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DISCLAIMER

OBSERVATION OF DYNAMIC E2 MIXING VIA KAONIC X-RAY INTENSITIES*

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ABSTRACT

We have observed a nuclear resonance effect between a kaonic atom and a nuclear transition in ^{98}Mo. Our measurement gave $^{98}\text{Mo}(n=6\rightarrow5)/^{92}\text{Mo}(n=6\rightarrow5) = 0.16 \pm 0.16$ instead of the no-mixing value of 1. Dynamic E2 mixing caused kaons to be strongly absorbed from the ^{98}Mo atomic state n=6, ℓ=5 in agreement with theoretical predictions.

Several authors[1] have considered the effect of dynamic E2 mixing of the states of nuclei and hadronic atoms. The effects were generally believed to be small. However, M. Leon[2] found that for certain nuclei the effect would be significant for kaonic atoms and would drastically alter the intensity ratios of some of the x-ray lines. The effect occurs when the energy of a nuclear excited state nearly equals a kaonic atom de-excitation energy. In ^{98}Mo mixing of the $|\text{kaon } n=6,\ell=5\rangle|\text{nucleus } 0^+$ ground state$\rangle$ with the $|\text{kaon } n=4,\ell=3\rangle\,|\text{nucleus } 2^+$ excited$\rangle$ is expected to cause kaons to be strongly absorbed from the new $n=6,\ell=5$ eigenstate. Leon predicted that in ^{98}Mo the ratio $I(n=6\rightarrow5)/I(n=7\rightarrow6)$ should be attenuated from 0.93 (no mixing) to 0.18 (with mixing). We measured this ratio to be 0.13 ± 0.13 which is consistent with mixing. Furthermore, we looked at the x rays from ^{92}Mo in which no mixing is expected due to the large difference between kaonic and nuclear transition energies. With no mixing it is reasonable to assume that the kaon's atomic capture and subsequent cascade were identical in ^{92}Mo and ^{98}Mo. In ^{92}Mo we measured $I(n=6\rightarrow5)/I(n=7\rightarrow6) = 0.83 \pm 0.14$, which is consistent with Leon's ^{98}Mo (no mixing) value of 0.93. The presence of the mixing effect is most obvious in comparing ^{98}Mo and ^{92}Mo where we found $^{98}\text{Mo}(n=6\rightarrow5)/^{92}\text{Mo}(n=6\rightarrow5) = 0.16 \pm 0.16$.

Using the new high efficiency kaon beam at the Bevatron, we obtained the kaonic x-ray spectra of ^{98}Mo and ^{92}Mo. In a previous paper[3,4] we reported the intensities of the kaonic x rays of ^{nat}Mo. We noticed that the $n=6\rightarrow5+n=8\rightarrow6$ intensity was lower than for neighboring elements but were not certain of its significance before testing some pure isotopes of Mo. Fig. 1 shows portions of the experimental spectra obtained for

^{92}Mo and ^{98}Mo. Approximately the same number of kaons stopped in each target as evidenced by the equal intensity n=7→6 lines. Clearly the n=6→5 line is present in ^{92}Mo and absent in ^{98}Mo.

Table I shows the results of our measurements. We could not make a new calibration of the number of kaons stopped for lack of accelerator time. Therefore, absolute intensities are given for the new data by setting the ^{92}Mo n=8→7 intensity and the ^{98}Mo n=8→7 intensity equal to the n=8→7 intensity of ^{nat}Mo. There should be no isotope effect for n=8→7 transitions. We know the relative number of kaons stopped in ^{98}Mo and ^{92}Mo and found I(n=8→7) equal for the two targets.

Columns 2 and 3 of Table II show the calculated kaonic n=6→4 transition energy and the nuclear $0^+ \to 2^+$ transition energies for ^{98}Mo and ^{92}Mo. No mixing is expected in ^{92}Mo due to the large energy difference. Leon's calculated mixing amplitude a is in the fourth column. The factor a is defined by

$$\left|\begin{matrix}\text{New n=6→5 eigenstate}\\ \text{of the K-nucleus system}\end{matrix}\right\rangle = \left|\begin{matrix}\text{kaon}\\ n=6,\ell=5\end{matrix}\right\rangle \left|\begin{matrix}\text{nucleus}\\ 0^+\text{ ground}\end{matrix}\right\rangle + a\left|\begin{matrix}\text{kaon}\\ n=4,\ell=3\end{matrix}\right\rangle \left|\begin{matrix}\text{nucleus}\\ 2^+\text{ excited}\end{matrix}\right\rangle$$

The fifth column shows the predicted attenuation in I(n=6→5) for the mixing.

In conclusion, we have for the first time observed the effect predicted by Leon, that kaonic atom x-ray intensities can be attenuated if the nucleus has a correctly placed excited state that is reachable from the ground state by an E2 transition.

We express our appreciation to the Bevatron Engineers, especially Christoph Leemann, for the new beam and to the Nuclear Instrumentation Group for the latest models of their x-ray spectrometers.

FOOTNOTE AND REFERENCES

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CAPTION FOR FIGURE

Fig. 1. Portions of the kaonic x-ray spectra of ^{92}Mo and ^{98}Mo showing the attenuation of the n=6→5 line in ^{98}Mo.

TABLE I. Intensities of kaonic x-ray lines. Data for ^{nat}Mo were taken from Ref. 3. Column 1 lists the targets. Columns 2 and 3 give the principal quantum numbers of the initial and final states. Intensities in x rays per kaon stopped in the targets are listed in column 4 and their statistical errors in column 5. The asterisk (*) indicates that the intensities were scaled so that I(n=8→7) equals ^{nat}Mo I(n=8→7). Improved detectors that were able to resolve n=8→6 transitions (281.8 keV) from n=6→5 (284.3 keV) were used for ^{92}Mo and ^{98}Mo.

Nuclei	n_i	n_f	I x rays per K_{stop}	ΔI
^{nat}Mo	8	7	0.21	0.016
	7	6	0.21	0.015
	8	6		
	+ 6	5	0.11	0.019
^{92}Mo	8	7	*0.21	0.015
	7	6	0.23	0.017
	6	5	0.19	0.029
^{98}Mo	8	7	*0.21	0.016
	7	6	0.24	0.019
	6	5	0.03	0.029

TABLE II. Parameters used by Leon[2] to calculate the dynamic E2 mixing effect in ^{98}Mo and in ^{92}Mo. The n=6' state is a mixture of the n=6 state and the n=4 state. The asterisk (*) indicates that the ratio has been assumed to be 1.00 for ^{92}Mo.

Target (1.1 g/cm^2)	Calculated kaonic $(n=6,\ell=5)\rightarrow(n=4,\ell=3)$ energy in keV	Nuclear $0^+\rightarrow 2^+$ energy in keV	Mixing amplitude $\lvert a \rvert$	Calculated $\frac{I(n=6'\rightarrow 5)}{I(n=6\rightarrow 5)}$	Experimental $\frac{I(n=6'\rightarrow 5)}{I(n=6\rightarrow 5)}$
^{98}Mo	798.2 -i 12.7	787.4	0.033	0.19	0.16 $\pm$0.16
^{92}Mo	799.1 -i 12.7	1540.	0.001	1.00	1.00*

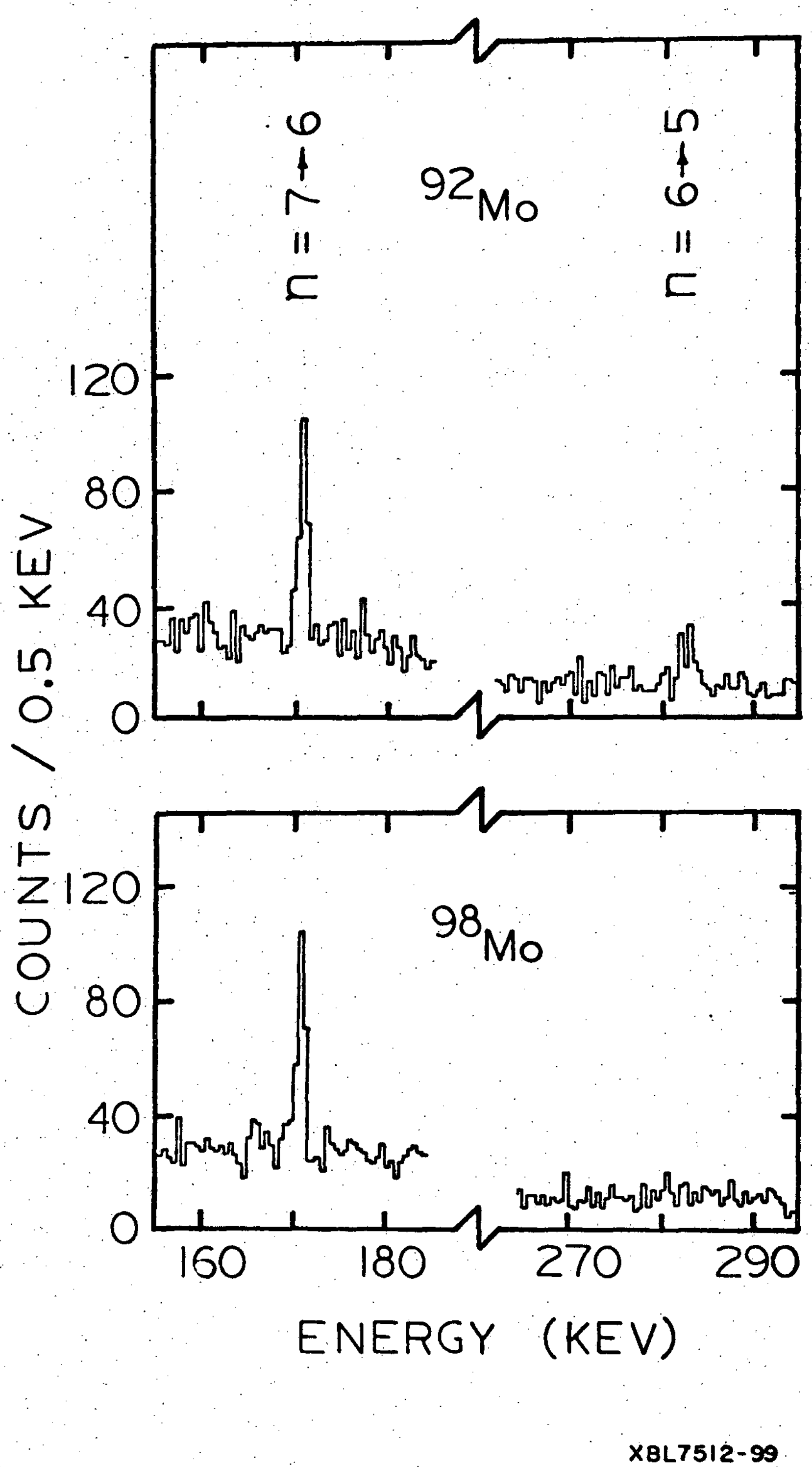
n = 7→6
n = 6→5
92Mo
98Mo
COUNTS / 0.5 KEV
120
80
40
0
160
180
270
290
ENERGY (KEV)
XBL7512-99

Fig. 1.

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