Atoms, Elements, Compounds, and the Periodic Table

Atoms and Elements

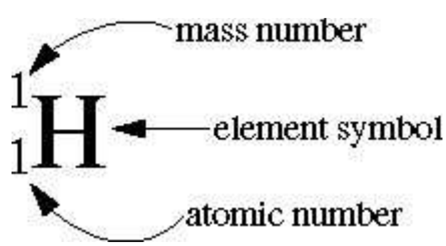
1. All matter is made of particles, which are constantly in motion.
2. The smallest indivisible particle is called the ATOM. An atom has a central, positively charged NUCLEUS which is surrounded by orbiting electrons.
3. Atoms are made up of three *sub-atomic particles*: protons, neutrons, and electrons

Fill in this chart (your text may be helpful):

Particle	Location	Charge	Mass	Symbol
Proton			1	p^+
Neutron			1	n^o
Electron			1/1860	e^-

4. The number of protons an atom has determines which ELEMENT it is. For example, an atom with 3 protons is lithium (Li). Which element has atoms with
   a. 7 protons ___________________
   b. 15 protons ___________________
   c. 99 protons ___________________

5. The number of protons in an atom is called the ATOMIC NUMBER of the atom.
6. The MASS NUMBER of an atom is the total number of protons + neutrons in the nucleus. (It is also known as the NUCLEON NUMBER). The symbol of an element is often given like this:



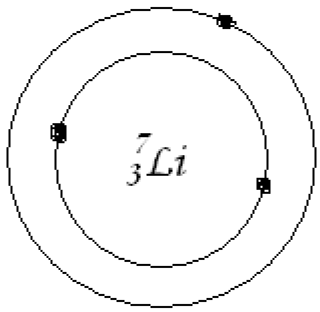
This is hydrogen. Hydrogen has 1 proton, no neutrons, and 1 electron.

7. How many protons, neutrons, and electrons do the following atoms have?

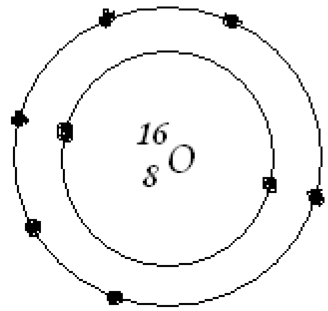
	$^{4}_{2}He$	$^{12}_{6}C$	$^{40}_{18}Ar$	$^{235}_{92}U$
# of p^+				
# of n^o				
# of e^-				

Atomic Structure

1. Electrons circle the nucleus in specific orbits called ENERGY LEVELS (or SHELLS).
2. The first energy level can hold only TWO electrons. Then it is full.
3. The second and third levels can hold EIGHT electrons before they are filled.
4. We can make Bohr diagrams (named after Niels Bohr, who figured a lot of this out) that show how electrons are arranged around the atom. Here are two examples.
    a. Lithium



    b. Oxygen



5. Now you try it! Draw Bohr diagrams for:
    a. Fluorine
    b. Chlorine
    c. Sodium
    d. Potassium

6. Did you notice that? How many electrons are there in the outer shell of both
    a. Fluorine and chlorine: ____________
    b. Sodium and potassium: ____________

    In fact, the outer shell is called the VALENCE SHELL – it contains the electrons that are involved in chemical reactions. These pairs of elements have the same number of valence electrons!

7. Because of this, elements that have the same electron arrangement in their valence shell also share similar physical and chemical properties. They belong to the same chemical FAMILY (or chemical GROUP). So, sodium and potassium belong to the same group (called the Alkali Metals), as do fluorine and chlorine (called the Halogens).

The Periodic Table

1. The Periodic Table of the Elements was developed in the mid-1800's by the Russian chemist Dmitri Mendeleev.
2. It lists all of the known elements horizontally (or, across) in order of their atomic number, and vertically (or, up and down) in order of the number of electrons in the valence shell.
3. For each element, the periodic table usually gives the atomic number, the symbol, the atomic mass, and the name of the element. The periodic table below only gives the atomic number and the symbol.

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	110 Unn								

58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

4. Let's fill in some more detail to the diagram above. You may need to look at a complete periodic table (like the one in the back of your homework diary) to help you.
   a. The vertical columns are called groups. Label groups 1 to 18.
   b. Use coloured pencil crayons to shade
      i. the metals *blue*
      ii. the transition metals *yellow*
      iii. the non-metals *red*
   c. Use arrows that point to and label the following groups:
      Alkali metals *Alkaline earth metals* *Halogens* *Noble gases*

5. You may have noticed that the last digit of the Group number is the same as the number of electrons in the valence shell. How many outer electrons does each atom have:
   a. F ___
   b. C ___
   c. Mg ___
   d. Be ___
   e. P ___

Ions

1. Atoms will gain or lose electrons until they have a full outer shell (like the Noble Gases). This makes them stable. ☺
2. When an atom has gained or lost an electron, it is no longer neutral. It has a charge because the number of protons is not the same as the number of electrons. Charged atoms are called IONS.
3. Metals have a weak hold on their outer electrons, so they tend to lose them and form positive ions, or CATIONS ('cat-ions', not 'kay-shuns').
4. Non-metals tend to gain electrons and form negative ions, or ANIONS.
5. The charge is determined by the following equation:

Charge	=	# of protons - # of electrons

Example:

Oxygen gains two electrons to fill its valence shell.

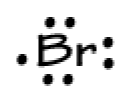
Charge = 8 protons - 10 electrons

= -2

6. Draw Bohr diagrams that show each of the following atoms gaining or losing electrons to have a full outer shell. State the charge on the ions.
   a. Lithium
   b. Fluorine
   c. Sulphur
   d. Magnesium

Note: A simpler type of drawing is called the **'Lewis Dot Diagram'**. It shows only the valence electrons. To draw Lewis diagrams, start by writing down the elements' symbol:

Then, starting at the top, place one dot for each electron, going around the element symbol clockwise and adding dots until you're out of valence electrons:

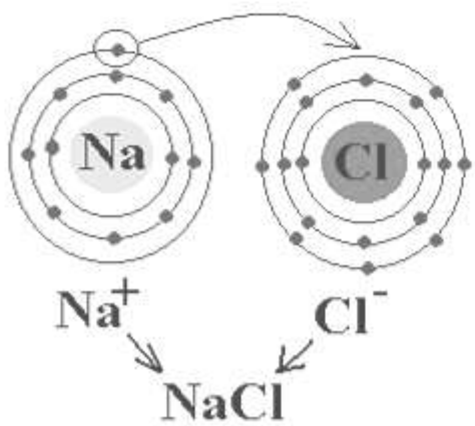


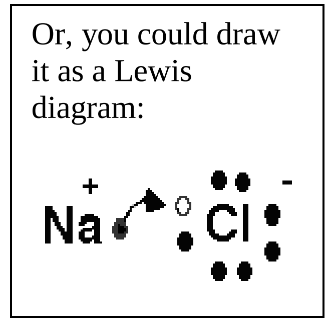
Here are a few more examples:

In the right margin, draw Lewis diagrams for atoms a to d.

Ionic Compounds

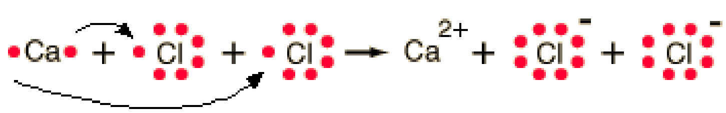
1. When a metal and a non-metal react, electrons are transferred from the metal to the non-metal so that each has a full outer shell. The resulting ions have opposite charges (one is positive, the other is negative), and *therefore they attract each other*.
2. The attraction force between oppositely charged ions is called an IONIC BOND. Here's a sketch that shows the process:





As you can see, the sodium cation is attracted to the chlorine anion, forming the IONIC COMPOUND sodium chloride, NaCl (this is *table salt*!).

3. When metals and non-metals react the electrons are transferred so that the elements achieve a full outer shell. In this case, one sodium atom is enough to satisfy one chlorine atom, so we end up with the neutral compound NaCl.
4. But if calcium reacts with chlorine, the situation is different: chlorine requires just one electron to form a stable ion, but calcium must get rid of *two* electrons. So it takes two chlorine atoms to satisfy one calcium, and the compound formed is calcium chloride, or $CaCl_2$. This can be shown using Lewis diagrams; arrows show electron movement:



5. Use Lewis diagrams to show ionic bonding and chemical formula for the compounds made when the following elements react:
   a. Li and Br
   b. Ca and O
   c. Al and P
   d. K and N

6. When naming ionic compounds, it is standard to write the metal ion first, followed by the non-metal ion. The name of a compound is therefore given as 'METAL NON-METALIDE'. For example: sodium chloride, magnesium oxide

7. List the standard names for the compounds you made in number 5 here:

Multi-valent Transition Metals in Ionic Compounds

Not all metals form ions by achieving a full outer shell of electrons. The transition metals follow different rules for forming stable ions, and many of them are capable of forming two or more stable ions of different charge (they are called 'multi-valent', since they can have more than one valence).

Example: Iron can lose two e^- to form the stable Fe^{2+} ion
Iron can also lose three e^- to form the stable Fe^{3+} ion

It's almost impossible to predict what the stable ions of the transition metals are, so you will always be told, in one way or another, which charge to use. So it is still possible to predict the compounds that can be formed by these metals.

Example: Fe^{2+} + O^{2-} → FeO (black powder)
Fe^{3+} + O^{2-} → Fe_2O_3 (rust)

Now we have a problem: what do we name these compounds? The name 'iron oxide' doesn't work, because they are two different compounds – they can't have the same name!

Chemists use the Stock system (named after Alfred Stock, who figured it out) to distinguish these compounds from each other. **A *Roman numeral* is used to indicate the ionic charge of the transition metal**:

FeO is iron (II) oxide (pronounced 'iron two oxide')
Fe_2O_3 is iron (III) oxide (pronounced 'iron three oxide')

Use the Stock system to name these compounds:

a. $CuCl_2$ ______________________________
b. $PbBr_4$ ______________________________
c. SnF_2 ______________________________
d. CoP ______________________________
e. Au_2S_3 ______________________________

Compound Ions

Some ions are made of groups of charged atoms. You should know their names, formulae, and charges.

Ion	NH_4^+	SO_4^{2-}	NO_3^-	CO_3^{2-}	HCO_3^-	OH^-
Name	Ammonium	Sulphate	Nitrate	Carbonate	Hydrogen Carbonate	Hydroxide
Charge	+1	-2	-1	-2	-1	-1

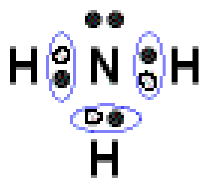
Molecular Compounds and the Covalent Bond

1. Non-metals can also combine to form compounds. However, non-metals don't like to give up electrons, so when they combine, they *share* electrons.
2. Non-metals will share pairs of electrons until they have 'filled' their outer shell, however, no ions are formed in this process.
3. Here's an example:

Nitrogen has 5 electrons and hydrogen has 1 e^- in the outer shell

Nitrogen wants another 3 to fill its outer shell and hydrogen wants another 1

So, if they share pairs of electrons like this, they can both be satisfied!



The compound formed is NH_3, which is also called ammonia.

4. When atoms share electrons, they become attached to each other. This attraction force is called a *covalent bond*. Covalent bonds are different from ionic bonds because
   a. No ions are formed.
   b. They are specific (the nitrogen is only attracted to the three hydrogens around it, not to any other hydrogens).
   c. A molecule is formed.

5. Many covalent compounds already have special names, like ammonia, water (H_2O), or methane (CH_4). If you don't know such a name, use the **prefix system.**
   a. Use the prefixes di- (2), tri- (3), tetra- (4), penta- (5), and hexa- (6) to indicate how many of an element is present. For example:
      i. H_2O would be 'dihydrogen oxide'
      ii. CH_4 would be 'carbon tetrahydride'
      iii. NI_3 is 'nitrogen triiodide'
      iv. N_2O is dinitrogen oxide
      v. CO_2 is carbon dioxide

6. Use Lewis Dot diagrams to show how the covalent compounds in #5 above are formed.