statistical considerations. With 2-kev x-rays the pulse height distribution shown in Fig. 1b was obtained, on which we have plotted also the noise pulse height distribution. The interpretation of this curve in terms of detection efficiency must await further calculations and measurements, but rough considerations indicate a detection efficiency of greater than 50 and less than 80 percent. This high detection efficiency of NaI(Tl) crystals for low energy x-rays sees to differ markedly from the sharp drop in the detection efficiency of anthracene crystals for low energy electrons[2] (<15 kev). Part of the latter effect may perhaps be due to a low light-collection efficiency in that experiment.

The average pulse height, which we identified with the peak pulse height for all energies except for 2 kev, varied linearly (within the experimental error) with the x-ray energy from 2 to 411 kev. For the measurement at 411 kev we used the gamma-ray[3] from Au^{198}. The linearity test was made in three different overlapping energy ranges, indicated by (a), (b), and (c) in Fig. 2. In each energy range different pulse height distributions were measured with a definite photo-multiplier tube voltage—about 700 volts for (a) and (b) and 800 volts for (c). One particular crystal was used

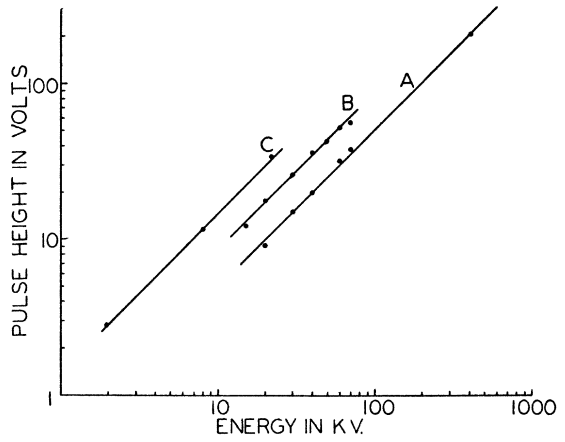

FIG. 2. Average pulse height (normalized to a gain of 1000) *vs.* incident x-ray energy for three different experimental arrangements, showing the proportionality of NaI(Tl) from 2 kev to 411 kev.

during one day, so that the crystal surface would not deteriorate during one set of measurements. The pulse height distributions were not measured with the same amplifier gain, but in Fig. 2 the gain of all points is arbitrarily normalized to 1000.

At incident x-ray energies above 33 kev, the binding energy of the K-electrons in iodine, two peaks were seen in the pulse height distribution. Figure 3 shows the distribution obtained with 44-kev x-rays. The peak at the higher energy corresponds to the full energy of the incident x-ray: both the iodine photo-electron and the iodine K x-ray energy are absorbed in the crystal. The peak at the lower energy is caused by the occasional escape of the iodine K x-rays from the front face of the crystal. That this interpretation is correct is demonstrated by the fact that at different energies of the incident x-rays (above 33 kev) the energy difference between the two peaks remains constant and approximately equal to the iodine K x-ray energy.

This "escape" peak is also observed in gas proportional counters,[4] where it is of the same order of magnitude as the main peak and where both the K_α and K_β escape peaks can be resolved because of the much larger number of pulse-forming electrons available. In the present case the escape probability is at most $\frac{1}{3}$ for incident x-rays just above 33 kev and decreases rapidly for higher energies, in agreement with rough theoretical considerations. This escape of the iodine K x-rays will, of course, lower the over-all detection efficiency for the incident x-rays unless the pulse

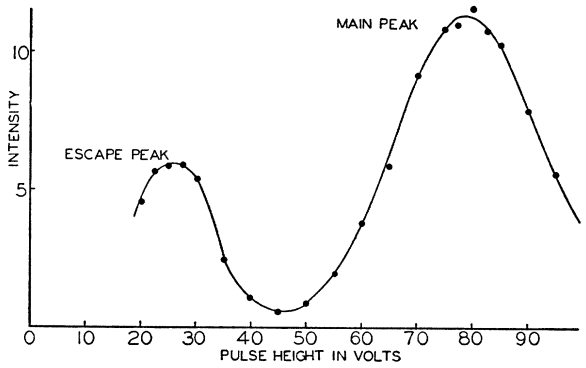

FIG. 3. Pulse height distribution due to 44-kev x-rays, showing small peak due to escape of I K-x-rays.

height discriminator bias is made low enough to detect the lower energy peak. We have also placed additional crystals close to the detector crystal and have observed the capture of most of the escaping radiation.

These and other experiments will be described elsewhere in the near future. We wish to thank Dr. J. A. McIntyre, Mr. W. Anderson, and Mr. L. Rieser for their help with this work.

* This work was supported by the joint program of the ONR and AEC.
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Binding Energy of the Triton*

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AS is well known, low energy two-body nuclear data can be described satisfactorily in terms of a shape-independent approximation.[1] On the other hand, predictions of high energy $n-p$ scattering data and of the triton binding energy depend on the assumed shape of the interaction potential. We have investigated in a limited way the dependence of the binding energy of H^3 on the range of the tensor force part of such a potential.

A nuclear interaction potential, consisting of central and tensor terms, was assumed as given below:

$$V(r)=-V_0\{[1-\tfrac{1}{2}g+\tfrac{1}{2}g(\boldsymbol{\sigma}_1\cdot\boldsymbol{\sigma}_2)]\exp(-r/r_c)/r/r_c + \Gamma S_{12}\exp(-r/r_t)/r/r_t\}.$$

It has met with success in describing low energy scattering processes and in accounting for the properties of the deuteron. Singlet and triplet wells can be obtained from such a potential, and charge independence of nuclear forces can be preserved.[2]

Calculations have been carried out to determine more accurately the shape of this well by using, instead of scattering data, the experimental value of the binding energy of H^3 to set the range of tensor forces. Whereas scattering data are in general insensitive to variations in tensor range, the binding energy may be expected to be reasonably sensitive.

The central force range r_c was obtained from singlet scattering data, primarily on $p-p$ scattering. The constant g was fixed by consideration of the difference between singlet and triplet well depths in $n-p$ scattering. From r_c and assumed values of r_t, the constants Γ and V_0 were set by use of two-body data, and an upper limit to the triton binding energy was computed by the Ritz method.

The linear variation function first used contained four terms (one S state and three D states). Its flexibility was then increased by using, instead of one S state, a linear combination of two S states of the form

$$A_{s1}\exp[-\tfrac{1}{2}\lambda_1(r_1+r_2+\rho)]+A_{s2}\exp[-\tfrac{1}{2}\lambda_2(r_1+r_2+\rho)],$$

where r_1, r_2, and ρ are, respectively, $n-p$, $n-p$, and $n-n$ separations. This caused a drop in calculated binding energy of several percent. A similar procedure applied to the two most important D states produced negligible improvement.

An approximate value of the relativistic correction to the kinetic energy was computed, and a set of values of $E(H^3)$ *vs* r_t obtained, from which suitable results could be found by interpolation. Table I indicates the values of the phenomenological

TABLE I. Values of the phenomenological constants.

$E=$	7.65	8.50	Mev
$r_c=$	1.184	1.184	$\times10^{-13}$ cm (assumed)
$r_t\simeq$	1.58	1.67	$\times10^{-13}$ cm
$\Gamma\simeq$	0.69	0.54	
$V_0\simeq$	42.7	46.1	Mev
$g\simeq$	−0.044	−0.004	

constants corresponding to respective variationally computed binding energies of 7.65 and 8.50 Mev, representing (corrected) upper bounds of 90 percent and 100 percent of the triton binding energy. One notes that, for the second case in particular, g can be placed approximately equal to zero, so that singlet and triplet central potentials become identical, and the number of required constants is reduced.

Equivalent $n-p$ triplet scattering ranges were also computed, and were respectively 1.72 and 1.73×10^{-13} cm, in excellent agreement with the latest determinations.[3] The respective Coulomb energies for He^3 were 0.99 and 1.02 Mev, higher than the experimental value[4] of 0.77 Mev. The possible compensatory effect of magnetic moment interaction is being investigated. Work on increasing further the flexibility of the wave functions, by multiplication by power series in suitable combinations of interparticle distances, is also in progress.

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Beta-Spectrum of As^{77}

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STEINBERG and Engelkemeier[1] found a maximum energy of 0.8 Mev for the beta-rays[2] of 40-hr As^{77} on the basis of the half-thickness value in aluminum. Mandeville, *et al.*,[3] state that the beta-rays of As^{77} have a range of 0.192 g/cm² in aluminum. This corresponds to a maximum energy[4] of 0.56 Mev.

A source of As^{77} was made available to us through the courtesy of Mr. W. J. Heiman and Dr. A. F. Voigt of this laboratory. The As^{77} was separated chemically from a germanium dioxide sample which had been wrapped with cadmium foil and bombarded with neutrons in the pile of the Argonne National Laboratory. The radiations from As^{77} were examined with a thin lens beta-ray spectrometer.[5] The As^{77}, in the form of arsenic trisulfide, was deposited on a Formvar-polystyrene film having a surface density of about 40 μg/cm². In order to obtain a reasonable counting rate a rather thick source of about 0.8 mg/cm² was required.

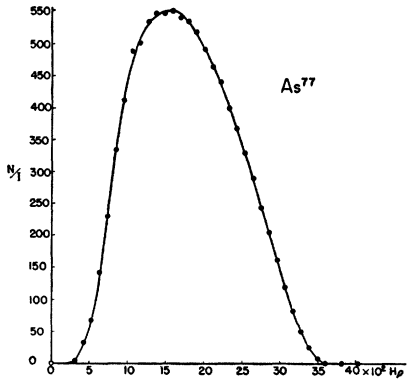

FIG. 1. The beta-spectrum of As^{77}. N is the counting rate and I is the current in the spectrometer coil. The data have not been corrected for counter window absorption.

The beta-spectrum is shown in Fig. 1. The data have not been corrected for window absorption. The allowed Kurie plot is shown in Fig. 2. By the method of least squares, using the points with $W>1.65\ mc^2$, the maximum energy is found to be $2.330\ mc^2$, giving a maximum kinetic energy of 0.679 ± 0.004 Mev. The deviations of the points from the straight line, at $W<1.65\ mc^2$, are thought to be due to the rather thick source required. No internal conversion lines were observed. A search was made for photo-electron lines using a lead foil, but none were found. However, the source was very weak and therefore the evidence is not conclusive.

Using a half-life[6] of 38 hr the ft value is calculated to be 4.7×10^5. According to the nuclear shell model,[7] a regular filling of the levels would give a $f_{5/2}$ state to the As^{77} nucleus and a $g_{9/2}$ state to the Se^{77} nucleus. This gives a spin change of two units with a change in parity. This would be a first forbidden transition in which the correction factor $a=(W_0-W)^2+\Lambda(W^2-1)$ is appropriate,[8] and log (ft) should have a value[9] between 8 and 9. This is contrary to the experimental evidence presented in this paper.

The experimental data[10–12] on the spin of Se^{77} are conflicting, but there is some evidence[10,12] that the spin is ½. This would give the Se^{77} nucleus a $p_{1/2}$ state. A $p_{1/2}$ level for 43 neutrons is explained by Mayer[7] on the basis that the greater pairing energy causes the $g_{9/2}$ state to fill in pairs. Experimentally it is found that all elements with odd Z from 29 to 35 inclusive have a spin[13] of 3/2 with a $p_{3/2}$ state.[7] This suggests that As^{77} may perhaps have a $p_{3/2}$ state. This assignment is again explained on the basis that a greater pairing energy causes the $f_{5/2}$ state to fill in pairs. With the assignments of $p_{1/2}$ and $p_{3/2}$ for Se^{77} and As^{77}, respectively, this gives a transition in which the spin change is one unit with no change in

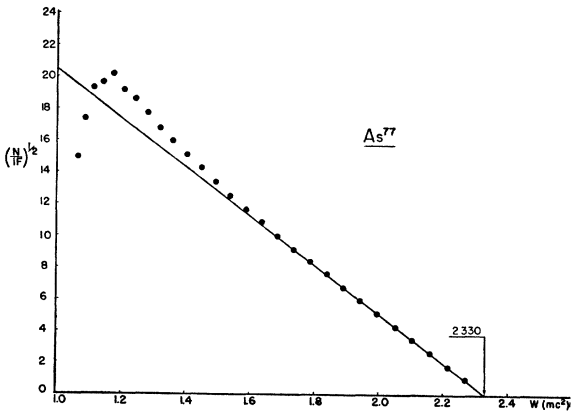

FIG. 2. The allowed Kurie plot of the As^{77} beta-spectrum.