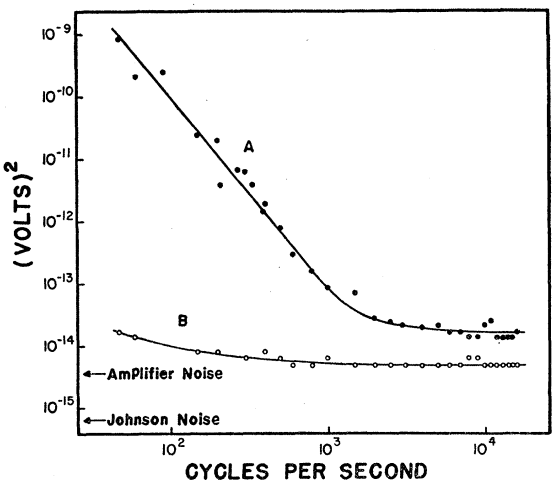

FIG. 1. Noise spectra (13-cps band width) for InSb photocell cooled to 77°K. *A* is for 300°K background. *B* is for 77°K background.

Avery *et al.*[1] for pure InSb. The time constant of the response was less than 2 microseconds, the minimum value that could be measured with our present apparatus.

Figure 1 shows noise spectra for the cell at 77°K. Curve *A* was observed when the cell was exposed to room-temperature radiation. Curve *B* was observed when the cell was covered with a light shield at 77°K. Shielding decreased the noise at all frequencies. The noise given by curve *B* is virtually amplifier noise and the slight rise at low frequencies is attributed to a small radiation leak. The Johnson noise for the cell was below amplifier noise. For the cell exposed to 300°K radiation the noise showed a white spectrum above 2 kc/sec while below 2 kc/sec it followed an approximate f^{-d} law with $d\cong 3$. This result is a curious one since the cell was operated without bias.

It is interesting to compare the detectivity of the cell exposed to a 300°K background with the limiting detectivity set by photon noise.[2] To compute the latter, it is assumed that the cell has unity quantum efficiency for $\lambda<5.5\mu$ and cuts off abruptly. Considering only the noise created by random arrival of photons, the theoretical detectivity of a 1 mm^2 cell is calculated to be 1.1×10^{-8} sec/photon. The measured detectivity is 0.09×10^{-8} sec/photon. The conditions of measurement were: cell area 1 mm^2, responsivity 10.5 volts/(watt/cm^2) at 2μ, noise 0.11 microvolt for $f>2$ kilocycles and a band width of 13 cps.

A more detailed account of this work will be published in the future.

The authors are indebted to Mr. H. Berman for valuable discussion and criticism.

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Energies of the *K* Transitions of π^- Mesonic X-Rays*

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IN a previous letter[1] we reported on the energy shifts, presumably arising from specifically nuclear interactions, of the $2p\rightarrow1s$ π-mesonic x-rays in lithium and beryllium. For these elements the energy was measured with the critical absorption technique. Here we wish to report further on measurements of *K*-transition energy shifts in carbon, nitrogen, oxygen, and fluorine. Since the critical absorption method could not be extended to these elements, the energy was determined by a measurement of pulse height.

The experimental setup has been previously described.[2] For the present measurements the scale of the pulse height selector was calibrated by means of other mesonic x-ray lines whose energies could be calculated sufficiently accurately (see Table I). The experimental procedure was to bracket each *K* line under investigation with two or more calibration lines. The line to be measured and its calibrating lines were run alternately at least three times. Usually the reproducibility was excellent, peaks drifting only a fraction of a channel, so that the data could be added to give better statistics. μ-meson transitions were used as the calibrating lines for oxygen and fluorine since for $Z\gtrsim17$ there may be measurable nuclear shifts in the π $3d\rightarrow2p$ transition energies

TABLE I. Computed energies of $2p\rightarrow1s$ transitions and their calibrating lines.

Element for π $2p\rightarrow1s$	Element for calibration	Type meson	Type of transition	Uncorr. trans. energy[a] (kev)	Vac. polar. corr.[b] (kev)	Finite size corr.[c] (kev)	Corrected energy (kev)
Be	P	π	$4f\rightarrow3d$	40.4	+0.10		40.5
	F	π	$3d\rightarrow2p$	41.4	+0.13		41.5
				43.8	*+0.20*	*−0.12*	*43.9*
	Cl	π	$4f\rightarrow3d$	51.9	+0.15		52.1
C	Al	π	$3d\rightarrow2p$	86.7	+0.37		87.1
		π		*99.2*	*+0.57*	*−0.76*	*99.0*
	Si	π	$3d\rightarrow2p$	100.6	+0.43		101.0
N	P	π	$3d\rightarrow2p$	115.6	+0.53		116.1
				135.4	*+0.84*	*−1.57*	*134.6*
	S	π	$3d\rightarrow2p$	131.6	+0.63		132.2
O	Cl	π	$3d\rightarrow2p$	148.7	+0.74		149.4
	O	μ	$2p\rightarrow1s$	134.4	+0.77	−1.28	133.9
				177.3	*+1.20*	*−2.92*	*175.5*
	F	μ	$2p\rightarrow1s$	170.3	+1.04	−2.31	169.0
	K	π	$3d\rightarrow2p$	186.0	+0.97		186.9
F	F	μ	$2p\rightarrow1s$	170.3	+1.04	−2.31	169.0
				225.0	*+1.60*	*−5.27*	*221.3*
	Na	μ	$2p\rightarrow1s$	254.8	+1.73	−5.84	250.7

[a] The π^- energies were calculated with the Klein-Gordon equation by using the reduced π^--meson mass (assuming $m\pi^-=272.5m_e$) and a point-charge Coulomb potential. The μ^- energies were calculated similarly, but with the Dirac equation and the assumption $m\mu^-=207.0m_e$.

[b] Vacuum polarization correction; H. C. Corben and A. Mickelwait, Phys. Rev. (to be published).

[c] Finite size correction; made by using hydrogenic wave functions in a first order perturbation calculation neglecting the specifically nuclear interaction between meson and nucleus.

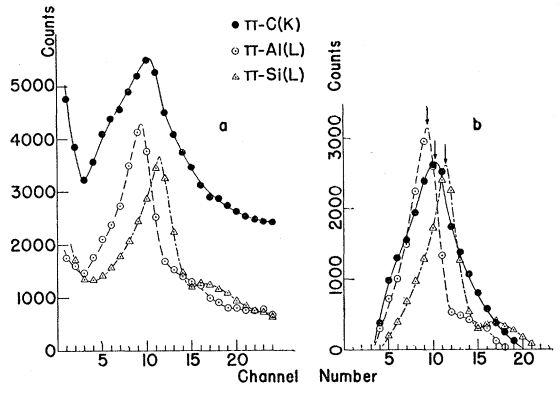

FIG. 1. Typical set of data for carbon and its calibration lines. Part (a) shows the data as obtained directly on the pulse height selector. Part (b) shows the peaks obtained after subtracting the background. In this particular run the shift obtained for carbon was (-5.6 ± 3) percent.

themselves. For $Z\lesssim16$ no discernible shifts were found when checks were made of the $3d\rightarrow2p$ π lines against $2p\rightarrow1s$ μ lines (of comparable energy).

Typical runs are shown in Figs. 1(a) and 2(a). After subtraction of background [Figs. 1(b) and 2(b)] the peak positions were determined and the energy of the investigated line was obtained by interpolation. Several runs of the kind described were made for each element and the resultant energies were then averaged to obtain the final measured energy.

The theoretical energies of the π $2p\rightarrow1s$ transitions were computed without taking into account nuclear

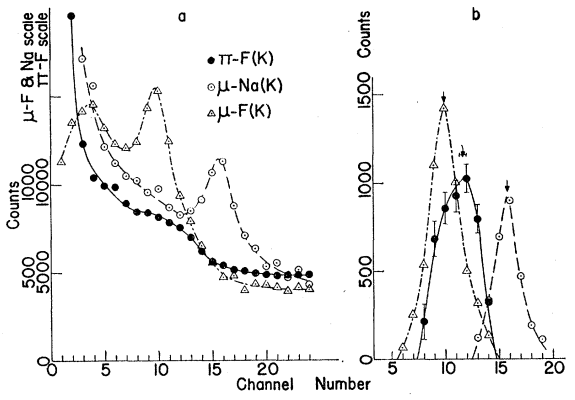

FIG. 2. Typical set of data for fluorine and its calibration lines. Part (a) shows the data as obtained directly on the pulse height selector. Part (b) shows the peaks obtained after subtracting the background. In this particular run the shift obtained for fluorine was (-14.5 ± 4) percent. The fluorine K yield is quite small, about 10 percent that of carbon (see reference 2).

interactions (Table I). The result of the comparison between the experimental and calculated energy is shown in Fig. 3 in the form of percentage shifts. The errors indicated express the reproducibility of the data when one takes into consideration statistics, background subtraction, and the consistency of repeated runs. However, they do not include possible systematic errors such as Compton degradation and the presence of unresolved lines in the observed peaks.

The effect of Compton degradation in the target material was investigated experimentally with radioactive sources and was found to produce no detectable shift in peak position, although some broadening of the line was observed on the low-energy side. Unresolved lines can arise from μ mesons stopping in the target, from π mesons stopping in surrounding materials, and from higher π-meson K transitions. There is good experimental evidence that the contribution from stopped μ mesons is negligible. A weak π carbon line arising from mesons stopping in counters could be observed, but its effect on the determination of the peak position could be adequately estimated. Perhaps the most troublesome of the unresolved lines would be the $3p\rightarrow1s$ π-meson transition which is 18 percent higher than the $2p\rightarrow1s$ line under investigation. The effect of any such additional K transition would be to make the observed peak energies appear too high and therefore give smaller measured shifts than would exist for pure $2p\rightarrow1s$ lines. A measure of such an effect might be obtained by comparing with the critical absorption technique. In the case of beryllium, where the energy could be measured by both methods, the agreement is within the accuracy of the experiments. For carbon only a lower limit on the energy shift could be obtained with the critical absorption technique, and this is in agreement with the measured peak position energy. This would indicate that for these elements there is not very much of the higher K lines in the observed peaks; however, their relative abundance is likely to increase with higher Z. Such an additional component might reveal itself as a broadening of the peaks, and indeed we observe that the π K lines are wider than the

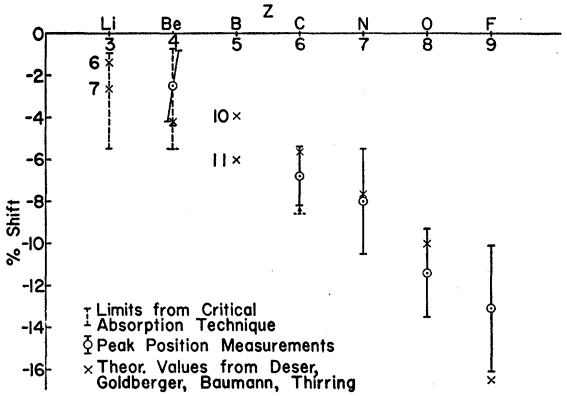

FIG. 3. Percent shift of the measured K transition peak energies relative to the calculated $2p\rightarrow1s$ lines. Measurements from both peak position and critical absorber work are shown. The errors indicated are estimates of standard deviations and do not include possible systematic errors. Agreement with the theoretical points may be fortuitous for the several reasons given in the text.

calibrating lines of the same energy. Though the additional width could be due to nuclear capture from the $1s$ level, it is possible that it originates at least in part from this unresolved line. In the case of μ mesons a corresponding broadening is not observed, but the different behavior of the two mesons could be explained in terms of the large nuclear capture probability of pions in the $2p$ state, which thus depresses the $2p\rightarrow 1s$ line relative to the $3p\rightarrow 1s$.

There have been some recent theoretical investigations[3,4] on the nuclear shifts of the $1s$ π-mesonic level. In Fig. 3 we have plotted the results obtained from the paper of Deser, Goldberger, Bauman, and Thirring. The agreement with experiment is quite good. However, this may be fortuitous both because of some possible $3p\rightarrow 1s$ admixture in our peaks, and because of the extrapolation and oversimplification involved in the theoretical estimate. In addition our preliminary results on boron, though not yet sufficiently consistent to be reported, seem to contradict the trend indicated in Fig. 3.

* Supported in part by the U. S. Atomic Energy Commission.
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Average Number of Neutrons Emitted During the Spontaneous Fission of Cf^{252}*

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THE average number of neutrons per spontaneous fission of Cf^{252} has been found to be 3.10 ± 0.15 by the manganous sulphate moderator-absorber system.

Since the discovery of spontaneous fission by Petrzhak and Flerov[1] in 1940, measurements of the number of neutrons per fission, ν, have been made upon various nuclides. Littler[2,3] and Barclay, Galbraith, and Whitehouse[4] found the best value of $\nu(U^{238})=2.4\pm0.2$, and the latter authors report $\nu(Th^{232})=2.6\pm0.3$. Recently, Barclay and Whitehouse[5] measured $\nu(Cm^{242})=3.0\pm0.3$.

Since the ratio of alpha decay to spontaneous fission is only about 42 in the decay of Cf^{252},[6] there is no measurable contribution from (α,n) reactions on low Z elements to the total number of neutrons observed from a sample. For this reason, Cf^{252} makes an ideal standard for the calibration of other neutron counting devices.

A sample of Cf^{252} of about 5×10^{-3} micrograms was mounted on a one-inch platinum disk and the number of fissions per minute was determined by direct counting. The sample was placed in a Lucite tube and immersed in a tank filled with saturated $MnSO_4$ solution until the Mn^{56} radioactivity formed by neutron capture in Mn^{55} had reached an equilibrium level. The sample was removed and the intensity of the radiations from the Mn^{56} in the tank was measured with an immersion counter which utilized an NaI crystal as a detector. The tank and counter were calibrated by measuring the activity produced from a standardized mock fission source,[7] and by comparing the activity produced by the fission spectrum from Cm^{244} in this tank with that produced in a tank which was large enough to be essentially infinite for the absorption of the neutrons from standard polonium-beryllium sources. Neutrons from the polonium-beryllium sources are presumed to be more energetic than those from any spontaneous fission source.

Over-all errors in the average value obtained from several measurements are thought to be less than 5 percent. Work is continuing on several other heavy element nuclides.

We wish to express our gratitude to J. Harper and L. Mann for their work on the electronic equipment.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
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Hyperfine Splitting and the Sign of the Magnetic Moment of Cs^{134m}

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PREVIOUSLY published low-frequency data[1,2] from magnetic resonance experiments with 3.1-hr Cs^{134m} atomic beams, when correctly substituted in the Breit-Rabi equation, yield a hyperfine splitting $\Delta\nu=3684.3\pm0.5$ Mc/sec if a positive nuclear magnetic moment is assumed, and $\Delta\nu=3695\pm0.5$ Mc/sec if this magnetic moment is taken to be negative.

The direct hyperfine transition in Cs^{134m} has been observed at 3684.5 ± 0.5 Mc/sec in an atomic beam experiment at this laboratory. The previous data and the present measurement are consistent only with the assumption of a positive nuclear magnetic moment.

Details will be published in a paper to be submitted in the near future.

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