

Radioactive Decay Worksheet

Alpha decay: nucleus spontaneously emits an alpha particle (symbol: α particle), which is $2p^+$ and $2n$ (or also the same as a Helium (He) atom).

Result: atomic number decreases by 2 (lost $2p^+$)

Result: atomic mass decreases by 4 (lost $2p^+$ and $2n = 4\text{ amu}$)

Beta decay: neutron in nucleus spontaneously emits a beta particle (symbol: β particle), which is essentially an electron trapped in a neutron. The neutron, therefore, turns itself into a proton.

Result: atomic number increases by 1 (gained $1p^+$)

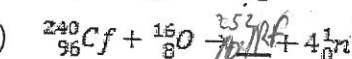
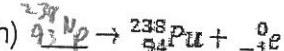
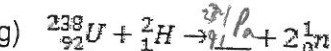
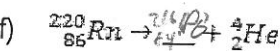
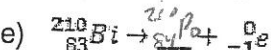
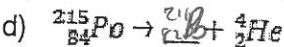
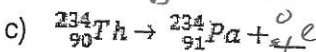
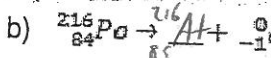
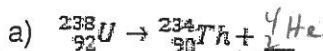
Result: atomic mass stays same (no mass lost or gained: β particle or electrons have no mass)

Beta or electron capture: proton in nucleus captures a beta particle (symbol: β particle), which is essentially an electron that can become part of a neutron. The proton, therefore, turns itself into a neutron.

Result: atomic number decreases by 1 (lost $1p^+$)

Result: atomic mass stays same (no mass lost or gained: β particle or electrons have no mass)

1. Fill in the missing isotope or emitted particle



The Periodic Table of the Elements

1 H Hydrogen 1.00794																	2 He Helium 4.00260
3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.00643	8 O Oxygen 15.99903	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.989769	12 Mg Magnesium 24.30409											13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938044	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90584	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.36	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.757	52 Te Tellurium 127.6	53 I Iodine 126.905	54 Xe Xenon 131.29
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.90547	58 Ce Cerium 140.12	59 Pr Praseodymium 140.90766	60 Nd Neodymium 144.242	61 Pm Promethium 145	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93033	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967	
87 Fr Francium [223]	88 Ra Radium [226]	89 Ac Actinium [227]	90 Th Thorium [232]	91 Pa Protactinium [231]	92 U Uranium [238]	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 [260]	

Example

Original	alpha decay	beta decay	alpha decay	beta capture	beta decay	alpha decay
85	83	84	82	81	82	80
At	Bi	Po	Pb	Tl	Pb	Hg
Astatine	Bismuth	Polonium	Lead	Thallium	Lead	Mercury
210	206	206	202	202	202	198

Complete this table

Original	beta decay	alpha decay	beta capture	alpha decay	alpha decay	beta decay
90	91	89	88	86	89	85
Th	Pa	Ac	Ra	Rn	Po	At
Thorium						
232	232	228	228	224	220	220

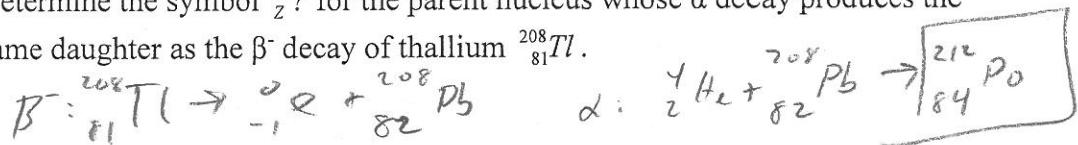
Complete this table

Original	beta capture	alpha decay	alpha decay	beta capture	alpha decay	beta decay
92	91	89	87	86	87	85
U	Pa	Ac	Fr	Rn	Po	At
Uranium						
238	238	234	230	230	226	226

1. Polonium 214 ($m_{Po} = 213.995186 \text{ u}$) decays by alpha radiation ($m_{\alpha} = 4.002602 \text{ u}$) to Lead 210 ($m_{Pb} = 209.984173 \text{ u}$). How much energy is released as the alpha particle leaves the nucleus? (7.83 MeV)

$$\begin{array}{r} 213.995186 \\ - 4.002602 \\ - 209.984173 \\ \hline \end{array} \Delta m = 0.008411 \text{ u} \quad (931.5 \text{ MeV}) = \boxed{7.83 \text{ MeV}}$$

2. Determine the symbol ${}^A_Z X$ for the parent nucleus whose α decay produces the same daughter as the β^- decay of thallium ${}^{208}_{81}\text{Tl}$.



3. How much energy is released when tritium (${}^3_1\text{H}$ $m = 3.016049 \text{ u}$) decays by β^- emission to ${}^3_2\text{He}$ ($m = 3.016029 \text{ u}$)? (18.6 keV)

$$\begin{array}{r} 3.016049 \\ - 3.016029 \\ \hline \end{array} 0.00002 \text{ u} \quad (931.5) = 0.01863 \text{ MeV} = \boxed{18.6 \text{ keV}}$$

4. Does ${}^{11}_6\text{C}$ $m = 11.011434 \text{ u}$ decay by β^- to become ${}^{11}_7\text{N}$ $m = 11.011334 \text{ u}$ or β^+ to become ${}^{11}_5\text{B}$ $m = 11.009306 \text{ u}$? What is the energy released?

$$\begin{array}{r} 11.011434 \\ - 11.009306 \\ \hline \end{array} 0.002128 \text{ u} \quad (931) = \boxed{1.98 \text{ MeV}}$$

unstable: ${}^{11}_5\text{B}$ is daughter

5. Berkelium 247 ($m = 247.070299 \text{ u}$) decays to Americium 243 ($m = 243.061373 \text{ u}$) through α decay. Assuming that Berkelium was originally at rest and that energy and momentum are conserved, find the speed of the α particle (~~$5.283 \cdot 10^7 \text{ m/s}$~~)

$$\sum \vec{p}_i = 0 = \sum \vec{p}_f \therefore p_{\alpha} = p_{Am}$$

$$m_{\alpha} v_{\alpha} = m_{Am} v_{Am}$$

$$\begin{array}{r} 247.070299 \\ - 243.061373 \\ - 4.002602 \\ \hline \end{array} \Delta m = 0.006324$$

$$E = 2.47 \text{ MeV} = 3.97 \cdot 10^{17} \text{ J}$$

$$KE_{\text{tot}} = KE_{\alpha} + KE_{Am}$$

$$= \frac{1}{2} (m_{\alpha} v_{\alpha}^2 + m_{Am} v_{Am}^2)$$

$$= \frac{1}{2} (m_{\alpha} v_{\alpha}^2 + m_{\alpha} v_{\alpha}^2 \left(\frac{m_{\alpha}}{m_{Am}}\right))$$

$$= \frac{1}{2} m_{\alpha} v_{\alpha}^2 \left(1 + \frac{m_{\alpha}}{m_{Am}}\right)$$

$$v_{\alpha} = \sqrt{\frac{2KE_{\text{tot}}}{m_{\alpha} \left(1 + \frac{m_{\alpha}}{m_{Am}}\right)}} = \boxed{1.08 \cdot 10^7 \text{ m/s}}$$

\uparrow
KE_{tot}