Chapter 22.
The Nuclear Atom

G2 | Ji Yutong | 11/2023

Atom

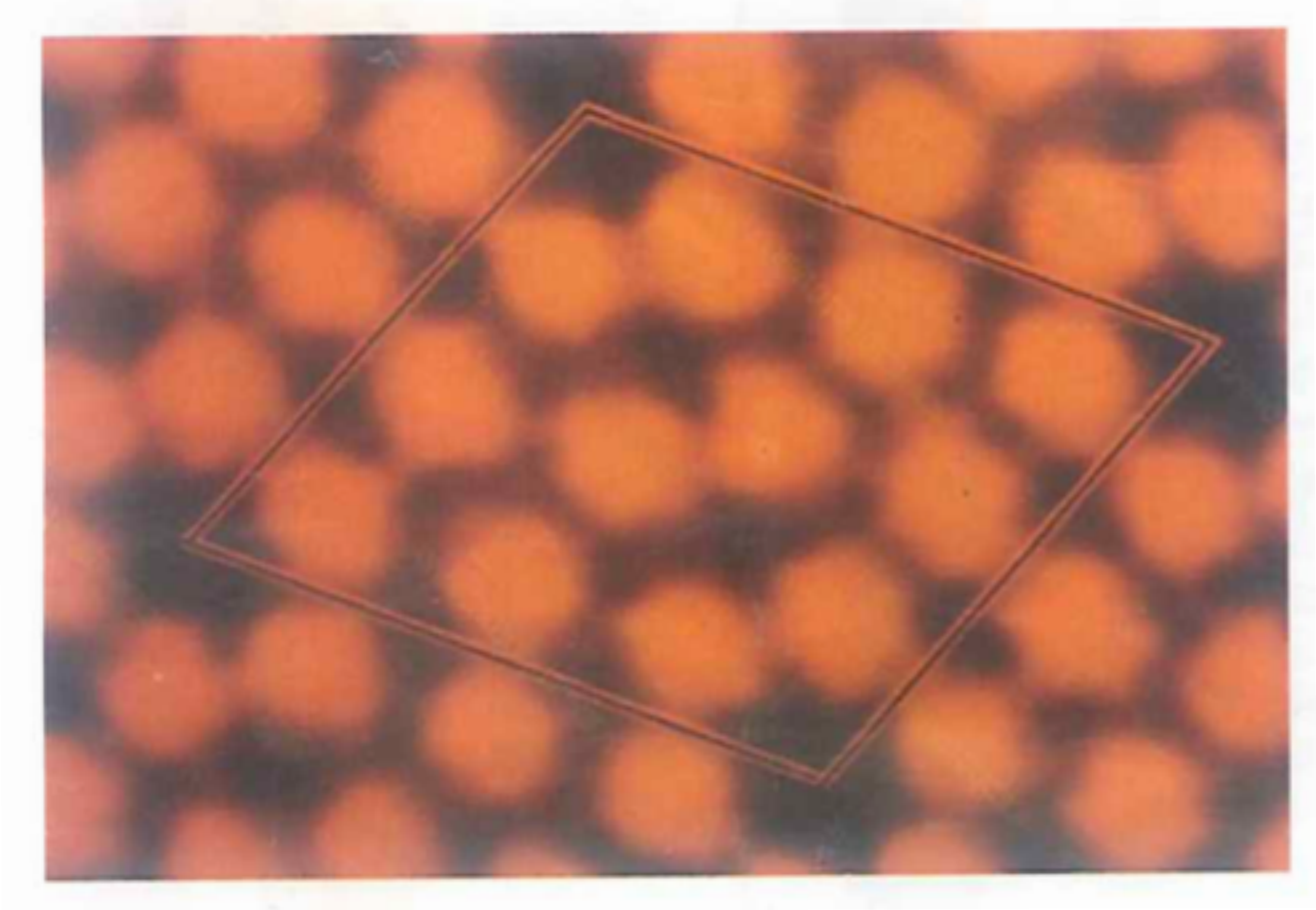
What are we/everything made of?

Atoms:

- very tiny but can be seen
- NEUTRAL

Is atom the smallest particle?

Democritus



- All things are made from indivisible pieces of different shapes and sizes: “atoms”.
- Between these indestructible atoms is only empty space.

Atom Structure

In 1890s, J.J. Thomson discovered a much smaller particle with negative charge =>**electron**.

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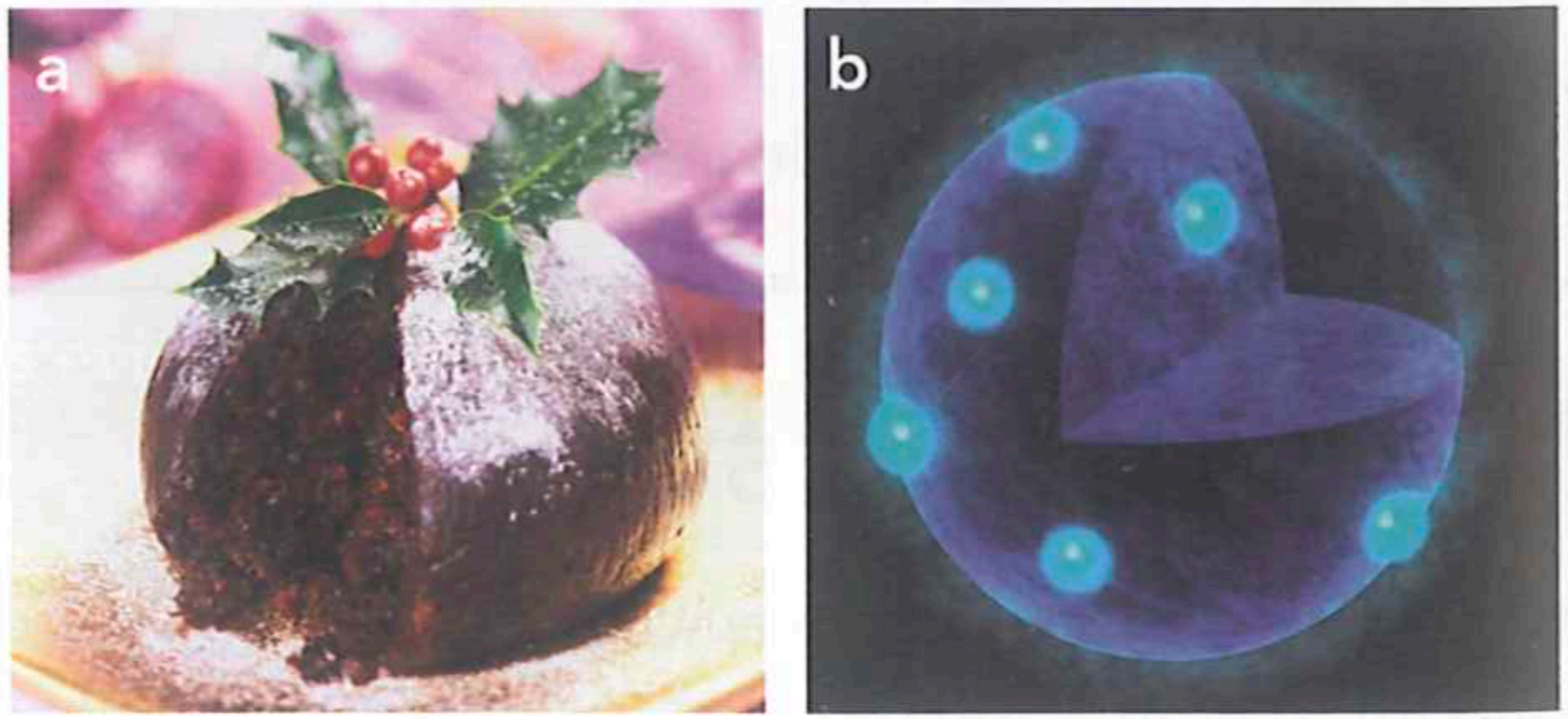
Electrons: mass 1/1836 of a hydrogen atom, carry negative charge.

Atom: overall no charge =>something else with an equal amount of positive charge in the atom,

mass of electron too small => the positive charge account for most of the mass => Plum pudding model

Electrons are the negatively charged plum dotted in a positively charged pudding.

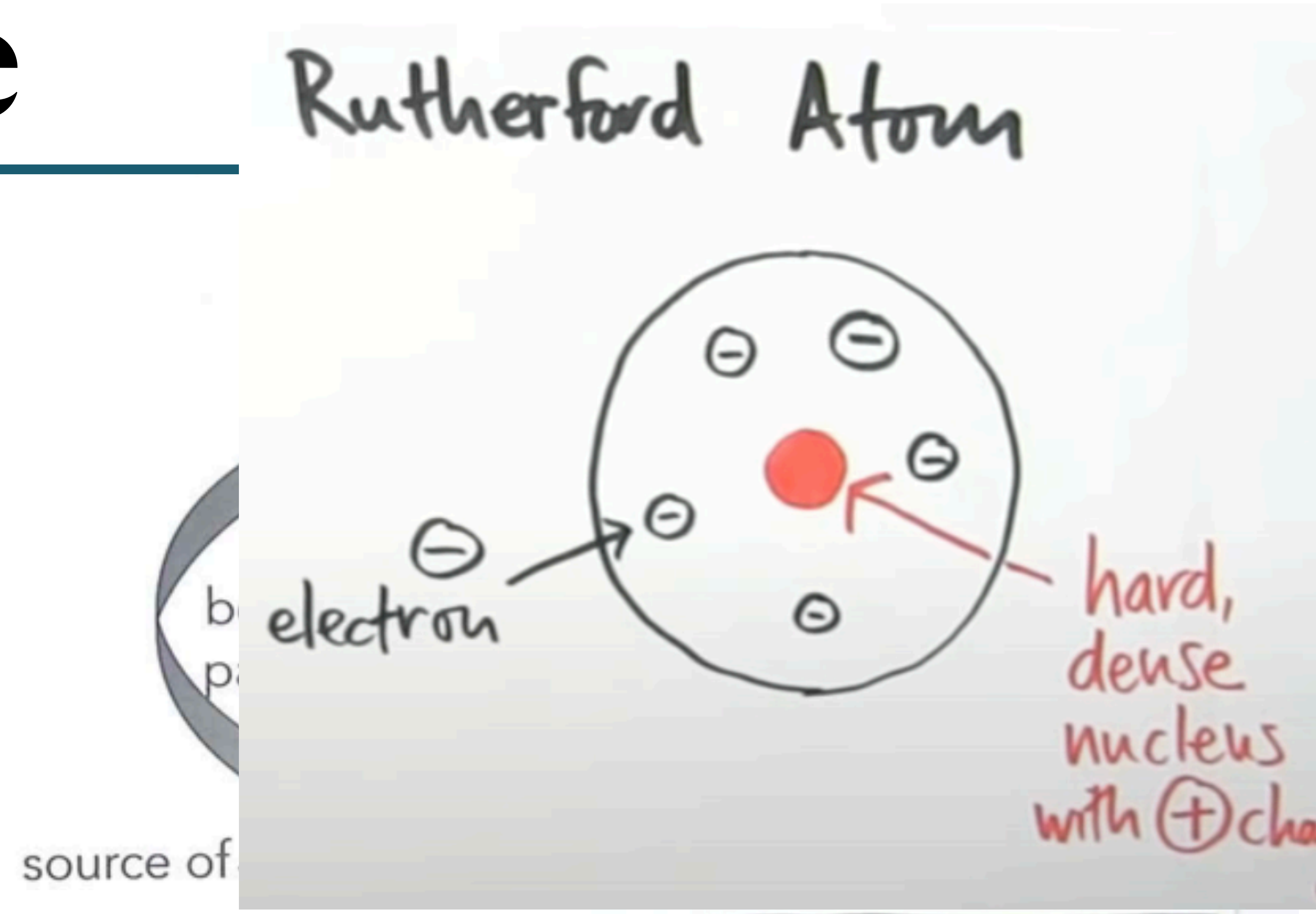


Atom Structure

Is Plum pudding model right? How can you prove it right or w

➜ **Alpha particle scattering experiment**

How was the experiment carried out?

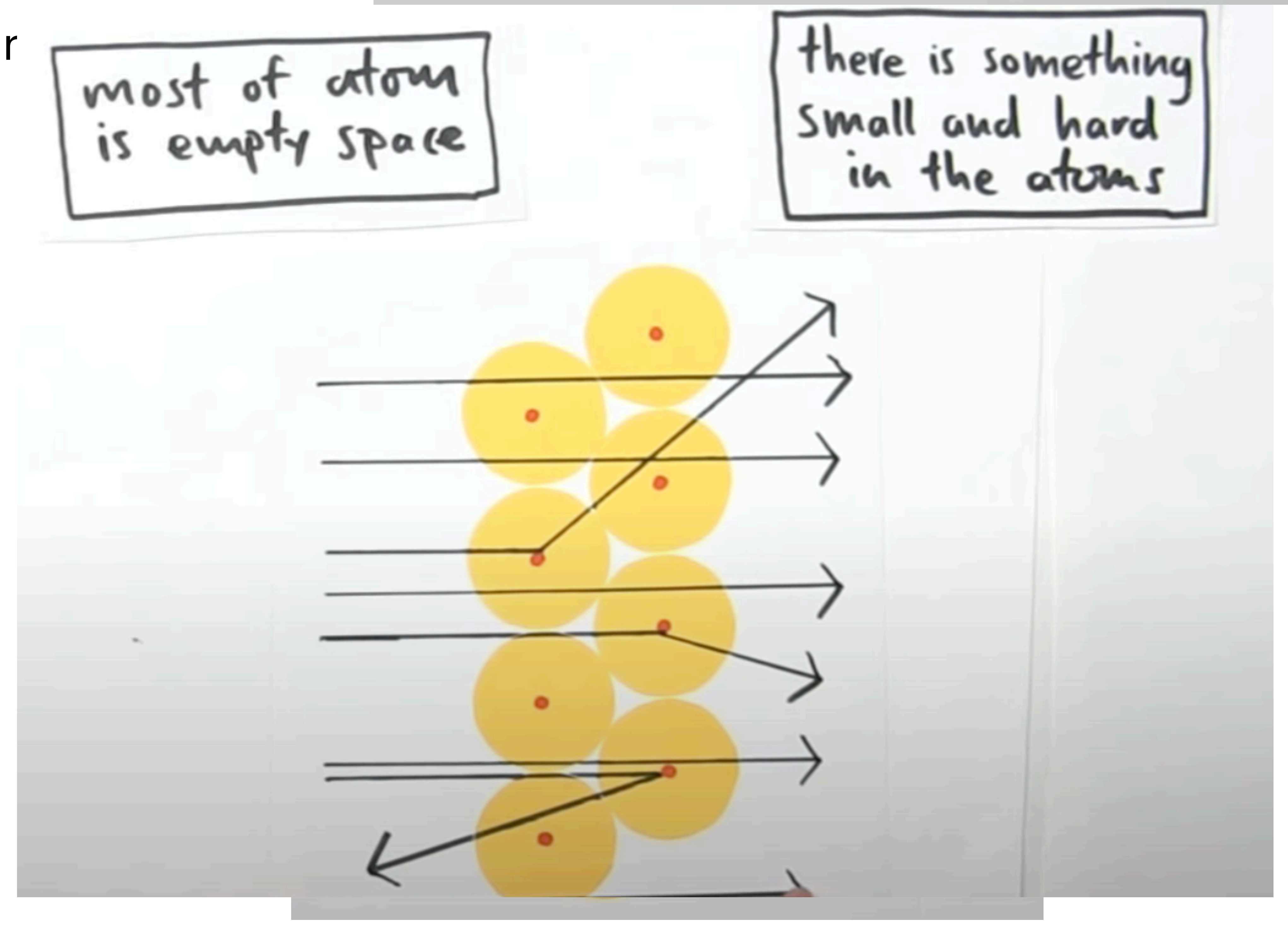


Observations:

- Most alpha particles pass straight through;
- Some are scattered a bit;
- A few, 1/8000, are scattered back towards the source(>90 degr

Conclusions:

- The tiny core of concentrated charge at the heart of an atom is atom's nucleus
- Most of the mass of an atom is concentrated in the central nucleus;
- The nucleus is positively charged;
- A very small nucleus surrounded by mostly empty space



It was as if you fired a fifteen-inch artillery shell at a piece of tissue paper and it came back and hit you

Atom Structure

Atom structure: a **positively** charged **nucleus**(center, small) + **negatively** charged **electrons** in orbit around the nucleus

A sense of scale: atom: football pitch $1\ \mathrm{\mathring{A}} = 10^{-10}\ \mathrm{m}$ . . . 1 angstrom

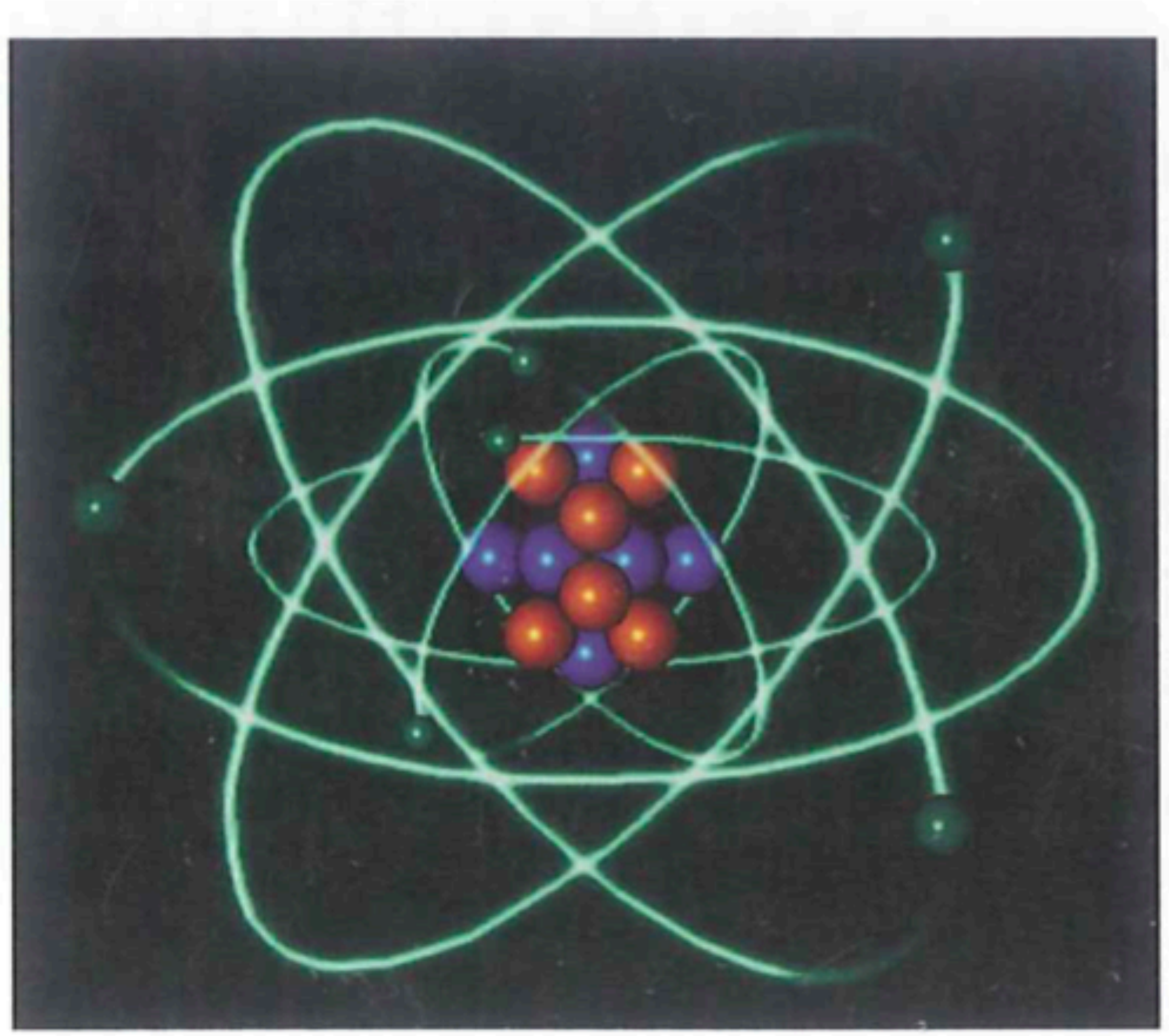
nucleus: marble $1\ \mathrm{fm} = 10^{-15}\ \mathrm{m}$ . . . 1 femtometer, 1 fermi

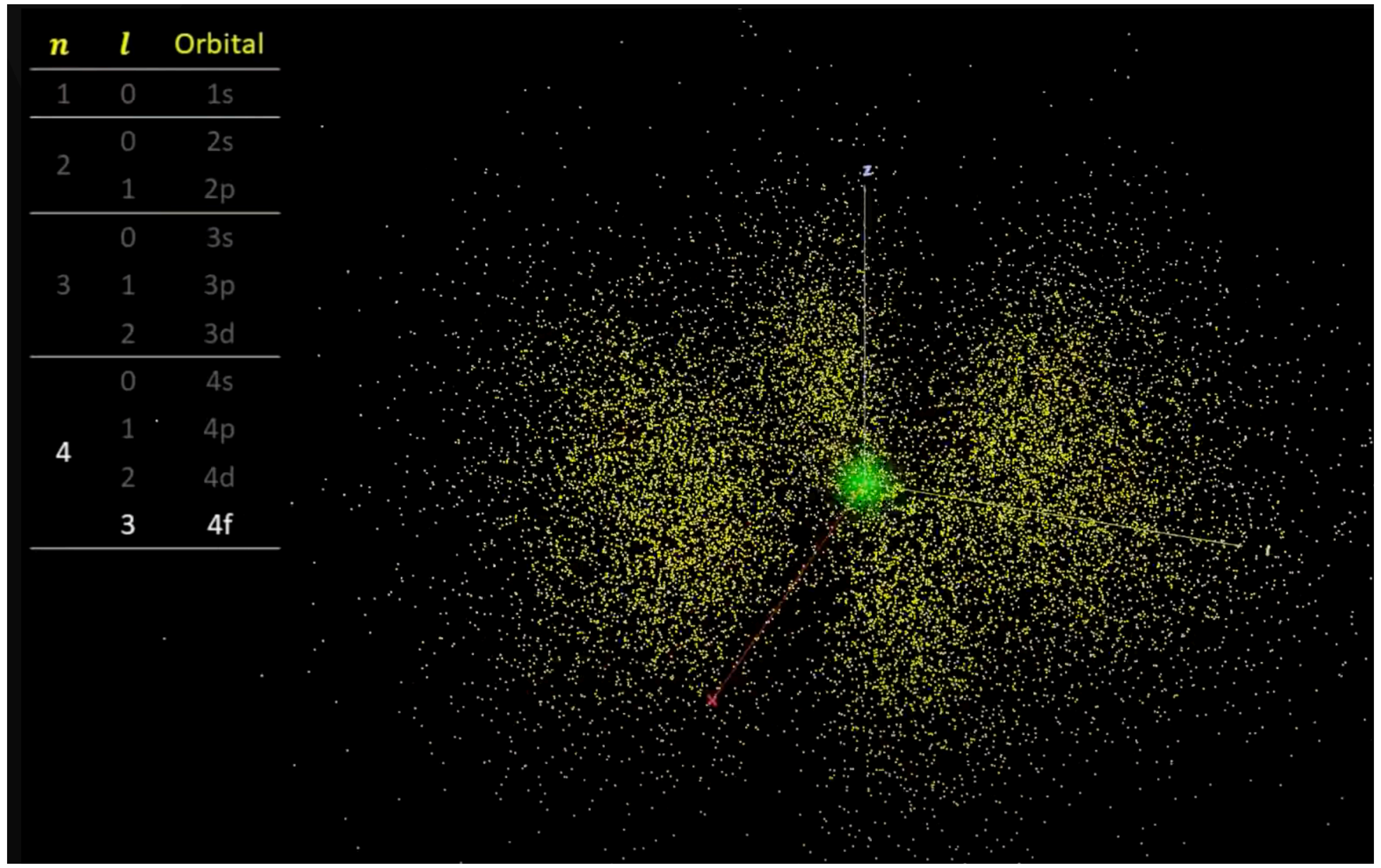
electron: dust

Ionization: when a particle(Atom or molecules) becomes electrically charged by losing or gaining electrons;

gain: negative ion, lose: positive ion

More about the model





Nucleus

Why does nucleus carry positive charge?

Proton: postive charge

Neutron: neutral

Protons & Neutrons: are nucleons, similar mass, much much heavier than electrons

Electrons: negative charge

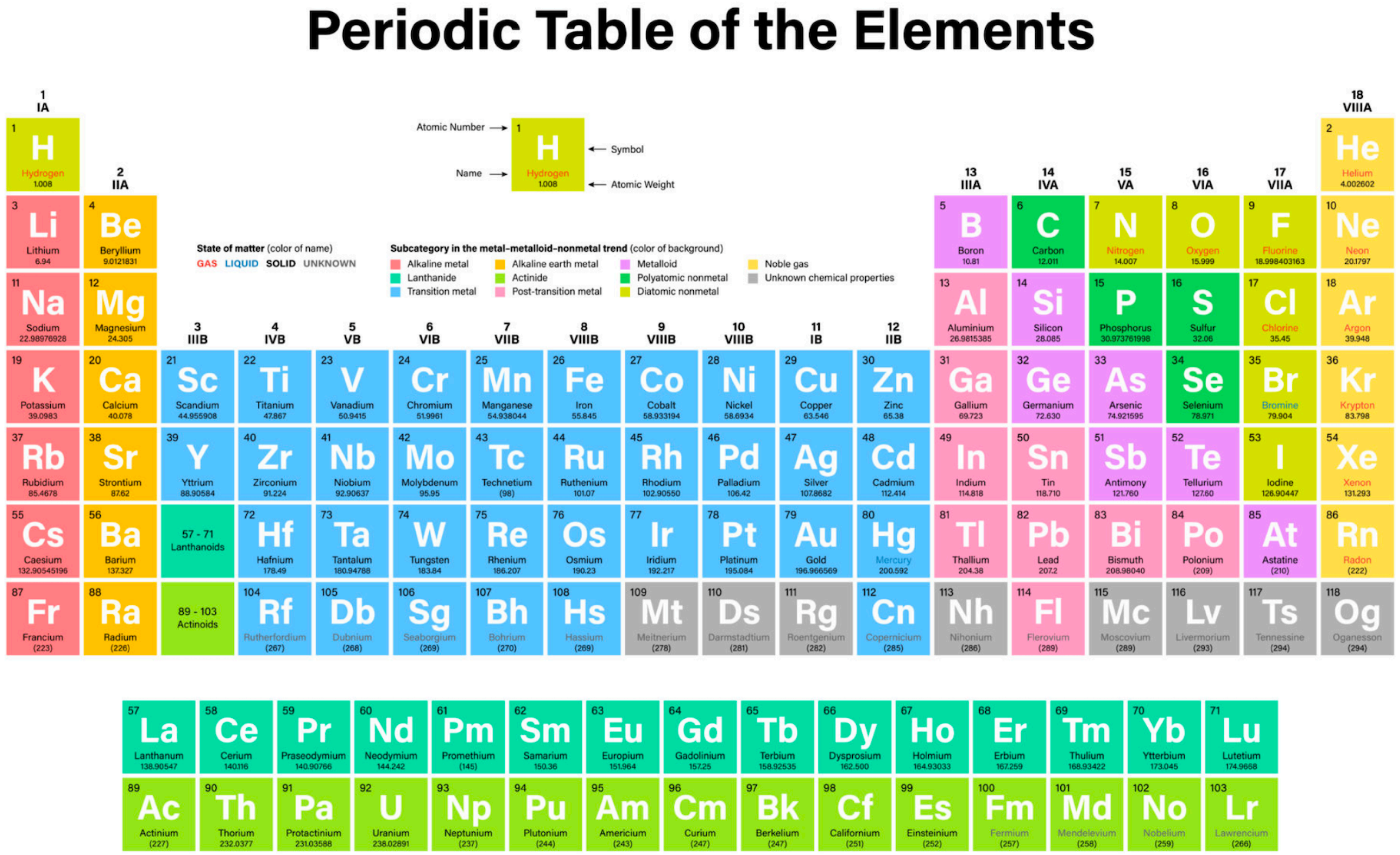
Relative mass: the mass of a particle relative to the mass of a proton

Relative charge: the charge of a particle relative to the charge of a proton

Particle	Position	Charge/C	Relative charge	Mass/kg	Relative mass
proton	in nucleus	$+1.6 \times 10^{-19}$	+1	1.67×10^{-27}	1
neutron	in nucleus	0	0	1.67×10^{-27}	1
electron	orbiting nucleus	-1.6×10^{-19}	−1	9.11×10^{-31}	$\frac{1}{1836}$ (practically zero)

Different atoms & different elements

number of protons == element number



More complex particles are possible: atoms$\rightarrow$ molecules$\rightarrow$ meta materials.

Nuclide Notation

Proton number(Z): atomic number, the number of protons in an atomic nucleus

Neutron number(N): the number of neutrons in an atomic nucleus

Nucleon number(A): the mass number, the number of nucleons (protons + neutrons) in an atomic nucleus

Nuclide notation:

$$^{A}_{Z}X$$

Exercise

1. Write down the nuclide notation for hydrogen, helium

2. What are proton/neutron/nucleon number of $^{12}_{5}B$

Atom

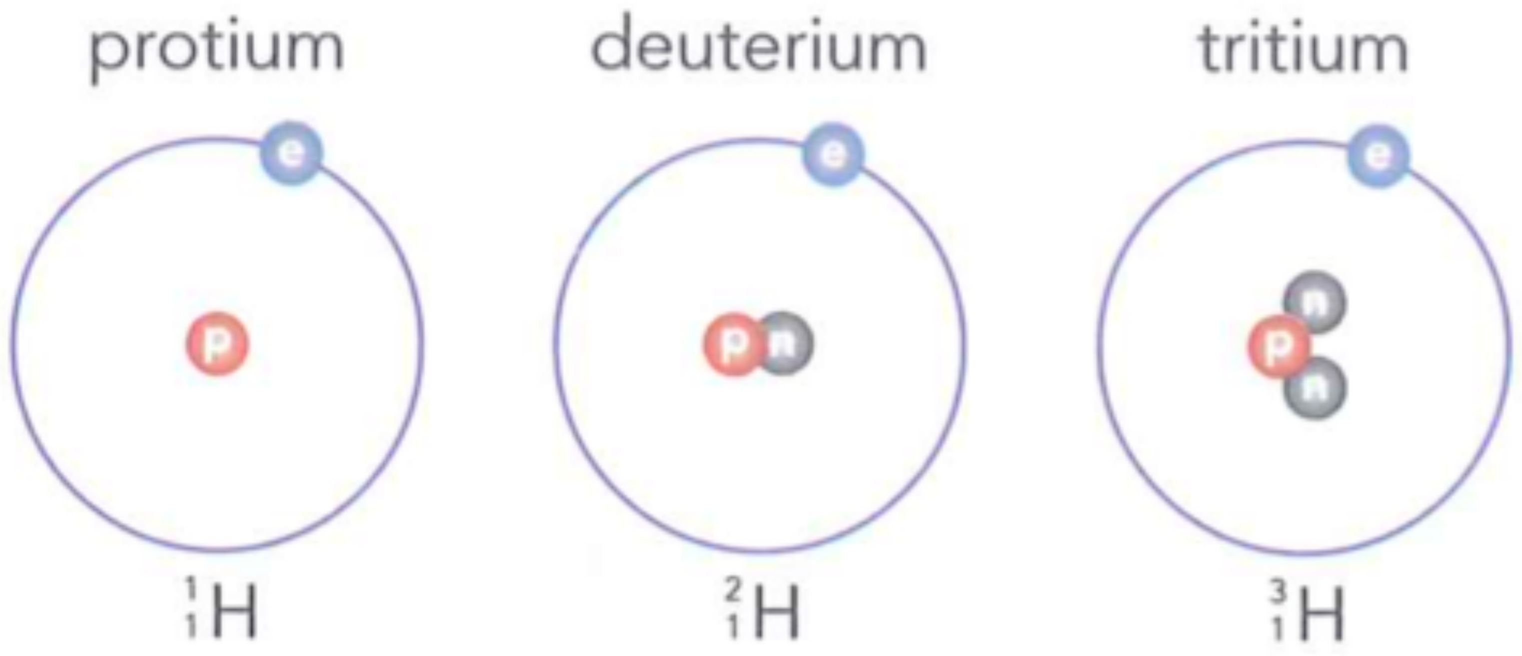
Charge & mass of nuclei:

mass determined by nucleon number, charge determined by proton number;
mass of atom == mass of nucleus

Isotope

Isotope of an element:

same chemical properties(proton number), different mass(different neutron number)

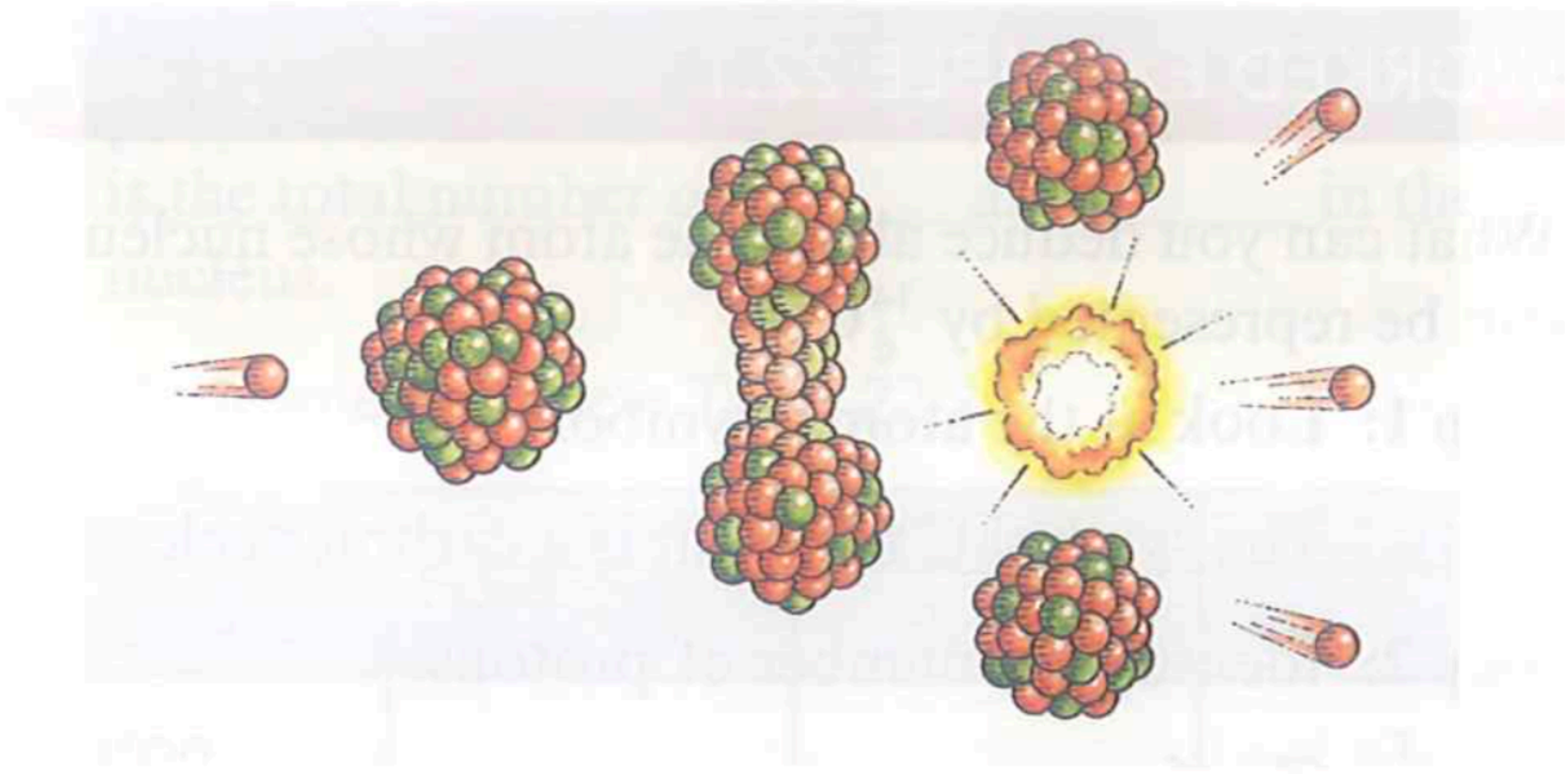


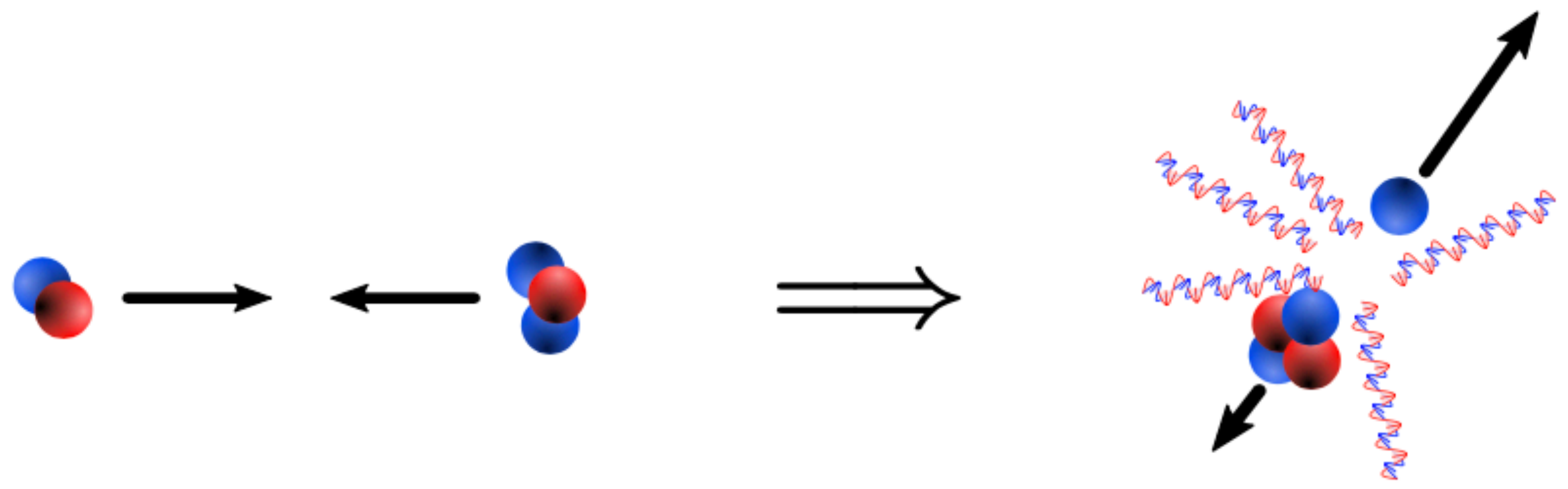
Symbol for isotope	Proton number Z	Neutron number N	Nucleon number A
${}^{4}_{2}He$	2	2	4
${}^{3}_{2}He$	2	1	3

Symbol for isotope	Proton number Z	Neutron number N	Nucleon number A
${}^{235}_{92}U$	92	143	235
${}^{238}_{92}U$	92	146	238

Unstable Isotope => radioactive decay

Nuclear fission and fusion:





$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{92}_{36}\mathrm{Ba} + {}^{141}_{56}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} + \text{energy}$$

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

Where does the energy come from?

$$E = mc^2$$