400 BC DEMOCRITUS

MATTER CONSISTED OF TINY PARTICLES

ATOMOS

1803 JOHN DALTON

1ST WORKABLE ATOMIC THEORY (BASED ON EVIDENCE)

1. MATTER COMPOSED OF ATOMS
2. ATOMS OF SAME ELEMENTS ARE THE SAME (MASS & PROPERTIES)
   ATOMS OF DIFFERENT ELEMENTS ARE DIFFERENT

3. Atoms combine to form compounds in small whole number ratios

Joseph Proust (1798)

$2H_2 + O_2 \rightarrow 2H_2O$

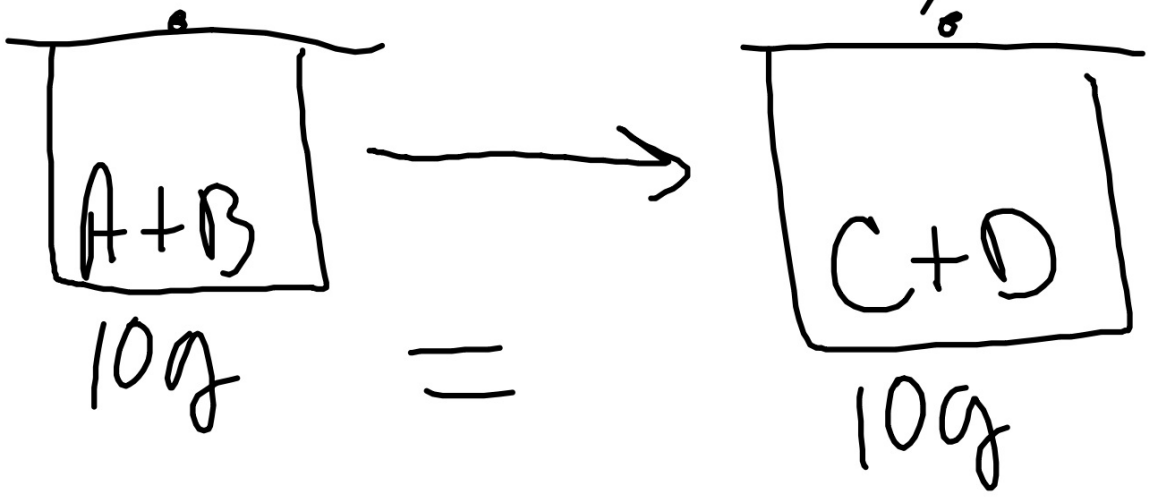
2 : 1

Law of Definite Composition (Proportions)

atoms combine in small whole number ratios to form compounds

4. Atoms are the units of Change separate, rearrange, and recombine in chemical reactions

Antoine Lavoisier (1798) (Change)



Law of Conservation of Mass (Matter)

a given amount of matter that can not be changed

(Can not create or destroy matter)

Law of Multiple Proportions

(Dalton)

* CO Carbon monoxide

CO_2 Carbon dioxide

$FeCl_2$

$FeCl_3$

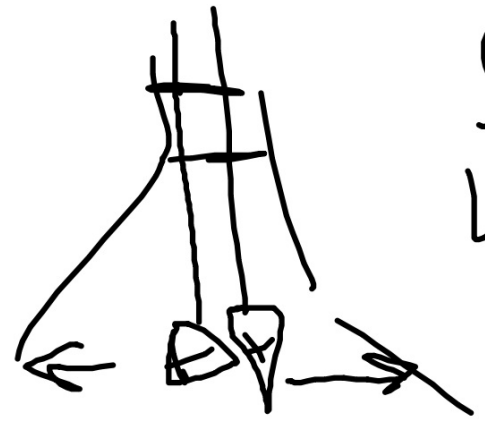
Electricity - flow of electrons

+ & − electricity.

Like charges repel
opposite charges attract

associated with matter

BEN FRANKLIN



LAWS OF CONSERVATION OF ELECTRICITY

1833 MICHAEL FARADAY

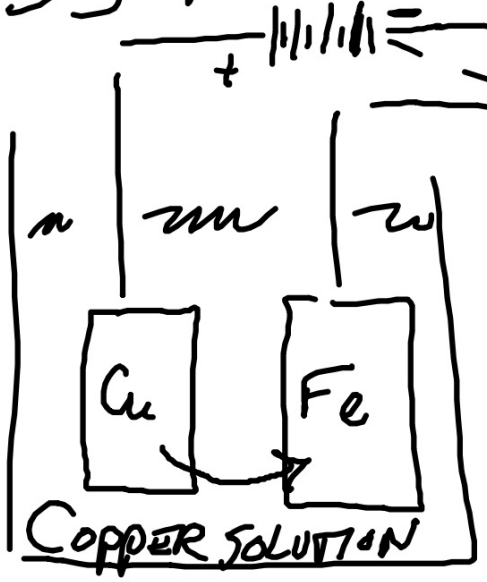


plate Cu onto Fe

electroplating

electrolysis

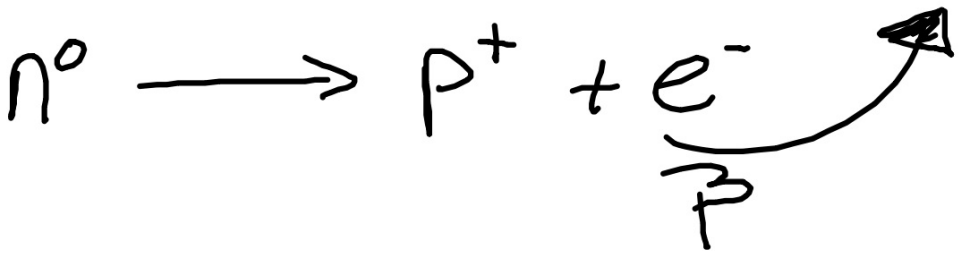
Fundamental particle of electricity

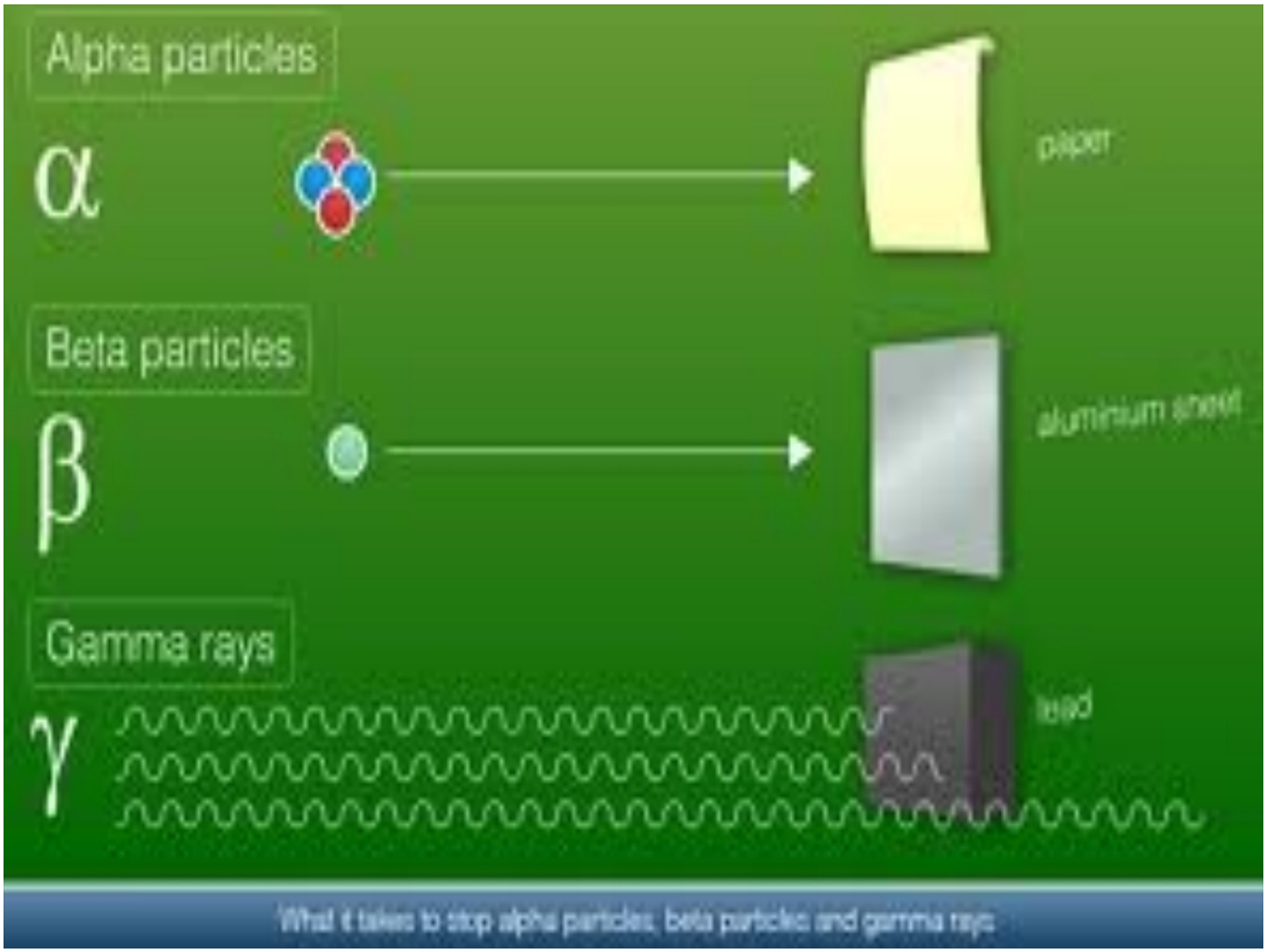
"Atom" of electricity

1896 Henri Bequeral
working with the mineral
pitchblende
X-rays ?
MARIE CURIE took pitchblende
isolated 2 new elements
Polonium, Radium

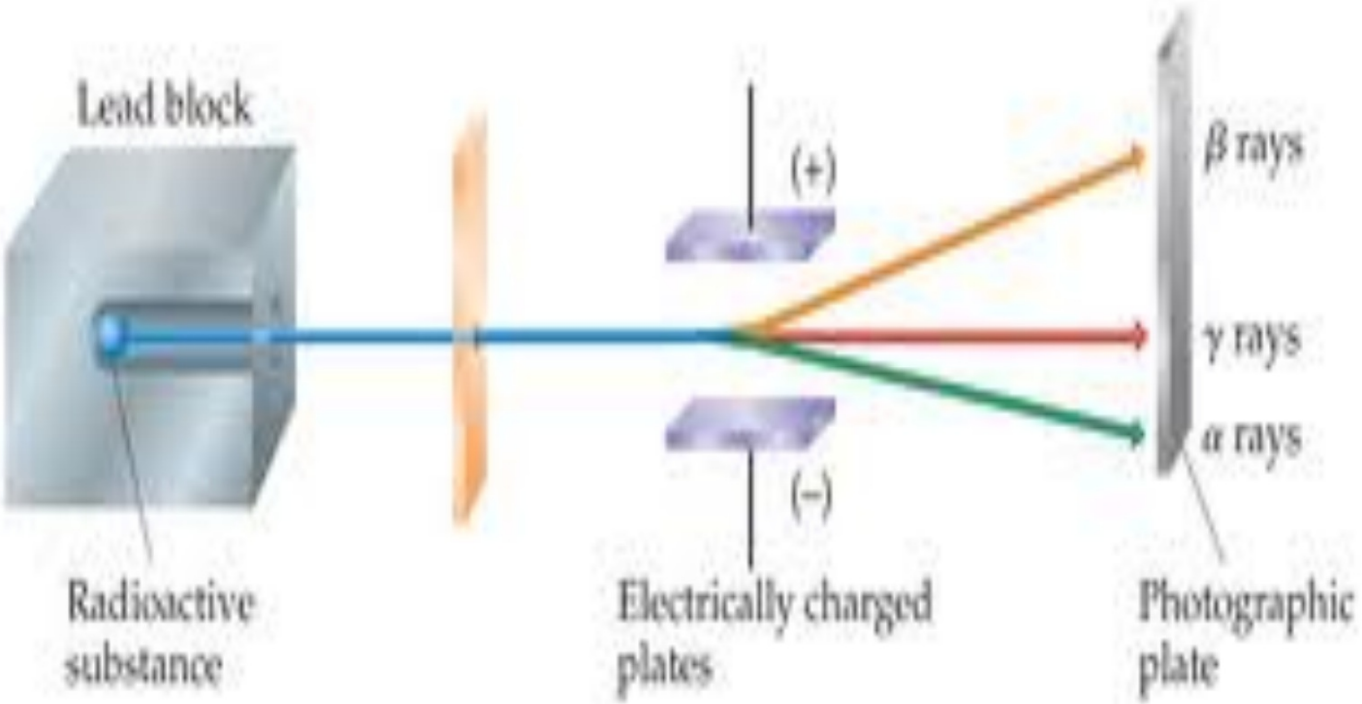
Radioactivity the release of particles and/or energy from the nucleus of an atom

radiation	makeup	mass	charge
alpha (α)	He nucleus (2 p+s & 2 n°s)	4	+2
beta (β)	electron (e^-)	0	-1
gamma ray (γ)	energy (photons)	0	0


n°
p+
+ e-
p



What it takes to stop alpha particles, beta particles and gamma rays



▲ **Figure 1.21 Behaviour of alpha (α), beta (β) and gamma (γ) rays in an electric field.** The α rays consist of positively charged particles and are therefore attracted to the negatively charged plate. The β rays consist of negatively charged particles and are attracted to the positively charged plate. The γ rays, which carry no charge, are unaffected by the electric field.

1898 J J Thomson

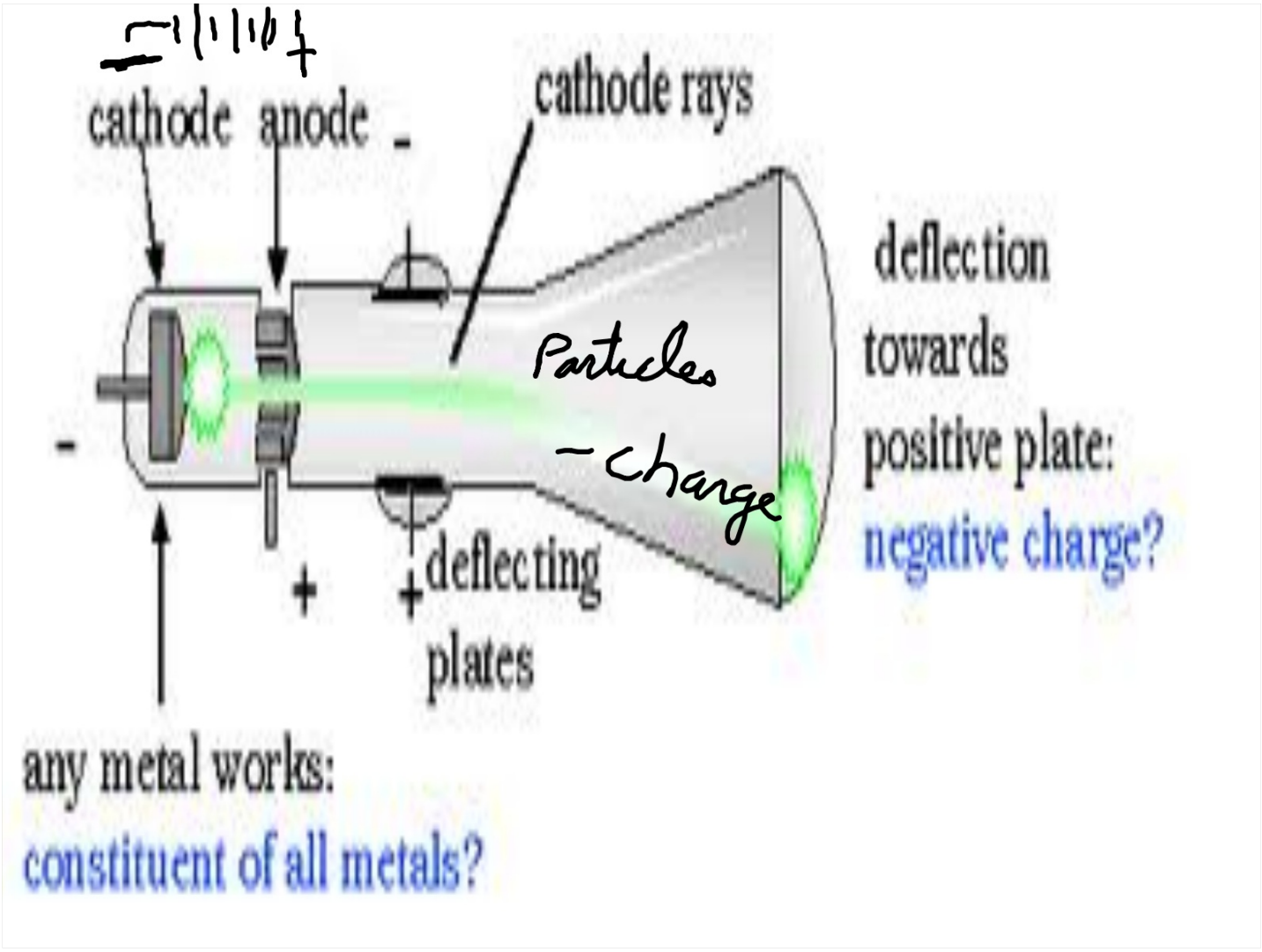
Cathode ray tube

(CROOKES)

discovered the electron

" " proton

$\beta = e^-$


cathode
anode
cathode rays
deflection towards positive plate: negative charge?
Particles
- charge
deflecting plates
any metal works:
constituent of all metals?

1911 RA Millikan

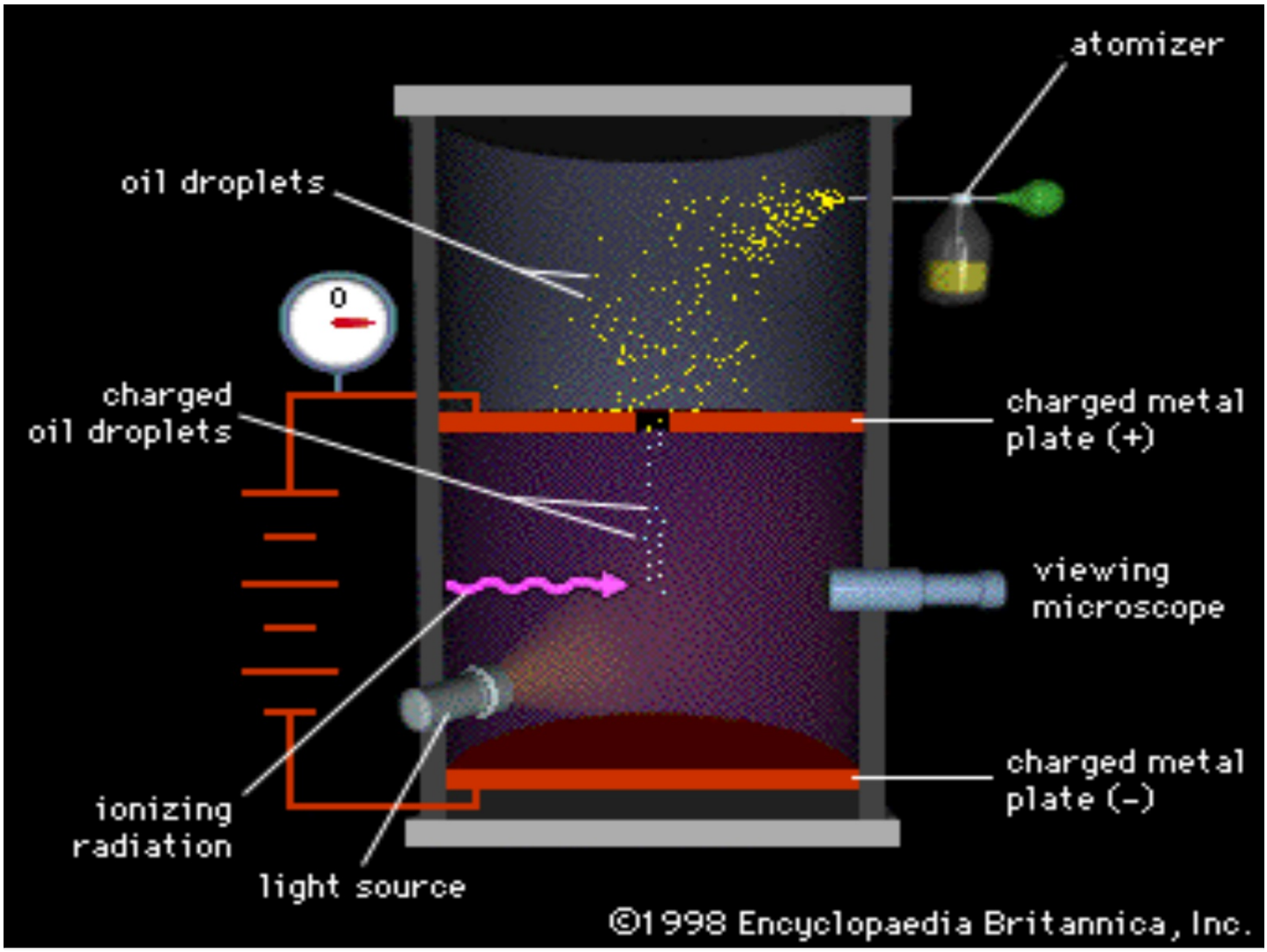
determined CHARGE of THE ELECTRON

OIL DROP EXPERIMENT

CHARGE of electron

$-1.602\,177\,33 \times 10^{-19}$ Coulombs

1C = 1amp X 1p (C)


atomizer
oil droplets
0
charged
oil droplets
charged metal
plate (+)
viewing
microscope
charged metal
plate (–)
ionizing
radiation
light source
©1998 Encyclopaedia Britannica, Inc.

1932 JAMES CHADWICK
DISCOVERED THE NEUTRON

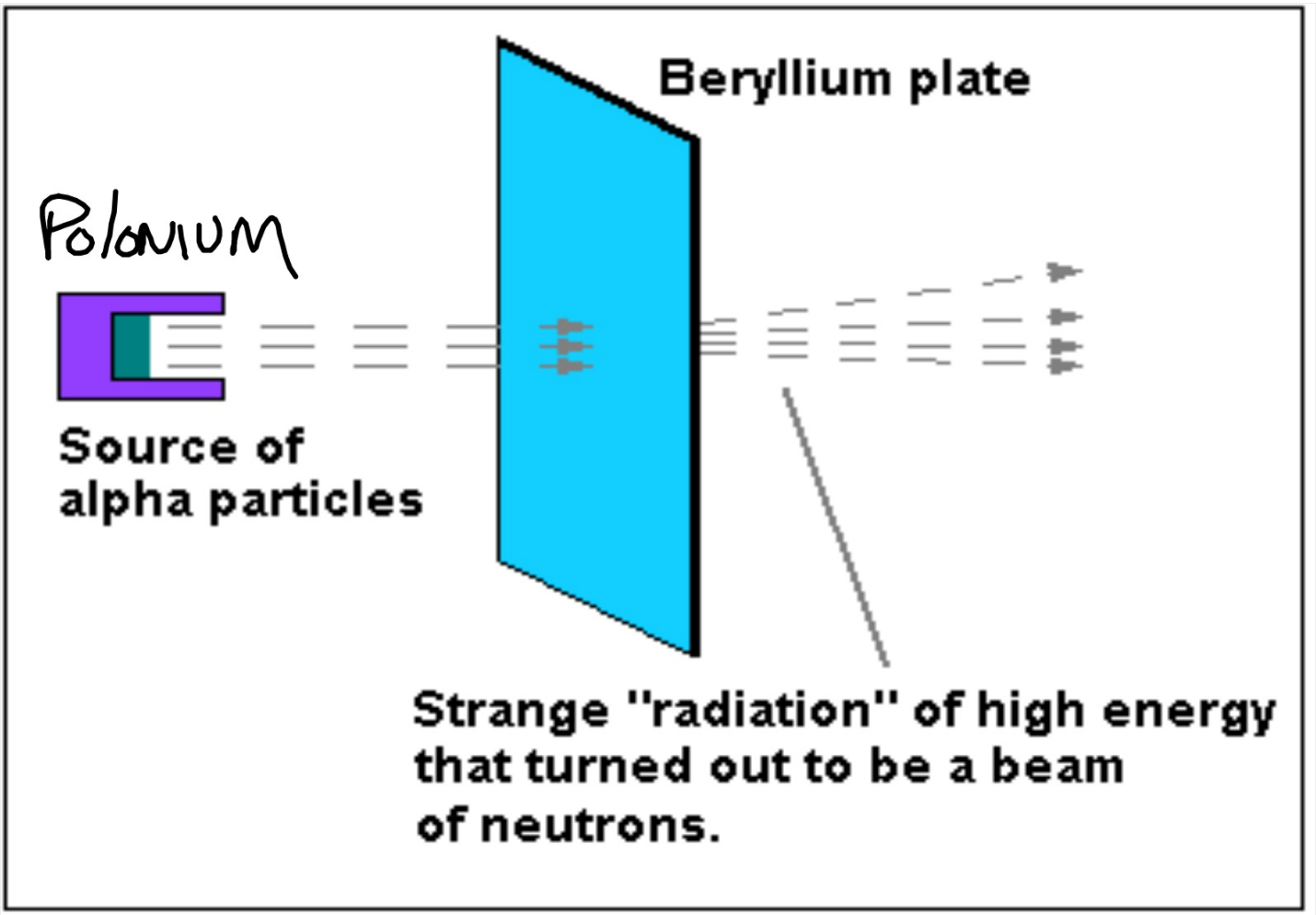
particle	symbol	Charge	mass
PROTON	p^+, $_{+1}^{1}p$	$+1\left(1.602\times10^{-19}\,C\right)$	1 amu
electron	e^-, $_{-1}^{0}e$	$-1\left(-1.602\times10^{-19}\,C\right)$	$\left(1.672\times10^{-24}\,g\right)$ → 0 amu $\left(9.109\times10^{-28}\,g\right)$

neutron ${}^{1}_{0}n$, ${}^{1}_{0}n^{0}$, 0(0) 1amu (1.674×10^{-24} g)

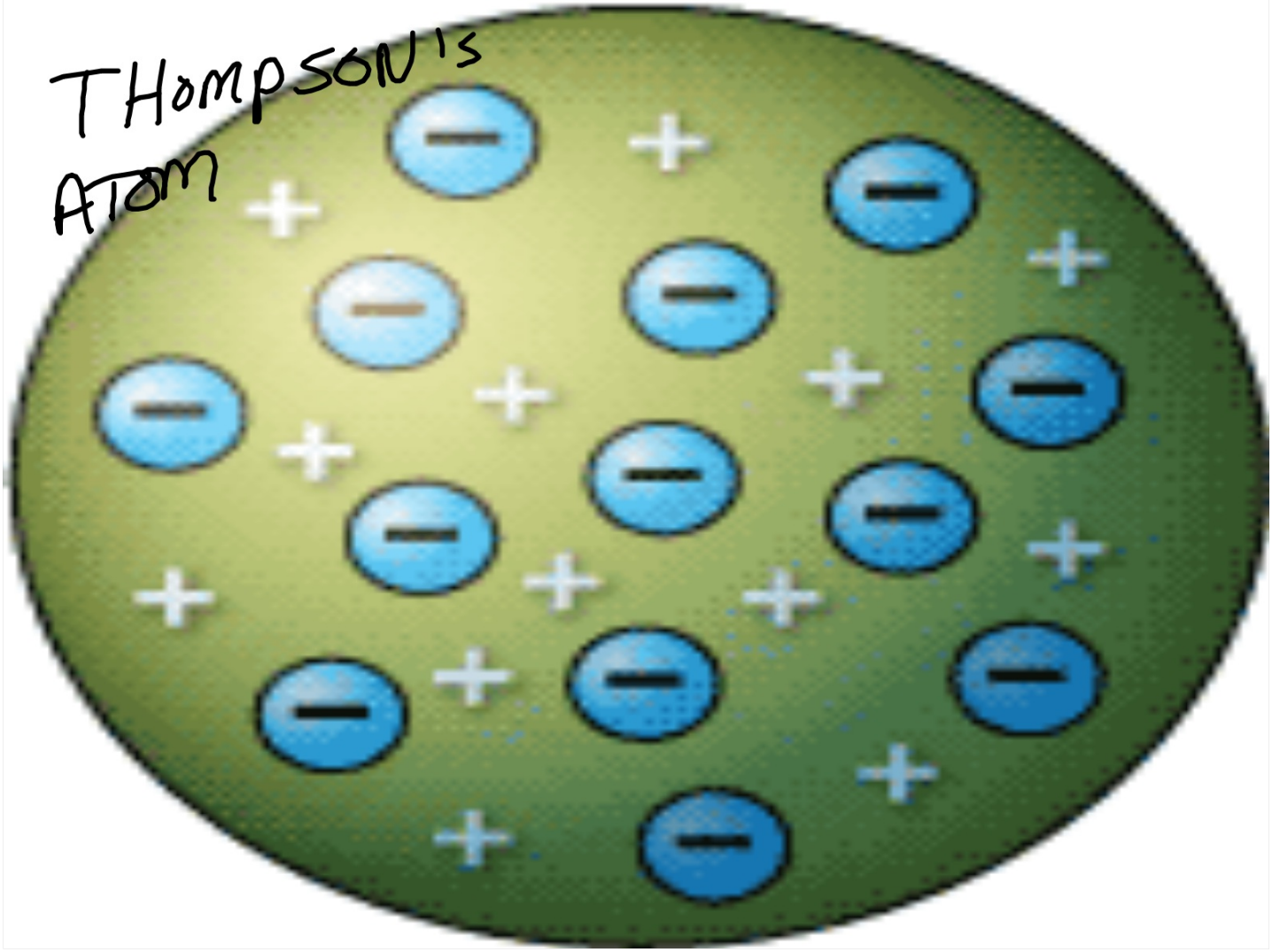
MODELS OF ATOM

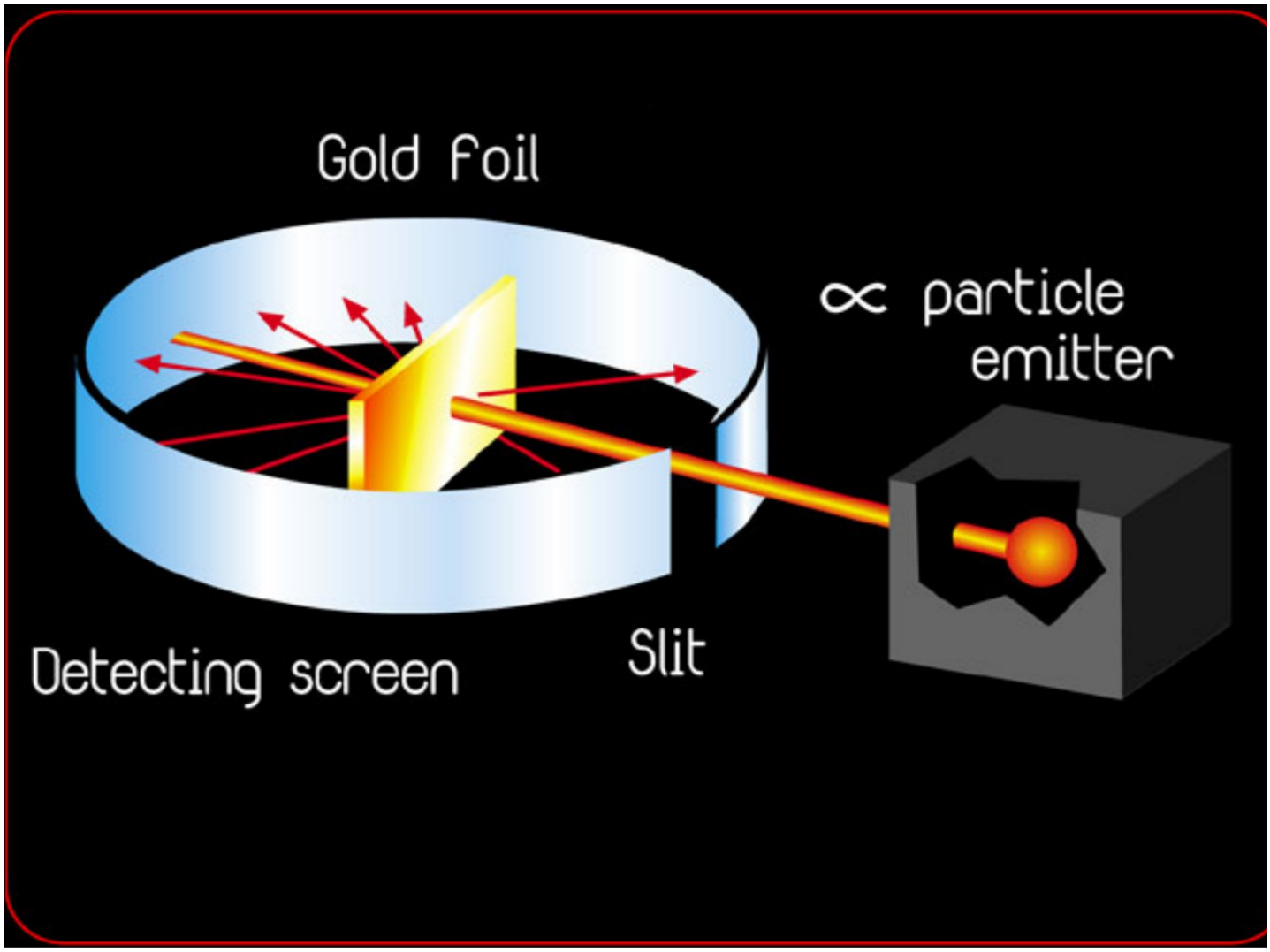
THOMPSON'S MODEL OF ATOM
"PLUM PUDDING"

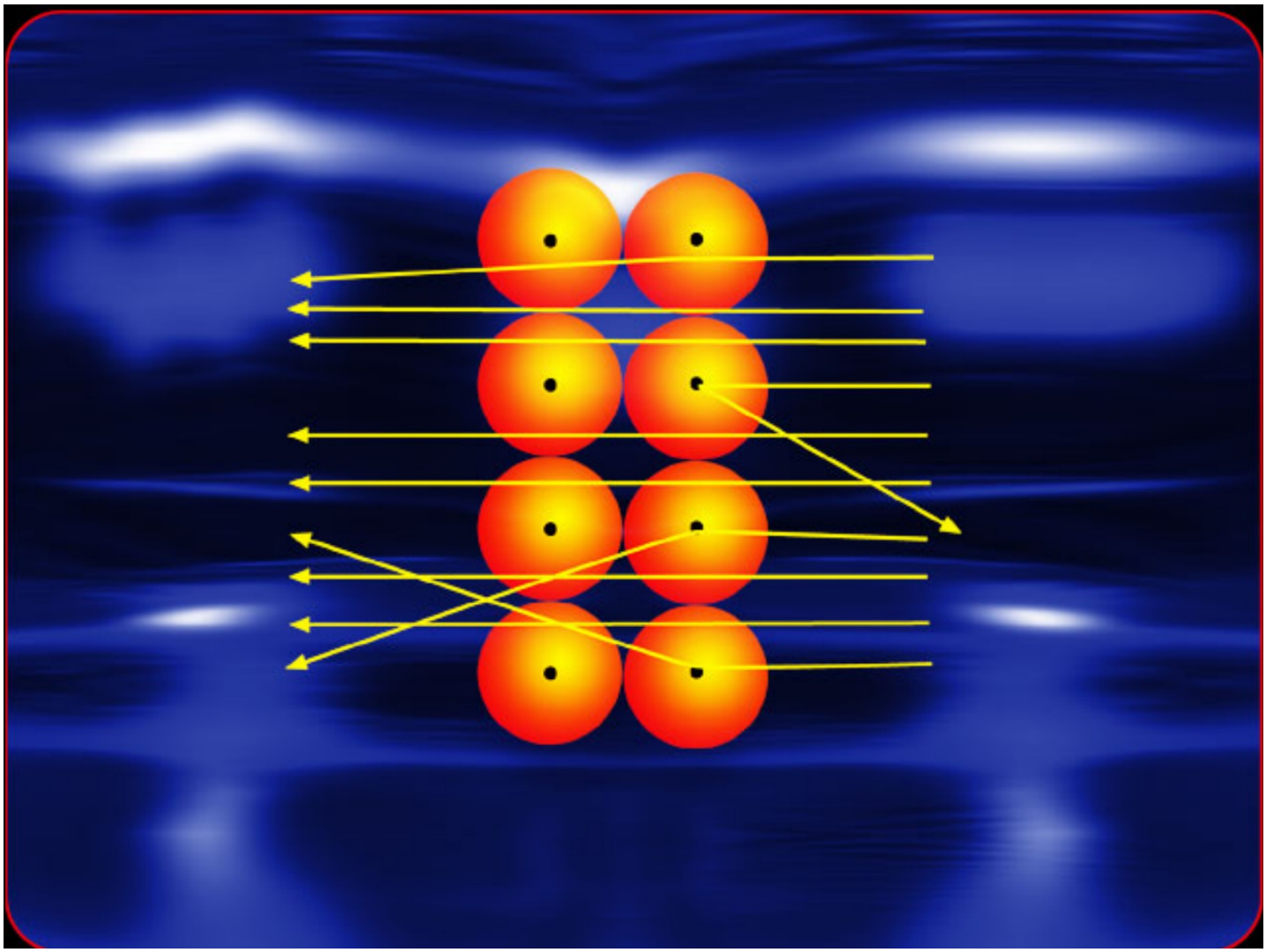
RUTHERFORD "PLANETARY ATOM"



Detection of neutrons

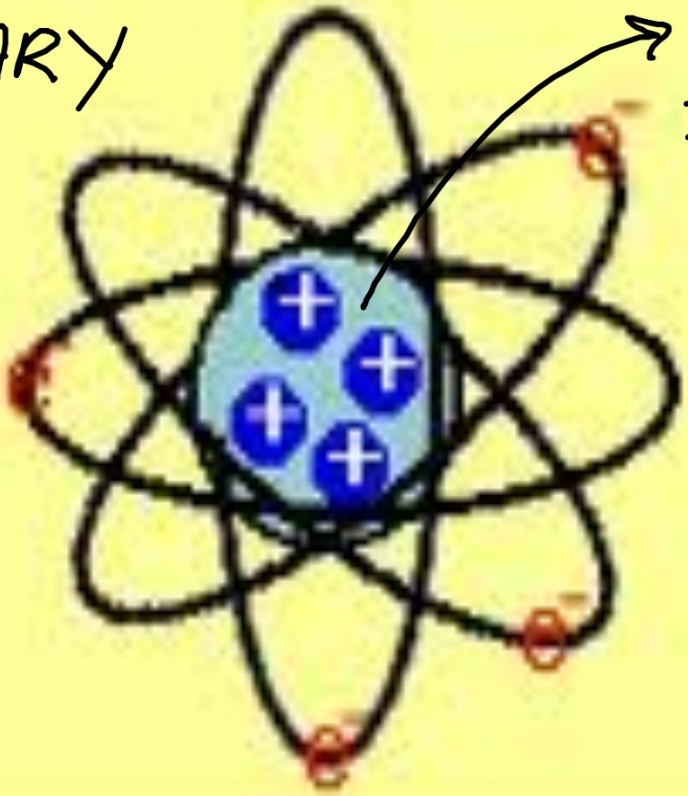

THOMPSON'S
ATOM


Gold foil
∝ particle
emitter
Detecting screen
Slit



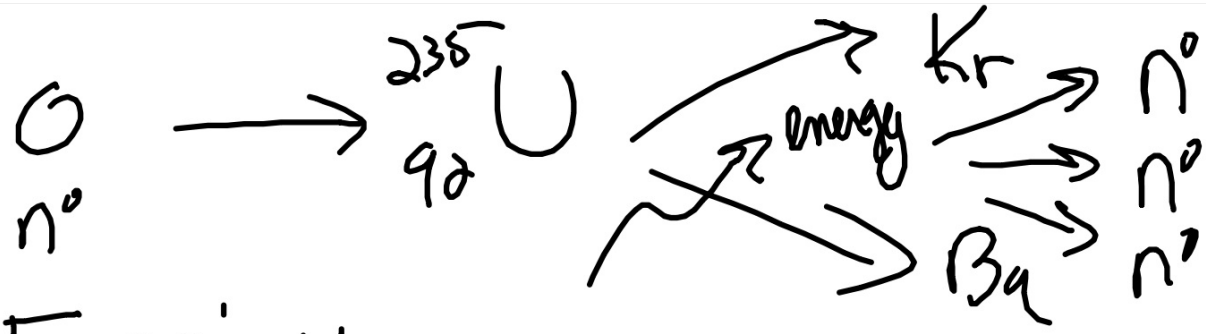
Rutherford's Atom

"PLANETARY ATOM"



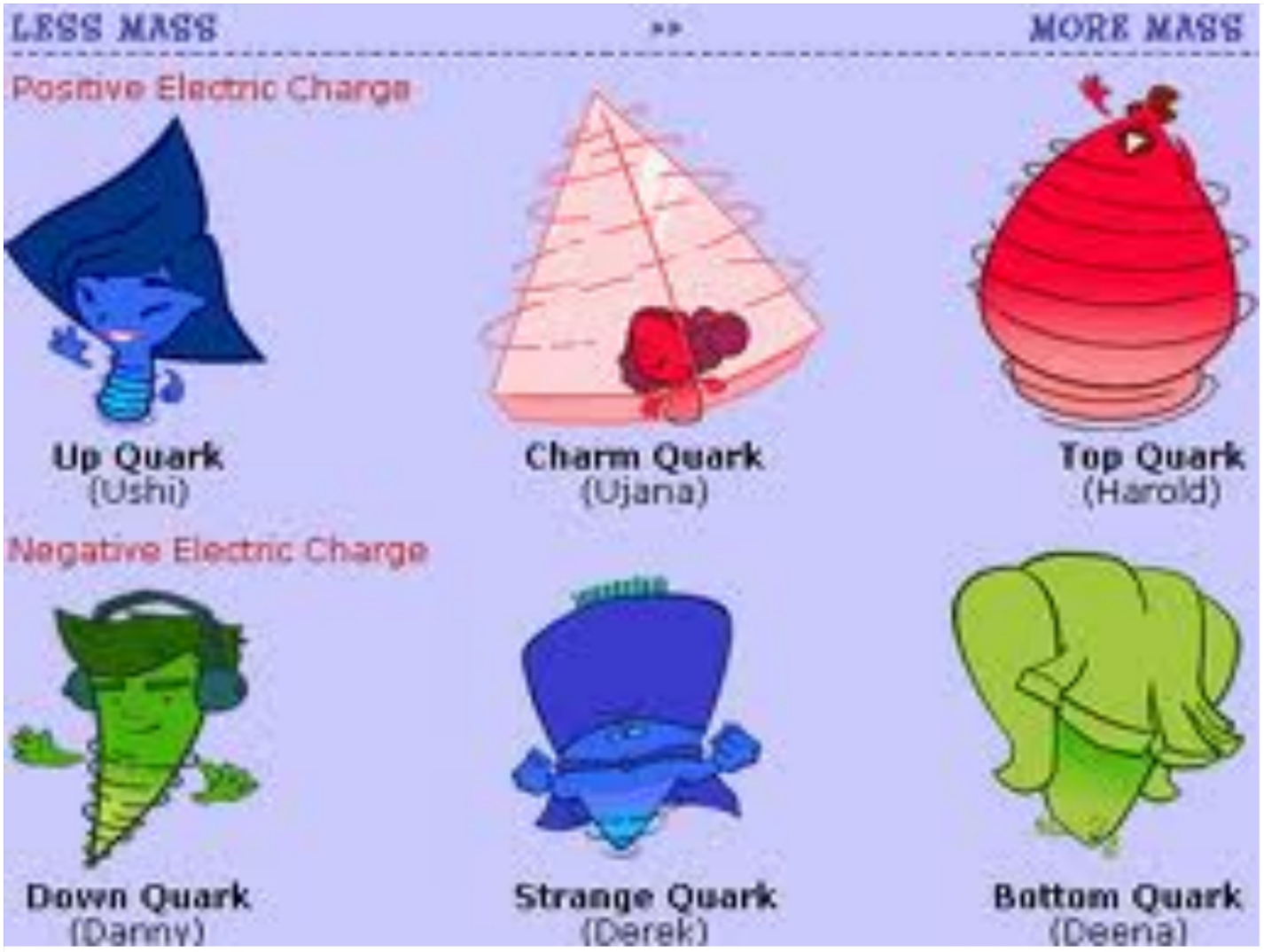
nucleus
tiny core
10^{-12} cm
(10^{-13} cm)

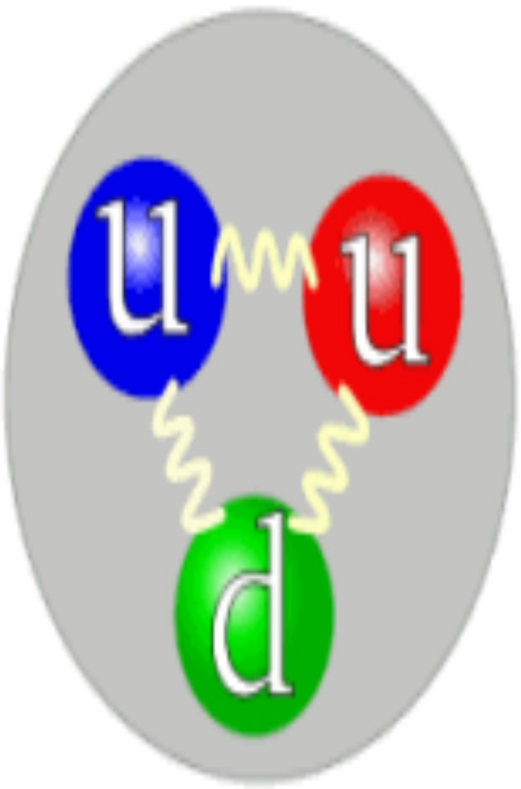
e^-s
100 ± 20
(79 e^-)



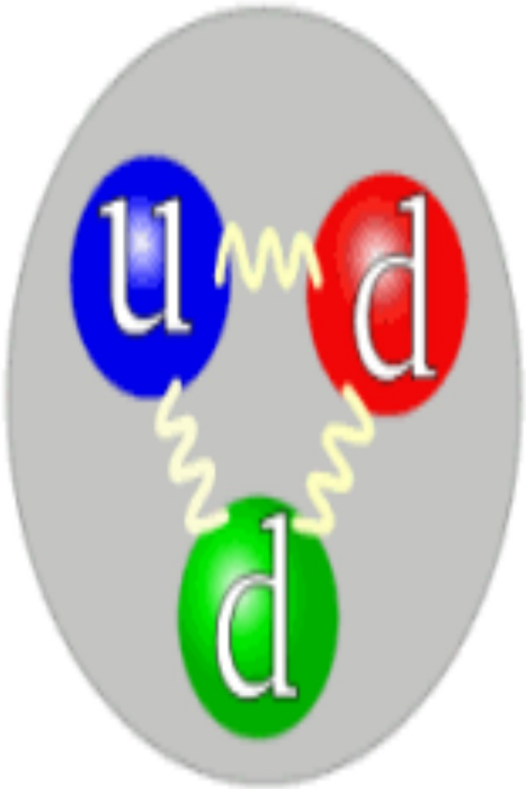
FISSION - SPLITTING AN ATOM

UP TO 100 other particles IN THE NUCLEUS


LESS MASS
MORE MASS
Positive Electric Charge
Up Quark
(Ushi)
Charm Quark
(Ujana)
Top Quark
(Harold)
Negative Electric Charge
Down Quark
(Danny)
Strange Quark
(Derek)
Bottom Quark
(Deena)

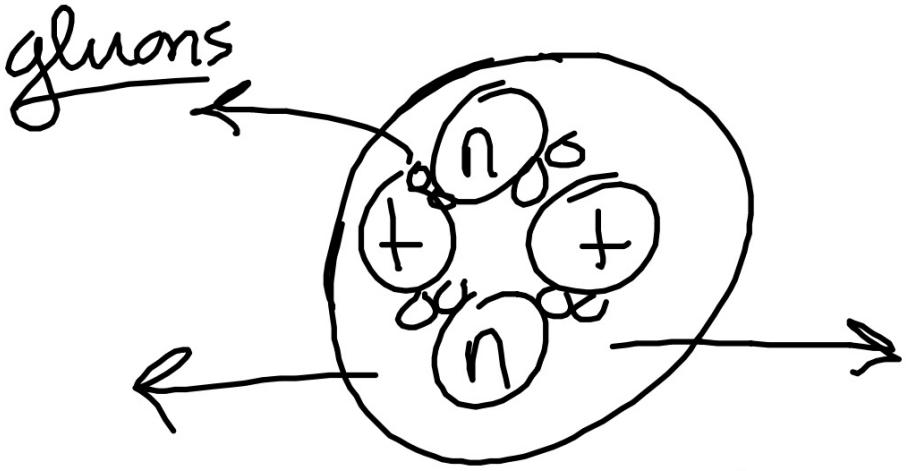


Proton

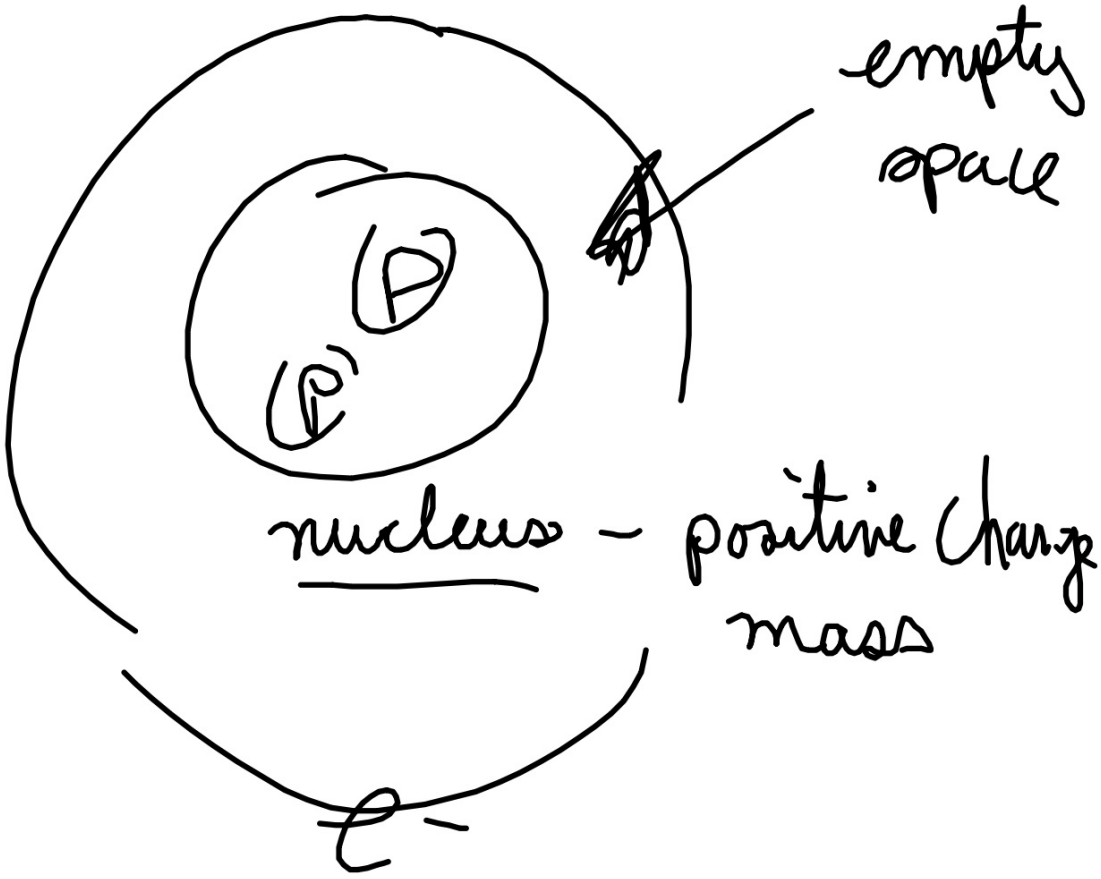


Neutron

Quark composition of a proton and a neutron (diagrams from *Wikipedia*)



nucleus is held together by a strong force – nuclear binding force

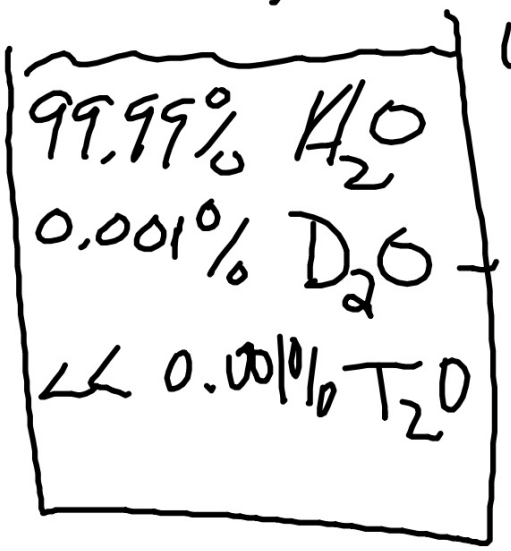

empty space
P
P
nucleus - positive charge mass
e-

isotopes atoms of an element with different masses

isotopes of H

names (symbol)	p+	n°	mass	abundance
hydrogen-1 (protium) ($^{1}_{1}H$)	1	0	1	99.99%
hydrogen-2 (deuterium) ($^{2}_{1}H$)	1	1	2	0.001%

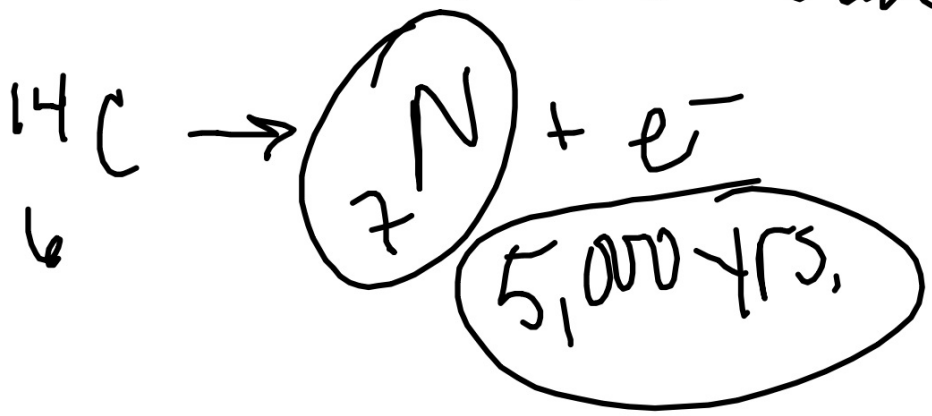
hydrogen-3 ($^{3}_{1}H$) 1 2 3 $<<$ 0.001%
(tritium) radioactive - β emitter



$^{12}_{6}C$ Carbon-12

$^{13}_{6}C$ Carbon-13

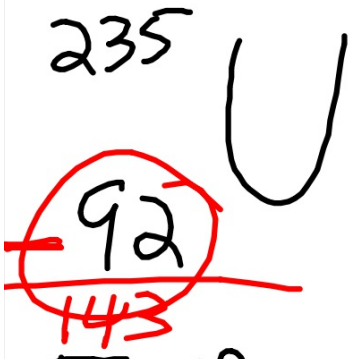
$^{14}_{6}C$ Carbon-14 radioactive



atomic number (Z)
(nuclear charge)
gives the number of protons

mass number (A)
gives protons + neutrons

number of protons = 1
number of electrons = 1
number of neutrons = A - Z = 0



FIND

number of protons = 92

number of electrons = 92

number of neutrons = 143, 146

boron-10 19.91% 10.0129 amu

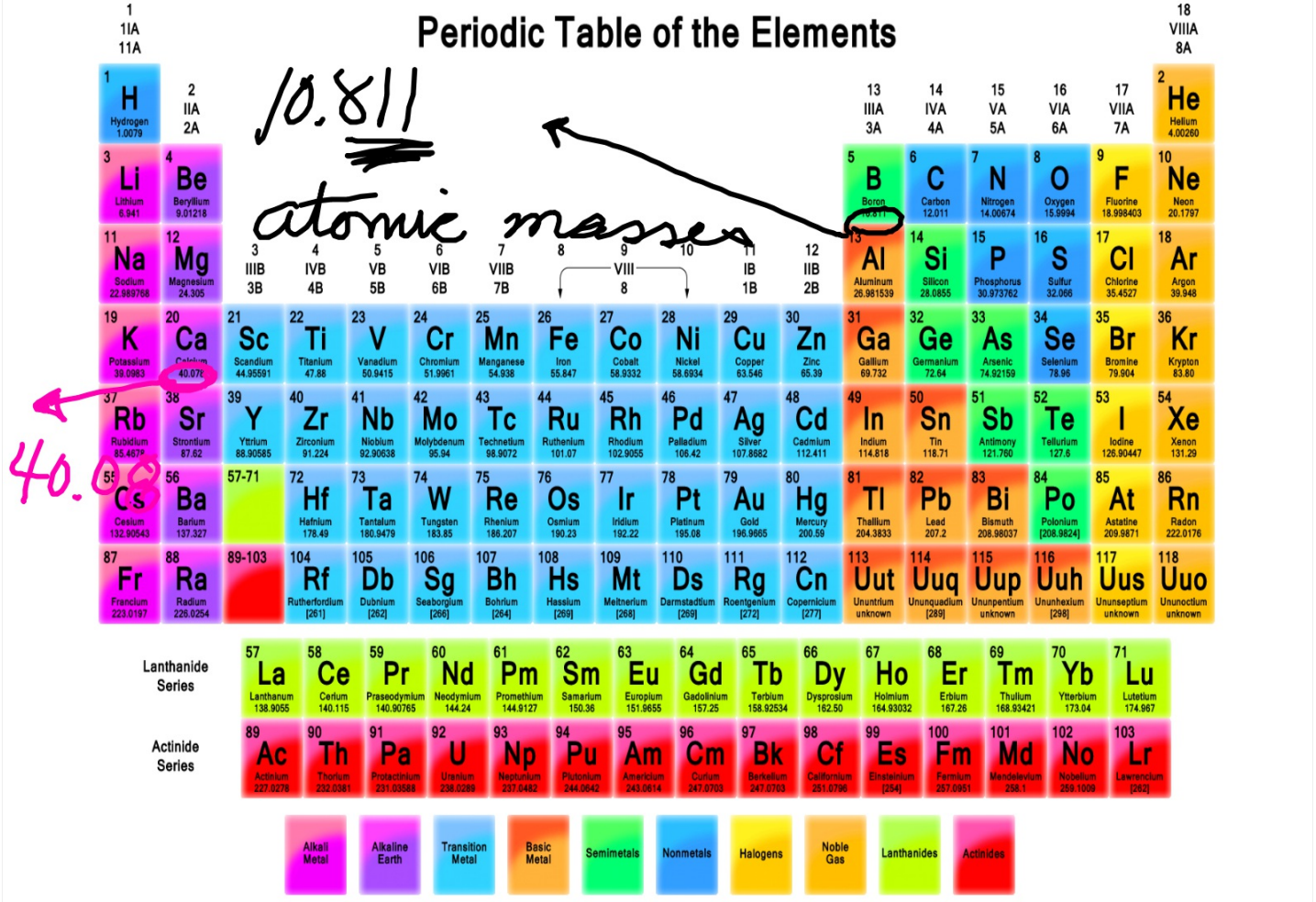
boron-11 80.09% 11.0093 amu

$$\text{atomic mass} = \frac{(\%\ \text{isotope 1})(\text{mass}) + (\%\ \text{isotope 2})(\text{mass})}{100}$$

$$\text{atomic mass B} = \frac{(\%\ \text{B-10})(\text{mass B-10}) + (\%\ \text{B-11})(\text{mass B-11})}{100}$$

$$= \frac{(19.91\%)(10.0129\ \text{amu}) + (80.09\%)(11.0093\ \text{amu})}{100\%}$$

$$= 10.81\ \text{amu}$$


Periodic Table of the Elements
10.811
atomic masses
40.08

THE MOLE CONCEPT *

1 mole (mol, n) of a any substance contains 6.022×10^{23} (Avogadro's Constant, N_A) atoms or molecules and has a mass equal to its atomic or molecular mass in grams

1 mol H contains 6.022×10^{23} atoms of H and has a MASS OF 1.008 g.

whereas 1 mol of Fe contains 6.022×10^{23} atoms of Fe and has mass of 55.8 g

$$\text{atoms} = (\text{mols})(N_A)$$

$$N_A = 6.022 \times 10^{23} \frac{\text{atoms}}{\text{mol}}$$

$$*\text{mols} = \frac{\text{atoms}}{N_A}$$

$$*\text{mols} = \frac{g}{\text{at. mass}} \qquad g = (\text{mol})(\text{at. mass})$$

$$\text{at. mass} = \frac{g}{\text{mol}}$$

Example number of atoms

How many atoms are contained in 80.0g of calcium (Ca)?

$$\text{atoms} = (\text{mols})(N_A)$$

$$= (2\ \text{mol})\left(6.022 \times 10^{23}\ \frac{\text{atoms}}{\text{mol}}\right)$$

$$= 1.2 \times 10^{24}\ \text{atoms}$$

$$\text{mol Ca} = \frac{\text{g Ca}}{\text{at. mass Ca}}$$

$$= \frac{80.0 \text{ g Ca}}{40.08 \frac{\text{g}}{\text{mol}}}$$

$$= 2 \text{ mol}$$

Example 2 number of grams

How much would 4.8×10^{24} atoms of magnesium (Mg) mass out to?

$$g = (\text{mol})(\text{at. mass})$$

$$= (8 \text{ mol})\left(24 \text{ g/mol}\right) = 180 \text{ g}$$

$$\text{mol Mg} = \frac{\text{atoms Mg}}{N_A}$$

$$= \frac{4.8 \times 10^{24} \text{ atoms Mg}}{6.022 \times 10^{23} \frac{\text{atoms}}{\text{mol}}}$$

$$\approx 8 \text{ mols}$$

Worksheet

1a-h $\text{mol} = \dfrac{\text{g}}{\text{at mass}}$

1b $\text{mol Fe} = \dfrac{280\text{ g}}{55.8\text{ g/mol}}$

1. $i - l$

$$mol = \frac{atoms}{N_A}$$

$$N_A = 6.022 \times 10^{23} \frac{atoms}{mol}$$

$l\ m - p$ $\quad atoms = (mol)(N_A)$

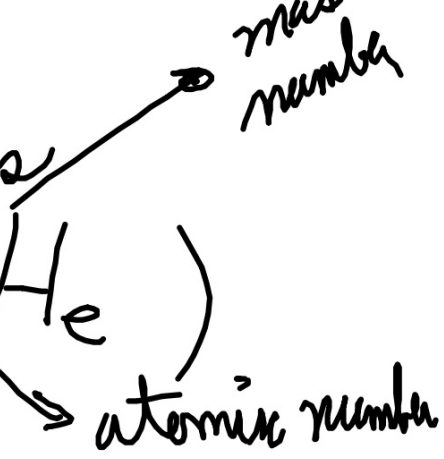
NUCLEAR CHEMISTRY

alpha particles (α)

is a helium nucleus

2 p+s and 2 n°s

penetrating power = 1



e.g. $^{238}_{92}U \longrightarrow {}^{4}_{2}H + {}^{234}_{90}Th$

terms: nucleon is a particle found in the nucleus of an atom (p^+s and n^0s)

$^{238}_{-92}U$

$92p^+s + 146n^0s = 238$ nucleons

specified number of n^0s and p^+s the particle is called a nuclide

radionuclide → radioactive nucleus

$^{238}_{92}U$ $^{235}_{92}U$ are isotopes

Los Alamos LAB

radioisotopes

* Law of Conservation of Matter

a given amount of matter in the universe that can not be added to or subtracted from.

$$^{238}_{92}U \longrightarrow {}^{4}_{2}He + {}^{234}_{90}Th$$

$$238 = 4 + 234$$

$$92 = 2 + 90$$

<u>beta particle</u> (β) an e^- $\left({}^{0}_{-1}e, {}^{0}_{-1}\beta\right)$

penetrating power = 100

$${}^{1}_{0}n \longrightarrow {}^{1}_{+1}p + {}^{0}_{-1}e$$

$$^{32}_{15}P \longrightarrow {}^{0}_{-1}e + {}^{32}_{16}S$$

gamma radiation (γ)

very high energy light

penetrating power = 10,000

$$^{125}_{53}I \longrightarrow {}^{125}_{54}X_e + {}^{0}_{-1}e + \gamma$$

Position emission

Charged e^- ($^{0}_{+1}e$) positively antimatter

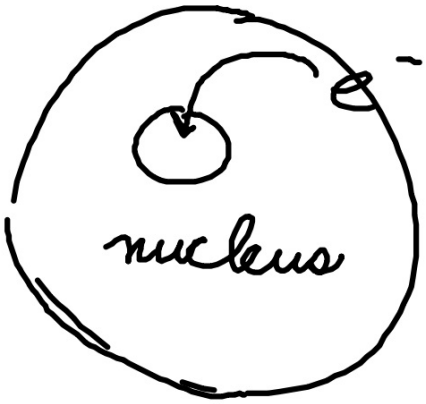
emitted

to $^{0}_{-1}e$

$$^{1}_{+1}p \longrightarrow {}^{0}_{+1}e + {}^{1}_{0}n$$

$$^{11}_{6}C \longrightarrow {}^{0}_{+1}e + {}^{12}_{6}C$$

electron Capture



$$^{1}_{+1}p + ^{0}_{-1}e \rightarrow ^{1}_{0}n$$

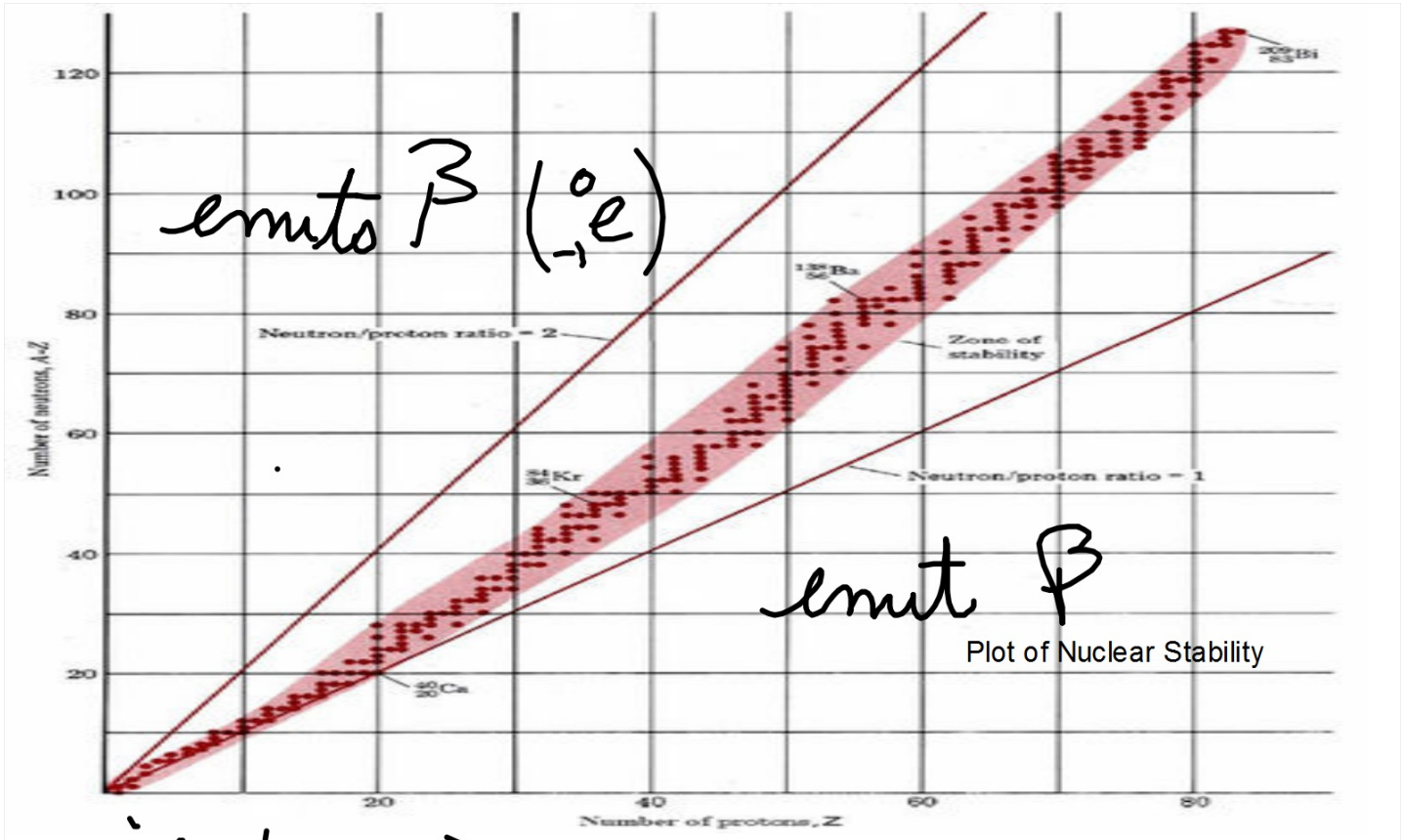
$$^{81}_{37}Rb + ^{0}_{-1}e \rightarrow ^{82}_{37}Rb$$

Radioactivity is the result of an unstable nucleus

$_{1}^{1}H$ $_{2}^{2}H_{e}$

neutrons buffer repulsion between positive charges.

need a certain ratio between $_{+1}^{1}P$ and $_{0}^{1}n$ in nucleus

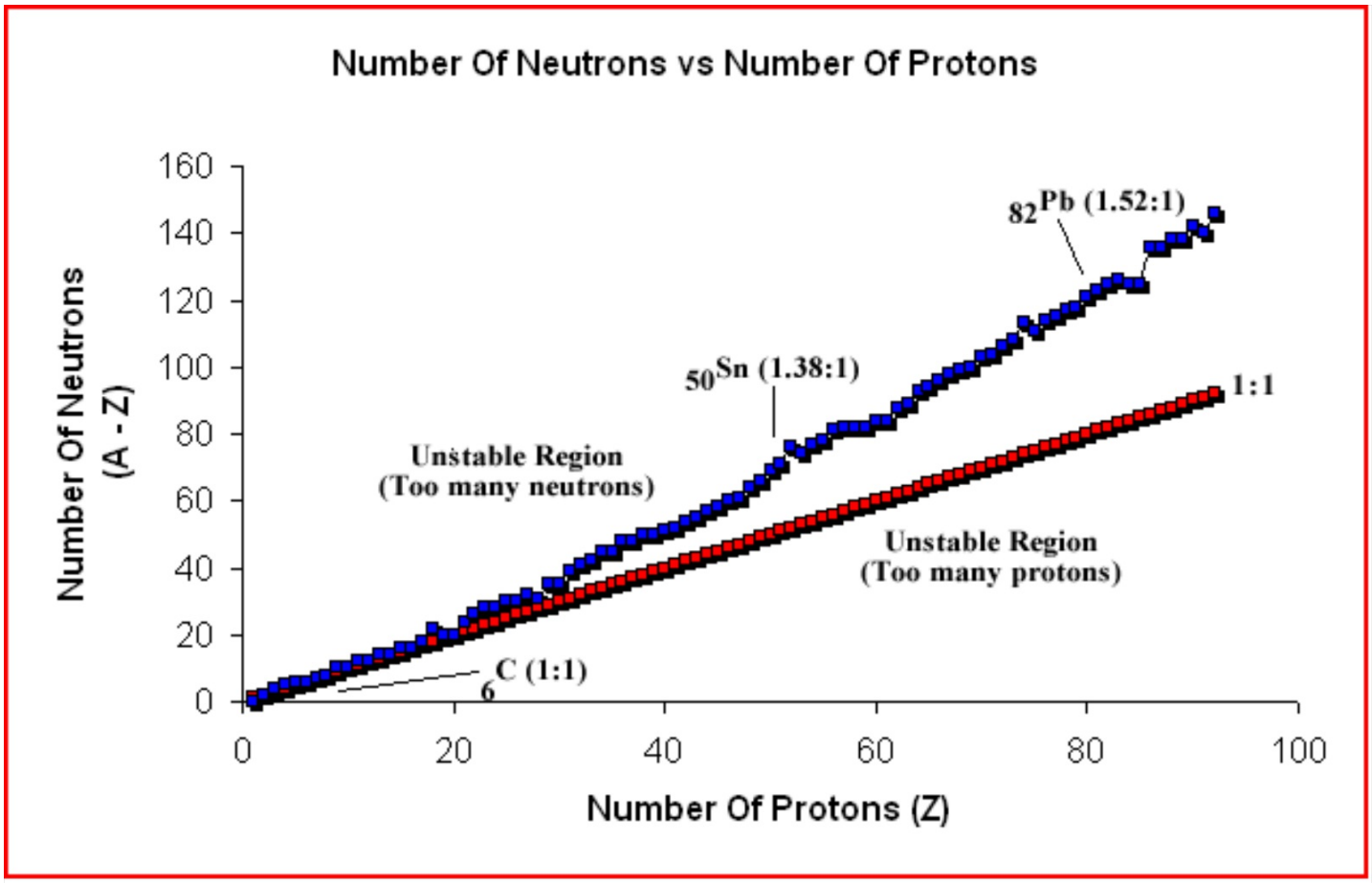


Plot of Nuclear Stability

if at. no. ≥ 84 emits α

$$^{14}_{6}C \longrightarrow {}^{0}_{-1}e + {}^{14}_{7}N$$

radiocarbon dating (Carbon-14 dating)


Number Of Neutrons vs Number Of Protons
Number Of Neutrons (A - Z)
Number Of Protons (Z)
0
20
40
60
80
100
120
140
160
0
20
40
60
80
100
82Pb (1.52:1)
50Sn (1.38:1)
1:1
Unstable Region
(Too many neutrons)
Unstable Region
(Too many protons)
6C (1:1)

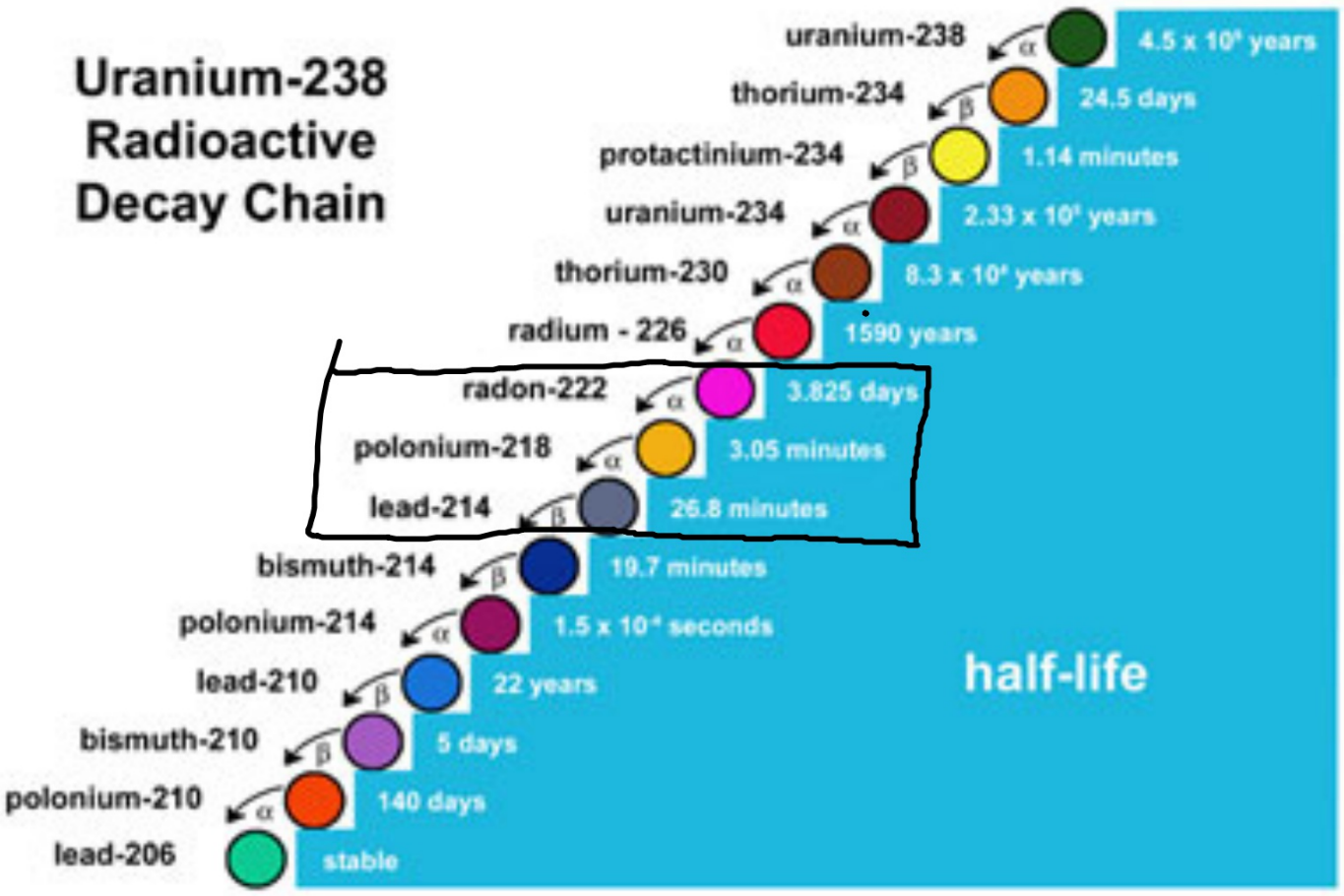
MAGIC NUMBERS FOR STABILITY

based on the theory $^{1}_{+1}p + {}^{1}_{0}n$

exist in energy levels

nuclei with 2, 8, 20, 28, 50, 82 or 114 $^{1}_{+1}p$

or 2, 8, 20, 28, 50, 82, 126 or 184 $^{1}_{0}n$

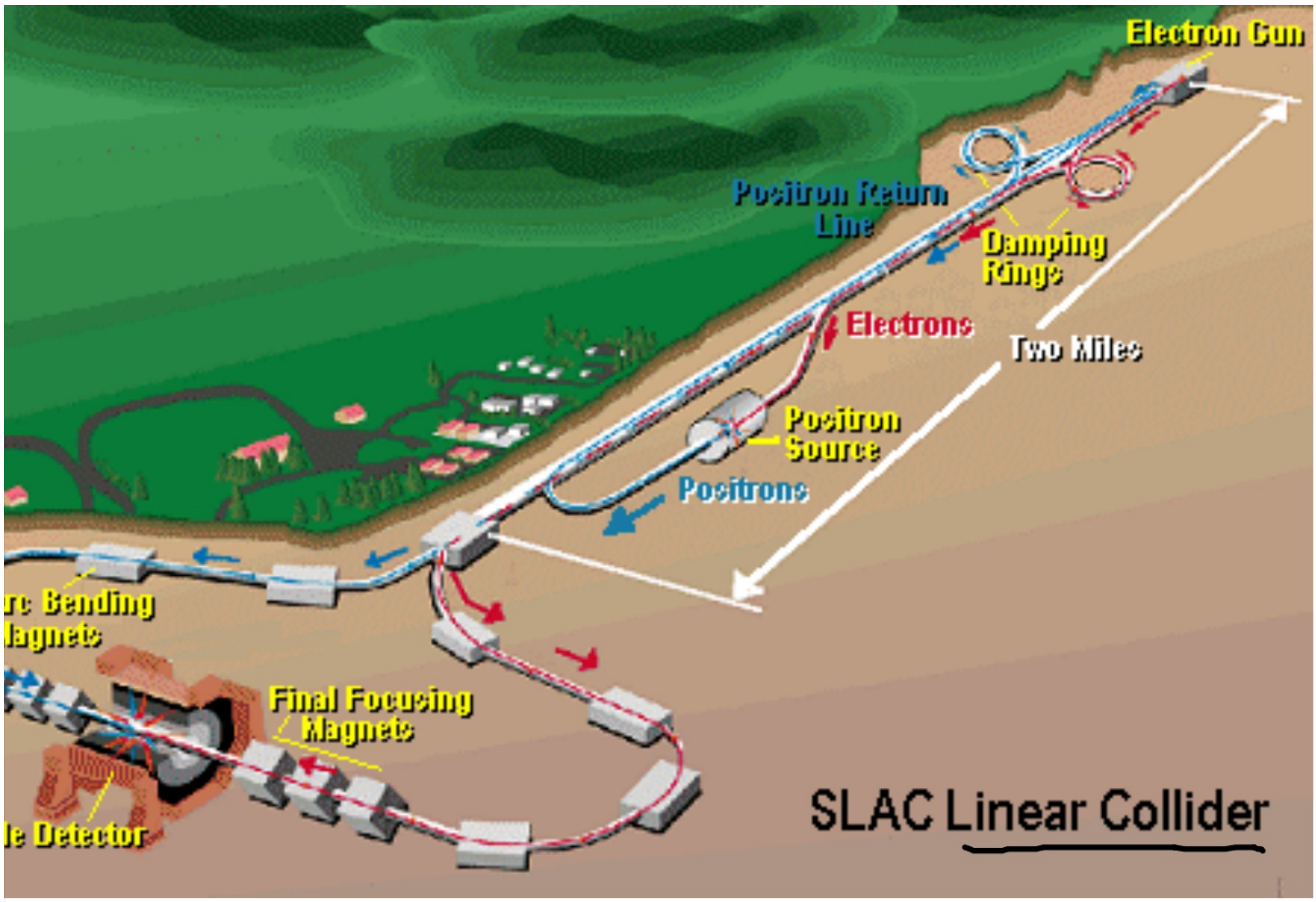

Uranium-238
Radioactive
Decay Chain
uranium-238
α
4.5 x 10⁹ years
thorium-234
β
24.5 days
protactinium-234
β
1.14 minutes
uranium-234
α
2.33 x 10⁵ years
thorium-230
α
8.3 x 10⁴ years
radium - 226
α
1590 years
radon-222
α
3.825 days
polonium-218
α
3.05 minutes
lead-214
β
26.8 minutes
bismuth-214
β
19.7 minutes
polonium-214
α
1.5 x 10⁻⁴ seconds
lead-210
β
22 years
bismuth-210
β
5 days
polonium-210
α
140 days
lead-206
stable
half-life

Nuclear transmutations

form new elements

ex: $^{18}_{8}O + {}^{1}_{1}H \rightarrow {}^{13}_{7}N + {}^{4}_{2}He$

– if done with charged particles moving fast


Electron Gun
Positron Return Line
Damping Rings
Electrons
Two Miles
Positron Source
Positrons
Final Focusing Magnets
SLAC Linear Collider

if particle neutral it doesn't need to be accelerated

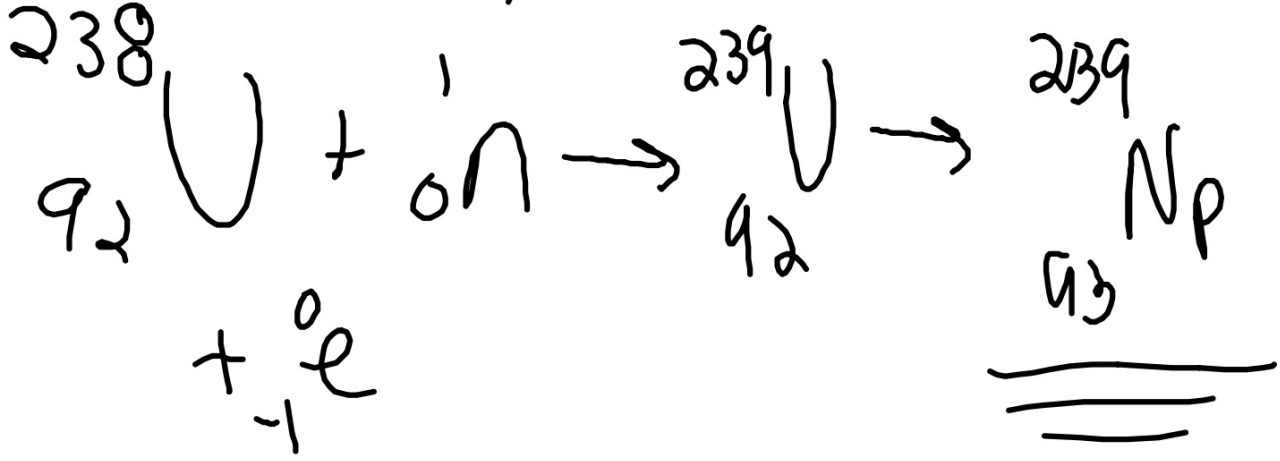
Ex: $^{58}_{26}Fe + {}^{1}_{0}n \longrightarrow {}^{59}_{26}Fe$

$^{59}_{26}Fe \longrightarrow {}^{59}_{27}Co + {}^{0}_{-1}e$

$^{59}_{27}Co + {}^{1}_{0}n \longrightarrow {}^{60}_{27}Co$ nuclear medicine

transuranium elements -
at. no. > 92

1940 GLEN SEABORG
UC BERKLEY



$$^{209}_{83}Bi + ^{64}_{28}Ni \longrightarrow ^{272}_{96}X + ^{1}_{0}n$$

3 atoms

< ms

MAGIC #s 114 p^+s

184 n°

1936 - 1939

Hahns OTTO and Lise Meitner

fired a ${}^{1}_{0}n$ into ${}^{235}_{92}U$ (1%)

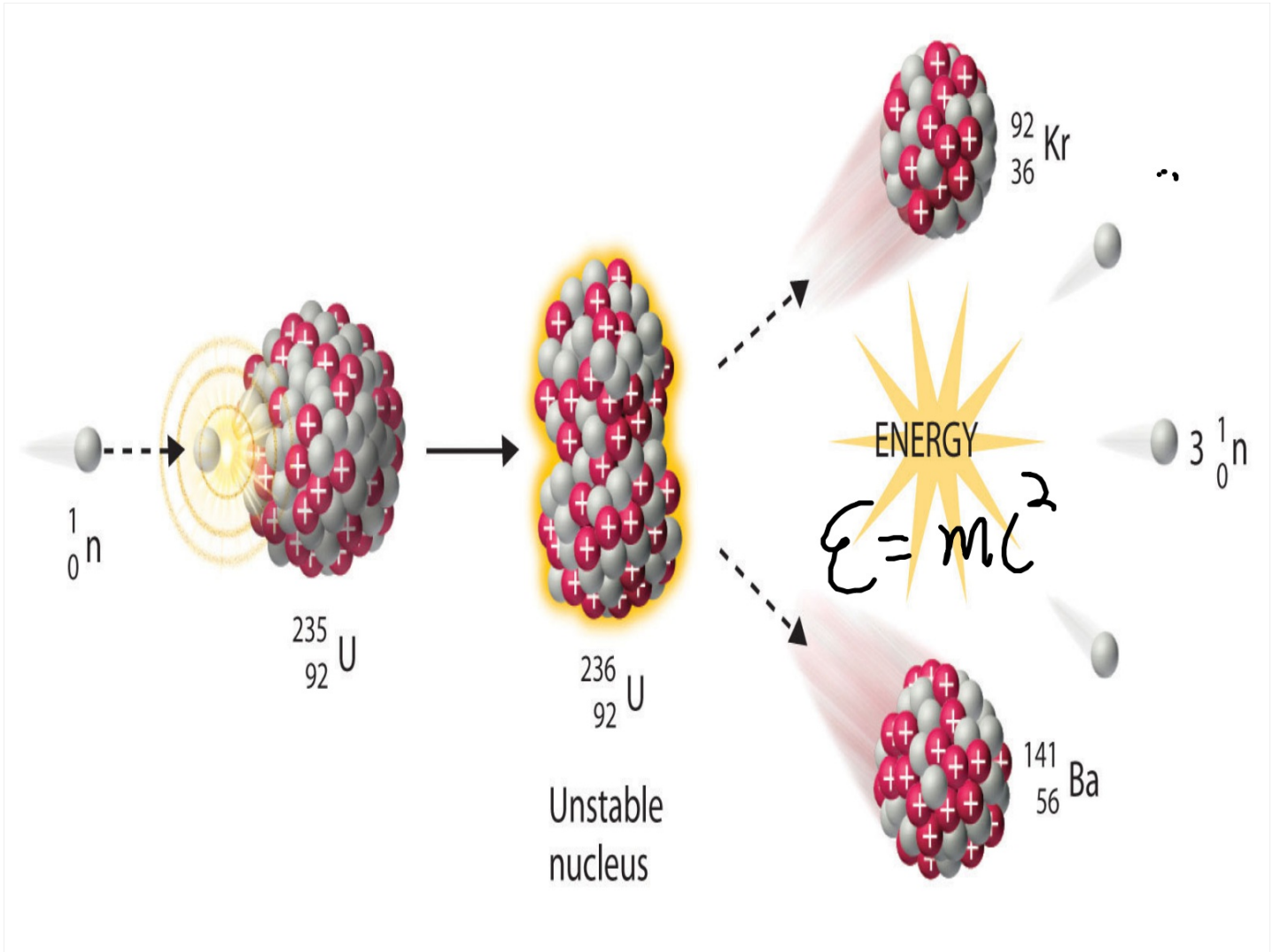
nuclear fission

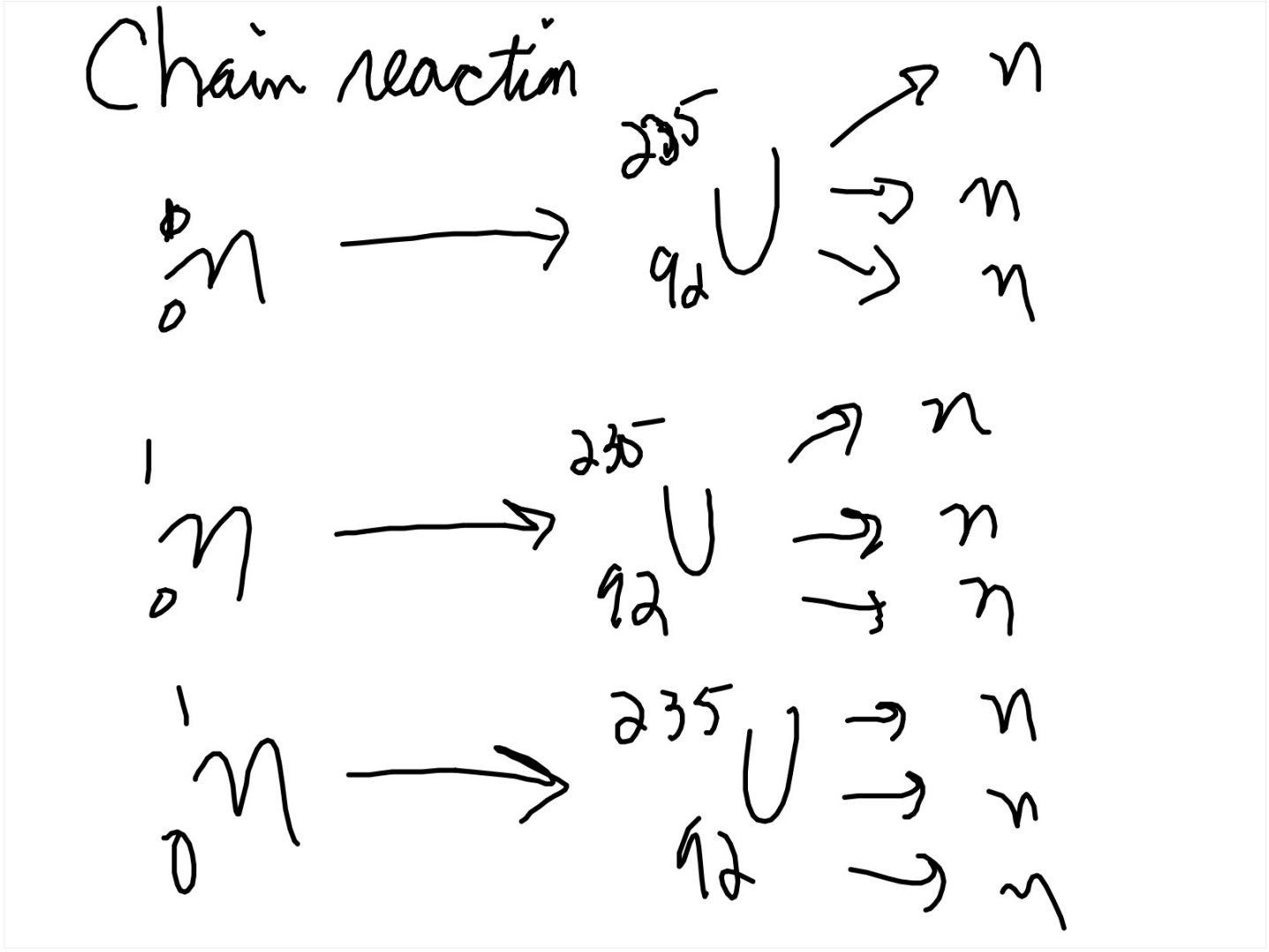
$$^{239}_{93}Np \longrightarrow {}^{239}_{94}Pu + {}^{0}_{-1}e$$

in an accelerator

$$^{239}_{94}Pu + {}^{4}_{2}He \longrightarrow {}^{242}_{96}Cm + {}^{1}_{0}n$$

Curium


$^{1}_{0}n$
$^{235}_{92}U$
$^{236}_{92}U$
Unstable nucleus
$^{92}_{36}Kr$
ENERGY
$E = mc^2$
$3\,^{1}_{0}n$
$^{141}_{56}Ba$


Chain reaction
0 n
235 92 U
n
n
n
1 0 n
235 92 U
n
n
n
1 0 n
235 92 U
n
n
n

2 paths with nuclear fission

(1) control release of n's and harness energy

(2) quick release of energy - bomb

MANHATTAN PROJECT

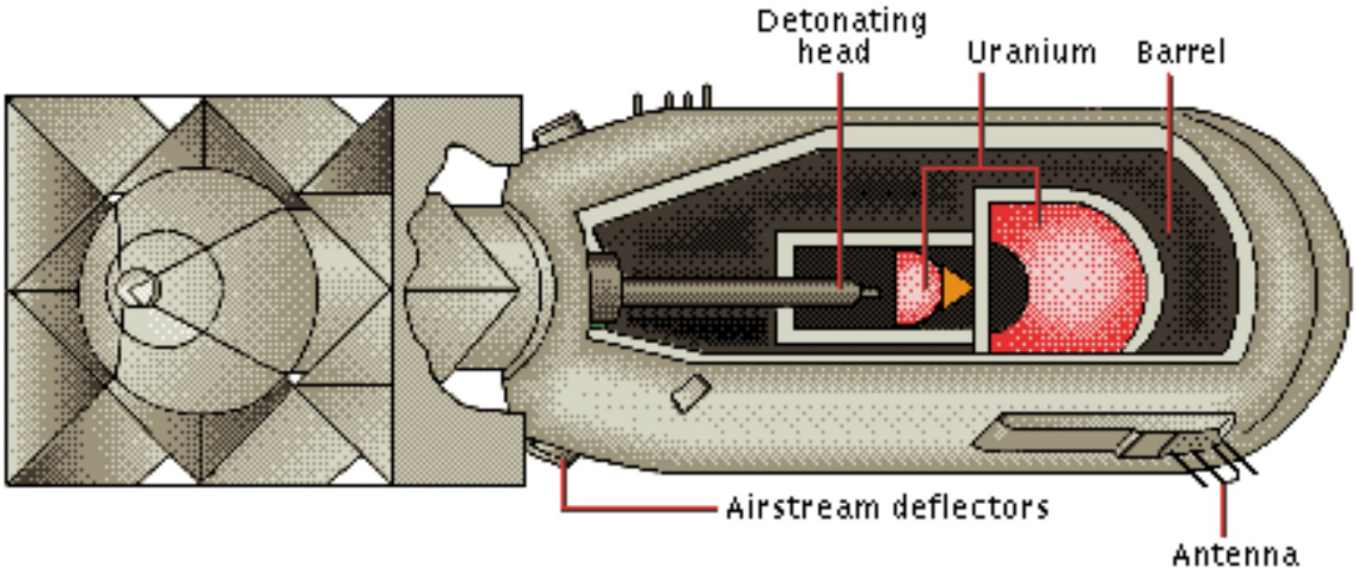
LOS ALAMOS, NM

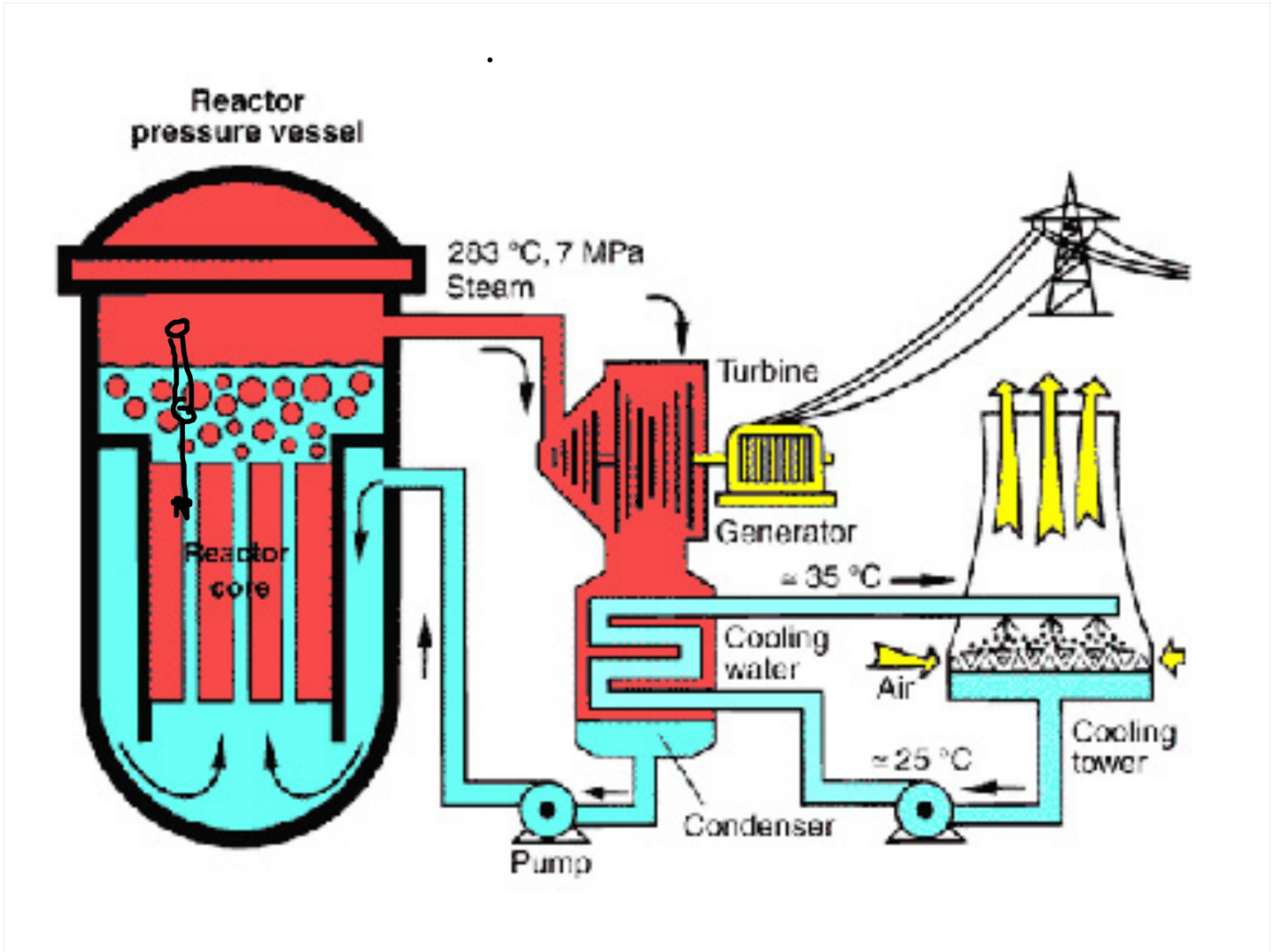
WORKING ON CRITICAL MASS

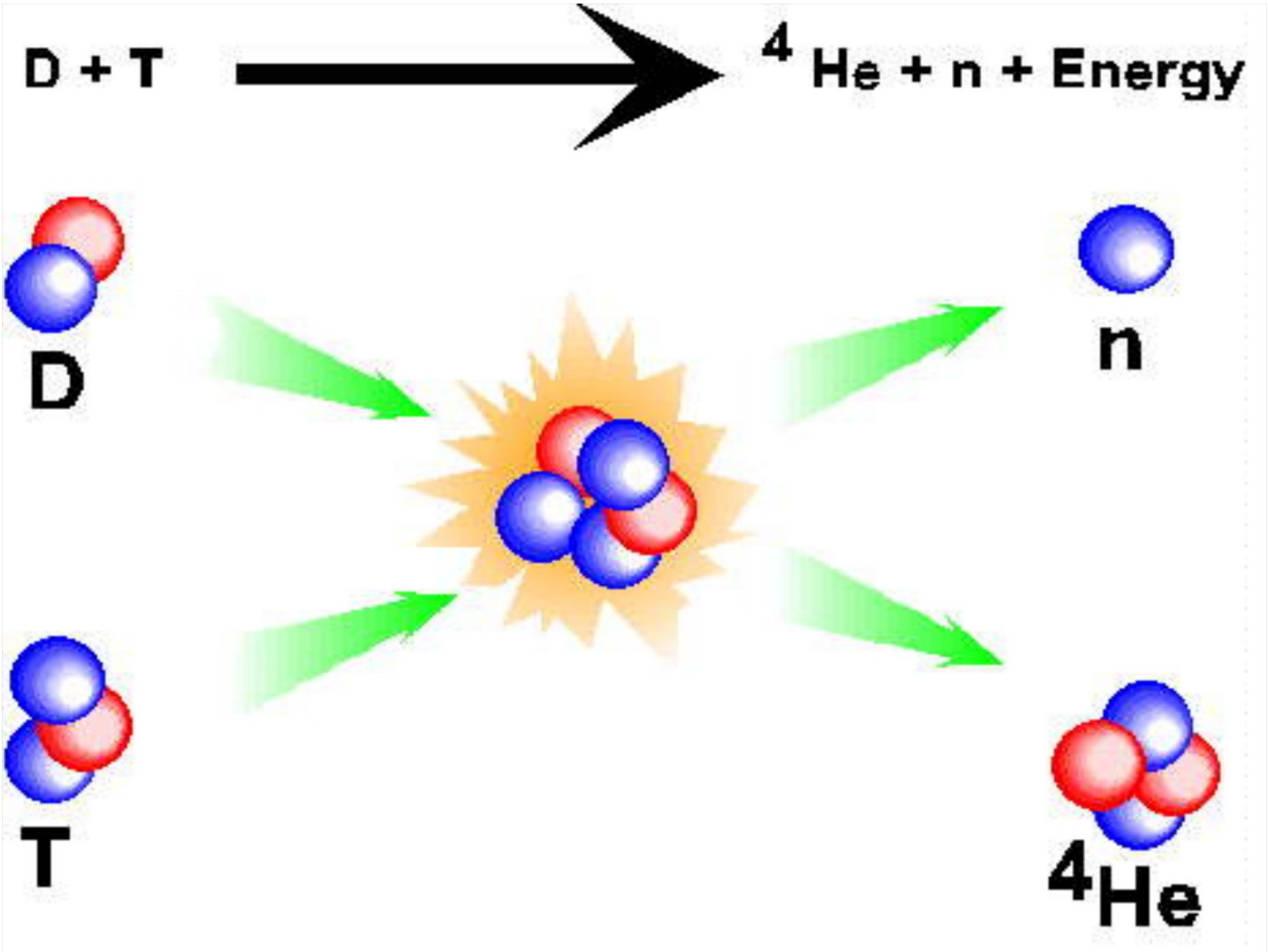
(1 kg - 2.2 lbs)

HANAFORD, WA

U ⟶ Pu


Detonating head
Uranium
Barrel
Airstream deflectors
Antenna


Reactor
pressure vessel
283 °C, 7 MPa
Steam
Turbine
Generator
Reactor
core
≈ 35 °C
Cooling
water
Air
Cooling
tower
≈ 25 °C
Condenser
Pump


D + T
4 He + n + Energy
D
T
n
4He