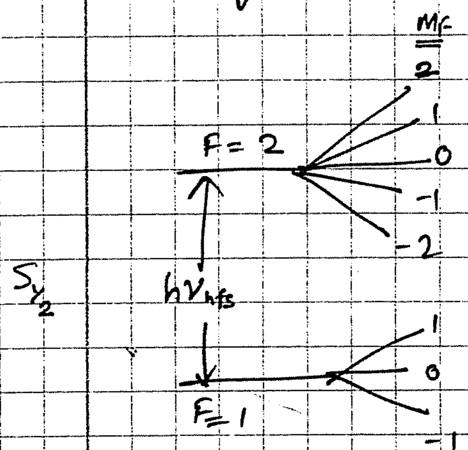
Carlos

(EPR)

$$\Delta\nu = \frac{2\mu_0}{3}\left(\frac{d\nu}{dB}\right) K_0\, \mu_{^3He}\, n_{^3He}\, P$$

Looking at K^{39} (19.5 MHz)



$I = 3/2 \quad S = 1/2 \quad F = 1, 2$

$\therefore$ $m_F = -1, 0, 1$ for $F = 1$

$m_F = -2, -1, 0, 1, 2$ for $F = 2$

① $[K_0]_K = [K_0]_{Rb} \times 0.95$

$= [4.52 + 0.00934\, T(^\circ C)] \times 0.95$

$= [4.52 + 0.00934 \times 225] \times 0.95 = 6.29$

② $n_{^3He}$ = density of ^{3}He. $= n_{fill}\left(\frac{1+v}{t+v}\right)$

n_{pc} = in pumping chamber.

$$= n_{fill}\left(\frac{1 + V_{pc}/V_{tc}}{\frac{T_{pc}}{T_{tc}} + V_{pc}/V_{tc}}\right)$$

for Carlos

+1

$V_{pc} = 128.446$ ml

$V_{tc} = 92.073$ ml $(= 92073\ mm^3)$

$T_{pc} = 225^\circ C$

$T_{tc} = 23^\circ C$

$n_{fill} = 8.56$ amg $= 8.56 \times 2.689 \times 10^{25} / m^3$

$\mu_{^3He} = 1.075\times10^{-30}\, J/G = 1.075\times10^{-30}\, J/10^{-4}T = 1.075\times10^{-26}\, J/T$

$\mu_0 = 4\pi\times10^{-7}\, N/A^2$

Calculation of $\left(\frac{d\nu}{dB}\right)$ (Jaidep) Page (23).

$$\frac{d\nu_\pm}{dB} = \frac{g_I\mu_N - g_s\mu_B}{h[I]}\sum_{n=0}^{5} b_n \frac{x^n}{[I]^n}$$

$[I] = 2I+1$ $\quad x = (g_I\mu_N - g_s\mu_B)\frac{B}{h\nu_{hfs}} = \frac{AB}{h\nu_{hfs}}$

Lets put $(g_I\mu_N - g_s\mu_B) = A$

$$\frac{d\nu_\pm}{dB} = \frac{A}{h(2I+1)}\, b_0\frac{x^0}{(2I+1)^0} + \frac{A}{h(2I+1)}\, \frac{b_1 x^1}{(2I+1)^1} +$$

$$\frac{A}{h(2I+1)}\, b_2\frac{x^2}{(2I+1)^2} + \frac{A}{h(2I+1)}\, b_3\frac{x^3}{(2I+1)^3}$$

$$+ \frac{A}{h(2I+1)}\, b_4\frac{x^4}{(2I+1)^4}$$

$$+ \frac{A}{h(2I+1)}\, b_5\frac{x^5}{(2I+1)^5}$$

$$\Rightarrow \frac{d\nu}{dB} = \frac{A}{h(2I+1)}\left[b_0 + \frac{b_1 AB}{h\nu_{hfs}(2I+1)} + \frac{b_2 A^2B^2}{(2I+1)^2h^2\nu_{hfs}^2} + \frac{b_3 A^3B^3}{h^3\nu_{fs}^3(2I+1)^3}\right.$$

$$\left. + \frac{b_4 A^4B^4}{h^4\nu_{hfs}^4(2I+1)^4} + \frac{b_5 A^5B^5}{h^5\nu_{hfs}^5(2I+1)^5}\right]$$

$b_0 + b_1x + b_2x^2 + b_3x^3$

$A = g_I \mu_N - g_s \mu_B$

e^-

For $^{39}K \rightarrow$ $\mu_N = 0.39146$ $\mu_B = 9.27400095 \times 10^{-24}\ JT^{-1}$

$g_I = 0.26097$ $g_s = -2.0023$

For $S_{1/2}$ $\nu_{hfs} = 461.719$ MHz

2^{-1} $=$ for Rb 406.1197 MHz

$A = g_I \mu_N - g_s \mu_B$

$= 0.26097 \times 5.0507 \times 10^{-27}\ JT^{-1} - (-2.0023) \times 9.274 \times 10^{-24}\ JT^{-1}$

$= [1.437 \times 10^{-27} + 18.569 \times 10^{-24}]\ JT^{-1}$

$= [1.437 \times 10^{-27} + 18569 \times 10^{-27}]\ JT^{-1}$

$= \underline{18570.437 \times 10^{-27}\ JT^{-1}}$

$\vec{B} = 26 \times 10^{-4}\ T$ $\quad 1G = 1 \times 10^{-4}\ T$

$h\nu = 6.626 \times 10^{-34}\ J.s \times 461.719 \times 10^{6} / s$

$= 3059.35 \times 10^{-28}\ J$

$2I + 1 = 4$

$$\frac{AB}{h\nu(2I+1)} = \frac{18.57 \times 10^{-24}\ JT^{-1} \times 26 \times 10^{-4}\ T}{4 \times 30.59 \times 10^{-26}\ J} = 3.95 \times 10^{-2}$$

$$b_0 = 1$$

$$b_1 = \mp 4I \qquad \left(\pm \Rightarrow m_F = \pm\left(I + \tfrac{1}{2}\right)\right)$$

$$= \mp 4 \times 3/2 = \mp 6$$

$$b_2 = 6I(2I-1) = 9(3-1) = 18$$

$$b_3 = \mp 8I(4I^2 - 6I + 1)$$

$$= \mp 12(9 - 9 + 1) = \mp 12$$

$$b_4 = 10I(2I-1)(4I^2 - 10I + 1)$$

$$= 15 \times 2 \times (9 - 15 + 1) = 30 \times -5 = -150$$

$$b_5 = \mp 12I(16I^4 - 80I^3 + 80I^2 - 20I + 1)$$

$$= \mp 18\left(16 \times \frac{81}{16} - 80 \times \frac{27}{8} + 80 \times \frac{9}{4} - 20 \times 3/2 + 1\right)$$

$$= \mp 18[81 - 270 + 180 - 30 + 1]$$

$$= \mp 18[-300 + 262]$$

$$= \mp 18 \times (-38) = \pm 684$$

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so, $$\frac{d\nu}{dB} = \frac{18.57 \times 10^{-24}\ JT^{-1}}{4 \times 6.626 \times 10^{-34}\ Js}\Big[1 + 6 \times (3.95 \times 10^{-2}) + 18 \times (3.95 \times 10^{-2})^2$$
$$+ 12 \times (3.95 \times 10^{-2})^3 - 150(3.95 \times 10^{-2})^4$$
$$+ 684(3.95 \times 10^{-2})^5\Big]$$

$$= 0.70064 \times 10^{10}\ \frac{Hz}{T}\Big[1 + .237 + 0.0280 + 0.000739$$
$$- .00036515 + .0000657720\Big]$$

$$= 0.70064 \times 10^{10}\ \frac{Hz}{T}[1.265] = 0.8866 \times 10^{10}\ Hz/T$$

$$n_{3_{He}} = 8.56 \times 2.689 \times 10^{25}/m^3 \left[\frac{1 + \frac{128.446}{92.073}}{\frac{225+273}{24+273} + \frac{128.446}{92.073}}\right]$$

$$= 8.56 \times 2.689 \times 10^{25}/m^3 \left[\frac{1 + 1.395}{\frac{498}{297} + 1.395}\right]$$

1.68

$$= \frac{8.56 \times 2.689 \times 10^{25}}{m^3} \times \frac{2.395}{3} \times \frac{2.395}{10.77} = .222$$

$$= \cancel{5.109}\ 18.373 \times 10^{25}/m^3$$

$$\Delta\nu = \left[\frac{2 \times 4\pi \times 10^{-7}}{3} \frac{N}{A^2}\right]\left[\underbrace{0.8866 \times 10^{10}\ \frac{Hz}{T}}_{(d\nu/dB)}\right]\left[1.075 \times 10^{-26}\ \frac{J}{T}\ \mu_{H_e^3}\right]$$

$$\times \left[5.109 \times 10^{25}/m^3\right] \times P \times K_0$$

2

$$\cancel{27 \times 10^3 = 40.77 \times 10^{10}\ \frac{Hz}{\gamma}\ P}$$

$$\cancel{\frac{27 \times 10}{40}} = P$$

$$\Delta\nu = 2 \times 2 \times \frac{4\pi \times 10^{-7}}{3} \times 0.8866 \times 10^{10} \times 1.07 \times 10^{-26}$$

$$\times 18.373 \times 10^{25} \times 6.29$$

$$\Rightarrow 27 \times 10^3 = 1835.69 \times 10^2 \times P$$

$$\Rightarrow 27 \times 10^3 = 183.5 \times 10^3 \times P$$

$$\Rightarrow P = \frac{27}{183.5} \approx 0.147$$

$$\approx 15\%$$

Checking the Units !!

H = Henry

$$\frac{N}{A^2} = \frac{H}{m} = \left(\frac{Wb}{A}\right)\frac{1}{m}$$

$$\Rightarrow \frac{N}{A^2} = \underbrace{\left(\frac{m^2\,kg\,s^{-2}}{A^2}\right)\frac{1}{m}} \quad \left(= \frac{m^2\,kg\,C^2}{m}\right)$$

And $\boxed{T = 1\,Wb\,m^{-2} = kg\,s^{-2}A^{-1} = N A^{-1} m^{-1} = kg\,s^{-1}C^{-1}}$

Now, $\Delta\nu = \left(\frac{N}{A^2}\right)\left(\frac{Hz}{T}\right)\left(\frac{J}{T}\right)\left(\frac{1}{m^3}\right)$. (p)

$$= \frac{m^2\,kg\,s^{-2}}{A^2\,m} \times \left(\frac{Hz}{kg\,s^{-1}C^{-1}}\right) \times \left(\frac{\overbrace{kg\,m\,s^{-2}}^{\text{Force}}\cdot\overbrace{m}^{\text{dist}}}{kg\,s^{-1}C^{-1}}\right)\frac{1}{m^3} \quad (p)$$

$$= \frac{kg\,s^{-2}\,m}{C^2 s^{-2}} \times \frac{Hz\;kg\,m^2 s^{-2}}{kg^2 s^{-2} C^{-2}}\,\frac{1}{m^3} \quad (p)$$

$$= \frac{\cancel{kg^2}\,\cancel{s^{-4}}\,\cancel{m^3}\;Hz}{\cancel{C^2}\,\cancel{C^{-2}}\,\cancel{kg^2}\,\cancel{s^{-4}}\,\cancel{m^3}} \quad (p)$$

$$\boxed{\Delta\nu = Hz \;(p)}$$

Consistent !!

inputs

V_{to} = vol. of the target chamber
V_{tto} = " " " transfer tube
V_{po} = " " " pumping chamber
T_{to} = temp. of target ch.
T_{po} = " " pumping "
nHe = Density
ppc = pressure in pumping chamber (atm)
ptc = " " target " (atm)

$$V_p = V_{po} + V_{tto}/2$$
$$V_t = V_{to} + V_{tto}/2$$

$$T_p = 273.15 + T_{po}$$
$$T_t = 273.15 + T_{to}$$

$$\boxed{ntn = \frac{1}{\left[\frac{T_p}{T_t} + \left(\frac{V_t}{V_p+V_t}\right)\times\left(1-\frac{T_t}{T_p}\right)\right]}}$$ Target ch. rel. density

$$\boxed{npn = \frac{1}{\left[\frac{T_p}{T_t} + \left(\frac{V_p}{V_p+V_t}\right)\left(1-T_p/T_t\right)\right]}}$$ pumping ch. rel. density

$$\boxed{nt = nHe \times ntn}$$ abs density of target ch
$$\boxed{np = nHe \times npn}$$ " " pump. ch.

$$ppc = np \times T_p/273.15$$

$$ptc = nt \times T_t/273.15$$

ν_{hf} = hfs = 461.719

I = nuc spin = K = 3/2

μ_I = mm = 0.39146

freq = EPR freq =

shift = s.

h = planck.

A = hfs * (10^(6)) * h

→ $h \nu_{hf} \times 10^{6}$ Hz

(zero field HFS)

g_K = nuclear mag. moment

= mm/K

= 0.39146/3/2

=

$\mu_N = 5.05 \times 10^{-27}$ → nuclear magneton

g = 2.0023193053737 → electron mag mom.

$\mu_B = 927.400899 \times 10^{-26}$ (Bohr).

$$b = -\frac{\left[g\mu_B\left(\frac{A}{2K+1} - s h\, freq\right) - g_K \mu_N\left(\frac{2KA}{2K+1} - s h\, freq\right)\right]}{s\, g \times \mu_B\, g_K\, \mu_N}$$

B-R b-coefficient

c = s * h * freq * (A − s * h * freq) / $g\mu_B g_K \mu_N$

c-coeff.

$B_0 = \left(-b - s\sqrt{b^2 - 4c}\right)/2$

Shift s = +1 Hat, −1 well

inputs.

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T_{to} = temp. of target ch.
T_{po} = " " pumping "
nHe = Density
ppc = pressure in pumping chamber (atm)
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$$V_p = V_{po} + V_{tto}/2$$
$$V_t = V_{to} + V_{tto}/2$$

$$T_p = 273.15 + T_{po}$$
$$T_t = 273.15 + T_{to}$$

$$\boxed{ntn = \frac{1}{\left[\frac{T_p}{T_t} + \left(\frac{V_t}{V_p+V_t}\right)\times\left(1-\frac{T_t}{T_p}\right)\right]}}$$ Target ch. rel. density

$$\boxed{npn = \frac{1}{\left[\frac{T_p}{T_t} + \left(\frac{V_p}{V_p+V_t}\right)\left(1-T_p/T_t\right)\right]}}$$ pumping ch. rel. density

$$nt = nHe \times ntn$$ abs density of target ch
$$np = nHe \times npn$$ " " pmp. ch.

$$ppc = np \times T_p/273.15$$