

## Chapter 2: Atoms and elements

A few important laws... (what is a scientific law?)

Law of conservation of mass: in a chemical reaction, matter is neither

Antoine Lavoisier, 1743-1794 (France)

Law of definite proportions: any sample of a **compound** will have the same proportions of elements

Two different samples of  $\text{CO}_2$ :

Sample 1: 25.6 g O; 9.6 g C

Sample 2: 21.6 g O; 8.10 g C

## Laws

Law of multiple proportions: Different compounds of the same elements have whole number proportions of elements.

Water and hydrogen peroxide: both have H and O

Water: 0.136 g H for every 1 g O

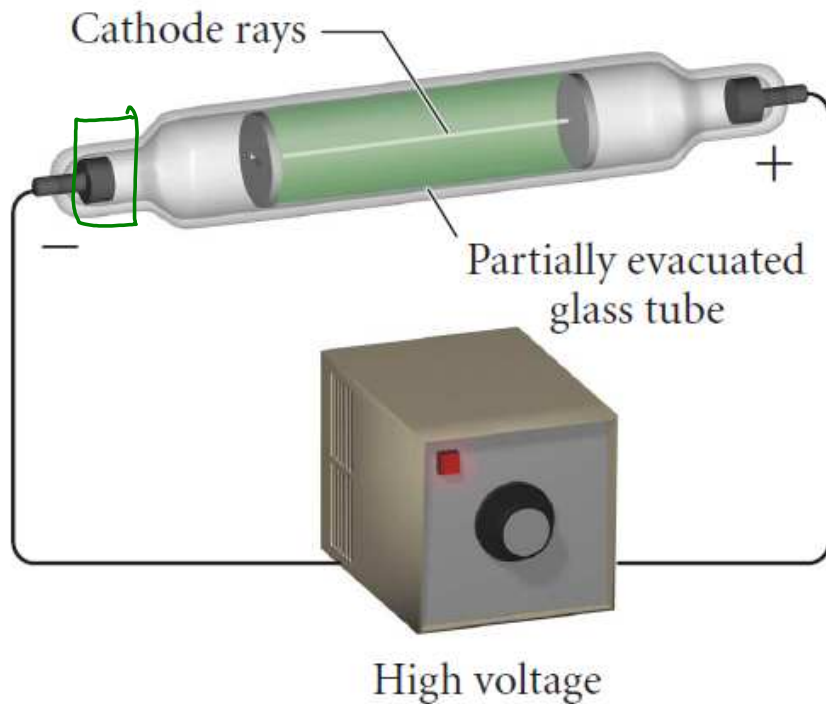
Hydrogen peroxide: 0.0630 g H for every 1 g O

**Atomic theory**: John Dalton, 1808

1. Atoms = indestructible, smallest unit of element to retain identity
2. An element has all the same type of atoms
3. A compound contains atoms of 2 or more elements in a fixed ratio
4. In a chemical reaction, atoms rearrange to form new substances

## Discovery of the electron

J. J. Thomson, 1897: cathode ray tube



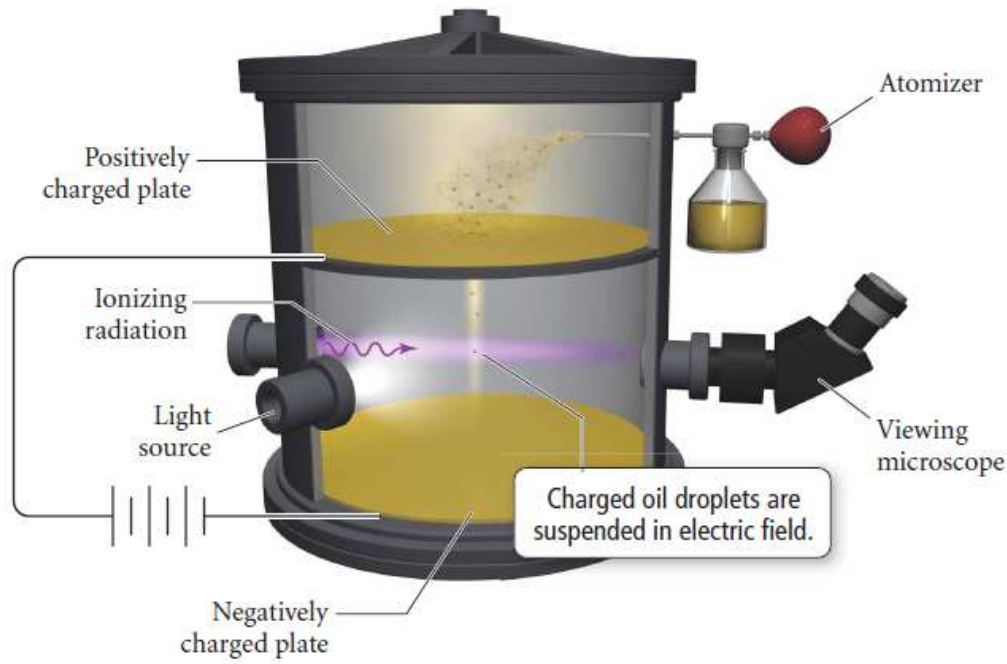
Cathode rays contain a single type of particle:

- Negatively charged
- The same from any element
- Calculated mass/charge ratio

Thomson called it the **electron**.

## Oil drop experiment

### Robert Millikan: 1909 Oil drop experiment

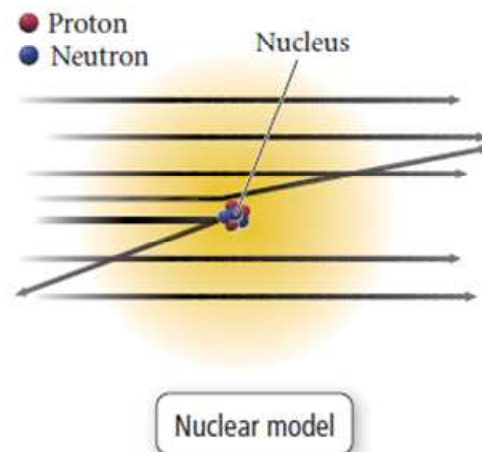
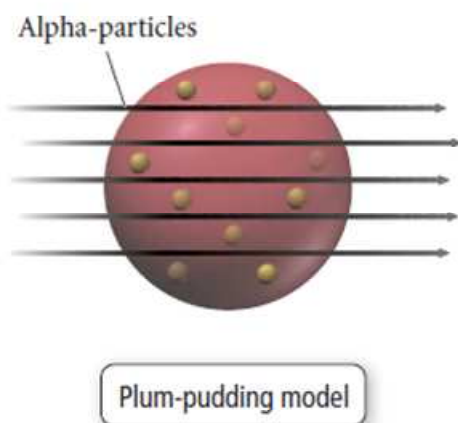
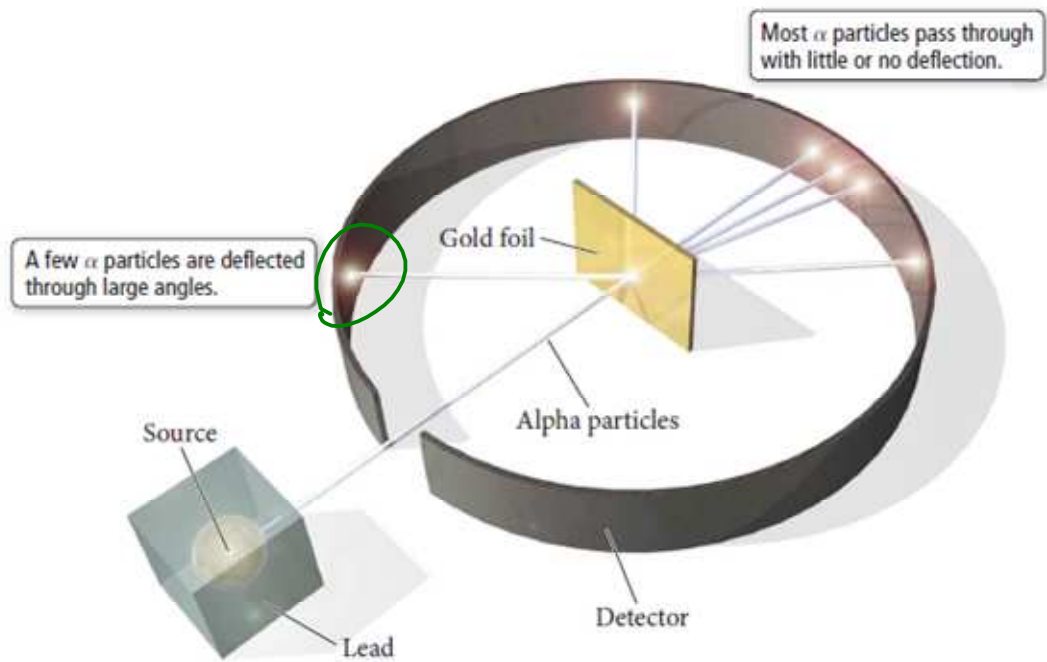


Charge of an electron:  $1.602 \times 10^{-19}$  coulombs (C)

Mass of an electron:  $9.109 \times 10^{-28}$  g

## Gold foil experiment

### Ernest Rutherford: 1911 gold foil experiment



## Nuclear model

### Rutherford's nuclear model:

1. Most of atom's mass is in a tiny dense nucleus
2. Most of the volume is empty space, with tiny electrons around the nucleus
3. In a neutral atom, the number of protons equals the number of

## Elements and isotopes

### **Atomic number (Z):**

### **Mass number (A):**

A certain nucleus contains 11 protons and 12 neutrons.

Z =

A =

**Nuclide**: a nucleus with a certain atomic and mass number (a given number of protons and neutrons)

**Isotopes**: have same atomic number, different mass #'s (same number of \_\_\_\_\_, different number of \_\_\_\_\_)

### **Nuclide symbol:**

### **Isotope name:**



## Periodic table

Dimitiri Mendeleev, 1869

Originally arranged  
elements in order of  
atomic weight  
(now use atomic # to  
order)



Periodic law: elements with similar properties recur in a regular pattern

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.

### Periodic table:

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

Group numbers: roman numeral then A/B

- A: main-group
- B: transition

### 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.

## Parts of the periodic table

### Some important groups:

- IA: alkali metals
- IIA: alkaline earth metals
- VIIA: halogens
- VIIA: noble gases

### Metals:

### Nonmetals:

### Metalloids (semimetals):

# Periodic Table of the Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	IA	IIA	IIIB	IVB	VB	VIB	VII	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA	
1	1 <b>H</b> 1.008																	2 <b>He</b> 4.003	
2	3 <b>Li</b> 6.939	4 <b>Be</b> 9.012											5 <b>B</b> 10.81	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.00	10 <b>Ne</b> 20.18	
3	11 <b>Na</b> 22.99	12 <b>Mg</b> 24.31											13 <b>Al</b> 26.98	14 <b>Si</b> 28.09	15 <b>P</b> 30.97	16 <b>S</b> 32.07	17 <b>Cl</b> 35.45	18 <b>Ar</b> 39.95	
4	19 <b>K</b> 39.10	20 <b>Ca</b> 40.08		21 <b>Sc</b> 44.96	22 <b>Ti</b> 47.90	23 <b>V</b> 50.94	24 <b>Cr</b> 52.00	25 <b>Mn</b> 54.94	26 <b>Fe</b> 55.85	27 <b>Co</b> 58.93	28 <b>Ni</b> 58.69	29 <b>Cu</b> 63.55	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.72	32 <b>Ge</b> 72.61	33 <b>As</b> 74.92	34 <b>Se</b> 78.96	35 <b>Br</b> 79.90	36 <b>Kr</b> 83.80
5	37 <b>Rb</b> 85.47	38 <b>Sr</b> 87.62		39 <b>Y</b> 88.91	40 <b>Zr</b> 91.22	41 <b>Nb</b> 92.91	42 <b>Mo</b> 95.96	43 <b>Tc</b> (98)	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.4	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.75	52 <b>Te</b> 127.60	53 <b>I</b> 126.90	54 <b>Xe</b> 131.29
6	55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33	57-70 *	71 <b>Lu</b> 174.97	72 <b>Hf</b> 178.49	73 <b>Ta</b> 180.95	74 <b>W</b> 183.84	75 <b>Re</b> 186.21	76 <b>Os</b> 190.23	77 <b>Ir</b> 192.22	78 <b>Pt</b> 195.08	79 <b>Au</b> 196.97	80 <b>Hg</b> 200.59	81 <b>Tl</b> 204.38	82 <b>Pb</b> 207.2	83 <b>Bi</b> 208.98	84 <b>Po</b> (209)	85 <b>At</b> (210)	86 <b>Rn</b> (222)
7	87 <b>Fr</b> (223)	88 <b>Ra</b> (226)	89-102 **	103 <b>Lr</b> (257)	104 <b>Rf</b> (261)	105 <b>Db</b> (262)	106 <b>Sg</b> (271)	107 <b>Bh</b> (272)	108 <b>Hs</b> (270)	109 <b>Mt</b> (276)	110 <b>Ds</b> (281)	111 <b>Rg</b> (280)	112 <b>Uub</b> (285)	113 <b>Uut</b> (284)	114 <b>Uuq</b> (289)	115 <b>Uup</b> (288)	116 <b>Uuh</b> (292)	117	118 <b>Uuo</b> (294)
				57 <b>La</b> 138.91	58 <b>Ce</b> 140.12	59 <b>Pr</b> 140.91	60 <b>Nd</b> 144.24	61 <b>Pm</b> (147)	62 <b>Sm</b> 150.36	63 <b>Eu</b> 151.96	64 <b>Gd</b> 157.25	65 <b>Tb</b> 158.93	66 <b>Dy</b> 162.50	67 <b>Ho</b> 164.93	68 <b>Er</b> 167.26	69 <b>Tm</b> 168.93	70 <b>Yb</b> 173.04		
				89 <b>Ac</b> (227)	90 <b>Th</b> 232.04	91 <b>Pa</b> 231.04	92 <b>U</b> 238.03	93 <b>Np</b> (237)	94 <b>Pu</b> (244)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (247)	98 <b>Cf</b> (251)	99 <b>Es</b> (252)	100 <b>Fm</b> (257)	101 <b>Md</b> (258)	102 <b>No</b> (259)		

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

## Ions and the periodic table

Neutral atoms have the same number of protons and electrons

**Ions** have a different number of  $p^+$  and  $e^-$ .

Metals usually lose electrons to form positively charged cations:

Nonmetals usually gain electrons to form negatively charged anions:

Main group elements tend to form stable ions with the same # electrons as the nearest noble gas.

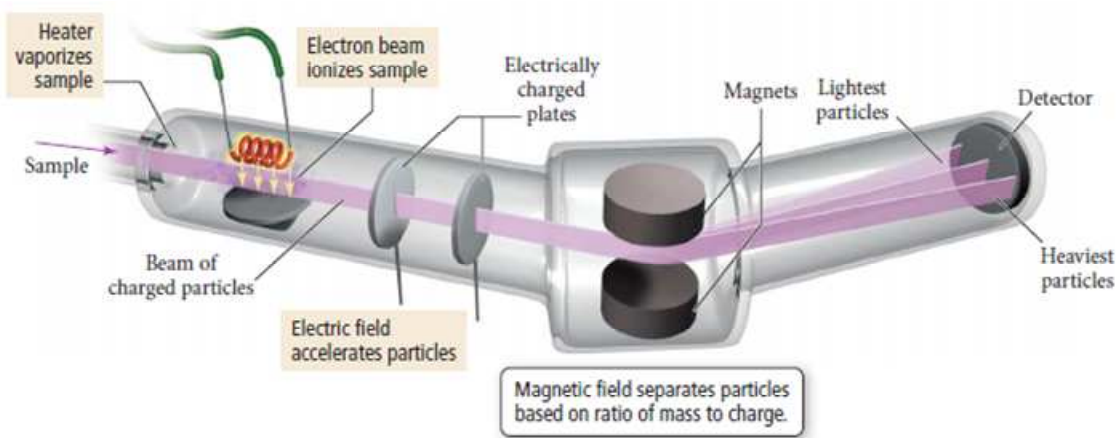
## Atomic mass

**Atomic mass**: relative mass of an atom

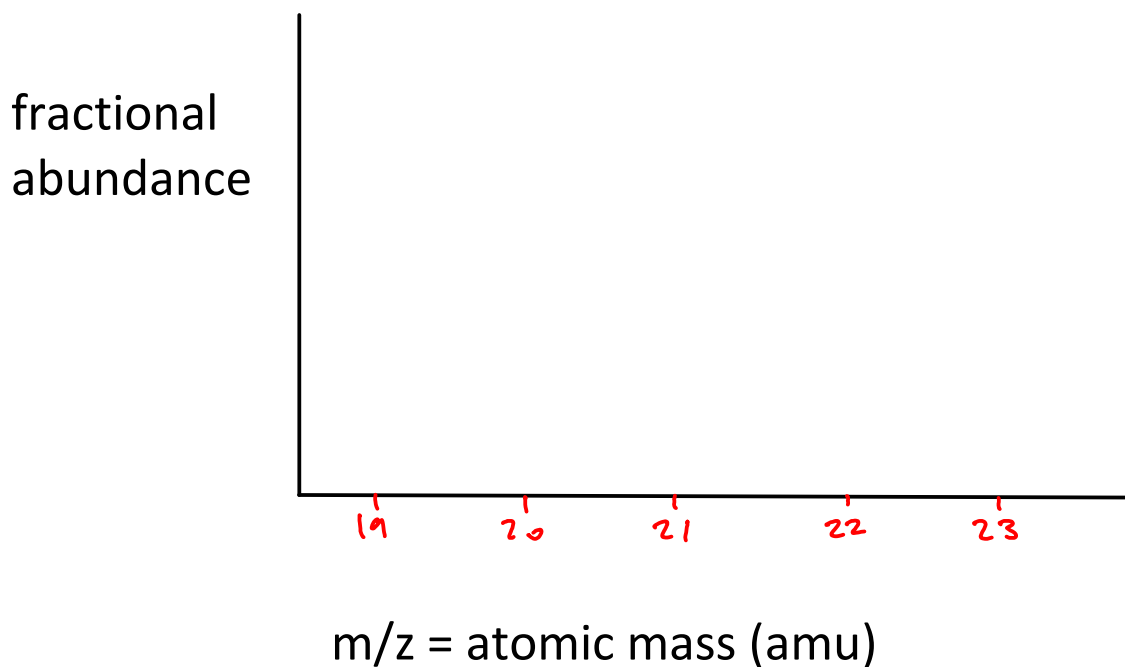
Unit = amu (atomic mass unit),  
(also called Dalton, abbrev u)

Definition of amu: 12 amu = mass of 1 carbon-12 atom

Mass spectrometry: measures mass/charge ratio of particles deflected by magnetic field



Sample of natural neon:



## Atomic mass

<u>isotope</u>	<u>atomic mass</u>	<u>abundance</u>
neon-20	19.992 amu	0.9051
neon-21	20.994 amu	0.0027
neon-22	21.991 amu	0.0922

## Molar mass

The mole = the chemist's dozen

1 pair = 2 objects

1 dozen = 12 objects

1 mole =  $6.022 \times 10^{23}$  objects

$6.022 \times 10^{23}$  particles/mol = Avogadro's number

1.38 mol Al = ? Al atoms

$9.23 \times 10^{25}$  Pb atoms = ? mol Pb

	<u>Atomic mass</u>	<u>Molar mass</u>
carbon-12	12 amu exactly	12 g/mol exactly
carbon	12.01 amu	12.01 g/mol
neon	20.18 amu	20.18 g/mol

12.5 g Si = ? mol Si

2.6 mol Ag = ? g Ag