Chapter 3: Atomic Structure

Scientists

- Democritus- Matter composed of atoms (indivisible) (~450B.C.)
- Lavoisier – conservation of mass
- Proust – law of constant composition
- Dalton – modern atomic theory (KNOW the 4 postulates)

Dalton’s Atomic Theory

- All matter is composed of atoms
- Atoms of different elements are different, atoms of the same element are identical
- Matter is conserved
- A given compound has the same elements in the same ratio

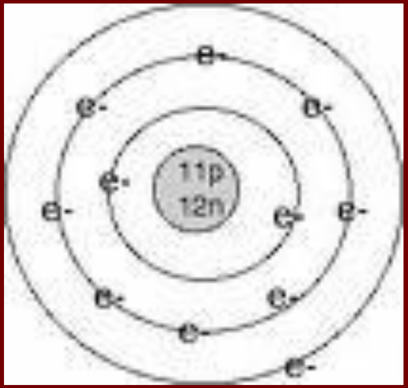
…more scientists

- Faraday – Atoms contain charged particles
- Thomson – atoms are divisible, he discovered electrons
- Millikan – found the charge and mass of electrons

…still more scientists

- Becquerel –discovered radioactivity
- Marie Curie – isolated radioactive elements.
- Rutherford – suggested the existence of the nucleus and neutrons

Rutherford



- Close to the modern atom
- Nucleus - central charge concentrated into a very small volume in comparison to the rest of the atom
- Electrons circling around the nucleus like planets around the sun.
- A lot of empty space

Modern Atomic Theory

- Atoms are composed of three fundamental particles
  - Protons (p^+)
  - Neutrons (n^o)
  - Electrons (e^-)

Modern atomic theory (continued)

- The nucleus is made of protons and neutrons…so it is positively charged
- Electrons orbit the nucleus in an electron cloud…this is negatively charged
- Overall the atom is **neutral**…
  - the $\#p^+ = \#\ e^-$

Particle	Location	Charge	Mass (g)	Mass (amu)
Proton	Inside Nucleus	+	1.673×10^{-24}	~ 1
Neutron	Inside Nucleus	0	1.675×10^{-24}	~1
Electron	Outside nucleus	-	9.109×10^{-28}	~0

Atomic Number

- Atoms identity comes from the number of protons in the nucleus
- In a chemical reaction, atoms gain/lose electrons and become an **ion**.
- Ion is a charged particle. This can be + or – depending on whether an electron is gained or lost.

Calculating charges and writing ions.

- If an electron is **gained**, the charge becomes **negative**.
- If an electron is **lost**, the charge becomes **positive**.
- Charge = # protons - # electrons
  - ❖ Ex. Magnesium

    Charge = #of protons - #of electrons

    2+ = 12 - 10

    Ion is written as **Mg^{+2}**

Isotopes

- **Isotopes** - atoms of the same element (same #p^+) but different number of neutrons.
- Most elements have isotopes.
- Isotopes of elements are almost indistinguishable (they exhibit the same properties)

Nuclear symbols … used to show number of p^+, n^0, and e^-

- Mass number = $p^+ + n^0$
- The mass number is used to differentiate between isotopes.
- Mass number → 37

(mass number)

$^{37}_{17}Cl$ or Cl - 37

- Atomic number→17

More Examples

Cl-35	C-12	C-14
$^{35}_{17}Cl$	$^{12}_{6}C$	$^{14}_{6}C$
p^+	p^+	p^+
n^0	n^0	n^0
e^-	e^-	e^-

Even MORE examples

Ions

56	16	27
Fe^{+2}	O^{2-}	Al^{+3}
26	8	13

p^+	p^+	p^+
n^0	n^0	n^0
e^-	e^-	e^-

Average Atomic Mass

- Atomic Mass (atomic weight) = average atomic mass of all existing isotopes
- Measured in amu’s
- AMU = atomic mass unit = 1/12 the weight of a carbon-12 atom

Calculation of average atomic mass

Weighted average of all existing isotopes

[(Percent abundance/100) * isotope mass]

[(Percent abundance/100) * isotope mass]

\+ <u>[(Percent abundance/100) * isotope mass]</u>

Average Atomic Mass

Lithium – 6 (7.42%) =[6 x (7.42/100)] = 0.4452

Lithium – 7 (92.58%)=[7 x (92.58/100)] = + <u>6.4806</u>

6.9258 amu

You try it!

Neon – 20 (90.92%)

Neon – 21 (0.26%)

Neon – 22 (8.82%)

[20*(90.92/100)] = 18.18

[21*(0.26/100)] = 0.055

[22*(8.82/100)] = + 1.94

20.18 amu

Changes in the nucleus

- Nuclear Reactions – Change the composition of the nucleus.
- Atoms undergo nuclear decay and produce new elements!

What governs nuclear stability?

- strong nuclear force
  - force which holds the nucleus together
- part of reason is the # of p^+ and # n^o
  - "belt of stability" – as atomic number increases, you need more neutrons to keep the atom stable

- All atoms with an atomic number greater than 83 are radioactive
- Radioactive isotopes spontaneously undergo radioactive decay

Radioactive Decay

- Release of radiation to become more stable

Types of radiation

- Alpha:
  - High-energy alpha particles
  - $2p^+$ and $2\ n^0$.
  - Weak…stopped by paper or clothing
  - Mass number 4
  - Symbol $^{4}_{2}\alpha$ or $^{4}_{2}He$

- **Beta:**
  - **High speed electrons**
  - **Mass number = 0**
  - **Can pass through clothing, some damage to skin**
  - **symbols** ${}^{0}_{-1}\beta$ **or** ${}^{0}_{-1}e$

- **Gamma:**
  - **Most dangerous**
  - **Consists of radiation waves**
  - **Only stopped by heavy dense material like lead/concrete**
  - **symbol** $^{0}_{0}\gamma$

Writing nuclear equations:

Mass Number

Chemical symbol

Atomic Number

- Example:

$^{14}_{6}C$

Alpha decay…

- When a nucleus emits an alpha particle, the mass decreases by 4 amu's and the atomic number decreases by 2 amu's.

$$^{226}_{88}\text{Ra} \rightarrow\ ^{222}_{86}\text{Rn} +\ ^{4}_{2}\alpha$$

Beta decay…

- When a nucleus emits a beta particle, the mass of the atom is practically unchanged, but the atomic number increases by one unit.

$$ {}^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\beta $$

Gamma decay…

- **When a nucleus emits a gamma ray, both the atomic number and atomic mass remain the same.**

$$^{113}_{49}\mathrm{In} \rightarrow\ ^{113}_{49}\mathrm{In} +\ ^{0}_{0}\gamma$$

Application of Nuclear Chemistry

- Use of half life + Radioactive Dating
- Nuclear Bombardment – Reactions
- Create radioactive isotopes used in medicine
- Power Generation
- Fission – Limerick Generating Plant
- Fusion – “research”

- **Radioisotope – an isotope that is radioactive.**
- **Half-life – The amount of time it takes for ½ of a sample of a radioactive isotope to decay. (1/2 of the radioactive atoms)**
- **Ex. Sr – 90 = 28.8 yrs**

Radiocarbon Dating

- uses carbon-14
- carbon-14 is radioactive
- half-life is 5370 yrs
- Produced naturally from reaction between N-14 and cosmic rays
- Living things…rate of production carbon-14 = rate of decay of carbon-14