1. The heat of vaporization of H_2O is about 1.5 times that of CCl_4. Which liquid should have the larger surface tension? 10%

2. Why does C_p (the heat capacity at constant pressure) exceed C_v (the heat capacity at constant volume) for an ideal gas? Give a molecular explanation. 10%

3. Suppose that three indistinguishable molecules are distributed among three energy levels. The energy of the levels are: 0, 1, 2, units.

   (a) How many different arrangements are possible if there is no restriction on the energy of the three molecules? 5%

   (b) How many different arrangements are possible if the total energy of the three molecules is fixed at one unit? 5%

   (c) Find the number of different arrangements if the total energy is two units, and calculate the increase in entropy accompanying the energy increase from one to two units. (Express your answer in terms of Boltzmann constant k_B) 10%

4. Classically, a rigid rotor that has its angular momentum directed exclusively along the z-axis is rotating solely in the xy-plane. Argue that this would violate the uncertainty principle for a quantum rotor. 10%

5. Draw an energy level diagram and indicate energy spacings for the $1s$ and $2p$ levels in the hydrogen atom in a magnetic field, including spin. 10%

6. State and rationalize the Franck-Condon principle and indicate its importance. 10%

7. Construct all possible wavefunctions for the excited states of helium atom using the product of $1s$ and $2s$ hydrogen-like orbitals. Which are the lowest excited states? 15%

8. A certain reaction is first order; after 540 seconds, 30.5% of the reactant remains.

   (a) Calculate the rate constant for the reaction. 7%

   (b) What length of time would be required for 25% of the reactant to be decomposed? 8%