Advanced Physical Chemistry

(1) Explain the following terms: (20%)
   (a) Micelles and Hydrophobic interactions
   (b) Fluorescence and Phosphorescence

(2) Give the derivation and state the reasoning for the Boltzmann distribution law. (15%)

(3) The eigenfunction for a 1s electron of a hydrogen atom is given by
   \[ \Psi = N e^{-r/a_0}, \] where \( a_0 \) is the radius of the first Bohr orbit for hydrogen, and
   \( N \) is the normalization constant.
   (a) Show that the radius at which there is a maximum probability of finding a
       1s electron (in any direction) is just \( r_{\text{max}} = a_0 \). (10%)
   (b) Derive the normalization constant (\( N \)) and calculate the mean distance \( <r_{1s}> \) between
       the nucleus and 1s electron. (assume that \( a_0 = 52.9 \) pm). (15%)  

   \[ \int_0^\infty x^n e^{-ax} \, dx = n!/a^{n+1} \]

(4) Sketch and then tell the first three diffraction planes for the fcc and bcc lattice.
   How can you tell a molecular crystal whether it has fcc or bcc structure? (10%)

(5) Two blocks of the same metal are of the same size but are at different temperatures, 
    \( T_1 \) and \( T_2 \). These blocks of metal are brought together and allowed to come to the 
    same temperature.
    (a) Express the entropy change in terms of \( C_p \), \( T_1 \) and \( T_2 \). (10%)
    (b) Show that the entropy change in the problem above is spontaneous and in agreement 
        with the second law of thermodynamics. (10%)

(6) For the reaction \( \text{H}_2\text{O} \xrightleftharpoons[k_{-1}]{k_1} \text{H}^+ + \text{OH}^- \), the relaxation time, \( \tau \) (sec) may be written as
    \[ \tau = \frac{1}{k_1 + k_{-1}([(\text{H}^+)] + [\text{OH}^-])} \]
    If \( \tau \) is \( 3.6 \times 10^{-6} \) sec, what are the values of \( k_1 \) and \( k_{-1} \)? (10%)