Solutions

1) Lifetime $= \tau = 17\,ns = 17\times10^{-9}s$.

$$\Delta\nu = \frac{1}{2\pi\tau} = \frac{1}{2\times\pi\times17\times10^{-9}s} = 9.36\times10^{6}s^{-1} = 9.36\,MHz$$

$$\Delta\nu_{nat} = c\,\Delta\bar{\nu} \qquad \Delta\bar{\nu} = \frac{\Delta\nu}{c}$$

$$= \frac{9.36\times10^{6}s^{-1}}{3\times10^{10}\,cm\cdot s^{-1}} = 3.12\times10^{-4}\,cm^{-1}$$

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2) $$\Delta\nu_{Doppler} = 7.17\times10^{-7}\times\nu\times\sqrt{\frac{T}{M}}$$

$T = 300\,K$. $\quad m = 27$ for HCN $\quad \nu = 10\,cm^{-1}$ (rotational)

$$\Delta\nu_D = 7.17\times10^{-7}\times10\times\sqrt{\frac{300}{27}}$$

$$= 2.39\times10^{-5}\,cm^{-1}$$

Repeat for other problems

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3) Doppler width for Na transition in problem 1.

$\lambda = 589\,nm \qquad \bar{\nu} = \frac{1}{\lambda} = \frac{1}{589nm} = 16977.9\,cm^{-1}$

$$\Delta\nu_D = 7.17\times10^{-7}\times16977.9\times\sqrt{\frac{300}{23}} = .044\,cm^{-1}.$$

$$\Delta\nu_{nat} = 3.12\times10^{-4}\,cm^{-1} \text{ (problem 1)}$$

$$\Delta\nu_D > \Delta\nu_{Nat}$$

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4 Done earlier

5 Laser wavelength : $\lambda = 1064\ nm \Rightarrow$
$\bar{\nu} = 9398.4\ cm^{-1}$

The first Stokes lines appears 6B away from the exciting line.
$B = 2\ cm^{-1}$ $\therefore 6B = 12\ cm^{-1}$

Position of 1st Stokes line : $9398.4 - 12\ cm^{-1}$
$= 9386.4\ cm^{-1}$
$\Rightarrow 1065.4\ nm$

~~Repea~~ The next line appear 6B+4B away from the exciting line
$\Rightarrow 10B$ away $= 20\ cm^{-1}$

$\therefore$ Position of 2nd Stokes line $= 9398.4 - 20.0\ cm^{-1}$
$= 9378.4\ cm^{-1}$
$\Rightarrow 1066.3\ nm$

The first anti Stokes lines appears 6B to higher wavenumbers of exciting line. $\therefore$ Occurs at $9398.4 + 12\ cm^{-1} = 9410.4\ cm^{-1}$
$\Rightarrow 1062.7\ cm^{-1}$

(Note: You cannot add and subtract wavelengths.)

6) $\Delta E = g\,\beta_N\,B_z\ J = 5.585 \times 5.05 \times 10^{-27} \times 5.65\,T = 1.6556 \times 10^{-25}\ J$

ΔE in frequency (Hz) $= \dfrac{1.6556 \times 10^{-27}}{h} = \dfrac{1.6556 \times 10^{-27}\ J}{6.36 \times 10^{-34}\ Js} = 250\ MHz$

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7) $$\frac{n_2}{n_1} = e^{-\Delta E/RT} = e^{-1.6556\times10^{-25}/(1.38\times10^{-23})(300K)}$$

$$= 0.9999996$$

i.e. ~~n~~ if $n_1 = 1$, $n_2 = 0.9999996$

Fraction of $n_2 = \dfrac{.9999996}{1.9999996} = 0.4999998$ //.

8) $\Delta B_z = .00001\,T$

Hence change in frequency $= \dfrac{g \cdot \beta_N \Delta B_z}{h}$

$$= \frac{5.585\times5.05\times10^{-27}\times.00001}{6.63\times10^{-34}}$$

$$= 425.4\ Hz$$

Change in field of $.00001\,T$ can cause a change in ~~f~~ resonance frequence of $425.4\ Hz$.

(Hence stable fields are required)