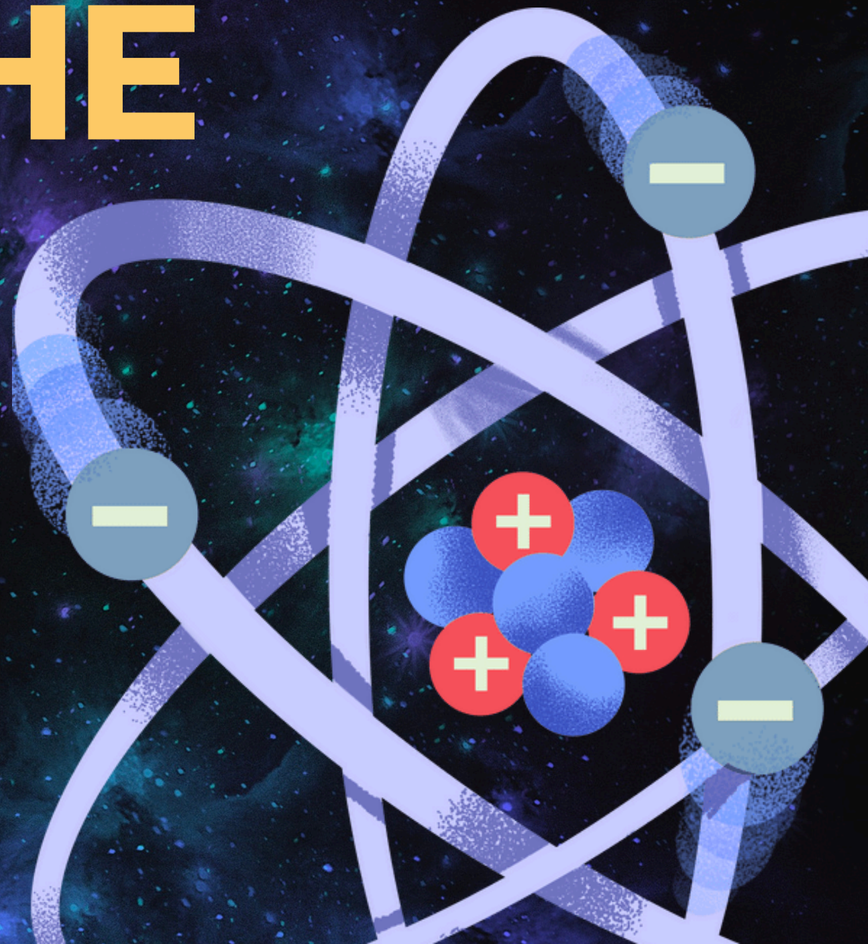
GRADE 11 | PHYSICAL SCIENCE

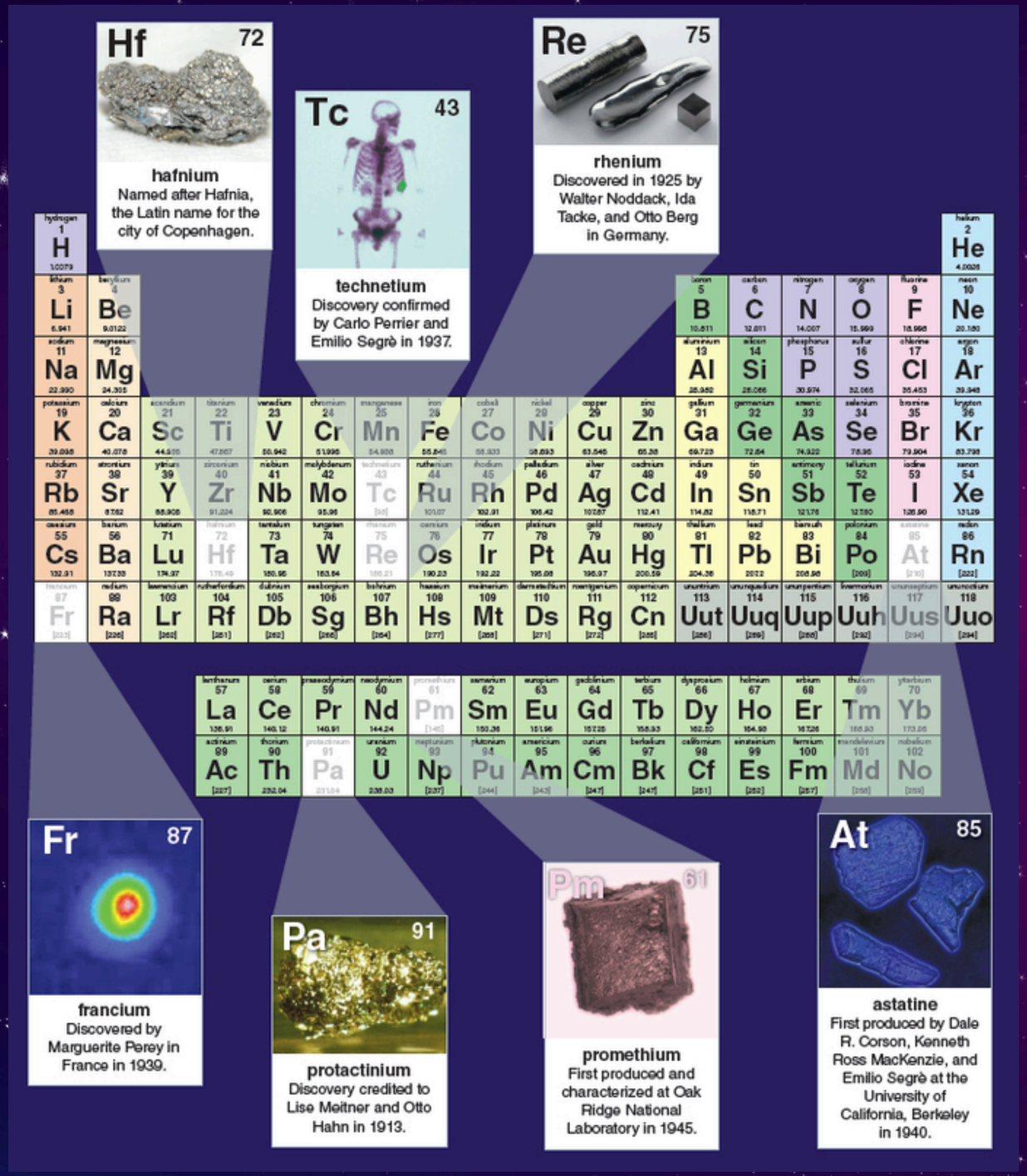
THE ATOMIC NUMBER AND THE SYNTHESIS OF NEW ELEMENTS



THE ATOMIC NUMBER AND THE SYNTHESIS OF NEW ELEMENTS

Dmitri Mendeleev devised the periodic classification of the chemical elements, arranging them in order of increasing atomic weight and recognizing repeating patterns in their properties. He even left gaps for undiscovered elements and correctly predicted their properties.

Henry Moseley later discovered that the atomic number, rather than atomic weight, is the correct basis for arranging elements. By systematically studying the X-ray spectra of elements, he found that certain atomic numbers were missing, indicating the absence of the corresponding elements.



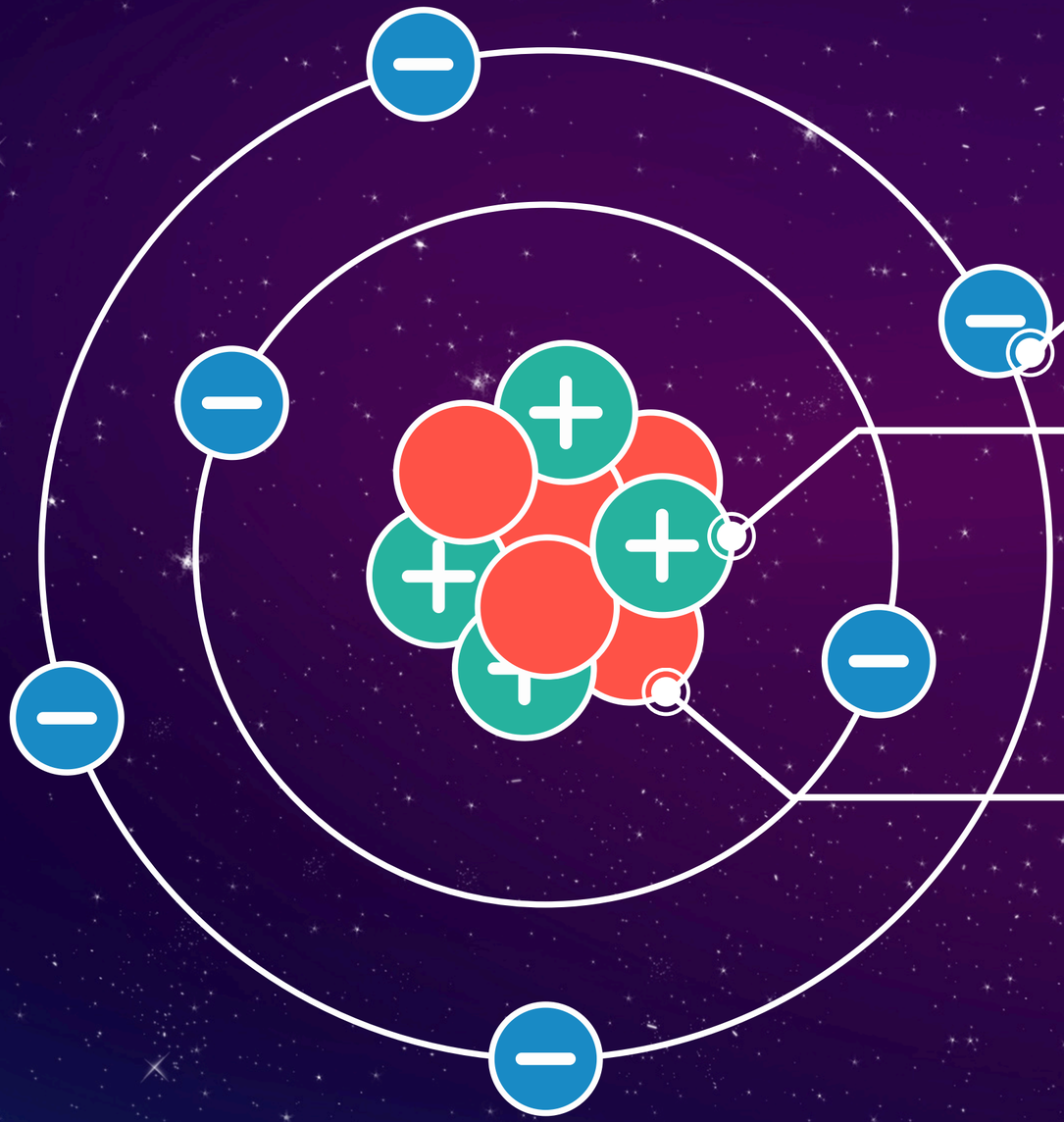
Moseley identified gaps at atomic numbers 43, 61, and 75 which were later identified as technetium (43), promethium (61), and rhenium (75). Following his methods, other researchers extended this approach and identified additional gaps in the periodic table. These gaps corresponded to the elements hafnium (72), astatine (85), francium (87), and protactinium (91).

THE PERIODIC TABLE OF ELEMENTS

1 H HYDROGEN 1.008																	2 He HELIUM 4.003
3 Na LITHIUM 6.941	4 Be BERYLLIUM 9.012											5 B BORON 10.811	6 C CARBON 12.011	7 N NITROGEN 12.007	8 O OXYGEN 15.999	9 F FLUORINE 18.998	10 Ne NEON 20.180
11 Na SODIUM 22.990	12 Mg MAGNESIUM 24.305											13 Al ALUMINUM 26.982	14 Si SILICON 28.086	15 P PHOSPHORUS 30.974	16 S SULFUR 32.066	17 Cl CHLORINE 35.453	18 Ar ARGON 39.948
19 K POTASSIUM 39.098	20 Ca CALCIUM 40.078	21 Sc SCANDIUM 44.956	22 Ti TITANIUM 47.88	23 V VANADIUM 50.942	24 Cr CHROMIUM 51.996	25 Mn MANGANESE 54.938	26 Fe IRON 55.933	27 Co COBALT 58.933	28 Ni NICKEL 58.693	29 Cu COPPER 63.546	30 Zn ZINC 65.39	31 Ga GALLIUM 69.732	32 Ge GERMANIUM 72.61	33 As ARSENIC 74.922	34 Se SELENIUM 78.972	35 Br BROMINE 79.904	36 Kr KRYPTON 84.80
37 Rb RUBIDIUM 84.468	38 Sr STRONTIUM 87.62	39 Y YTTRIUM 88.906	40 Zr ZIRCONIUM 91.224	41 Nb NIOBIUM 92.906	42 Mo MOLYBDENUM 95.95	43 Tc TECHNETIUM 98.907	44 Ru RUTHENIUM 101.07	45 Rh RHODIUM 102.906	46 Pd PALLADIUM 106.42	47 Ag SILVER 107.868	48 Cd CADMIUM 112.411	49 In INDIUM 114.818	50 Sn TIN 118.71	51 Sb ANTIMONY 121.760	52 Te TELLURIUM 127.6	53 I IODINE 126.904	54 Xe XENON 131.29
55 Cs CESIUM 132.905	56 Ba BARIUM 137.327	57-71	72 Hf HAFNIUM 178.49	73 Ta TANTALUM 180.948	74 W TUNGSTEN 183.85	75 Re RHENIUM 186.207	76 Os OSMIUM 190.23	77 Ir IRIDIUM 192.22	78 Pt PLATINUM 195.08	79 Au GOLD 196.967	80 Hg MERCURY 200.59	81 Ti THALLIUM 204.383	82 Pb LEAD 207.2	83 Bi BISMUTH 208.980	84 Po POLONIUM [208.982]	85 At ASTATINE 209.987	86 Rn RADON 222.018
87 Fr FRANCIUM 223.0	88 Ra RADIUM 226.025	89-103	104 Rf RUTHERFORDIUM [261]	105 Db DUBNIUMT [262]	106 Sg SEABORGIUM [266]	107 Bh BOHRIUM [264]	108 Hs HASSIUM [269]	109 Mt MEITNERIUM [268]	110 Ds DARMSTADTIUM [269]	111 Rg ROENTGENIUM [272]	112 Cn COPERNICIUM [277]A	123 Uut UNUNTRIUM UNKNOWN	124 Fl FLEROVIUM [289]	125 Uup UNENPENTIUM UNKNOWN	126 Lv LIVERMORIUM [298]	127 Uus UNUNSEPTIUM UNKNOWN	128 Uuo UNUNOCTIUM UNKNOWN

57 La LANTHANUM 138.906	58 Ce CERIUM 140.115	59 Pr PRASEODYMIUM 140.908	60 Nd NEODYMIUM 144.24	61 Pm PROMETHIUM 144.913	62 Sm SAMARIUM 150.36	63 Eu EUROPIUM 151.966	64 Gd GADOLINIUM 157.25	65 Tb TERBIUM 158.925	66 Dy DYSPROSIUM 162.50	67 Ho HOLMIUM 164.930	68 Er ERBIUM 167.26	69 Tm THULIUM 168.934	70 Yb YTTERBIUM 173.04	71 Lu LUTETIUM 174.967
89 Ac ACTINIUM 227.028	90 Th THORIUM 232.038	91 Pa PROTACTINIUM 231.036	92 U URANIUM 238.029	93 Np NEPTUNIUM 237.048	94 Pu PLUTONIUM 244.064	95 Am AMERICIUM 243.061	96 Cm CURIUM 247.070	97 Bk BERKELIUM 247.070	98 Cf CALIFORNIUM 251.080	99 Es EINSTEINIUM [254]	100 Fm FERMIUM 257.095	101 Md MENDELEVIUM 258.1	102 No NOBELIUM 259.101	103 Lr LAWRENCIUM [262]

THE STRUCTURE OF AN ATOM



electron

proton

neutron

make up the atomic nuclei

NUCLIDE NOTATION

Nuclides are specific types of atoms or nuclei. Every nuclide has a chemical element symbol (X) as well as an atomic number (Z) which is equal to the number of protons in the nucleus, and a mass number (A) which is equal to the sum of protons and neutrons in the nucleus. The symbol for the element is as shown below:

NUCLIDE NOTATION

Atomic Mass
= number of protons
+ neutrons

Atomic Number
= number of protons

Element Symbol

In a neutral atom, the number of protons is equal to the number of electrons.

Number of neutrons = atomic mass – atomic number

Element	Atomic Mass	Atomic Number	Number of protons	Number of electrons	Number of neutrons
Oxygen	16	8	8	8	8

Element	Atomic Mass	Atomic Number	Number of protons	Number of electrons	Number of neutrons
Uranium	238	92	92	92	146

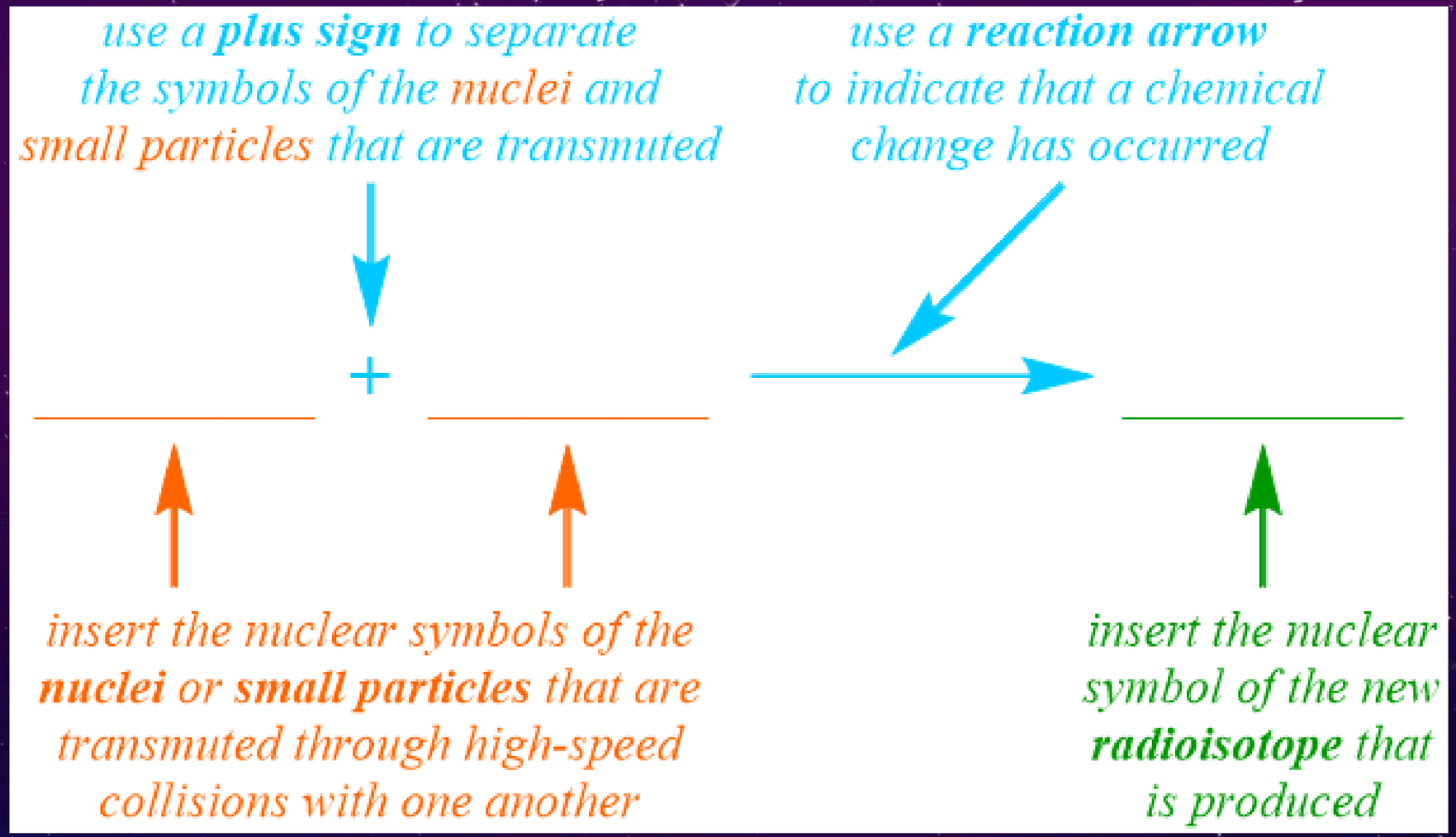
TRANSMUTATION

Conversion of One Element to Another

TRANSMUTATION is the process of converting one chemical element into another, which occurs when an atom's nucleus changes the number of protons. It may be induced by a nuclear reaction or occur spontaneously by radioactive decay.

NUCLEAR EQUATION

A symbolic representation of a nuclear reaction showing the reactants (nuclei or particles entering the reaction) and the products (nuclei or particles produced), including any emitted radiation or neutrons.



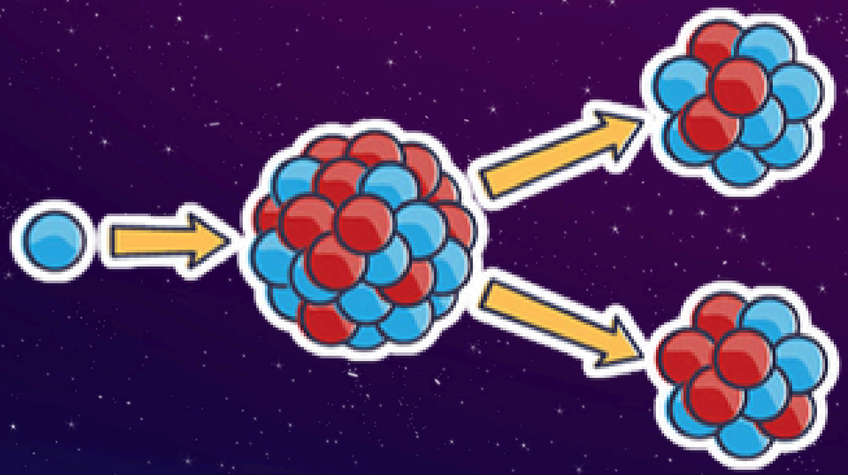
NUCLEAR REACTIONS

A nuclear reaction is a process in which two nuclei, or a nucleus and an external subatomic particle, collide to produce one or more new nuclides

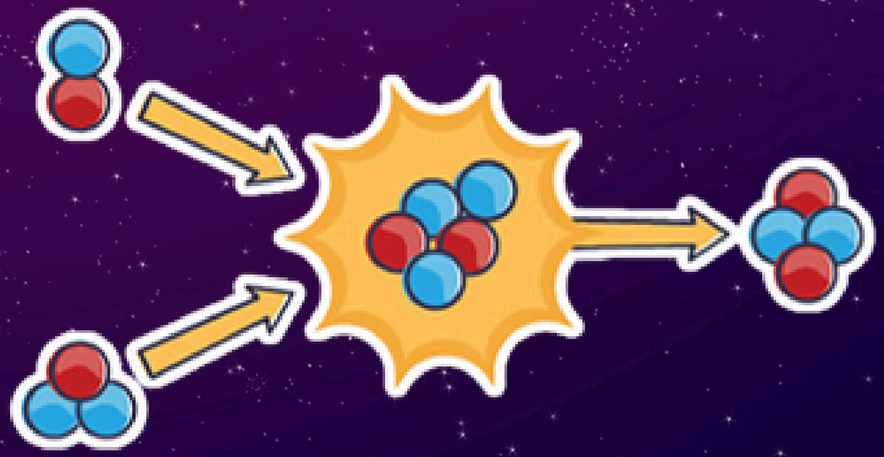
FISSION vs. FUSION

Both are physical processes that produce energy from atoms.

Splits a larger atom into 2 or more smaller ones.

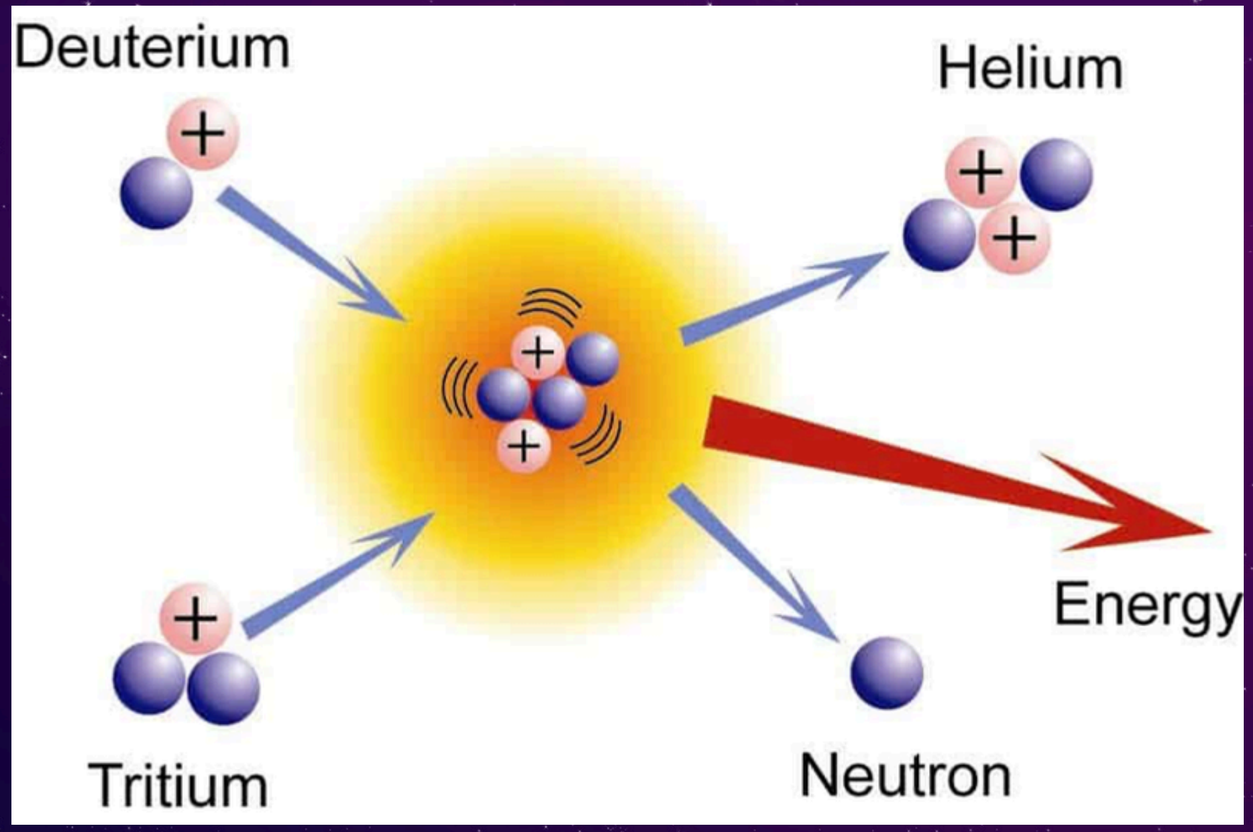


Joins 2 or more lighter atoms into a larger one.



Nuclear Fusion

Fusion happens when two light atoms combine to form a heavier atom, releasing energy. This type of reaction happens in the Sun, which is why the Sun produces so much energy!



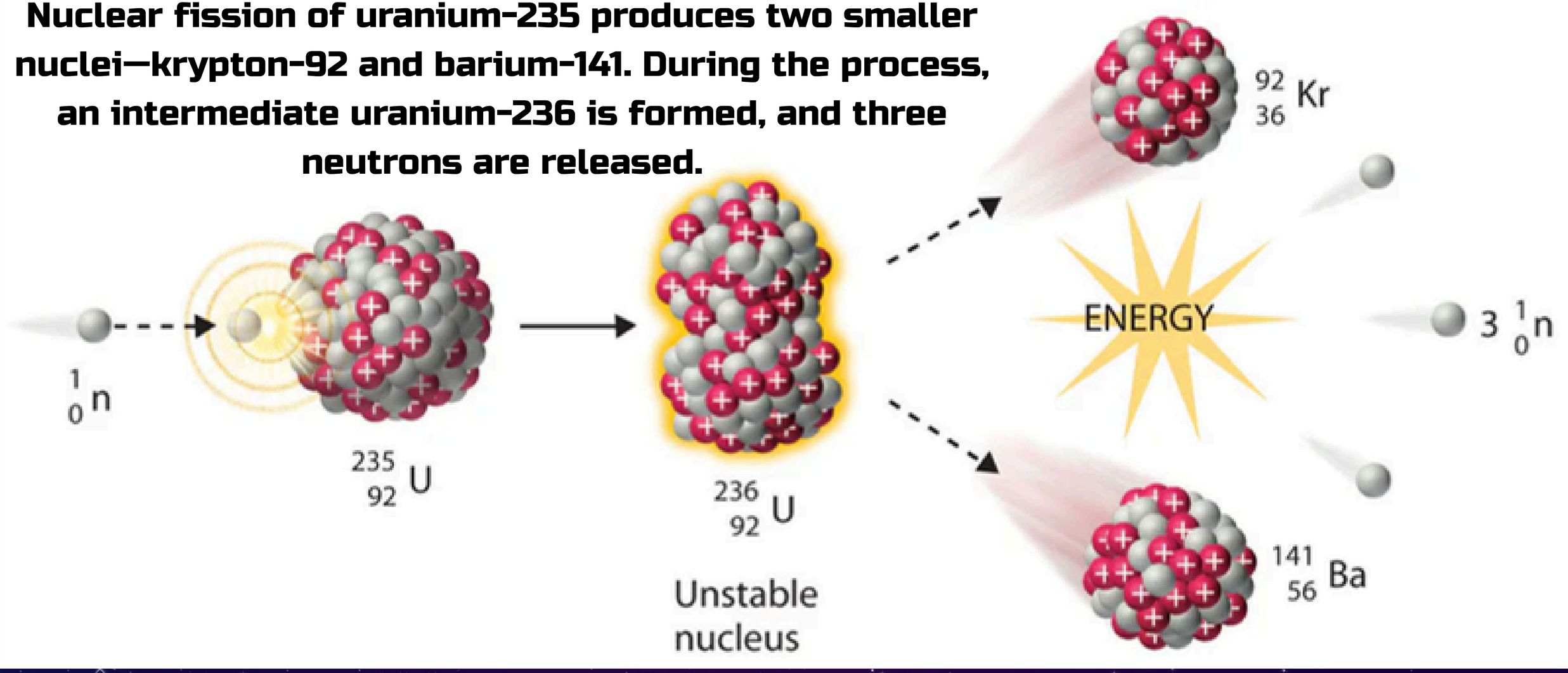
Two hydrogen isotopes—Deuterium (^2H) and Tritium (^3H)—join to form Helium (^4He), releasing a neutron and a large amount of energy.

$$^2H + {}^3H \rightarrow {}^4He + {}^1n + \text{energy}$$

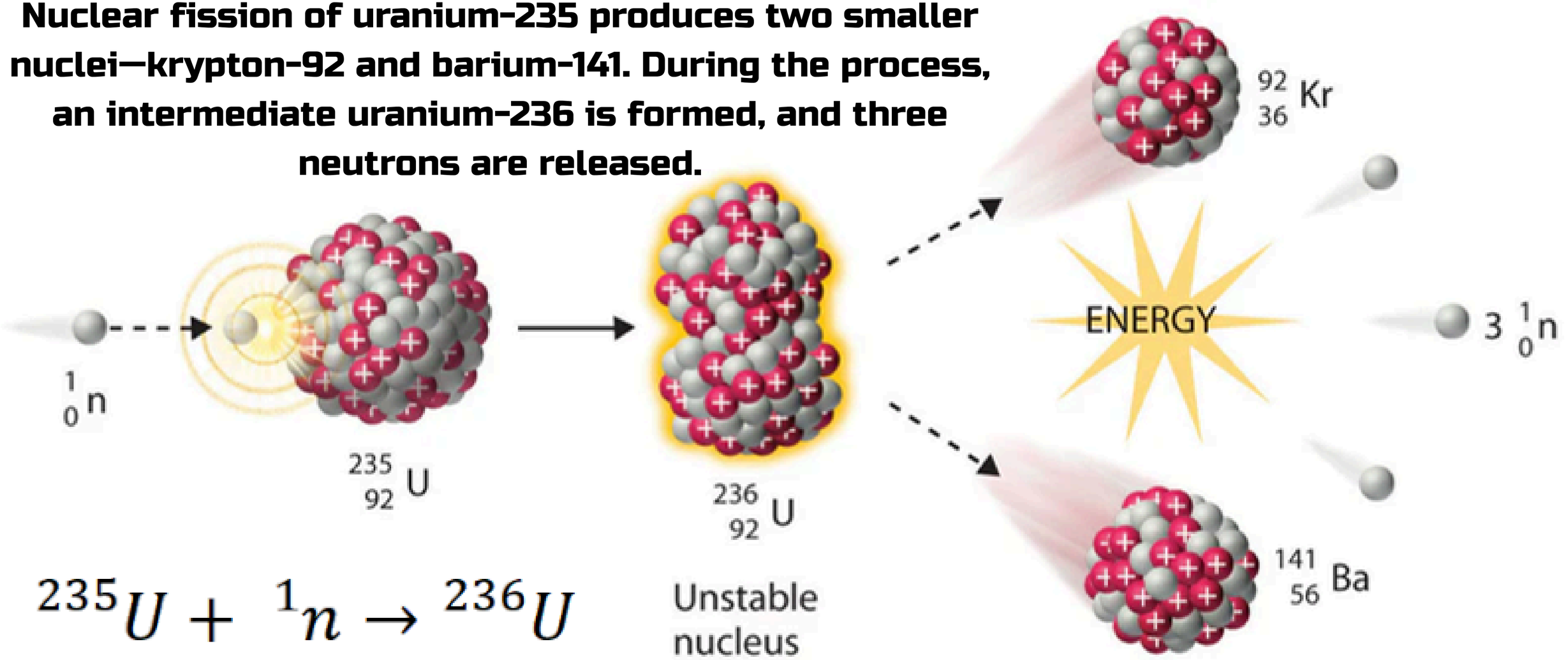
Nuclear Fission

Fission happens when a heavy atom splits into two lighter atoms, releasing energy.

Nuclear fission of uranium-235 produces two smaller nuclei—krypton-92 and barium-141. During the process, an intermediate uranium-236 is formed, and three neutrons are released.



Nuclear fission of uranium-235 produces two smaller nuclei—krypton-92 and barium-141. During the process, an intermediate uranium-236 is formed, and three neutrons are released.



$$^{235}U + {}^{1}n \rightarrow {}^{236}U$$

$$^{236}U \rightarrow {}^{141}Ba + {}^{92}Kr + 3\,{}^{1}n + energy$$

RADIOACTIVE DECAY

Radioactive decay is the process where an unstable atomic nucleus loses energy by emitting radiation, transforming it into a more stable form.

alpha decay

beta decay

gamma decay

Name	Symbol(s)	Representation	Description
Alpha particle	$^4_2\mathrm{He}$ or $^4_2\alpha$		(High-energy) helium nuclei consisting of two protons and two neutrons
Beta particle	$^0_{-1}\mathrm{e}$ or $^0_{-1}\beta$		(High-energy) electrons
Gamma ray	γ		Very high-energy electromagnetic radiation

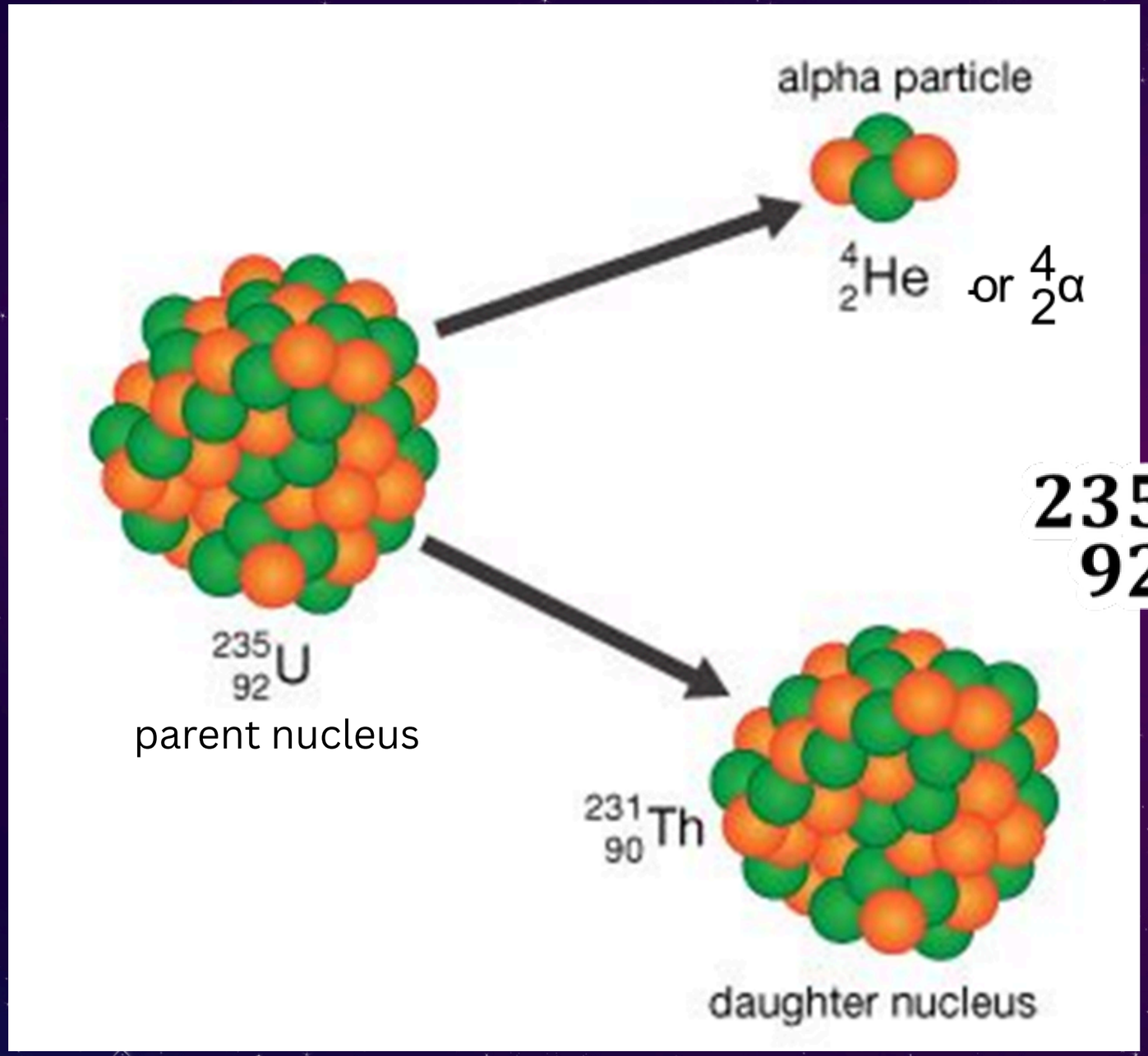
- **An alpha particle is a high energy helium nucleus.**
- **A beta particle is a high energy electron.**
- **A gamma ray is a very high energy electromagnetic radiation**

ALPHA DECAY

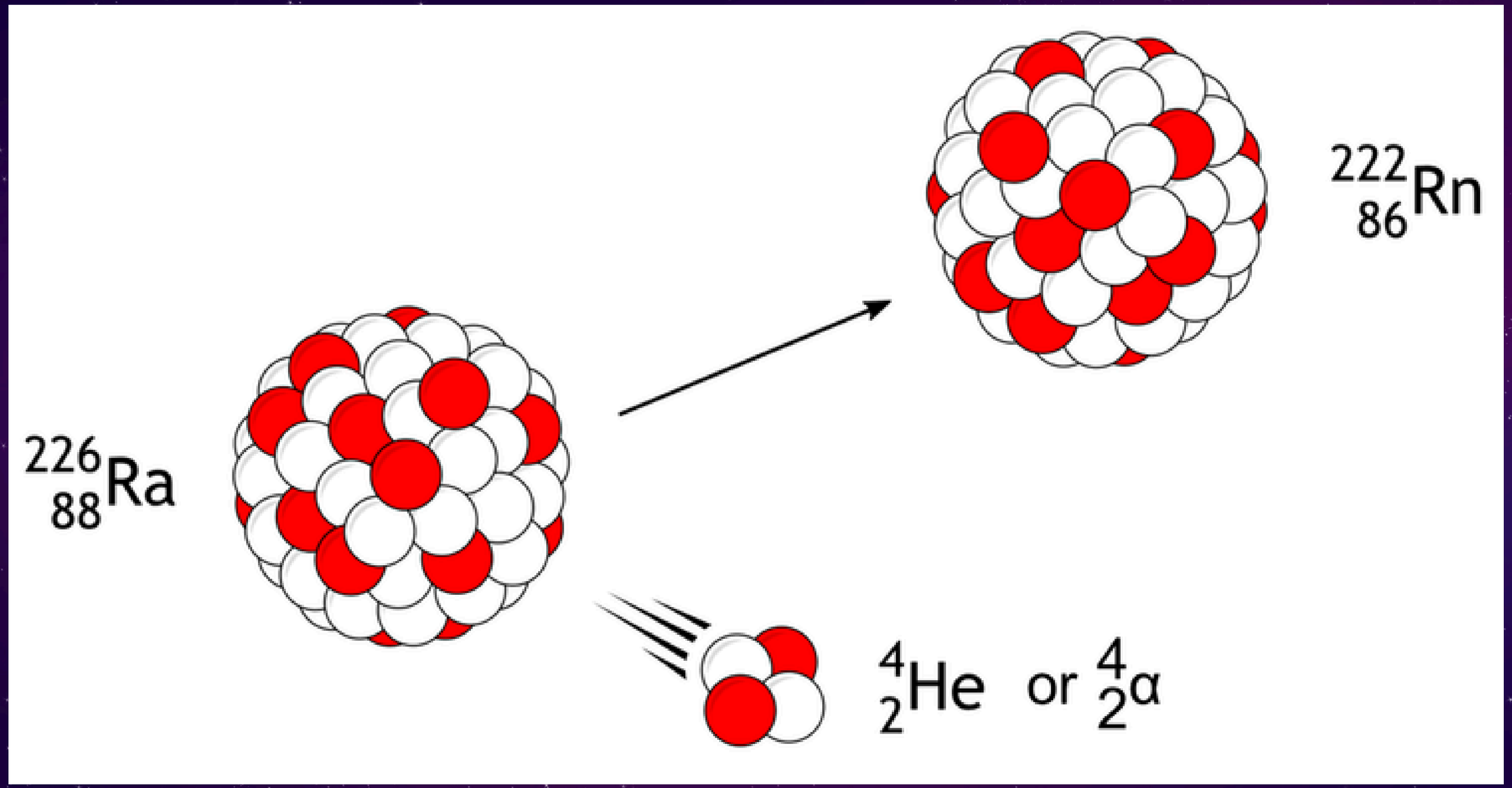
An unstable nucleus emits an alpha particle consisting of two protons and two neutrons. This reduces the atomic number of the atom by two and the mass number by four.

FORMULA:

$$ {}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha $$



$$^{235}_{92}U \rightarrow {}^{231}_{90}Th + {}^{4}_{2}\alpha$$



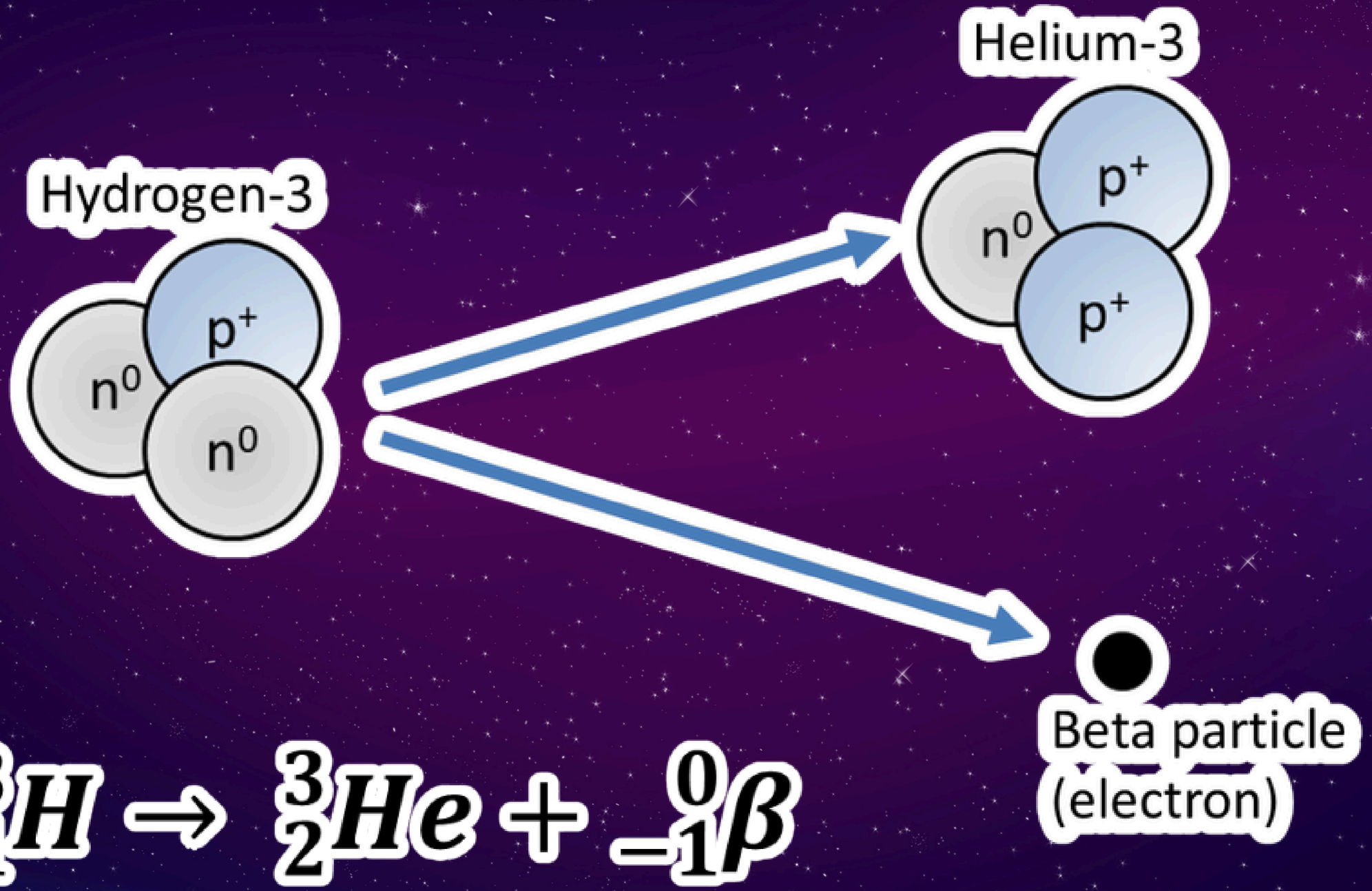
$$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}\alpha$$

BETA DECAY

A neutron in the nucleus converts into a proton, which is then ejected along with an electron, called a beta particle. This process increases the atomic number by one while keeping the mass number the same.

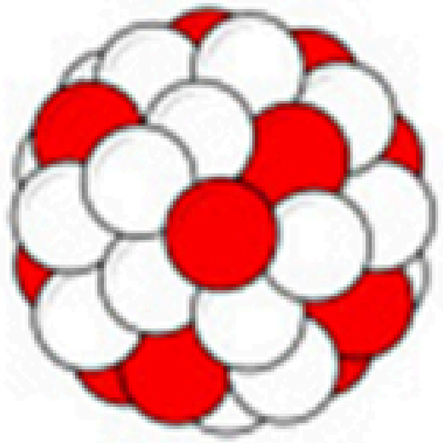
FORMULA:

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta $$



$$^{3}_{1}H \rightarrow {}^{3}_{2}He + {}^{0}_{-1}\beta$$

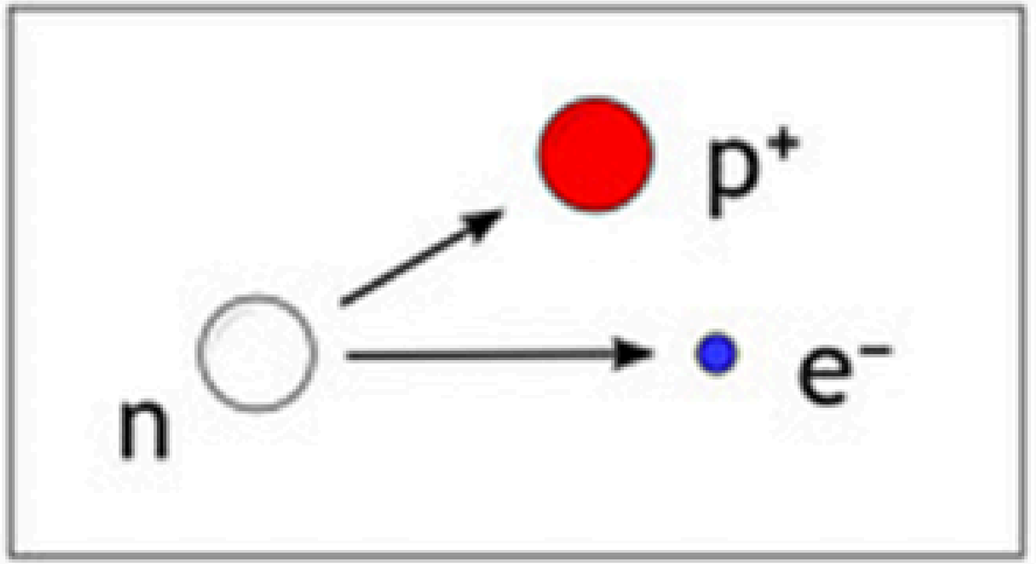
$$^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + {}^{0}_{-1}\beta$$



$^{137}_{56}$Ba

$^{137}_{55}$Cs

e⁻



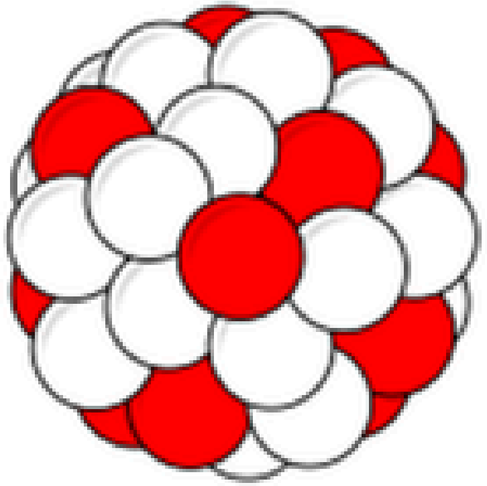
GAMMA DECAY

nucleus that is in an excited state releases excess energy in the form of gamma rays, which are high-energy photons. This type of decay does not change the atomic number or mass number of the nucleus, but rather lowers the energy of the nucleus to a more stable state.

FORMULA:

$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z}Y + {}^{0}_{0}\gamma $$

$$^{137}_{56}Ba \rightarrow {}^{137}_{56}Ba + {}^{0}_{0}\gamma$$



$^{137}_{56}$Ba

$^{137}_{56}$Ba