compared to the centrifugal barrier. A prominent peak at 150 Å has been observed in the soft x-ray absorption spectrum of tellurium by Woodruff and Givens.[8] They suggest that this peak is due to an interband transition from the $4p$ state to the conduction band. In our opinion this peak reflects the characteristic absorption of the $4d$ electron of the atom irrespective of crystal structure, for two reasons. The half-width of the maximum is two Rydbergs, greatly exceeding the width of any solid-state band. Secondly, the oscillator strength[9] associated with this peak is about 12, where typical interband transitions have oscillator strengths less than one.

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[10] Since this Letter was submitted, Lukirskii, Britov, and Zimkina [A. P. Lukirskii, I. A. Britov, and T. M. Zimkina, Opt. i Spectroskopiya 17, 438 (1964)] have published data on the photoionization cross section in xenon from 23 Å to 250 Å. They made six determinations of the cross section in the wavelength region covered by the present measurements. The agreement between the two sets of measurements is excellent.

INTERACTION OF MAXIMA IN THE ABSORPTION OF SOFT X RAYS

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Maxima have recently been detected in the photoabsorption cross sections of Ar[1,2] and Xe[3] which do not lie at or near any known absorption edge. These maxima, which are much too broad (~40-50 eV) to be interpreted as due to the excitation of autoionizing discrete states, represent a departure from the familiar hydrogenlike behavior of photoabsorption cross sections in the x-ray range where the cross sections increase sharply at absorption edges and then decrease monotonically and smoothly with increasing energy. This behavior follows from Stobbe's treatment[4] which utilizes a screened hydrogenic approximation for the wave functions of initial and final states, and provides an excellent description of the energy dependence of the photoeffect at excitation energies >10 keV.

The purpose of this note is to point out that the observed maxima are predictable by a one-electron nonhydrogenic central-field model. In fact the observations on Ar may be regarded as verifications of a result reported previously.[5] In order to explore the situation in Xe, further calculations utilizing the method of reference 5 have been performed for the $4d$ shell of Xe. The result shows a peak in the cross section even sharper and higher than that observed by Ederer.[3]

First consider the case of argon. In reference 5 the cross section for $3p^6$ photoionization was shown to have two maxima, one at threshold and a second one ~100 eV higher in energy. The existence of the second maximum was shown to be due to the dipole matrix element for $p \rightarrow d$ transitions having opposite sign at threshold and at large energies, implying that the partial cross sections for these transitions must vanish at some intermediate energy. While this calculation fails to match well the observed cross section near threshold, it should be much better at higher energies. Figure 1, which compares the observed and calculated cross sections in the region of the second maximum, supports this belief and the interpretation that the observed maximum at about 70 eV is a second maximum in the $3p^6$ subshell photoionization even though it lies energetically above the M_{I} edge. Corresponding secondary maxima are to be expected in the photoeffect cross sections of most elements,[6] although their detection may be obscured by their small size relative to the contributions from subshells lying closer to the nucleus.

In Xe the situation is somewhat different since we are concerned with the first maximum for ionization from the $4d^{10}$ subshell. A calculation of the cross section for this process[7] is shown along with the experimental results[3] in Fig. 2. The dominant contribution to this process at threshold arises from $d \rightarrow p$ transitions since the f wave is excluded from the region of maximum charge density of the $4d^{10}$ subshell by the centrifugal force. This is confirmed experimentally by the observation of discrete structure below the ionization threshold corresponding to transitions $4d^{10} \rightarrow 4d^9np$ without any trace of the corresponding $4d^{10} \rightarrow 4d^9nf$ transitions.[8] As the energy increases the f wave can penetrate the centrifugal barrier so the partial cross section for $d \rightarrow f$ transitions rises rapidly and becomes the dominant contribution. However, $4d^{10}$ is a nodal subshell[6] similar to $3p^6$ in argon so the dipole matrix element will have opposite signs at threshold and at much higher energy; consequently, the $d \rightarrow f$ partial cross section must return to zero at an intermediate energy.

In the calculation this zero occurs at ~80 eV above threshold, and this accounts for the calculated shape of the cross section. Also, it should be noted that a second extremely broad maximum at much higher energies appears in the cross section, analogous to the second maximum in Ar. Correlations, due primarily to exchange effects,[9] would, if included, broaden and shift to higher energies the first maximum of the ionization cross section for both the Xe $4d^{10}$ and Ar $3p^6$ subshells. These effects, which are neglected in our model, should account for the difference between observed and calculated cross sections in both cases.

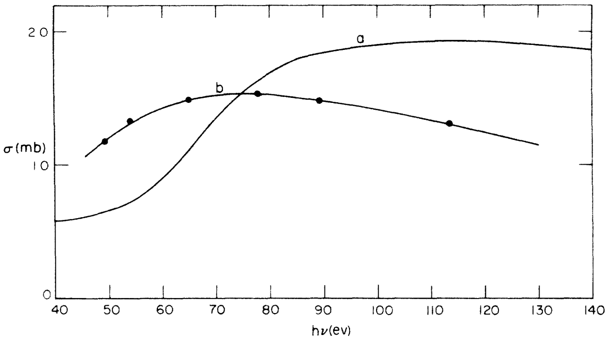

FIG. 1. Photoinization cross sections for Ar. (a) is the calculated curve for ionization from the $3p^6$ subshell; (b) is the experimental curve of reference 1. Experimental points are indicated by solid circles.

The rapid rise of the Xe cross section from threshold to its maximum is related to xenon's lying just before the rare earths in the periodic table. A $4f$ electron bound in Xe has an orbit lying mostly outside the occupied $n = 5$ orbits. However, if the potential were slightly stronger the electron would lie <u>within</u> the $n = 5$ shell and, consequently, would have its maximum charge density much closer to the nucleus

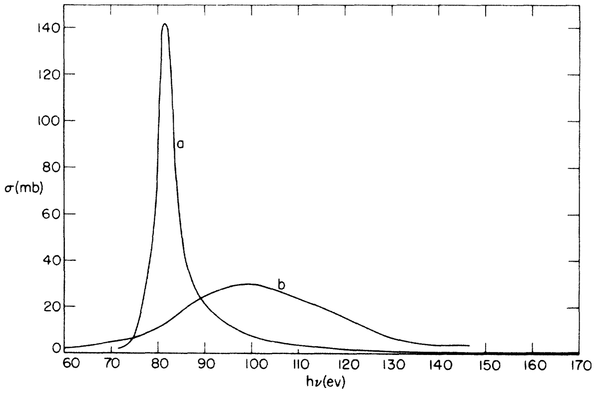

FIG. 2. Photoionization cross sections for Xe. (a) is the calculated curve for ionization from the $4d^{10}$ subshell; (b) is the experimental curve of reference 3.

Table I. Position of the first maximum in the f radial wave function of Xe vs incident energy.

E (eV)	R_{max} (a.u.)
71.5	9.6
75.8	5.9
78.3	1.1
81.7	0.94
85.1	0.88
100	0.75

and a much higher binding energy. In fact, it is this rapid increase in binding energy as a function of Z which causes the $4f$ subshell to start filling at $Z = 58$.[10] For Xe ($Z = 54$) this behavior of the $4f$ orbital as a function of Z is reflected in the f continuum wave as a function of energy. Thus the first maximum of the f-wave radial function will shift from outside the $n = 5$ shell to inside it with increasing energy just as the single maximum of the $4f$ wave function shifts when Z increases past 58 and the $4f$ becomes an inner subshell. This behavior is shown in Table I.

The above effects are expected to be typical of the behavior of photoeffect cross sections in the soft x-ray region. Peaks away from thresholds represent a breakdown of the hydrogenlike treatment of the photoeffect, but not of the one-electron central-field treatment. Collective effects are certainly present, but they tend only to smooth out the rapid variations of the cross section predicted by the one-electron model.

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[6] Secondary maxima exist only in the photoeffect from subshells whose radial wave functions have nodes. A discussion of this point, based on the calculations reported in reference 5, has been given. See U. Fano, Proceedings of the Second International Conference on the Physics of Electronic and Atomic Collisions, Boulder, Colorado, June 1961 (W. A. Benjamin, Inc., New York, 1961), pp. 10-11. A calculation for the $3d^{10}$ subshell of Kr, whose radial wave function is nodeless, shows only a single, low, very broad maximum.

[7] In these calculations we have used the $4d$ orbital and effective central potential given by F. Herman and S. Skillman, in Atomic Structure Calculations (Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1963). The method of calculation is the same as that discussed in reference 5.

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CALCIUM-37†

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This Letter reports the observation of the previously unreported ^{37}Ca by measurements on the delayed protons following its β^+ decay.

There has been much recent interest in the detection of solar neutrinos by means of the reaction $^{37}\mathrm{Cl} + \nu_{\mathrm{solar}} \to {}^{37}\mathrm{Ar} + e^-$. Bahcall[1] has shown that this reaction may proceed either to the ground or to any of three excited states of ^{37}Ar. The total cross section for this reaction was predicted using the measured lifetime for the ground-state inverse transition $^{37}\mathrm{Ar} \to {}^{37}\mathrm{Cl}$, a calculated ft value for the transition to the first $T = \frac{3}{2}$ state of ^{37}Ar, and estimated ft values for transitions to the two other excited states.

It has been pointed out[2] that a better estimate for branching to the latter two states can be obtained from a knowledge of the lifetime of ^{37}Ca, since the positron decay of $^{37}_{20}\mathrm{Ca}_{17}$, namely $^{37}\mathrm{Ca} \to {}^{37}\mathrm{K} + e^+ + \nu$, is the mirror reaction