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Results in the $K\beta$ group of molybdenum obtained with a spectrograph containing a plastically deformed rocksalt crystal.

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A method for a uniform plastic deformation of rocksalt crystals is elaborated. The bending of the crystal is carried out by a steel spring acting as a bearer stretching uniformly the texture of the cross-section; the steel spring was of steel „Poldi A. K. V. N.“ the elasticity of which increases with temperature in the region of plasticity of rocksalt (at 300° C). Rocksalt crystals thus cylindrically deformed were used in Kunzl's focusating method for the study of the lines of the β group of K series in molybdenum. These lines are suitable for the comparison of results obtained with the present authors' method and those of Johann and Cauchois, since both methods reveal — by means of deformed crystals — new forbidden Mo lines (quadrupol lines) and non-diagram lines. The present authors obtained all such lines already described, except the line $\beta_4 x$. Besides these, some other hitherto non-classified lines were found.

The results show that crystals plastically deformed in the present authors' manner give the largest attainable resolving power with an extreme luminosity.

Hitherto plastically deformed crystals did not bring any advantage in X-ray spectrography. An attempt was made by Hámos,[1]) who used rocksalt crystal in Gouy's[2]) focusating arragement. Hámos was thus able to show that the theoretically suggested Gouy's arragement really leads to lines, the intensity of which depends on the height of the crystal used. Hámos[1]) results, however, do not show any advantage over the use of the ordinary plain crystal.

Our first studies of the X-ray reflexion on plastically deformed crystals showed that such crystals may be used only in weak exposures, since during long exposures defaults become more prominent, brought in by the plastical deformation of the crystal.

The Cu $K\alpha$ lines are well defined at a weak exposure; however when this exposure is prolonged, besides these lines their traces appear irregularly shifted owing to irregularities in the deformation in various places of the crystal. Such defaults exclude, of course, any application of plastically deformed crystal in X-ray spectroscopy. Endeed as long as we tried the usual way of deformation we did not succeed to obtain faultless products. This is perhaps the reason why Hámos has not succeeded with his spectrograph to obtain new results. We hawe, therefore, tried to work out a method of a uniform plastic deformation of the crystal into a rotational cylindrical surface. For this aim we have applied a steel spring bearer adapted so as to stretch uniformely the texture of the cross-section.[3]) Under this bearer the rocksalt crystal was placed for bending. The whole arrangement was kept in an oil bath at a temperature at which plastic deformation is possible (see fig. 1). For

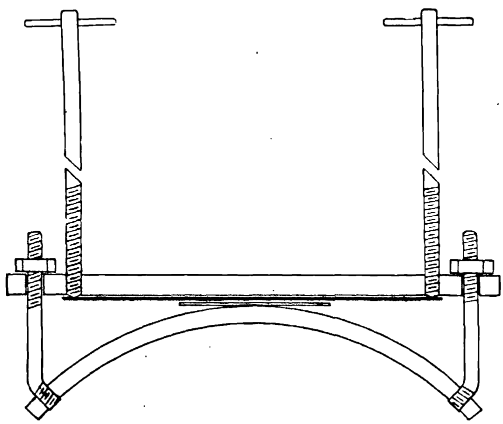

Fig. 1.

this 300° C is a suitable temperature. At these conditions the steel spring was bent by tying up screws and hereby the crystal was pressed on to an iron cylindrical support, which had the required curvature. To avoid decrease of elasticity of the spring, special steel „Poldi A. K. V. N." was applied, the elasticily of which increases with temperature.

The results show that crystals deformed in this manner are curved much more uniformly than when bent in the usual way, which consists of pressing an elastic crystal between two rigid surfaces corespondingly curved beforehand.

The principal lines of Cu and Mo reflected on crystals deformed in our manner are sharp and exhibit a great resolving power, so that the proper width of the lines may be estimated. We intend to show here advantages of using crystals deformed plastically in our manner, as they present themselves in the exposure of very faint X-ray lines. The β-group of the Mo K-series was chosen for our particular study. This element has been measured with modern focusating methods by several authors who revealed there several new lines (like the quadrupollines and the non-diagram lines).

The present authors used Bragg's spectrographic arrangement with Kunzl's[4]) focusation. The radius of curvature of the bent crystal was 8 cm, its dimensions $3{,}5 \times 2{,}5$ cm^2, its thickness 1 mm. Correspondingly to the curvature of the crystal the radius of the spectrograph was 37 cms. The lines were recorded in the first order.

Photographic methods with plane crystals reveal only the lines $\beta_{1,3}$ and β_2 except in few light elements, where Beuthe[5]) found and Leide[6]) a new line in Mo, which was subsequently found in other elements and termed β_4. Bloch and Ross[7]) have examined the range of Mo lines with a double crystal spectrometer by means of an ionization record; they found lines of wave lengths 627,691 X. U., 627,019 X. U. and 625,646 X. U.; the latter two lines are now termed β_6 and β_5. The authors point out that the condition of obtaining such lines is a perfect crystal; they used calcite which has been etched.

Other lines of very faint intensity in the Mo β group were found photographically only by the introduction of focusating methods.[8]) In this way the spectrographic luminosity is considerably increased, so that the time of exposure can be shortened and thus the photographic blackening due to diffuse radiation lessened. But even then the new lines are shown only very indistinctly on the background of continuous radiation. Cauchois and Ingelstam[9]) tried to remove this continuous radiation, due to reflexions of higher orders, by suitable absorption filters. In their work they used Montmatre gypsum and cut plates of quartz and topaz, elastically deformed into rotational cylindrical surfaces. Such focusating methods depend, however, on a number of geometrical conditions for perfect image, which require very difficult technical adjustment. Moreover, the crystals must be perfect and as elastic as possible. Othervise the bending of the crystal into the cylindrical surface, as Cauchois supposes, does not deform the elementary crystals but only changes their orientation, keeping the angles between the atomic planes of the mosaic crystal and the plane perpendicular to the plane which passes through the centre of the mosaic crystal, unchanged.

The crystals used by the above mentioned authors were deformed elastically. The possibility of using a plastically deformed rocksalt crystal was first pointed out — as mentioned above — by

Hámos. Rocksalt crystals are usually regarded as imperfect. According to Ewald and Renninger[10]) only small rocksalt crystals give a reflexion of an ideal structure, whereas larger surfaces show a mosaic structure. However, it is interesting that e. g. Beuthe found the line β_5 in light elements with rocksalt, which proves that its reflexion was faultless.

As pointed out above, the present authors used the plastically deformed rocksalt crystal bent by their own method and investigated its properties in Bragg's spectrograph modified by Kunzl.[11]) In this arrangement a bunch of rays emerging from the slit inpinges on the cylindrically bent crystal so that the axis of the cylinder is perpendicular to the axis of the spectrograph; the radius of curvature of the crystal is given as $\varrho = R \sin \varphi$, where R denotes the spectrograph radius and φ the glancing angle. Through this arrangement the image on the film is brought to the slit („stigmatic image"). The divergent rays are thus focussed vertically similarly as in Gouy's method, and differ in this from the methods of Johann and Cauchois, which focus the horizontal rays[3]).

With our arrangement we were able to obtain in the $K\beta$ group of Mo all lines hitherto ascertained except the line β_{4x} as given in Table 1.

Table 1.

	λ X. U.	ν/R mes.	ν/R calc.
β_4	618,65	1473,19	1473,0
β_2	(619,70)		
β_8	621,79	1465,56	
	622,25	1464,47	—
β_9	624,31	1459,63	—
β_5	625,72	1456,34	1456,3
β_6	627,35	1452,56	—
	627,99	1451,08	—
β_7	628,96	1448,85	—
β_1	(630,978)		
β_3	(631,562)		
β_0	634,8	1435,5	1435,9
η	636,4		—
	639,2		—

The wave lengths of the lines are referred to the lines $\beta_{1,3}$ and β_2 the value of which are given in brackets. In Table 2 the comparison of values found by Bloch and Ross, Carlsson and Ingelstam, Cauchois and Hulubei are compared to ours.

The comparison reveals a fair agreement; only the accuracy given by Bloch and Ross seems overestimated, since other values differ even in tenths of X. U.

Table 2.

	Carlson (Ingelstam)	Hulubei-Cauchois	Bloch-Ross	Ingelstam	Bačkovský-Neprašová
β_4	618,73 X. U.	618,64 X. U.	618,8 X. U.†)	618,68 X. U.	618,6 X. U.
β_{4x}				618,94	
β_2				[619,70]	[619,70]
β_8		622,25		622,20	621,79 622,25
β_9		624,34		624*)	624,31
β_5	625,75	625,67	625,646	625,74	625,72
β_6	627,21	627,54	627,019	627,17	627,35
			627,691	628,05*)	627,99
β_7	629,15	628,99		628,91	628,9
β_1				[630,978]	[630,978]
β_3				[631,562]	[631,562]
β_0		635,62			634,8
η				637,4*) 638,4*) 639,3*)	636,4 639,2

*) Only photometrically.
†) A. Leide 1925.

The lines are well defined, as evident from the enlarged photograph of the group in the first order (fig. 2). One can well see the lines β_5, β_6; even the lines $\beta_{8,9}$ are faintly indicated. The line β_7 as well as well as β_4 coalesce at everexposure practically with the strong lines $\beta_{1,3}$; β_2 so that only their edges are measurable. We were unable to measure β_5 separately — as given by Ingelstam — probably since it is covered in overexposure by β_2 which is quite elose to β_4.

Besides these, we have measured one line at 628,3 X. U.; the classification of which will be possible when it will be observed in other elements. The range of η lines on the long wavelength side of the $\beta_{1,3}$ — lines — measured only by Ingelstam — is evident on the spectrogram (fig. 3). The latter author measured these lines only photometrically. In our spectrograms we may measure their group quite well visually. The figures in Table 2 show that this group extends from 636,4 X. U. to 639,2 X. U. This agrees with Ingelstam values, who derived from the photometric curve three separate values in this group. Our spectrograms show a certain structure in these group, yet single lines are not well distingeuished. Besides these Cauchois found a line 635,62 X. U. X and termed

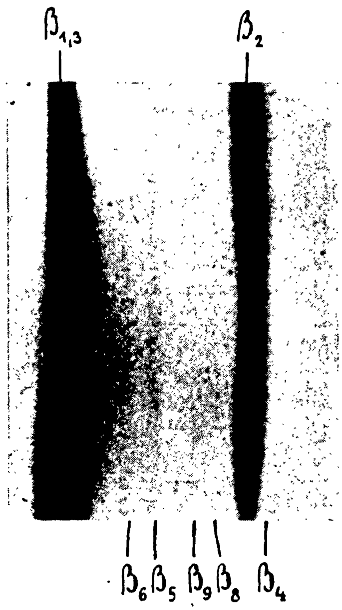

Fig. 2.

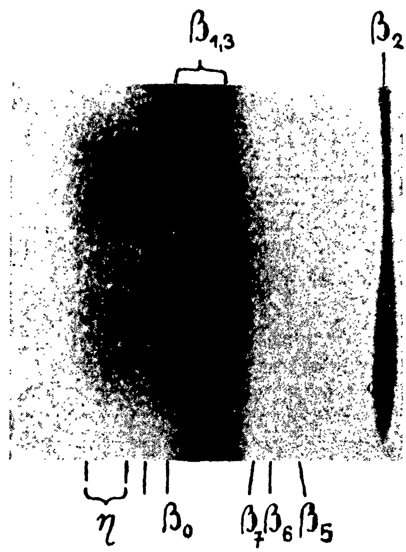

Fig. 3.

it β_0 which Ingelstam, however, has not confirmed. In that place we have measured a line of wave length X 634,8 X. U., which corresponds to $\nu/R = 1436{,}80$. This value agrees well with that calculated from the Bohr-Coster scheme for the forbidden transition MK, at which the quantum number l does not change. The calculated value $\nu/R = 1435{,}9$, so that $\lambda = 634{,}63$ X. U. The existence of this line and occasional analogous lines $L_I \rightarrow K$, $N_I \rightarrow K$ would indicate that besides the transitions $M_{IV,V} \rightarrow K$, $N_{IV,V} \rightarrow K$, which were explained as quadrupol — lines, there are in reality also transitions $\Delta l = 0$, which would contradict the rules of selection. The transition $N_I \rightarrow K$, whose value $\nu/R =$

$= 1468{,}5$ X $\lambda = 620{,}6$ X. U., is, however difficult to be found, as it comes too close to the intense line β_2 which would cover it in overexposure.

Although β_5 was found in several spectrograms in varions intensities, its widening towards longer wave-lengths has not been observed although Bloch and Ross give its widening as 0,4 X. U. and explain it as the Auger — effect accompaying the quadrupol-line. — Ingelstam's results also seem to indicate that such a widening does not take place.

The level scheme of our lines is given in the fig. 4.

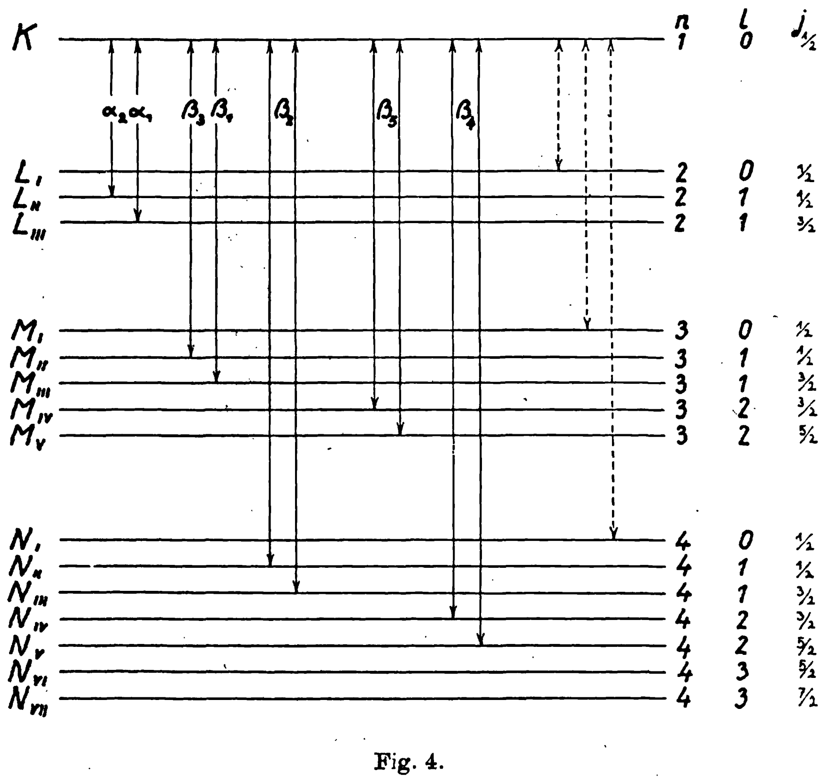

Fig. 4.

The greatly overexposed and coalescing lines $\beta_{1,3}$ and β_2 shown on some spectrograms, exhibit in their middle part a small widening towards longer wave-lengths. This effect is explainade by the widening of the bunck of rays owing to its reflexion on the mosaic crystal in Bragg's arrangement of the spectrograph.

The present authors express their best thanks to profesor V. Dolejšek for his interest and help richly spent to them in this investigation.

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O fokusačním spektrografu s plasticky deformovaným krystalem a výsledcích v $K\beta$ skupině molybdenu.

(Obsah předešlého článku.)

Autoři podávají metodu k plastické deformaci krystalů. Touto metodou se docílí rovnoměrného zakřivení do rotační válcové plochy, jak se užívá u krystalů, které lze ohýbati elasticky v metodách fokusačních pro paprsky X. Současně podávají autoři výklad, proč nemohlo býti dosud použito plasticky deformovaných krystalů pro reflexi paprsků X.

Používají ocelových pružin řešených jako nosník s rovnoměrně namáhanými vlákny průřezu (podle způsobu Dolejšek-Tayerle). Pružiny jsou z ocele Poldi AKVN, jejíž pružnost v teplotním oboru kolem 300° stoupá.

Takto válcově deformovaných krystalů NaCl bylo použito ve fokusační metodě Kunzlově s Braggovým uspořádáním ke studiu skupiny β serie K molybdenu. Na tomto prvku lze nejlépe porovnati reflekční mohutnost užitého krystalu a světelnost užité metody, neboť v poslední době byly nalezeny u něho fokusačními metodami (typu Cauchois) s užitím elasticky deformovaných krystalů nové zakázané čáry β_4, β_5 (quadrupollinie) a čáry nediagramové β_{4x}, β_6, β_7, β_8, β_9. Mimo to na dlouhovlnné straně nalezen obor několika čar, nazvaných Ingelstamem analogicky k lehčím prvkům obor η.

Všechny tyto čáry, nalezené Cauchois a Ingelstamem byly autory potvrzeny až na čáru β_{4x}; mimo to nalezeny některé čáry další, jejichž klasifikace bude podána později po studiu u sousedních prvků.

Quadrupol linie β_4, β_5 byly měřeny také Blochem a Rossem pomocí dublecrystalspectrometru s ionisačním záznamem. Tito autoři pozorovali u nich rozšíření na stranu delších vlnových délek, které vysvětlují zjevem Augerovým při vzniku quadrupollinií. Toto rozšíření však nebylo v této práci potvrzeno.

Podle výsledků získaných krystaly deformovanými popsaným způsobem je viděti, že byla získána při krajní rozlišovací mohutnosti značná světelnost, která se úplně vyrovná světelnosti moderních metod s elasticky ohnutými krystaly.
