Physics 13-01 Radioactivity **Name: ______________**

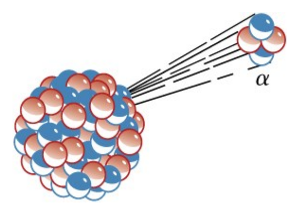
Structure of the atom

- Rutherford's Experiment
  - Shot ___________ at thin ___________foil
  - Expected to pass mostly straight though with ___________scattering
  - Most passed straight through without scattering; Some scattered ___________ – even straight back
  - Showed the nucleus was very ___________and much ___________space around it
  - Planetary model of the atom: Nucleus like ________, Electrons like ___________, Electrical force like ___________
- Nucleus
  - Contains ___________and ___________
- Atomic mass unit (u)
  - Neutral carbon-12 = 12 u
  - C-12 has 6 protons, 6 neutrons
  - Proton and neutrons = ___________
  - 1 u = ___________ MeV/c^2

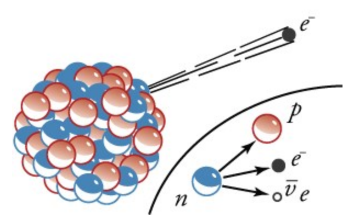
6
C
12.011

- Atomic Number (Z)
  - Number of ___________ in nucleus
  - Determines the ___________
- Mass Number (A)
  - Number of ___________and ___________
- Isotopes
  - Same element can have different number of ___________
  - ${}^{A}_{Z}X$ or ${}^{A}X$
  - Then number of neutrons changes behavior of ___________
- Strong nuclear force
  - Holds ___________together
  - Acts at distance less than ___________
- Electric forces try to ___________nucleus apart
  - When electric forces are more than strong nuclear force, nuclear particles are ejected from nucleus – ___________
- Nucleus wants
  - About ___________number of protons and neutrons
  - Smaller radius than strong ___________force

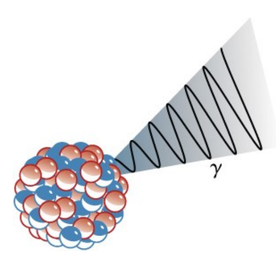
Types of Radioactivity



- Alpha Decay (α)
  - Most ___________decay type
  - Happens when too many ___________in nucleus
  - Nucleus ejects ___________ and ___________ (___________nucleus)
  - ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\text{He} \quad \rightarrow \quad {}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}$
  - During α-decay, the atomic number changes and one element ___________into another
    - The α-particle quickly gains two electrons and becomes a stable ___________atom
    - The total number of ___________stays the same
      - Law of Conservation of ___________and ___________
        - Any change in mass is converted to energy by _______
      - Law of Conservation of ___________



- Beta decay (β)
  - Imbalance of ___________and ___________
  - A neutron ___________into a ___________and ___________or vice versa
  - ${}^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y + e^{-} + \nu \quad \rightarrow \quad {}^{14}_{6}C \rightarrow {}^{14}_{7}N + \nu + e^{-}$
    - e is ___________, ν is ___________
- Gamma decay (γ)
  - Occurs when nucleus drops from ___________state to ground state releasing energy as a photon
  - ${}^{A}_{Z}X \rightarrow {}^{A}_{Z}X + \gamma \quad \rightarrow \quad {}^{137}_{56}Ba \rightarrow {}^{137}_{56}Ba + \gamma$



Physics 13-01 Radioactivity *Name:* ______________

- α-particles are massive (4 u) and have +2 charge, so they quickly interact with matter and can be stopped quickly
  - ______________________, ___________ of air, ______________________ of tissue
- β-particles are smaller (mass of e) and −1 charge, so they penetrate farther
  - ______________________ plate, ______________ of tissue
- γ-particles have no mass or charge and barely interact with matter, so they penetrate very far
  - ______________ of lead, ___________of concrete

Write the complete decay equation in ${}_Z^AX$ notation for beta decay producing ${}_{28}^{60}\text{Ni}$. Refer to the periodic table for values of Z.

Find the energy emitted in the α decay of ${}^{226}\text{Ra}$.

Practice Work

1. What leads scientists to infer that the nuclear strong force exists? (HSP C22.2)
2. What influence does the strong nuclear force have on the electrons in an atom? (HSP 22.10)
3. What is the source of the energy emitted in radioactive decay? Identify an earlier conservation law, and describe how it was modified to take such processes into account. (OpenStax C31.5)
4. Explain why an alpha particle can have a greater range in air than a beta particle in lead. (OpenStax C31.7)
5. Arrange the following according to their ability to act as radiation shields, with the best first and worst last. Explain your ordering in terms of how radiation loses its energy in matter.
   (a) A solid material with low density composed of low-mass atoms.
   (b) A gas composed of high-mass atoms.
   (c) A gas composed of low-mass atoms.
   (d) A solid with high density composed of high-mass atoms. (OpenStax C31.8)
6. Often, when people have to work around radioactive materials spills, we see them wearing white coveralls (usually a plastic material). What types of radiation (if any) do you think these suits protect the worker from, and how? (OpenStax C31.9)
7. The weak and strong nuclear forces are basic to the structure of matter. Why do we not experience them directly? (OpenStax C31.11)
8. What are isotopes? Why do different isotopes of the same element have similar chemistries? (OpenStax C31.13)

In the following eight problems, write the complete decay equation for the given nuclide in the complete ${}_Z^AX$ notation. Refer to the periodic table for values of Z.

9. β^- decay of ${}^{3}H$ (tritium), a manufactured isotope of hydrogen used in some digital watch displays and manufactured primarily for use in hydrogen bombs. (OpenStax 31.17) $\boldsymbol{{}_1^3H \rightarrow {}_2^3He + e^- + \nu}$
10. β^- decay of ${}^{40}K$, a naturally occurring rare isotope of potassium responsible for some of our exposure to background radiation. (OpenStax 31.18) $\boldsymbol{{}_{19}^{40}K \rightarrow {}_{20}^{40}Ca + e^- + \nu}$
11. α decay of ${}^{210}Po$, the isotope of polonium in the decay series of ${}^{238}U$ that was discovered by the Curies. A favorite isotope in physics labs, since it has a short half-life and decays to a stable nuclide. (OpenStax 31.23) $\boldsymbol{{}_{84}^{210}Po \rightarrow {}_{82}^{206}Pb + {}_2^4He}$
12. α decay of ${}^{226}Ra$, another isotope in the decay series of ${}^{238}U$, first recognized as a new element by the Curies. Poses special problems because its daughter is a radioactive noble gas. (OpenStax 31.24) $\boldsymbol{{}_{88}^{226}Ra \rightarrow {}_{86}^{222}Rn + {}_2^4He}$

Physics 13-01 Radioactivity **_Name: ______________**

In the following four problems, identify the parent nuclide and write the complete decay equation in the $^{A}_{Z}X$ notation. Refer to the periodic table for values of Z.

13. β^- decay producing ^{137}Ba. The parent nuclide is a major waste product of reactors and has chemistry similar to potassium and sodium, resulting in its concentration in your cells if ingested. (OpenStax 31.25) $\boldsymbol{^{137}_{55}Cs \rightarrow ^{137}_{56}Ba + e^- + \nu}$

14. β^- decay producing ^{90}Y. The parent nuclide is a major waste product of reactors and has chemistry similar to calcium, so that it is concentrated in bones if ingested (^{90}Y is also radioactive.) (OpenStax 31.26) $\boldsymbol{^{90}_{38}Sr \rightarrow ^{90}_{39}Y + e^- + \nu}$

15. α decay producing ^{228}Ra. The parent nuclide is nearly 100% of the natural element and is found in gas lantern mantles and in metal alloys used in jets (^{228}Ra is also radioactive). (OpenStax 31.27) $\boldsymbol{^{232}_{90}Th \rightarrow ^{228}_{88}Ra + ^{4}_{2}He}$

16. α decay producing ^{208}Pb. The parent nuclide is in the decay series produced by ^{232}Th, the only naturally occurring isotope of thorium. (OpenStax 31.28) $\boldsymbol{^{212}_{84}Pa \rightarrow ^{208}_{82}Pb + ^{4}_{2}He}$

17. (a) Write the complete α decay equation for ^{226}Ra. (b) Find the energy released in the decay. ($^{226}_{88}Ra = 226.025402\ u$, $^{222}_{86}Rn = 222.0175763\ u$, $^{4}_{2}He = 4.002602\ u$(OpenStax 31.35) **4.87 MeV**

18. (a) Write the complete α decay equation for ^{249}Cf. (b) Find the energy released in the decay. ($^{249}_{98}Cf = 249.074844\ u$, $^{245}_{96}Cm = 245.058830\ u$, $^{4}_{2}He = 4.002602\ u$)(OpenStax 31.36) **12.5 MeV**

19. (a) Write the complete β^- decay equation for the neutron. (b) Find the energy released in the decay. ($^{1}_{0}n = 1.008664915\ u$, $^{1}_{1}H = 1.007276466\ u$, $e^- = 0.000548579\ u$, $\nu \approx 0\ u$) (OpenStax 31.37) **0.7823 MeV**

20. (a) Write the complete β^- decay equation for ^{90}Sr, a major waste product of nuclear reactors. (b) Find the energy released in the decay. ($^{90}_{38}Sr = 89.9077279\ u$, $^{90}_{39}Y = 89.9071519\ u$, e^- =included in the mass of Y, $\nu \approx 0\ u$) (OpenStax 31.38) **0.537 MeV**