TABLE I. Comparison of recent data on I^{131}, including our hitherto unpublished results. Gamma-intensities are given relative to that of the 364-kev gamma-ray arbitrarily taken as 100. Figures in parentheses were obtained from an assumed decay scheme, except for order of magnitude.

β-rays	Metzger and Deutsch[a]	Owen *et al.*[b]	Lind *et al.*[c]	Moe *et al.*[d]	Cork *et al.*[e]	Kern *et al.*[f]	Our values[g]
1. Energy (kev)	315±20	—	—	—	(259)	250±30	306±15
Intensity (%)	15	—	—	—	—	14	~20
2. Energy (kev)	600±5	597±5	—	—	(600)	605±5	606±5
Intensity (%)	85	—	—	—	—	86	~80
γ-rays							
1. Energy (kev)	80±1	83±2	80.133±0.005	—	80.1	80±2	80
Intensity	(7.6)	—	(8.7)	—	—	(22)	—
2. Energy (kev)	—	163±3	—	159	163.6	163	—
3. Energy (kev)	—	—	—	—	177.0	—	—
4. Energy (kev)	—	—	—	208(?)	—	—	—
5. Energy (kev)	283±3	286±6	284.13±0.1	284	284.1	282±1	284
Intensity	7.6	—	8.7	—	—	4.5	~9
6. Energy (kev)	363±3	368±7	364.18±0.1	364	364.2	363±2	364
Intensity	100	—	100	—	—	100	100
7. Energy (kev)	638±5	—	—	638	(625)	637±2	639±4
Intensity	19	—	—	—	—	17	~13

[a] See reference 1.
[b] Owen, Moe, and Cook, Phys. Rev. **74**, 1879 (1948).
[c] Lind, Brown, Klein, Muller, and DuMond, Phys. Rev. **75**, 1544 (1949).
[d] Moe, Owen, and Cook, Phys. Rev. **75**, 1270 (1949).
[e] See reference 2.
[f] See reference 3.
[g] The calibration of our spectrometer was checked against the accurate values of Lind *et al.* (reference c) for the 80-, 284-, and 364-kev γ-energies.

Figure 1 shows a Fermi plot of our beta-spectrum. The principal component is seen to have an end point at 606±5 kev, and the soft component at 306±15 kev. The latter value agrees within the limits of experimental error with that of Metzger and Deutsch, but cannot be easily reconciled with that of Kern *et al.*

The source[5] used was deposited on a 1.7 mg/cm² Al backing in the form of AgI with an average surface density of 0.5 mg/cm², and the counter window thickness was 1.0 mg/cm² mica. Our previous experience indicates that under these conditions the shape of the beta-spectrum is not appreciably affected above about 100 kev. The Fermi plot of the soft component was obtained using only points between 100 and 240 kev, since internal conversion lines distort the spectrum above 240 kev.

Table I summarizes the results of recent measurements on I^{131} by various authors, including our hitherto unpublished results. The 163-kev gamma-ray reported by several investigators has been identified as due to a 12-day isomer of Xe^{131} produced in about one percent of the I^{131} decay transitions.[6] It may be pointed out that the thicker the beta-source used the more likely it is that this radioactive Xe^{131} gas will be trapped in the source and its radiation observed.

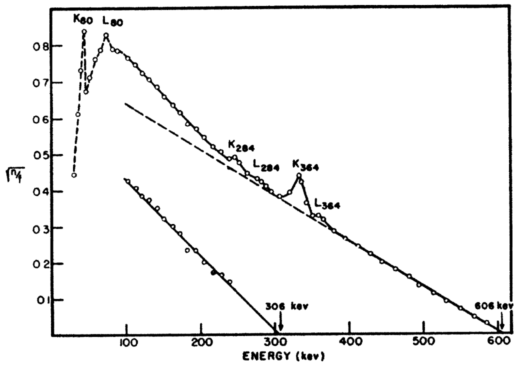

FIG. 1. Fermi plot of I^{131} beta-spectrum. The original relativistic Fermi function $f(Z,\eta)$ was used in making this plot.

On comparing the various decay schemes that have been proposed, our results tend to support that of Metzger and Deutsch. Further information of great value in deciding between these schemes would be a more accurate determination of the intensity of the 80-kev gamma-ray than has thus far been made.

We are indebted to the NBS Computation Laboratory for evaluation of the relativistic Fermi function $f(Z, \eta)$. This work was assisted by the AEC.

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[1] F. Metzger and M. Deutsch, Phys. Rev. **74**, 1640 (1948).
[2] Cork, Keller, Sazynski, Rutledge, and Stoddard, Phys. Rev. **75**, 1621 (1949).
[3] Kern, Mitchell, and Zaffarano, Phys. Rev. **76**, 94 (1949).
[4] This investigation was carried out in the summer of 1948, and included a study of both beta- and gamma-spectra as well as beta-gamma- and gamma-gamma-coincidence absorption measurements. Publication was withheld, however, in the hope of determining the critical intensity of the 80-kev gamma-rays and the origin of the gamma-gamma-coincidences observed.
[5] The I^{131} used in this investigation was obtained from the Oak Ridge National Laboratory.
[6] Brosi, DeWitt, and Zeldes, Phys. Rev. **75**, 1615 (1949).

The Scattering of Electrons by Hydrogen Atoms

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IN a recent paper Hsuang[1] has applied a variational method to investigate the scattering of slow electrons by hydrogen atoms. His method does not allow for exchange effects. In the course of a systematic study of the usefulness of variational methods in atomic collision problems we have applied Hulthèn's variational method[2] to the hydrogen atom. The trial wave functions we have used are, in atomic units, of the form

$$\psi(r_1, r_2)=\exp(-r_1)f(r_2, r_{12})\pm\exp(-r_2)f(r_1, r_{12}), \tag{1}$$

where

$$r_2 f(r_2, r_{12})=\sin kr_2+\{a+\exp(-r_2)(b+cr_{12})\}(1-\exp(-r_2)\cos kr_2.$$

Here r_1, r_2, and r_{12} are the distances of the electrons from the nucleus and from each other, respectively, k is $2\pi mva_0/h$, and v the velocity of the incident electron. The second term of (1) allows for electron exchange, the ± signs corresponding to the cases in which the spins of the atomic and incident electrons are antiparallel and parallel, respectively. Except for the exchange terms the trial function is exactly the same as that used by Hsuang in his method which is, however, not the same as that of Hulthèn which we have employed. The term involving r_{12} allows for polarization of the atom by the incident electron, and the possibility of introducing such allowance is an important feature of the variation method.

We have, so far, determined the zero-order phase angle $\eta_0(=\tan^{-1}a)$, for the following cases (a) exchange neglected, no polarization correction (i.e., $c=0$), (b) exchange neglected, polarization correction included (i.e., c included as a variable parameter), (c) exchange included, no polarization correction (i.e., $c=0$), (d) exchange included, polarization correction included but $b=0$.

Cases (a) and (b) correspond to the cases considered by Hsuang. In general we reproduce his results in that η_0 tends to π as k tends to 0 in case (b), whereas in case (a) it tends to 0. On the other hand, our values of η_0 tend in both cases, as k increases, to those calculated by Macdougall[3] by numerical integration of the differential equation for the motion of electrons in the static field of a hydrogen atom.

The results for case (c) may be compared directly with those obtained by Morse and Allis[4] by exact numerical solution of the integro-differential equations which can be set up when polarization is ignored. Good agreement is found.

Finally, in case (d) the effect of including polarization in addition to exchange is found to be much less noticeable than when

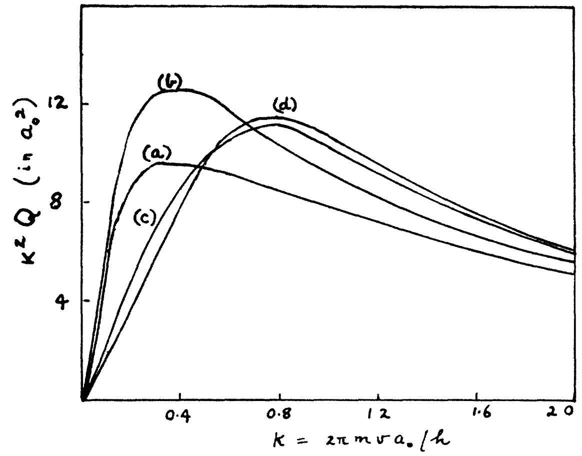

FIG. 1. The elastic scattering cross section Q for atomic hydrogen calculated by the Hulthèn variational method for the cases (a), (b), (c), (d) described in the text.

exchange is ignored. This is particularly true for the antisymmetric case, as would be expected. The antisymmetry already ensures that the two electrons are kept apart.

These results may be seen by reference to Fig. 1, in which the collision cross sections derived in the various cases are illustrated.

A full account of this work will be published later.

Our thanks are due Miss K. Blunt for carrying out many of the extensive numerical calculations involved.

[1] S. S. Hsuang, Phys. Rev. **76**, 477 (1949).
[2] L. Hulthèn, K. Fys. Sällsk, Lund Förhandl **14**, No. 21 (1944).
[3] J. McDougall, Proc. Roy. Soc. **A136**, 549 (1932).
[4] P. M. Morse and W. P. Allis, Phys. Rev. **44**, 269 (1933).

On the Sudden Increase in Cosmic-Ray Intensity on November 19, 1949

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CONTINUOUS recording of cosmic-ray intensities by Geiger-Müller counters is being carried on at Ottawa and at Resolute (latitude 74°41′ N; longitude 94°55′ W; geomagnetic latitude 83°). The equipment and arrangement of counters at both stations are identical. Four counter trays are used, three in a vertical line with 6 in. of lead between (1) and (2) and $8\frac{1}{2}$ in. of lead between (2) and (3). The bottom tray (3) is surrounded with at least 4 in. of lead. A fourth counter tray, unshielded except for the building roof and $\frac{1}{16}$ in. of aluminum, is located nearby. At both stations coincidences are recorded between (1) and (2) and between (1) and (3) and the total counts in (3) are recorded. At Ottawa the total counts in all trays are recorded as well as the above coincidences.

At Ottawa on November 19 at 1048 GMT the intensity started to increase suddenly. It reached about 170 percent of the mean of the previous 12 hr. in about 6 min. The peak was narrow and sharp and reached roughly the same relative height in shielded counters, unshielded counters, and coincident pairs. The variation was so rapid at the peak that the necessity of counting over short intervals makes an accurate measure of its height impossible. The figures obtained vary from 50 to 90 percent with the different arrangements of counters. After the peak the intensity appears to decay roughly exponentially, though there are some significant irregularities in the decay curve. It returned to about 10 percent above the average in about an hour. A sudden increase on November 19 was first reported by Dauvillier[1] who found an increment of 3.6 percent at Bagneres, France. Forbush, Stinchcomb, and Schein[2] report a 43 percent increase at Cheltenham and Godhaven, a larger increase at Climax, and none at Huancayo. The time given by Forbush, Stinchcomb, and Schein is about 1045 and the Ottawa peak was obviously coincident with this. The increase found by Dauvillier occurred somewhat later and reached a maximum about 1200 hr. At Resolute the intensity started to rise at about 1100 GMT and the curve shows a broad peak 12 to 15 percent in height centered about 1145 hours, or approximately fifty minutes after the Ottawa peak. It was recorded by the shielded counter and both coincidence channels. This probably represents the same increase found by Dauvillier.

The delay in time and the significant irregularities in the Ottawa curve suggest that after the initial increase in intensity there were irregular subsequent bursts. If the subsequent bursts were composed of particles, then they might be expected to strike the earth at different localities because of their different energies or directions. Figure 1 shows a plot for eight days of the results from a shielded and an unshielded counter tray and a coincidence unit (6 in. of lead) at Ottawa, and from a similar coincidence unit and a shielded tray at Resolute. An expanded plot from an unshielded tray at Ottawa is also shown.

Previous observations of sudden increases[3,4] of this type have been associated with solar flares and have shown a decrease of 10 percent or more occurring some hours after the increase. After the increase on November 19 a sudden decrease did not occur. The decrease has been associated with the sudden commencement of a magnetic storm. An examination of magnetometer records taken at the same station at Ottawa does not show any strong sudden commencement but rather a gradually increasing magnetic disturbance starting about 1800 hr. On the days following November 19 the variations in intensity shown in Fig. 1 are probably meteorological.

On November 29 another unusual increase in intensity occurred at Ottawa. The unshielded trays showed an increase of about 35 percent lasting about 3 hr., centered about 1330 GMT. The shielded tray and the coincidence units indicated nothing irregular. A careful investigation eliminated any possibility of interference by radioactive sources in the neighborhood. Doan[5] and Wait and McNish[6] have reported increased ionization during rain, the former in an unshielded ionization chamber used for cosmic-ray

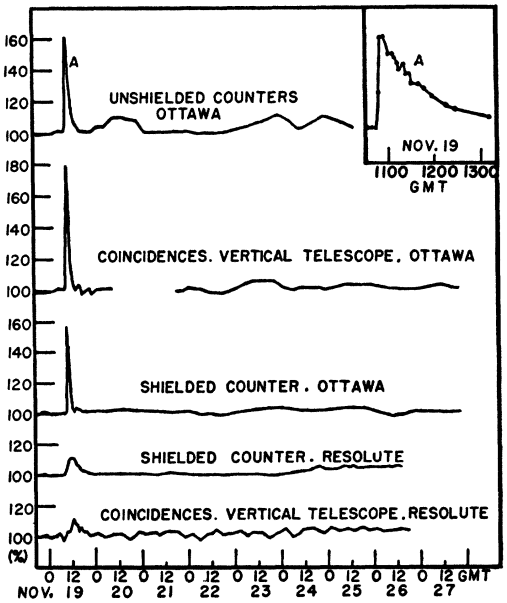

FIG. 1. Sudden increase in cosmic-ray intensity on November 19, 1949