$\delta\nu_c = 2,67\ GHz$

Doppler

$$\delta\nu_D = 2,15 \times 10^5 \times \frac{1}{10\times10^3} \sqrt{\frac{300}{44}}\ MHz$$

$$= 53\ MHz$$

→ As colisões causam um alargamento muito maior do que o alargamento de Doppler.

~~3.12.~~

3.13

a) $1s_0 - 2p_1$; $\lambda = 58,4\ nm$ $f = 0,28$ $g_2 = 1$; $g_1 = 3$

$$A_{21} = \frac{1}{4\pi\varepsilon_0} \frac{2e^2 \omega_{21}^2}{m_e c^3} \cdot f \frac{g_2}{g_1}$$

$$= \frac{8,99\times10^9 \times 2\times(1,6\times10^{-19})^2 \times (2\pi)^2 \times 0,28}{9,11\times10^{-31} \times 3\times10^8 \times (58,4\times10^{-9})^2} \frac{1}{3} \qquad \omega_0 = \frac{2\pi c}{\lambda_0}$$

$$\omega_0 = \frac{2\pi}{\nu}$$

$$= 1,82\times10^{-9}\ rad/s$$

b)

$T = 300\ K$

$\lambda = 58,4\ nm$

$$a(\nu) = -\sigma(\nu)\left[N_2 - \frac{g_2}{g_1}N_1\right] = \qquad \text{como } N_2 \sim N \text{ e } N_1 \sim 0$$

$$= -\frac{\lambda^2}{8\pi \underset{1}{n}} A_{21}\, S(\nu) \frac{g_2}{g_1} N_2$$

b)

$$\frac{d}{dt}(n_2 + q_\nu) = -(T_2 + A_{21}) n_2 + p - \frac{c}{2L}(1 - r_1 r_2) q_\nu$$
$$\overset{||}{0}$$

$$-(T_2 + A_{21}) \bar{n}_2 + p - \frac{c}{2L}(1 - r_1 r_2) \bar{q}_\nu = 0$$

$$\bar{q}_\nu = \frac{-(T_2 + A_{21}) \bar{n}_2 + p}{\frac{c}{2L}(1 - r_1 r_2)}$$

4.8.

$g_0(\nu) = 0{,}025\ cm^{-1}$

$l = 10\ cm$

$$g_{limiar} = -\frac{1}{2l} \ln(r_1^2)$$

a)

$$r^2 = e(-g_{limiar} \cdot 2l)$$

$$r = 0{,}779$$

b)

$$\frac{N^{o}\ de\ modos}{V} = \frac{8\pi \times (1 \times 10^9)^2}{(3 \times 10^8)^3} =$$

TP2

4.1.

$$\left(\frac{1}{c}\frac{\partial}{\partial t} + \frac{\partial}{\partial z}\right) I_\nu = \sigma(\nu)\left(N_2 - \frac{g_2}{g_1}N_1\right) I_\nu$$

$$\frac{d I_\nu^+}{d z} = g(\nu)\, I_\nu^+$$

$\rightarrow$ como o que muda é a direção temos que

$$\frac{d I_\nu^-}{d z} = g(\nu)\, I_\nu^-$$

4.2

a)

$$\frac{d}{dt}(m_2 + q_\nu) = -(\Gamma_{21} + A_{21})\, m_2 + p - \frac{c}{2L}(1 - r_1 r_2)\, q_\nu$$

$$= -\frac{c}{2L}(1 - r_1 r_2)\, m_2 + p - \underbrace{\frac{c}{2L}(1 - r_1 r_2)}_{\Gamma_{total}}\, q_\nu$$

$$= -(m_2 + q_\nu)\, \Gamma_{total} + p$$

No estado estacionário (solução particular)

$$\frac{d}{dt}(m_2 + q_\nu) = 0 \quad \Leftrightarrow \quad (m_2 + q_\nu) = \frac{p}{\Gamma_{total}}$$

Solução da equação homogénea

$$\frac{d}{dt}(m_2 + q_\nu) = (\ldots)$$

$g_2 = 3$

$g_1 = 1$

$A_{21} = 1,8 \times 10^9$ rad/s

$N = 4,65 \times 10^{24}$ Torr

$\sim 3,2 \times 10^{22}$ m^{-3}

Doppler:

$S(\nu) = ?$

$$\delta\nu_D = 2,15 \times 10^5 \left(\frac{1}{58,4} \sqrt{\frac{300}{4}} \right) \text{MHz}$$

$$= 31,88 \text{ GHz}$$

$$a(\nu) = (58,4 \times 10^{-9})^2 \times \frac{1,8 \times 10^9}{8\pi} \frac{1}{3} \times 3,2 \times 10^{22} \times \frac{1}{31,9 \times 10^9} \times 0,939$$

$$= 6,85 \times 10^5 \text{ m}^{-1}$$