Chapter 21
Study Guide - Answers

Name: _____

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1. Define:
   a. mass defect: the difference in mass between the nucleus and the masses of its nucleons
   b. binding energy: the energy required to separate a nucleus into its nucleons (or the energy released when a nucleus forms from protons and neutrons)
2. Explain the formula $E = mc^2$: Mass and energy are proportional. If a system loses mass, it loses energy (exothermic). If a system gains mass, it gains energy (endothermic). Since c^2 is a large number, small changes in mass cause large changes in energy.
3. The mass of a lithium-7 atom is 7.01600amu. Calculate it mass defect.

   Proton Mass 1.007276amu
   Neutron Mass 1.008665amu
   Electron Mass 0.0005486amu

   Li-7 has $3p^+$, $4n^o$ & $3e^-$.

   $[3(1.007276\ u) + 4(1.008665\ u) + 3(0.0005486\ u)] - 7.01600\ u = 0.0421338\ u$

   $0.04213\ u$
4. Oxygen has an unstable isotope O-17 that has a mass of 17.00454. Calculate the binding energy of the oxygen nucleus in MeV.

   O-17 has $8p^+$, $9n^o$ & $8e^-$.

   $[8(1.007276\ u) + 9(1.008665\ u) + 8(0.0005486\ u)] - 17.00454\ u = 0.1360418\ u$ *(Mass Defect)*

   $$\frac{0.136041\ \cancel{u} \mid 1.6605 \times 10^{-27}\ kg}{\mid\ 1\ \cancel{u}} = 2.25896 \times 10^{-28}\ kg$$

   $e = mc^2 = (2.25896 \times 10^{-28}\ kg)(3.00 \times 10^8\ m/s)^2 = 2.0330 \times 10^{-11}\ kg \cdot m^2 \cdot s^{-2} \approx 2.033 \times 10^{-11}\ J$ *(Binding Energy in Joules)*

   $$\frac{2.033 \times 10^{-11}\ \cancel{J} \mid 1\cancel{eV} \mid 1MeV}{\mid 1.60 \times 10^{-19}\ \cancel{J} \mid 1000000\ \cancel{eV}} = 127.0625\ MeV \approx 127\ MeV$$
5. Describe the forces in the nucleus: Protons repel one another due to the electromagnetic force of their charges. Protons and neutrons attract one another and each other due to the strong nuclear force. The strong nuclear force is stronger over short distances, but the electromagnetic repulsion is stronger over larger distances which is why larger nuclei require more neutrons to be stable and are more likely to experience decay.
6. Why do heavier nuclei experience more repulsion in the nucleus? Heavier nuclei have more protons (more repulsion)
7. What is the "band of stability"? A trend of $n^o : p^+$ ratios around which stable isotopes cluster. Unstable isotopes fall above the band (too high a number of neutrons) and below the band (too high a number of protons).
8. What is the ratio of neutrons to protons in smaller atoms? 1 : 1 for stable nuclides
9. What is the ratio of neutrons to protons in larger atoms? 1.5 : 1 for stable nuclides
10. What characteristics contribute to the stability of a nucleus? All nuclei with 83 or more protons are unstable. Nuclei with small even numbers of protons and neutrons are more stable. Nuclei with a "magic number" of protons or neutrons (2, 8, 20, 28, 50, 82), 114 (protons), or 126 neutrons are more stable.

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11. Define
    a. radioactivity: the spontaneous decay of unstable nuclei
    b. transmutation: the changing of one element into another by radioactive decay, nuclear bombardment, or similar processes
    c. nuclear reaction: a reaction in which the nucleus of an atom is altered
    d. radionuclide: an unstable isotope that releases radiation as it breaks down and becomes more stable.

12. How does the nucleus change during
    a. alpha decay? A very heavy nucleus decays by emitting an incredibly stable particle identical to the nucleus of a helium atom. The daughter nucleus has fewer protons and neutrons than the parent nucleus.
    b. beta decay? A neutron becomes a proton while emitting a beta particle (high energy electron) and a neutrino. The number of protons in the daughter nucleus will be higher than that of the parent but have essentially the same mass. Occurs when $n^o : p^+$ ratio is too high.
    c. positron emission? A proton becomes a neutron while emitting a positron (high energy anti-electron with a positive charge) and a neutrino. The number of neutrons increases and the number of protons decreases making the nucleus more stable. The number of protons in the daughter nucleus will be lower than that of the parent but have essentially the same mass. Occurs when $n^o : p^+$ ratio is too low.
    d. electron capture? The nucleus captures an electron from the electron cloud surrounding the nucleus. This is similar to the reverse of beta decay. A nuclear proton changes to a neutron emitting a neutrino and gamma radiation. The number of neutrons increases and the number of protons decreases. Occurs when $n^o : p^+$ ratio is too low.

13. Describe the difference between beta decay and electron capture. Beta decay occurs when $n^o : p^+$ is too high by emitting an electron as a neutron changes into a proton. Electron capture (or K-capture) occurs when $n^o : p^+$ is too low by absorbing an electron as a proton changes into a neutron.

14. Fill in the table below describing the three main types of radiation.

	Alpha Emission	Beta Emission	Positron Emission	Electron Capture	Gamma Emission
Formula(s)	$^4_2\alpha = {}^4_2He$	$^0_{-1}\beta = {}^0_{-1}e$	$\beta^+ \ {}^0_{+1}e$	$^0_{-1}e$	$^0_0\gamma$
Particle or ray?	Particle	Particle	Particle	Particle	Ray
Mass	4 *u*	Essentially 0 *u*	Essentially 0 *u*	Essentially 0 *u*	No mass
Relative Penetration	Very little	Moderate	Moderate	N/A	Complete
Can also be described as a(n):	Helium Nucleus	High Energy Electron	Anti-electron Beta Plus	N/A	EM Radiation

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15. Complete the following

$^{218}_{88}Ra \rightarrow {}^{218}_{89}Ac + {}^{0}_{-1}e$ Beta Decay

$^{234}_{92}U \rightarrow {}^{230}_{90}Th + {}^{4}_{2}\alpha$ Alpha Decay

$^{38}_{19}K \rightarrow {}^{38}_{18}Ar + {}^{0}_{+1}\beta$ Positron Emission

$^{106}_{47}U + {}^{0}_{-1}e \rightarrow {}^{106}_{46}Pd$ Electron Capture

16. A sample of radioactive material has a half-life of 37 years, fill in the table below.

Timescale	Mass
148 years ago	640
111 years ago	320
74 years ago	160
37 years ago	80.
Currently	40. grams
37 years from now	20.
74 years from now	10.
111 years from now	5.0
148 years from now	2.5

17. How many half-lives must pass before 7/8 of a radioactive sample decay? 3

If ⅞ has decayed, ⅛ remains, so after 1st half-life, ½ remains : 2nd half-life, ¼ remains : 3rd half-life, ⅛ remains

18. Define fission: the division of the nucleus – may occur spontaneously in unstable nuclei

19. Define fusion: the combination of smaller nuclei into larger nuclei

20. What nuclear process occurs in the sun? fusion

21. What nuclear process occurs in a nuclear reactor? fission

22. Define chain reaction: A reaction in which the material that starts the reaction is also one of the products and can start another reaction