Unit 3 Lesson III (3.3)
Nuclear Reactions, Half-Life & Stability

Objective: The student will be able to (1) predict the products of nuclear reactions, (2) determine the amount of time it takes for these decay processes, (3) describe why these processes occur.

Nuclear Reactions
& Nucleosynthesis

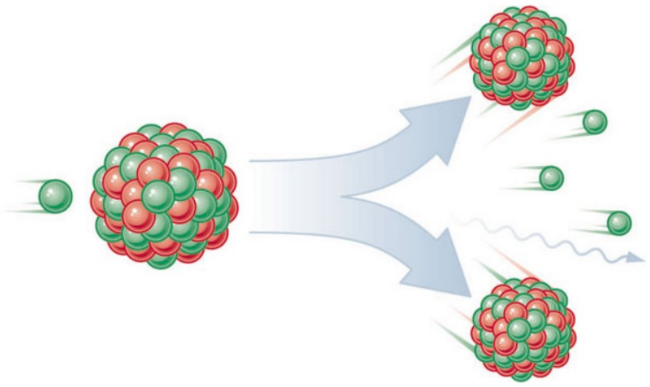
By far the most common nuclear reactors are the center of stars.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Uuu	Uub	Uut	Fl	Uup	Lv	Uus	Uuo

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

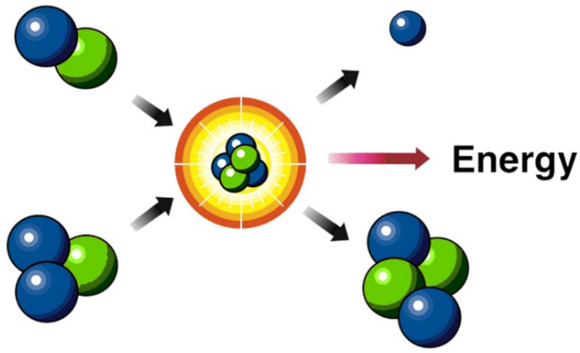
Stars **Supernovae** **Synthetic**

Types of Nuclear Reactions



1. Fission

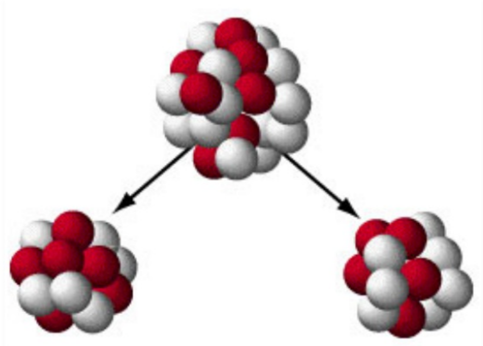
one nucleus is broken apart to form multiple nuclei by force



2. Fusion

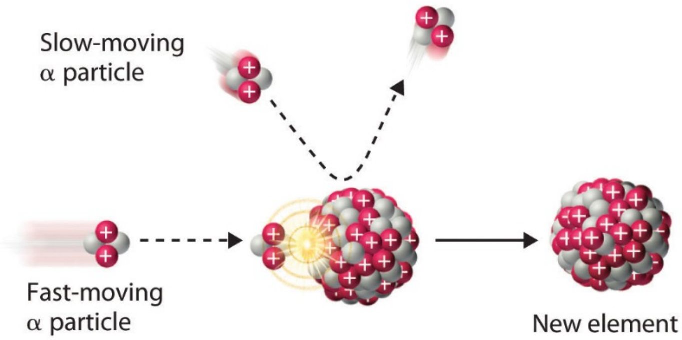
multiple nuclei are brought together to form a single nucleus

Types of Nuclear Reactions



3. Decay (spontaneous)

splitting of a single atom into multiple products on its own



4.Transmutation

bombardment of a particle to create a single new element

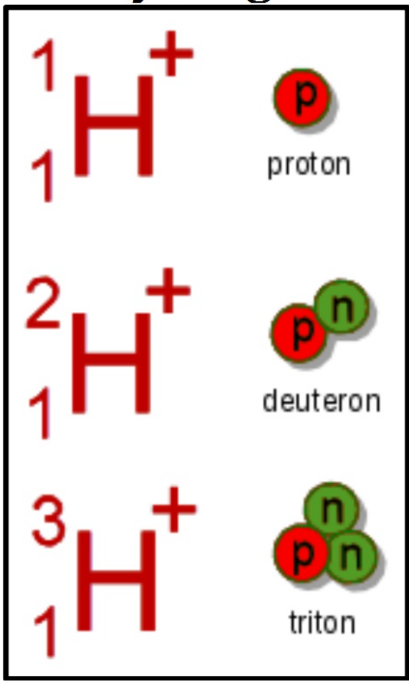
Particles You Should Know

$^{4}_{2}He$ $^{0}_{-1}\beta$ $^{0}_{0}\gamma$

$^{0}_{+1}\beta$ $^{0}_{-1}e$

$^{1}_{1}p$ $^{1}_{0}n$ $^{0}_{-1}e$

Isotopes of Hydrogen



Balancing Nuclear Reactions
The Law of Conservation of Mass

Example 1:

1. Al-27 + He-4 ➔ P-30 + ________

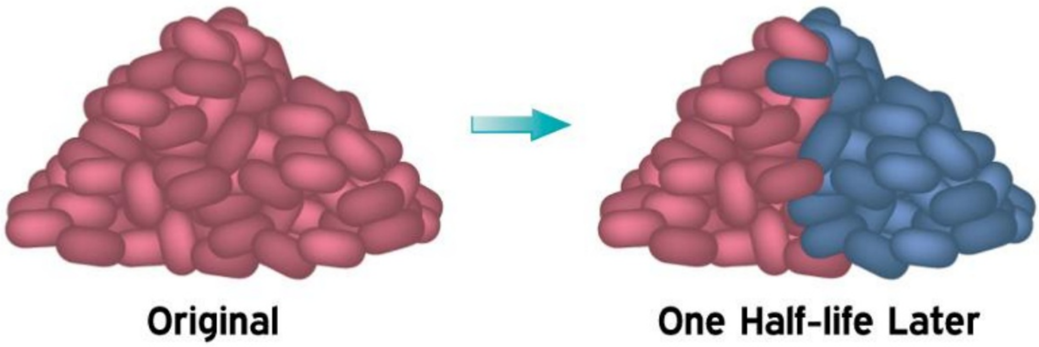
Example 2
Short-Hand nuclear reactions

Complete the following nuclear reactions:

Li-6 (p,γ)???

Half-Life

The time required for a quantity to fall to half its value as measured at the beginning of the time period.



Occurs with most forms of matter, but more quickly in radioactive substances

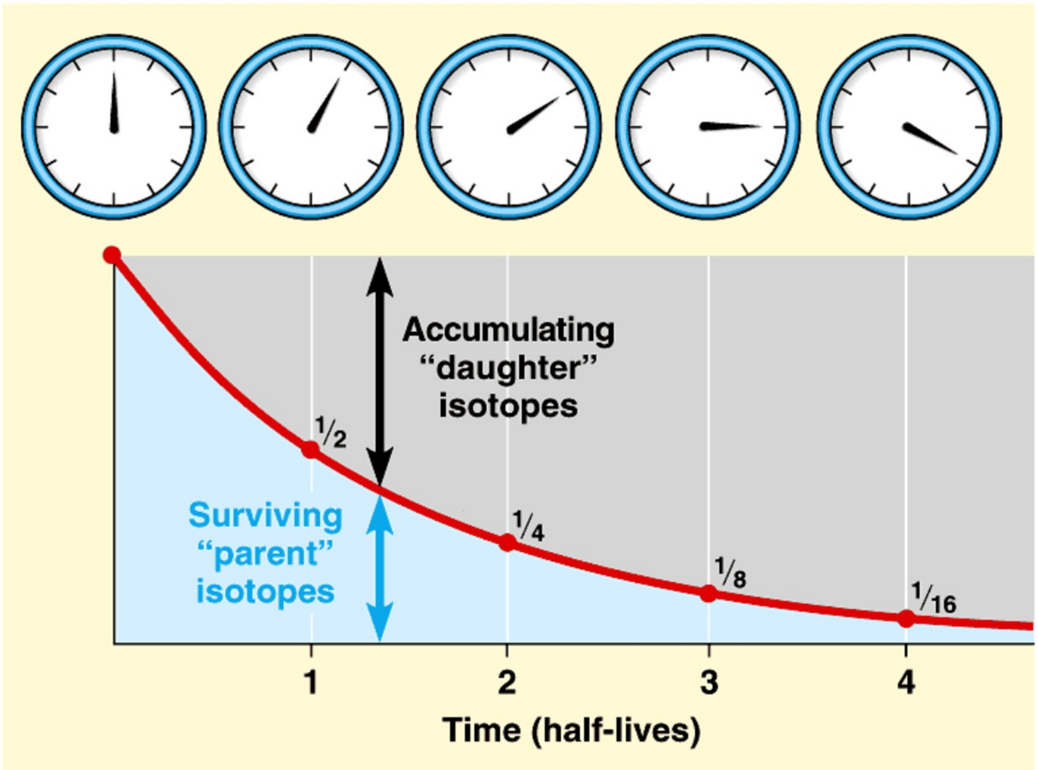
Simple Half-Life Problems

The half-life of radium-222 is 38 seconds. How many grams of radium-222 remain in a 12-gram sample after 76 seconds? After 114 seconds?

If the passing of 5 half-lives leaves 25.0 mg of strontium-90 sample, how much was present in the beginning?

Rarely as "cut-and-dry" however.

Half-life represented graphically



Equations

$$t_{(1/2)} = \frac{\ln(2)}{k}$$

$$A_0 = A_t e^{kt}$$

Variables:

$t_{(1/2)}$ ≡ half -life

ln ≡ natural log function (on calculator)

k ≡ decay rate constant

A_0 ≡ "A - naught" or initial amount of substance

A_t ≡ "A sub t" or amount at some time "t"

e ≡ exponential function (inverse operation of ln)

t ≡ time

Derivation of Formula

End: $t_{(1/2)} = \dfrac{\ln(2)}{k}$

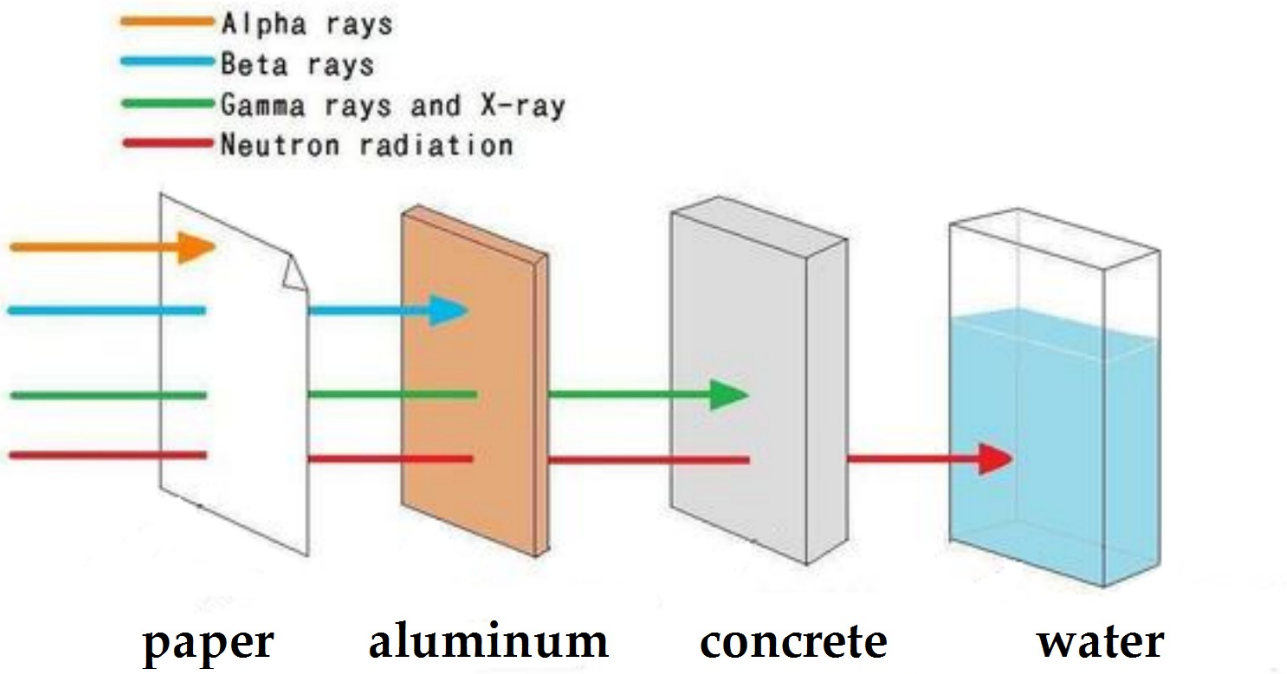
Example 1

What is the value of the decay rate constant (k) for Sn-121 if its half-life is known to be 76 years?

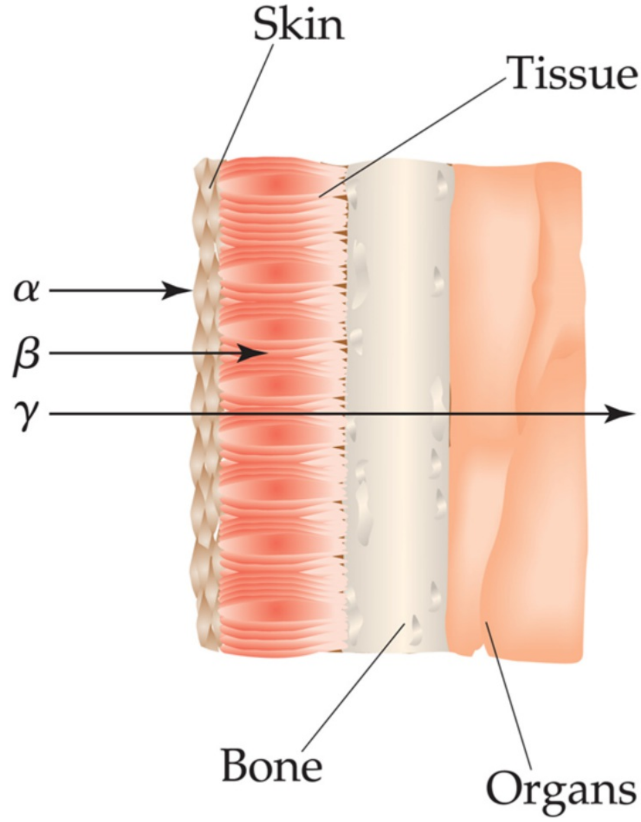
Example 2

Es-253 undergoes alpha decay at a rate of 20.47 days. (a) How many days would it take or a 5.60-mg sample to decay until only 7.72% remained? (b) What is the resulting nuclide?

Degree of Penetration



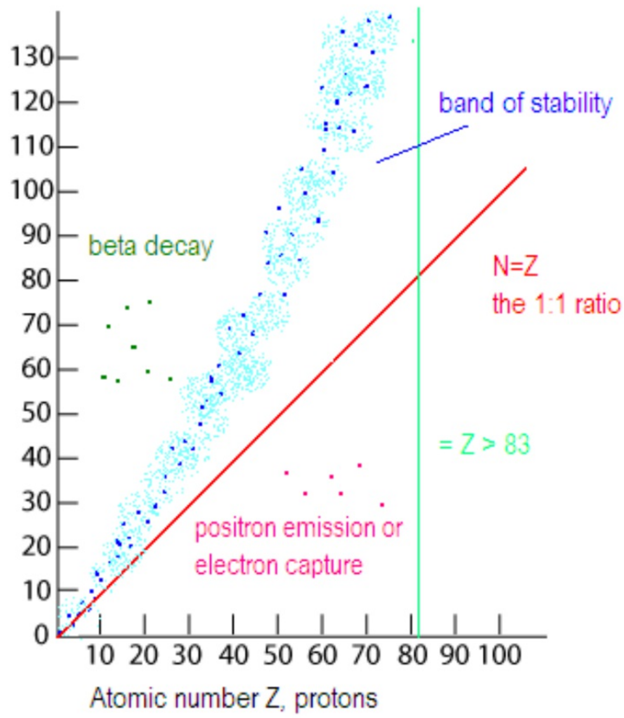
Penetrative Degree of Radioactivity for Humans



The Band of Stability

A plot of the number of neutrons vs. the atomic number

Generally, if the Z > 83 the nucleus is unstable (radioactive)



the principle factor: proton:neutron ratio

Examples: Ca-40, Hg-160 Zn-80, Tb-159

Magic Numbers

2, 8, 20, 28, 50, 82, and 126 (either p^+ or n^0)

These nuclei have a higher average binding energy and are more stable against nuclear decay.

Number of Stable Isotopes	Protons	Neutrons
157	Even	Even
53	Even	Odd
50	Odd	Even
5	Odd	Odd

Magic Numbers

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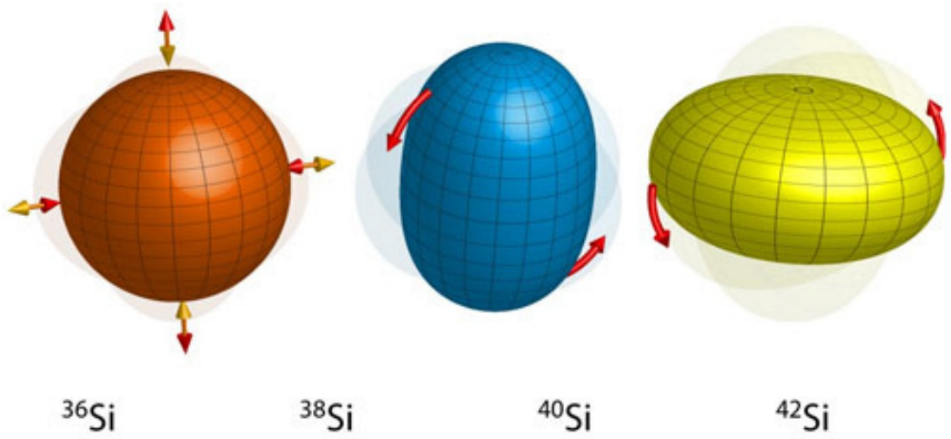


Examples: O-18, Ni-78, Cr-52

Double Magic Numbers

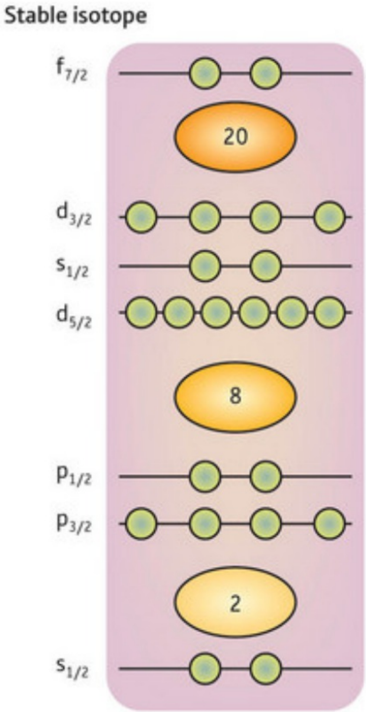
Occurs when both the neutron and proton numbers are equal to magic #s (does not have to be the same magic number).

Examples: He-4, O-16, Ca-40, Ca-48, Ni-48, and lead-208

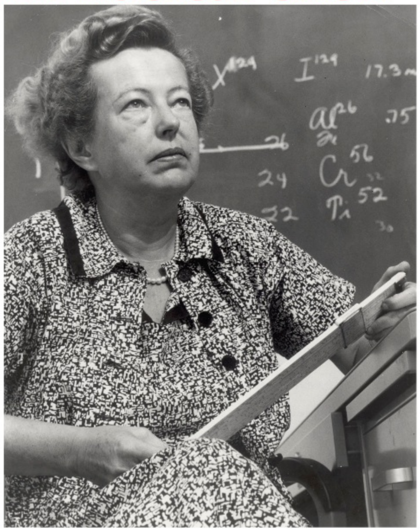
2, 8, 20, 28, 50, 82, and 126 (either p^+ or n^0)

Maria Goeppert Mayer
Mother of Nuclear Stability

Lead development of mathematical and physical explanations of nuclear stability.



Inspired by the work of Bohr and Schrödinger to develop a model of protons and neutrons in nuclear shell model.



Radioactivity

Examples:

Identify whether the following isotopes would be radioactive or stable.

Two factors to consider:

Sn-118 Mg-24 At- 215 Fr-224

2, 8, 20, 28, 50, 82, and 126 (either p^+ or n^0)