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Date: 20/02/2025
Time: 01 pm

MPHYCC 10 – 13

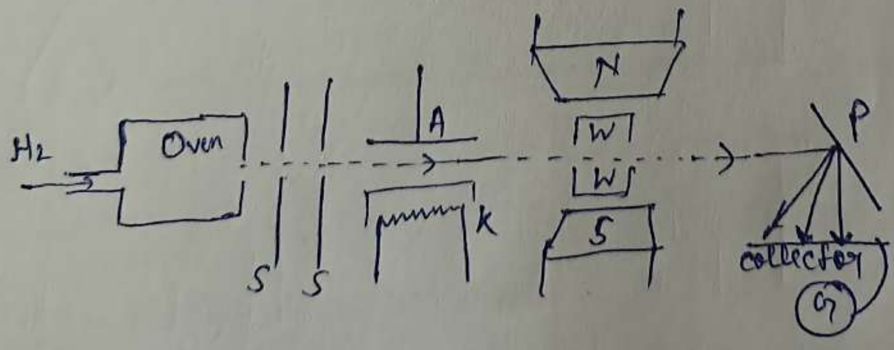
R.C William studied the fine structure of H_α & D_α lines extensively using triple-prism spectrograph and a micro-photometer. There were two main differences between theory and experiment

(a) The component Ia was observed weaker than IIb which is in contradiction with theory. IIIb was observed to be stronger than as predicted to the theory. This may be due to unequal excitation of the level $n=3$.

(b) Separation between Ia & IIb was observed to be $0.319\ cm^{-1}$ against theoretical separation $0.329\ cm^{-1}$. Similarly the sepration between IIb & IIIb was observed to be $0.134\ cm^{-1}$ instead of $0.108\ cm^{-1}$.

Lamb shift :→ Lamb & Retherford in 1947 performed a micro-wave experiment on Hydrogen atom & showed that for hydrogen like atoms the states of a particular n values having terms with the same j value but different l values such as $2^2P_{1/2}$ & $2^2S_{1/2}$ are not degenerate but are seprated. This sepration is known as 'Lamb shift'.

Experimental arrangements :→



The experimental arrangement of Lamb-Retherford experiment is shown in the above figure.

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(a) Molecular hydrogen H_2 enters into the oven was dissociated into atom allowed to leave oven and passed through slits S, S.

(b) This beam of hydrogen atoms passed through a vacuum diode in which electrons were emitted from cathode K and accelerated towards anodes

(c) Some of the normal atoms ($1^2S_{1/2}$) passing through this region collided with the electrons and were excited to $2^2S_{1/2}$, $2^2P_{1/2}$ & $2^2P_{3/2}$ states.

(d) These excited atoms moved towards the tungsten plate P and collide with this plate. During this the atoms in $2^2P_{1/2}$ & $2^2P_{3/2}$ states returned to the $1^2S_{1/2}$ state

(e) But the atoms in the metastable state $2^2S_{1/2}$ donot return to $1^2S_{1/2}$ as $\Delta l \neq 0$. These metastable atoms returned to their ground state through collision with P from which electrons were emitted.

(f) Now these streams of e's were collected and passed to a galvanometer which measures the metastable atomic beam intensity.

(g) Mechanism causes metastable $2^2S_{1/2}$ atoms to make transition to $2^2P_{3/2}$ will result fall in the galvanometer reading i.e fall in galvanometer reading is sensitive to the metastable atoms.

(h) Metastable atoms transition were induced by passing the atoms through the waveguide WW which creates microwaves of variable frequency.

(i) At certain frequency the metastable atomic beam intensity suddenaly reduced. It was due to absorption of microwave frequency by $2^2S_{1/2}$ atoms which were excited to the $2^2P_{3/2}$ state from which these atoms come to the ground state.

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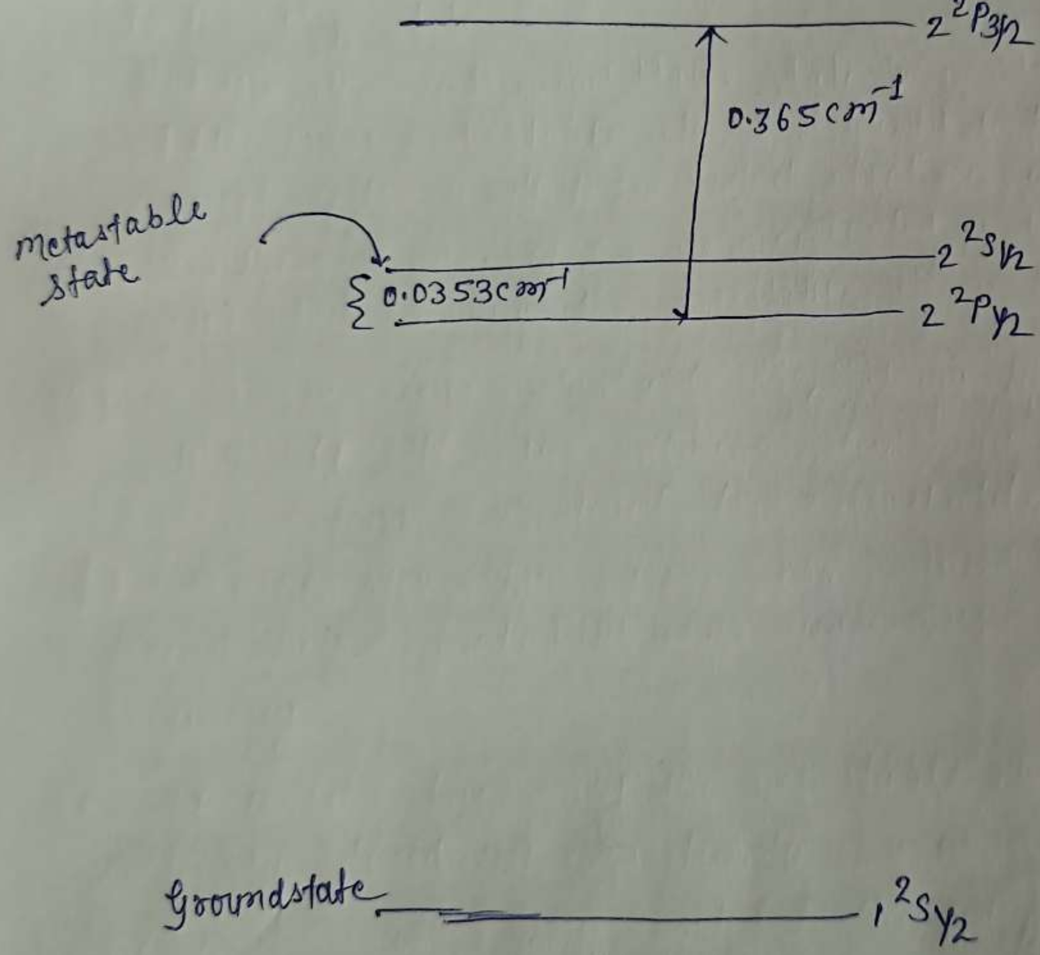
(j) The atoms reaching the tungsten plate were in their in ground state and could not eject electron from it. Therefore the frequency was measure of the term difference between $2^2S_{1/2}$ & $2^2P_{3/2}$ states. This difference was not $0.365\,cm^{-1}$ but less ($0.0353\,cm^{-1}$).

(k) Instead of adjusting the frequency of microwave for maximum reduction in the metastable atomic beam intensity. The energy levels can be adjusted by means of magnet NS.



Q.1. The doublet spliting for the first excited state $^2P_{1/2}$ - $^2P_{3/2}$ of Hydrogen atom is $0.365\,cm^{-1}$. Calculate the corresponding spliting for He^+.

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Hyperfine structure of spectral lines :-

Under highest possible ~~intr~~ resolution instrument fine structure components of spectral lines further splitted into components of sepration of the order $1\ cm^{-1}$. This is very much smaller than the ordinary multiplet structure. This splitting is caused by atomic nucleus and is termed as 'Hyperfine structure'.

There are two types of nuclear effects which produces hyperfine structure.

(1) Isotope effect (2) Nuclear spin & Hyperfine splitting.

(I) Isotope effect: →

* — Isotope:— The element having same atomic number with different mass number is called isotope. example $_1H^1$, $_1H^2$, $_1H^3$.

Nuclear mass is present in the Rydberg's constant for an atom. Different isotopes have different values of Rydberg's constant. The same transitions in different isotopes give rise to slightly different wave numbers.

example: First four members of Balmer series H_α, H_β, H_γ & H_δ has a very weak companion on the short wave length side at distance 1.79, 1.33, 1.19 & 1.12 Å respectively.

$H_\beta = 4861.33\text{Å}$ we have to calculate shift for this line for $_1H^2 = D$

we know that $\frac{1}{\lambda_H} = R_H\left[\frac{1}{2^2} - \frac{1}{4^2}\right]$ --- (1)

$$\frac{1}{\lambda_D} = R_D\left[\frac{1}{2^2} - \frac{1}{4^2}\right] \quad \text{--- (2)}$$

$$\frac{\lambda_D}{\lambda_H} = \frac{R_H}{R_D} \quad \text{--- (3)}$$

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$$\frac{\lambda_D - \lambda_H}{\lambda_H} = \frac{R_H - R_D}{R_D} \quad , \quad \Delta\lambda = \lambda_D - \lambda_H$$

$$\Delta\lambda = \lambda_D - \lambda_H = -\lambda_H \left[\frac{R_D - R_H}{R_D}\right] = -4861.33\text{Å} \left[\frac{109707\,cm^{-1} - 109677.6\,cm^{-1}}{109707.4\,cm^{-1}}\right]$$

$$\boxed{\Delta\lambda = -1.32\,\text{Å}}$$

Note: → In the heavy atoms the main contribution to isotope shift is not due to difference in mass but due to change in nuclear radius with mass & Deviation of the nuclear magnetic field from being purely a coulombion one.