a set of foils, thick at the outer radius but thinning to zero about one inch inside the inflector radius. The injected beam particles lose a few Mev in ionization in the foils; so their equilibrium orbit radii shrink enough to clear the inflectors after the first turn. After several turns, the beam particles have equilibrium orbits at radii at or less than the inside edge of the foils.

The possibility exists of storing a number of beam pulses in these storage rings, since space charge and gas scattering effects are small at high energies. Preliminary calculations have been carried out on a hypothetical set of storage rings for the 3-Bev, 20 cycle per second Princeton-Pennsylvania proton synchrotron. Since the storage rings would be simple and almost entirely passive devices, their cost would be small compared with that of the accelerator itself. It was estimated that a pair of storage rings operating at 18 000 gauss with a 2 in.$\times$6 in. good-n region would weigh a total of 170 tons. The magnet of the synchrotron itself would weigh 350 tons, and would be of much more complicated laminated transformer iron. In the event that one could obtain an average current of 1 microampere from the synchrotron, and an average particle lifetime of a few seconds for the storage rings, there would be about 1000 strange-particle-producing reactions per second at each of two beam crossover points, for an estimated 1.5-millibarn total cross section. The center-of-mass energy, 7.8 Bev, would be equivalent to that of a 31-Bev conventional accelerator. If storage rings could be added to the 25-Bev machines now being built at Brookhaven and Geneva, these machines would have equivalent energies of 1300 Bev, or 1.3 Tev.

If only one storage ring were used, tangential to the accelerator itself, the interaction rate would be reduced by a factor S/D, where S is the average number of beam pulses stored in each ring, and D is the fraction of time the accelerator beam is at full energy. The interaction rate would be proportional to S^2 if two storage rings were used.

The advantage of systems involving energy-loss foils is that they provide an element of irreversibility; with foils, the area in phase space available to a particle can be made to decrease with time. This makes it possible to insure that particles once injected will never subsequently strike the injector, no matter how long they may circulate in the storage ring. Preliminary work with a stabilized electronic analog computer indicates that foils may also allow the stable and irreversible capture of roughly half of the circulating particles by a fixed-frequency rf system, which in turn may allow the storage of a large number of beam pulses in each storage ring. It appears that a thin hydrogen jet inside the equilibrium orbit of a conventional synchrotron would, in some energy ranges, reduce radial betatron oscillations even when scattering is taken into account.

The major difficulties in the use of storage rings with foils may result from the amplification of radial betatron oscillations by the foils. Quantitative calculations of this effect have been carried out on the analog computer. It was found that the effect would be serious unless the initial injection to the storage rings could be very precise. However, calculations were also made on a system involving a second foil placed at the inner limit of the good-n region. This foil would move the particle orbits inward as soon as betatron oscillation became serious, and would then continue reducing the betatron oscillation amplitude until the foil itself was rotated out of the median plane. During the long interval (about 0.1 second, or 600 000 turns) before the next beam pulse, the betatron oscillations would continue to be reduced by a thin hydrogen "target" jet also at the radius of the second foil. The process of orbit shrinkage would stop when the particles were captured in stable synchrotron phase by a low-power fixed-frequency rf system; the reduction in betatron oscillations due to the hydrogen would continue. The rf system would define an equlibrium orbit just outside the radius of the hydrogen jet, so that particles whose betatron oscillation amplitudes had been reduced to low values would circulate in a high-vacuum region, where the mean lifetime for nuclear interactions would be long. When the moving foil returned to assist in the acceptance of the next beam pulse, all particles that had been captured by the rf in previous pulses would have small oscillation amplitudes, and so would miss the foil. In this way particles from many beam bursts could be concentrated in a small region, with very little deviation in energy or position.

The author takes pleasure in acknowledging very helpful discussions on this subject with Dr. M. G. White and Dr. F. C. Shoemaker. The assistance of Dr. I. Pyne in setting up problems for the GEDA computer of the Princeton engineering school is also very gratefully acknowledged.

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[1] Between the dates of submitting this letter and its publication, it has come to the author's attention that the basic idea of a storage-rung synchrotron has also occurred, at about the same time, to W. M. Brobeck of the Berkeley accelerator group, and to D. Lichtenberg, R. Newton, and M. Ross of the MURA group.

Multiple Ionization in Xenon Following Internal Conversion

ARTHUR H. SNELL AND FRANCES PLEASONTON
Oak Ridge National Laboratory, Oak Ridge, Tennessee
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THERE has perhaps been an insufficient appreciation of the damage that can be produced in the electron structures of atoms as the result of the creation of a vacancy in an inner shell. We have recently applied the methods of magnetic analysis[1] to the stable Xe^{131} atoms that are produced following the isomeric nuclear transition of Xe^{131m} (12-day half-life), and find the distribution in charge given in Table I. In a transi-

TABLE I. The charge states of Xe^{131} following the isomeric transition of Xe^{131m}.[a]

Charge	Percent intensity	Charge	Percent intensity	Charge	Percent intensity
1	0.62±0.12	11	6.22 ±0.10	21	0.012±0.001
2	0.97±0.03	12	3.01 ±0.04	22	0.013±0.001
3	1.62±0.06	13	1.78 ±0.03	23	0.006±0.001
4	4.26±0.06	14	1.09 ±0.01	24	0.010±0.001
5	5.36±0.10	15	0.55 ±0.01	25	0.004±0.002
6	10.42±0.13	16	0.242±0.004	26	0.004±0.001
7	15.69±0.25	17	0.098±0.002	27	0.002±0.001
8	20.88±0.19	18	0.036±0.001	28	0.007±0.001
9	15.74±0.24	19	0.023±0.001	29	0.006±0.002
10	11.32±0.19	20	0.014±0.001	30	0.001±0.001

[a] Average charge = 8.04±0.04. This may be compared with the value 8.5±0.3 reported by M. L. Perlman and J. A. Miskel [Phys. Rev. **91**, 899 (1953)].

tion of this kind, there is of course no electrostatic perturbation arising from a change in nuclear charge, and what is observed is the atomic consequence of the simple removal of an innershell electron through internal conversion.

The charge 1 state corresponds to the emission of the original conversion electron, and its intensity shows how rarely the vacancy is filled by purely radiative transitions. What usually happens (charge 8) is that the whole outer electron shell is depopulated. Charge 27 corresponds to the removal of half of the normal complement of electrons in xenon. We believe that there is real intensity in the charge spectrum out to charge 29.

Note added in proof.—Since these measurements were made, an experimental effect has been found that throws the figures for the higher charges into doubt. The relative intensities up to charge 20 are probably approximately correct, but pending remeasurement, those above charge 20 must be viewed with caution.

[1] A. H. Snell and F. Pleasanton, Phys. Rev. **100**, 1396 (1955).

Interpretation of K-Meson Decays*

SIDNEY A. BLUDMAN
Radiation Laboratory, University of California, Berkeley, California
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THIS note is concerned with a possible explanation of the K-meson lifetimes that may be subject to experimental verification. The only previous explanation[1] of the near equality of the τ and θ lifetimes involves the assumption of electromagnetic conversion of one heavy meson into the other. If τ and θ are not both spin-zero particles, then Lee and Orear require either different strangeness assignments for τ and θ, or a finite but exceptionally small mass difference ($\lesssim$100 kev) between τ and θ. While this latter possibility would be very hard to rule out experimentally, such an accidental near-coincidence of masses would be exceptional. If τ and θ are 0^- and 0^+ particles, respectively, a large mass difference ($\gtrsim$10 Mev) is needed. The mass differences, if any, are considerably smaller than this.[2]

Unless τ and θ have rather high spins or a very peculiar internal structure, only one can decay into three pions and only the other into two pions. They are both, however, capable of decaying in the $K_{\mu2}$, $K_{\mu3}$, and K_β modes. (For simplicity, in what follows, $K_{\mu3}$ and K_β will be included in the $K_{\mu2}$ mode.) The explanation of the nearly equal lifetimes to be proposed here is as follows: τ and θ are two parents that decay into $\mu+\nu$ at the same rate $R_{\tau\mu}=R_{\theta\mu}$; for both τ and θ this is the predominant decay mode. Then the τ and θ lifetimes are bound to be approximately equal, the differences in lifetime arising through the remaining $K_{\pi3}$ and $K_{\pi2}$ modes.

On this hypothesis, $K_{\mu2}$ should show a composite differential decay curve unless the τ and θ lifetimes are equal. The present data show no significant difference in $R_\tau=1/\tau_\tau$ and $R_\theta=1/\tau_\theta$, the total transition rates for τ and θ. From the fractional abundances N_μ, N_2, N_3 of $\mu2$, $\pi2$, $\pi3$, respectively, one finds:

(a) If, as proposed here, $R_{\tau\mu}=R_{\theta\mu}=R_\mu$, then the fraction f of τ's in the K beam at production must be small,

$$f=N_3/(1-N_\mu)=0.18,$$

and

$$R_\mu/R=N_\mu=0.62,$$

where $R=R_\theta=R_\tau$.

(b) Lee and Yang[3] and Gell-Mann[4] have proposed describing the strange particles by a new operator $\mathcal{R}$, which is conserved in strong interactions. A prediction of their theory is that τ and θ should be produced in equal fractions $f=1-f=\frac{1}{2}$. Then the small amount N_3 of $\pi3$ observed requires that τ decay predominantly into the $\mu2$ mode,

$$R_{\theta\mu}/R=1-2N_2=0.38, \quad R_{\tau\mu}/R=1-2N_3=0.87.$$

The conjecture of equal θ and τ transition rates into $\mu+\nu$ and the $\mathcal{R}$-degeneracy picture are definitely incompatible. In fact, if one assumes both $R_{\theta\mu}=R_{\tau\mu}$ and $f=\frac{1}{2}$, the observed ratios N_μ:N_2:N_3 can be obtained[5] only if the τ lifetime is unreasonably short ($\sim$ one-third the θ lifetime).

An attractive feature of possibility (a) is that one can assume a universal meson-lepton interaction.[6] If this interaction is vector or axial (which helps explain the absence of $e+\nu$ decays) and if the universal coupling constant is fitted to the pion lifetime, one then obtains $\tau_\theta=\tau_\tau=1/R=1.1\times10^{-8}$ second. This quantity is in good agreement with experiment.[7]

The whole question admits of an experimental determination. If different transition rates R_τ and R_θ are detected, then an analysis of the $K_{\mu2}$ decay rate

$$dN_\mu/dt=R_{\tau\mu}f\exp(-R_\tau t)+R_{\theta\mu}(1-f)\exp(-R_\theta t),$$

and of the abundance overdetermines the quantities f, $R_{\tau\mu}$, $R_{\theta\mu}$. It may turn out that neither $f=\frac{1}{2}$ nor $R_{\tau\mu}=R_{\theta\mu}$ is tenable!

The $K_{\mu2}$ lifetime now observed is the mean,

$$\bar{\tau}_\mu=\int t\,dN_\mu\bigg/\int dN_\mu.$$