Chem 103, Section F0F
Unit I - An Overview of Chemistry
Lecture 4

- Some observations that led to the nuclear model for the structure of the atom
- The modern view of the atomic structure and the elements
- Arranging the elements into a (periodic) table

Lecture 4 - Observations that Led to the Nuclear Model of the Atom

Dalton's theory proposed that atoms were indivisible particles.

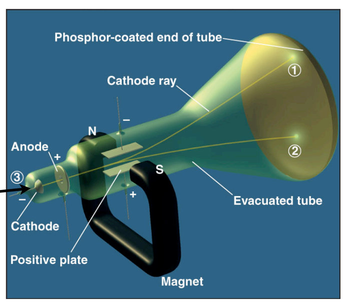
- By the late 19th century, this aspect of Dalton's theory was being challenged.
- Work with electricity lead to the discovery of the electron, as a particle that carried a negative charge.

Lecture 4 - Observations that Led to the Nuclear Model of the Atom

The cathode ray

- Cathode rays were shown to be electrons

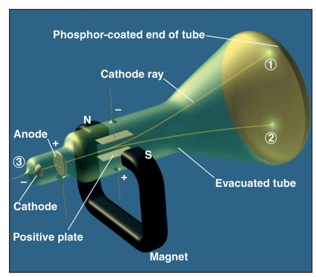
Cathode rays are released by metals at the cathode



Lecture 4 - Observations that Led to the Nuclear Model of the Atom

In 1897, J.J. Thomson (1856-1940) studies how cathode rays are affected by electric and magnetic fields

- This allowed him to determine the mass/charge ration of an electron

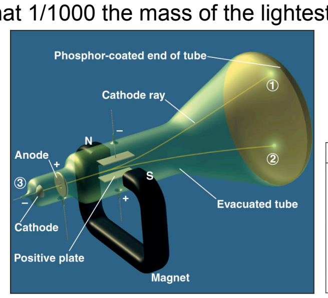


OBSERVATION	CONCLUSION
1. Ray bends in magnetic field	Consists of charged particles
2. Ray bends toward positive plate in electric field	Consists of negative particles
3. Ray is identical for any cathode	Particles found in all matter

Lecture 4 - Observations that Led to the Nuclear Model of the Atom

In 1897, J.J. Thomson (1856-1940) studies how cathode rays are affected by electric and magnetic fields

- Thomson estimated that the mass of an electron was less that 1/1000 the mass of the lightest atom, hydrogen!!



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Lecture 4 - Observations that Led to the Nuclear Model of the Atom

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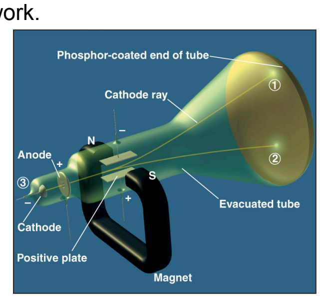
- Thomson received the 1906 Nobel Prize in Physics for his work.



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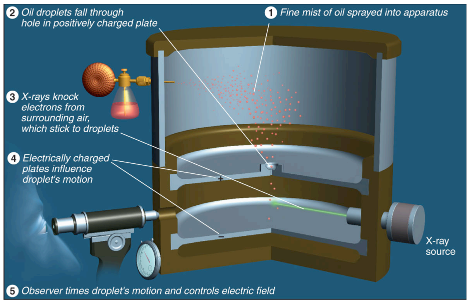
Lecture 4 - Observations that Led to the Nuclear Model of the Atom

In 1909, the American scientist Robert Millikan (1868-1953), was able to accurately measure the charge on an electron.

- He did this with his famous oil-drop experiment



Lecture 4 - Observations that Led to the Nuclear Model of the Atom

In 1909, the American scientist Robert Millikan (1868-1953), was able to accurately measure the charge on an electron.

- He was able to determine a value of the charge, which was within 1% of the currently accepted value:

-1.602×10^{-19} C
(C is the Coulomb, which is the SI unit of charge)

- Combining his results with J.J. Thomson's, he was able to also determine the mass of the electron:

9.109×10^{-31} kg

Lecture 4 - Observations that Led to the Nuclear Model of the Atom

In 1909, the American scientist Robert Millikan (1868-1953), was able to accurately measure the charge on an electron.

- For his discoveries, Robert Millikan was awarded the 1923 Nobel Prize in physics.

Lecture 4 - Observations that Led to the Nuclear Model of the Atom

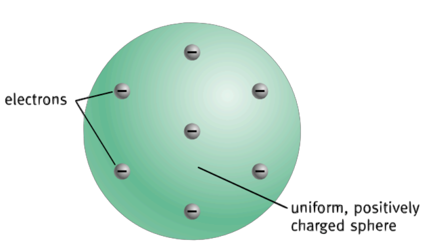
Given the mass and charge of an electron, there was obviously more to an atom than electrons.

- Something was needed to balance the negative charge of the electron.
- Something was needed to account for the mass of the atom.

Lecture 4 - Observations that Led to the Nuclear Model of the Atom

In the early 1900's, Thomson proposed his "plum pudding" model for the atom:

Thomson's model

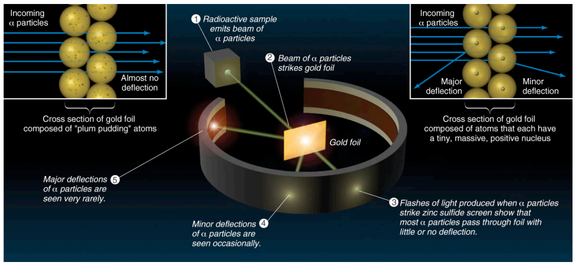


Lecture 4 - Observations that Led to the Nuclear Model of the Atom

In 1910, New Zealand-born Ernest Rutherford (1871-1937) showed that there was something wrong with Thomsons model.

Lecture 4 - Observations that Led to the Nuclear Model of the Atom

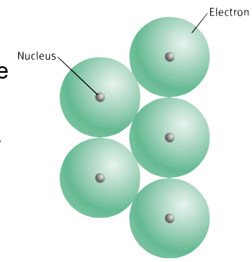
Rutherford's gold film experiment:



Lecture 4 - Observations that Led to the Nuclear Model of the Atom

In 1910, New Zealand-born Ernest Rutherford (1871-1937) showed that there was something wrong with Thomsons model.

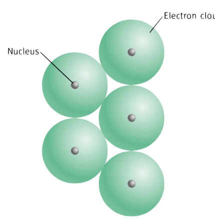
- Rutherford proposed that atoms had a nucleus, which contained 99.97% of the mass of the atom and all of the positive charge of the atom
- He estimated that the radius of the nucleus is about 1/100,000 radius of an atom!!!
- For his discoveries, Ernest Rutherford was awarded the 1908 Nobel Prize in physics.



Lecture 4 - Clicker Question 1

If we were to construct a life-size model of gold foil using marbles having diameters of 1 cm for the nuclei, how far apart should we place the marbles.

A) 1 m (an arm span)
B) 10 m (from here to the door of the classroom)
C) 100 m (the approximate length of a football field)
D) 1000 m = 1 km (from here to Water St.)
E) 100 km (from here to the Minnesota boarder)



Lecture 4 - Problem

Describe J. J. Thomson's model of the atom. How might it account for the production of cathode rays?

Lecture 4 - Problem

When Ernest Rutherford's coworkers bombarded gold foil with α-particles, they obtained results that overturned Thomson's model of the atom. Explain

Lecture 4 - The Atomic Theory Today

Thomson showed us that atoms contained *electrons*

- These particles are negatively charged and weigh less than 1/1000 the mass of the hydrogen atom.

Rutherford showed us that most of the mass of the atom, and all of its positive charge was packed into a small, dense, nucleus at the center of the atom.

- He proposed the nucleus was made up of positively charged particles that he called *protons.*
- Rutherford's model, however, could not account for all of the mass present in most atoms.

James Chadwick resolved this issue in 1932, with his discovery of a third subatomic particle, the *neutron*.

Lecture 4 - The Atomic Theory Today

The properties of the subatomic particles

Table 2.2 Properties of the Three Key Subatomic Particles

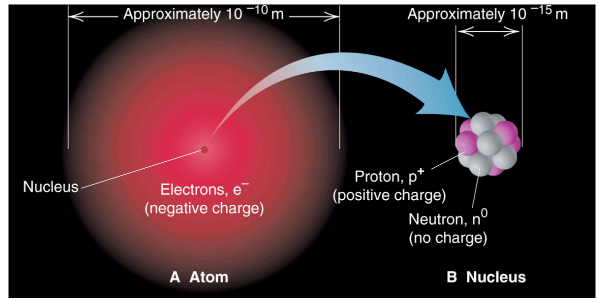
	Charge		Mass		
Name (Symbol)	Relative	Absolute (C)*	Relative (amu)†	Absolute (g)	Location in Atom
Proton (p^+)	1+	$+1.60218 \times 10^{-19}$	1.00727	1.67262×10^{-24}	Nucleus
Neutron (n^0)	0	0	1.00866	1.67493×10^{-24}	Nucleus
Electron (e^-)	1−	-1.60218×10^{-19}	0.00054858	9.10939×10^{-28}	Outside nucleus

*The coulomb (C) is the SI unit of charge.
†The atomic mass unit (amu) equals 1.66054×10^{-24} g; discussed later in this section.

- The atoms of all the elements are made up of these same three subatomic particles.
- The properties of atoms can be understood by understanding the contributions that the subatomic particles make to these properties.

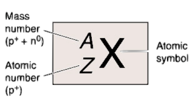
Lecture 4 - The Atomic Theory Today

The general features of an atom



Lecture 4 - The Atomic Theory Today

There is a formalism used to describe the subatomic particles that an atom contains:



- *Z* give the **atomic number**, which is equal to the number of protons that an atom contains.
  - Each element has a unique atomic number

Lecture 4 - The Atomic Theory Today

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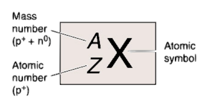

- *X* is the **atomic symbol** of the element that has the atomic number *Z*

Lecture 4 - The Atomic Theory Today

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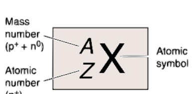

- *A* is the **mass number** of the atom and is equal to number of protons plus the number of neutrons.
  - *A* is an integer that is approximately equal to the mass of the atom in *amu.*
  - The number of neutrons (*N*) that an atom contains can be determined by subtracting the atomic number from the mass number ($N = A - Z$).

Lecture 4 - The Atomic Theory Today

For example

$$^{35}_{17}\text{Cl}$$

- **Cl** is the **chemical symbol** for chlorine
- Chlorine has an **atomic number** of 17 and its atoms contain 17 protons.
  - The atomic number can be omitted, ^{35}Cl
- This atom of chlorine contains 35 - 17 = 18 neutrons
- This atom can also be referred to as **chlorine-35**.

Lecture 4 - Clicker Question 2

Which of the following pairs of atoms have the same number of protons?

A) $^{16}_{8}O$ and $^{17}_{8}O$

B) $^{40}_{18}Ar$ and $^{41}_{19}K$

C) $^{60}_{27}Co$ and $^{60}_{28}Ni$

Lecture 4 - Clicker Question 2

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Lecture 4 - The Atomic Theory Today

All atoms of the same element contain the same number of protons.

They can, however, have different numbers of neutrons.

- Atoms with the same number of protons but different numbers of neutrons are called **isotopes** of one another.
  - Chlorine-35 and Chlorine-37 are isotopes of one another

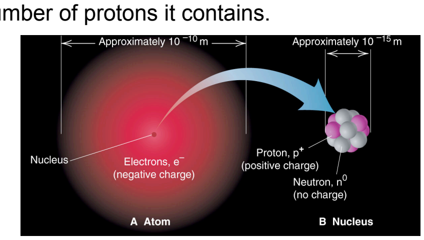
$$^{35}_{17}Cl \text{ and } ^{37}_{17}Cl$$

- Except for their masses, isotopes have almost identical physical and chemical properties.

Lecture 4 - The Atomic Theory Today

The chemical and physical properties of the elements are determined primarily by the number of electrons it contains

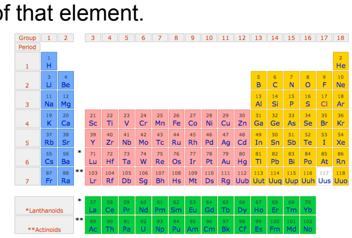
- Remember, most of an atom's volume is made up of electrons.
- The number of electrons in a neutral atom is determined by the number of protons it contains.



Lecture 4 - The Atomic Theory Today

The mass of an atom in atomic mass units is its mass *relative* to 1/12 the mass of the carbon-12 isotope.

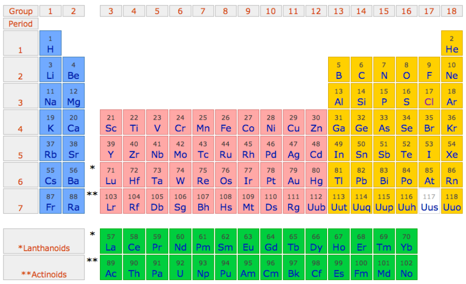
- The masses reported on the periodic table are an average based on the the natural abundance of the different isotopes of that element.



Webelements website: http://www.webelements.com/

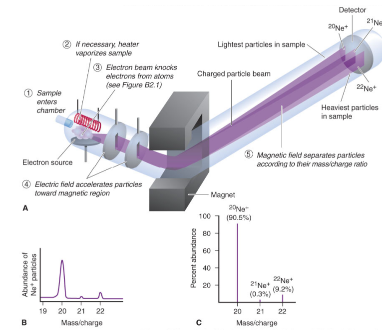
Lecture 4 - Problem

Based on the natural abundance and isotope masses of the naturally occurring isotopes of chlorine, determine the average mass of chlorine in amu.



Lecture 4 - The Atomic Theory Today

The isotope masses and natural abundance of isotopes can be determined using a mass spectrometer.

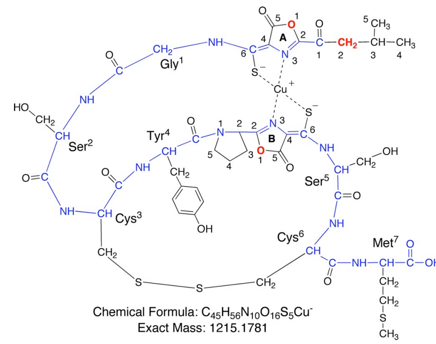


Lecture 4 - The Atomic Theory Today

The chemistry department has a time-of-flight mass spectrometer

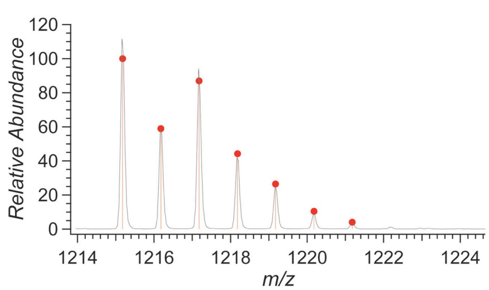
Lecture 4 - The Atomic Theory Today

Methanobactin



Lecture 4 - The Atomic Theory Today

Methanobactin



Lecture 4 - The Atomic Theory Today

Summary:

- All matter is composed of atoms.
- Atoms of one element cannot be converted into atoms of another element ina a chemical reaction.
- All atoms of an element have the same number of protons and electrons, which determines the chemical behavior of the element.
- Compounds are formed by the chemical combination of two or more elements in specific ratios.

Lecture 4 - The Atomic Theory Today

The elements are arranged into a periodic table.

Group	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																			
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

*Lanthanoids	*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
**Actinoids	**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Lecture 4 - The Atomic Theory Today

In the 19th century, investigators looked for ways to organize what was known about the various elements.

Dmitri Mendeleev (1836-1907) created one of the most useful arrangements, in which the elements were arranged by mass.

- In his arrangement, Mendeleev also grouped elements with similar physical and chemical properties.

Lecture 4 - The Atomic Theory Today

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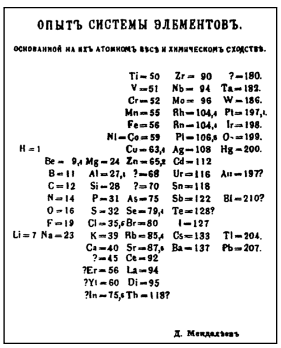


ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

Ti = 50 Zr = 90 ? = 180.
V = 51 Nb = 94 Ta = 182.
Cr = 52 Mo = 96 W = 186.
Mn = 55 Rh = 104,4 Pt = 197,4.
Fe = 56 Rn = 104,4 Ir = 198.
Ni = Co = 59 Pl = 106,6 Os = 199.
H = 1 Cu = 63,4 Ag = 108 Hg = 200.
Be = 9,4 Mg = 24 Zn = 65,2 Cd = 112
B = 11 Al = 27,4 ? = 68 Ur = 116 Au = 197?
C = 12 Si = 28 ? = 70 Sn = 118
N = 14 P = 31 As = 75 Sb = 122 Bi = 210?
O = 16 S = 32 Se = 79,4 Te = 128?
F = 19 Cl = 35,5 Br = 80 I = 127
Li = 7 Na = 23 K = 39 Rb = 85,4 Cs = 133 Tl = 204.
Ca = 40 Sr = 87,6 Ba = 137 Pb = 207.
? = 45 Ce = 92
?Er = 56 La = 94
?Yt = 60 Di = 95
?In = 75,6 Th = 118?

Д. Менделѣевъ

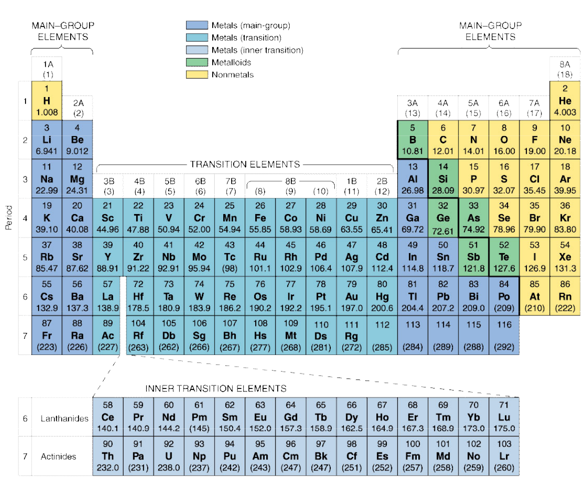
Lecture 4 - The Atomic Theory Today

The modern periodic table has the elements arranged left-to-right and top-to-bottom by atomic number instead of atomic mass.

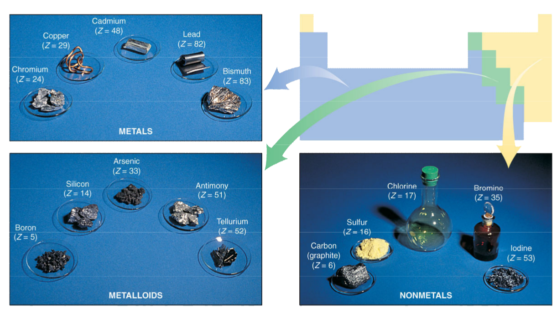
- The rows are called **periods**
- The columns are called **groups**
  - The are labeled 1A to 8A and 1B to 8B
  - The ones labeled 1A to 8A are the **maingroup** or **representative elements.**
  - The ten groups that are labeled 1B to 8B are the **transition elements**.

Elements found in the same group share similar physical and chemical properties.

- We will also see that they share a common electronic configuration.



Lecture 4 - The Atomic Theory Today



Lecture 4 - Problem

How can iodine (Z = 53) have a higher atomic number yet a lower atomic mass than tellurium (Z = 52)?

Mendeleev also recognized that these two elements were out of order back in 1871, when he made his periodic table.

Unit I - Up Next

- Energy and matter
- Different forms of energy and their interconversions
- Heat energy and chemical change

The End