Natural Gas Law: \( PV = NkT \)

Kinetic Theory of Gasses:
\[ U = \frac{3}{2} NkT \text{ or } \frac{\text{Heat of Freedom}}{2} \]

Where degrees of freedom kick in: Trans/rot/vib (Ch 10)

Solid: \( 3NkT \)

Ch 3

3.1 Crossed E & B fields, \( \eta/m \) ratio

3.3 Line spectra - Easier with Bohr model

3.4 Quantization (# waves in a box)

3.5 Black Body Radiation (BBR)
   - Ultraviolet Catastrophy
   - \( \lambda_{\text{max}} = 2.898 \times 10^{-3} \text{ m K} \)
   - \( R(T) = \frac{C}{\lambda^4} \)
   - \( C = 5.6705 \times 10^{-8} \text{ W/m}^2 \text{K}^4 \)

\[ R(T) \]

- \( E = h f \) - smaller \( \lambda \)'s have more energy
  - Planck's constant: \( h = 1239.6 \text{ eV nm} \)

3.6 Photoelectric effect
   - \( KE_{\text{max}} = \frac{h \lambda}{\phi} - \phi \)
   - Work function
   - 2 no electrons till \( \frac{h \lambda}{\phi} > \phi \)

Quantum - electrons prompt, need \( \lambda \) specific to start
Classic - have to have electrons absorb a while

3.7 X-rays
   - \( E_0 = \frac{hc}{\lambda_{\text{min}}} \) - highest energy electron gives smallest \( \lambda \)
3.8 Compton Effect \( \lambda' - \lambda_0 = \frac{h}{mc^2} (1 - \cos \Theta) \)

Remember your compton horns
- introduced \( E = mc^2 \), \( E' = \frac{p^2}{2m} + n^2 \frac{c^4}{8} \) need for \( v \approx \text{few} \times c \)
- \( E = E_{\text{kinetic}} + n^2 \frac{c^4}{8} \)

3.9 Pair production \( e^+ e^- \to \gamma \to e^+ e^- \)
- Like photoelectric effect, need a nucleus present to conserve momentum and energy, must have \( E_{\text{kin}} = 2mc^2 \)
- \( e \) inverse effect \( e^+ \to \gamma \to e^- \) as in lab

4.2 \( N(\Theta) = \frac{N_0 h}{4 \pi \varepsilon_0} \left( \frac{e^2}{2m_0} \right)^2 \frac{Z_1^2 Z_2^2}{r^2 k^2 \sin^4 (\Theta/2)} \)

\# of scattering nuclei/area

\( N_0 \) = \# of incident particles
\( r \) = distance from target
\( K \) = kinetic energy
\( n = \frac{\# \text{ nuclei (volume)}}{\text{thickness}} \)

4.3 Classical electron orbiting loses energy

4.4 Bohr Model \( L = n h \), remember how we derived it.

4.5 \( r = \frac{4\pi \varepsilon_0 n^2 h^2}{m_0^2} = n^2 a_0 \) \( a_0 = 0.0529 \times 10^{-10} \text{ m} \)

4.6 \( E_0 = -13.6 \text{ eV} = \frac{m_0^2}{2m \varepsilon_0^2(K^2)} \) (goes like \( Z^2 \) of nucleus)

- Transitions \( -13.6 \text{ eV} \left( \frac{1}{n_2^2} - \frac{1}{n_f^2} \right) \) characteristic X-rays
- Bohr's hydrogen, agree?
- Limit of quantum \( \rightarrow \) classical should agree with classical
- Problems with Bohr model?

4.7 Example of peaks in mercury with electron bombardment
- Also saw later with He Ne laser
- \( \theta \) collisions way to excite \( \psi \) following transition rules

5.1 \( n \gamma = 2d \sin \Theta \)

5.2 \( \lambda = \frac{h}{p} \) de Broglie waves \( \xi \) like Bohr's quantization condition
5.3) Electron scattering (Electrons have wavelike behavior)
Complex relationship to crystal planes

\[ \theta = \alpha \sin(\theta) \]

These planes can dictate the max energy.

5.4) Waves
\[ \psi(x,t) = A \sin(kx - \omega t) \]
Angular frequency \( \omega = \frac{2\pi}{\tau} \)
Phase velocity \( \frac{d\phi}{dk} \) (Don't see it final)
Point of constant phase moves at \( \frac{\partial}{\partial x} (kx - \omega t) = 0 \)

\( v = \lambda t \)

\( \theta \) used to motivate uncertainty principle.

5.5) Single & double slit experiments to motivate uncertainty principle.

5.6) \( \Delta x \Delta p_x \geq \frac{\hbar}{4\pi} \)
Heisenberg uncertainty principle
\( \Delta E \Delta t \geq \frac{\hbar}{4\pi} \)
Estimates with \( \alpha \) assume \( \alpha \) is the min.
Or put in Energy eqn and find minimum (did for H, Osc.)

5.7) Wave function is probability distribution
\[ \int_{-\infty}^{\infty} |\psi(x)|^2 \, dx = 1 \]

Add to uncertainty principle
And can't know \( x \) & \( p_x \) exactly.
Only measurement collapses the \( \psi(x) \).

(Recall our Bell inequality.)

5.8) Particle in a box 1st time
\[ \frac{\hbar^2}{8m} \left( \frac{n_x^2}{L_x^2} + \frac{n_y^2}{L_y^2} + \frac{n_z^2}{L_z^2} \right) \]

From filling waves in a box etc.
Essential review notes by section

5.4:
Choice of a travelling wave
- Amplitude, phase velocity, wave number, wavelength
- Note: the only real use we had for group velocity was remembering the deBroglie momentum

5.5
Know the single slit as an example of the uncertainty principle

5.6
Applications of uncertainty principle (UP) like in homework and lecture
- Know how to do a minimization problem
- Different flavors of the UP xp,Et,Ltheta etc.

5.7
Know how to sketch wave functions:
- Where it's like e^(ikx) and e^(-ax)
- How a potential affects the wavelength
(See section 6.1)
- Mathematical form of the probability density

5.8
Calculate energy, know wave functions for 1d, 2d, 3d particle in a box
(See section 6.3, and 6.5 too)

6.1
Recognize the correct form of the Schrodinger equation, using it on wave functions
- Normalizing the wave function, properties of valid wave functions

6.2
Calculating expectation values, x,p,x^2,p^2 etc.
6.3
Particle in a well again: the wave functions, using Schröd. Eqn to solve energy

6.4
Finite square well:
- know how to match wave functions at a boundary
- sketch the wave function
- understand the energy levels qualitatively.

(it is too hard to do the whole problem in a test!, but the semi-infinite square well is not too bad to solve (except the last step), and certainly you should understand the solutions so you can use them like in the homework (difficult equations etc. should be provided))

- using boundary conditions to get Reflection/Transmission

6.5
refer to 5.8, understand the degeneracy of the energy levels

6.6
Know the energy levels, be ready to manipulate the solutions like in the homework

6.7
Understand the barrier tunneling formula
- know how to use it if $E < V$ and $E > V$

7.1-7.2
Know how to use the solutions for expectation values (tough integrals provided)

7.3
Know the 3 quantum numbers (no spin yet!) and how many different ways a particle can populate an "$n".
Test3 Notes
Section 7.3
Know the quantum numbers for the different states
n: principle quantum number
ell: Orbital angular momentum
ml: magnetic
And the degeneracy for different n's, ell's

Section 7.4
Zeeman effect
- how it splits an orbital
- the energy splitting (how to calculate it
- the spots on a stern gerlach apparatus due to angular momentum (spin, ell, total)

Section 7.5
Spin
- how it contributes to the degeneracy
- Pauli exclusion principle
- Energy splitting due to spin

Section 7.6
Intro shell filling
Selection rules (primarily delta-ell = +/- 1)
We talked about the probability distribution in terms of filling up states
(e.g. S shell fills first)

8.1
Review how shells fill up, and how to read the periodic table.
I'm not too big on the chemistry, but recall the noble gasses
tend to be inert (not react) and small. The 1st column elements
tend to be reactive (and large). Elements near the middle of the
periodic table can have unpaired electrons etc.

8.2
Total angular momentum, j.
forming j from ell and s, mj's and degeneracy.
Example from class of doing a p level with j.
Many electron atoms: know how to fill them up, find the ground state as in class
Recall the states in helium where the spins are aligned (S=1) or opposite (S=0)
and what it meant for allowed transitions. (your book has a similar example for
magnesium)

8.3
Know that spins and orbital momenta can combine to split levels in a magnetic
field.
Remember how we derived the Lande g factor.

9.2
Remember how we got to the speed by considering each dimension and building
up the v^2 dv

9.3
Equipartition should be a review for you, but remember how it works.

9.4
How to get expectation values from the $f(v)dv$ and what $f(v)dv$ is.

9.5
A good exercise here is to get $f(v)dv$ in terms of energy and get the same behavior by considering the gas as particles in a square well. I.e. how to build up the number of particles considering the number of states and the probability they are occupied. Remember the bulk behavior of the 3 distributions and how they look the same in the high temperature limit.

9.6
Recall our description of conduction and how we found the Fermi-momentum. Here is another chance to review how we build up #particles from states, and what the Fermi energy is.

9.7
Recall how we got the blackbody formula (classical and quantum) considering again the number of states and the occupation probability.

Good things to remember from the course for any test:

Energy and momentum from wavelength and frequency.

Energy states of the harmonic oscillator.

Energy states of the particle in a box.

10.1 molecular bonds

behave like SHO in their vibration $E = (n + \frac{1}{2})\hbar \omega$

& experience quantized rotation

rotation kicks in 1st followed by vibration for diatomic like H₂

- did some applications involving methods from ch 9

10.2 - used einstein's ideas to get back BBR distribution & motivate stimulated emission