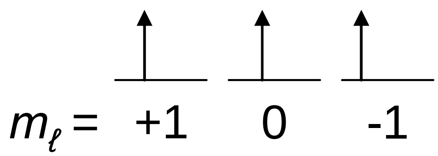
Quiz 9
CHEM 325
Spring 2009

Name: ____

1a. (7 Points) What is the ground state term symbol for N (include *J*)? You are given that the electronic configuration of N is [He] $2s^2\ 2p^3$. Hint: use the shortcut method discussed in class.

> **Using the short cut method (and labeling the orbitals as shown), gives the following microstate.**
>
> 
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>
> **For this microstate** $M_L = 0$ **and** $M_S = 3/2$**. This can only arise from a term with** $L = 0$ **<u>and</u>** $S = 3/2$**, which is** ^4S**.**
>
> **The possible** J **values are** $L + S, L + S - 1, \ldots |L - S|$**, which in this case is 3/2 (since** $L + S = |L - S| = 3/2$**). The ground state is therefore** $^4S_{3/2}$**.**

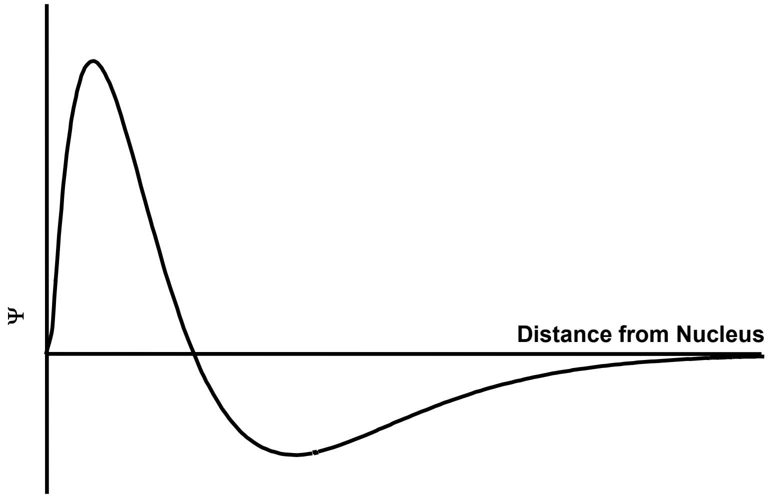
b. (4 Points) The other two terms that arise from nitrogen's electronic configuration are ^2P and ^2D. Which one is lower in energy? Why?

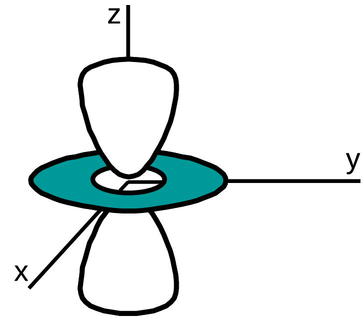
> **Hunds's Rules predict that when two states have the same spin (multiplicity) the one with the largest** L **is lowest in energy as this minimizes** e^-**-**e^- **interactions. In this case it is** ^2D**.**

c. (4 Points) Is a transition from the ground state to either the ^2P or to the ^2D state allowed? Why? If you did not get an answer for part *a*, list the criteria for a transition to be allowed and state which one will be the most important. For this analysis you may ignore *J*.

> **Since the ground state is** ^4S **and the excited states are** ^2P **and** ^2D**, the two possible transitions (**$^2D \leftarrow {}^4S$ **and** $^2P \leftarrow {}^4S$**) are both spin forbidden (**$\Delta S \neq 0$**). Although the** $^2P \leftarrow {}^4S$ **transition would be orbitally allowed (**$\Delta L = +1$**), it would not be expected to be observed because for atomic system being spin forbidden dominates all other considerations. So at best, the** $^2P \leftarrow {}^4S$ **transition would be extremely weak.**

2. (10 Points) The radial and angular portions of a certain hydrogen wavefunction are shown below.





a. The number of radial nodes is/are **1**.

b. The number of angular nodes is/are **2**.

c. For this orbital ℓ equals **2**.

d. The possible m_ℓ value/s for this ℓ is/are **±2, ±1, 0**.

e. The actual value of m_ℓ for this orbital is **0**.

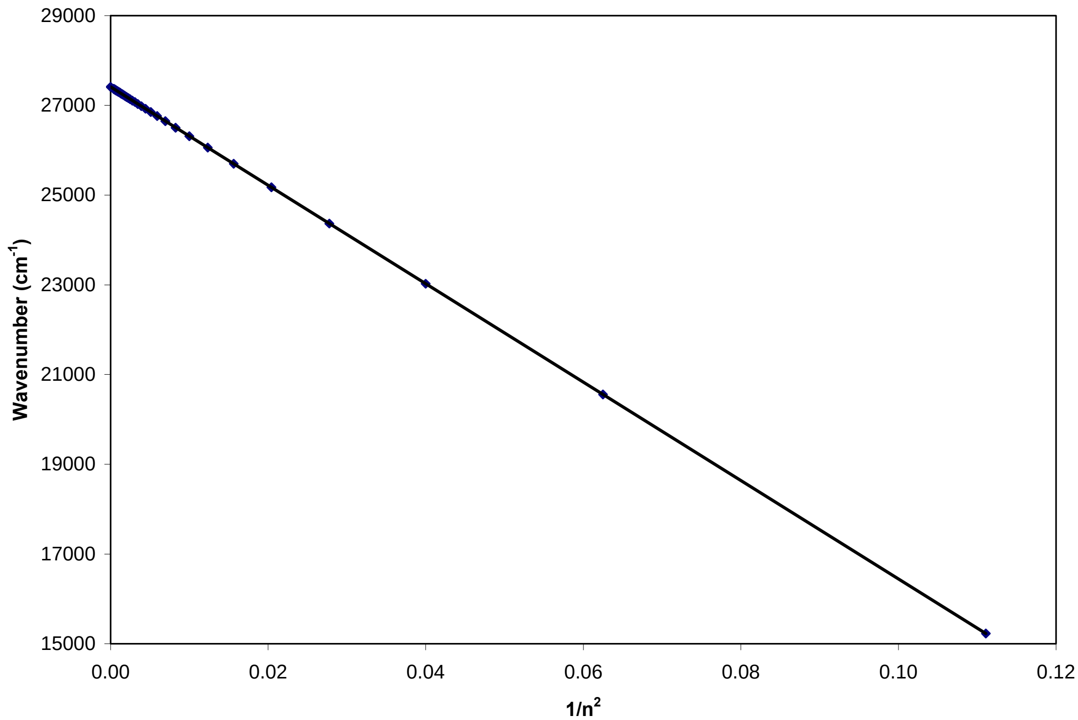
f. For this orbital *n* equals **4**.

g. The name of this orbital is **$4d_{z^2}$**.

h. When compared to an s orbital of the same *n* in the <u>hydrogen</u> atom, this orbital's energy is
greater than   less than   **the same as**   the s orbital's energy. (circle one)

i. When compared to an s orbital of the same *n* in the <u>iron</u> atom, this orbital's energy is
greater than   less than   the same as   the s orbital's energy. (circle one)

3. (8 Points) When the energy of a particular series of lines in the H atom absorption spectrum are graphed as a function of $1/n^2$, where n is an integer, the data can be fit to a straight line with a slope of -109642.89 cm^{-1} and an intercept of 27410.72 cm^{-1}, as shown below. Determine the value of R_H and the value of the n for the other term involved in the transition.



The term energy in the hydrogen atom is given by the equation $E_n = -\frac{R_H Z^2}{n^2}$**. Since a transition requires a change in energy on the atom's part, it must result from the single electron moving from a term with some** $n_{initial}$ **to a term with some** n_{final}**. Thus, we may write** $\Delta E = E_{final} - E_{initial} = \left(-\frac{R_H Z^2}{n_{final}^2}\right) - \left(-\frac{R_H Z^2}{n_{initial}^2}\right)$**, where** $n_{final} > n_{ititial}$ **for absorption. Since** $Z = 1$**, we can simplify this to** $\Delta E = \frac{R_H}{n_{initial}^2} - \frac{R_H}{n_{final}^2}$**. A given series of lines in the hydrogen absorption spectrum are transitions from the same** $n_{initial}$ **to different** n_{final} **values. This means that** $n_{initial}$ **is a constant and the changing** n^2 **in the graph shown above is due to** n_{final}**. Thus, the equation** $\Delta E = \frac{R_H}{n_{initial}^2} - \frac{R_H}{n_{final}^2}$ **is in the form of a straight line with a slope of** $-R_H$ **and** $\frac{R_H}{n_{initial}^2} = intercept$**, or** $n_{initial} = \sqrt{\frac{R_H}{intercept}}$**. Therefore** $R_H = 109642.89\ cm^{-1}$ **and**

$$n_{initial} = \sqrt{\frac{R_H}{intercept}} = \sqrt{\frac{109642.89\ cm^{-1}}{27410.72\ cm^{-1}}} = 2.$$