Lecture Notes: Atomic and Molecular Structure

Wallace D. Derricotte

Morehouse College Fall 2017

Early Experimental Insights Into Atomic Structure

John Dalton's Atomic Theory (1808):

- 1. All matter is composed of atoms. Atoms are indivisible and indestructible
- 2. All atoms of a given element are identical in mass and properties.
- 3. Compounds are formed by a combination of two or more different kinds of atoms.
- 4. A chemical reaction is a rearrangement of atoms, i.e. a change in the way they are bound together. The atoms themselves are not changed.



Figure 1: John Dal
Voltage Source

ton (1766-1844)

b) Applied Voltage

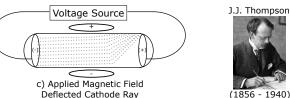


Figure 2: Schematic representation of J.J. Thomson's cathode ray tube experiment. a) The bare cathode ray tube is pictured with a negatively and positively charged metal plate at each end. b) A voltage bias is applied to the tube which causes an electrical current to flow through the system from the negative to the positive plate. c) A magnetic field is applied to the system causing the current to bend toward the positive plate.

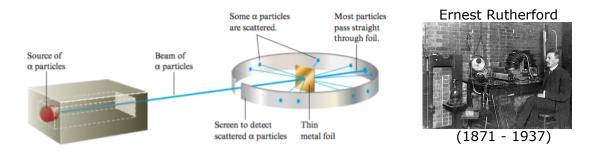


Figure 3: Schematic representation of Ernest Rutherford's experiment involving the bombardment of gold foil with α -particles.

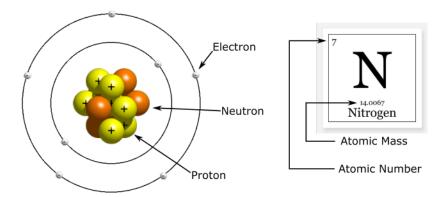


Figure 4: Schematic of electronic structure. The nucleus is composed of positively charged particles called **protons** and neutral particles called **netrons**. The atom itself has a neutral overall charge that is balanced by negatively charged particles called **electrons**. The amount of subatomic particles determines the identity of the element which can be determined from its periodic table entry.

Atomic Structure: Isotopes and Ions

Problem 1: If the volume of a proton were similar to the volume of an electron, how will the densities of these two particles compare to each other?

- **Isotopes**: atoms with the same number of protons but a different number neutrons giving is a non-standard atomic mass
- Ions: an atom or group of atoms that have a net positive or negative charge

Problem 2: Write symbols for each of the following ions:

- a) 63 protons, 60 electrons, 88 neutrons
- b) 50 protons, 68 neutrons, 48 electrons
- c) 16 protons, 18 neutrons, 18 electrons
- d) 16 protons, 16 neutrons, 18 electrons

Molecules, Molecular Structure, and Bonding

- Molecule: a collection of atoms held together via chemical bonds
- Chemical Bond: the forces that hold atoms together
- Covalent Bond: chemical bonds that result from the sharing of electrons

Ammonia(NH₃) N: Ball-and-stick Model Model

Figure 5: Example of covalent bonding in the ammonia molecule (NH₃) the nitrogen and 3 hydrogen atoms explicitly share electrons in order to form this molecule. Two molecular models are shown for ammonia, the "ball and stick" model which most explicitly highlights the molecular geometry and orientation while the "space filling" model highlights the relative atomic sizes.

Fundamental Laws of Chemistry

- Law of Conservation of Mass: Mass is neither created nor destroyed in a chemical reaction.
- Law of Definite Proportion: A given compound always contains exactly the same proportion of elements by mass.
- Law of Multiple Proportions: When two elements form a series of compounds, the ratios of the masses of the second element that combine with 1g of the first element can always be reduced to small whole numbers.

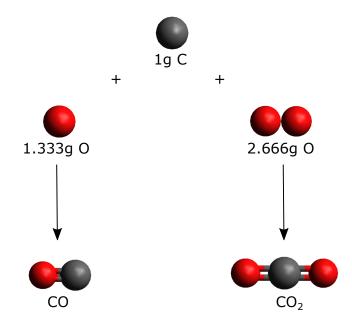


Figure 6: Illustration of the law of multiple proportions: Carbon can form a series of two different compounds with oxygen based on the ratio of the masses of oxygen with 1g of carbon.

Problem 1: The following data were collected for two compounds of phosphorus and chlorine:

	Mass of Chlorine That							
	Combines with 1 g of Phosphorus							
Compound A	3.432 g							
Compound B	$5.725 \mathrm{\ g}$							

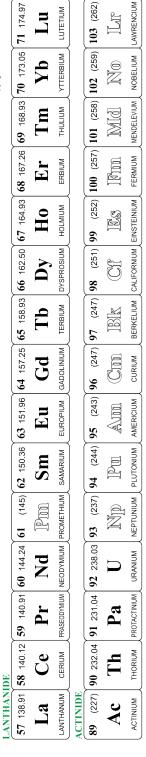
A Show that this experimental data follows the law of multiple proportions.

B If it is discovered that Compound A is PCl₃, propose a plausible formula for Compound B.

PERIODIC TABLE OF THE ELEMENTS

18 WIIIA

4.0026 Je).180	Ne		39.948	1	NO	3.798		NOT	31.29	ِ .	NO	(222)	u	NO	(294)	<u>n</u> d	NOSS
7	8 10 20.180	Z	NEON	18	Ar	ARGON	4 36 83.798	Kr	KRYPTON	0 54 131.29	Xe	XENON	98	Rn	RADON	() 118 (294)		E OGANESSON
17 WIII	9 18.998	<u></u>	FLUORINE	17 35.45	C	CHLORINE	35 79.904	Br	BROMINE	53 126.90	_	IODINE	85 (210)	At	ASTATINE	(117 (294)		TENNESSINE
91	1	0	OXYGEN	16 32.06	S	SULPHUR	34 78.971	Se	SELENIUM	52 127.60	Te	TELLURIUM	84 (209)	P_0	POLONIUM	116 (291)		LIVERMORIUM
	14.	Z	NITROGEN	15 30.974	Ь	PHOSPHORUS	33 74.922	As	ARSENIC	51 121.76	$\mathbf{S}\mathbf{p}$	ANTIMONY	83 208.98	Bi	BISMUTH	115 (289)	Me	MOSCOVIUM LIVERMORIUM
	12.011	C	CARBON	14 28.085	Si	SILICON	32 72.64	Ge	GERMANIUM	50 118.71 51 121.76	Sn	NIT	82 207.2	Pb	LEAD	114 (287)		FLEROVIUM
	10.81	B	BORON	13 26.982 1	A	ALUMINIUM	31 69.723	Сa	GALLIUM	49 114.82	In	INDIUM	81 204.38	Ξ	THALLIUM	113 (285) 1		NIHONIUM
	(r			1		()	30 65.38 3	Zn	ZINC	48 112.41	Cd	CADMIUM	80 200.59	Hg	MERCURY	112 (285) 1		
						1 8 1	29 63.546 3	Cn	COPPER	47 107.87	Ag	SILVER	79 196.97	Au	GOLD	111 (280) 11		ROENTGENIUM COPERNICIUM
CE		\$(1)				10	28 58.693 2	Z	NICKEL	46 106.42 4	Pd	PALLADIUM	78 195.08 7	Pt	PLATINUM	110 (281)		
GROUP NUMBERS CHEMICAL ABSTRACT SERVICE	(00	RELATIVE ATOMIC MASS (1)		IAME			27 58.933 2	င္	COBALT	45 102.91 4	Rh	RHODIUM P	77 192.22	Ir	IRIDIUM	109 (276)	MIG	MEITNERIUM DARMSTADTIUM
GROUP N EMICAL ABS	<u>(1)</u>	RELATIVE A		ELEMENT NAME		8	26 55.845 2	Fe	IRON	(98) 44 101.07 4	Ru	RUTHENIUM	76 190.23 7	S	OSMIUM	108 (277) 1		HASSIUM
l E		10.811	B	BORON			54.938	Mn	MANGANESE		2		186.21	Re	RHENIUM	07 (272) 1		BOHRIUM
ABERS ENDATION	13	IMBER — 5	SYMBOL			7	24 51.996 25	Cr	CHROMIUM	2 95.95 43	Mo	MOLYBDENUM TECHNETIUM	73 180.95 74 183.84 75	>	TUNGSTEN	06 (271) 1	50 V2	SEABORGIUM
GROUP NUMBERS IUPAC RECOMMENDATION	(5061)	ATOMIC NUMBER	S			9 9	23 50.942 2	>	VANADIUM	1 92.906	NP PP	NIOBIUM M	3 180.95 7	La	TANTALUM 1	05 (268) 1		DUBNIUM
I I I I I I I I I I I I I I I I I I I							22 47.867 2	Ë	TITANIUM	40 91.224 41 92.906 42	Zr	ZIRCONIUM	72 178.49	Hf	HAFNIUM	104 (267) 105 (268) 106 (271)		RUTHERFORDIUM
						4 all	21 44.956 2	Sc	SCANDIUM .	9 88.906 4	>	YTTRIUM Z	57-71	La-Lu	Lanthanide	89-103	Ac-Lr	Actinide RU
S	9.0122	Be	BERYLLIUM	12 24.305	Mg	MAGNESIUM 3	20 40.078 2	Ca	CALCIUM	37 85.468 38 87.62 39 88.906	${ m Sr}$	STRONTIUM .	56 137.33	Ba	BARIUM $\int L_{\ell}$	88 (226)	Ra	RADIUM ,
1.008 H HYDROGEN	6.94	ij	LITHIUM	11 22.990 T	Na	SODIUM M	19 39.098 20	×	POTASSIUM	7 85.468 3:	Rb	RUBIDIUM S	55 132.91 5	Cs	CAESIUM	(223)	Fr	FRANCIUM
EBIOD -	<u>_</u>	7		1	ю		<u> </u>	4	<u> </u>	(K)	v	<u>"</u>	35	9		87	۲	<u>"</u>



Copyright © 2017 Eni Generalić



(1) Atomic weights of the elements 2013, Pure Appl. Chem., **88**, 265-291 (2016)