Chapter 2

Atoms

Questions to be Answered

- What is an atom?
- What led to our current theory of an atom?
- What is an element?
- What information is stored in the periodic table?

It all started with matter

- The Greeks
  - Aristotle and Democritus
  - "atomos" – indivisible
- 3 Laws

Law of Mass Conservation

- Matter cannot be created or destroyed…
- … but it can be changed!

A student heats 1.00 g of a blue compound and obtains 0.64 g of a white compound and ? g of a colorless gas.

Law of Definite Composition

- No matter what its source, a particular compound is composed of the same elements in the same parts by mass.

A student heats 1.00 g of a blue compound and obtains 0.64 g of a white compound and 0.36 g of a colorless gas.

A second student heats 3.25 g of the same blue compound and obtains 2.08 g of the white compound and 1.17 g of the colorless gas.

Law of Multiple Proportions

- If elements A and B react to form two compounds, the different masses of B that combine with a fixed mass of A can be expressed as a ratio of small whole numbers

Multiple Proportions Example

- Carbon and oxygen can form carbon monoxide and carbon dioxide
- 24 g of oxygen and 36 g of carbon will form carbon dioxide.
- 28.8 g of oxygen and 21.6 g of carbon will form carbon monoxide.

Dalton's Atomic Theory

- Matter is made up of atoms which cannot be created or destroyed.
- Atoms of one element cannot be converted into atoms of another element.
- Atoms of one element are identical in mass and have the same properties. The mass and properties of atoms of one element are different from atoms of another element.
- Compounds form from atoms in specific ratios.

3 Key Experiments that Led to Nuclear Atom Model

- JJ Thomson: Cathode ray tube – electron mass:charge ratio

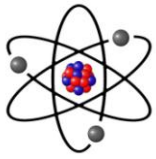
https://www.youtube.com/watch?v=O9Goyscbazk

- Millikan: Oil drop experiment – charge of electron

https://www.youtube.com/watch?v=XMfYHag7Liw

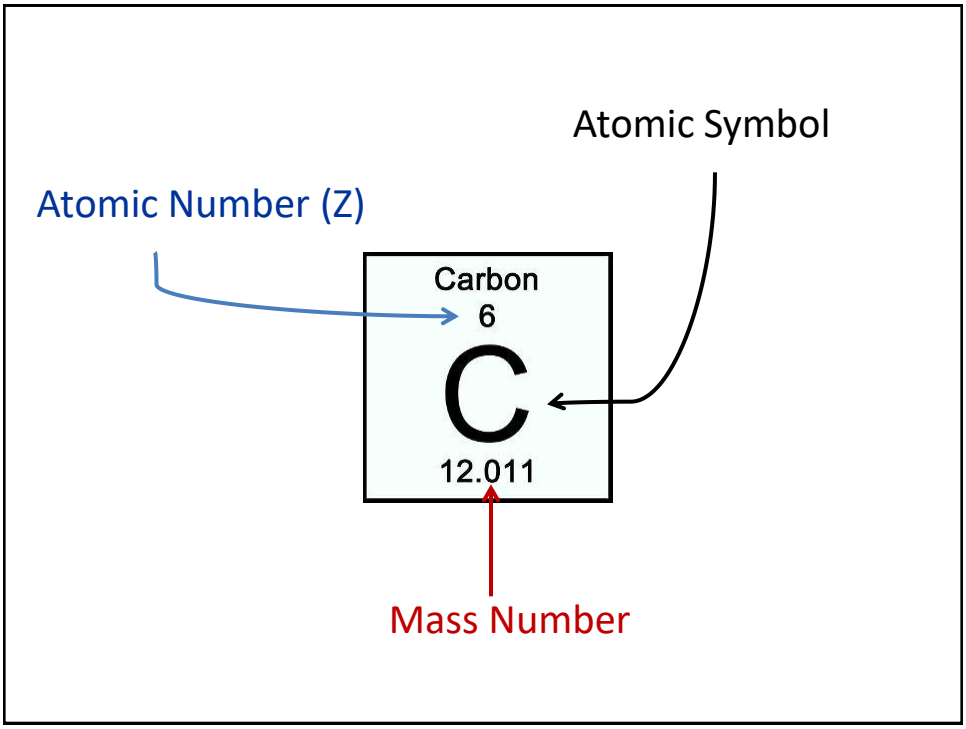
- Rutherford: Gold foil experiment – existence of nucleus, atom structure

https://www.youtube.com/watch?v=XBqHkraf8iE&t=107s



Atomic Theory

- Spherical sphere
- Electrically neutral with positive central nucleus surrounded by negative clouds
- Subatomic particles
  - Electrons – negatively charged, negligible mass
  - Protons – positively charged, significant mass
  - Neutrons – no charge, significant mass



Periodic Table

1																	18
1 H 1.008	2											13	14	15	16	17	2 He 4.0026
3 Li 6.94	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305	3	4	5	6	7	8	9	10	11	12	13 Al 26.982	14 Si 28.085	15 P 30.974	16 S 32.06	17 Cl 35.45	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.630	33 As 74.922	34 Se 78.97	35 Br 79.904	36 Kr 83.798
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.95	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71 *	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89-103 #	104 Rf (265)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (294)	118 Og (294)

* Lanthanide series	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
# Actinide series	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	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 (262)

How many p^+, e^- and n do the following elements have?

- C-13
- Indium-115 (In-115)

Question you MUST be able to answer!

Silver has two natural isotopes: ^{107}Ag, 106.90509 amu at 51.84% and ^{109}Ag, 108.90476 amu at 48.16%. What is the atomic mass of silver?

How were the atomic masses on the periodic table determined?

What are the units of mass for an atom?

The ***atomic mass unit*** (amu) is 1/12 the mass of the carbon-12 atom.

How is the mass of an atom measured experimentally?

Mass spectrometry

Silver has two natural isotopes: ^{107}Ag, 106.90509 amu at 51.84% and ^{109}Ag, 108.90476 amu at 48.16%. What is the atomic mass of silver?

Question you MUST be able to answer!

What is the chemical formula for the compound potassium oxide?

Potassium and Oxygen Form Compound!

How does this happen?

K (potassium)
- →metal
- →loses electrons
- →forms cation (positively charged)

O (oxygen)
- →nonmetal
- →gains electrons
- →forms anion (negatively charged)

Positive and negative charges must balance.

Charges on Ions

- Charge goes up 1 for every electron LOST
- Charge goes down (negative) 1 for every electron GAINED

- K – how many electrons will it lose?
- O – how many electrons will it gain?
- Balance the charges.

And why is it called potassium oxide?

Binary Ionic Compounds

Always name the cation first and the anion second.

- Name the cation using the name of the metal.
- Name the anion using the root of the nonmetal name and add the suffix *ide*.

Compounds with Metals that can Form More than One Ion

- Transition Metals, Sn (tin), Pb (lead)
- NOT Group 1 or 2

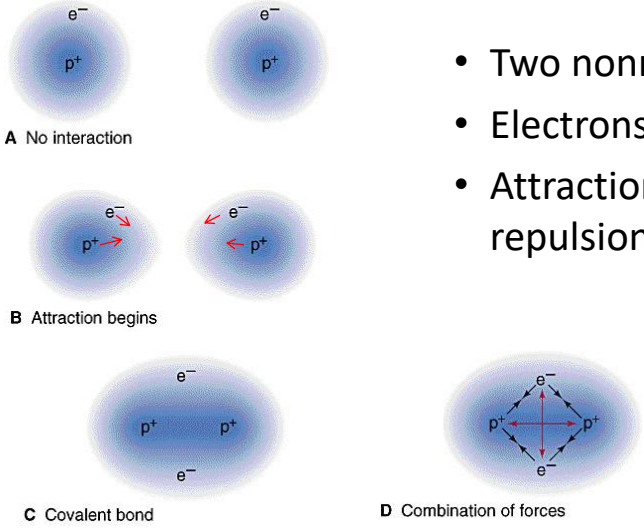
Naming compounds with these elements

- Insert a Roman numeral in parentheses immediately after the cation's name to indicate its ionic charge
- Older method of designation (-ous and –ic)

Question you MUST be able to answer

What is the name of the compound $NaNO_3$?

Covalent Bonds



- Two nonmetals
- Electrons shared
- Attraction = repulsion

Polyatomic Ions

- Polyatomic – many atoms covalently bound to each other
- Ions – having more or less electrons that the sum of the atoms

N2K: Polyatomic Ions

- NH_4^+ - ammonium
- CH_3COO^- - acetate
- CN^- - cyanide
- OH^- - hydroxide
- ClO^- - hypochlorite
- ClO_2^- - chlorite
- ClO_3^- - chlorate
- ClO_4^- - perchlorate
- NO_2^- - nitrate
- NO_3^- - nitrate
- MnO_4^- - permanganate
- CO_3^{2-} - carbonate
- CrO_4^{2-} - chromate
- $Cr_2O_7^{2-}$ - dichromate
- O_2^{2-} - peroxide
- PO_4^{3-} - phosphate
- SO_3^{2-} - sulfite
- SO_4^{2-} - sulfate

Families of Oxoanions

Many of the polyatomic ions are *oxoanions* – that is, an element, usually a nonmetal, is bonded to one or more oxygen atoms.

There are several families of oxoanions . . .

SO_3^{2-}, sulfite ion
SO_4^{2-}, sulfate ion

NO_2^-, nitrite ion
NO_3^-, nitrate ion

ClO^-, hypochlorite ion
ClO_2^-, chlorite ion
ClO_3^-, chlorate ion
ClO_4^-, perchlorate ion

What is the name of the compound $NaNO_3$?

Hydrated Ionic Compounds

- Water molecules associated with ionic compounds in a specific ratio

$MgSO_4 \bullet 7H_2O$

magnesium sulfate heptahydrate

$CuSO_4 \bullet 5H_2O$

Acid Names

- *Binary acid* solutions form when certain gaseous compounds (eg., halogen hydrides) dissolve in water.

  Hydro + *anion root* + ic acid

  HCl

- *Oxoacids* are formed from oxoanions, and are named similarly except for two suffix changes

  - *ate* in the anion becomes - *ic* in the acid
  - *ite* in the anion becomes – *ous* in the acid

  $HClO_4$

  HNO_2

Binary Covalent Compounds

Two elements – both nonmetals

1. The element with the lower group number in the periodic table is the first word in the name. *Exception* – when a compound contains oxygen and any halogen, the halogen always is named first.
2. If both elements are in the same group, the element with the higher period name (further down on periodic table) is named first.
3. The second element is named with its root and the suffix *– ide*.
4. Covalent compounds have Greek numerical prefixes to indicate the number of atoms of each element in the compound. The first word has a prefix only when more than one atom of that element is present.

Common names – NH_3 (ammonia); H_2O (water); CH_4 (methane)

CS_3 N_2O_4 $BrCl_3$

What is the molecular mass of water?

- Molecular mass = sum of masses of atoms in compound

  H_2O

  $Mg(NO_3)_2 \bullet 5H_2O$