Nuclear Chemistry

The nuclei of some unstable isotopes undergo change by releasing energy and particles collectively known as radiation.

Spontaneous nuclear reactions:
Radioactive Decay

Review: Atomic Number

Protons
Neutrons
Electrons
Atomic Mass
Isotopes

Isotopes of Hydrogen

$^1\text{H}$ protium
most abundant isotope,
nucleus consists of ___________

$^2\text{H}$ deuterium
nucleus consists of ___________
often given the symbol “D”
$\text{D}_2\text{O}$;

$^3\text{H}$ tritium
nucleus consists of ___________
radioactive isotope: half-life of 12.3 y
not found in nature.

Isotope effects
Properties that depend on mass will be different for different isotopes of the same element.

Examples:
Nuclear Chemistry

The nuclei of some unstable isotopes undergo change by releasing energy and particles collectively known as _________.

Ionizing Radiation;

Long wavelength = __________ energy

Short wavelength = __________ energy

Five Types of Radioactive Decay

1) Emission of $\alpha$-particles: $^4_2He$

2) Emission of $\beta$-particles: $^0_1e = ^0_1\beta$ electrons

3) Emission of $\gamma$-rays: $^0_0\gamma$

4) Emission of positrons: $^0_1e = +1e = \beta^+\text{particles}$

5) Electron Capture: $e^-$ from a surrounding orbital
Alpha Decay

Spontaneous emission of $^4_2\alpha$ particles
He-4 nucleus or $^4_2He$

Example:
$^{238}_{92}U \to ^{234}_{90}Th + ^4_2He$

Balancing Nuclear Reactions:
1) Balance Atomic number (# of $^1_1p$)
2) Conservation of mass

In air, $\alpha$-particles travel several cm.
In Al, $\alpha$-particles travel $10^{-3}$ mm.

Emission of $\beta$-particles

Emission of $\beta$-particles: $^0_{-1}e = \text{electrons.}$

Example:
$^{131}_{53}I \to ^{131}_{54}Xe + ^0_{-1}e$

$\beta$-particle emission converts a neutron to a proton:
$^1_0n \to ^1_1p + ^0_{-1}e$

Write the nuclear equation for thorium-231 decaying to form protactinium-231:

In air, $\beta$-particles travel 10 m.
In Al, $\beta$-particles travel 0.5 mm.
Emission of Gamma Rays

Emission of $\gamma$-rays is **energy lost** when remaining nucleons reorganize into more stable arrangements: $^{0}_{0}\gamma$

$\gamma$-ray emission changes neither atomic number nor mass.

In Al, $\gamma$-particles travel 5-10 cm.

Emission of positrons

Emission of positrons: same **mass** as electron, but **positive charge**

$\beta^+$-particles or $\overset{0}{+1}_e$

Example: $^{11}_6C \rightarrow ^{11}_5B + ^{0}_1e$

Positron emission converts a proton to a neutron:

$^{1}_1p \rightarrow ^{0}_0n + ^{0}_1e$

Positrons have a short lifetime because they recombine with electrons and annihilate:

$^{0}_1e + ^{0}_{-1}e \rightarrow 2^{0}_0\gamma$
Electron Capture

Electron Capture: an electron from the orbitals surrounding the nucleus can be captured and pulled into the nucleus.

Example: \[ ^{81}_{37}\text{Rb} + ^{0}_{-1}\text{e} \rightarrow ^{81}_{36}\text{Kr} \]

Electron capture converts a proton to a neutron:

\[ ^{1}_{1}\text{p} + ^{0}_{-1}\text{e} \rightarrow ^{1}_{0}\text{n} \]

Fill in the blanks

\[ ^{239}_{94}\text{Pu} \rightarrow ^{4}_{2}\text{He} + ? \]

\[ ^{234}_{91}\text{Pr} \rightarrow ^{234}_{92}\text{U} + ? \]

1. \(^{1}_{1}\text{p}\)
2. \(^{0}_{-1}\text{e}\)
3. \(^{1}_{0}\text{n}\)
4. \(^{4}_{2}\text{He}\)

\[ ^{192}_{77}\text{Ir} + ? \rightarrow ^{192}_{76}\text{Os} \]

\[ ^{18}_{8}\text{F} \rightarrow ^{18}_{8}\text{O} + ? \]