Chemistry Ch. 2 Notes – MATTER IS MADE UP OF ATOMS

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics.*

~~~~~~~~~~~~~~~~~~~~ ATOMS AND THEIR STRUCTURE ~~~~~~~~~~~~~~~~~~

I. Early Ideas About Matter

A. **atom**—*the smallest particle of an element retaining the properties of that element*

B. early theories and ideas, pro and con

1) Democritus of Abdera (460-370 B.C.): first atomic theory of matter
   "atoma" / "atomos"—indivisible, indestructible particles in matter
2) Aristotle (384-322 B.C.): did not believe in atoms
   a) "hyle"— continuous state of all matter
   b) His theory was widely accepted until the 17th century!
3) Sir Isaac Newton (1642-1727) worked without proof to support atomic theory (Laws of physics, gravitation....)
4) Robert Boyle (1627-1691) also worked to support atomic theory (gas laws, structured the scientific method, a founder of chem.)
5) Antoine Lavoisier (1743-1794) – "father of Modern Chemistry"
6) **atomic theory**—matter is made up of atoms

C. Atomic Model Development

1) John Dalton (1766-1844); his model (pub.1807) stated that atoms are indivisible
2) J.J. Thomson; (1856-1940); work begun in 1897
   a) adapted model with subatomic particles: protons and electrons
   b) *"plum pudding" model—electrons stuck in a proton lump*
3) E. Rutherford (1871-1937); model in 1911
   a) *nucleus as the dense center with p^+ and n^0; e^- outside it*
   b) the atom is mostly space (gold foil experiment)
4) Niels Bohr (1885-1962); model proposed in 1913
   a) *nucleus as the center, composed of p^+ and n^0*
   b) *e- orbit the nucleus; similar to planetary motion*
   c) e^- in an orbit have a fixed energy level
   d) lowest energy levels are closest to the nucleus
   e) *quantum*—a bundle of energy needed to make an electron "jump" to a higher level, which is a *quantum leap*
5) quantum mechanical model
   a) Erwin Schrödinger (1887-1961); model proposed 1926
   b) based on probability of e^- location, not exact path
   c) **electron cloud model**; "boundary surface diagram"

II. Development of the Modern Atomic Theory

A. Joseph Proust's (1754–1826) contribution:

1) **Law of Definite Proportions**—*in any compound, the masses of the element are always in the same proportions*
2) example: $C_{12}H_{22}O_{11}$ always has 12 C, 22 H, and 11 O

B. Dalton's atomic theory

"Father of Atomic Theory" – John Dalton (1766-1844)
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DALTON'S ATOMIC THEORY

1) All elements are composed of submicroscopic, indivisible particles called atoms. (He didn't know about subatomic particles and how to split an atom.)
2) Atoms of the same element are identical. (Not really true, as we'll see later.) Atoms of different elements are different.
3) Atoms of elements can physically mix or form compounds by chemically combining in whole-number ratios. (Law of Multiple Proportions)
4) Chemical reactions involve the separation, joining, or rearranging of atoms. Atoms of an element are never changed into atoms of another element in a chemical reaction. (He didn't know about nuclear reactions.)

C. Atomic theory, conservation of matter, and recycling
   1) natural cycles: nitrogen, carbon, phosphorus, sulfur, water (see http://www.kwanga.net/apesnotes/summary-of-biogeochem-cycles-notes.pdf for more)
   2) Laws of Conservation of Mass and Energy apply

D. Hypotheses, theories, and laws – the scientific method
   1) the *scientific method*
      a) a *systematic plan for testing ideas*
      b) *an organized way to solve problems*
      c) *Science is a process of learning*
      d) We can never witness all natural events, so we observe what we can.
   2) experimental and control setups
      a) *experiment—a controlled test of a hypothesis*
      b) *experimental setup—the variable being tested is present*
      c) *control setup: the variable being tested is absent*
   3) *variables*
      a) *anything affecting the outcome of the experiment*
      b) examples: temperature, air quality, amount of light, humidity
      c) *only one can be tested at a time for the experiment to be valid*
      d) *independent variable*
         - *changed by the experimenter*
         - abscissa: x axis
      e) *dependent variable*
         - *changes based on what the independent variable does*
         - ordinate: y axis
   4) *hypothesis*
      a) *educated guess; testable prediction*
      b) can be accepted or rejected
      c) many are made initially; most likely ones are chosen
      d) "What if?" experiments have no hypothesis
   5) *observation—recording of information*
      a) *direct observation—made with the senses* (sight, sound, smell, touch, hearing) "It is hot in here."
      b) *indirect observation—made with measuring instruments* (thermometers, rulers, scales, clocks, etc.) "It is 83° in the room."
      c) Observations are followed by posing questions.
   6) *data*
      a) *verbal (words) or numerical (numbers) information*
      b) descriptive research contains verbal data

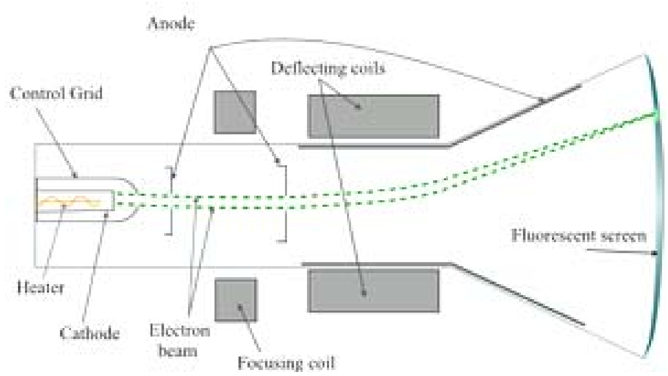
        c) data handling must be accurate
        d) graphs, tables, charts, etc.
    7) *research*
        a) review the existing literature
        b) experimental results are shared with other scientists
        c) repeat experiments to see if results are consistent
    8) **<u>theory</u>**
        a) *repeatedly and thoroughly tested and supported explanation*
        b) *long description which tells why*
        c) *can never be proven*

The layman's definition of theory is incorrect! ("I have a theory why he isn't talking to me.") Theories are not guesses, nor are they wild ideas. Real theories have substantial scientific evidence behind them.

    9) **<u>scientific law</u>**
        a) *concise statement which tells what*
        b) *can be proven*

III. The Discovery of Atomic Structure: subatomic particles

A. **<u>electrons</u>** (e^-)— negatively charged subatomic particles
    1) characteristics
        a) *fixed charge of -1*
        b) very light mass (9.11×10^{-28} g)
        c) orbit the center
    2) Sir Joseph John Thomson (1856-1940) discovered e^- by CRT experiments
        a) *CRT (cathode ray tube)*—a closed glass tube with metal electrodes at the ends, containing low-density gases at low pressure, subjected to high voltage.



        b) *cathode ray— glowing light beam* arising from the cathode (-) and traveling to the anode (+); *composed of electrons*
    3) Robert Millikan (1868-1953) – oil drop experiments on e^- charge & mass

B. **<u>protons</u>** *(p+)— positively charged subatomic particles*
(a hydrogen atom stripped of its electron is a "raw proton")
    1) characteristics
        a) *fixed charge of +1*
        b) same mass as a neutron (1.67×10^{-24} g)

c) located in the center of an atom

2) canal rays—positive CRT beam attracted to the cathode (found by Eugene Goldstein 1850-1930)

D. *neutrons (n^0)— neutral subatomic particles*

1) characteristics

a) *fixed charge of 0*

b) same mass as a proton (1.67×10^{-24} g)

c) located in the nucleus

2) Sir James Chadwick (1891-1974) discovered the neutron

E. other subatomic particles—(hundreds)

leptons: muon, tau, neutrino & *baryons,* composed of quark triplets & *mesons* etc.

1) Rutherford's gold foil experiment

a) Ernest Rutherford (1871-1937)

b) shot a stream of alpha (α) particles at a sheet of gold foil

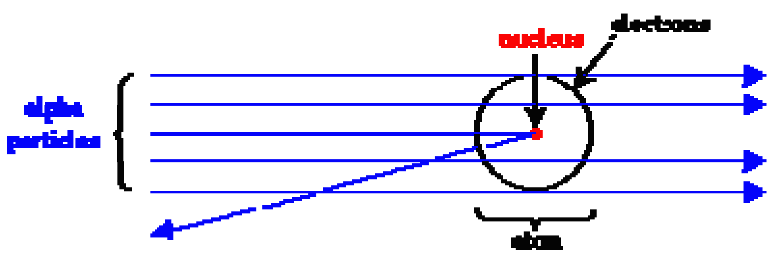
c) most of the particles went straight through (because the atoms are mostly empty space)

d) a few particles were deflected (those that grazed a nucleus)

e) even (~1/8000) fewer bounced directly back (those that hit a nucleus head-on)

THE ATOM IS MOSTLY EMPTY SPACE! *If an atom were the size of an average professional football stadium, the nucleus would be the size of a marble.*

From www.visionlearning.com:



2) the nuclear model of the atom

a) **nucleus**—*central core of an atom containing p^+ and n^0*

b) very dense as compared to the rest of the atom

c) the nucleus has an overall positive charge

IV. Atomic numbers and masses

A. **atomic number**—*number of protons in the nucleus of an atom*

1) characteristics

a) the atomic number is the unique I.D. number of an element

b) each element only has one atomic number

2) examples

E1) What is the atomic number of the following elements?

O (8) I (53) Cl (17) Au (79)

B. *atomic neutrality*

1) *atoms are electrically neutral*

number of protons = number of electrons in an atom

2) examples

E2) How many electrons does Cu have? (29)

E3) How many electrons does Rn have? (86)

C. **<u>mass number</u>**

MASS NUMBER = PROTONS + NEUTRONS
 # OF NEUTRONS = MASS NUMBER - ATOMIC NUMBER

1) symbols can be written two ways:

mass number / SYMBOL / atomic number: $^{12}_{6}C$	SYMBOL–mass number: C-12

2) *mass number is the total mass of the nucleus*

3) Mass number is *not* the decimal number on the periodic table! (that's atomic mass)

4) examples

E4) How many p^+, n^0 and e^- are in an atom of S-34?

S = sulfur, which is #16. S has **16 p^+** and because # p^+ = # e^-, S has **16 e^-**.
Mass number = 34. # n^0 = mass # - atomic # = 34-16 = **18 n^0**.

E5) How many p^+, n^0 and e^- are in an atom of $^{41}_{19}K$?

K = potassium, which is #19. K has **19 p^+** and because # p^+ = # e^-, K has **19 e^-**.
Mass number = 41. # n^0 = mass # - atomic # = 41-19 = **22 n^0**.

D. **<u>Isotopes</u>**—*atoms of the same element that contain different numbers of neutrons*

1) same number of p+
2) different mass numbers
3) different atomic masses
4) in nature, most elements occur as a mix of two or more isotopes
5) examples:

ISOTOPE	MASS #	ATOMIC #	p^+	n^0	e^-
O-16	16	8	8	8	8
O-17	17	8	8	9	8
O-18	18	8	8	10	8

Remember, # n^0 = mass number - atomic number.

E. **<u>atomic mass</u>**—*a weighted average based on mass and relative abundance of all naturally occurring isotopes of an element*

ATOMIC MASS =
(MASS x RELATIVE ABUNDANCE) of natural isotope #1 +
(MASS x RELATIVE ABUNDANCE) of natural isotope #2 +
(MASS x RELATIVE ABUNDANCE) of natural isotope #3 … etc.

1) unit is amu = atomic mass unit
2) synthetic isotopes (made in lab, not found in nature) are not considered
3) example

Magnesium has three isotopes: Mg-24, Mg-25, and Mg-26:

ISOTOPE	ABUNDANCE	ATOMIC MASS
Mg-24	78.70%	23.985
Mg-25	10.13%	24.986
Mg-26	11.17%	25.983

The atomic mass of Mg:
ATOMIC MASS = (MASS x RELATIVE ABUNDANCE)
(23.985)(0.7870) + (24.986)(0.1013) + (25.983)(0.1117) = **24.31 amu**

~~~~~~~~~~~~~~~~~~~~~~~ ELECTRONS IN ATOMS ~~~~~~~~~~~~~~~~~~~~~~

V. Electrons in motion

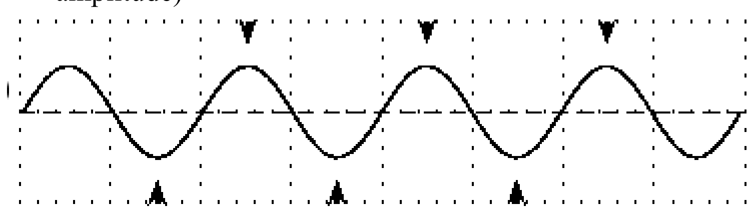
A. electron motion and energy: electrons are kept in motion so they don't fall into the positively-charged nucleus

B. see Bohr model in section I, #4

VI. The electromagnetic spectrum

A. waves transfer energy: wave anatomy

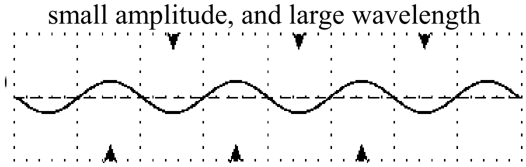
1) *origin,* zero line, base line—flat line running horizontally, cutting the wave in two; line of zero movement
2) *crest* ("peak")
3) *trough* ("valley")
4) *amplitude*—vertical distance from the origin to the crest, or from the origin to the trough
5) *wavelength* (λ)—horizontal distance between two equivalent points on a wave, such as between two crests or two troughs
6) *wave height*—vertical distance from crest level to trough level; (2 x amplitude)



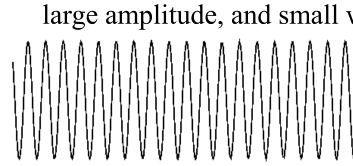
B. *frequency* (symbol: ν, lowercase Greek letter nu… *not* a regular v)

1) the number of cycles per unit time
2) measured in Hertz (Hz)—cycles per second, cps, 1/sec, or sec^{-1}

Slow wave with low energy, low frequency, small amplitude, and large wavelength



Fast wave with high energy, high frequency, large amplitude, and small wavelength



C. *WAVE-PARTICLE DUALITY OF NATURE:*

waves can act as particles AND particles can act as waves
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D. ELECTROMAGNETIC (em) SPECTRUM—broad radiation spectrum

(low energy)

1) **RADIO WAVES**
2) **MICROWAVES**
3) **INFRARED (IR) RADIATION**
4) **VISIBLE LIGHT** **"ROYGBIV": red, orange, yellow, green, blue, indigo, violet**
5) **ULTRAVIOLET (uv)**
6) **X-RAYS**
7) **GAMMA RAYS**

(high energy)

VII. Electrons and Light

A. **<u>emission spectrum</u>**—*array of colors from a heated element, separated by a prism*

B. evidence for **<u>energy levels</u>**: explanation of atomic spectra

1) **ground state**—electron(s) at their lowest possible energy level
2) *excited state*
   a) electron(s) at higher energy than normal
   b) electrons absorb energy and jump to higher levels where there is room

C. Bohr model of the atom—flat, with electron "rings"

D. *spectroscopy*—the study of substances exposed to continuous energy

1) *when exposed to intense energy, atoms absorb energy and become excited*
2) when atoms are in their excited state, their electrons jump to higher energy levels
3) *when the electrons eventually return to their normal (ground) state, energy is given off (emitted)*

VIII. The **<u>Electron Cloud Model</u>**

A. see quantum mechanical model in section I, #5

B. the quantum concept: Max Planck (1858-1947)

1) energy is given off in *packets* or *bundles* called *quanta* (singular, *quantum*)
2) What happens to energy as substances are heated? Planck tried to explain atomic spectra with equations.

B. electrons in energy levels

1) **<u>valence electrons</u>**—the *electrons in the highest energy level* of at atom
2) *for Group A elements, valence number = group number*

3) Electron dot structures (**<u>Lewis dot diagrams</u>**)—diagrams of valence electrons as *dots around the symbol of the element*

1) *only the valence electrons* are shown
2) used to see the numbers of shared and unshared electron pairs around an atom
3) number of unpaired electrons can show how many bonds can form
4) procedure (NOTE: this is a different system from the book)

a) write the symbol of the element
b) imagine four rectangles framing the symbol
c) place dots around the symbol according to the number of valence electrons

There are a few different methods of placing the dots, but we will use this way…
A common way to place the dots follows the saying ***"right, left, up, down, top all the way around."***

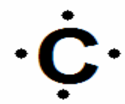
	3 5	
2 6	SYMBOL	1 8
	4 7	

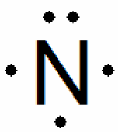
5) exception to the procedure is helium **He:**
6) examples:

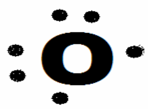

Group IA


Group IIA

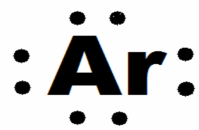

Group IIIA


Group IVA


Group VA


Group VIA


Group VIIA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