Bond length of O_2 and N_2

The atmosphere is made up of 79% N_2 and 20% O_2. To apply rotational or vibrational spectroscopy formulae to these diatomic molecules, you will need to use the reduced mass, given by:

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

A. Calculate the reduced mass for both N_2 and O_2 in kilograms.

B. Given the rotational constant $\tilde{B}$ = 1.99 cm^{-1} for N_2 and 1.45 cm^{-1} for O_2 determine the bond length of each molecule.

C. Calculate the intensity of the J=0 → J=1 transition in the rotational spectra of N_2.

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A. Calculate the reduced mass for both N_2 and O_2 in kilograms.

Solution: for oxygen.

$$\mu = \frac{m_0 m_0}{m_0 + m_O} = \frac{m_0}{2} = \frac{16}{2}(1.660\ x\ 10^{-27}\ kg) = 1.328\ x\ 10^{-26}\ kg$$

and for nitrogen

$$\mu = \frac{m_N m_N}{m_N + m_N} = \frac{m_N}{2} = \frac{14}{2}(1.660\ x\ 10^{-27}\ kg) = 1.162\ x\ 10^{-26}\ kg$$

Bond length of O_2 and N_2

B. Given the rotational constant $\tilde{B}$ = 1.99 cm^{-1} for N_2 and 1.45 cm^{-1} for O_2 determine the bond length of each molecule

The rotational constant $\tilde{B}$ is:

$$\tilde{B} = \frac{h}{8\pi^2 c \mu R^2}$$

If given $\tilde{B}$ you can solve for the internuclear distance of a diatomic as follows.

$$R = \sqrt{\frac{h}{8\pi^2 c \mu \tilde{B}}}$$

Bond length of O_2 and N_2

B. Given the rotational constant $\tilde{B}$ = 1.99 cm^{-1} for N_2 and 1.45 cm^{-1} for O_2 determine the bond length of each molecule

For nitrogen

$$R = \sqrt{\frac{6.626\ x\ 10^{-34}\ Js}{8(3.141)^2\left(2.99\ x\ 10^{10}\ \frac{cm}{s}\right)(1.162\ x\ 10^{-26}\ kg)(1.99\ \mathrm{cm}^{-1})}} = 1.1\ \text{Å}$$

For oxygen

$$R = \sqrt{\frac{6.626\ x\ 10^{-34}\ Js}{8(3.141)^2\left(2.99\ x\ 10^{10}\ \frac{cm}{s}\right)(1.328\ x\ 10^{-26}\ kg)(1.45\ \mathrm{cm}^{-1})}} = 1.3\ \text{Å}$$

Bond length of O_2 and N_2

C. Calculate the intensity of the J=0 → J=1 transition in the rotational spectrum of N_2.

Solution: Neither N_2 nor O_2 has a dipole moment. Therefore, neither has a pure rotational (microwave) absorption spectrum.