Name: _____

Class: _____

Due Date: _____

E.3 Radioactive Decay

Understandings

- Isotopes.
- Nuclear binding energy and mass defect.
- The variation of the binding energy per nucleon with nucleon number.
- The mass-energy equivalence as given by $E = mc^2$ in nuclear reactions.
- The existence of the strong nuclear force, a short-range, attractive force between nucleons.
- The random and spontaneous nature of radioactive decay.
- The changes in the state of the nucleus following alpha, beta, and gamma radioactive decay.
- The radioactive decay equations involving α, β^-, β^+, and γ.
- The existence of neutrinos ν and antineutrinos $\bar{\nu}$.
- The penetration and ionizing ability of alpha particles, beta particles, and gamma rays.
- The activity, count rate, and half-life in radioactive decay.
- The changes in activity and count rate during radioactive decay using integral values of half-life.
- The effect of background radiation of count rate.

Equations

$E = mc^2$

$\lambda = \frac{hc}{E}$

Additional HL Understandings

- The evidence for the strong nuclear force.
- The role of the ratio of neutrons to protons for the stability of nuclides.
- The approximate constancy of binding energy curve above a nucleon number of 60.
- The spectrum of alpha and gamma radiations provides evidence for discrete nuclear energy levels.
- The continuous spectrum of beta decay as evidence for the neutrino.
- The decay constant λ and the radioactive decay law as given by $N = N_0 e^{-\lambda t}$.
- The decay constant approximates the probability of decay in unit time only in the limit of sufficiently small λt.
- The activity as the rate of decay as given by $A = \lambda N = \lambda N_0 e^{-\lambda t}$.
- The relationship between half-life and the decay constant as given by $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$.

Additional HL Equations

$$N = N_0 e^{-\lambda t}$$

$$A = \lambda N = \lambda N_0 e^{-\lambda t}$$

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$$

The Evil Revealed in First US Nuclear Test: 74 Years Ago Over Bikini
https://www.activistpost.com/2020/06/the-evil-revealed-in-first-us-nuclear-test-74-years-ago-over-bikini.html

MIT Scientists: Nuclear Fusion Energy Could Be Closer Than Thought
https://oilprice.com/Alternative-Energy/Nuclear-Power/MIT-Scientists-Nuclear-Fusion-Energy-Could-Be-Closer-Than-Thought.html

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Use your favorite sources to answer the following questions

1. Define *isotope.*

2. *Isotopes* have the same _____ properties but different _____ properties.

3. Define *mass defect*. Units?

4. Which has more mass: two individual protons or two protons in the same nucleus?

5. Define *binding energy*. Units?

6. **Use a pencil and ruler!** Draw and label the *binding energy curve*. Label the horizontal and vertical axis. Label the most stable element.

7. Define *atomic mass unit*. Units?

8. Use the equation $\Delta E = \Delta m \times c^2$ to find the energy equivalent of 1 u in Joules and $\frac{\text{MeV}}{\text{c}^2}$.

9. Determine the binding energy per nucleon for a neutral carbon atom.

10. Define *transmutation.*

11. What happens in nuclear decay if the *mass difference* is positive? Is nuclear decay possible?

12. What happens in nuclear decay if the *mass difference* is negative? Is nuclear decay possible?

13. Describe the *strong nuclear force*.

14. Define *random* and *spontaneous.*

15. *Radioactive decay* is both _____ and _____.

16. Define *alpha particle*. What is it made of? Charge?

17. What is the difference between an *alpha particle* and a *helium atom*?

18. Give two examples of *alpha decay*:

19. Define *neutrino*. What is it made of? Charge? Mass?

20. Define *anti-neutrino*. What is it made of? Charge? Mass?

21. Define *positron*. What is it made of? Charge? Mass?

22. Define *beta plus particle*. What is it made of? Charge? Mass?

23. What happens to a proton in a decaying nucleus during *beta plus decay*?

24. Give two examples of *beta plus decay*:

25. Define *beta minus particle*. What is it made of? Charge? Mass?

26. What is the difference between a *beta minus particle* and an *electron*?

27. What happens to a neutron in a decaying nucleus during *beta minus decay*?

28. Give two examples of *beta minus decay*:

29. Why was the neutrino postulated?

30. What is the charge and mass of an electron? What is the charge and mass of a neutrino ν?

31. Define *gamma ray*. What is it made of? Charge? Mass?

32. Why is it not correct to use the term *gamma particle*?

33. What is happening to an atom during *gamma decay*?

34. Give two examples of *gamma decay*: Gamma decay takes an excited and unstable atom and then makes it stable by releasing energy (as an electromagnetic wave) from the nucleus.

35. Define *ionization.*

36. Which particles have the most *ionizing ability* out of alpha particles, beta particles, and gamma rays?

37. Define *to penetrate.*

38. Define *penetrating power*. Which object can we use to stop an *alpha particle*? A *beta particle*? A *gamma ray*?

39. Define *activity*. Units? Use a **pencil and ruler!** Draw an activity vs. time graph for a radioactive/unstable element.

40. Define *count rate*. Units?

41. Define *half-life*. Units?

42. Define *background radiation.*

Additional HL Content

43. Why do stable nuclei have more neutrons than protons?

44. What is the ratio of neutrons to protons for stable nuclei?

45. Circle the correct answer: Alpha particles leave the nucleus with *continuous/discrete* energy levels.

46. Circle the correct answer: Beta minus particles leave the nucleus with *continuous/discrete* energy levels.

47. Circle the correct answer: Beta plus particles leave the nucleus with *continuous/discrete* energy levels.

48. Circle the correct answer: Gamma rays leave the nucleus with *continuous/discrete* energy levels.

49. What is the meaning and units of the *decay constant* λ?

50. Describe and define the variables in the radioactive decay law equation $N(t) = N_0 e^{-\lambda t}$.

51. What is the meaning and units for *activity A*? Describe and define the variables in the equation $A(t) = \lambda N(t) = \lambda N_0 e^{-\lambda}$.

52. State the relationship between the half-life and the decay constant.