Physics 262 Exam 7 Name Solutions

$E_n = -\frac{13.6eV}{n^2}$
$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$
$N(t) = N_0 e^{-t/\tau}$
$T_{1/2} = \tau \ln(2) \cong 0.693\tau$
$U_{Zeeman} = m\mu_B B$
$m_e = 0.000549$ u
$m_p = 1.007276$ u
$m_n = 1.008665$ u
$m_\alpha = 4.002603$ u
1 u = 931.5 MeV/c^2
1 eV = 1.6 x 10^{-19} J
c = 3 x 10^8 m/s
E = γmc^2
Periodic table (overhead)

1. In spectroscopic notation, what is the ground state of Titanium, Z=22?

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

2. If the outermost electron in titanium is excited into a 5s state, how much **additional** energy would be needed to ionize it?

$Z_{eff} = 1$ so E_{5s} Ti $= E_{5s}$ H $= -\frac{13.6}{n^2}$

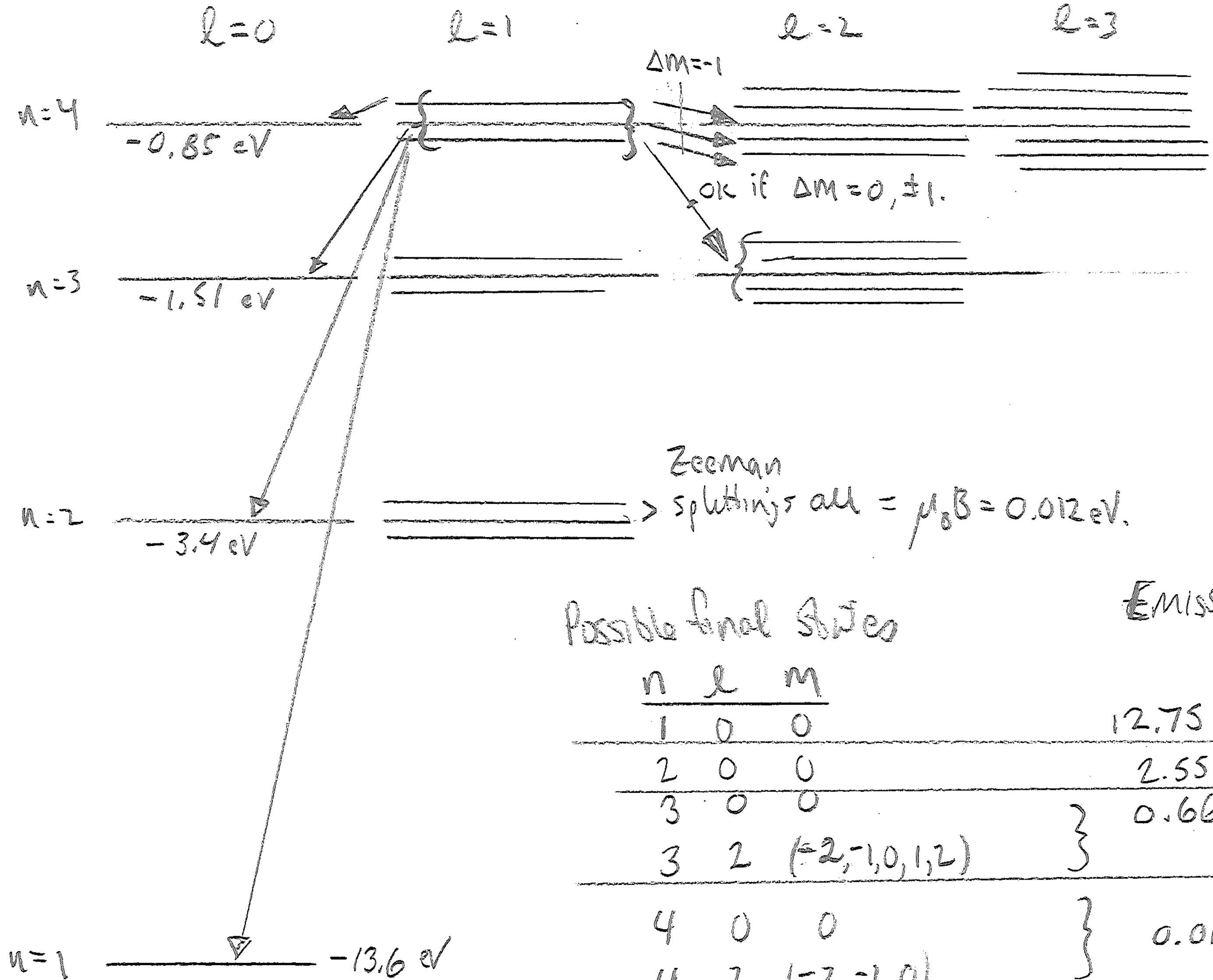
$E = 0.544$ eV.

3. Consider a collection of H atoms in the state n=4, l=1, with all allowed values of m, in a 200 T magnetic field. If this atom emits a photon, list all possible final states the atom could be in. (Ignore spin.)

See attached

4. For each transition in Q3, what is the energy of the emitted photon? (Ignore spin, hyperfine interaction, & spin orbit coupling of course!) The ionization energy of hydrogen is 13.6 eV, and the Bohr magneton is 5.8x10^{-5} eV/T.

see attached.



Possible final States

n	l	m		Emission Lines
1	0	0		12.75 eV ± 0, 0.012 eV
2	0	0		2.55 eV ± 0, 0.012 eV
3	0	0	}	0.66 eV ± 0, 0.012 eV
3	2	(-2,-1,0,1,2)	}	
4	0	0	}	0.012 eV.
4	2	(-2,-1,0)	}	

5. What kind of shielding is needed to stop the following types of radiation?

a) alpha paper

b) beta mm of aluminum

c) gamma cm of lead

6. The atmospheric abundance of ^{14}C is 1 part per trillion. A 1-gram sample of carbon from a piece of charred wood shows 4 decays per minute. How old is the wood? The half life of ^{14}C is 5730 years. Note that the weight of carbon is 12 grams per mole, and that a mole is $6x10^{23}$ atoms.

Original decay rate $\frac{dN}{dt} = -\frac{N}{\tau}$ $T_{1/2} = \ln 2 \cdot \tau$ so $\tau = 8266.6$ yrs $= 4.3\times10^{9}$ min.

$$N(0) = \frac{1}{12} \cdot 6\times10^{23} \cdot 10^{-12} = 5\times10^{10}$$

(10^{-12} ← 1 ppt)

So

$$\left.\frac{dN}{dt}\right|_0 = \frac{5\times10^{10}}{4.3\times10^{9}} = 11.63 \text{ dpm.}$$

Now $R(t) = R(0)\, e^{-t/\tau}$ (where $R = \frac{dN}{dt}$)

so

$$\ln \frac{R(0)}{R(t)} = \frac{t}{\tau} \qquad t = \tau \ln \frac{R(0)}{R(t)} = 8267\text{y} \cdot \ln\left(\frac{11.63}{4}\right)$$

$$= 8803 \text{ yrs.}$$

7a. In the following nuclear decay of sodium to neon, what is the most massive particle produced (other than the daughter neon nucleus)?

$^{22}_{11}Na \rightarrow ^{22}_{10}Ne + ?$ β^+ $(+\ \nu_e)$ ← nearly massless.

7b. The mass of sodium-22 is 21.9944364 u; the mass of neon-22 is 21.991385114 u.
Does the reaction above occur spontaneously? If so, how much energy is released (in MeV)?
(You may ignore the mass of any other particles *except* the daughter **and** the particle you identified in part a.)

$\Delta m = 0.0025\ u.$ $(m\ of\ \beta^+ = m\ of\ \beta^-)$ $\boxed{\Delta E = 2.33\ MeV}$

$= (\gamma - 1) m_\beta$ $\gamma = 5.558$

7c. Ignoring nuclear recoil and any additional particles, how fast is the particle in 7a ejected?
Give your answer as a fraction of c.

with $\gamma = 5.558$, $V = 0.98c$.

8a) Since neutrons stick together by the strong nuclear force, why are there no stable nuclei with, say, 100 neutrons and no protons?

β decay $n \rightarrow p^+ + \beta^- + \bar{\nu}$ lowers energy by redistributing nucleons into lower energy states.

b) Why are there no stable nuclei with, say, 100 protons and no neutrons?

Coulomb repulsion and/or β^+ decay & electron capture.