Phyx 135-3-02 Final **Name ____________________________________**
Winter 2015
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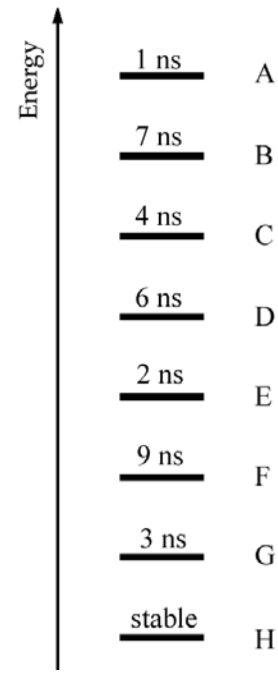
1) (10 points) A muon is an unstable particle with a half-life of 1.52 x 10^{-6} s. An alien spaceship with an muon-rocket propulsion system is passing the Earth at 0.5 *c* while firing a muon beam out the back of the spaceship at a speed of 0.9 *c* relative to the spaceship. What is the half-life of the muons from your point of view on Earth?

2) (10 points) You are observing distant galaxies with the Hubble Space Telescope when you see the green color of a spectral line of the rare element Hypotheticalium. Your measurements reveal that this spectral line has a wavelength of 520 nm, with an error of $\pm$ 1 nm. Since your instruments are perfect, you know this means the error is due *solely* to basic quantum mechanics. Use this information to estimate how long excited electrons remain in that quantum level of Hypotheticalium before decaying.

3) At right is a schematic of the energy levels of the very rare element Hypotheticalium. The bottom level is the ground level; the energy of the levels increases as you go up. The time shown for each level is the half-life (in nanoseconds) of any electron excited into that level.



a) (3 points) If I excite a large number (~ 10^{20}) of Hypotheticalium atoms with an electric discharge, what is the maximum number of spectral lines (of any wavelength) the gas may give off?

b) (2 points) Which energy level is going to give rise to the faintest (fewest photons per second) spectral line?

c) (3 points) If the shortest wavelength radiated by the Hypotheticalium is 150 nm, what is the energy difference between level A and level H?

4) The Bohm-Aharonov Effect is an exotic quantum phenomena which results when an electron is diffracted around a magnetic field. When I was in graduate school, another student asked my advice about measuring this effect using a clunky old magnet that he'd found in a storage closet.

a) (5 points) His magnet was 5 cm in diameter. Estimate the maximum kinetic energy (in joules) that an electron can have if it is to experience any significant degree of diffraction around an object of this size. State *very briefly* how you are making your estimate.

b) (3 points) Assume that the inside of your vacuum chamber for measuring the Bohm-Aharonov Effect is sealed off from all light, radio waves, or other external radiation. However, the chamber is at room temperature, or 290 K. What would be the most predominant energy of the remaining photons?

c) (2 points) Using your answers to Parts a and b, give one specific reason why I all but fell on the floor laughing after the student left my lab.

5) (10 points) Natural uranium today consists of 99.7% $^{238}U_{92}$ and 0.3% $^{235}U_{92}$. Given half-lives of 4.468×10^9 years for U-238 and 7.038×10^8 years for U-235, what would have been the relative percentages of U-238 and U-235 in natural uranium when the Earth was formed 4.5 billion years ago?

6) (10 points) A catfish is floating 2.00 m below the surface of a smooth lake. What is the diameter of the circle on the surface through which the catfish can see the world outside the water? (Assume that $n = {}^{4}/_{3}$ for water.)

7) (6 points) Carbon-14 undergoes β-decay into nitrogen-14. What is the maximum kinetic energy that the antineutrino produced in this reaction can carry away? (Please convert your answer to keV.)

Some atomic masses, and other numbers

^{14}C = 14.003241989 u

^{13}C = 13.003354838 u

e = 5.4858×10^{-4} u

u = $1.660538782 \times 10^{-27}$ kg

1 eV = 1.602×10^{-19} J

^{14}N = 14.0030740048 u

^{15}N = 15.0001088982 u

n = 1.00866491597 u

c = 2.998×10^{8} m/s

Multiple Choice Questions (2 points each)

_____ **8)** When I turn on my computer monitor, and the screen lights up, the mass of the monitor:

A) begins to radiate away
B) depends on what software I am using
C) decreases
D) stays the same
E) increases
F) is partly converted to electricity

_____ **9)** I am shining light of a single wavelength on the surface of a metal, but no photoelectrons are being emitted. To rectify this problem, I should:

A) use light of a longer wavelength
B) use light of a shorter wavelength
C) use the same light but increase the intensity
D) use the same light but decrease its intensity
E) use a laser with the same wavelength
F) heat the metal

_____ **10)** Which of the following is true for the photons in a laser beam?

A) They have the same frequency
B) They have a short half-life
C) They can only be red or green
D) They have the same polarization
E) They have the same phase
F) A, D, and E
G) A and B
H) C and D

_____ **11)** How many values of the magnetic quantum number "m" are possible for an electron if it is in an $l = 8$ state?

A) 9   B) 15   C) 5   D) 8   E) 3   F) 17

_____ **12)** β-decay occurs in an unstable nucleus when:

A) a proton is converted to an electron by the strong force
B) a proton is converted to a neutron by the strong force
C) a neutron is converted to a proton by the weak force
D) a neutron is converted to an alpha particle by the weak force
E) a neutron is converted to a beta particle by the weak force
F) an alpha particle escapes from the nucleus

_____ **13)** $^{235}U_{92}$ is radioactive and decays to $^{227}Th_{90}$, but not with one reaction. It decays using a series of reactions. In this series, the particles ejected must consist of:

A) one α-particle and three β-particles
B) three α-particles and one β-particle
C) one α-particle and four β-particles
D) two α-particles and one β-particle
E) two α-particles and two β-particles
F) one α-particle and two β-particles

_____ **14)** The wavelength of a beam of light passing through a liquid is 360 nm, but it changes to 469 nm when the beam of light leaves the liquid and enters a vacuum. What is the index of refraction of the liquid?

A) 1.10 B) 1.05 C) 1.50 D) 1.70
E) 1.90 F) 1.30 G) 1.43

_____ **15)** Which of the following nuclear reactions is impossible? (e = electron, n = neutron)

A) $n + {}^{235}U_{92} \rightarrow {}^{90}Sr_{38} + {}^{136}Xe_{54} + 10n$
B) ${}^{238}U_{92} + n \rightarrow {}^{239}Pu_{94} + 2e + 2$ anti-neutrinos
C) ${}^{228}Th_{90} \rightarrow {}^{228}Ac_{89} + e$ + anti-neutrino
D) three ${}^{4}He_{2} \rightarrow {}^{12}C_{6}$
E) ${}^{16}O_{8} + {}^{4}He_{2} \rightarrow {}^{20}Ne_{10}$
F) ${}^{3}H_{1} \rightarrow {}^{3}He_{2} + e$ + anti-neutrino

_____ **16)** The three rare-earth elements gadolinium, terbium, and dysprosium are elements 64, 65, and 66, respectively. Which one of the following statements is true?

A) Gadolinium is the rarest of the three rare earths.
B) Terbium is the rarest of the three rare earths.
C) Dysprosium is the rarest of the three rare earths.
D) Gadolinium and terbium are equally rare.
E) Terbium and dysprosium are equally rare.
F) Gadolinium and dysprosium are equally rare.