Problems from 27.2 - Atomic Physics

Closest Approach: $E_K = \frac{1}{2}mv^2$ and $E_P = qV_e = \frac{kq_1q_2}{r}$ $q_1 = 2e$, $q_2 = Ze$

1. An alpha particle (m = 6.64x10^{-27} kg) going 5.14x10^6 m/s will get how close to a silver (Z = 47) nucleus if it hits head on? (2.47x10^{-13} m)
2. A speeding alpha particle (m = 6.64x10^{-27} kg) hits a mercury (Z = 80) nucleus head on. If it comes within 17.0 nm of the nucleus' center, how fast was it going to start with? (2.56x10^4 m/s)
3. An alpha particle (m = 6.64x10^{-27} kg) going 4.12x10^6 m/s will get how close to a bismuth (Z = 83) nucleus if it hits head on? (6.80x10^{-13} m)
4. A speeding alpha particle (m = 6.64x10^{-27} kg) hits a lead (Z = 82) nucleus head on. If it comes within 12.0 nm of the nucleus' center, how fast was it going to start with? (3.08x10^4 m/s)
5. An alpha particle (m = 6.64x10^{-27} kg) going 2.37x10^6 m/s will get how close to a gold (Z = 79) nucleus if it hits head on? (1.95x10^{-12} m)

Electron Transitions: $E = -\frac{13.6}{n^2}eV$ and $\lambda = \frac{hc}{E}$

6. What is the wavelength of the photon associated with an electron transition from n = 3 to n = 1 in a hydrogen atom? Is the photon being absorbed, or emitted? (103 nm, emitted)
7. What is the wavelength of the photon associated with an electron transition from n = 3 to n = 6 in a hydrogen atom? Is the photon being absorbed, or emitted? (1095 nm, absorbed)
8. What is the wavelength of the photon associated with an electron transition from n = 2 to n = 1 in a hydrogen atom? Is the photon being absorbed, or emitted? (122 nm, emitted)
9. What is the wavelength of the photon associated with an electron transition from n = 2 to n = 4 in a hydrogen atom? Is the photon being absorbed, or emitted? (487 nm, absorbed)
10. What is the wavelength of the photon associated with an electron transition from n = 6 to n = 2 in a hydrogen atom? Is the photon being absorbed, or emitted? (411 nm, emitted)

Nuclear Radius or Heisenberg: $R = R_0A^{1/3}$ or $\Delta x \Delta p \geq \frac{h}{4\pi}$ or $\Delta E \Delta t \geq \frac{h}{4\pi}$

11. What is the radius of C-14 nucleus? (2.89x10^{-15} m)
12. What is the likely mass number of a nucleus with a radius of 3.51x10^{-15} m? (25)
13. To effect an alpha decay, an alpha particle must "borrow" 31.1 MeV of energy. What time does it have to escape? (1.06x10^{-23} s)
14. An Alpha particle takes 1.80x10^{-23} s to "tunnel" through a potential barrier. What is the amount of energy it can "borrow" during this time in MeV? (18.3 MeV)
15. An electron has an uncertainty in its velocity of ±2.10x10^4 m/s. What is the minimum uncertainty in its position? (1.38x10^{-9} m)
16. An electron has an uncertainty in its position of 2.40x10^{-10} m (total range) . What is the minimum uncertainty (the total range) of its velocity? (2.41x10^5 m/s)
17. A proton has an uncertainty in its position of 3.51x10^{-15} m (total range). What is the minimum uncertainty (the total range) of its velocity? (8.98x10^6 m/s)
18. A proton has an uncertainty in its velocity of ±4.30x10^6 m/s. What is the minimum uncertainty in its position? (3.66x10^{-15} m)

Part A: Find the missing decay product:

1	$\tau^- \rightarrow \pi^- + \pi^o + ??$ υ_τ	$?? \rightarrow \pi^+ + \pi^o + \overline{\upsilon_\tau}$ τ^+	$\tau^- \rightarrow \upsilon_\tau + ?? + \overline{\upsilon_e}$ e^-	$\tau^+ \rightarrow \overline{\upsilon_\tau} + e^+ + ??$ υ_e
2	$\tau^- \rightarrow ?? + \mu^- + \overline{\upsilon_\mu}$ υ_τ	$\tau^+ \rightarrow ?? + \mu^+ + \upsilon_\mu$ $\overline{\upsilon_\tau}$	$?? \rightarrow e^- + \overline{\upsilon_e} + \upsilon_\mu$ μ^-	$\mu^+ \rightarrow e^+ + ?? + \overline{\upsilon_\mu}$ υ_e
3	$\mu^- \rightarrow e^- + \overline{\upsilon_e} + \upsilon_\mu + e^+ + ??$ e^-	$\mu^+ \rightarrow e^+ + ?? + \overline{\upsilon_\mu} + e^+ + e^-$ υ_e	$K_L^o \rightarrow \pi^+ + ?? + \overline{\upsilon_\mu}$ μ^-	$K^+ \rightarrow ?? + \upsilon_\mu$ μ^+

Part B: For these reactions, indicate if it is possible, or indicate <u>every</u> law it violates:

1	$p + n \rightarrow K^+ + \eta^o + \Xi^o$ No, baryon number, Strangeness	$p + n \rightarrow p + \bar{p} + \bar{n}$ No, charge and baryon number	$n + n \rightarrow \Lambda^o + \Sigma^o$ No, Strangeness	$n + n \rightarrow \Omega^+ + \Omega^-$ No, baryon number
2	$p + p \rightarrow \Omega^+ + e^+ + \Lambda^o + \Sigma^o + n$ No, Le, Strangeness	$p + p \rightarrow p + n + n + \Omega^+$ No, Strangeness	$p + p \rightarrow \tau^+ + \upsilon_\tau + \mu^+ + \overline{\upsilon_\mu}$ No, Baryon and Lμ	$p + n \rightarrow n + n + \tau^+ + \upsilon_\tau$ Yes
3	$p + \bar{p} \rightarrow \tau^- + \Lambda^o + \Omega^+ + \overline{\upsilon_\tau}$ No, Strangeness	$p + \bar{n} \rightarrow \tau^+ + \tau^-$ No, charge	$\bar{n} + n \rightarrow \tau^+ + \tau^-$ Yes	$p + \bar{p} \rightarrow \Sigma^- + \Omega^+$ No, Strangeness
4	$p + p \rightarrow p + p + \pi^o$ yes	$p + p \rightarrow p + n + \pi^+$ yes	$n + n \rightarrow \Xi^+ + \overline{\Lambda^o} + \Omega^- + n + n + n$ yes	$\pi^- + p \rightarrow \pi^o + n + \pi^- + \pi^+$ yes

Part C: Write the quark combinations that make up a proton and a neutron: p =__________ n =__________
Identify the following quark combinations as either a meson, or a baryon. Determine the baryon number, strangeness, and the charge of each:

		Baryon or Meson?	B = ?	S = ?	q = ?
1	$s\bar{s}$	M	0	0	0
2	dsc	B	+1	-1	0
3	$\bar{u}\bar{u}\bar{u}$	B	-1	0	-2
4	$s\bar{u}$	M	0	-1	-1
5	$d\bar{s}$	M	0	+1	0
6	sss	B	+1	-3	-1
7	$\bar{u}\bar{u}\bar{c}$	B	-1	0	-2
8	$u\bar{s}$	M	0	+1	+1
9	$c\bar{d}$	M	0	0	+1
10	$\bar{s}\bar{s}\bar{c}$	B	-1	+2	0
11	ucc	B	+1	0	+2
12	$s\bar{b}$	M	0	-1	0

Charge	Quarks			Baryon number
$\frac{2}{3}e$	u	c	t	$\frac{1}{3}$
$-\frac{1}{3}e$	d	s	b	$\frac{1}{3}$

All quarks have a strangeness number of 0 except the strange quark that has a strangeness number of −1

Data Packet reference for decays:

Charge	Leptons		
−1	e	μ	τ
0	υ_e	υ_μ	υ_τ

All leptons have a lepton number of 1 and antileptons have a lepton number of −1