Table I. Summary of results.

Nuclide	E_α (MeV)	$t_{1/2}$ (sec)
Te^{107}	3.28 ± 0.03	2.2 ± 0.2
Te^{108}	3.08 ± 0.03	5.3 ± 0.4

ing ratios are not known.

The most alpha-labile tellurium isotope is expected to be Te^{104} since it can undergo alpha decay to the double-closed-shell nuclide Sn^{100}. Our first experiments were directed toward producing this nuclide by the reaction Ru^{96}(O^{16}, $8n$)Te^{104}. We could not, however, detect any alpha groups at a bombarding energy favorable for this reaction or at energies favorable for the (O^{16}, $7n$) and (O^{16}, $6n$) reactions. We feel that perhaps part of the reason for the absence of these activities may be due to very small reaction cross sections. However, there is also a possibility that the 52-, 53-, and 54-neutron isotopes of tellurium may be proton-unstable with very short half-lives.

We expect that it will also be possible to observe alpha decay from the very neutron-deficient isotopes of iodine and xenon.

We would like to thank Professor I. Perlman, Professor J. O. Rasmussen, Dr. E. K. Hyde, and A. Ghiorso for their interest in this work. One of us (R.D.M.) would like to express his appreciation to the Chemistry Division of the Lawrence Radiation Laboratory for their kind hospitality.

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*Research performed under the auspices of the U. S. Atomic Energy Commission.

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EFFECT OF A Y_{40} DEFORMATION ON PROTON INELASTIC SCATTERING*

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The existence of a Y_{40} term in the shape of deformed heavy nuclei has been strongly suggested by the analysis of alpha-decay rates.[1-5] A method is proposed here for measuring the term more directly by means of proton inelastic differential cross-section measurements.

Calculations have been made on the inelastic cross sections for the scattering of 16 and 20 MeV protons on U^{238}, using the adiabatic approximation.[6,7] This is equivalent to a full coupled-channels calculation (coupling <u>all</u> states in the $K=0$ rotational band) if the excitation energies can be neglected in comparison with the incident proton energy. The proton-nucleus potential was taken to be that of a deformed optical model,[8] with a Woods-Saxon shape for the real part and a derivative Woods-Saxon shape for the imaginary part, the form factors being the same as those used by Perey.[9] The nuclear shape was taken to be $R=R_0(1+\beta_2Y_{20}+\beta_4Y_{40})$. The potential $V(r,R)$ was expanded in a series of Legendre polynomials, $V(r,R)=\sum_L v_L(r,R_0)P_L(\cos\theta)$, and the functions $v_L(r,R_0)$ were evaluated by numerical integration with respect to $\cos\theta$. The depth of the real part of the potential was obtained by means of the energy-dependent formula given by Perey.[9]

The results are shown in Figs. 1 and 2. The effect of the Y_{40} term on the elastic cross section, $\sigma_0(\theta)$, is too small to be noticeable, and the effect on the first inelastic cross section, $\sigma_2(\theta)$, is not very marked (except over a very small angular region in the forward direction). In the case of the second inelastic cross section, $\sigma_4(\theta)$, the magnitudes at certain angles are changed by factors of up to about 20 for $\beta_4=0.1$, and up to about 6 for $\beta_4=0.05$. In this case the term of first order in β_4 in the second-excited-state scattering amplitude is competing with second-order terms in β_2, and at some angles this gives rise to destructive interference and a lowering of the cross section.[10] Over most of the angular range, however, the second-excited-state cross section is strongly enhanced, and an experimental measure-

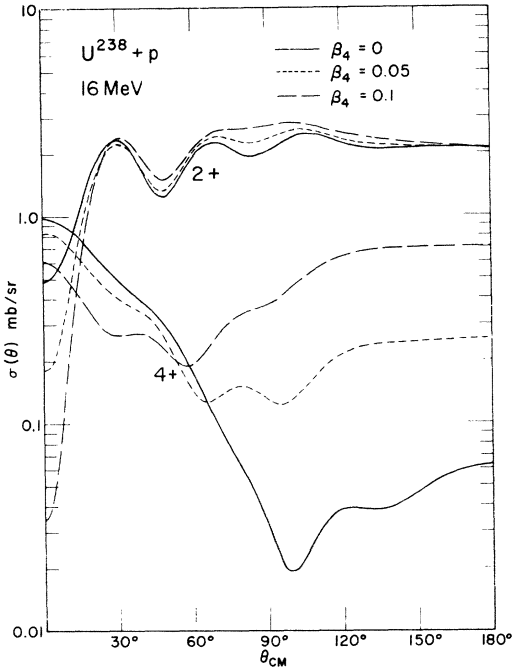

FIG. 1. Differential cross sections for the scattering of 16-MeV protons by U^{238}. The optical-model parameters used were $V_S = 61.2$ MeV, $W_S = 0$, $W_D = 14$ MeV, $r_{0I} = r_{0S} = 1.2$ fm, $a_S = 0.67$ fm, $a_I = 0.75$ fm, $\beta_2 = 0.28$.

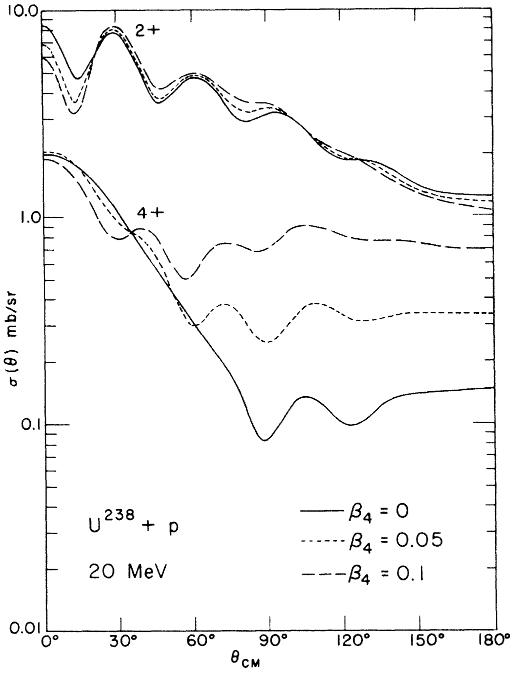

FIG. 2. Differential cross sections for the scattering of 20-MeV protons by U^{238}. $V_S = 58.8$ MeV; other parameters as in Fig. 1.

ment of the relative magnitudes of $\sigma_0(\theta)$, $\sigma_2(\theta)$, and $\sigma_4(\theta)$ should give an estimate for β_4.

The validity of the adiabatic approximation was checked by doing a coupled-channels calculation, using a computer code of Buck[11]; the results for $Q = 50$ keV and $Q = 0$ (where Q is the first-excited-state energy) were almost identical. Using the same code, a similar check was made of the importance of spin-orbit forces (which were neglected in the adiabatic calculations). The results showed that, at least in the case of heavy deformed nuclei, the spin-orbit force has very little effect on either the elastic or first-excited-state cross sections. (Cross sections for higher excited states are not given by this code.)

The computer code used in the adiabatic calculations was developed in part at Argonne National Laboratory and checked at the University of Washington against a code written by J. Wills. It is a pleasure to acknowledge the hospitality of Argonne National Laboratory and the University of Washington during the Summer of 1964, and to thank Professor J. S. Blair and Professor L. Wilets for some interesting discussions. Thanks are also due to the staffs of the computer centers at Columbia University, Argonne National Laboratory, and the University of Washington for their cooperation.

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[10] The adiabatic approximation includes both successive excitations, which come from higher order matrix elements, and direct excitations, which come from higher order terms in the expansion of the potential in powers of β_2 and β_4. Each $v_L(r, R_0)$ in the Legendre polynomial expansion of the potential in-

cludes all powers of β_2 and β_4. This expansion was cut off in the calculations after $L = 4$, which means that the terms neglected in the second-excited-state scattering amplitude were $O(\beta_4\beta_2^2)$ and $O(\beta_2^4)$.

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CP INVARIANCE IN WEAK INTERACTIONS AND THE PION DECAY ASYMMETRY*

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All known particle reactions, whether they be strong, electromagnetic, or weak, are in accordance with *CP* invariance, with the notable exception of the recent experimental results of Christenson, Cronin, Fitch, and Turlay[1] on the apparent decay of K_2^0 mesons into two pions with a branching ratio of 2.3×10^{-3}. Several explanations of this effect may be proposed, which take account of the fact that this apparent *CP* nonconservation is "very small." They include the following:

(1) External fields not invariant under *CP* of *TCP*. Such a mechanism could make the long-lived component have a small admixture of K_1^0, thus leading to a small two-pion mode. The smallness of the apparent *CP* nonconservation is then due to the smallness of these external fields,[2,3] say due to a very weak long-range coupling of hypercharges, or the local density of neutrinos.[4]

(2) "Maximal" *CP* nonconservation in a rare decay channel. Either the $\Delta I=\frac{3}{2}$ part of the nonleptonic decay amplitude[5] or the $I=\frac{3}{2}$, $\Delta Q = -\Delta S$ leptonic decay amplitude[6] could be chosen to fit the role.

(3) The reinterpretation of the decay modes as decay into two particles, at least one of which differs in spin-parity assignment from the pion. Since Christenson et al. measured the masses of the two particles rather carefully, we must assume that such particle (or particles) is degenerate with pions in mass.

In a recent investigation, two of us have found some evidence for a small but significant correlation between the direction of emission of the decay muon and the initial direction of emission of the pion produced in the τ-decay mode of K^+ mesons. Elsewhere[7] these two authors have announced this effect (the Bakunine effect) and presented a brief analysis of the experimental data. If we believe in the existence of such a genuine correlation, at least some of these "pions" must possess spin, but have nearly the same mass as the usual pseudoscalar pion.

We therefore propose that a new particle, called the spion (spinning pion), is involved in the "two-pion" mode of K_2^0 and (some of) the "three-pion" mode of K^+. *CP* nonconservation is no longer implied by the observation of Christenson et al.; and the observed π-μ decay correlations would be explained.

Such a decay mechanism would have several direct experimental tests:

(i) The spion would be expected to have more or less equal rates for decay into the electron and muon leptonic modes.[8] The π-μ decay asymmetry could be explained by an admixture of at least 5% of spions in τ decay; we therefore expect that at least 3% of all the "pions" from τ's decay into electrons.[9]

(ii) The muons (and electrons) from spion decay would be polarized oppositely to those from pion decay. Hence, in particular, we would expect the muons from the two-meson decay of K_2^0 to exhibit a polarization different from the polarization of muons from pion decay.

(iii) Since at least one of the mesons in the Christenson experiment is a spion, the electron decay mode would be expected to be quite frequent (between 25 and 50%).

(iv) If the spion occurs only in the charged form, the $\Delta I=\frac{1}{2}$ rule would be violated by several percent in τ decay. If neutral spions exist, they are forbidden to decay into two photons if their spin is 1; in such a case the preferred mode will be decay into an electron-positron pair plus a photon. There will thus be an anomalous number of Dalitz pairs.

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