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**R.Arlt, R.Engfer, W.D.Fromm , Dz.Gansorig,
T.Krogulski, H.-G.Ortlepp, S.M.Polikanov
B.M.Sabirov, U.Schmidt, H.Schneuwly**

EMISSION OF SHIFTED ELECTRONIC X-RAYS FROM MUONIC URANIUM ATOMS

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R.Arlt,[1] R.Engfer,[2] W.D.Fromm , Dz.Gansorig,
T.Krogulski, H.-G.Ortlepp, S.M.Polikanov
B.M.Sabirov, U.Schmidt, H.Schneuwly[3]

EMISSION OF SHIFTED ELECTRONIC X-RAYS FROM MUONIC URANIUM ATOMS

[1] Technische Universität, Dresden, DDR.

[2] Laboratory for High Energy Physics, ETH-Zürich, Switzerland.

[3] Physics Department, University of Fribourg, Switzerland.

Арльт Р., Энгфер Р., Фромм В.Д., Ганзориг Ж., Крогульски Т., Ортлепп Х.-Г., Поликанов С.М., Сабиров Б.М., Шмидт У., Шнефли Г.

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Эмиссия смещенного рентгеновского электронного излучения при образовании мюонных атомов урана

Обнаружено новое физическое явление: при образовании мюонных атомов урана происходит эмиссия смещенного электронного рентгеновского излучения.

Предполагается, что наблюдаемый эффект обусловлен неполной экранировкой единичного атомного заряда ядра мюоном.

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Arlt R., Engfer R., Fromm W.D., Gansorig Dz., Krogulski T., Ortlepp H.-G., Polikanov S.M., Sabirov B.M., Schmidt U., Schneuwly H.

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Emission of Shifted Electronic X-Rays from Muonic Uranium Atoms

The electronic X-ray lines from muonic uranium atoms have been observed. These lines have occured to be shifted on some hundreds of electronovolts respectively to characteristic X-rays of photoactinium.

One of possible experiments is incomplete screening of one charge unit of the nucleus by muon in its orbits.

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Dubna, 1974

At the negative muon beam of the JINR synchrocyclotron the γ-rays emitted in the interaction of μ^- with metallic uranium were measured in the energy range from 14 to 500 keV.

The measurements were performed with Ge(Li) detectors of 2.4 and 3 cm^3 volume each and an energy resolution better than 1 keV at 100 keV. The μ-stop events in the uranium target were registered in the counter telescope consisting of four plastic scintillators operating in the usual $123\bar{4}$ coincidence mode. The time distribution of gamma-events was measured with a time-to-pulse height converter. Energy spectra corresponding to different time intervals with respect to the μ-stop moment were recorded by means of a digital discriminator unit working on-line with the HP 2116 C computer.

The energy calibration was performed with the standard gamma-ray sources of ^{169}Yb, ^{241}Am and ^{57}Co /1/ and well-known muonic transitions of the light elements C, N and O /2/ which were also present in our spectra.

The γ-rays from the radioactive sources were detected continuously in the experiments as chance coincidences with the μ-stop signal in a wide time interval (1.5 μs). The spectra were analysed with the computer code GAMMA at the CDC 6200 computer. The lines were approximated with symmetric gaussian. In the case of single peaks a linear background was used, elsewhere, a parabola was applied. The nonlinearity of the apparatus was described with a cubic polynomial.

In the figure the prompt and delayed γ-ray spectra are shown. In the prompt spectrum muonic transitions of uranium and the light elements mentioned are visible. Electronic X-rays of uranium which are produced by the muons stopping in the target are also present. In the delayed spectrum the electronic X-rays of protactinium and uranium originate from nuclear muon capture and excitation of the target material by secondary particles.

Table
Energies of electronic X-ray transitions

	Pa [keV] (1)	Pa* [keV] (exp)	μU [keV] (exp)	μU−Pa [eV]
$K\alpha_2$	92.287	92.341 ± 0.056	92.616 ± 0.076	329 ± 76
$K\alpha_1$	95.868	95.807 ± 0.055	96.250 ± 0.051	382 ± 51

(1) Ref. /3/.

Their activity decays with a mean life-time of $\tau \sim 80$ ns which is characteristic for the life-time of the μ^- in the 1s orbit in heavy elements. The energies of the measured X-rays of U and Pa are in good agreement with the published data (table). In the prompt spectrum there exists a group of 2 lines forming a pattern like X-rays from $Z=91$, but shifted more than 2 channels to higher energies. Furthermore in the spectra there are no unidentified transitions. Therefore, it seems to be evident that the shifted lines are the electronic X-rays of muonic uranium atoms.

Vacancies in the K-shell are produced by muonic Auger transitions. The shifted X-rays may result in their refilling process if the screening of one charge unit of nucleus is not complete as one has to expect for sufficient high muonic orbits according to Vogel's predictions /4/. It should however be noted that at least a part of the observed shifts can be explained by the presence of additional vacancies in the L-shell at the moment of the

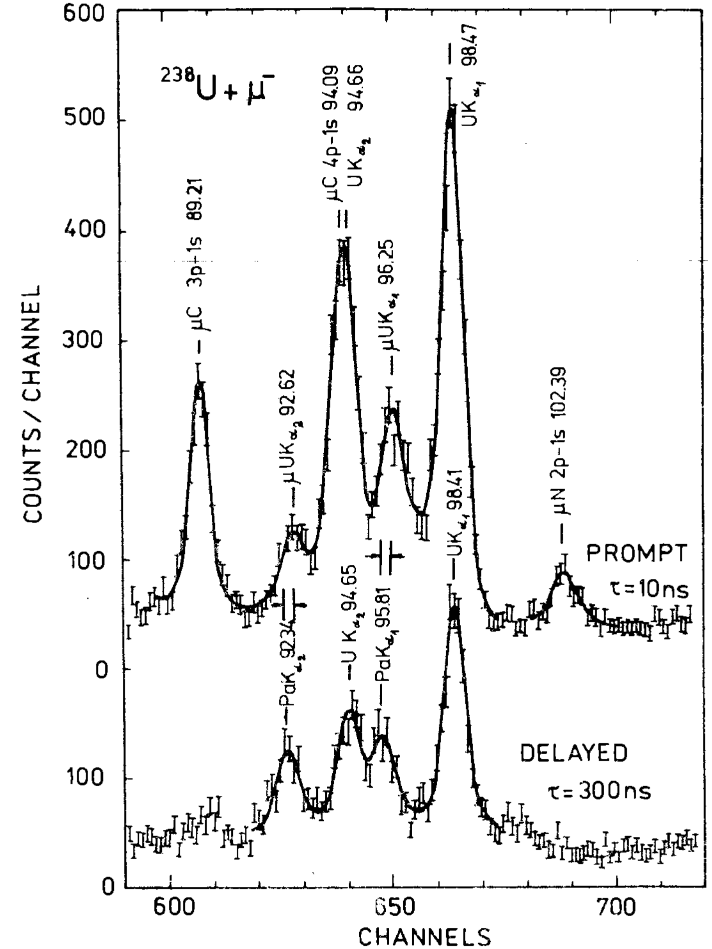

Fig. Electronic X-ray spectrum observed in the interaction of negative muons with uranium. Between the prompt and delayed spectra a pause of 20 ns was inserted. The full lines indicate the results of the fit to the data which are drawn with statistical errors. The numbers quoted behind the line identifications are the corresponding energies in keV. μZ -muonic atom of the element Z.

atomic KX -transition. A similar situation exists in the X -ray emission accompanying heavy ion collisions [5].

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References

1. N.Lavi. Nucl.Instr. Meth., 107, 197 (1973);
   R.C.Greenwood et al. Nucl.Instr. Meth., 77, 141 (1970).
2. T.Dubler et al. Nucl.Phys., A219, 29 (1974).
3. E.Storm and H.I.Isreel. Nucl. Data Tables, A7, 641 (1970).
4. P.Vogel. Phys.Rev., A7, 63 (1973).
5. D.Burch and R.Patrick. Phys.Rev.Lett., 25, 938 (1970).

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