Unit 3B - Nuclear Chemistry Study Guide

1. Nuclear Radiation

I. Introduction

A. Nucleons

1. Neutrons and protons

B. Nuclides

1. Atoms identified by the number of protons and neutrons in the nucleus

a. radium-228 or $^{228}_{88}Ra$

Do This → page 664 #2 - online book, page 703 in class

① Equal #s of p^+ and n^0
② Even # of both p^+ and n^0
③ Magic #s of p^+ and n^0 in the nucleus

II. Radioactivity

A. Radioactive Decay

1. The spontaneous disintegration of a nucleus into a slightly lighter and more stable nucleus, accompanied by emission of particles, electromagnetic radiation, or both

B. Nuclear Radiation

1. Particles or electromagnetic radiation emitted from the nucleus during radioactive decay

C. Unstable Nuclides

1. All nuclides beyond atomic # 83 are unstable and radioactive

III. Types of Radioactive Decay

A. Alpha Emission

1. Alpha particle (α) is a helium nucleus (^4_2He), so it has a 2+ charge

2. Alpha emission is restricted almost entirely to very heavy nuclei

$$^{210}_{84}Po \rightarrow ^{206}_{82}Pb + ^4_2He$$

B. Beta Emission

1. Beta particle (β) is an electron emitted from the nucleus during nuclear decay

$$^1_0n \rightarrow ^1_1p + ^0_{-1}e$$

2. Beta particles are emitted when a neutron is converted into a proton and an electron

$$^{14}_6C \rightarrow ^{14}_7N + ^0_{-1}e$$

15. a) decrease Mass # by 4, " At. # by 2 — α
b) increase At. # by 1, no change in Mass # — β^-
c) decrease At. # by 1, no change in Mass # — β^+
d) decrease in At. # by 1, no change in mass # — e^- capt.

* Do This: page 661 online or 703 in class #15

Nuclear Equations

Do This → Complete each nuclear equation by filling in the blank space. Then name the type of decay.

1. $^{214}_{84}Po \rightarrow ^{210}_{82}Pb +$ ^4_2He alpha
2. $^{222}_{86}Rn \rightarrow$ $^{218}_{84}Po$ $+ ^4_2He$ alpha
3. $^{230}_{90}Th \rightarrow ^{226}_{88}Ra +$ ^4_2He alpha
4. $^{214}_{82}Pb \rightarrow$ $^{214}_{83}Bi$ $+ ^0_{-1}e$ beta
5. $^{226}_{88}Ra \rightarrow$ $^{222}_{86}Rn$ $+ ^4_2He$ alpha
6. $^{239}_{93}Np \rightarrow$ $^{239}_{94}Pu$ $+ ^0_{-1}e$ beta
7. $^{238}_{92}U$ $\rightarrow ^{234}_{90}Th + ^4_2He$ alpha
8. $^{234}_{92}U \rightarrow ^{234}_{93}Np +$ $^0_{-1}e$ beta
9. $^{206}_{82}Pb + ^4_2He \rightarrow$ $^{210}_{84}Po$ transmutation
10. $^{254}_{91}Pa \rightarrow$ $^{254}_{92}U$ $+ ^0_{-1}e$ beta
11. $^{226}_{88}Ra \rightarrow$ $^{222}_{86}Rn$ $+ ^4_2He$ + gamma rays alpha
12. $^{214}_{82}Pb \rightarrow$ $^{214}_{83}Bi$ $+ ^0_{-1}e$ + gamma rays beta

42. $^{232}_{90}Th \rightarrow ^4_2He + ^{228}_{88}Ra \rightarrow ^0_{-1}e + ^{228}_{89}Ac \rightarrow ^0_{-1}e + ^{228}_{90}Th \rightarrow ^4_2He + ^{224}_{88}Ra$

* Now Try: #42 pg. 665 - online, 704 - textbook

III Transmutation Reactions

A. Transmutations

1. A change in the identity of a nucleus as a result of a change in the number of its protons

B. Nuclear Reaction

1. A reaction that affects the nucleus of an atom
2. Small amounts of mass are converted to LARGE amounts of energy
   a. $E = mc^2$

C. Balancing Nuclear Reactions

1. Total atomic numbers and mass numbers must be equal on both sides

$$^{9}_{4}Be + ^{4}_{2}He \rightarrow ^{12}_{6}C + ^{1}_{0}n$$

Complete the following nuclear equations.

1. $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}p$
2. $^{185}_{79}Au \rightarrow ^{181}_{77}Ir + ^{4}_{2}He$
3. $^{241}_{95}Am \rightarrow ^{4}_{2}He + ^{237}_{93}Np$
4. $^{238}_{92}U + ^{12}_{6}C \rightarrow ^{246}_{98}Cf + 4^{1}_{0}n$
5. $^{142}_{61}Pm + ^{0}_{+1}e \rightarrow ^{142}_{60}Nd$
6. $^{14}_{7}N + ^{1}_{0}n \rightarrow ^{14}_{6}C + ^{1}_{1}p$
7. $^{13}_{6}C + ^{1}_{0}n \rightarrow ^{14}_{6}C$
8. $^{239}_{94}Pu + ^{4}_{2}He \rightarrow ^{1}_{1}H + 2^{1}_{0}n + ^{240}_{95}Am$

3. **Fission and Fusion of Atomic Nuclei**

I Nuclear Fission

A. Nuclear Fission

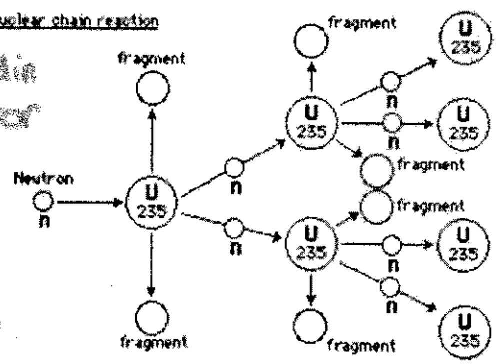
1. A very heavy nucleus splits into more stable nuclei of intermediate mass
2. The mass of the products is less than the mass of the reactants. Missing mass is converted to energy
   a. Small amounts of missing mass are converted to HUGE amounts of energy ($E = mc^2$)

B. Nuclear Chain Reaction

1. A reaction in which the material that starts the reaction is also one of the products and can start another reaction

#37. The fuel contains fissioning material. The coolant absorbs heat created in the reaction. The moderator slows down fast neutrons produced by fission. Sheilding protects the surroundings from radiation. Control rods limit the number of free neutrons by absorbing them.

A nuclear chain reaction



Do This → page 704 # 35+37

35. When slow moving neutrons are absorbed by uranium-235, the atom splits + emits more neutrons which in turn bombards more uranium atoms, and so on.

C. Critical Mass

1. The minimum amount of nuclide that provides the number of neutrons needed to sustain a chain reaction

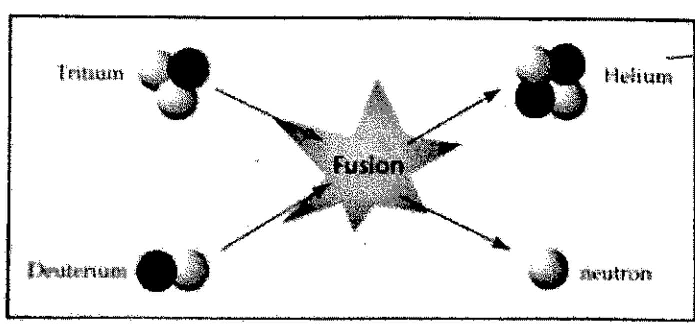
II Nuclear Fusion

A. Nuclear Fusion

1. Light-mass nuclei combine to form a heavier, more stable nucleus

38. 4 hydrogen nuclei combine at extremely high Temp + Pressure to create Helium

Do This → page 704 #38+39



→ $^{3}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$

39. fusion reactions produce so much heat that nothing can contain them.

C. Gamma Emission

1. Gamma rays (γ) are high-energy electromagnetic waves emitted from a nucleus as it changes from an excited state to a ground energy state
2. Gamma rays are produced when nuclear particles undergo transitions in energy levels
3. Gamma emission usually follows other types of decay that leave the nucleus in an excited state

10^{-12}	10^{-10}	10^{-8}	4 to 7×10^{-7}	10^{-4}	10^{-2}	1	10^{2}	10^{4}
gamma	xrays	UV	visible	IR	micro	Radio waves		
						FM	short	AM

Do This → page 703 #20 in class, 664 - online book

a) high energy electromagnetic radiation

b) Scientists believe gamma rays are produced when nuclear particles undergo transition in nuclear energy levels.

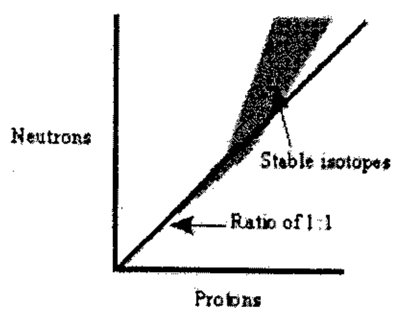
2. Radioactive Decay

I. Nuclear Stability and Decay

A. Neutron-to-Proton Ratio determines the type of decay that occurs

1. Band of Stability

Do This → page 703 #s 9+10, 704 # 44, 705 # 51 (online book page 669 + 667)



9. $^{12}_{6}C$ $\frac{n^0}{p^+} = \frac{6}{6}$ → 1:1 ratio

$^{3}_{1}H$ $\frac{n^0}{p^+} = \frac{2}{1}$ → 2:1 ratio

$^{206}_{82}Pb$ $\frac{n^0}{p^+} = \frac{124}{82}$ → 1.5:1 ratio

$^{134}_{50}Sn$ $\frac{n^0}{p^+} = \frac{84}{50}$ → 1.7:1 ratio

10. $^{12}_{6}C$ → stable $^{206}_{82}Pb$ → stable

51. $^{56}_{26}Fe$ → $\frac{30}{26}$ 1.2:1 ratio stable even # of n° and p+

$^{59}_{26}Fe$ → odd # of neutrons less stable

II. Half-Life

A. Half-Life ($t_{1/2}$)

1. The time required for half the atoms of a radioactive nuclide to decay
   a. More stable nuclides decay slowly
   b. Less stable nuclides decay rapidly

Table 22-2	Representative Radioactive Nuclides and Their Half Lives		
Nuclide	*Half-life*	*Nuclide*	*Half-life*
$^{3}_{1}H$	12.32 years	$^{214}_{84}Po$	163.7 μseconds
$^{14}_{6}C$	5715 years	$^{218}_{84}Po$	3.0 minutes
$^{32}_{15}P$	14.28 days	$^{218}_{85}At$	1.6 seconds
$^{40}_{19}K$	1.3 x 109 years	$^{238}_{92}U$	4.46 x 10^9 years
$^{60}_{27}Co$	10.47 minutes	$^{239}_{94}Pu$	2.41 x 10^4 years

Do This → page 704 #s 41+43 +28, page 665 online text

41. $t_T = 4797$ yrs. $n = \frac{4797}{1599} = 3$
$t_{1/2} = 1599$ yrs
$m_f = m_i(.5)^n = (0.250g)(.5)^3 = 0.0313g$

43. $t_{1/2} = 3.66d$ $n = \frac{7.32d}{3.66d} = 2$
$t_T = 7.32d$
$m_i = \frac{m_f}{(.5)^n} = \frac{0.0500g}{(.5)^2} = 0.200g$

28. $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4} \times \frac{1}{2} = \frac{1}{8} \times \frac{1}{2} = \frac{1}{16}$
1 2 3 4
$n = 4$ $t_{1/2} = \frac{t_T}{n} = \frac{26.76h}{4} = 6.69h$

B. Fusion Reactions

1. More energetic than fission rxns
2. Source of energy of the hydrogen bomb
3. Could produce energy for human use if a way can be found to contain a fusion rxn (magnetic field?)

4. **Radiation in Your Life**

A. Penetrating Ability

1. Alpha Particles
   a. Least penetrating ability due to large mass and charge
   b. Travel only a few centimeters through air
   c. Cannot penetrate skin
   d. Can cause harm through ingestion or inhalation
2. Beta Particles
   a. Travel at speeds close to the speed of light
   b. Penetrating ability about 100 times greater than that of alpha particles.
   c. They have a range of a few meters in air.
3. Gamma rays
   * a. Greatest penetrating ability
   * b. Protection requires shielding with thick layers of lead, cement, or both

C. Penetrating ability of radiation

Increasing penetrating ability →

ALPHA ⟶ BETA ⟶ GAMMA

Least harmful ... most harmful

C. Radioactive Elements

1. All isotopes of all man-made elements are radioactive
2. Some naturally isotopes are radioactive
   a. All isotopes of all elements beyond bismuth (atomic #83) are radioactive

Do This: pg 704 (LIS) #31 *

31. Gamma Rays have much more penatrating ability and can cause the most damage to human tissue