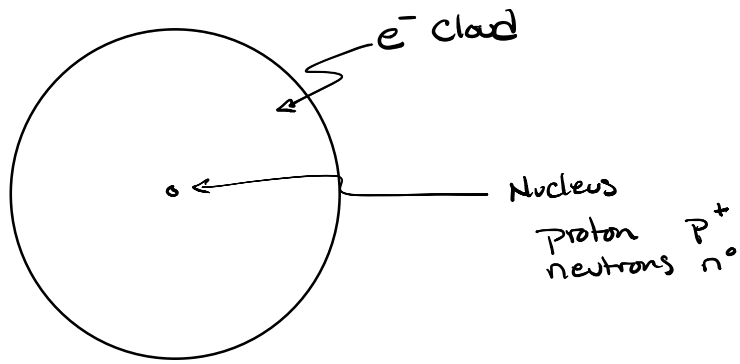
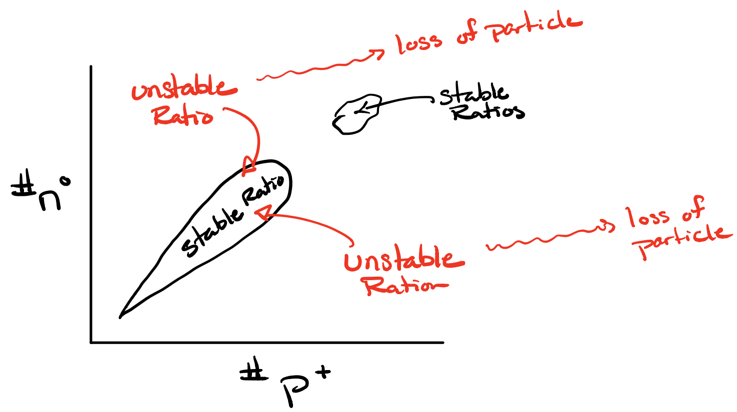
Activity 24 - Radioactivity Worksheet

Atom





- light weight atoms $\frac{P}{n} \approx 1$
- large particles $\# p > 84$ unstable
- even #'s of protons are more stable than odd
- All isotopes where $\# p > \# n$ are unstable

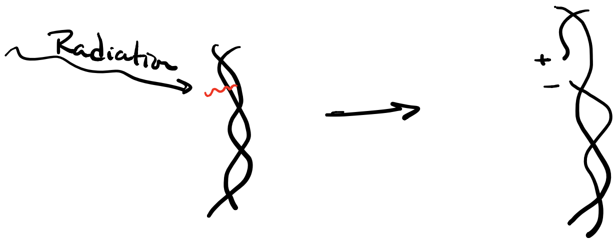
unstable = Radioactive

Radiation = Ionizing Radiation

$$\xrightarrow[\text{Particle}]{\text{Radiation}} X - Y \xrightarrow{\text{Heterolytic}} X^{+} + Y^{-}$$

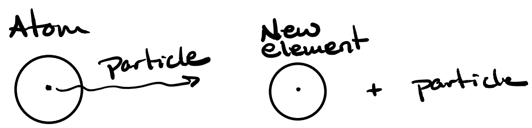
neutral molecule

ions



Damaged DNA
Replication Errors
Coding Errors
Causes unregulated cell growth = Cancer
or
Cell death
or
Protein Construction errors

Types of Radiation



Particle

α (alpha) $^{4}_{2}He$ Low energy

mass # = p + n

atomic # = p

$^{4}_{2}He \rightarrow$ mm solid material

Stopped Lab coats & gloves

β (Beta) ${}^{0}_{-1}e$ ${}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e$

neutron changing into proton by loss of an e^-

β^+ (Positron) ${}^{0}_{+1}e$ ${}^{1}_{1}p \rightarrow {}^{1}_{0}n + {}^{0}_{+1}e$

proton changing into neutron by loss of a e^+ (positron – a positive electron)

Both are much higher energy than α particle. These will pass entirely through the body causing ionization of tissue. These are stopped only by dense material such as lead shielding

γ (gamma Ray) just energy

Very High energy

only stopped by many meters of thick lead

Nuclear Equations

α

mass # must be provided in some way

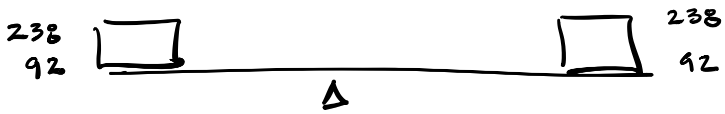
mass # new element

$$^{238}_{92}U \longrightarrow {}^{4}_{2}He + {}^{238-4\,=\,234}_{92-2\,=\,90}Th$$

off PT

The atomic # of the new element

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



Balanced for mass → Conservation of Matter

$$^{241}_{95}Am \longrightarrow {}^{4}_{2}He + {}^{237}_{93}Np$$

β (Beta)

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

$$^{131}_{53}I \longrightarrow {}^{0}_{-1}e + {}^{131}_{54}Xe$$

$$^{32}_{15}P \longrightarrow {}^{0}_{-1}e + {}^{32}_{16}S$$

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.30											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.84	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 97.91	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Cesium 132.9	56 Ba Barium 137.3		72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222
87 Fr Francium 223	88 Ra Radium 226		104 Rf Rutherfordium 261	105 Db Dubnium 262	106 Sg Seaborgium 263	107 Bh Bohrium 262	108 Hs Hassium 265	109 Mt Meitnerium 266	110 Ds Darmstadtium 269	111 Rg Roentgenium 272	112 Cn Copernicium 277	113 Nh Nihonium	114 Fl Flerovium 289	115 Mc Moscovium	116 Lv Livermorium 289	117 Ts Tennessine	118 Og Oganesson

Lanthanides	57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium 145	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinides	89 Ac Actinium 227	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium 237	94 Pu Plutonium 244	95 Am Americium 243	96 Cm Curium 247	97 Bk Berkelium 247	98 Cf Californium 251	99 Es Einsteinium 252	100 Fm Fermium 257	101 Md Mendelevium 258	102 No Nobelium 259	103 Lr Lawrencium 262

$\beta+$ (positron)

$${}^{11}_{6}C \longrightarrow {}^{0}_{+1}e + {}^{11}_{5}B$$

$${}^{18}_{9}F \longrightarrow {}^{0}_{+1}e + {}^{18}_{8}O$$

γ (gamma ray)

meta stable (nucleus in excited state)

$${}^{99m}_{43}Tc \longrightarrow {}^{99}_{43}Tc + \gamma$$

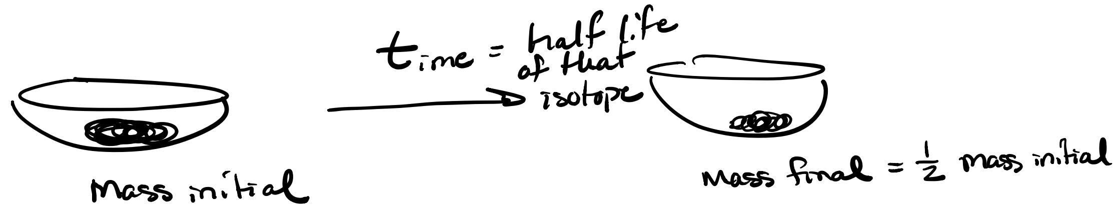
High energy photon = gamma ray

$${}^{60}_{27}Co \longrightarrow \underbrace{{}^{0}_{-1}e + \gamma}_{\beta + \gamma \text{ emmission}} + {}^{60}_{28}Ni$$

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

Half Life

Half life is a measurement of the life of an isotope.



$$m_f = m_I\left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

m_f = mass final

m_I = mass initial

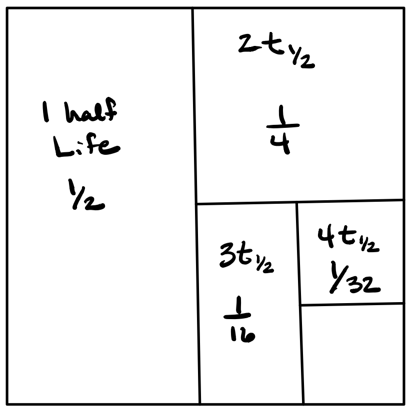
must be in same units of time

$$\left\{\begin{array}{l} t = \text{time} \\ t_{1/2} = \text{half life (the time required for half material to decompose)} \end{array}\right.$$

$^{14}_{6}C$	5730 years	$^{131}_{53}I$	8.1 days
$^{60}_{27}Co$	5.3 years	$^{24}_{11}Na$	15 hours
$^{3}_{1}H$	12.3 years	$^{235}_{92}U$	710 million years (7.10×10^8 years)

Visual Representation of Half life

$$m_f = m_i \left(\tfrac{1}{2}\right)^{t/t_{1/2}}$$



$$\frac{m_f}{m_i} = \frac{1}{2}^{\frac{t}{t_{1/2}}}$$

\# of $t_{1/2}$

$$\frac{m_f}{m_i} = \frac{1}{2}^{1} = \frac{1}{2^1} = \frac{1}{2} \qquad 1$$

$$\frac{1}{2}^{2} = \frac{1}{2^2} = \frac{1}{4} \qquad 2$$

$$\frac{1}{2}^{3} = \frac{1}{2^3} = \frac{1}{8} \qquad 3$$

$$\frac{1}{2}^{4} = \frac{1}{2^4} = \frac{1}{16} \qquad 4$$

$\vdots$

Ex

50.0 mg of $^{131}_{53}I$ is used to treat hypothyroidism, is stored for 32.4 days. If the half life is 8.1 days how much iodine remains in mg?

$m_f = ?$

$m_i = 50.0\,mg$

$t = 32.4\,d$

$t_{1/2} = 8.1\,d$

$$m_f = m_i \left(\tfrac{1}{2}\right)^{t/t_{1/2}}$$

$$= \overset{3}{50.0}\,mg \left(\tfrac{1}{2}\right)^{\frac{32.4\cancel{d}}{8.1\cancel{d}}}$$

$$= 3.125\,mg$$

$$= \boxed{3.13\,mg}$$

most TI calc $\quad 50.0 \times (1 \div 2) \underset{y^x}{\wedge} (32.4 \div 8.1) =$

Ex

Estimate the age of an artifact that has $\frac{1}{8}$th the amount of Carbon-14 (relative to C-12) compared to living organisms. The half life of Carbon-14 is 5730 years.

photon — Sun

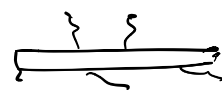
$^{12}CO_2 \longrightarrow {}^{14}CO_2$

produced in the environment

$^{14}CO_2 \rightarrow$

$\rightarrow$ Sugars $^{14}C_6H_{12}O_6$

$\downarrow$



Time capsule

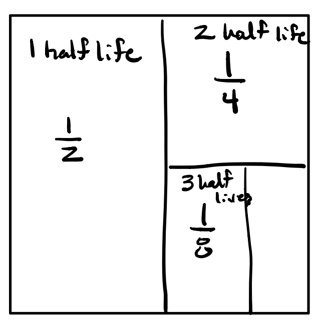
$^{14}C_6H_{12}O_6$

$${}^{14}_{6}C \xrightarrow{t_{1/2} = 5730\,\text{years}} {}^{0}_{-1}e + {}^{14}_{7}N$$

$$m_f = m_i \left(\frac{1}{2}\right)^{\frac{t}{t_{1/2}}}$$

$$\frac{m_f}{m_i} = \left(\frac{1}{2}\right)^{t/t_{1/2}}$$

$$\frac{1}{8} = \left(\frac{1}{2}\right)^{t/t_{1/2}}$$



$$\frac{1}{8} = \left(\frac{1}{2}\right)^3 \Rightarrow \frac{t}{t_{1/2}} = 3$$

$$t = 3\,t_{1/2}$$

$$t = 3(5730\text{ yrs})$$

$$t = 17{,}190\text{ yrs}$$

$$\boxed{t = 17{,}200\text{ yrs} \qquad 3\text{ SF}}$$

$$m_f = m_i\left(\frac{1}{2}\right)^{t/t_{1/2}}$$

$$\frac{m_f}{m_i} = \frac{1}{2}^{t/t_{1/2}}$$

$$\frac{1}{8} = \frac{1}{2}^{t/t_{1/2}}$$

$$\log_{10}\frac{1}{8} = \log_{10}\frac{1}{2}^{t/t_{1/2}}$$

$$\frac{\log\frac{1}{8}}{\log\frac{1}{2}} = \frac{\frac{t}{t_{1/2}}\log\frac{1}{2}}{\log\frac{1}{2}}$$

$$t_{1/2} \times \frac{\log\frac{1}{8}}{\log\frac{1}{2}} = \frac{t}{t_{1/2}} \times t_{1/2}$$

$$\text{Log } A^B = B\log A$$

$$t_{1/2}\,\frac{\log\frac{1}{8}}{\log\frac{1}{2}} = t$$

$$5730\left[\frac{\log\frac{1}{8}}{\log\frac{1}{2}}\right] = 17190\text{ yrs}$$

$$\boxed{= 17200\text{ yrs} \quad \text{or} \quad 1.72\times10^{4}\text{ yrs}}$$