Nuclear Chemistry

Name: ____________________

AP Chemistry Lecture Outline

Video 2103 (4:29)

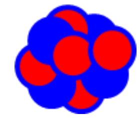
Introduction to Nuclear Chemistry

_____________________________ involve changes with electrons.

_____________________________ involve changes in atomic nuclei.

Spontaneously-changing nuclei emit _______________ and are said to be

______________________.



nucleons:

mass number:

isotopes: atoms having the same number of p^+, but different numbers of n^0

-- radioactive ones are called ________________________

-- ALL isotopes of an element behave the same, ______________.

nuclide: a nucleus ^{w}/a specified number of p^+ and n^0

-- radioactive ones are called ________________________

atomic number:

Radioisotopes (or radionuclides) have too many or too few neutrons.

Nucleus attempts to attain a _____ energy state by ____________ extra energy as radiation.

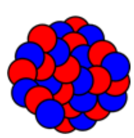
e.g.,

Video 2106 (7:42)

Transmutation via Radioactive Decay

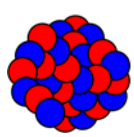
For nuclear equations, mass (top) and charge (bottom) must balance.

alpha (α) decay:



α-particle (i.e., a He nucleus):

beta (β) decay:



β-particle (i.e., a fast-moving electron):

In β-decay, the ***effect*** is that a n^0 is converted into a p^+, ejecting an e^- from the nucleus.

NOTE: There are no e^- in the nucleus. The ejected e^- is formed when energy released from the nucleus "congeals" into mass, via ______.

Video
2109
(6:57)

gamma radiation:

-- can penetrate to internal organs

-- gamma ray:

→ emitted when nucleons rearrange into a more stable configuration

-- gamma radiation often accompanies other nuclear decays

positron decay:

positron: identical to an e^-, but (+)

electron capture: nucleus captures orbiting e^-

The ***effect*** of positron decay AND electron capture is to turn a p^+ into a n^0.

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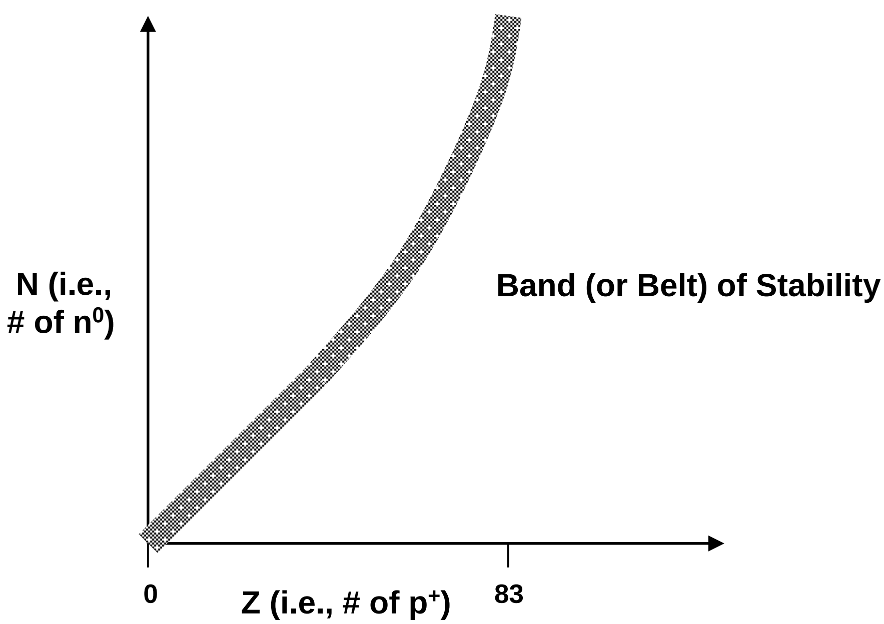
(9:45)

Nuclear Stability

Nucleons are held together by the ________________________.

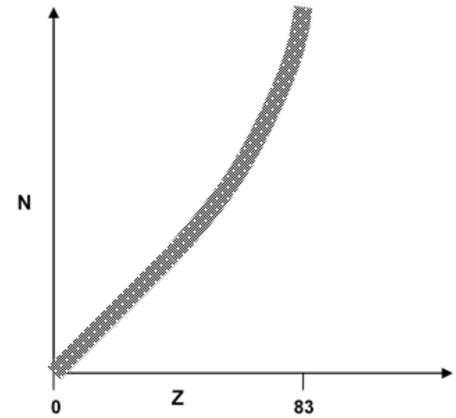


Nuclei that…	…have too many…	…and stabilize by…
…are above belt…		
…are below belt…		
…have Z > 83…		

Examples: $^{242}_{94}\text{Pu}$

$^{163}_{64}\text{Gd}$

$^{125}_{65}\text{Tb}$



A <u>radioactive series</u> is the sequence a radionuclide goes through to become stable.

e.g.,

-- there are three basic series, ending with…

Also, nuclei having "magic numbers" of p^+ or n^0 tend to be more stable than those that don't.

→ p^+:

→ n^0:

The <u>shell model</u> of the nucleus, which says that the nucleons reside in shells, has been proposed to explain these observations. This theory is analogous to the "shells of e^-s" theory.

Finally, nuclides with an even number of p^+ AND an even number of n^0 tend to be stable.

Video 2115 (6:24)

Transmutation via Nuclear Reactions

These are induced by a bombarding particle,
and typically have two reactants and two products:

target nucleus   bombarding particle   ejected particle   product nucleus

This reaction is abbreviated…

EX. Predict the missing species and write the shorthand. $^{27}_{13}\text{Al} + ^{1}_{0}\text{n} \rightarrow \ ? + ^{24}_{11}\text{Na}$

EX. Predict the missing species and write the equation. $^{14}_{7}\text{N} \ (\alpha, p) \ ?$

Particle accelerators are used to accelerate charged particles (e.g., α). We cannot accelerate neutrons, but we can use n^0-emitters to produce artificial isotopes. Often, β-emission follows n^0 absorption. For example:

First… then… and then…

Video
2118
(7:08)

Rates of Radioactive Decay

Each radioisotope has a unique rate of decay, its half-life, $\mathbf{t_{1/2}}$, which is the time required for half of a sample of a radioisotope to decay into something else. An isotope's half-life is independent of…

Radioactive decay is a first-order kinetic process. Recall the first-order rate law:

AND the first-order equation for half-life:

EX. Molybdenum-99 has a half-life of 67.0 hours. How much of a 1.000 mg sample of Mo-99 is left after 16.0 days?

Video
2121
(7:29)

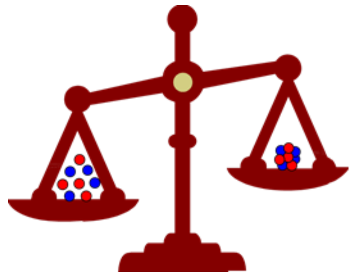
Energy Changes in Nuclear Processes

Energy and mass are two sides of the same coin.

When a system LOSES/gains energy, it _______/_______ mass.

In chemical reactions, the mass change is nearly undetectable, so we speak of mass as being "conserved," when it really isn't. The amount of "mass-and-energy-together," however, **IS** conserved. Mass changes in nuclear reactions are much larger, and are (fairly) easily measured.

Nuclear Binding Energy mass of nucleons ◯ mass of nucleus



mass defect =

rest masses: n^0 = 1.00866 amu = 1.67493 x 10^{-24} g
p^+ = 1.00728 amu = 1.67262 x 10^{-24} g
e^- = 0.0005486 amu = 9.113 x 10^{-28} g

Use mass defect, $E = mc^2$, and # of nucleons to calculate binding energy per nucleon (BE/n).

-- large BE/n means great nuclear ___________

-- BE/n is largest for Fe-56, meaning:

(1) Larger-than-Fe-56-nuclei…

(2) Smaller-than-Fe-56-nuclei…

Video
2124
(5:42)

EX. Calculate the binding energy per nucleon of N-14, which has a nuclear mass of 13.999234 amu.

Video
2127
(9:15)

Fission and Fusion

Nuclear Fission

chain reaction: one nuclear event leads to add'l ones

"fissionable" means...

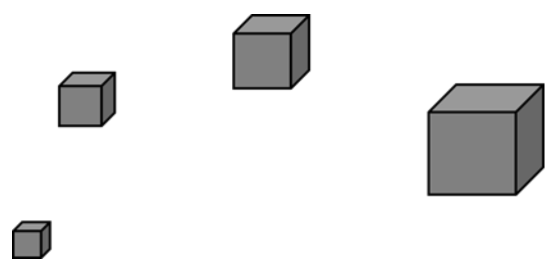
"fissile" means...

Fission probability increases when we have...

Important fissile nuclei:

critical mass: the mass of fissile material required to maintain a chain reaction at a constant rate

supercritical mass: the minimum mass for which the chain rxn accelerates



Nuclear Fusion

stars:

-- products are generally NOT radioactive

-- requires high temperatures

-- Research into controlling fusion continues.

Video
2130
(8:37)

Fission Reactors

-- fuel is…

-- <u>control rods</u> of B or Cd…

-- <u>moderator</u>:

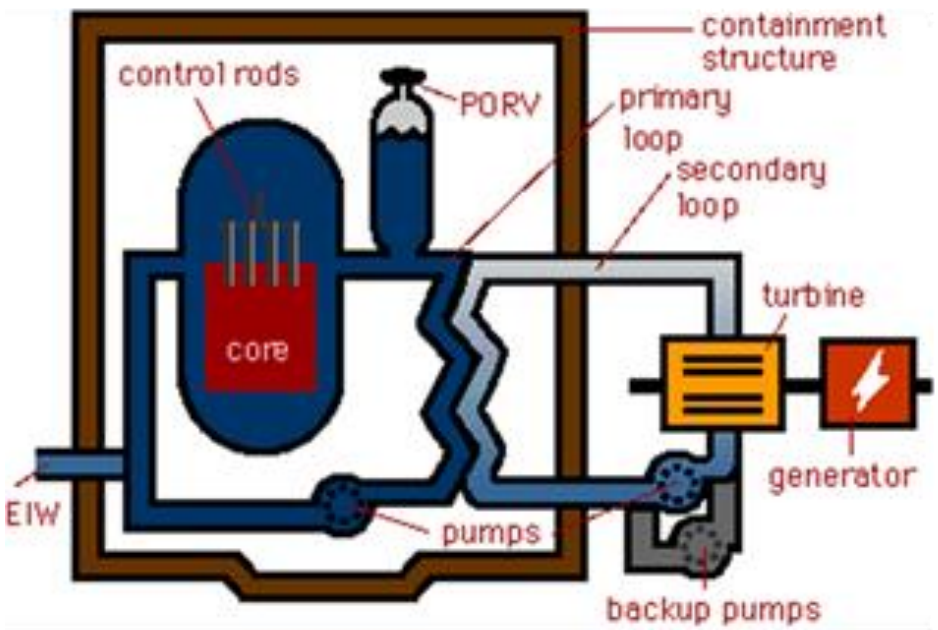
→ reactors in former USSR:

→ in the rest of the world:

Use LOW molar-mass mat'ls because they will...

-- water is heated to steam, which spins electrical-generating turbines

Schematic of a Nuclear Power Plant



EIW = Emergency Injection Water

PORV = Pressure Release Valve

Main benefits:

(1)

(2)

(3) <u>breeder reactors</u>: reactors that generate new fissile material at a greater rate than the original fuel is consumed

-- non-fissile U-238 is transmuted into fissile Pu-239

Main problem:

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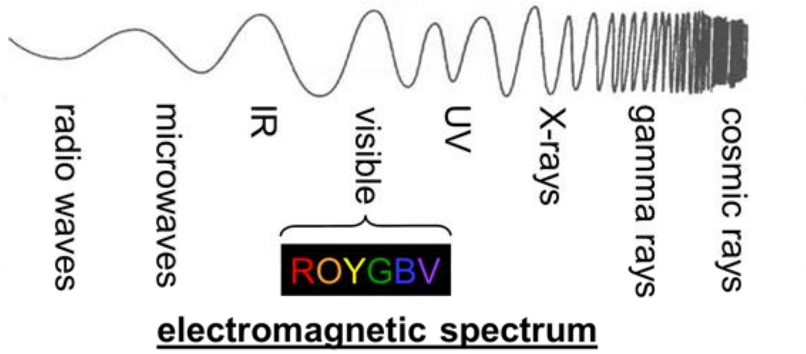
2133
(7:08)

Biological Effects of Radiation

nonionizing radiation: bumps e^- to higher energy levels OR heats molecules

ionizing radiation: knocks e^- OUT OF molecules

-- e.g.,



Ionizing radiation affects living tissue, thus: (1)

(2)

-- the tissues most damaged by radiation are the ones with cells that rapidly reproduce:

-- low doses over a long time can induce cancer, which is…

Units for Radiation Doses

1 bequerel (Bq) = 1 disintegration/sec

1 Curie (Ci) = 3.7 x 10^{10} disintegrations/sec

1 gray (Gy) = absorbing 1 J/kg of tissue

1 rad = absorbing 1 x 10^{-2} J/kg of tissue

Since the various types of radiation damage tissue with various degrees of efficiency, each type has its own relative biological effectiveness (RBE).

Radon -- an α-emitter from the decay of radium in rocks and soil

-- very dense; seeps into basements and is readily inhaled

-- estimated to be responsible for _____ of U.S. lung cancer deaths