(2.6) When the rotational quantum number n_r goes from 0 to 1 in $H^{35}Cl$, it is accompanied by the absorption of light with a wave number of 20.6 cm^{-1}. From this it is possible to calculate the interatomic distance between hydrogen and chlorine in the molecule. What is this distance?

First we need to define the atomic mass unit, *u*, the electron volt, *eV*, the Boltzmann constant, ***k***, and the Planck constant, ***h*** (values from Appendix III):

$u := 1.660540\cdot 10^{-27}\cdot kg$ $\quad eV := 1.6021773\cdot 10^{-19}\cdot joule$ $\quad nm := 10^{-9}\cdot m$

$k := 1.23980\cdot 10^{-4}\cdot eV\cdot cm$ $\quad h := 4.135669\cdot 10^{-15}\cdot eV\cdot sec$

Furthermore, we need to define the atomic masses of H- and Cl-atoms (data from Table 2.1):

$M_H := 1.007825$ $\quad M_{Cl} := 34.968853$ $\quad$ hence: $\quad m_H := M_H\cdot u$ $\quad m_{Cl} := M_{Cl}\cdot u$

The wave number is stated as:

$\nu := 20.6\cdot cm^{-1}$

Using eqn. (2.30) and the statement that the rotational quantum number changed from 0 to 1 we can write:

$$I_{rot} := \frac{h^2\cdot 1\cdot(1+1)}{8\cdot\pi^2\cdot k\cdot\nu}$$

This rotational moment of inertia is valid for a reduced mass, m_{red}, calculated from (p. 24 below eqn. (2.29)):

$$m_{red} := \frac{1}{\left(\frac{1}{m_H}+\frac{1}{m_{Cl}}\right)}$$

Then we finally obtain the separation distance between the mass centra, *r*, from eqn. (2.29) as follows:

$$r := \sqrt{\frac{I_{rot}}{m_{red}}} \qquad r = 1.293\cdot 10^{-10}\cdot m \qquad r = 0.1293\cdot nm$$