

# Nuclear Chemistry

Balancing nuclear equations, decay modes, decay kinetics, binding energy, and fission/fusion.

## 01 Conserve A and Z

CORE RULE

Both mass number A (top) and atomic number Z (bottom) are conserved: the sums must match on each side of a nuclear equation.

## 02 Particles

REFERENCE

| Particle   | Symbol (A, Z)               |
|------------|-----------------------------|
| alpha      | ${}^4_2\text{He}$ (4, 2)    |
| beta-minus | ${}^0_{-1}\text{e}$ (0, -1) |
| positron   | ${}^0_{+1}\text{e}$ (0, +1) |
| neutron    | ${}^1_0\text{n}$ (1, 0)     |
| proton     | ${}^1_1\text{p}$ (1, 1)     |
| gamma      | ${}^0_0\gamma$ (0, 0)       |

## 03 Decay modes

REFERENCE

| Mode             | Effect on nucleus                      |
|------------------|----------------------------------------|
| alpha            | A - 4, Z - 2                           |
| beta-minus       | A same, Z + 1 (n → p)                  |
| positron         | A same, Z - 1 (p → n)                  |
| electron capture | A same, Z - 1 (e <sup>-</sup> on left) |

## 04 Multi-step decay counting

CORE RULE

For x alphas + y betas: solve  $4x = \text{mass difference}$  and  $2x - y = \text{atomic-number difference}$  simultaneously.

## 05 Decay kinetics (first order)

CORE RULE

Decay is first-order:  $k = \ln 2 / t_{1/2} = 0.693 / t_{1/2}$  (units of inverse time).

Fraction remaining:  $N/N_0 = e^{(-kt)} = (1/2)^{(t/t_{1/2})}$ . Use the half-life form when  $t/t_{1/2}$  is a simple ratio.

## 06 Activity & dating

CORE RULE

Activity is proportional to the atom count, so  $\ln(A/A_0) = -kt$  substitutes directly, the basis of radiocarbon and other radiometric dating.

## 07 Mass defect & binding energy

CORE RULE

Mass defect  $\Delta m = (\text{mass of free protons + neutrons}) - (\text{actual nuclear mass})$ . Binding energy  $BE = \Delta m \cdot c^2$  ( $c = 2.998 \times 10^8 \text{ m/s}$ ).

## 08 Binding energy per nucleon

CORE RULE

$BE/A = \text{total binding energy} \div A$  (MeV/nucleon). The curve peaks near iron-nickel (Fe-56  $\approx 8.8$  MeV/nucleon), the most stable nuclei.

## 09 Fission vs fusion

CORE RULE

Fission: a heavy nucleus splits into two mid-mass nuclei + neutrons. Fusion: light nuclei combine. Both release energy when products sit higher on the BE/A curve (toward iron-nickel).

## 10 Activity $A = \lambda N$

CORE RULE

Activity  $A = \lambda N$ ,  $\lambda = \ln 2 / t_{1/2}$ ,  $N$  = number of radioactive atoms (from mass via molar mass and  $N_A$ ). SI unit: becquerel (1 Bq = 1 decay/s).