The Spectroscopy of the Solid State: Copper and Chromium*

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The M_{23} emission curves of copper and chromium have been obtained by using a vacuum recording spectrograph.

WE have obtained the M_{23} (valence to $3P_{\frac{3}{2},\frac{1}{2}}$) emission curves of copper and chromium, using the spectrograph previously described.[1] We have made minor changes to facilitate focusing of the electron beam and to increase the power input into the evaporating furnace. Both curves have sharp emission edges and clearly show the M_{23} separation.

The chromium curve was taken with 600-volts bombarding voltage and 3-ma target current. The copper curve was taken with 500-volts bombarding voltage and 3-ma target current. The experimental curves are shown in Figs. 1 and 2. The range shown is from 40 to 160 counts per second. Both emission curves show satellites on the high energy side. In fact, at 700-volts bombarding voltage, the satellites completely obscure the emission edge. The curves were taken with the evaporation furnace running during the observation time, but even with this precaution, contamination (especially for chromium) was a serious problem. Therefore, the chromium curve had to be taken in a shorter time than was consistent with the response time of the counting-rate meter. As a result, the kink in the M_2 edge is due to the response time of the counting-rate meter and is not real. On curves where we only observed the high energy side, the inflection does not occur. In other respects, the chromium curve agrees with the curves taken with a slower speed of transversal over smaller energy ranges.

In Fig. 3 the experimental copper curve is plotted with the background eliminated and the ordinate divided by a factor proportional to the fourth power of the energy. The M_3 bands and M_2 bands are shown separated out by graphical means. The low energy end of the curve is not reliable, and this part of the curve

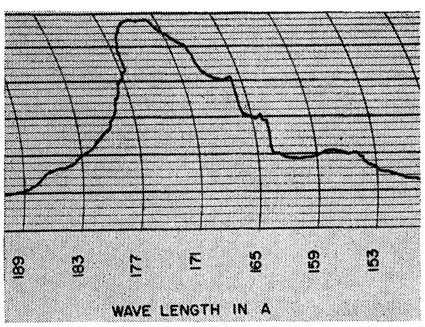

FIG. 1. Band emission curve of copper. $E_b=500$ volts, $I_b=3$ ma.

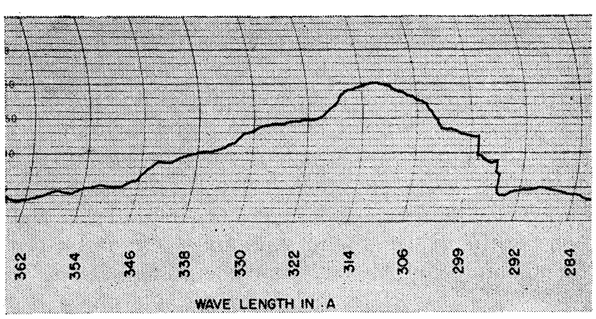

FIG. 2. Band emission curve of chromium. $E_b=600$ volts, $I_b=3$ ma.

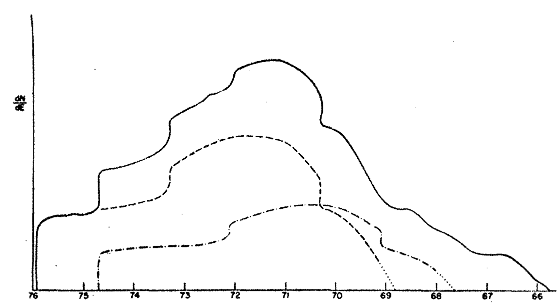

FIG. 3. Electron distribution in copper.

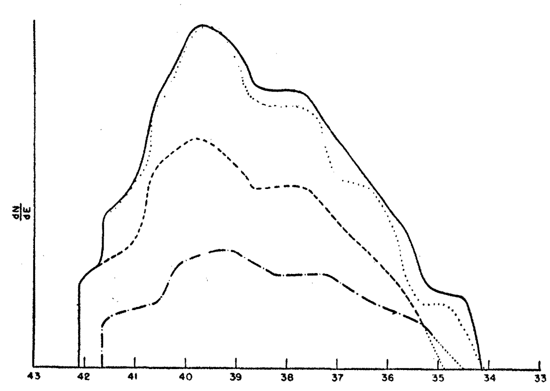

FIG. 4. Electron distribution in chromium.

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[1] Piore, Harvey, Gyorgy, and Kingston, Rev. Sci. Instr. 23, 8 (1952).

TABLE I. Summary of experimental results.

	Bandwidth (ev)	M_2 emission edge (ev)	M_{23} separation (ev)	Ratio of M_3 to M_2 intensities
Copper	7.1±0.5	75.9±0.2	1.2 ±0.1	0.51±0.03
Chromium	7.2±1.0	42.1±0.2	0.45±0.1	0.52±0.04

is emphasized by the E^4 factor. Therefore, the M_2 and M_3 bands were completed by the dotted lines at the low energy end, showing the probable position of the bottom of the Brillouin zone.

In order to minimize the effect of fluctuations, the average of experimental chromium curves is plotted modified by the E^4 factor in Fig. 4. The curve shown in Fig. 2 is shown (dotted) for comparison. M_2 and M_3 bands are completed by extrapolation.

The results are summarized in Table I.

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Elastic π-Carbon Scattering*

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Elastic scattering of 60-Mev π-mesons on carbon is analyzed to determine the following qualitative features of elementary π-nucleon scattering at this energy: p-wave scattering is predominant, with some s-wave interference at a relative phase that favors backscattering. The rather crude interpretation does not indicate d-wave scattering. Spin flip scattering is essentially absent from the C^{12} scattering. The Coulomb interference provides an absolute calibration, from which it is inferred that the p-wave "resonance" energy lies above 60 Mev.

1. INTRODUCTION AND SUMMARY

THE elastic scattering of 60-Mev π-mesons by carbon is analyzed to determine some qualitative features of the elementary π-nucleon scattering process. A second-order perturbation treatment is used, which takes into account the possibly "resonant" nature of the elementary scattering process. The final expressions are similar to a first-order scattering from C^{12} with the addition of a "form factor" arising from the asymmetry of the elementary scattering. A crude estimate of this asymmetry is obtained from comparison with the measured angular distribution from C^{12}. Because of the neglect of multiple scattering, the estimated asymmetry is actually a minimum estimate, and only qualitative conclusions can be drawn.

The qualitative conclusions are that for π-nucleon encounters at 60 Mev in the c.m. system (a) p-wave scattering is predominant, (b) some s-wave scattering is present, and (c) the relative phases of s- and p-wave scattering are such as to favor backscattering at the expense of forward scattering. The rather crude interpretation does not indicate the presence of d-wave scattering.

Spin flip of the nucleon in elastic scattering from C^{12} is forbidden by the exclusion principle. Its absence, within 20 percent limits, is indicated by the experimental data. This absence makes it impossible to determine from elastic C^{12} measurements the relative amounts of $p_{\frac{1}{2}}$ and $p_{\frac{3}{2}}$ scattering.

The pronounced Coulomb interference dip in the $C-\pi^+$ scattering at about 20° makes it possible to form some estimate of the absolute phases of the nuclear scattering amplitudes, since that of the Coulomb scattering is known. It is found that the p-wave scattering is compatible with a "resonance" at an energy higher than 60 Mev and with a half-width of the same order of magnitude. The s-wave scattering has rather little absorption and can be most satisfactorily represented in terms of a repulsive potential or possibly in terms of a far-away bound level of the meson.

2. FORMULATION

We wish to consider the scattering of π-mesons by an aggregation of nucleons, in particular C^{12}. The scattering is assumed to be the sum of single-nucleon scatterings alone; any scattering by multibody potentials is neglected. An important effect in the C^{12} scattering is the possibility that the individual nucleons do not scatter isotropically, as is generally the case if a quasi-compound state of an excited nucleon is formed.[1] A straightforward way to exhibit this anisotropy is by means of a second-order perturbation calculation. Suppose a nucleon fixed in space with internal wave function U_0 in the ground state and U_c in an unstable "compound" state of excitation energy $E_c-i\Gamma_c/2$. The cross section for elastic scattering of spinless mesons by a nucleon with initial spin $s_0=\frac{1}{2}$ is[2]

$$\sigma=\frac{\pi}{k^2}\frac{1}{(2s_0+1)}\sum_{m_i,m_f}\left|\left\langle m_i\left|\sum_c\frac{M_i^cM_f^{c*}}{E-E_c+i\Gamma_c/2}\right|m_f\right\rangle\right|^2, \quad (1)$$

* This work was performed under the research program of the AEC.

[1] K. A. Brueckner, Phys. Rev. 86, 106 (1952).
[2] H. A. Bethe and G. Placzek, Phys. Rev. 51, 450 (1937).