## Which Chapter/Sections are covered?

Chapters 1-3 (chapter 4 is important that you know but this was not on HW1 nor will it be on the exam). Most of the exam (~80%) will be on Chapter 12. All the material on the exam has been covered in homeworks 1, 2, and 3. Concentrate on the subject matter emphasized in class and on the homeworks. Come in mentally prepared to answer at least 20 questions, maybe a few more. Yes, there will be calculations, but most of the exam will be theory and concepts. You need to *understand* the theory and concepts to the level at which we studied it. I don't expect you to solve the Schrödinger equation, but I do think you should understand what it meant towards modern atomic theory. And, just because you got a homework question right does not necessarily mean you really understand the material. Try explaining the concepts to someone else to see if you really understand.

## Energy traveling at the speed of light

Know what electromagnetic radiation is and how we depict it on the page and conceptually.

Know the basics of the entire electromagnetic spectrum (see Figure 12.3, p. 512). Know the approximate wavelengths for each type of radiation given (LOOK at that figure). Know also, that visible light is in the 400-700 nm range (that's blue end to red end). Other than the two ends, I do not expect you to know the wavelengths of all the colors of the rainbow – however, you SHOULD know the ordering of the colors (think Roy G. Biv).

Know the two basic equations that describe electromagnetic radiation:

$$E = h\nu \qquad c = \lambda\nu$$

Know how to use this equations to calculate various wavelengths, frequencies, and energies of photons.

Know the two views of electromagnetic radiation: as a wave and as a particle (photons)

## Do all moving particles have wavelength?

Yes. Louis de Broglie said if light can be treated as a particle (photon) then why not the other way around? Any moving particle with mass and velocity should have a corresponding wavelength.

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$ where $p$ is momentum ($p = mv$)

The most important moving object for us is the electron. Now we can treat the electron as a wave. When confined to the region around the nucleus, the electron behaves as a *standing* wave.

What is the essence (observations) of the photoelectric effect? (p. 515)

How did Einstein explain this effect?
How does this relate to the work function ($\Phi$) of a metal:

$$\tfrac{1}{2}mv^2 = h\nu - \Phi$$

Be able to calculate any part of this equation ($m$, $v$, $\Phi$, or $\nu$) if given any 3 of the 4 variables in it

## The Emission Spectrum of Hydrogen

Check out those lines. Lines I tell you. Not broad bands of continuous wavelengths but very very narrow precise lines. It's like hydrogen is speaking to us. What is it saying? It is saying, "I have quantized energy levels!" "When I'm excited, I spit out very specific quanta of energy." Who listened? Several smart guys but lets chalk one up for Bohr for realizing that the photon that is emitted is due to the energy difference in quantum levels within the atom. As an electron falls from an excited state to a lower energy state, a photon is emitted that corresponds to the energy gap. Balmer looked at the visible spectrum of hydrogen and wrote out an equation to fit the emission lines. Shortly after that, Rydberg came up with a more general equation for hydrogen emission:

$$\nu = \mathcal{R}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad n_1 = 1, 2, \ldots \quad n_2 = n_1+1, \ n_1+2, \ldots$$

You can use this equation to calculate all kinds of energy transitions. These equation works great! Let's now count how many different atoms it works for... hmmmm It will work really well as long as you have a nucleus with a charge of +1 and ONE electron somewhere near it. OK, well that's hydrogen and now your done - answer 1 atom type. OK, so we are somewhat limited here in our equation. The good that comes out of this is that we are now starting to get a more quantitative feel for how energy is in fact quantized within the atom. Note that $n_1$ and $n_2$ ARE essentially quantum numbers in this equation. So how do we get a better equation for more electrons? Unfortunately, we will need to increase the complexity of the equation. So yes, the complexity will steeply rise as we proceed through the periodic table and investigate atoms with far more than one electron. The key here is that there WILL be an equation that WILL have quantum numbers associated with it. A better way to go about getting the right equation is to utilize the Schrödinger equation. OK, don't just utilize it, SOLVE it and find the proper wavefunction ($\psi$) for the electron that you are interested in.

## Schrödinger's Equation

$$-\frac{\hbar^2}{2m}\frac{\mathrm{d}^2\psi}{\mathrm{d}x^2} + V(x)\psi = E\psi$$

Impressive, isn't it? Can you say differential equation? I knew you could. What's it for? What comes out of it? Can it be solved exactly for all atoms?

The solving of this equation totally depends on setting it up properly. We must mathematically define the boundary conditions for this equation. We'll use spherical coordinates for this ($r$, $\theta$, $\phi$) as described in Figure 12.15 on page 537 in your book. Oh my! Check out some of the answers ($\psi$'s) that come out of this thing. (Table 12.1) Scary isn't it. Maybe we should hang on a minute and handle a much easier system with only ONE dimension (not three). Of course I'm referring to the particle-in-a-box problem.

## Particle in a box  -  Standing Waves

Yes, if we confine a particle, in a very very small space, its wavelike behavior starts taking over. Only certain waves will fit into the "box". Tada! These waves are quantized. Each wave has a specific wavelength and energy associated with it.  Oh yeah, our "box" has only one dimension, length - not really a box at all is it? Some books call it a particle-on-a-line - better name? Not the historical name though. Anyway... You can solve this problem using the Schödinger equation (bottom of page 531). Once solved, let's look at the derived formula for the energy levels:

$$E_n = \frac{n^2 h^2}{8mL^2} \qquad n = 1, 2, 3, \ldots \quad \text{(p. 534)}$$

What is so significant about this equation? Why did we even bother to talk about it? What can be learned from this? How is this a nice "friendly" segue into the various solutions to the Schrödinger equation? Compare and contrast the similarities of this equation and the equation that Schrödinger arrived at for the energy levels within the hydrogen atom:

$$E_n = -\frac{h\mathcal{R}}{n^2} \qquad \mathcal{R} = \frac{m_e e^4}{8h^3 \varepsilon_0^2} \qquad n = 1, 2, 3, \ldots$$

(p. 537 in book)

How would these solutions look graphically? See Figure 12.18 (p. 542).

In general, you will get a quantum number for each dimension you use in the Schrödinger equation. We use 3 dimensions so there are 3 quantum numbers ($n$, $l$, and $m_l$) that describe the SPACE that the electron is occupying for a given level of energy. Later, another property of the electron had to be accounted for which was spin and the 4th quantum number, $m_s$ was born.

## Quantum Numbers

Know the names, symbols, and values for the four quantum numbers $n$, $l$, $m_l$, and $m_s$ .

**Principal** $\qquad\qquad\qquad\qquad$ $n = 1, 2, \ldots$
**Quantum Numbe**r

**Angular Momentum** $\qquad\qquad$ $l = 0, 1, 2, \ldots n\text{-}1$
**Quantum Number**

**Magnetic** $\qquad\qquad\qquad$ $m_l = \text{-}l \ldots \text{-}1, 0, 1, \ldots l$
**Quantum Number**

**Spin** $\qquad\qquad\qquad\qquad$ $m_s = +1/2, \text{-}1/2$
**Quantum Number**

Out from these quantum numbers and the solution to the Schrödinger equation comes wavefunctions. What does the wavefunction, $\psi$, tell us? Ultimately it allows us to map out in three dimensions the likelihood of finding an electron in a given amount of space. This is what gives us the orbitals of the hydrogen atom that we are (now) all familiar with.

## Know your orbitals

Know the basic differences in each orbital type: *s, p, d,* and *f.* Your should even be able to follow the trend to *g, h, i,* etc. . .  What do nodes have to do with the shapes of these orbitals? What kind of nodes are there in these orbitals? Answer: There are nodal planes, nodal cones, (aka angular nodes) and nodal spheres (aka: radial nodes). How do these influence the shapes of atomic orbitals?  How does the most probable distance for the electron vary with different orbitals

More questions to get straight. What's the maximum number of electrons that will fit into ANY orbital? Each orbital type (*s, p, d,* . . . ) comes in sets. How many orbitals per set? What is the maximum number of electrons per set? What are the relative energies of the various orbitals for the hydrogen atom? for other atoms?

## Electron Configurations

You should be able to write (OK, pick out the answer from a list) out the electron configuration of any element on the periodic table. Yes, you WILL have your own copy of the periodic table to use. You should also be able to write out electron configurations for various ions whether cations or anions. Know which ions are isoelectronic with one another.

## The Periodic Table

First off, this thing will really help you out with those electron configurations. Second, you can really learn a lot about elements by studying the trends in the table. What do you know? You know what and where are the alkali metals. Same goes for the alkaline earth metals, the halogens, and the noble gases. Where are the metals, nonmetals, and metalloids? What are the *d*-transition metals? *f*-transition metals? Know what the following are (definitions) AND what their trends are on the periodic table.
Atomic Radii, Ionic radii, ionization energies, electron affinities.

## TRENDS

Know your trends. This is section 12.15. A quick reminder here though. Ionization Energy (aka: ionization potential) - also know difference in first, second, third, etc... what does first, second, and third refer to? Electron

## Groups and Classifications

Check out Figure 12.39 on page 569. Know your group names and what being in a "group" means chemically. We will refer to the representative elements many times when bonding comes along. What are the representative elements? Hint, go back and read page 554.

## What Equations do you have to memorize?

You should memorize all the equations on this review sheet with the green background. Other equations will be given if necessary. ALL constants that go into the equations will be given.

## Standard Disclaimer

Any mistakes on this review sheet are NOT intentional. You should crosscheck all stated information. You should double check your book too (see errata).