**Physics Group Problem**

This problem talks the hydrogen atom and multi-electron atoms.

a) How many different hydrogen atom quantum states are there with \( n=3 \) and \( \ell=2 \)?

\[
m_\ell \text{ ranges from } -\ell \text{ to } \ell, \text{ so can be either } -2, -1, 0, +1, \text{ or } +2. m_s \text{ can be } +\frac{1}{2} \text{ or } -\frac{1}{2}
\]

So there are ten such states.

b) Describe the physical property of the orbits in a) that distinguish them from one another. (Think about what the different quantum numbers mean, and the analogous classical orbits corresponding to the quantum states).

These different states have different \( m_\ell \) and \( m_s \) values. Since the z-component of the orbital angular momentum is \( L_z = m_\ell \hbar \), these all have different directions of the orbital angular momentum. Classically, the angular momentum is perpendicular to the plane of the orbit, so the orbital planes are tilted at different angles.

c) Potassium is the element with 19 electrons. What are the quantum numbers of the last filled quantum state?

States fill according to their energy, lowest to highest.

- 2 1s states
- 2 2s states
- 6 2p states
- 2 3s states
- 6 3p states, total so far = 18

The last electron goes into one of the 4s states.

d) How many electrons would the next heavier element with similar chemical properties have?

Atoms with similar chemical properties have the same outer-electron configuration. They are in the same column of the periodic table. So the next largest atom with similar chemical properties would have 1 electron in the 5s state. So need to finish filling 4s, then fill 3d, then 4p, and one more to put in the 5s.

- 4s needs 1
- 3d needs 10
- 4p needs 6
- 5s needs 1

A total of 18 more electrons, so 37 total electrons. This is rubidium (Rb).