three explicitly stated premises of Dirac a fourth premise, namely, that
the characteristic values of \( \frac{z}{c} \), \( \frac{y}{c} \), \( \frac{z}{c} \), \( \sqrt{1 - \beta^2} \) are \( \pm 1 \).

2 Pauli, Jr., W., Zs. Phys., 43, 601 (1927); see also H. Weyl, Ibid., 46, 1 (1927).
5 Gordon, W., Zs. Phys., 40, 117 (1926).

REGULARITIES EXHIBITED BETWEEN CERTAIN MULTIPLETS FOR ELEMENTS IN THE SECOND LONG PERIOD

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If, for a sequence of iso-electronic systems starting with any element in the periodic table, the energy levels representing any of the possible electron configurations be plotted on a Moseley type of diagram, the lines connecting points for corresponding terms of each successive element will be very nearly straight lines. Furthermore, it is found that the radiated frequencies resulting from those electron transitions involving no change in total quantum number (which in some cases involve more than a hundred radiated lines) are displaced to higher and higher frequencies by very nearly a constant value. These general rules, the regular displacement of multiple levels and of multiplets which were found to hold so well for sequences of iso-electronic systems in the first long period, have now been extended to the elements in the second long period.

In the so-called “iron group” of elements most of the strong lines in the various spectra are the result of the electron transitions \( 4p \) to \( 4s \) in the presence of \( 0, 1, 2, 3 \ldots 10, 3d \) electrons, whereas, in the second long period the transitions become \( 5p \) to \( 5s \) in the presence of \( 0, 1, 2, 3 \ldots 10, 4d \) electrons.

In general the electron transitions \( a^{n-1} p \) to \( a^{n-1} s \), where \( n \) is the number of extra nuclear electrons in the atom or ion in any state of ionization in excess of that in the neutral atom of the next preceding rare gas, involves so many radiated lines that in order to represent the position in the spectrum of each electron transition it is desirable to select a single line out of all those radiated.

The wave numbers given in table 1 and shown graphically in figure 1
<table>
<thead>
<tr>
<th>MOLECULES</th>
<th>QUARTETS</th>
<th>TRIPLETs</th>
<th>DOUBLeTs</th>
<th>SEXTETS</th>
<th>OCTETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rb I</td>
<td>^2P_1 - ^2P_3</td>
<td>^4F_3 - ^4F_5</td>
<td>^4F_4 - ^4F_6</td>
<td>^4F_5 - ^4F_7</td>
<td>^4F_6 - ^4F_8</td>
</tr>
<tr>
<td>Sr II</td>
<td>^2P_1 - ^2P_3</td>
<td>^4F_3 - ^4F_5</td>
<td>^4F_4 - ^4F_6</td>
<td>^4F_5 - ^4F_7</td>
<td>^4F_6 - ^4F_8</td>
</tr>
<tr>
<td>Yt III</td>
<td>^2P_1 - ^2P_3</td>
<td>^4F_3 - ^4F_5</td>
<td>^4F_4 - ^4F_6</td>
<td>^4F_5 - ^4F_7</td>
<td>^4F_6 - ^4F_8</td>
</tr>
<tr>
<td>Zr IV</td>
<td>^2P_1 - ^2P_3</td>
<td>^4F_3 - ^4F_5</td>
<td>^4F_4 - ^4F_6</td>
<td>^4F_5 - ^4F_7</td>
<td>^4F_6 - ^4F_8</td>
</tr>
</tbody>
</table>

**TABLE 1**

**REGULAR DISPLACEMENT OF MULTIPLETS BY SUCCESSIVE ADDITION OF 4d ELECTRONS**
are chosen in the following way. In the one and eleven electron systems, columns one and eleven, the strongest line of the principal doublet \( ^{3}s_{1} - ^{2}P_{2} \) is chosen to represent the electron transition \( p \to s \). For the two and
d

![Diagram](image-url)

**FIGURE 1**

Transitions in iso-electronic sequences \((d^{8-2}p \to d^{8-1}s)\).

ten electron systems, columns two and ten, the strongest line \( ^{3}D_{3} - ^{3}F_{4} \) is chosen to represent the transitions \( dp \to ds \) and \( d^{3}p \to d^{3}s \), respectively.
Similarly, for the three and nine electron systems the line $^4F_5 - ^4G_6$ is chosen to represent the transitions $d^{2p}$ to $d^{2s}$ and $d^{8p}$ to $d^{8s}$, respectively.

In like manner this process is repeated for each of the remaining sequences of iso-electronic systems, choosing each time the transition which
takes place between two levels involving the highest \( R, L \) and \( J \) values. The diagram for elements of the first long period as it appears in figure 1, which includes several extensions to that given in a previous report,\(^2\) along with the corresponding figure below for elements of the second long period offers some very interesting and valuable comparisons. The points along any vertical line represent the almost linear progression of frequency with atomic number in a sequence of iso-electronic systems. With these diagrams extended as far as they have been further extrapolations can be made with considerable accuracy. For a number of the points given above the radiated lines were predicted within one or two angstroms of their observed values, indicating that this is a powerful method of attack upon the spectra arising from atoms in higher states of ionization.

The recognized similarities between both the arc and the spark spectra of the corresponding elements in these two periods have been used by several investigators to unravel some of the more complex spectra in the second long period. With data now available for the arc spectra of ten of the elements in the second long period a comparison can be made with the arc spectra of the corresponding elements in the first long period. Similarities between these two periods are well brought out (following a scheme suggested by Russell\(^3\) for the iron group of elements) in figure 2.

Here the electron configurations \( d^{n-2}s^2, d^{n-1}s, d^{n-1}p, \) and \( d^n \) are represented, where known, by plotting the lowest energy level of each configuration with respect to \( d^{n-1}s \) as zero. Although the spectra of masurium is not yet known it is evident from the two figures that a similar break in the relative energies of binding of the different configuration occurs at the same place in each period. In passing through these two periods of elements the decreasing energies of binding of the \( d^{n-2}s^2 \) configurations are clearly brought out.

\(^1\) R. C. Gibbs and H. E. White, Physical Review, 31, 309, 1928.
\(^2\) R. C. Gibbs and H. E. White, these PROCEEDINGS, 13, 525, 1927.

REFERENCES TO TABLE 1

Pd II, Unpublished data by A. G. Shenstone.
Ag III, Unpublished data by authors.
Rb I; L. A. Sommer, Zs. Phys., 45, 147, 1927.
Cb I; W. F. Meggers, Jour. Wash. Acad. Sci., 14, 442, 1924.
Mo I; C. C. Kiess, J. O. S. A., 10, 287, 1925.
ANGULAR SCATTERING OF ELECTRONS IN HYDROGEN AND HELIUM

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Communicated June 9, 1928

In view of the recent work which has been done by Davisson and Germer,\(^1\) G. P. Thomson,\(^2\) and others in investigating the angular scattering of electrons by crystals, and the work of E. G. Dymond\(^3\) in extending these investigations to the scattering of electrons by helium, it was thought worthwhile to see if similar results could be obtained for this scattering by other monatomic and diatomic gases. The phenomena observed when electrons are scattered by crystals are susceptible of explanation in a very satisfactory way on the wave mechanics hypothesis, but the theory is less fully developed for the case of gases and the results obtained by Dymond for scattering in helium have so far met with no adequate explanation. However, selective angular scattering might conceivably be expected in a monatomic gas. In this case it might be supposed that atomic hydrogen would also give rise to similar phenomena, and in view of its greater simplicity an explanation would present less serious mathematical difficulties. Hence, the following work was undertaken primarily to investigate the possibility of selective angular scattering in atomic hydrogen. Molecular hydrogen was also used though there was less reason to expect the phenomena in a diatomic gas. Finally, the experiments performed by Dymond in helium were repeated under as nearly similar conditions as possible.

The apparatus used is shown in figure 1. The scattering chamber consisted of a glass bulb about ten centimeters in diameter. A large ground glass stopper mounted vertically through a mercury seal carried the electron gun, \(G\). This consisted of a tungsten filament mounted behind two collimating slits about a quarter of a millimeter wide and a centimeter and a half apart. By means of the ground glass stopper this could be rotated through nearly a complete circle. The angular setting could be read by means of a pointer attached rigidly to the stopper carrying the gun and an angular scale attached to the bulb. The front slit of the gun