

emulsion for different track lengths; (3) variation of (n, p) scattering cross section with energy.

Table I shows the total correction factor that must be applied

TABLE I. Correction factors for neutron groups.

Neutron group Proton energy	Main group ground state A	205 kev C	428 kev B	745 kev D
2.705 Mev	1	0.55	0.25	—
3.120 Mev	1	0.67	0.38	0.16

to each of the groups before determining their relative intensities.

Using the correction factors of Table I the intensity of the 428-kev group relative to the main group is 0.08 ± 0.02 for both sets of data. If there is a group at D there are only two tracks in the data which could correspond to this group. The relative intensity is found to be less than one percent. It is difficult to decide whether there is a group corresponding to the points marked C. The number of tracks that can be assigned reasonably to such a group in each case is no more than could be considered to be background. In each set of data there are about six tracks that may be considered to be in such a group. The relative intensity would be five percent of the main group if all of these did arise from a level at 205 kev in each set of data.

¹ J. C. Grosskreutz and K. B. Mather, Phys. Rev. **77**, 580 (1950).

² Brown, Chao, Fowler, and Lauritsen, Phys. Rev. **78**, 88 (1950).

³ T. Lauritsen and R. G. Thomas, Phys. Rev. **78**, 88 (1950).

⁴ Johnson, Laubenstein, and Richards, Phys. Rev. **77**, 413 (1950).

⁵ Lattes, Fowler, and Cuer, Proc. Phys. Soc. **59**, 883 (1947).

The $3\nu_3$ -Band of Telluric CO_2 in the Solar Spectrum*

LEO GOLDBERG, ORREN C. MOHLER, A. KEITH PIERCE, AND
ROBERT R. MCMATH

McMath-Hulbert Observatory, University of Michigan, Pontiac, Michigan
February 14, 1950

OBSERVATION of the lines of the $3\nu_3$ -band of telluric CO_2 that appear in the solar spectrum is possible only when the earth's atmosphere is very dry. Numerous strong lines of the 0 2 1, 1 0 1, 1 2 0, and 2 0 0 bands of H_2O occupy the same wavelength region. One of the results of guest investigator arrangement

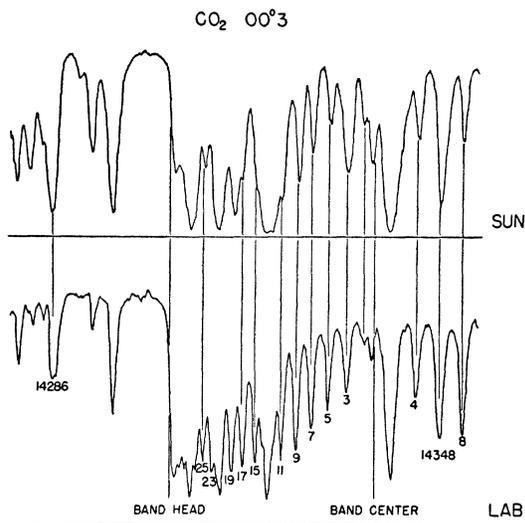


FIG. 1. The $3\nu_3$ -band of CO_2 in the solar spectrum, with laboratory comparisons.

between the Mount Wilson and Palomar Observatories and the McMath-Hulbert Observatory, for the direct-intensity recording of the solar spectrum, is a spectrophotometric tracing made on an exceptionally dry day (December 20, 1949), at Mount Wilson, California. The weakened H_2O absorption unmasks many lines of the $3\nu_3$ -band of CO_2 .

The top half of Fig. 1 is a part of this record; the bottom half is a laboratory comparison. The intensity increases upward from the straight line below each tracing. Broken lines connect corresponding features of the two tracings and indicate the positions of the band head and band center. The numbers 14,286 and 14,348 are the wave-lengths in angstroms of the absorption lines immediately above them. Beneath the CO_2 lines in the laboratory tracing are the upper quantum numbers for the lines in the short wavelength branch, and the lower quantum numbers for the lines in the long wavelength branch of the band.

14,308A(H_2O) and 14,313A(H_2O) complicate the strong CO_2 band head at 14,305A in the solar spectrum, and the line at 14,338A(H_2O) obscures the band center. On all tracings obtained up to December 20, 1949, H_2O lines completely mask the analogous isotopic (C^{13}O_2)¹⁶ band head at 14,700A.

We wish to acknowledge continued financial aid from the McGregor Fund of Detroit.

* Report on work supported in part by Contract N6onr-232-V with the ONR.

A Precise Determination of the Energy of the Cs^{137} Gamma-Radiation*

LAWRENCE M. LANGER AND R. DOUGLAS MOFFAT

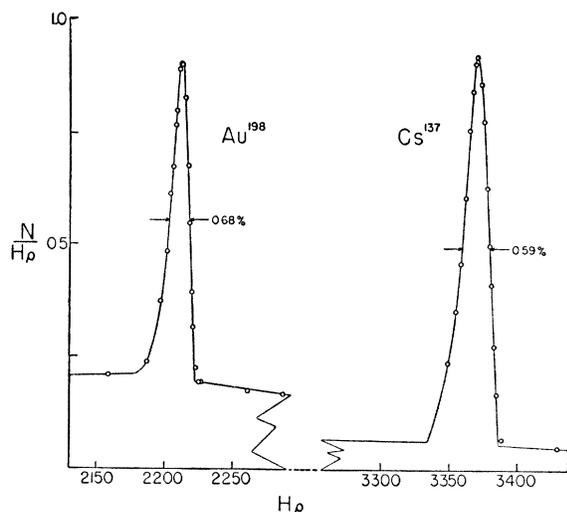
Indiana University, Bloomington, Indiana

February 16, 1950

FOR the absolute calibration of nuclear spectrometers, it has become common practice to make use of the photo-electrons ejected from a radiator or the internal conversion electrons resulting from a gamma-ray of known energy. Since the shape of photo-lines depends somewhat on the position of the source relative to the radiator and also on the thickness of the radiator, the use of an internal conversion line appears to be preferable. Although the energy of the Au^{198} gamma-ray has been measured with great precision,¹ the relatively short half-life provides a calibration source of only temporary utility. It is felt that the conversion electrons from the 0.66-Mev gamma-ray which follows the disintegration of Cs^{137} provide a much more suitable calibration standard. The 33-year half-life makes possible the preparation of an essentially permanent laboratory source of monoenergetic electrons. There is also the advantage that the conversion line lies at a higher energy and is completely separated from the main nuclear beta-spectrum. In an attempt to establish Cs^{137} as a calibration standard, the energy of the internal conversion electrons has been carefully determined by direct comparison with that of the 0.4112-Mev gamma-ray of Au^{198} .

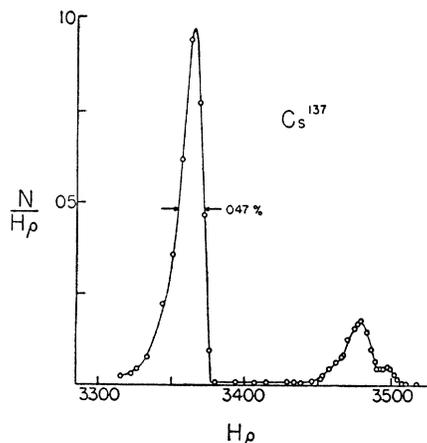
The measurements were made with the 40-cm radius of curvature, 180 degree focusing, shaped magnetic field spectrometer.² A composite source of Au^{198} and Cs^{137} was prepared on a 0.00025-in. Al backing. The source was 0.25 cm wide and 2.5 cm high and was spread with the aid of insulin. An electrically grounded source of mechanical permanence was thus obtained. The scattering from the aluminum backing causes only a slight broadening of the lines and does not affect the energy determinations which are made in terms of the extrapolation of the high energy edges. The source thickness was estimated to be 0.03 mg/cm² of Au^{198} and 0.1 mg/cm² of Cs^{137} .

Figure 1 shows a typical momentum distribution curve of the electrons which are internally converted in the K shells of Hg^{198} and Ba^{137} . For these measurements, the detecting slit was 0.40 cm wide and the distance between the center of the source and the center of the slit was $2\rho = 80.58$ cm. In determining the energy

FIG. 1. Internal conversion electrons from Au¹⁹⁸ and Cs¹³⁷.

from the extrapolated high energy edge, a small correction was made for the finite resolution by using for ρ , one-half the minimum distance between source and detector slit. In all cases the magnetic field was measured immediately below and above each line by means of a flip coil and ballistic galvanometer as well as by balancing the voltage picked up by a continuously rotating search coil against that picked up in a standard Helmholtz field. The interpolation of points actually on the lines was made in terms of the energizing current of the magnet which was stabilized electronically to about 0.01 percent and measured by means of a type K potentiometer and standard resistance. In any one run, the magnet current was varied only in one direction. On the basis that the electrons from the Au¹⁹⁸ gamma-ray correspond to an extrapolated high energy edge of $H\rho = 2219.6$ gauss-cm, the electrons following the Cs¹³⁷ disintegration are observed at $H\rho = 3381$ gauss-cm. The corresponding kinetic energy of the electrons is 0.6239 Mev and the energy of the gamma-radiation is 0.6614 ± 0.0007 Mev.

Additional runs were made on the Cs¹³⁷ conversion lines with the same source but with the detector slit reduced from 0.40 cm to 0.20 cm. The profiles of the lines are shown in Fig. 2. Even with

FIG. 2. Internal conversion electrons from Cs¹³⁷.

the extremely high resolution employed, the broadening of the lines because of backing and source thickness is such that the individual L and M lines are not sufficiently separated to be useful

for additional calibration purposes. The calibration in terms of the K line is summarized in Table I.

TABLE I. Gamma-ray energies.

	H gauss-cm	Electron energy Mev	K binding Mev	Gamma-energy Mev
Au ¹⁹⁸	2219.6	0.3280	0.0832	0.4112
Cs ¹³⁷	3381	0.6239	0.0375	0.6614 ± 0.0007

* This work was assisted by a grant from the Frederick Gardner Cottrell fund of the Research Corporation and by the Joint Program of ONR and AEC.

¹ DuMond, Lind, and Watson, Phys. Rev. **73**, 1392 (1948).

² L. M. Langer and C. S. Cook, Rev. Sci. Inst. **19**, 257 (1948).

On the $\gamma - \gamma$ -Angular Correlation in Pd¹⁰⁶

J. A. SPIERS

Clarendon Laboratory, Oxford, England

February 15, 1950

WE denote the successive γ -emissions and nuclear spins in Pd¹⁰⁶ by

$$\begin{array}{c} \xrightarrow{\gamma_3} \\ J_1 \rightarrow J_2 \rightarrow 0 \\ \xleftarrow{\gamma_1 \quad \gamma_2} \end{array}$$

the ground state of Pd¹⁰⁶, (even-even), being taken to have zero spin. The measured angular correlation¹ of γ_1 and γ_2 is given by

$$W(\theta) = 1 - 1.66 \cos^2\theta + 2.16 \cos^4\theta.$$

As Ling and Falkoff² have shown, this cannot be explained theoretically on the assumption that γ_2 is pure quadrupole ($J_2=2$) and γ_1 pure quadrupole ($J_1=0$) or mixed dipole-quadrupole ($J_1=1, 2, 3$). Also γ_2 cannot be dipole ($J_2=1$) or there would be no $\cos^4\theta$ -term in $W(\theta)$.

The author³ has calculated the correlation to be expected on the assumption that γ_2 is pure octupole ($J_2=3$) and γ_1 pure octupole ($J_1=0$), pure quadrupole ($J_1=1$) and mixed dipole-quadrupole ($J_1=2, 3$). Using the obvious notation WJ_1J_20 we obtain:⁴

$$W_{030} = 1 + 111 \cos^2\theta - 305 \cos^4\theta + 225 \cos^6\theta,$$

$$W_{130} = 1 + (47/54) \cos^2\theta - (15/27) \cos^4\theta,$$

$$W_{230} = 2|\alpha|^2(23 - 9 \cos^2\theta) + 5|\beta|^2(8 - 3 \cos^2\theta + 5 \cos^4\theta) + 6(30)^{1/2}R(1 - 3 \cos^2\theta),$$

$$W_{330} = 16|\alpha|^2(13 + 9 \cos^2\theta) + (48/9)|\beta|^2(51 + 3 \cos^2\theta - 20 \cos^4\theta) + 96R(1 - 3 \cos^2\theta).$$

None of these functions fits the facts; for instance, none of them has a $\cos^4\theta$ -term whose coefficient is or can be made positive and of order of twice the constant term.

Higher values of J_1 ($J_1=4, 5, 6$, with $J_2=2, 3$) were also tried, with the same result.

It is possible however to account for $W(\theta)$ in a very simple manner if we are willing to suppose that one of the excited levels of Pd¹⁰⁶ consists in fact of two levels with different spins but sufficiently close together in energy not to have been resolved. $W(\theta)$ is then a superposition of two correlation functions sharing a common value of J_1 (or J_2).

One at least of these two functions must have a $\cos^4\theta$ -term whose coefficient is positive and twice the constant term. Of all the functions with $J_2=2, 3$, and $J_1=0$ to 4, only W_{020} satisfies this condition. The second function cannot then have $J_1=0$ also, since this would forbid completely the observed crossover transition γ_3 ; we are left with functions of the form WJ_120 , the upper excited level being the one that is in fact two levels, with spins $J_1=0$ and $J_1'=1, 2, 3$, respectively (see Fig. 1).

Assuming for a start that γ_1' is a pure dipole, and taking $J_1'=1$, we have

$$\begin{aligned} W(\theta) &= AW_{020} + BW_{120} \\ &= A5/4(1 - 3 \cos^2\theta + 4 \cos^4\theta) + B3/8(3 - \cos^2\theta), \end{aligned}$$