Physics. — *An Eighth Isotope of Molybdenum.* By J. DE GIER and P. ZEEMAN.

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The method of the carbonyls being applied with good results to *Ni* and *Fe*[1]) was also successful with Molybdenum. A new isotope of mass number 102 was discovered, the number of isotopes of *Mo* now being no less than eight.

The first attempts made by ASTON according to the method of accelerated anode rays were unsuccessful. Later on ASTON[2]) obtained a sample of the carbonyl of molybdenum and now seven isotopes were found.

Photometry of the group was not easy, the total intensity being spread over seven almost equally intensive components. So the lines had to be photographed in a position of the plate giving less than normal resolution. The results which, according to ASTON, must be taken as provisional only were:

Mass numbers:	92,	94,	95,	96,	97,	98,	100.
% abundance:	14.2,	10.0,	15.5,	17.8,	9.6,	23.1,	9.8.

Our experiments were also made with the hexacarbonyl. A free sample was sent to us by the I. G. Farben Industrie at Frankfurt. We are very grateful for this generous gift, which made the present experiments possible.

The vapour pressure of the white crystalline powder was just high enough for the sample to be used in the common way. As with *Ni* and *Fe* carbonyl, we were forced to admix a quantity of oxygen.

This time the percentage of O_2 amounted to fifty and more. Otherwise a coating of *Mo* would have been formed on the inner wall of the discharge tube.

Such a metallic mirror in the cathodic region soon disturbed the discharge and the bundle became deflected in a short time. When mixing the carbonyl with some fifty percent of oxygen, the tube could be held in a steady state during several exposures. But by doing so, the intensity of the *Mo* lines was appreciably reduced. Moreover, a carbonyl molecule contains as much as six *CO*-groups. So we were obliged to use wide canals to obtain a sufficient intensity for the *Mo* parabolas.

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1) J. DE GIER and P. ZEEMAN, Proc. Royal Acad. Amsterdam, **38**, 810, 959 (1935).

2) F. W. ASTON, Proc. Roy. Soc. **130**, 308 (1931).

Of course wide canals impair the sharpness of the parabolas. By so doing, the lines were never totally resolved. For this reason an estimation of the intensities was almost impossible.

These difficulties made it very hard to obtain a plate good enough for reproduction. When the time of exposure was short, the faint line 102 did not appear. With a much longer time of exposure the whole group of seven intensive isotopes formed a black cluster and the new isotope was apt to disappear in the diffuse background of the cluster. Many plates were used before a small number was obtained that more or less satisfied the conflicting requirements.

The reproduction of one of these plates will clearly show all of the seven well-known isotopes.

At the same time the intensity is just great enough to show isotope 102 as a faint line. In the reproduction a trace of it is still visible.

ASTON reported on his trouble with the doubly ionized *Hg* atoms. This group just falls in the region of *Mo* lines. So we took precautions to reduce the *Hg* vapour-pressure in the tube. Although a slight mercury vapour from the diffusion pumps is frequently unavoidable, we obtained several plates on which the *Hg* parabolas could not be found.

Other plates only revealed the primary *Hg* line having little or no prolongation towards the magnetic axis, indicating that the parabolas of the second order were not to be feared. Exposures without carbonyl confirmed this conclusion.

In the reproduction several carbonyls of *Mo* will be seen, such as $MoCO, Mo(CO)_2$. On more intensive plates all the compounds up to $Mo\,(CO)_6$ could be distinguished, though with decreasing intensity where the number of *CO*-groups increased.

On the original plate and a few others faint lines could be detected for $^{102}Mo\,CO$ and even a shadow of line $^{102}Mo\,(CO)_2$ was discovered. A confirmation of our explanation about the identity of the new line was also found in the prolongation of the parabolas to the magnetic axis. The isotopes already known very frequently showed that phenomenon. A slight prolongation of ^{102}Mo, however, was also discovered on the most intensive plates.

It will be apparent that no good estimation of the relative abundance of the isotope could be given. The neighbouring isotope 100 was never quite free from the most intensive line 98. A reliable figure was not attainable. A provisional comparison led to about 2—3 % of the total.

Several isotopes of *Mo* have the property of being isobaric with isotopes of elements in the same region of the isotopic table. As ASTON pointed out, ^{96}Mo forms the lightest isobaric triplet with the zirconium isotope ^{96}Zr and the Ruthenium isotope ^{96}Ru.

In the same way the next triplet is now formed by ^{102}Mo being isobaric with ^{102}Ru and ^{102}Pd. Further ^{92}Mo and ^{94}Mo are isobaric with

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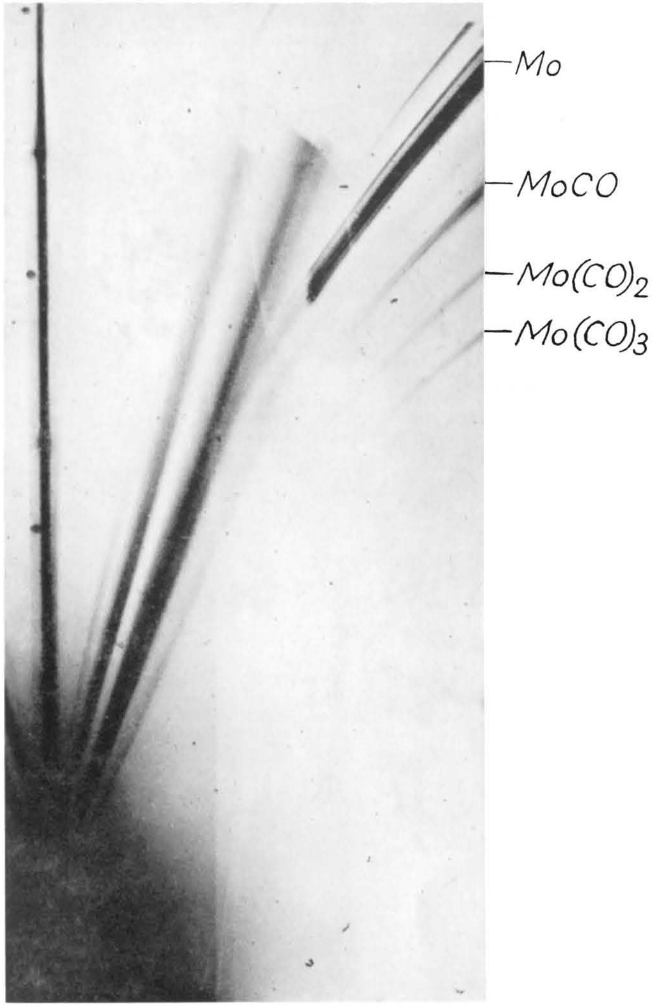

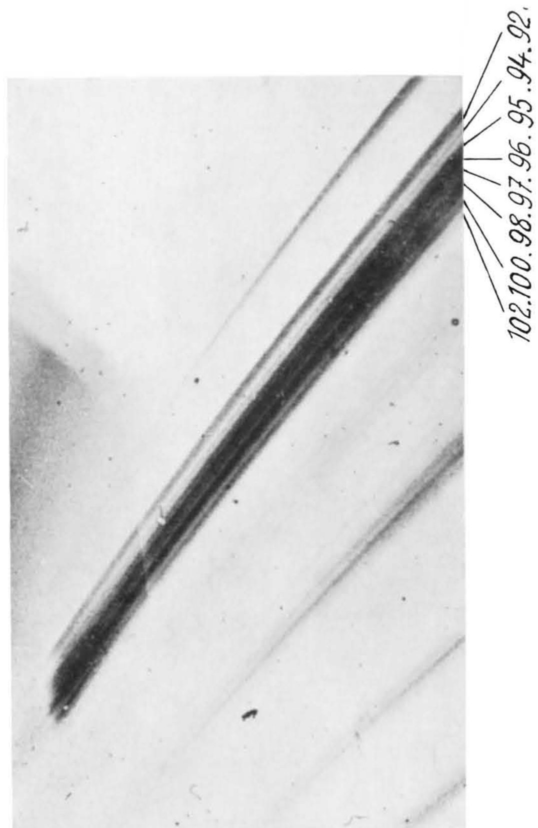

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^{92}Zr and ^{94}Zr respectively. Finally ^{98}Mo will form a doublet with the uncertain ^{98}Ru isotope.

^{102}Mo is also of some interest as to the limitation of the number of isotopes of the elements with even atomic number.

MATTAUCH [1]) decided upon three limits in different regions of the isotopic table.

These limits, as SITTE [2]) pointed out, are somewhat artificial. MATTAUCH looked for the element with the greatest number of isotopes in a certain region on the table and supposed the neighbouring elements would behave in exactly the same manner.

SITTE proposed a more conceivable limitation on refering to GAMOW's general conceptions of the binding energy of the core [3]). An energy valley is present in which the stable isotopes take their places.

In this way SITTE's limitation enabled him to predict a number of undiscovered isotopes which were mainly the same as those of MATTAUCH.

In some places, however, new isotopes seemed probable, in others MATTAUCH's isotopes became unlikely.

In the case of *Mo*, SITTE predicted ^{102}Mo where MATTAUCH decided upon ^{90}Mo. We looked for the latter, but even on the most intensive plates we could not find the slightest trace of it.

In this connection it may be of some interest to record our experiments with krypton and xenon. MATTAUCH predicted an isotope of krypton of mass number 88. Our experiments last year never revealed such an isotope.

From the curve of minimum energy SITTE concludes the isotope to be improbable.

No further isotopes of xenon were predicted. A greatly prolonged investigation did not lead to new results. We only found that the faint isotopes ^{124} and ^{126} were not equally abundant. The latter seemed about half as strong as the former.

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1) J. MATTAUCH, Zeitschr. f. Phys. **91**, 361 (1934).
2) K. SITTE, Zeitschr. f. Phys. **96**, 512 (1935).
3) G. GAMOW, Zeitschr. f. Phys. **89**, 593 (1934).