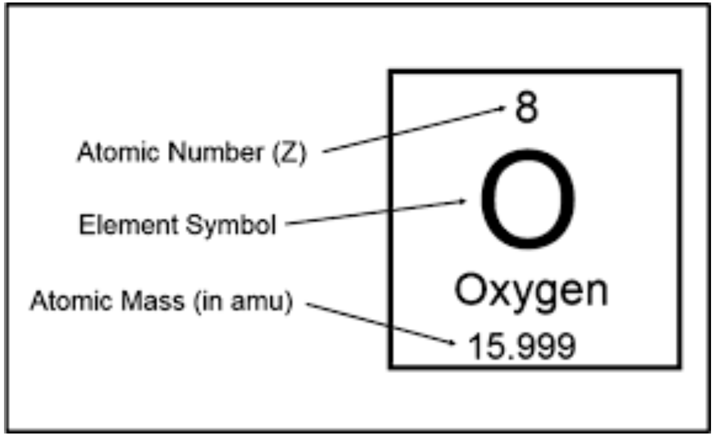


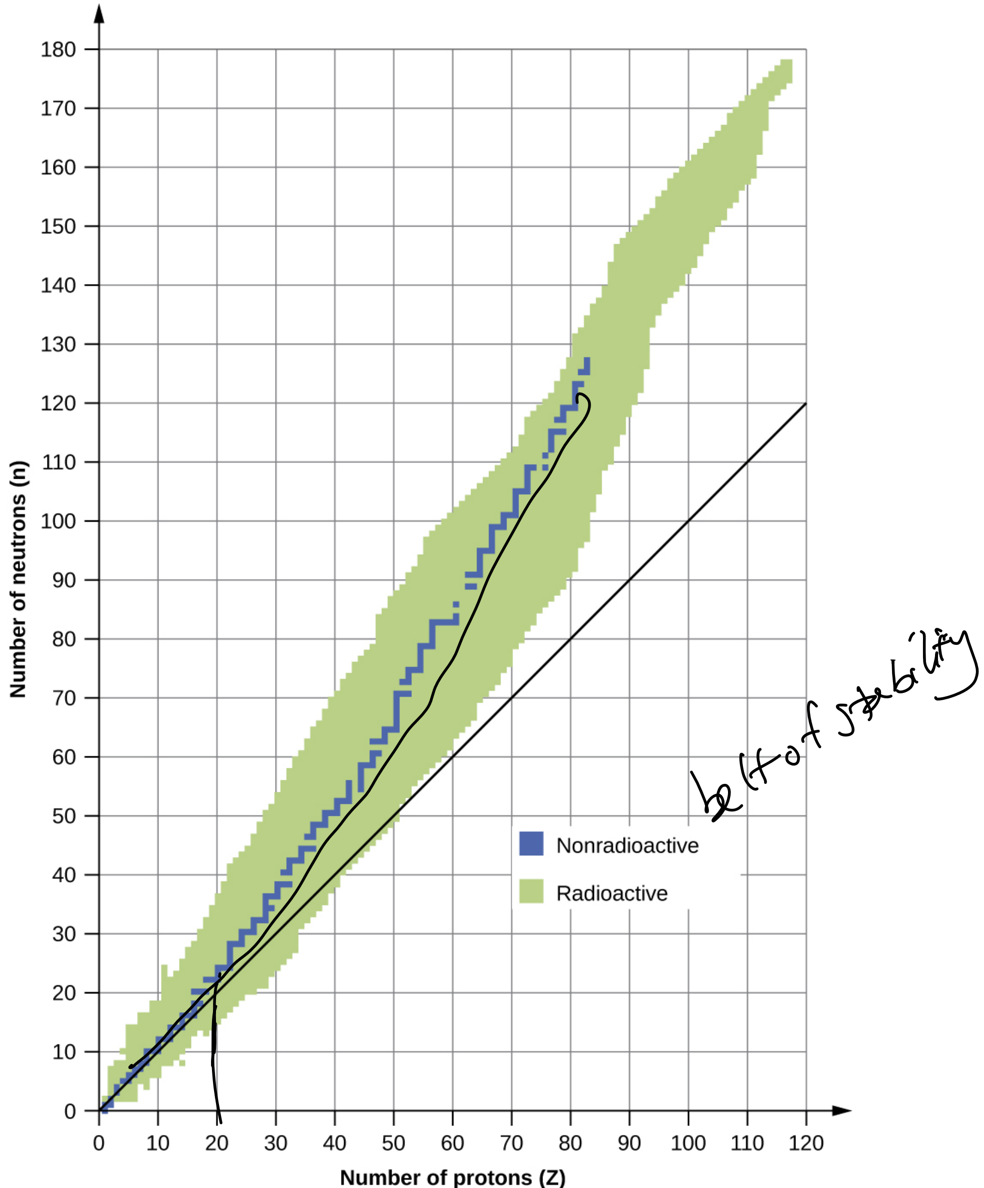
Isotopes

- Same number of protons but different number of neutrons
- Protons + neutrons are called nucleons

Radionuclides

- A nucleus is considered stable if it cannot transform without the addition of outside energy
- A radionuclide in contrast spontaneously decay into other nuclei until they reach a stable isotope

Belt of Stability



Types of Radioactive 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
Positron	${}^{0}_{+1}\mathrm{e}$ or ${}^{0}_{+1}\beta$		Particles with the same mass as an electron but with 1 unit of positive charge
Proton	${}^{1}_{1}\mathrm{H}$ or ${}^{1}_{1}\mathrm{p}$		Nuclei of hydrogen atoms
Neutron	${}^{1}_{0}\mathrm{n}$		Particles with a mass approximately equal to that of a proton but with no charge
Gamma ray	γ	 γ	Very high-energy electromagnetic radiation

https://openstax.org/books/chemistry-2e/pages/21-1-nuclear-structure-and-stability

Writing Nuclear Equations

- Al-27 undergoes alpha decay $^{4}_{2}\alpha$

$$^{27}_{13}Al \rightarrow ^{4}_{2}\alpha + ^{23}_{11}Na$$

- C-14 decays by beta emission $\rightarrow ^{0}_{-1}e$

$$^{14}_{6}C \rightarrow ^{0}_{-1}e + ^{14}_{7}N$$

- O-15 undergoes positron emission $^{0}_{+1}e$

$$^{15}_{8}O \rightarrow ^{0}_{+1}e + ^{15}_{7}N$$

- K-40 undergoes electron capture

$$^{40}_{19}K + ^{0}_{-1}e \rightarrow ^{40}_{18}Ar$$

- decay or emission of a particle products side
- capture particle is on reactant side.

Radioactive Decay

- Radioisotopes follow first order kinetics!

- $\ln(N_t) = -kt + \ln(N_o)$ and $t_{1/2} = 0.693/k$

b/c radionuclide

Example 1: Kinetics of Radioactive Decay

The half-life of cobalt-60 is 5.3 yr. How much of a 1.000-mg sample of cobalt-60 is left after 15.9 yr?

$$t_{1/2} = \frac{0.693}{K}$$

$\ln N_t - = -Kt + N_0$

or

$\frac{1}{2}$ lives $\frac{15.9 \text{ years}}{5.3 \text{ years}} =$

3 ½ lives

$\frac{1}{2^3} = \frac{1}{8} \cdot (1.000\text{mg})$

0.125mg

Example 2: Kinetics of Radioactive Decay

A wooden object from an archeological site is subjected to radiocarbon dating. The activity of the sample that is due to ^{14}C is measured to be 11.6 disintegrations per second. The activity of a carbon sample of equal mass from fresh wood is 15.2 disintegrations per second. The half-life of ^{14}C is 5715 yr. What is the age of the archeological sample?

$N_t = 11.6$ dis/sec

$N_0 = 15.2 \frac{dis}{sec}$

$$t_{1/2} = \frac{0.693}{k}$$

$$k = \frac{0.693}{5{,}715\ yr}$$

$$k = 1.21 \times 10^{-4}\ yr^{-1}$$

$$\ln N_t = -kt + \ln N_0$$

$$\ln N_t - \ln N_0 = -kt$$

$$\ln\left(\frac{N_t}{N_0}\right) = -kt$$

$$\ln\left(\frac{1.6}{15.2}\right) = -1.2\times10^{-4}\,yr^{-1}\,(t)$$

$$t = 2,252 \text{ years}$$

Potassium ion is present in foods and is an essential nutrient in the human body. One of the naturally occurring isotopes of potassium, potassium-40, is radioactive. Potassium-40 has a natural abundance of 0.0117% and a half-life $t_{1/2} = 1.28 \times 10^9$ yr. It undergoes radioactive decay in three ways: 98.2% is by electron capture, 1.35% is by beta emission, and 0.49% is by positron emission. **(a)** Why should we expect ^{40}K to be radioactive? **(b)** Write the nuclear equations for the three modes by which ^{40}K decays. **(c)** How many $^{40}K^+$ ions are present in 1.00 g of KCl? **(d)** How long does it take for 1.00% of the ^{40}K in a sample to undergo radioactive decay?

a) ^{40}K 19p + 21n > ∴ ratio n : p so undergo to radioactive rxn.

b) $^{40}_{19}K + ^{0}_{-1}e \rightarrow ^{40}_{18}Ar$

$^{40}_{19}K \rightarrow ^{0}_{-1}e + ^{40}_{20}Ca$

$^{40}_{19}K \rightarrow ^{0}_{+1}e + ^{40}_{18}Ar$

Cl? K^+ ions present in 1.00g KCl

$$1.00\text{g KCl} \times \frac{1\text{mol KCl}}{74\text{g KCl}} \times \frac{1\text{mol K}^+}{1\text{mol KCl}} \times \frac{6.02\times10^{23}\text{ ions}}{1\text{mol K}^+}$$

8.1×10^{21} K^+ ions

$^{40}K^+$ is 0.0117% - $(8.1\times10^{21})(0.000117)$

9.5×10^{17} K^+-40

d) How long does it take for 1.00% of K-40 to decay?

$$\ln\left(\frac{N_t}{N_0}\right) = -Kt$$

First find K

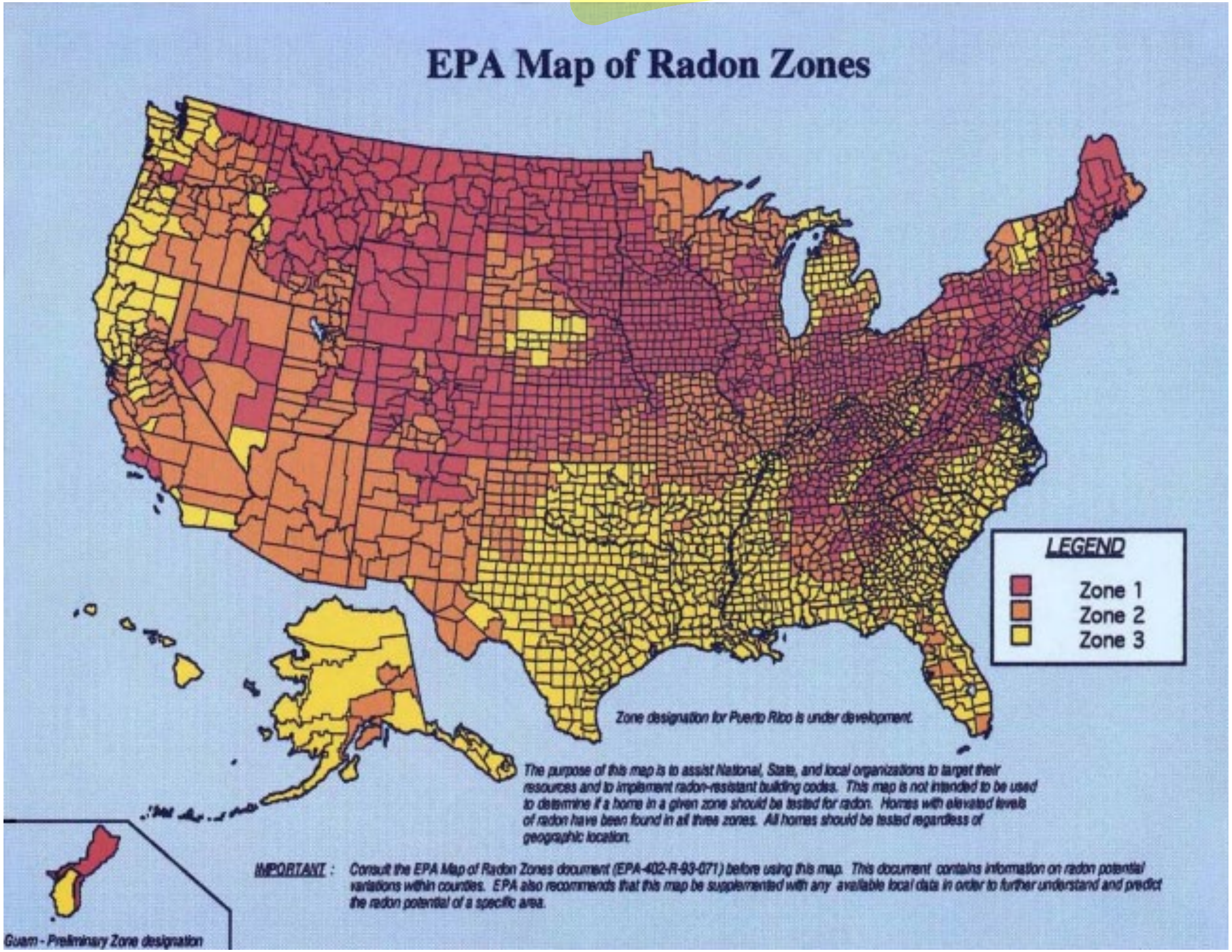
$$t_{1/2} = \frac{0.693}{K}$$

$$K = \frac{0.693}{1.28 \times 10^{9}\ yr}$$

$$K = 5.4 \times 10^{-10}\ yr^{-1}$$

$$\frac{\ln(0.99)}{-5.4 \times 10^{-10}\ yr^{-1}} = \frac{-5.4 \times 10^{-10}\ yr^{-1}(t)}{-5.4 \times 10^{-10}\ yr^{-1}}$$

$$t = 1.8 \times 10^{7}\ \text{years}$$



https://www.epa.gov/radon/epa-map-radon-zones-0