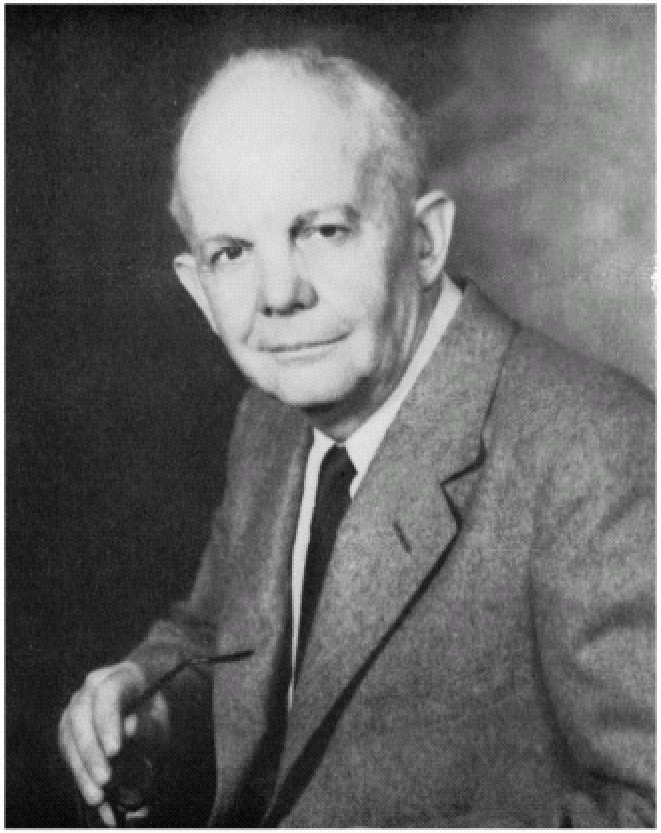
Shelter Island Revisited

APS Anaheim April 28, 2011



D. A. MacInnes

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- Assembled attendees of the 1947 Conference on Quantum Mechanics. Left to right are: Isidor I. Rabi, Linus Pauling, John van Vleck, Willis E. Lamb, Gregory Breit, Duncan MacInnes, Karl K. Darrow, George E. Uhlenbeck, Julian Schwinger, Edward Teller, Bruno Rossi, Arnold Nordsieck, John von Neumann, Hans Bethe, Robert Serber, Robert Marshak, Abraham Pais, Robert Oppenheimer, David Bohm, Richard Feynman, Victor F. Weisskopf, Herman Feshback. Not pictured is Hendrick A. Kramers.

- Not pictu

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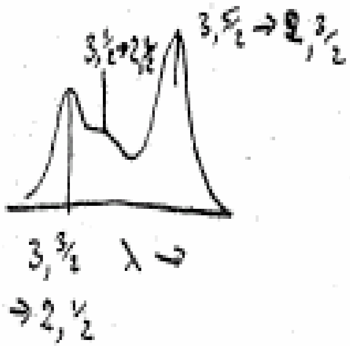
- Richard Feynman (seated, with pen in hand) illustrates a point at the conference.
  From left to right, standing, are: W. Lamb, K.K. Darrow, Victor Weisskopf, George E. Uhlenbeck, Robert E. Marshak, Julian Schwinger, David Bohm, From left to right, seated are: J. Robert Oppenheimer (holding pipe), Abraham Pais, Richard P. Feynman, Herman Feshbach.

- Karl K. Darrow

- Willis Lamb

Lamb

0.365 cm^{-1} = 11,000 Mc



Notes on Shelter Island Conference.

Kemble & Present

to explain 0.0[illegible] cm^{-1} raising ~~shift~~ of S level

cutting Coulomb potential off flat, or replace by infinite repulsion: Needs range 10^{-12} cm of repulsion

Houston
Williams } Deuterium spectrum

interpreted by Pasternack: Raise S level by .030 cm^{-1}

Richardson, Drinkwater & Williams:

Could be H impurity in D

... singularity in δ

Positron theory Uehling 1936

In region $5 \cdot 10^{-11}$ cm, potential changed; effectively increased (attraction)

(because decrease by polarization is less at high ~~frequency~~ wave number than for slowly varying fields), so S state lower than $P_{1/2}$; also magnitude of shift is much less than required!

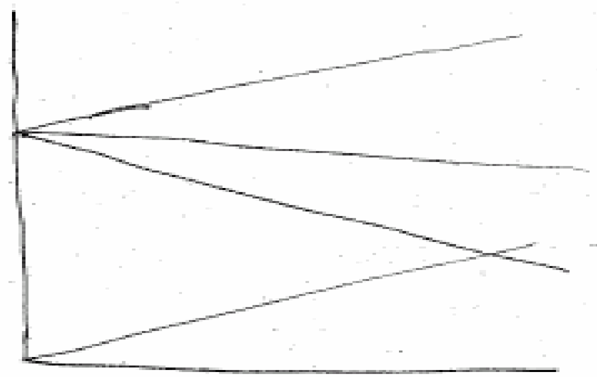
Lifetime of $S_{1/2}$ level about 2 × life of p levels

Apparatus: $H^2 \rightarrow H \rightarrow H^* \rightarrow$ Interaction space with RF $\rightarrow$ Detector

Detection: Secondary electrons can be ejected from W by metastable H atoms. About $1/10$ % efficiency.

Excitation ...

Frequency set, observe current as fn. of H
λ between 2.6 and 3.6 cm



Expected Zeeman frequencies

Result: S level shifted up by about 0.037 cm⁻¹ (1100 Mc)
Present width of lines probably increased by R F interaction

<u>Oppy</u> Positron theory (wave length dependence)

" " (high field)

Nuclear interaction

Electrodynamic term shift e^2

$$\sum_{p,r} \frac{S_{ir} S_{ri}}{(E_p + E_r - E_i) E_p} \qquad E_p = \text{energy}$$

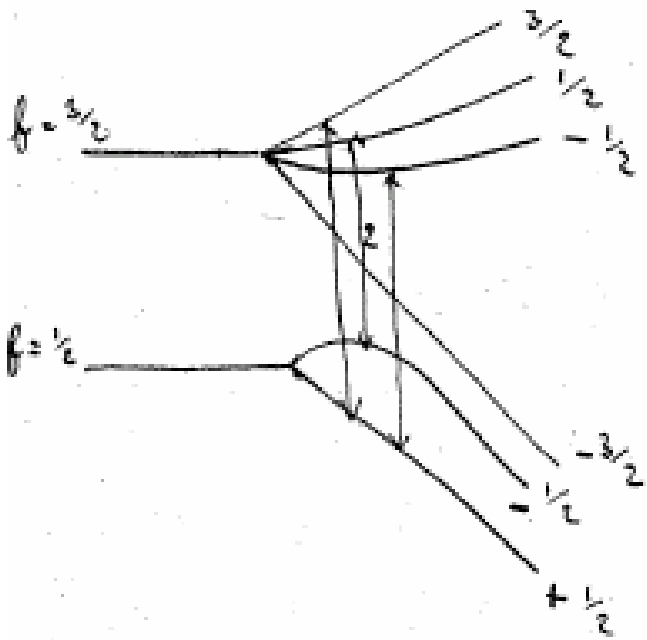
First term $\frac{S_{ir} S_{ri}}{E_p^2} = S^2_{ii}$ same for all levels ~~including~~ if Dirac theory is used

Second term $\frac{S_{ir} S_{ri} (E_r - E_i)}{E_p^3}$ also supposed to be same (Breit)

Third term $\frac{(E_r - E_i)^2}{E_p^4}$ converges and might explain Lamb's result.

Rabi   Nelson & Nafe

Deuterium ground state



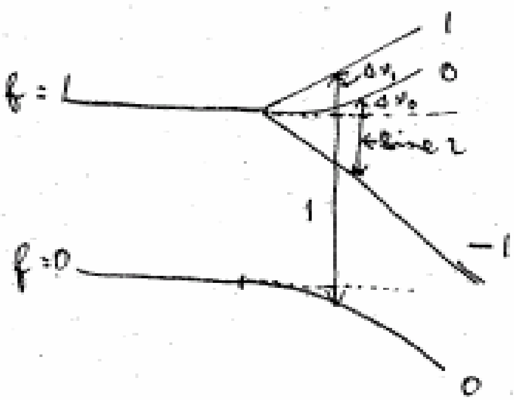
Line 2

$$\nu = \nu_D \left(1 + \frac{4}{9} x^2 \right)$$

$$x = \frac{g \mu_0 H}{\nu_D}$$

$$\nu_D = 327.38_5 \pm 0.005 \text{ Mc}$$

Hydrogen



$$\nu_1 = \nu_H + \Delta\nu_1 + \Delta\nu_0$$

$$\nu_2 = \Delta\nu_1 + \Delta\nu_0$$

$$\nu_1 - \nu_2 = \nu_H$$

$$\nu_H = 1421.3 \pm 0.2 \quad Mc$$

$$h\nu_{theor.} = \frac{8\pi}{3}\,\frac{2I+1}{I}\,\mu_N\,\mu_0\,\psi^2(0)$$

$$\nu = \frac{4}{3}\,\frac{2I+1}{I}\,\frac{g_N}{1836.6}\left(\frac{m_r}{m_0}\right)^3 \alpha^2 R_\infty$$

g_N = nuclear moment in nuclear magnetons

Calculated $\nu_H = 1416.9 \pm 0.54$ observed

$$\nu_D = 326.53 \pm 0.16$$

$$\frac{\nu_H}{\nu_D} = 4.3393 \pm 0.0014 \qquad 4.3416 \pm 0.0007$$

$$\frac{22}{42000} = 0.0005$$

$$\frac{4.4}{1400} \sim 0.3\%$$

$$\frac{0.85}{325} \sim 0.26\%$$

$$\frac{3/2}{3600} = 0.083\%$$

- Hendrick A. Kramers

Kramers

$$\mathcal{H} = \frac{(p - \frac{e}{c}\underline{A})^2}{2m} + e\phi + \frac{1}{8\pi}\int(E^2 + H^2)\,d\tau$$

In external field

$$m\ddot{\underline{R}} = e\underline{E} + \frac{e}{c}\dot{\underline{R}} \times \underline{H}$$

Elimination of longitudinal field:

$$\underline{E} = E_\perp - \nabla\phi$$

$$\nabla^2\phi = -4\pi\rho \qquad \text{div}\,\underline{A} = 0$$

1. Replace m by m_0 (mechanical mass)
2. " $\underline{A}$ "at electron" by $\int\rho\,\underline{A}\,d\tau$
3. Try to get structure-independent part of theory
4. Don't integrate field equations yet (retarded & advanced potentials)

$$\underline{A} = \underline{A}' + \underline{A}_0 \qquad \underline{A}_0 = \text{proper field}, \ \underline{A}' = \text{external field}$$

$$\underline{A}_0(P) = \text{Tr}\ \frac{\dot{R}}{c}\int\frac{\rho(Q)\,d\tau_Q}{r_{PQ}} \qquad \text{Tr} = \text{transverse part}$$

(so that $\nabla^2\underline{A}_0 = -\frac{4\pi}{c}(\rho\,\dot{\underline{R}})_{\text{transverse}}$
instead of $\Box\,\underline{A}_0 = \text{same}$)

By comparison:

Dirac

$$\frac{1}{2m}p^2 - \frac{e}{mc}\,p\cdot\underline{A} + \frac{e^2}{2mc^2}A^2 + U(R) + \frac{1}{8\pi}\int(H^2 + E_\perp^2)\,d\tau$$

Emission and absorption in Dirac from $p\cdot\underline{A}$

Now from U term which should be written in terms of $\underline{R}'$

$$U(R) = U\left(R' - \frac{e}{mc^2}Z'\right) = U(R') - \frac{e}{mc^2}Z\cdot DU + \frac{1}{2}\frac{e^2}{m^2c^4}(Z\cdot D)(Z\cdot DU)$$

$Z\cdot DU$ term replaces old $p\cdot\underline{A}$

$DU =$ m · acceleration $= k = \dot{p}$

$Z = \int A\,dt$

Al... ke

Inserting (10) and (9) into (6) and using relations between atomic constants, we get for an S state

$$W_{ns}' = \frac{8}{3\pi}\left(\frac{e^2}{\hbar c}\right)^3 \mathrm{Ry}\frac{Z^4}{n^3} \ln\frac{K}{\langle E_n - E_m\rangle_{\mathrm{Av}}}, \qquad (11)$$

where Ry is the ionization energy of the ground state of hydrogen. The shift for the $2p$ state is negligible; the logarithm in (11) is replaced by a value of about -0.04. The average excitation energy $\langle E_n - E_m\rangle_{\mathrm{Av}}$ for the $2s$ state of hydrogen has been calculated numerically[7] and found to be 17.8 Ry, an amazingly high value. Using this figure and $K = mc^2$, the logarithm has the value 7.63, and we find

$$W_{ns}' = 136 \ln[K/(E_n - E_m)]$$
$$= 1040 \text{ megacycles.} \qquad (12)$$

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[6] It was first suggested by Schwinger and Weisskopf that hole theory must be used to obtain convergence in this problem.