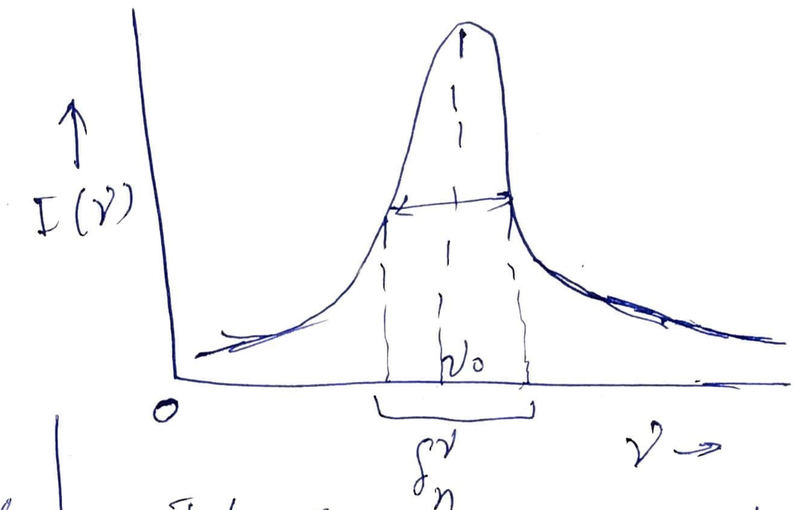
An ordinary Fourier analysis of the damped wave emitted by the oscillator gives for the energy, or better the intensity which is proportional to the energy radiated, as a function of the frequency

$$I(\nu) = \frac{\gamma}{2\pi} \cdot \frac{1}{4\pi^2(\nu_0-\nu)^2 + \left(\frac{\gamma}{2}\right)^2} \quad (12)$$

The general contour of such a distribution is shown in following figure



Intensity - frequency contour for the natural width of a spectrum line

The half-intensity breadth δ_n^ν of this symmetrical distribution, like the Doppler half-intensity breadth, is here defined as the interval between the two points where the intensity drops to half its maximum value.

From eqn (12) the intensity will drop to half its maximum when the two terms in the denominator are equal, i.e. when

$$\nu_0 - \nu = \frac{\gamma}{4\pi} = \frac{1}{2}\delta_2^\nu = \Delta\nu \quad (13)$$

which gives the natural half-intensity breadth

$$\delta_n^\nu = \frac{\gamma}{2\pi} = \frac{4\pi e^2 \nu_0^2}{3mc^3} \quad -(14)$$

Since $\frac{\Delta\nu}{\nu} = \frac{\Delta\lambda}{\lambda}$ and $c = \nu\lambda$

the half-intensity breadth, in terms of wave-length is

$$\delta_n^\lambda = \Delta\lambda = \frac{2\pi c}{\omega_0^2}\gamma = \frac{c}{2\pi\nu^2}\gamma$$

$$= \frac{4\pi e^2}{3mc^2} = 1.16 \times 10^{-12}\ \text{cm} \quad -(15)$$

which is constant and equal to $0.000116\,\mathring{A}$ for all wave-lengths, a value many times too small to be measured by ordinary spectroscope methods.

Natural Breadths and the Quantum Mechanics

According to the Q.M. principles an energy level diagram of an atom is not to be thought of as a set of discrete levels but as a sort of continuous term spectrum in which the probability distribution is concentrated in regions where the terms are observed

The natural line width, which is classically attributed to damping of radiation, Quantum mechanically is regarded as due to the finite life time and consequent uncertainty in energy ~~levels~~ values.

If $\Delta E \rightarrow$ spread in energy

$\Delta t \rightarrow$ mean life time

then $\Delta E \, \Delta t \approx \hbar$ —— (18)

for ground state $\Delta t \rightarrow$ large so uncertainty ΔE is very small. Also for a metastable state $\Delta t \rightarrow$ may be as large as several seconds and these states are also very sharp.

for an ordinary excited state $\Delta t \sim 10^{-8}$ sec

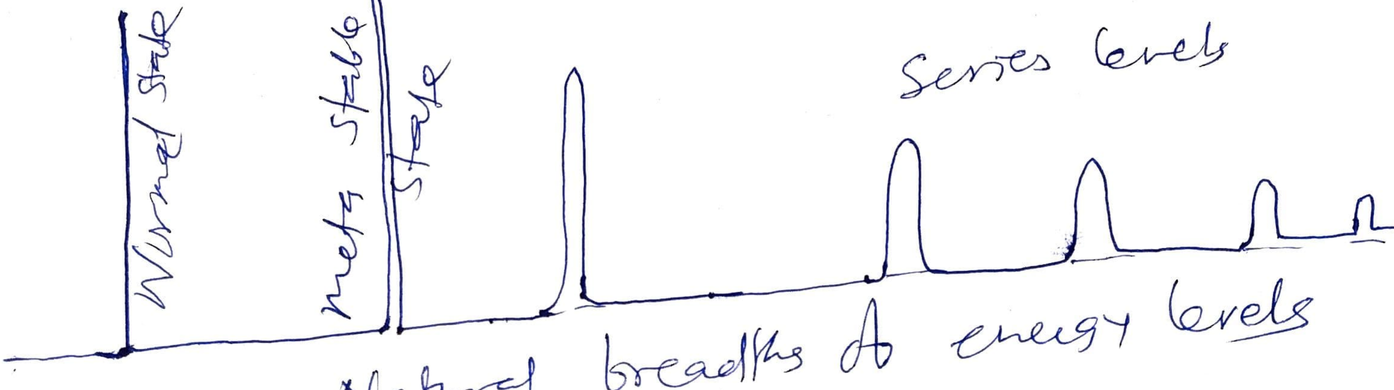
Then the broadening of spectral line due to the finite width of an excited energy state is about

$$\Delta \nu = \frac{1}{2\pi \Delta t} \simeq 10^{7} \text{ sec}^{-1} \quad \text{—— (19)}$$

for a visible line of $\lambda = 6000$ Å this corresponds to a wavelength broadening of only

$$\Delta \lambda = \frac{\lambda^2}{c} \Delta \nu \simeq 0.0001 \text{ Å} \quad \text{—— (20)}$$

From eqn (18), for ground state $\Delta t \rightarrow \infty$ hence, the broadening of the line takes place due to the broadening of excited level only.



Natural breadths of energy levels

(3) Width of the line due to other effects

(a) Collision Damping (broadening)

[redacted]

One of the important external causes in the broadening of spectral lines.

One of the effects produced by the collisions of two atoms → one of which is in the process of emitting or absorbing radiation.

Michelson and Lorentz → Assumptions

If, during the time an atom is emitting or absorbing radiation of frequency ν_0 it collides elastically with another atom, the phase and amplitude of the radiation have a chance of undergoing a considerable change.

Further at the time of emission or absorption the atoms are under heavy pressure, the rate of collision collisions increases which, enhance the effect. To calculate the magnitude of collision broadening the assumptions usually made are:

(1) The ~~mean~~ time between collisions is large compared with the collision time.

(2) With every impact the oscillations are either completely cut off, or they are disturbed for a moment (3) The oscillations ~~are~~ of same frequency are resumed, with a considerable change in phase and amplitude of oscillations.

We have two types of incoherent radiation.

Radiation before and after collisions. The half intensity breadth is given following fourier analysis,

$$\Delta\nu = \frac{1}{\pi l_0}\sqrt{\left(\frac{8RT}{\pi M}\right)}$$

$l_0 \rightarrow$ mean free path.

(b) Asymmetry and Pressure shift

It is also important to consider the radiations emitted during the collision process and, ~~whereas as the impact approximation~~. The calculation which takes into account the ignored radiations is known as static approximation.

At time of collisions, the emitting atom is under pressure of impact and the frequency of radiations emitted at this time is found to change.

There is asymmetry between the radiations emitted before and after the collision and those emitted during the collision. This result is asymmetry and pressure shift.

Explanation has been given that at close approach of a foreign atom the energy levels of the excited or radiating atoms are altered, due to polarization effect.

Stark Broadening: In an ordinary arc of high current density many ions are produced which upon collision with other atoms give rise to strong fields. The effect of these intermolecular fields is to produce a stark-effect broadening of the observed spectrum lines.