Weds: Discussion /quiz

Supp 131, 132, 133, 134

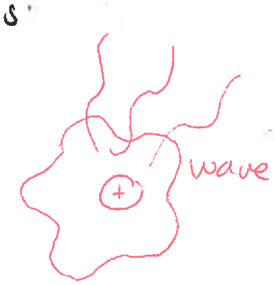
Ch 29 Q 8

Prob 26, 34, 35

Fri: Review

Quantum Physics for the Hydrogen Atom

Quantum theory provides a general framework for describing all sorts of physical situations. The framework usually functions as:



- Describe certain details of system e.g. potential energy $V = -k\frac{q_1 q_2}{r}$
- → Insert into Schrödinger equation and solve
- Gives ↓
  - Possible energy that system can have
  - Possible states and associated wave
    - ↳ Probabilities with which various measurement outcomes occur

The scheme does not refer to forces or accelerations and does not use Newton's laws.

The scheme can be applied to the hydrogen atom and some important results are:

1) The possible energies of the hydrogen atom are indexed by $n = 1, 2, 3, \ldots$ (principal quantum number) and the associated energy is

$$E_n = \frac{-13.6\,eV}{n^2}$$

This predicts the spectrum of the hydrogen atom.

2) The possible values for the magnitude of the orbital angular momentum are also discrete and are

$$L = \frac{h}{2\pi}\sqrt{l(l+1)}$$

Classically

$L = mvr$

where for any n; $l = 0, 1, 2, \ldots, n-1$

These all constitute distinct states for the atom.

3) It is possible to assign a value to one of the three components of the orbital angular momentum. Consider the z component, L_z. Then possible values of L_z are $L_z = mh/2\pi$ where

$$m = -l, -l+1, -l+2, \ldots, l-1, l$$

4) Independently of it's orbital motion the electron has a spin angular momentum and this can take one of two possible values, represented by

$$m_s = -\tfrac{1}{2} \text{ or } +\tfrac{1}{2}$$

Then describing the state of a hydrogen atom requires listing one of each of:

$$n = 1, 2, 3, \ldots$$

$$l = 0, 1, 2, \ldots, n-1$$

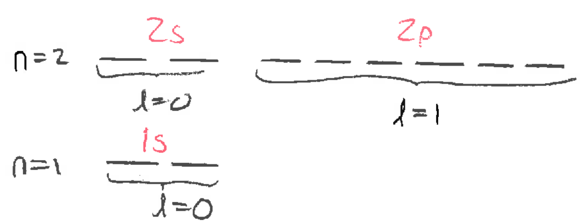
$$m = -l, -l+1, \ldots l-1, l$$

$$m_s = -\tfrac{1}{2} \text{ or } +\tfrac{1}{2}$$

One can chart these and create an energy level diagram. The notation for the states follows

n	l	m	m_s	notation
1	0	0	$+\frac{1}{2}$	1s
1	0	0	$-\frac{1}{2}$	
2	0	0	$+\frac{1}{2}$	2s
2	0	0	$-\frac{1}{2}$	
2	1	-1	$+\frac{1}{2}$	
2	1	-1	$-\frac{1}{2}$	
2	1	0	$+\frac{1}{2}$	2p
2	1	0	$-\frac{1}{2}$	
2	1	1	$+\frac{1}{2}$	
2	1	1	$-\frac{1}{2}$	

$ns \leftarrow l=0$ $\quad np \leftarrow l=1$ $\quad nd \leftarrow l=2$



Quiz 1 30% - 80%

Quiz 2 20% - 80%

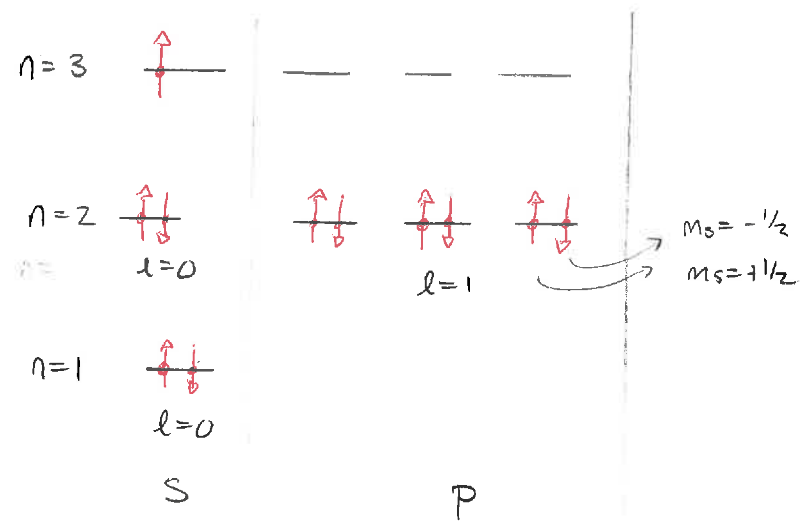
Multielectron Atoms

In principle the same basic scheme can be applied to atoms with more than one electron. However, the Schrödinger equation cannot be solved directly for this situation. Still the same basic structure to the indices that label the states applies. The only difference is that there is no formula for the values of energy. We can determine the structure of an atom using the rules:

1) each state can be occupied by at most one electron
2) in its ground state, the states are occupied from the lowest upwards

Example: Sodium has 11 electrons. Which states are occupied?

Answer:



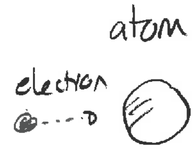
We see that there is only one electron in the n = 3 level. The atom with only one electron in the n = 2 level is Lithium. The atom with all n = 3 levels filled and one electron in the n = 4 level has 11 + 16 = 27 electrons. This is Rubidium. These three atoms have similar chemical properties and lie in the same column of the periodic table. The quantum theory atomic structure describes why this is so.

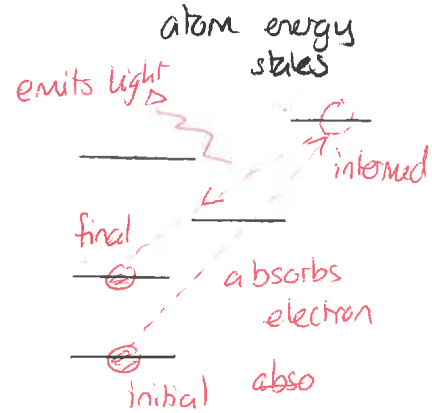
Excited states and spectra

An atom can be excited by

1) absorbing a photon

2) absorbing energy from a colliding particle e.g electrons





Demo PhET Hydrogen Atom

- Schrödinger
- Show spectrometer

The energy of an incoming free electron is not quantized and the atom can absorb any fraction of this energy. So incoming free electrons can easily excite the atom to any higher energy level.

Quiz 3