7.E: Rotational States (Exercises)

Q7.1

Consider a homonuclear diatomic molecule described by the rotational wavefunction $Y_1^0(\theta, \varphi)$.

a. Sketch graphical representations of this function by plotting the amplitude of the function vs. some coordinate with all other coordinates held constant.
b. Sketch a three-dimensional polar plot of this function where the three dimensions are x, y, and z.
c. Sketch a picture to show how this molecule is rotating in space.

Q7.2

Consider a homonuclear diatomic molecule of mass M and bond length D described by the rotational wavefunction $Y_2^{-1}(\theta, \varphi)$.

a. What is the rotational energy of this molecule?
b. What is the rotational angular momentum?
c. What is the z-component of the angular momentum?
d. What angle does the angular momentum vector make with respect to the z-axis?
e. If the molecule is oxygen, what are the numerical answers to 1) – 4)?

Q7.3

Develop an equation for the stimulated emission of a photon. Compare your result to Equation (7-58).

Q7.4

When centrifugal stretching is included in the energy for the states of the rigid rotor, equation has an extra term $v_{allowed} = 2B(J_i + 1) - 4D(J_i + 1)^3$, Equation (7-67), where J is the quantum number for the initial rotational state, B is the rotational constant and D is the centrifugal distortion constant. Use the data in Table 7.2 to determine both B and D graphically. Be careful how you use units. Compare the magnitudes of B and D. What is the percent difference between B determined without centrifugal stretching and that found here including centrifugal stretching? What would be the corresponding percent error in the bond length computed from B?

Q7.5

Write a paragraph explaining why you might expect the same functions involving spherical coordinates to describe both the rigid rotor and the hydrogen atom.

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