Atoms, Chemical Bonds and pH

Objectives:

1. At the end of the laboratory the student should be able to define these words and use them in appropriate context:

a. atom
b. acid
c. base
d. compound
e. covalent bond
f. element
g . electron
h . hydrogen bond
I. ion
j. ionic bond
k. isotope
l. molecule
m. nucleus
n . neutron
o. non-polar bond
p. orbital
q . polar bond
r. proton
s. pH

2. The student should be able to diagram an atom from the information given in the periodic table.
3. The student should be able to construct and draw simple molecules, with the appropriate number of bonds and three dimensional structure.
4. The student should be able to compare and contrast hydrogen, ionic and covalent bonds.
5. The student should be able to determine the acidity or alkalinity of a solution using the following materials: pHydrion paper, bromthymol blue, phenolphthalein, pH meter.
6. The student should be able to interpret pH in terms of H' . (hydrogen ion concentration)

Preface

The periodic table on the preceding page lists elements, which have been found occurring naturally or have been created. These are substances that differ from each other in their chemical and physical properties. They have been arranged in the table with respect to their properties.

An atom is the smallest unit of an element that has the chemical and physical properties of that element. The structure of an atom determines the way in which it will combine with other atoms. The typical atom contains particles known as protons, electrons and neutrons. The protons and neutrons are found in the nucleus or center of the atom. Each of these particles has a mass of one dalton or atomic mass unit, amu. Protons are positively charged while neutrons have a neutral charge.

Electrons have a mass of about 1/2000 dalton. The number of electrons in a neutral atom is equal to the number of protons, while the number of neutrons may vary giving rise to isotopes of the same element. Electrons spin in orbitals about the nucleus and move very quickly. Sometimes they have so much energy that they leave the atom. When they leave the atom the number of negative charges is reduced, thereby conferring a net positive charge on the atom. We now refer to it as an ion. If an atom loses electrons it becomes a positively charged ion, a cation. If an atom gains electrons it is referred to as an anion.

6 ←---- <u>atomic</u> number

C ←----- symbol

12.01 <----mass number

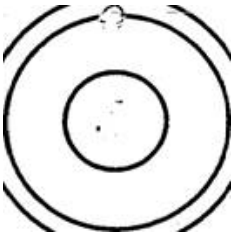
Note: The <u>atomic number,</u> will always be equal to the <u>number of protons.</u>

The <u>number of electrons</u> will equal the <u>number of protons</u> in a neutral atom. (The atom has a neutral charge.) But since electrons can be gained or lost, don't assume that the atomic number is the number of electrons. The <u>number of neutrons may vary,</u> giving different masses for the same element. These atoms with different masses will be Isotopes.

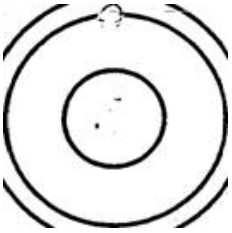
Diagram the following atoms using the Bohr model. In the Bohr model, the neutrons and protons are found in the nucleus while the electrons are placed in energy levels about the nucleus.

Place the electrons around the nucleus. Using the Bohr model, electrons are placed in energy levels around the nucleus. The level closest to the nucleus is the 1st energy level which can hold a maximum of two electrons. The next energy level is the L shell which can hold 8 electrons and the 3rd energy level which can hold 18 electrons. Other shells follow but we will largely concern ourselves with these first few shells. Diagram the following atoms. Carbon has been done for you.

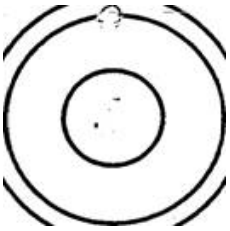
Diagram the following atoms; placing protons, neutrons and electrons in the model.



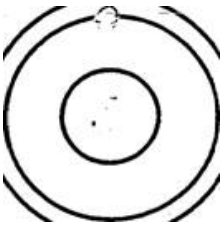
C



H

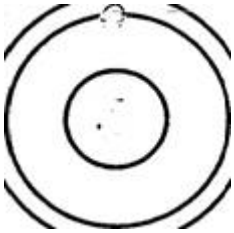


O

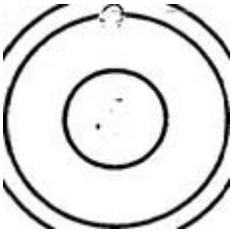


N

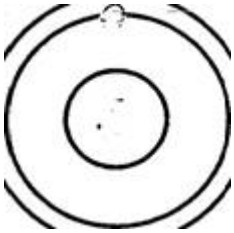
Three isotopes of carbon exist C-12, C-13, C-14. Diagram each of these using the Bohr model.



C-12



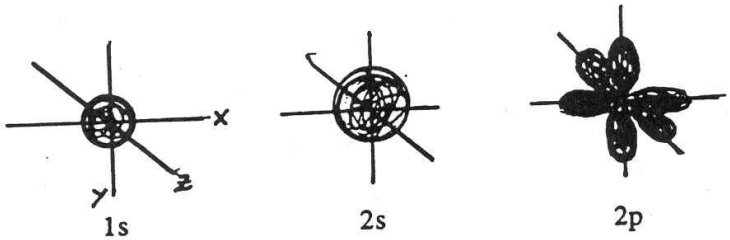
C-13



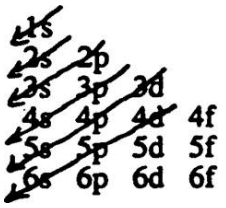
C-14

Orbitals

The energy shells themselves can be divided into orbitals. Each orbital can hold a maximum of 2 electrons. The lowest energy orbital is the 1s. This is the 1st shell. Here, we find two electrons in a spherical pattern spinning about the nucleus. The 2nd shell has two kinds of orbitals: 2s and 2p. While the 2s orbital is still spherical it is larger than the 1s. The 2p orbitals are dumbbell shaped and intersect on three axis in space. There are three of the 2p orbitals. Note the diagram.



Electrons fill their orbitals according to the following diagram.



Ionic Bonds: bonds of attraction between oppositely charged atoms or groups of atoms
The element sodium has an atomic number of 11 and a mass of 23 daltons. If we were to diagram it we would find that there was one electron in the 3rd energy level. A rule *known* as the octet rule suggests that atoms behave in certain ways in order to have a full outer shell of electrons, usually eight. If sodium loses its electron to another atom it will then have 11 positive charges and 10 negative charges giving it a net charge of +1. The sodium atom is charged and is now called an ion.

Complete the chart giving the correct number of protons, electrons and neutrons in the particle.

Particle	Protons	Electrons	Neutrons
Ca atom			
Ca++			
Na atom			
Na+			
K atom			
K+			
Cl atom			
Cl-			

Covalent bonds: bonds that are formed when two atoms <u>share</u> electrons with each other. The bonding capacity is determined by the arrangement of electrons and the need to complete their valence shell or energy level. A covalent bond is represented by a solid line connecting two atoms. If two atoms have the same electronegativity (tendency of an atom to pull electrons to it) then the shared electrons will be equally distributed about, the molecule. The difference in electronegativity (Table 1) of the two atoms is zero and a nonpolar bond results. This would be found in a molecule of H_2.

H-H A molecule of hydrogen.

A polar bond is the result when two atoms are sharing electrons and they have different electronegativities, such as hydrogen and oxygen. The shared electrons between the hydrogen and the oxygen are pulled more strongly toward the oxygen, which results in an unequal distribution of the electron cloud making the oxygen of the molecule more negative and the hydrogen atom more positive. The symbol or partial charge is ___ .

```
   O
  / \
H     H
```

H_2O is the water molecule.

Hydrogen bonds: a weak chemical bond that is formed when the small positive charge of a hydrogen atom in a polar covalent bond of one molecule is attracted to a negative atom involved in a polar covalent bond in another molecule. While hydrogen bonds are relatively weak bonds, they can stabilize a larger molecule if they are numerous. The hydrogen bond is directly responsible for many of the characteristics of water.
Note: hydrogen bonds are depicted variably in different sources, some texts. Some texts use broken. or dotted lines to show hydrogen bonding.

Atoms and Bonding Capacity

Determination of the bonding capacity of the atom can done by examining the structure of the atom,

focusing on the valence electrons. Using the information in the chart below, you should be able to build models of common molecules.

Carbon	C	4	- or -C=
Nitrogen	N	3	-N- or -N=
Hydrogen	H	1	H
Oxygen	0	2	-0- or O=

When constructing the molecules, follow these rules:

1. Attach the carbons to each other in a chain or ring.

2. Then add the nitrogen if needed.

3. Add oxygen atoms to the structure.

4. Fill in available bonds with hydrogen.

If all the atoms are used and nonbonding electrons still exist, use flexible double bonds.

Construct the following molecules, give the structural formula and draw them:

1. Hydrogen (molecular) H_2

2. Water H_2O

3. Methane CH_4

4. Ethane C_2H_6

5. Ethyl Alcohol C_2H_5OH

6. Glucose $C_6H_{12}O_6$

Acids and bases: An acid is a substance that releases H' in aqueous solution while a base is defined as a substance that removes W from

solution. Acidity and alkalinity are measured on a scale referred to as the pH scale. Most materials have a pH between 1 and 14 with 1 being the most acidic and 14 the most basic, while 7 is neutral.

Note: acids and bases must be handled carefully. Spills are to be cleaned immediately and contact with skin is to be avoided.

$[H+]\,[OH-] = 10^{-14}$, If the concentration of either ion is known, the concentration of the other can be calculated.

pH = - log [H+] (pH is equal to the reciprocal of the log of the concentration of hydrogen ions.)
f the concentration of H+ is .001 moles/liter or 1/1000 m/l. = 10-^{3} m/l. then the reciprocal of the log of 10^{-3} is equal to 3. If the concentration of ions is given as 10 to some exponent, then simply negate the exponent (multiply by a negative) and that number will be the pH.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

increasingly acidic ←---------- neutral----------→increasingly basic

pH Meter: The pH meter measures the hydrogen ion concentration of materials being tested. Note that standardized solutions are necessary to calibrate the machine. It is important that one carefully follow directions for the use of the pH meter.
Use of the pH meter-if there

(1) Switch dial to pH, lower electrodes into buffer. (2) Adjust temperature knob to temperature of buffer. (3) Calibrate so that the meter reads pH of *buffer.* (4) Raise electrodes, rinse with distilled water. (5) Lower electrodes into unknown solutions. Meter will read pH. (6) Raise and rinse electrodes, repeat for each unknown. (7) Switch to standby. (8) Store electrodes in buffer of 7 or lower. .

Approximate the pH of the solution and the concentration of H' in each solution that your instructor selects.

Solution	pHydrion Paper	Bromthymol Blue	Phenophthalein	Methyl Orange	PH meter (battery dead probably)
1					
2					
3					
4					
5					
6					

Questions 1. Compare and contrast covalent, ionic and hydrogen bonds.

2. What information can you gather from the periodic table?

3. What information is required in order that you are able to diagram an atom?

4. If the pH of a solution is 4 is it acidic or basic?

VALENCIA COMMUNITY COLLEGE CHEMISTRY TABLES

PERIODIC TABLE OF THE ELEMENTS

Period	Group IA (1)	IIA(2)	IIIB(3)	IVB(4)	VB(5)	VIB(6)	VIIB(7)	VIII (8)	VIII (9)	VIII (10)	IB(11)	IIB(12)	IIIA(13)	IVA(14)	VA(15)	VIA(16)	VIIA(17)	Noble Gases (18)
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.7	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57* La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra 226.0	89** Ac (227)	104 Unq (261)	105 Unp (262)	106 Unh (263)	107 Uns (262)	108 Uno (265)	109 Une (266)									

* Lanthanide Series 6	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
** Actinide Series 7	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

ELECTRONEGATIVITY

(After L. Pauling)

H 2.1																		He
Li 1.0	Be 1.5												B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne
Na 0.9	Mg 1.2												Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.5	Mn 1.8	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr	
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 2.4	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe	
Cs 0.7	Ba 0.9	La 1.1	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2	Rn	