Answer on Question #54475, Chemistry / General chemistry

Question:

The interatomic distance of $^{14}N^{16}O$ molecule is 115.1 pm. Calculate

(i) its reduced mass,

(ii) its moment of inertia,

(iii) the wave number of the line corresponding to lowest absorption in m^{-1} Unit, and

(iv) the energy in m^{-1} unit for the transition J = 2 to J = 3.

Solution:

(i) The mass of a nitrogen atom is 14.003 amu;

the mass of an oxygen atom is 15.995 amu;

and the conversion factor is $1.6605*10^{-27}$ kg/amu.

The reduced mass is

$$\mu = \frac{\mu_N \mu_O}{\mu_N + \mu_O}$$

$$\mu = \frac{14.003 * 15.995}{14.003 + 15.995} = 7.4664\ amu = 7.4664 * 1.6605 * 10^{-27}\ \text{kg} = 1.24 * 10^{-26}\ \text{kg}$$

(ii) The moment of inertia is

$$I = \mu R^2 = 1.24 * 10^{-26} * (115.1 * 10^{-12})^2 = 1.64 * 10^{-46}\ \ kg \cdot m^2$$

(iii) The rotational constant is

$$\bar{B} = \frac{h}{8\pi^2 c I}$$

$$\bar{B} = \frac{6.626\times10^{-34}\ \text{J s}}{(8\pi^2)(2.998\times10^{8}\ \text{m/s})(1.64\times10^{-46}\ \text{kg m}^2)} = 170.6\ \text{m}^{-1}$$

Since the energy at which each "line" is measured is given by $E_{J'}$-E_J, the shortest line or lowest energy transition occurs for J=0 --> J=1;

Wavenumber is

$$F = BJ'(J'+1) - BJ(J+1) = B\big(1(1+1) - 0(0+1)\big) = 2B = 2 * 170.6 =$$
$$= 341.2\ \text{m}^{-1}$$

(iv) $$E = BJ'(J'+1) - BJ(J+1) = B\big(3(3+1) - 2(2+1)\big) = 6B = 6 * 170.6\ \text{m}^{-1}$$

$$E = 1023.6\ \text{m}^{-1}$$