26 • Nuclear Chemistry The People (1 of 12)

- **Wilhelm Roentgen** (1845-1923) discovered X-rays, a high energy form of light. (1895)
- **Henri Becquerel** (1852-1909) found that uranium ores emit radiation that can pass through objects (like x-rays) and affect photographic plates. (1896)
- **Marie Sklodowska Curie** (1867-1934) Marie and Pierre worked with Becquerel to understand radioactivity. The three shared a Nobel Prize in Physics in 1903. Marie won a second Nobel Prize in Chemistry in 1911 for her work with radium and its properties.
- **E. O. Lawrence** invented the cyclotron which was used at UC Berkeley to make many of the transuranium elements.

26 • Nuclear Chemistry Terms I-- Radioactivity (2 of 12)

radioactivity	the spontaneous breakdown of atomic nuclei, accompanied by the release of some form of radiation (also called **radioactive decay**)
half-life	time required for half of a radioactive sample to decay
transmutation	one element being converted into another by a nuclear change
nuclides	isotopes of elements that are identified by the number of their protons and neutrons
emission	the particle ejected from the nucleus.

26 • Nuclear Chemistry Terms II--Radioactivity (3 of 12)

decay series	the sequence of nuclides that an element changes into until it forms a stable nucleus
radioactive dating	using half-life information to determine the age of objects. C-14/C-12 is common.
nuclear fission	large nucleus breaking down into pieces of about the same mass
nuclear fusion	two or more light nuclei blend to form one or more larger nuclei

26 • Nuclear Chemistry Types of Radiation (4 of 12)

Alpha particles are the same as a helium nucleus, $^{4}_{2}He$, with a mass of 4 amu. It travels about 1/10th the speed of light and is the most easily stopped of the three particles (a sheet of paper will stop them). It is the least dangerous.

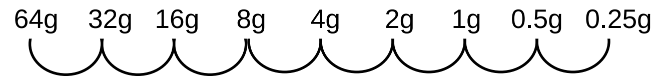
Beta particles are high speed electrons, $^{0}_{-1}e$, with a mass of 0.00055 amu and travels at nearly the speed of light. It can be stopped by a sheet of aluminum. It is more penetrating and therefore more dangerous than alpha.

Gamma rays are extremely high energy light, γ, with no mass, and are the most penetrating (several cm's of lead are needed to stop them). They can cause severe damage.

26 • Nuclear Chemistry
Half-Life Problems
(5 of 12)

In each half-life problem there are basically <u>four</u> variables:

- total time
- starting amount
- half-life
- ending amount

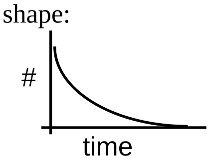


Question:
If you have 0.25 g of a radioactive substance with a half life of 3 days, how long ago did you have 64 grams?

Answer: Draw the chart to determine the number of half-lives to get from the ending amount to the starting amount… each half-life is worth 3 days…**24 days**.

26 • Nuclear Chemistry
Half-Life
(6 of 12)

The time it takes for half of a radioactive substance to decay. The graph has a characteristic shape:



The time it takes for the amount or the activity of the substance to drop to half is the same WHEREVER you start on the graph.

Half-lives can range from microseconds to thousands of years and is characteristic of each substance.

26 • Nuclear Chemistry
Nuclear Equations
(7 of 12)

Memorize the symbols for the important particles

alpha	**beta**	**positron**	**neutron**
${}^{4}_{2}He$	${}^{0}_{-1}e$	${}^{0}_{+1}e$	${}^{1}_{0}n$

Decay means the particle is on the right side of the equation:

example: **alpha** decay of U-**238**

$${}^{238}_{92}U \rightarrow {}^{4}_{2}He + {}^{234}_{90}Th$$

The 234 and 90 are calculated… the Th is found on the periodic table (find the element with atomic # = 90).
Several neutrons can be shown together and written as…

$3({}^{1}_{0}n)$ and would be counted as ${}^{3}_{0}n$ in the equation.

26 • Nuclear Chemistry
How Each Type of Decay Can Stabilize an Unstable Nucleus
(8 of 12)

Certain values of p+'s and no's in the nucleus are stable. A nucleus can be unstable (radioactive) for 3 reasons:

- the nucleus has **too many protons** compared to neutrons
  solution: **positron** decay
  (change a proton into a neutron and a positive electron… …a positron)
- the nucleus has **too many neutrons** compared to protons
  solution: **beta** decay
  (change a neutron into a proton and a negative beta particle)
- the nucleus is **too big** (too many protons <u>and</u> neutrons)
  solution: **alpha** decay (lose 2 p^+ and 2 n°)

26 • Nuclear Chemistry
Uses of Radioactivity
(9 of 12)

Radioactive Dating: In every living thing there is a constant ratio of normal C-12 and radioactive C-14. You can calculate the time needed to change from what is expected to what is actually found.
Radioisotopes: Many substances can be radioactive and then followed as they move through the body.

Fission Reactors: Current nuclear reactors use fission reactions to produce heat which is used to turn water into steam and drive turbine engines that produce electricity.
The Sun and Stars are powered by nuclear fusion… this is related to the fact that the most abundant element in the universe is hydrogen… followed by helium.

26 • Nuclear Chemistry
Fission and Fusion Reactions
(10 of 12)

U-235 is "**fissionable**" which means it can be split when bombarded by neutrons.

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + \text{energy}$$

The fact that each splitting nucleus can emit neutrons that can split other nuclei is the basis for the "chain reaction."
"Breeder reactors" use different isotopes. See page 774.

Fusion in the Sun involves several steps that can be summed up as: $4({}^{1}_{1}H) \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e + \text{energy}$
Thermonuclear devices use isotopes of hydrogen (deuterium and tritium): ${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n + \text{energy}$

26 • Nuclear Chemistry
Energy–Mass Conversions
(11 of 12)

Einstein's famous equation, $\mathbf{E = mc^2}$, is the basis for explaining where the energy associated with nuclear changes comes from.

When a nuclear change occurs, the mass of the products is slightly less than the mass of the reactants. This loss in mass is called the **mass defect.**

E = the energy
m = the mass defect
c = the speed of light, 3.00×10^8 m/s

As stated in your text, **1 kg of mass** converted into energy would be equivalent to burning **3 billion kg of coal!**

26 • Nuclear Chemistry
What Happens During Beta and Positron Decay
(12 of 12)

During **beta decay**,
1 neutron changes into 1 proton + 1 negative beta particle
(The atomic # increases by one due to the new proton. The mass # is unchanged… a neutron is gone. To maintain electrical neurtality, a negative beta particle is also formed.)

Example: ${}^{235}_{92}U \rightarrow {}^{0}_{-1}e + {}^{235}_{93}Np$

During **positron decay**,
1 proton changes into 1 neutron + 1 positron particle
(The atomic # decreases by one due to the loss of a proton. Since it changed into a neutron, the mass # is unchanged.)

Example: ${}^{235}_{92}U \rightarrow {}^{0}_{+1}e + {}^{235}_{91}Pa$