

## Chapter 4: Atoms and elements

Laws: constant composition and conservation of matter  
(1700s)

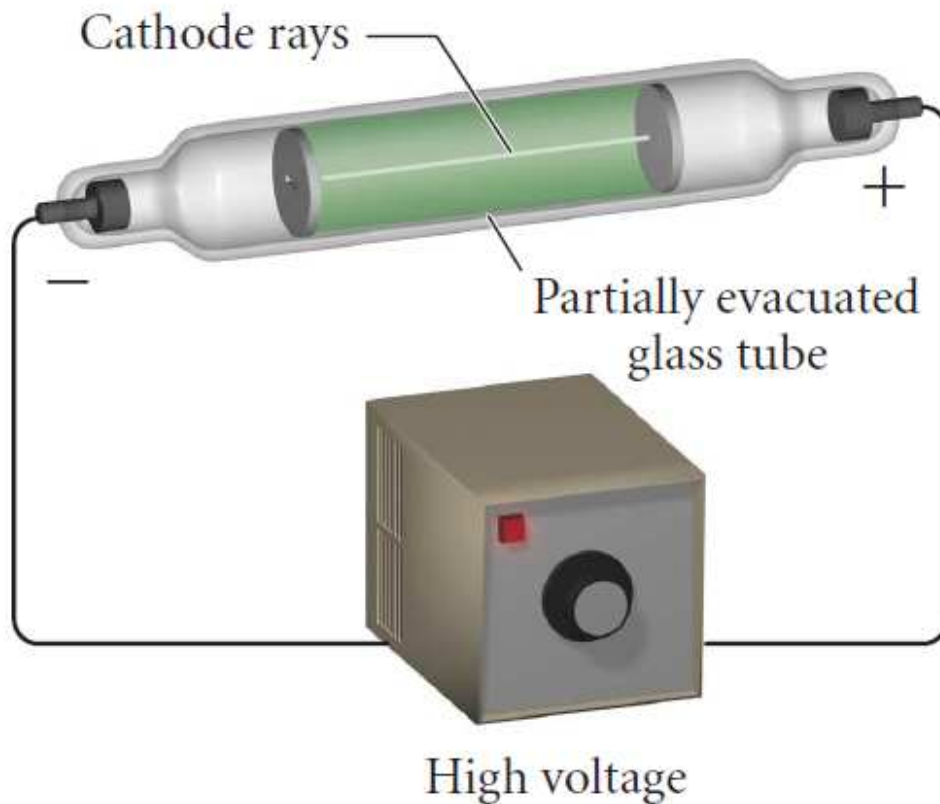
↳ *Compounds have fixed ratio of elements*

### Dalton's atomic theory: (early 1800s)

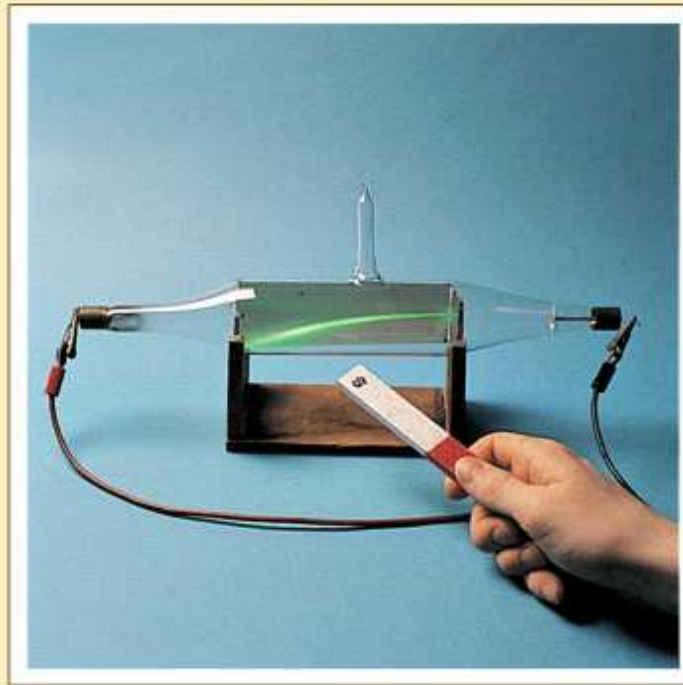
- Matter is made of indestructible atoms
- Atoms of one element are the same
- Atoms combine in simple ratios to make compounds

### Discovery of the electron: (J. J. Thomson, late 1800s)

- Cathode ray tube (beam of electrons)



**Figure 2.5: The Beam of Negative Particles Bends Downward**



Source: Photo by James Scherer.  
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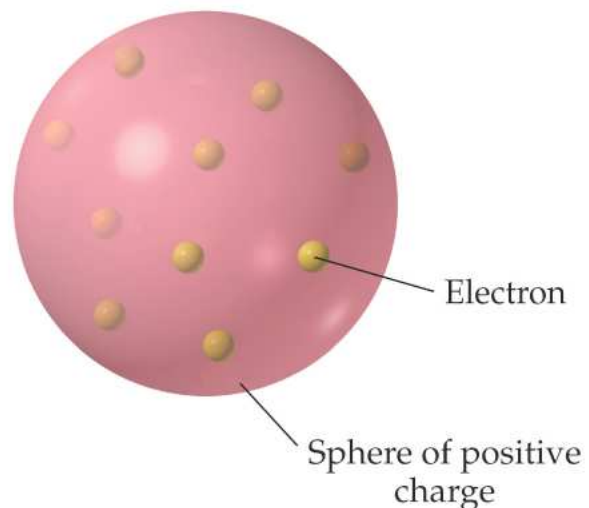
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Presentation of Line Art / Illustrations, 2a-10

**Electrons** are:

- the same no matter which substance they come from.
- particles that are smaller than atoms.
- negatively charged.

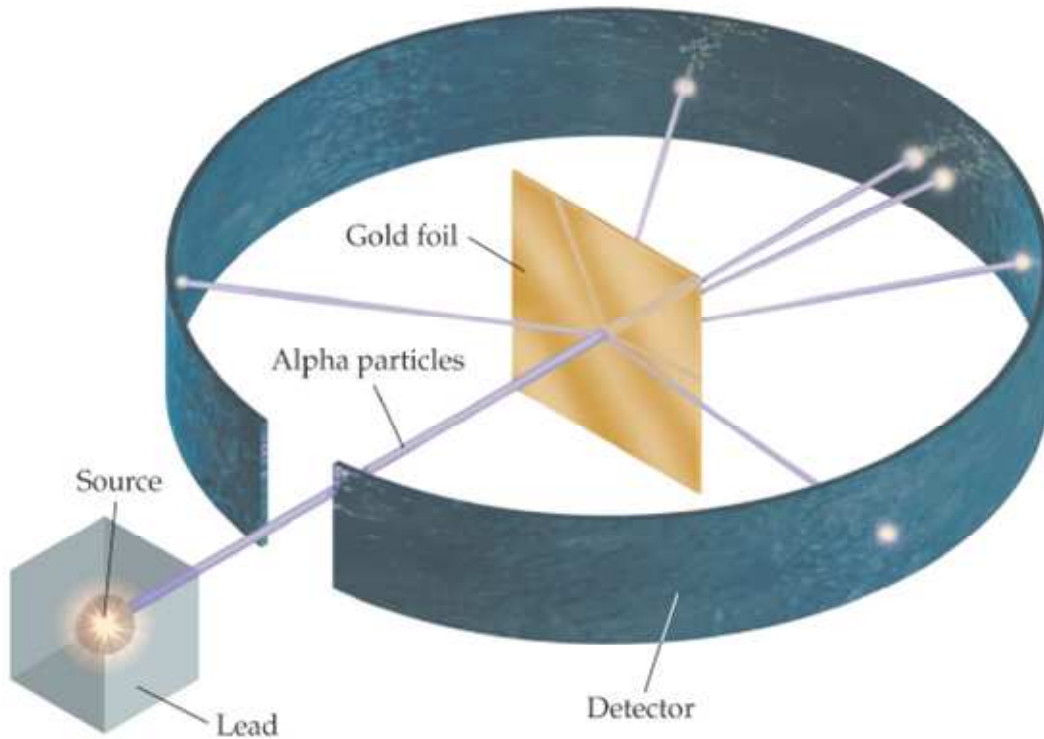
**Plum pudding model**



# Discovery of the nucleus

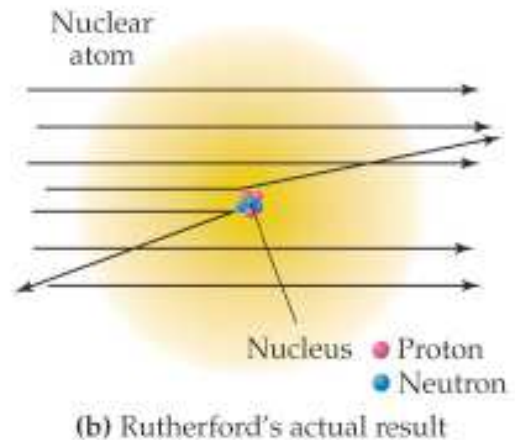
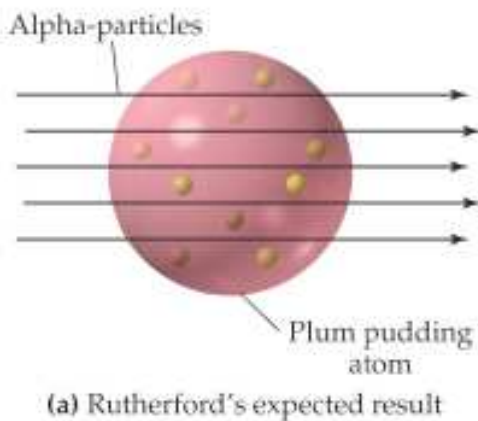
Rutherford

Gold foil experiment: to test plum pudding model



Expected: alpha particles to fly straight through foil

Actually: most went straight through, but some were strongly deflected.



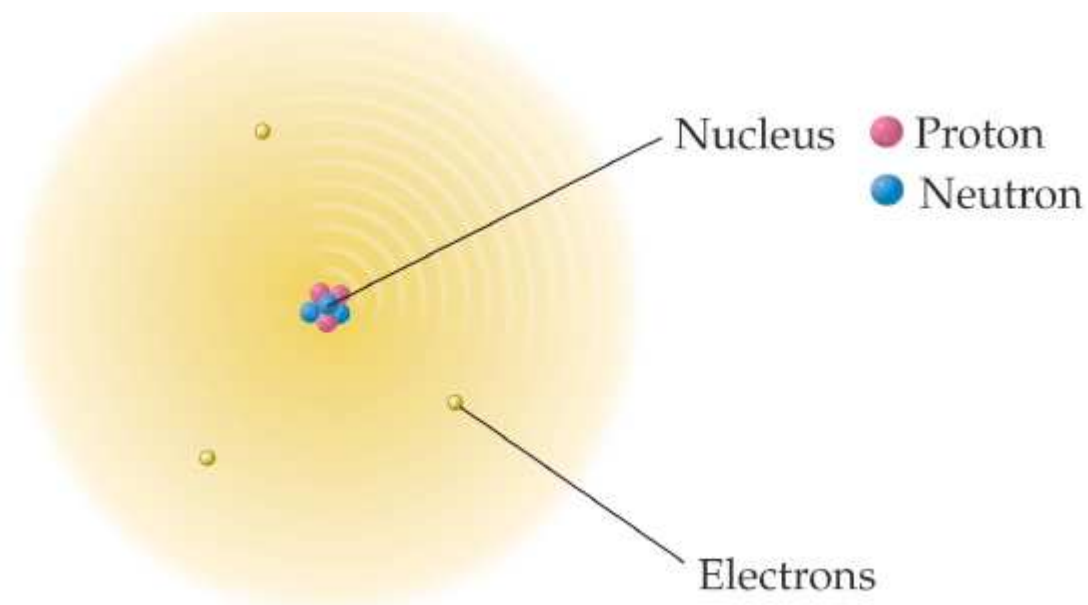
## Modern nuclear model of the atom

### Conclusions:

- Atoms are mostly empty space
- Atoms must contain a dense positively-charged core that is small but massive

**Nucleus:** Rutherford's name for the (+)-charged core of the atom

### Modern model of the atom:



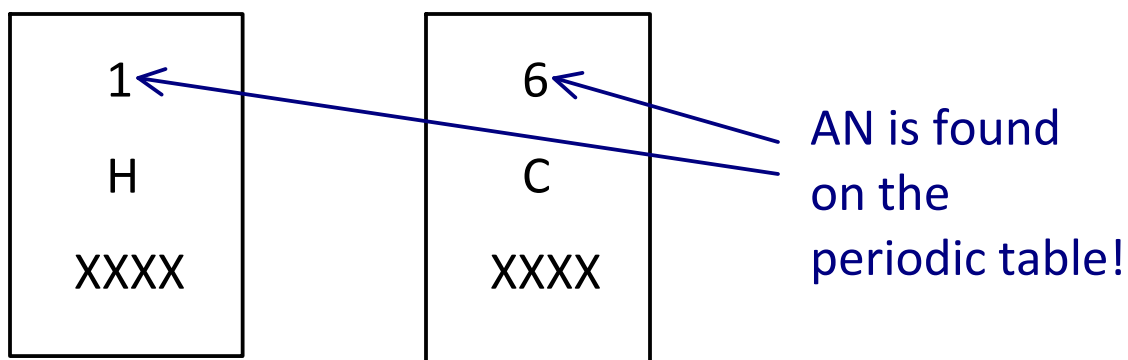
### 3 subatomic particles:

<u>charge</u>		
+	protons	$p^+$
	neutrons	$n^0$
-	electrons	$e^-$

## Elements

The number of protons determines which element an atom is.

Atomic number (AN) = # p<sup>+</sup> in nucleus



Hydrogen has 1 protons in its nucleus.

Carbon has 6 protons in its nucleus.

## Periodic table

Dimitri Mendeleev discovered that elements with similar properties are found every 8 elements when put in order of atomic number.



He, Ne, and Ar are all unreactive gases (atomic numbers 2, 10, and 18)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca

Elements with similar properties recur in a regular pattern.

### A Simple Periodic Table

1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca						

Elements with similar properties fall into columns.

### Periodic table:

- Columns = groups or families (18 groups)
- Rows = periods (7)

# Sections of periodic table

Main group "A" in roman num. group #'s  
 Transition elements "B"  
 Inner transition elements below rest of table

**Metals:** conductors (electricity/heat) all(s)  
 malleable, ductile except Hg(l)

**Nonmetals:** insulators, dull, brittle  
 all (s) or (g) except Br(l)

**Metalloids:** combination of properties  
 Si & Ge are semiconductors

VE: 1 2 3 4 5 6 7 8

Periodic Table of the Elements

1 IA H 1.008	2 IIA He 4.003	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA B 10.81	14 IVA C 12.01	15 VA N 14.01	16 VIA O 16.00	17 VIIA F 19.00	18 VIIIA Ne 20.18	
2 Li 6.939	3 Be 9.012	transition elements										6 B 10.81	7 C 12.01	8 N 14.01	9 O 16.00	10 F 19.00	11 Ne 20.18	
3 Na 22.99	4 Mg 24.31	transition elements										13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95	
4 K 39.10	5 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80	
5 Rb 85.47	6 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29	
6 Cs 132.91	7 Ba 137.33	57-70 La-Lu	71 Lu 174.97	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)
7 Fr (223)	8 Ra (226)	89-102 Ac-Lr	103 Ac (227)	104 Th 232.04	105 Pa 231.04	106 U 238.03	107 Np (241)	108 Pu (244)	109 Am (243)	110 Cm (247)	111 Bk (247)	112 Cf (251)	113 Es (252)	114 Fm (257)	115 Md (258)	116 No (259)	117	118 Uuo (294)
		57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (147)	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 173.04			
		89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (241)	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)			

inner-transition elements

Reference: <http://www.webelements.com>

## Some important groups

IA: alkali metals  $\text{Li, Na, K, ...}$   
all reactive w/  $\text{H}_2\text{O}$

IIA: alkaline earth metals  
burn w/ bright white flame

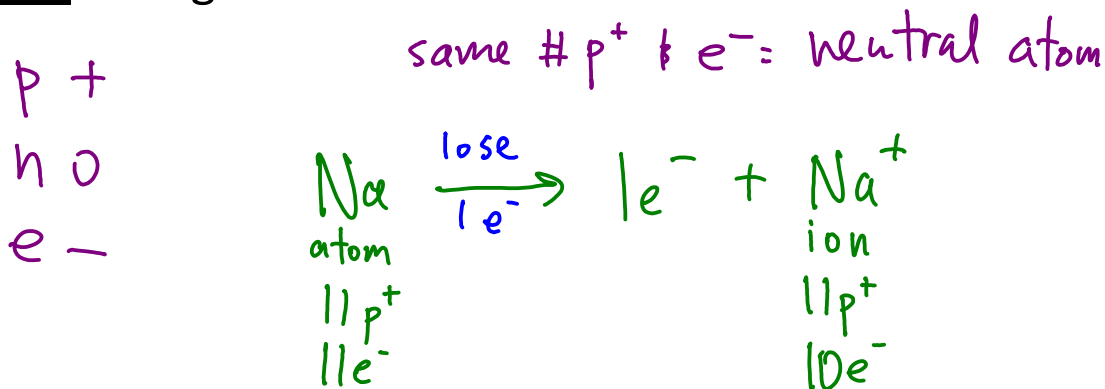
VIIA: halogens (pairs of atoms)  
 $\text{F}_2$  &  $\text{Cl}_2$  (g)      F-F  
 $\text{Br}_2$  (l)  
 $\text{I}_2$  (s)

VIIIA: noble gases      unreactive (inert)



# Ions

**Ions:** charged atoms or molecules



Stable ions have the same # electrons as the...  
nearest noble gas

**Valence electrons:** outermost electrons  
responsible for reactivity

for main-grp elements = group # (roman num)

Main-group metals: lose their valence electrons  
positive ions

Stable ions:

<u>IA</u>	<u>IIA</u>	<u>IIIA</u>
$\text{Li}^+$	$\text{Be}^{2+}$	
$\text{Na}^+$	$\text{Mg}^{2+}$	$\text{Al}^{3+}$
$\text{K}^+$	$\text{Ca}^{2+}$	$\text{Ga}^{3+}$

# Ions

Metallic elements are... neutral & usually unstable (reactive)

Metals in compounds are... + stable ions

Nonmetals: gain  $e^-$  to form stable ions



<u>VA</u>	<u>VIA</u>	<u>VIIA</u>	VIIIA
$N^{3-}$	$O^{2-}$	$F^-$	(Ne)
$P^{3-}$	$S^{2-}$	$Cl^-$	
	$Se^{2-}$	$Br^-$	
		$I^-$	

⊖ charge : group # - 8

Mass number

$$\text{Atomic \#} = \# \text{ protons}$$

$$\text{Mass \#} = \# p^+ + \# n^0$$

carbon-12:  $\# p^+ = 6$   
MN  $\# n^0 = 6$   
12 = MN

carbon-13  $\# p^+ = 6$   
 $\# n^0 = 7$   
13 MN

**Isotopes:** versions of an atom with the...

same  $\# p^+$   
different  $\# n^0$

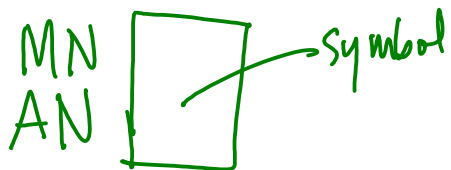
same AN, different MN

3 naturally-occurring isotopes of carbon:

<u>Isotope name</u>	<u>AN</u>	<u>MN</u>	<u>#p<sup>+</sup></u>	<u>#n<sup>0</sup></u>	<u>#e<sup>-</sup></u>	<u>Isotope Symbol</u>
carbon-12	6	12	6	6	6	<sup>12</sup> <sub>6</sub> C
carbon-13	6	13	6	7	6	<sup>13</sup> <sub>6</sub> C
carbon-14	6	14	6	8	6	<sup>14</sup> <sub>6</sub> C

use  button in  
MC

isotope symbol:



## Isotopes

An atom has 11 protons and 12 neutrons

$$AN = 11$$

$$MN = 23 = \#p + \#n$$

isotope name = sodium-23

isotope symbol =  ${}_{11}^{23}\text{Na}$

#e<sup>-</sup> if neutral = 11

#e<sup>-</sup> if stable ion = 10 (Na<sup>+</sup>)

Mass number:

will cover

Atomic mass:

Mon Feb 9

<u>Atom</u>	<u>MN</u>	<u>atomic mass</u>
carbon-12	12	exactly 12 amu
carbon-13	13	13.00335 amu
magnesium-24	24	23.98504 amu

## Atomic mass

A sample of natural carbon contains...

98.9% carbon-12

1.1% carbon-13

trace carbon-14

Atomic mass of "natural carbon":

On periodic table:

6
C
12.01

**Mass number is NOT on the periodic table!**