CHEM 205 section 03

LECTURE #4 Tues., Jan.15, 2008

ASSIGNED READINGS:

TODAY'S CLASS: start Ch.2

NEXT CLASS: finish most of Ch.2

(1)

CHAPTER 2: ATOMS & ELEMENTS

2.1 Atomic Structure: e^-s, p^+s, n^os
2.2 Atomic Number & Atomic Mass
2.3 Isotopes
2.4 Atomic Weight
2.5 Atoms & the Mole
2.6 The Periodic Table
2.7 Overview: Elements, Chemistry & Periodic Table
2.8 Essential Elements

Chapter Goals:

- Describe the structure of the atom and define atomic number & mass number
- Understand the nature of isotopes and calculate atomic weight from isotope abundances & exact atomic masses
- Explain the concept of the mole and use molar mass in calculations
- Know the terminology of the periodic table

(2)

2.1 Development of Atomic Structure: p^+, n^0, e^-

John Dalton's 1803 "Atomic Theory" *(word atom: Democritus)*

1. All matter is made of atoms.
2. All atoms of an element are identical. ⟵ **Not exactly_true…**
3. A given compound always has the same relative numbers & types of atoms.
4. Chemical reactions involve the reorganization of atoms, but the atoms themselves are not changed. ⟵ **True…except for nuclear reactions!**

Marie Curie (1876-1934)

- Discovered one of the pieces of evidence for the fact that atoms are made of smaller particles

Radioactivity:
= the spontaneous disintegration of some elements…accompanied by emission of unusual "rays"

1911 Nobel Prize in Chemistry: Marie & Pierre Curie

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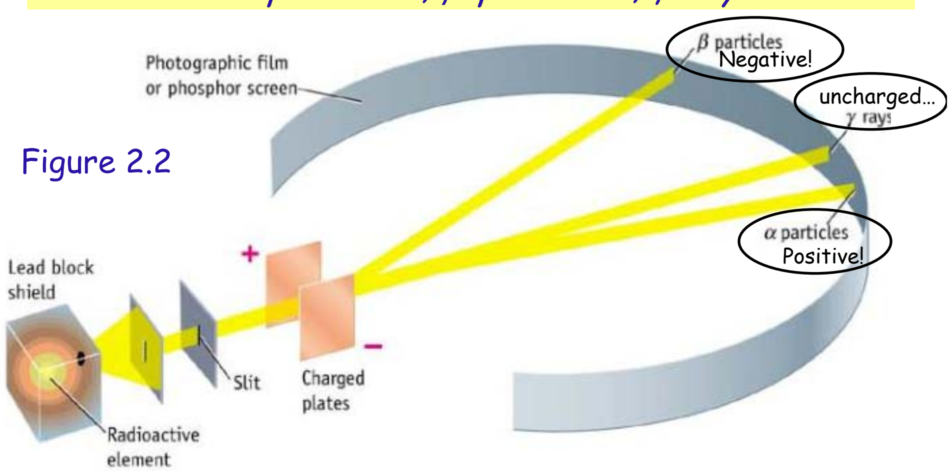
Radiation from radioactive elements: *α-particles, β-particles, γ-rays*

Figure 2.2



→ Atoms are NOT indivisible, since some can fall apart!
→ Understanding of atoms was growing…

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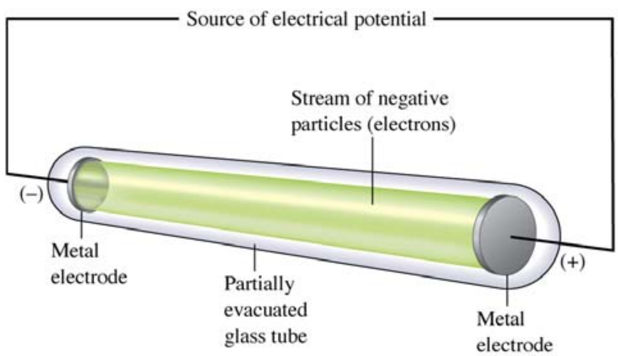
Characterizing the atom: early experiments (~ 1900)

1. J. J. Thomson (1856 – 1940) Nobel prize in Physics, 1906

- Proved the existence of the electron
- Experiments: to learn structure of the atom
  - Applied high voltage to a cathode ray tube



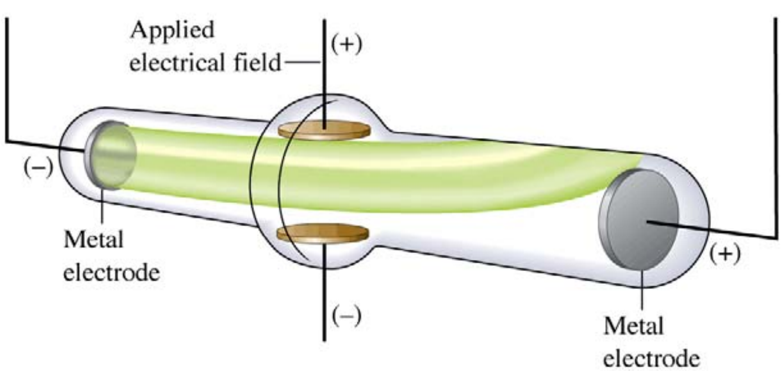
Voltage applied between electrodes:
⇒ high energy particles ejected from metal
⇒ transfer energy to gas
⇒ excited gas EMITS LIGHT
⇒ shows path of particle beam…

(5) Zumdahl's Figure 2.7 (see Kotz Fig. 2.3)

Thomson's expt to determine charge of particles

- Applied another voltage: across stream of particles
  ⇒ Particle stream bends towards POSITIVE

⇒ IMPLICATION: Particles must be **negatively** charged

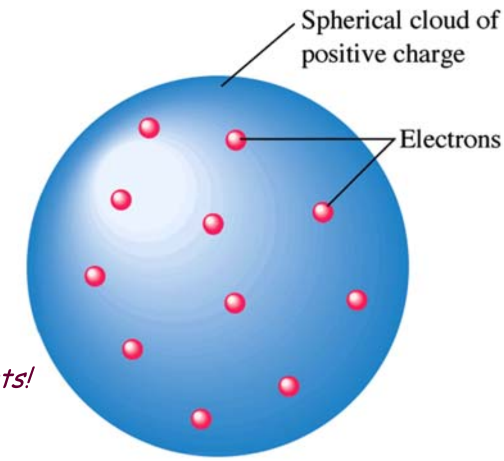


(6) Zumdahl's Figure 2.8 (see Kotz Fig. 2.3)

Thomson's hypothesis:

Electrons are present in all kinds of matter, in atoms of all elements…

Zumdahl's Figure 2.9: Thomson's "plum pudding" model of the atom.



Note: a preliminary model…

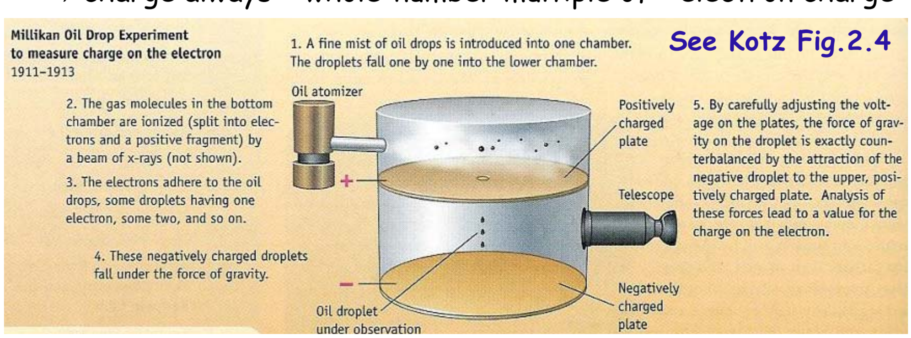
- *based on evidence available <u>from his experiments</u>*
- *did not account for protons*
- *instigated further experiments!*

(7)

Millikan's oil-drop experiment (1909)

to <u>quantify</u> the negative charge on the electron

- balance force of gravity by applying voltage ⇒ drops float
- measure mass of drop & voltage required to float
  ⇒ calculate charge on drop
  ⇒ charge always = whole-number multiple of "electron charge"



Charge on 1 electron = -1.60×10^{-19} Coulombs = "1 unit of negative charge"	Mass of 1 electron = 9.11×10^{-28} g

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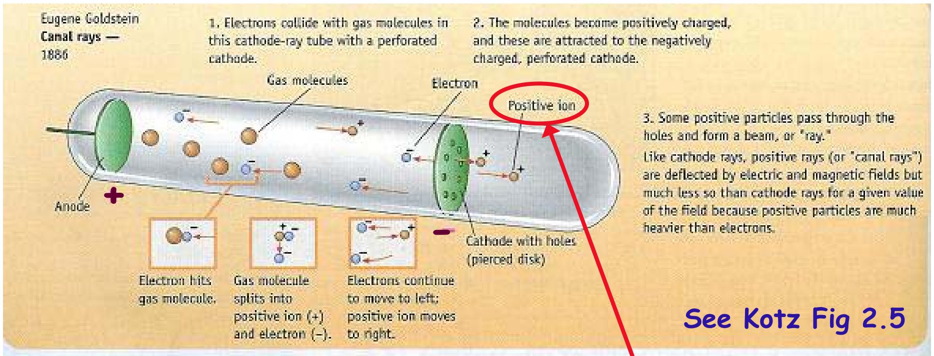
Characterizing the atom: early experiments (~ 1900)

3. Eugene Goldstein (1886) → protons



When hydrogen gas used: +ve particle with highest charge/mass ratio
⇨ a H atom stripped of electrons = a fundamental positive particle
"the proton"

(9) *Note: I use "+ve" as an abbreviation of "positive" on my slides (and similarly: "-ve")*

Characterizing the atom: early experiments (~ 1900)

1. J. J. Thomson (Nobel prize in Physics, 1906)
2. Robert Millikan (1909)

} **Electrons**

3. Eugene Goldstein (1886) } **Protons…but where?**

4. Ernest Rutherford

Nobel prize in Chemistry, 1908

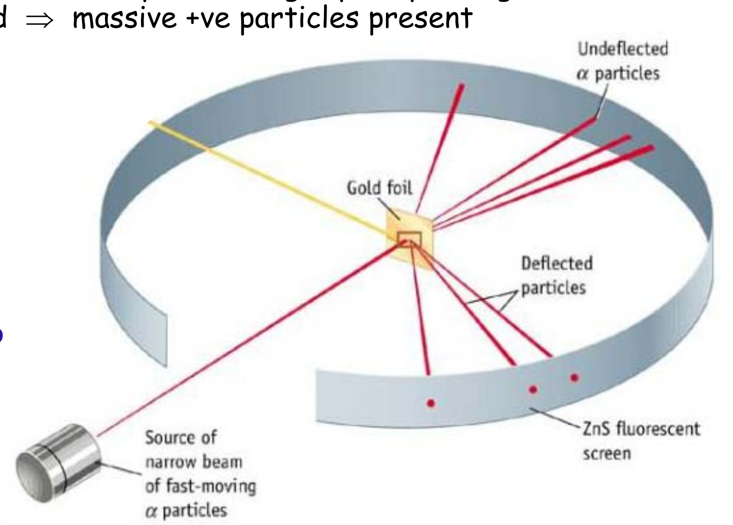
- Tested Thomson's plum pudding model
  – inconsistent with newly discovered protons…
  - So where ARE these protons?

(10)

Rutherford's gold foil experiment

Aimed beam of high energy, massive, +ve charged particles (α-particles) at thin metal foil

REASONING: should pass through "plum pudding"…
If deflected $\Rightarrow$ massive +ve particles present



See Kotz Figure 2.6

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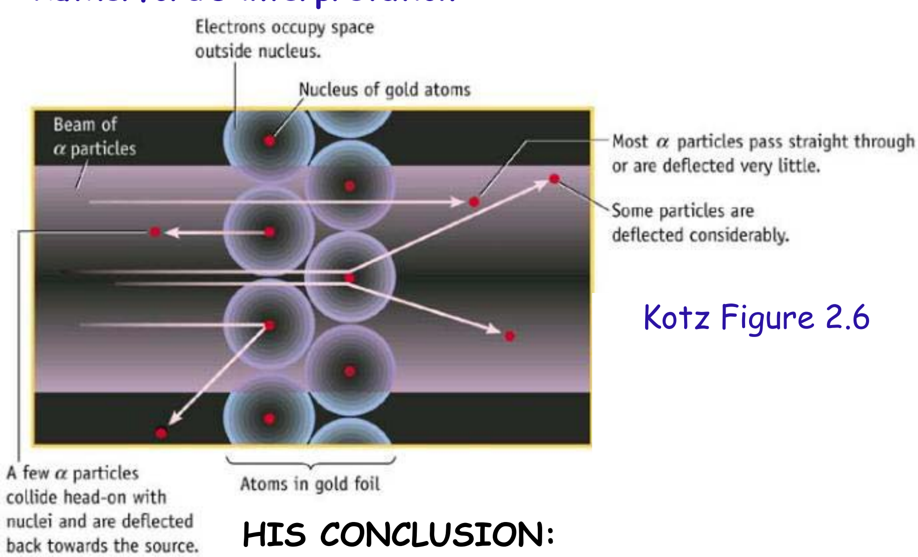
Rutherford's interpretation:



Kotz Figure 2.6

HIS CONCLUSION:
Atoms have a NUCLEUS of positive charge.

(12)

Characterizing the atom: early experiments (~ 1900)

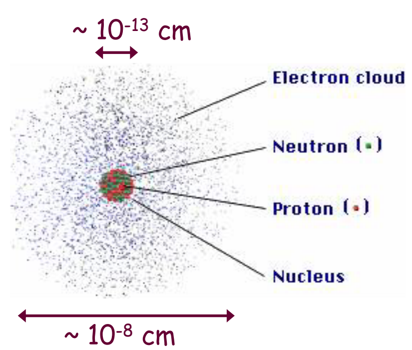
1. J. J. Thomson (Nobel prize in Physics, 1906) } Electrons
2. Robert Millikan (1909) } Electrons
3. Eugene Goldstein (1886) } Protons

4. Ernest Rutherford (1910): the nucleus.

5. James Chadwick (1932): neutrons also in nucleus
   but we won't discuss his experiments...

(13)

Modern view of BASIC atomic structure



Kotz Fig.2.1: A nuclear atom
cross-section view (not to scale)

Nucleus:
- small, dense, positive core
- made of protons & neutrons
- particles held together by the "strong nuclear force" *(see Physics)*
  - stronger than +/+ repulsion
  - active only at separations <10^{-14} m

Surrounding the nucleus:
- electrons in motion (tiny negative particles)
- stay within ~10^{-8} cm of nucleus

LATER ON (CH.7)...
WILL LEARN MORE ABOUT ELECTRONS

Zumdahl's **TABLE 2.1 The Mass and Charge of the Electron, Proton, and Neutron**

Particle	Mass	Charge*	Abbrev.
Electron	9.11×10^{-31} kg	1−	e^-
Proton	1.67×10^{-27} kg	1+	p^+
Neutron	1.67×10^{-27} kg	None	n^0

*The magnitude of the charge of the electron and the proton is 1.60×10^{-19} C.

Relative masses "atomic mass units" "amu"

- Reference point: ^{12}C assigned a mass of *exactly* 12 amu
- Translates into: ^{1}H has a mass of 1 amu
- How we use it: mass of 1 p^+ = mass of 1 n^0 = 1 amu

mass of 1 atom of ^{1}H = 1 amu = 1 p^+ + 0 n^0

(15)

2.2 Atomic symbols: atomic number & atomic mass

1.) Atoms are electrically NEUTRAL: # protons = # electrons

- POSITIVE: charge on nucleus = # protons
- NEGATIVE: charge on electrons = # electrons

counter each other

Neutrons are neutral…

2.) Identity of element determined by # of protons in atom

3.) Atomic symbol reveals nuclear composition of atoms

^{12}C or C-12
"carbon twelve"

Mass number "A" = # p^+ + # n^0

Atomic number "Z" = # p^+ (= # e^-)

$^{12}_{6}C$ ← Element's symbol

Element	*Latin*	Symbol	# p	# e	# n
sodium	*natrium*	$^{23}_{11}Na$			
gold	*aurium*	$^{197}_{79}Au$			

(16)

2.3 Isotopes have nearly identical chemical properties

ISOTOPES = Atoms with same # protons (∴ same element)
∴ same # electrons
BUT <u>different # neutrons</u> (∴ different mass)

Hydrogen:
mass of 1 atom of ^{1}H (protium) = 1 amu $1\ p^{+} + 0\ n^{0}$
mass of 1 atom of ^{2}H (deuterium) = 2 amu $1\ p^{+} + 1\ n^{0}$
mass of 1 atom of ^{3}H (tritium) = 3 amu $1\ p^{+} + 2\ n^{0}$

Carbon = 98.89% ^{12}C
1.11% ^{13}C
< 0.01% ^{14}C

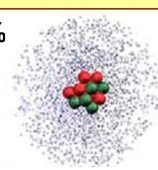
} Average atomic mass 12.01 amu

(17)

The periodic table shows AVERAGE atomic masses… …determined based on natural abundance

Boron (Z=5) has 2 isotopes:

20%
^{10}B
$5\ p^{+}$
$5\ n^{0}$



80%
^{11}B
$5\ p^{+}$
$6\ n^{0}$

Average atomic mass of B: 0.20x(10 amu) + 0.80x(11 amu) = 10.8 amu

Lithium: 6.941 amu
Isotopes: ^{6}Li & ^{7}Li
- How abundant is each?

- Let x = fraction ^{6}Li, & y = fraction ^{7}Li
- Only these 2 isotopes, so: x + y = 1

x(6 amu) + y(7 amu) = 6.941 amu
x(6 amu) + (1-x)(7 amu) = 6.941 amu
6x amu + 7 amu – 7x amu = 6.941 amu
x = 0.059 *unitless*

THUS, in any sample of lithium atoms: 5.9% are ^{6}Li
94.1% are ^{7}Li

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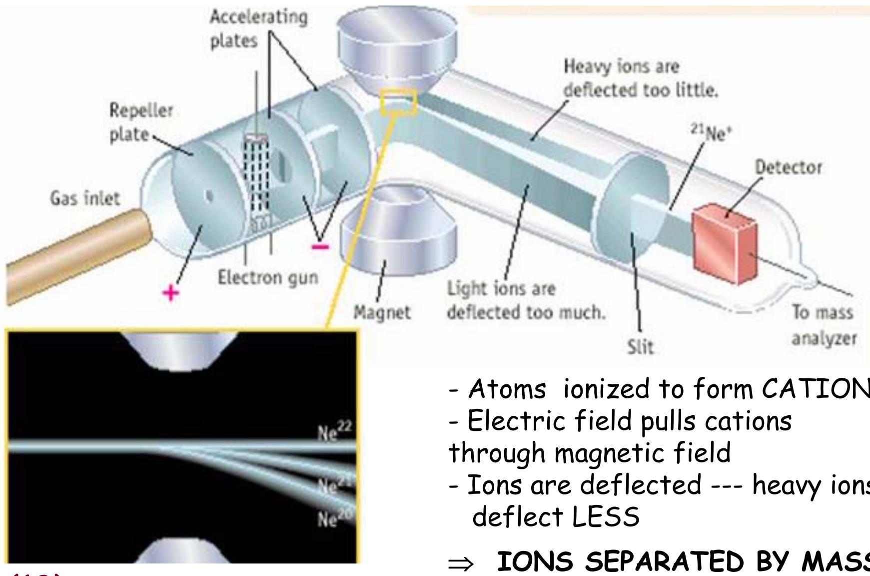
How do we measure masses of atoms & their isotopes? – using a mass spectrometer… See Fig. 2.8

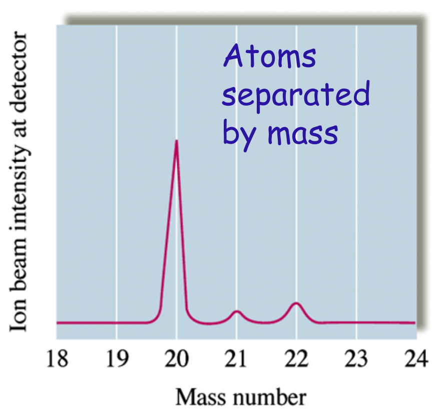


- Atoms ionized to form CATIONS
- Electric field pulls cations through magnetic field
- Ions are deflected --- heavy ions deflect LESS

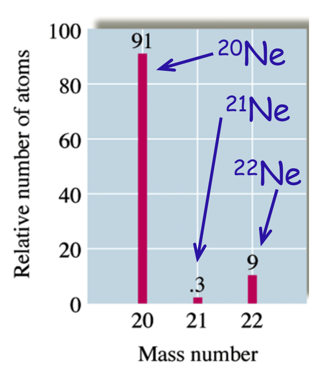
⇒ **IONS SEPARATED BY MASS**

Using mass spectrometry: natural isotope abundances for Ne

Neon gas glowing in a discharge tube.



Relative isotope abundances



Figures from Zumdahl

ASSIGNED READINGS

- BEFORE NEXT CLASS:

Read Ch.2 up to / including section 2.4

master *atomic composition, isotopes*

& work on Ch.2 exercises