CHEM 3520 – Physical Chemistry II – Part I

EXAM #1

Wednesday, February 6, 2002

INSTRUCTIONS:

1. Show all work, including all formulas used.
2. Provide all units.
3. Keep your work covered.
4. **PART II is at 12:00 TODAY!!!!!**
5. GOOD LUCK!

$h = 6.626 \times 10^{34}$ Js
mass of electron = 9.109×10^{-31} kg
1 J = 1 kg m^2/s^2

Part I – 58 pts total (out of 105 pts, which includes 5 pts extra credit)

1. What is the complex conjugate of the following? (4 pts)

$$x = Ae^{5i} - 3i + (6 + 3i)^2$$

2. Are the following functions eigenfunctions of: (a) the inversion operator (has the effect of replacing x with –x); (b) the operator d^3/dx^3? (12 pts total)
   (i) exp (-4x)
   (ii) – cos x
   (iii) $x^3 - 2x$

3. An electron is found in a linear region with a length of 120 pm. What are the minimum uncertainities in momentum and speed? (10 pts)

4. What type of equation is shown below? Name the parts of it. (4 pts)

$$\hat{\Omega}\psi = \omega\psi$$

5. What is the average square momentum for a free particle whose eigenfunction is: (16 pts)

$$\psi = e^{-2x}$$

6. Please identify whether each of the following is related to vibrational, translational, and/or rotational motion. Also, provide any other information requested. (12 pts)
   (a) zero-point energy
   What is zero-point energy?
   (b) even spacing between energy levels
   (c) tunneling
   What is tunneling?
   (d) degeneracy?
   What is meant by degeneracy?

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PART II

Part II – 47 pts total (out of 105 pts, which includes 5 pts extra credit)

4. Write the Schrödinger equation for a one-dimensional harmonic oscillator. (4 pts)

5. A rigid rotor is known to be in a state where $m_l = 3$ and $l = 4$. (6 pts)
   (a) What is the rotational energy in terms of l and ħ?

   (b) What is the magnitude of angular momentum of the rotor?

   (c) Determine the z-component of angular momentum.

3. What does the notation shown below represent? (2 pts)

$$\left\langle \psi_m \middle| \psi_n \right\rangle$$

4. Given a particle in a three-dimensional energy well. Assume this is cubic and the energy is:

$$E = \frac{101h^2}{8mL^2}$$

What is the degeneracy? (Show how this number is obtained.) (6 pts)

5. Do this problem in steps! (24 pts total)
   (a) What is the general form of the wavefunction for a one-dimensional box? (Provide this information in the normalized form.) (2 pts)

   (b) Suppose we know the particle in this box is in its n=1 or n=2 eigenstate. What will the wavefunction look like? (HINT: Superposition) (5 pts)

   (c) Suppose further that the particle is twice as likely to be in the n=2 state than in the n=1 state. What will the wavefunction look like? (HINT: Probability in each state) (5 pts)

   (d) Normalize the wavefunction obtained in part (c). (HINT: Recall δ_{mn}) *(If you do not have a result for Part (c), then use the wavefunction from Part (b).)* (12 pts)

EXTRA CREDIT (5 pts): Is **sin ayx** an eigenfunction of the operator d^{20}/dx^{20}? (Yes, the number is 20)