

---

# Chapter 22.

# The Nuclear Atom

# Atom

---

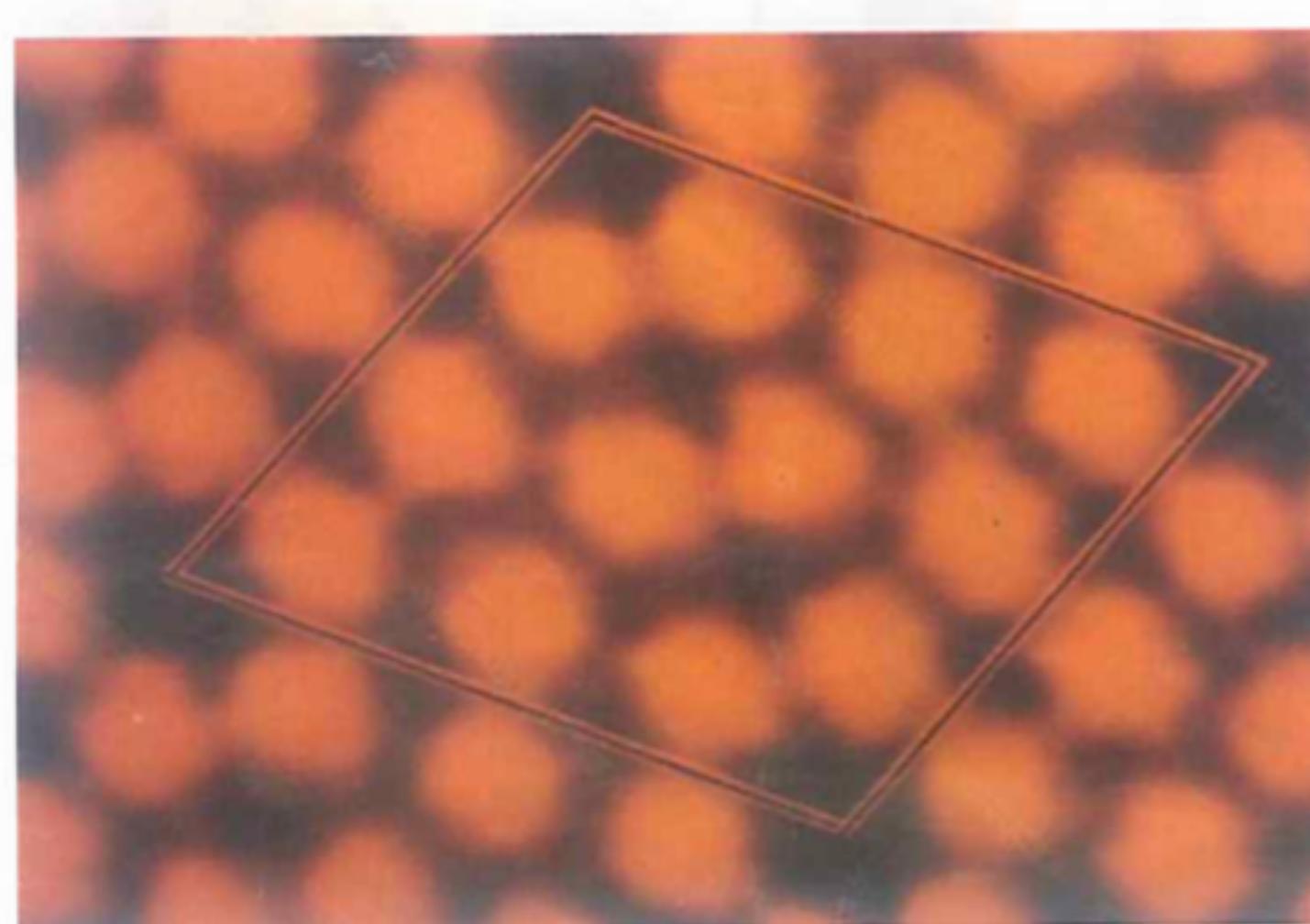
What are we/everything made of?

## 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.**

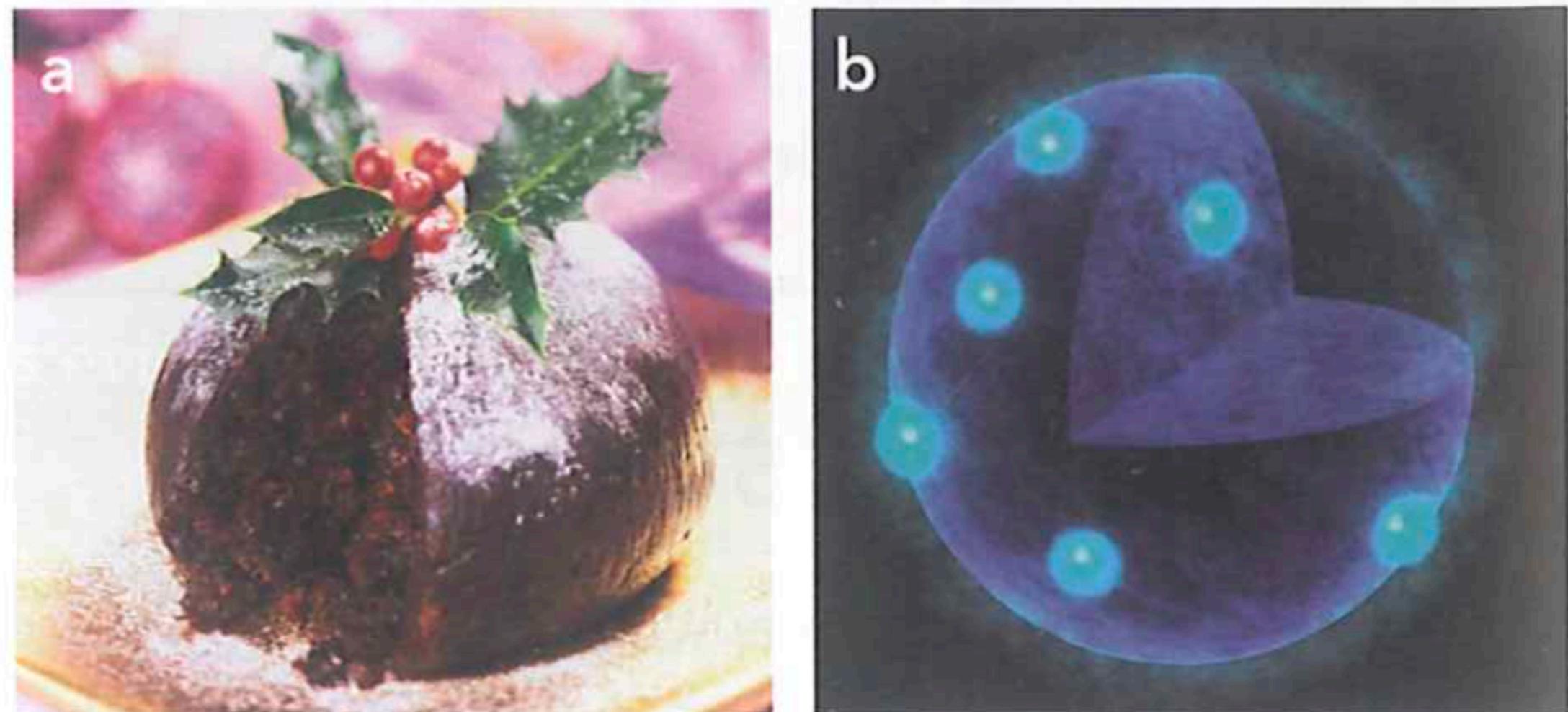
# Atom Structure

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

**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

Rutherford Atom

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

## → Alpha particle scattering experiment

How was the experiment carried out?

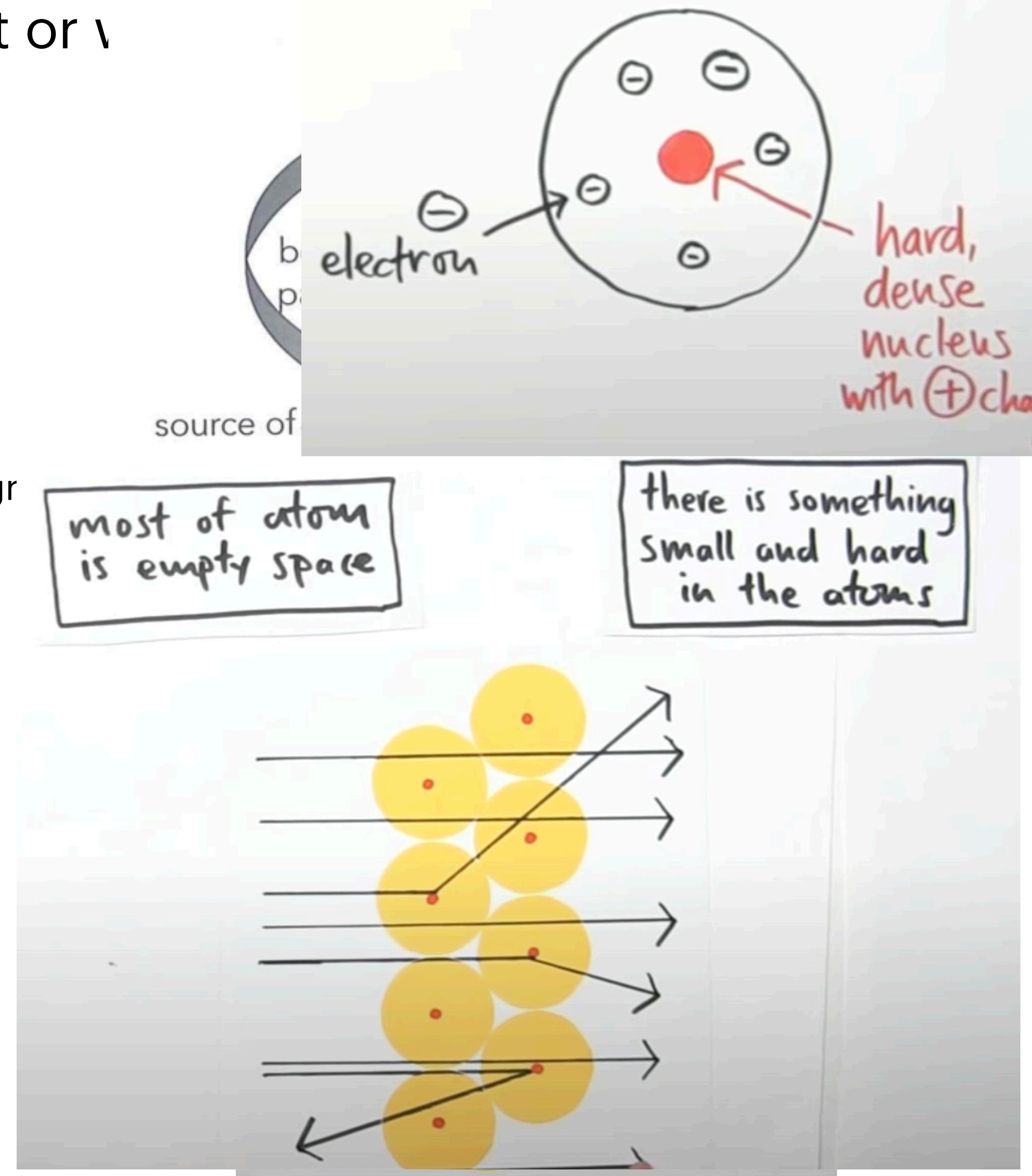
### Observations:

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

### 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  $1 \text{ \AA} = 10^{-10} \text{ m} \dots 1 \text{ angstrom}$

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

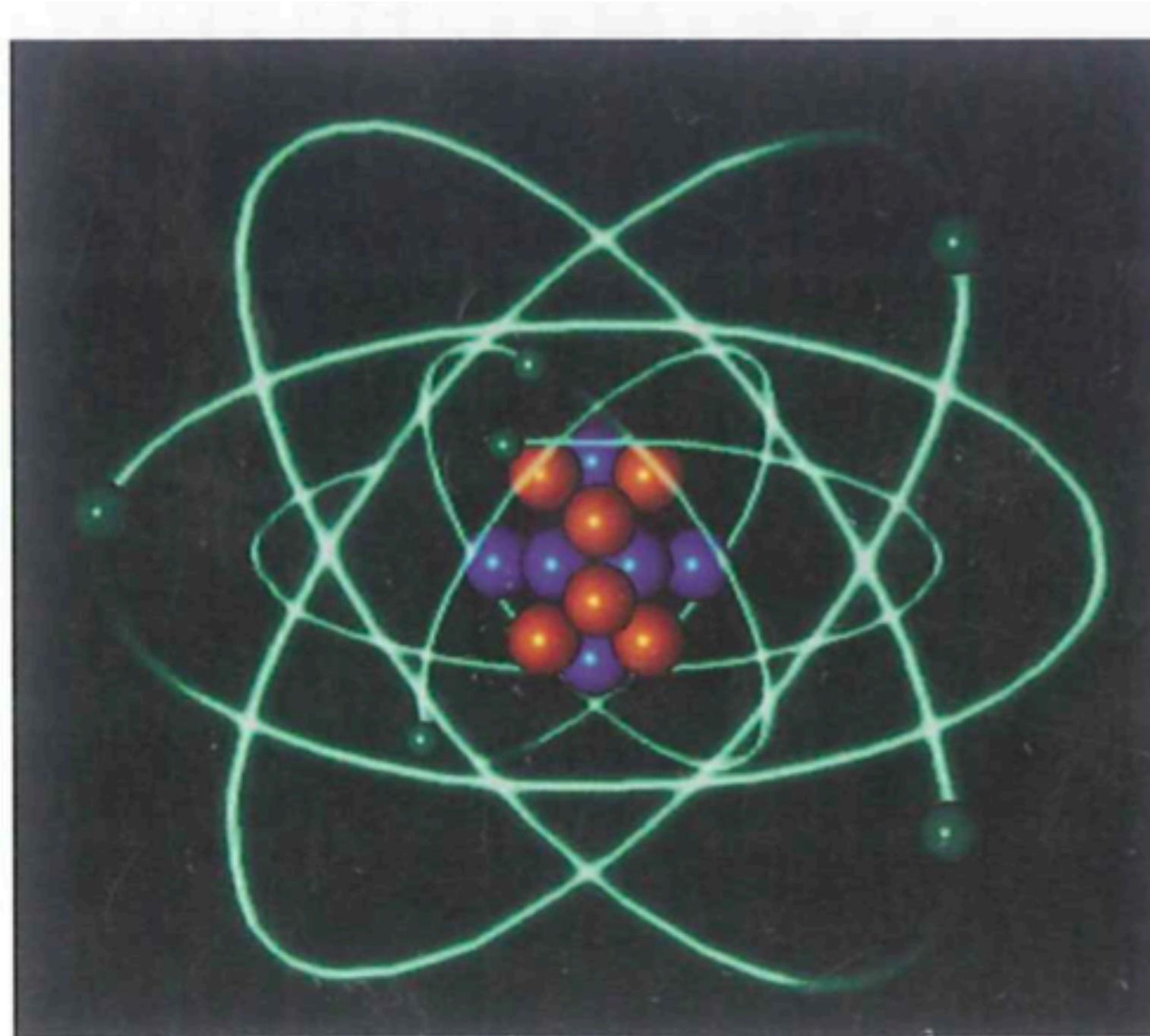
electron: dust

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

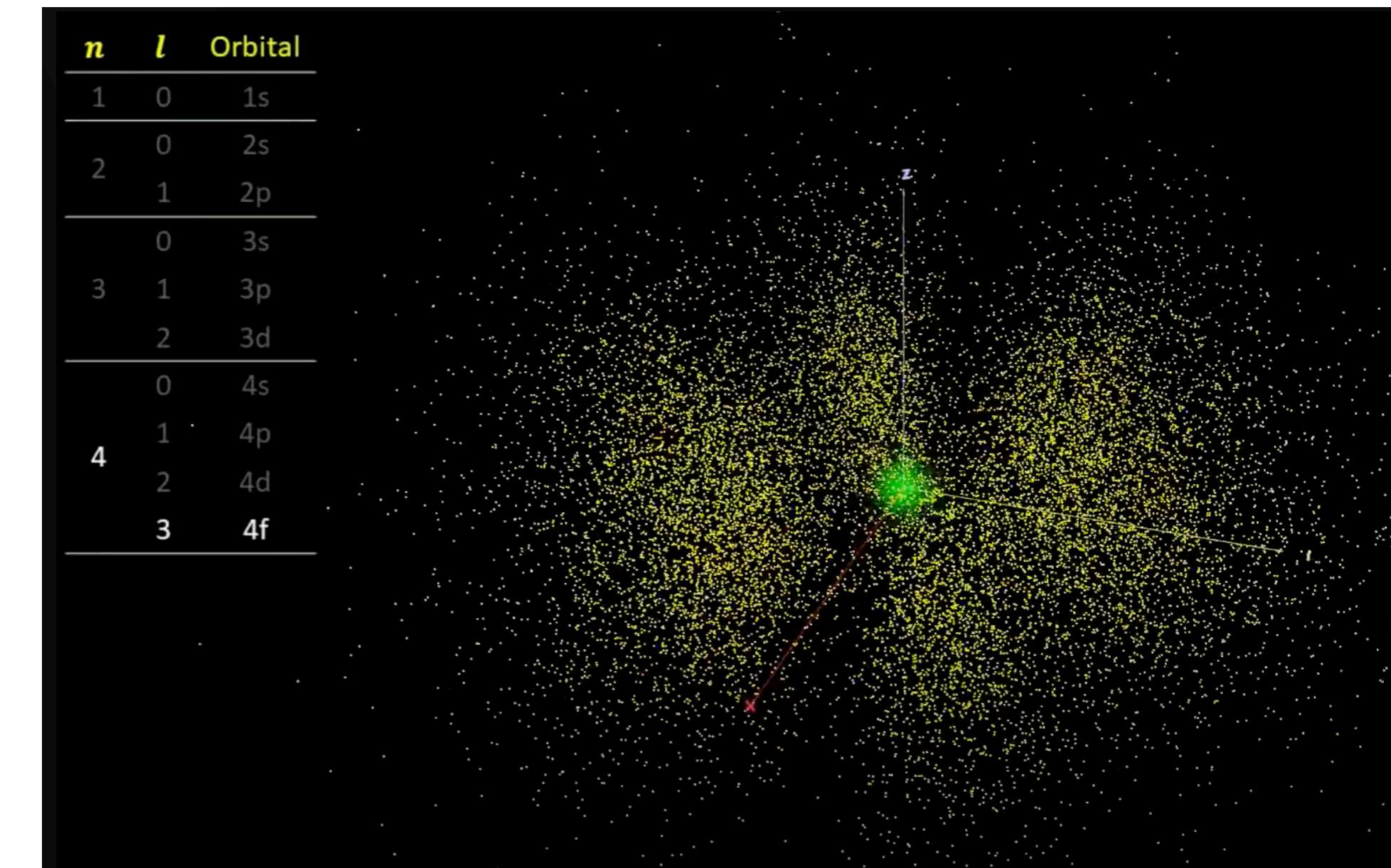
gain: negative ion, lose: positive ion

# More about the model

---



<b><i>n</i></b>	<b><i>l</i></b>	<b>Orbital</b>
1	0	1s
	0	2s
2	1	2p
	0	3s
3	1	3p
	2	3d
	0	4s
4	1	4p
	2	4d
	3	4f



# Nucleus

---

Why does nucleus carry positive charge?

**Proton:** positive 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	$1.67 \times 10^{-27}$	1
neutron	in nucleus	0	0	$1.67 \times 10^{-27}$	1
electron	orbiting nucleus	$-1.6 \times 10^{-19}$	-1	$9.11 \times 10^{-31}$	$\frac{1}{1836}$ (practically zero)

# Different atoms & different elements

number of protons == element number

## Periodic Table of the Elements

The Periodic Table of the Elements is a tabular arrangement of all known chemical elements. It consists of 18 groups and 7 periods. The elements are color-coded based on their category: Alkaline metals (pink), Alkaline earth metals (yellow), Lanthanides (light green), Actinides (light blue), Transition metals (medium blue), Post-transition metals (dark blue), Metalloids (purple), Nonmetals (green), Noble gases (orange), and Diatomic nonmetals (yellow-green). Each element cell contains its atomic number, symbol, name, atomic weight, and state of matter (GAS, LIQUID, SOLID, UNKNOWN). A legend at the top right provides a key for these categories.

1	IA	VIIA																		18	VIIIA																
1	H	Hydrogen 1.008	2	IIA																He	Helium 4.002602																
3	Li	Lithium 6.94	4	Be	Beryllium 9.012831																																
11	Na	Sodium 22.98976928	12	Mg	Magnesium 24.305	3	IIIB	4	IVB	5	VB	6	VIB	7	VIIIB	8	VIIIB	9	VIIIB	10	IIB	11	IIB	12	IIB												
19	K	Potassium 39.0983	20	Ca	Calcium 40.079	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
37	Rb	Rubidium 85.4678	38	Sr	Strontium 87.62	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
55	Cs	Cesium 132.90545196	56	Ba	Barium 137.327	57 - 71	Lanthanoids	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
87	Fr	Francium (223)	88	Ra	Radium (226)	89 - 103	Actinoids	104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn	113	Nh	114	Fl	115	Mc	116	Lv	117	Ts	118	Og
57	La	Lanthanum 138.90547	58	Ce	Cerium 140.016	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu						
89	Ac	Actinium (227)	90	Th	Thorium 232.0377	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr						

More complex particles are possible: atoms → molecules → meta materials.

# Nuclide Notation

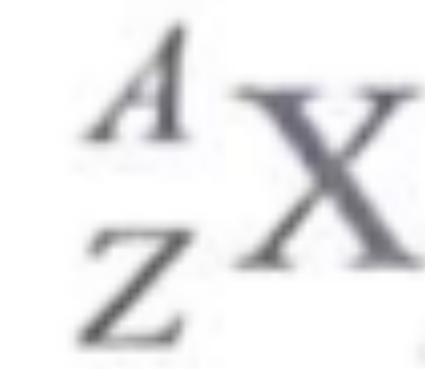
---

**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:



# Exercise

---

1. Write down the nuclide notation for hydrogen, helium
2. What are proton/neutron/nucleon number of  $^{12}_5\text{B}$

# Atom

---

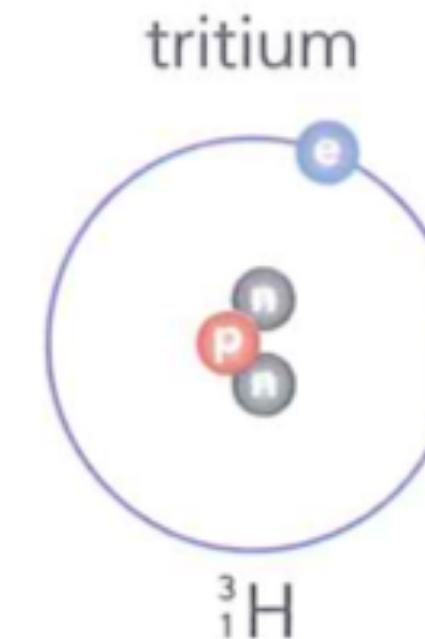
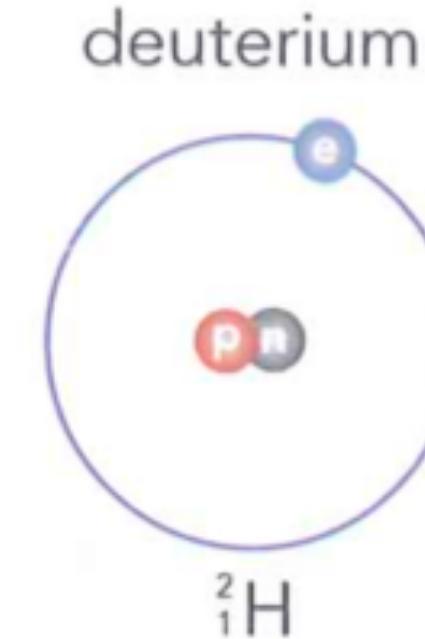
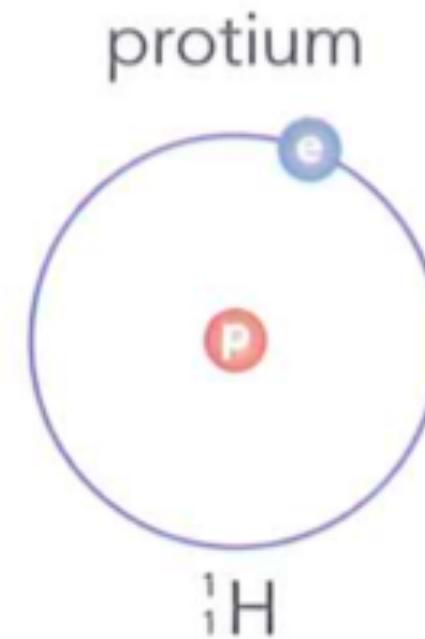
## **Charge & mass of nuclei:**

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)

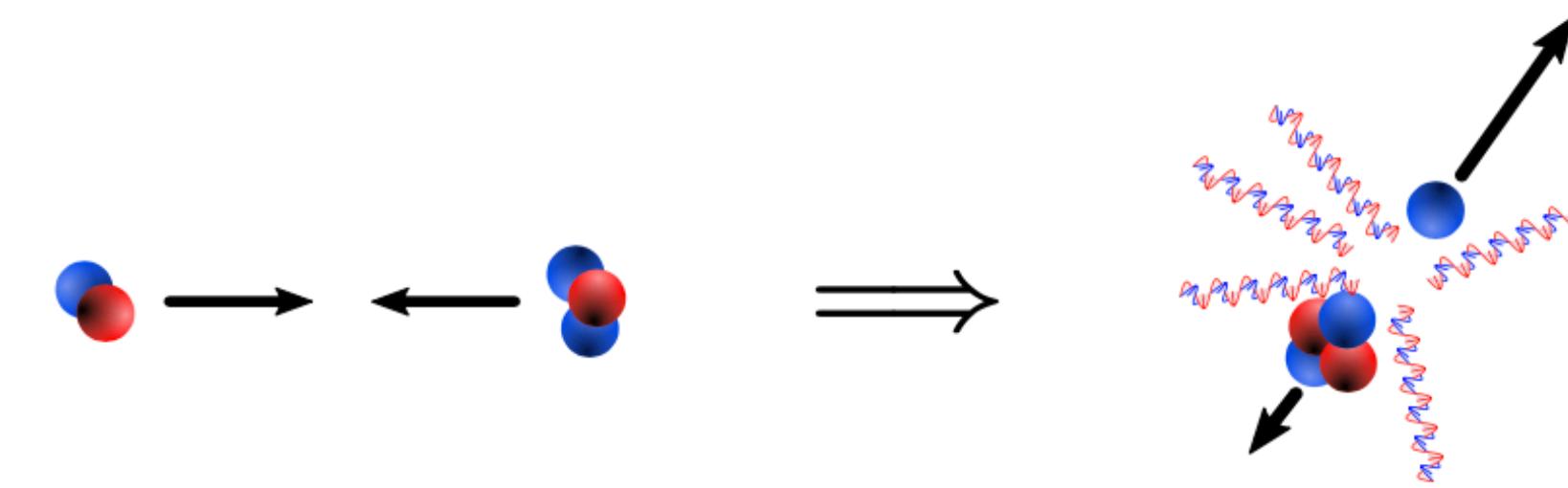
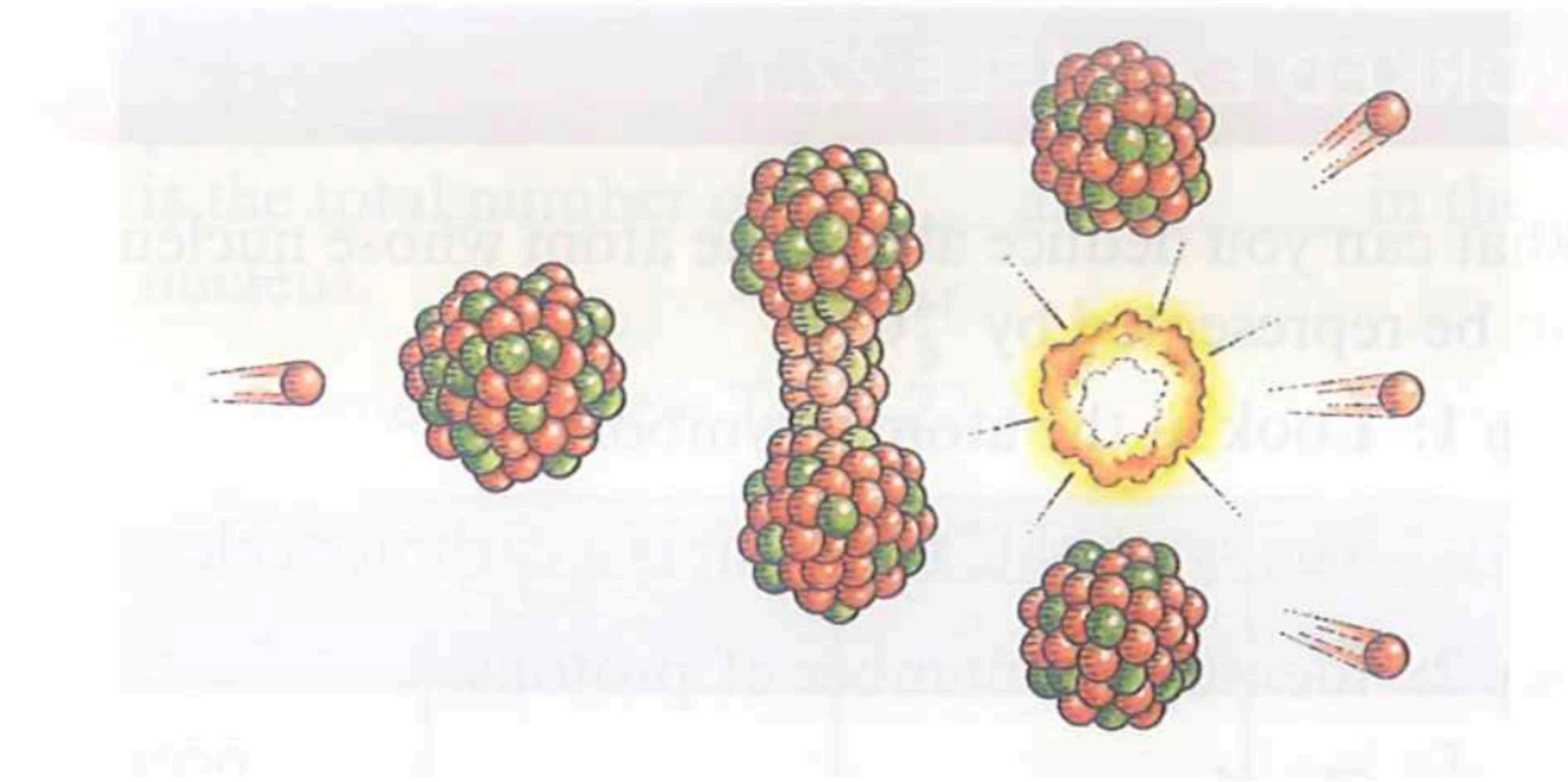


Symbol for isotope	Proton number $Z$	Neutron number $N$	Nucleon number $A$
${}^4_2\text{He}$	2	2	4
${}^3_2\text{He}$	2	1	3

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

Unstable Isotope => radioactive decay

# Nuclear fission and fusion:



Where does the energy come from?

$$E = mc^2$$