing between electrons
    3. caused by different numbers of neutrons
    4. caused by unequal charge distribution

58. Based on intermolecular forces, which of these substances would have the highest boiling point?
    1. He 2. O_2 3. CH_4 4. NH_3

Base your answers to questions 59-61 on your knowledge of chemical bonding and on the Lewis electron-dot diagrams of CO_2, H_2S, and F_2 below.





59. Which atom, when bonded as shown, has the same electron configuration as an atom of argon?

60. Explain, in terms of structure and/or distribution of charge, why CO_2 is a nonpolar molecule.

61. Explain, in terms of electronegativity, why a C–O bond in CO_2 is more polar than the F–F bond in F_2

62. Draw a Lewis electron-dot diagram for a molecule of chlorine, Cl_2.

63. Explain, in terms of electrons, why the bonding in NaCl is ionic.

64. Which element is malleable and can conduct electricity in the solid phase? 1. iodine 2. phosphorus 3. sulfur 4. tin

65. Which type of bond is found in sodium bromide? 1. covalent 2. hydrogen 3. ionic 4. metallic

66. Explain, in terms of molecular polarity, why hydrogen monochloride is more soluble than hydrogen in water under the same conditions of temperature and pressure.

Base your answers for questions 67, 68, and 69 on the information below.

Testing of an unknown solid shows that it has the properties listed here: It has a low melting point, it's nearly insoluble in water, it's a nonconductor of electricity, and it is a relatively soft solid.

67. State the type of bonding that would be expected in the particles of this substance.

68. Explain in terms of attractions between particles why the unknown solid has a low melting point.

69. Explain why the particles of this substance are nonconductors of electricity.

70. Metallic bonding occurs between atoms of 1. sulfur 2. copper 3. fluorine 4. carbon

71. The high electrical conductivity of metals is primarily due to
1. high ionization energies 2. filled energy levels 3. mobile electrons 4. high electronegativities

72. Which substance contains metallic bonds? 1. $Hg_{(L)}$ 2. $H_2O_{(L)}$ 3. $NaCl_{(S)}$ 4. $C_6H_{12}O_{6(S)}$

73. Which is a property of most nonmetallic solids?
1. high thermal conductivity 2. high electrical conductivity 3. brittleness 4. malleability

74. Which statement describes a chemical property of iron?
1. Iron can be flattened into sheets. 2. Iron conducts electricity and heat.
3. Iron combines with oxygen to form rust. 4. Iron can be drawn into a wire.

75. Which characteristic is a property of molecular substances?
1. good heat conductivity 2. good electrical conductivity 3. low melting point 4. high melting point

76. A substance that does not conduct electricity as a solid but does conduct electricity when melted is most likely classified as
1. an ionic compound 2. a molecular compound 3. a metal 4. a nonmetal

77. What sort of symmetry does a nonpolar molecule exhibit?

78. What sort of bonding exists in a carbon monoxide molecule?

79. What sort of bonding exists in an ozone molecule?

80. What sort of bonding exists in the compound copper (II) sulfate pentahydrate?

81. Draw six water molecules and clearly show the hydrogen bonding that exists between them.

82. Draw the Lewis dot diagram for sodium chloride

83. Draw the Lewis dot diagram for water.

84. Explain why fluorine and chlorine are gases at STP, but bromine is liquid, and iodine is a solid.

85. Name two compounds with molecular bonds only.

86. Name two compounds with ionic bonds only.

87. Why does Cl_2 have a nonpolar bond while HCl has a polar bond?

88. Rank these bonds from strongest to weakest polarity: HCl HF HI HBr

89. Which element has atoms that can form single, double, or triple covalent bonds with atoms of the same element?
1. Hydrogen 2. Oxygen 3. Carbon 4. Fluorine

90. Which substance represents a compound? 1. $C_{(S)}$ 2. $Co_{(S)}$ 3. $CO_{(G)}$ 4. $O_{2(G)}$

78. As two chlorine atoms combine to form one molecule of chlorine, energy is
1. absorbed 2. released 3. created 4. destroyed

79. Which bond type is formed when electrons are transferred from one atom to another atom?
1. covalent 2. ionic 3. hydrogen 4. metallic

80. Covalent bonds are formed when electrons are
1. transferred from one atom to another 2. captured by the nucleus
3. mobile within a metal 4. shared between two atoms

94. Which of these substances contains a coordinate covalent bond? 1. CO 2. CO_2 3. NaCl 4. Au

95. Which molecule here does not have radial symmetry and is polar? 1. CBr_4 2. $CHCl_3$ 3. CH_4 4. N_2

96. Explain why CCl_4 is a nonpolar molecule but contains polar bonds.

97. Explain what the valence electrons are doing in the molecule boron tri-iodide

98. Draw the electron dot diagram for sodium chloride

99. Draw the Lewis dot diagram for phosphorous trichloride

100. Contrast electron dispersion forces with dipole attraction forces.

Bonding Homework 4 Answers are online at arbuiso.com click on BONDING page

Fill in this chart, careful with the dots. Write YES/NO or POLAR/NONPOLAR

Molecular Compound	Lewis Dot Diagram	Polar or Non-polar Bonds?	Does this molecule have radial symmetry?	Is the molecule polar or non polar?
C_2H_6		C:C		
		C:H		
NI_3				
PH_2F		P:F		
		P:H		
CH_3Br		C:Br		
		C:H		
H_2O				
CO				
CBr_4				
CO_2				

Bonding Homework 3 Answers are online at arbuiso.com click on BONDING page

Fill in the chart below. Fill in the chart. Do not say polar when you could say single polar covalent. Do not say double when you mean double nonpolar covalent. Use the bonds' WHOLE NAMES. Don't be lazy. The last one has 2 different bonds in the one molecule, get both names.

	compound name	Formula	Correctly name the bond or bonds correctly full name.
2	sodium fluoride		
3	methane		
4		O_3	
5	silicon dioxide		
6		NH_3	
7	carbon dioxide		
8	sodium hydroxide		
9	aluminum fluoride		
10		LiBr	
11	iron (II) sulfide		
12	carbon tetraiodide		
14	ethyne	C_2H_2	
15	carbon monoxide		

Give examples of a compounds that makes these bonds. Write their Formulas			
single POLAR covalent bond		single POLAR covalent bond	
single NONPOLAR covalent bond		single NONPOLAR covalent bond	
double POLAR covalent bond		double POLAR covalent bond	
double NONPOLAR covalent bond		double NONPOLAR covalent bond	
triple POLAR covalent bond		triple NONPOLAR covalent bond	
Define			
coordination number			
alloy			
electronegativity			

On the back cover:

Draw 12 boxes, into each box write the FORMULAS for the following substances,

and Draw the correct LEWIS DOT DIAGRAMS for each

diatomic fluorine, diatomic nitrogen, diatomic hydrogen, diatomic oxygen, water, carbon dioxide, hydrogen monochloride, potassium chloride, aluminum oxide, magnesium chloride, calcium sulfide, and methane

Homework #1 Answers are online at arbuiso.com click on BONDING page Write the correct formula for each of these compounds AND draw the Lewis Dot Diagrams (show proper bracketing and charges for ionic compounds)	
aluminum bromide ______________	potassium sulfide ______________
zinc iodide ______________	methane ______________
carbon dioxide ______________	titanium (IV) oxide ______________
copper (I) chloride ______________	Water ______________

If you have troubles, call or text Mr. Arbuiso at 607-727-3865

or email him at cbarbuiso@vestal.k12.ny.us

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diatomic fluorine	magnesium chloride	diatomic hydrogen
diatomic oxygen	water	aluminum oxide
hydrogen monochloride	potassium chloride	diatomic nitrogen
carbon dioxide	methane	calcium sulfide