Physics 262 Practice Exam 7

1. In spectroscopic notation, what is the ground state of Scandium?
A periodic table will be given. Sc: Z=21 so gs = $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$

2a) List all the values of l and m that are allowed for n=2.
b) For each l,m, list L and L_z in units of h-bar. see following page

3. Consider a H atom in the state n=3, l=2, m unspecified. If the atom emits a photon in the absence of a magnetic field
A] the higher the m value, the bluer the photon
B] lower the m value, the bluer the photon
C] the photon will be of the same wavelength regardless of m

4. Consider a population of H atoms in the state n=3, l=2, with all different m values, in a magnetic field. How many spectral lines result from photon emission from these atoms, and what transitions are responsible for each line? (Ignore spin-orbit coupling.) see following page.

5a) What is the ground state of lithium (Z=3), in spectroscopic notation? $1s^2 2s^1$
b) The highest energy electron is promoted to the n=4 state. Estimate the additional energy needed to ionize this electron. (The ionization energy of the hydrogen ground state is 13.7 eV.)
This is just a Bohr/Rydberg atom $E = 13.7\left(\frac{1}{4^2}\right) = 0.856$ eV.

6. What kind of shielding is needed to stop the following types of radiation?
a) alpha sheet of paper
b) beta mm of metal e.g. al.
c) gamma cm of lead

7. Which is more "radioactive", in the sense of emitting more particles per second
a) 1 gram of carbon-14, with a half-life of 5730 years
b) 1 gram of plutonium-239, with a half-life of 24,100 years? See following page.

c) The atmospheric abundance of ^{14}C is 1 part per trillion. A 1-gram sample of carbon from a piece of charred wood shows 8 decays per minute. How old is the wood?

d) If the radioactivity of the wood was measured over an hour, what is the uncertainty in your age estimate?

8. What is X in the reaction:
$n \to p + \beta^- + \bar{\nu}$ electron.
$^{43}_{19}K \to ^{43}_{20}Ca + X.$

$mc^2 = 0.0014$ amu $= 1.3$ MeV.

9a). How much energy is released in the reaction in Q8? (Given the masses of the isotope of K and Ca.) $^{43}_{19}K$ 42.960 72 amu $^{43}_{20}Ca$ 42.95877 $e^- = 0.00055$
b) What is the approximate speed of the emitted particle X? (You may ignore recoil. and antineutrino!)
Kinetic energy of $\beta^- = 1.3$ MeV $= (\gamma - 1)mc^2 \Rightarrow 0.511$ MeV$(\gamma - 1) = 1.3$ MeV.
$\gamma - 1 = 2.54$
$\gamma = 3.54$

10a) Since neutrons stick together by the strong nuclear force, why are there no stable nuclei with, say, 100 neutrons and no protons?
$n \to p + \beta^- + \bar{\nu}$ will lower energy by Pauli principle
b) Why are there no stable nuclei with, say, 100 protons and no neutrons?
electrostatic repulsion overwhelms nuclear force.

$\frac{v}{c} = 0.96$.

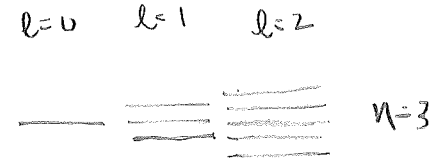
2a. $n=2$ $\ell=0$ $m=0$ $L_z=0$ $L=0$

$\ell=1$ $m=-1$ $L_z=-\hbar$

$L=\sqrt{2}\hbar$ $m=0$ $L_z=0$

$m=+1$ $L_z=+\hbar$

Problem 4:



4. Selection Rules $\Delta\ell=1$ $\Delta m=0,\pm1$

Highest energy: $m=+2$ to $m=+1$; $+1$ to $m=0$; 0 to $m=-1$ } $\ell: 2\to1$, $n: 3\to2$

Next highest: $m=+1\to+1$; $m=0\to0$; $m=-1\to-1$ } $\ell=2\to1$, $n=3\to2$.

Lower: $m=0\to+1$; $m=-1\to0$; $m=-2\to-1$ } $\ell=2\to1$, $n=3\to2$

Lowest!: $m=+2\to+1$; $m=+1\to0$; $m=0\to-1$ } $\ell=2\to1$, $n=3\to3$!

7. $1\,g\ {}^{14}C = \frac{1}{14}\,mol = 4.286\times10^{22}$ atoms. $N=N_0e^{-t/\tau}$ $t_{1/2}=0.693\tau$

(a)(b) $1\,g\ {}^{239}Pu = \frac{1}{239}\,mol = 2.5\times10^{21}$ atoms. so $\frac{dN}{dt}=-\frac{N_0}{\tau}e^{-t/\tau}$ $-\left.\frac{dN}{dt}\right|_0=\frac{N_0}{\tau}=\frac{0.693\,N}{t_{1/2}}=1.63\times10^{11}$ dps. $\frac{dN}{dt}=2.3\times10^{9}$ dps.

(c) $N_0=10^{-12}\times4.286\times10^{22}$ atoms $=4.286\times10^{10}$. Original $-\frac{dN}{dt}=9.86$ dpm.

$e^{-t/\tau}=\frac{8}{9.86}\Rightarrow\frac{t}{\tau}=0.209$ $t=\frac{0.209}{0.693}t_{1/2}=0.301\,t_{1/2}=1728$ yrs.

(d) $DPM=8\pm\frac{\sqrt{8}}{\sqrt{60}}$ ← "Poisson Stats" ← # of indpd mmts.

$=8\pm0.365$ $t_{min}=1360$ yrs. $t_{max}=2114$ yrs. $\pm$ ca. 400 yrs.