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The Role of Three–Particle Forces in the Three–Body Problem

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THE possible role of the so–called many-particle forces has been discussed recently.[1–6] There are indications that by taking account of three–particle forces, the calculated energies of light nuclei show improved agreement with experiment[7,8] In studying the contribution of three–particle forces, we have confined ourselves to three-body problems: a) the calculation of the binding energies of H^3 and He^3; b) the calculation of the neutron–deuteron scattering cross section. For simplicity, we have neglected the noncentral character and the spin dependence of two-particle nuclear forces. As the total energy operator of tritium we took the sum

$$H = -\sum_{i<j} V_0 \frac{\exp\{-\mu r_{ij}\}}{\mu r_{ij}} + f\,\frac{K_1(\mu(r_{12}+r_{23}+r_{31}))}{\mu^3 r_{12} r_{23} r_{31}} + \frac{\hbar^2}{2M}(\nabla_1^2+\nabla_2^2+\nabla_3^2),$$

with $i, j = 1,2,3$, where the first term represents the ordinary (two–particle) interaction, the constants $V_0 = 52$ mev and $1/\mu = 1.4 \times 10^{-13}$ cm being chosen to yield the correct deuteron binding energy.[9] The term representing the three–particle interaction was taken in the same form as in Refs.[1–3]. The constant f was not given a fixed value but was chosen to give the correct binding energy of H^3. The choice of the trial function in the variational problem took into account the smallness of the probability, because of strong three–particle repulsion, that the three particles would simultaneously be in very close proximity.

	0,42	2,63	6,71	14,7	26,9	35,0	42,0	60,4	82,2
a	3,76	2.68	1,47	0.485	0,141	0,082	0,049	0.020	0,010
b	3.51	2,48	1,41	0,543	0,211	0,152	0.120	0,074	0,054
c		2,74	1,39	0,784	0,470	0,371	0,315	0,224	0,162

In this way we obtained $f = 153$ mev, which agrees in order of magnitude with the value of 375 mev obobtained by Drell and Huang.[1] For He^3 the calculated value of the Coulomb energy (0.745 mev) was very close to the experimental value, whereas worse results were obtained[7,8] when three–particle forces were neglected. For the potential scattering of neutrons by deuterons, we took into account only the *s* and *p* states of the incident particle, with the system able to be in either a doublet or quartet state.[10] The phases of the scattered waves were determined by means of Schwinger's variational method[11,12] with the trial function

$$(a + br)\sin kr + (c + dr)\cos kr,$$

where *a, b, c* are the variational parameters.

The total cross sections in barns are given in the Table (*E* is the energy in mev in the laboratory system of coordinates. The letters *a* and *b* denote variants of the calculation).

In the Table, *a* denotes that only two–particle interactions were taken into account; *b* denotes that both two–particle and three–particle interactions were taken into account with $f = 153$ mev; *c* denotes the experimental values of the cross sections.[13] The inclusion of three–particle forces somewhat improves the agreement with experiment. But one cannot simultaneously obtain the correct binding energy of H^3, the correct neutron–deuteron scattering cross section and saturation of nuclear forces in heavy nuclei[1] by selecting a single value of the constant f, even when noncentral forces are taken into account. It can therefore be assumed that three–particle interactions play a relatively small part in nuclei, and that these cannot be the principal cause of the saturation of nuclear forces.

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New Short-Lived Isomers in the Millisecond Range

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WE have investigated isomeric states with half-lives in the millisecond range which resulted from interactions with 20 mev protons. In addition to previously observed isomers,[1] data have recently been obtained concerning new isomeric radioactivity in a number of elements.

The method of investigating short-lived activities was described in our previous article.[1] in the present measurements, the γ-energy was determined by the use of a FEU-19 photomultiplier with a (2.9 × 1.6 cm) NaI (Tl) crystal and single-channel differential analyzer. For each γ-energy measurement the spectrometer was calibrated by the Cr^{51} line ($E_\gamma = 0.33$ mev, $T_{1/2} = 26.5$ days). In addition, the accuracy of the apparatus was controlled by the γ-emission which results from proton irradiation of Ta ($T_{1/2} = 5.5 \pm 1.0$ m sec)[1,2].

The Table contains our average values for the half-lives and energies of the observed γ-radiation. The errors are the mean deviation of results in different experiments.

In some cases we used control targets consisting of different chemical compounds which contain a given element. The half-lives measured in compounds of a given element are in good mutual agreement.

After we had obtained the data in the Table, information concerning a few short-lived isomeric radioactivities was published in the literature. These findings can be compared with our own values.

Softky[2] showed that the γ-emission with $E_\gamma = 0.305$ mev which accompanies *K* capture in Se^{75} has the half-life $T_{1/2} = 18.0 \pm 1.5$ m sec. and must be assigned to an isomeric state of As^{75m} The short-lived radioactivity which we obtained from proton irradiation of Ge has a half-life and an energy which agree with the corresponding values for the γ-emission of As^{75m} ($T_{1/2} = 17.5 \pm 2.0$ m sec, $E_\gamma = 0.310$ mev) and must result from the reaction Ge^{76} (*p*, 2*n*) As^{75m} with

Target	$T_{1/2}$ *m* sec	E_γ, mev	Data from other authors		Suggested reaction
			$T_{1/2}$, *m* sec	E_γ, mev	
Ge	17.5±2.0	0,31	18±1.5[3] 14[4]	0.305 [3] 0.315 [4]	Ge^{76} (*p*, 2*n*)As^{75m}
$SrCO_3$	16.5±2.0	0.41±0.02	—	—	—
Y_2O_3	13	0.20±0.02	—	—	—
Zr	10±1	0.24±0.02	10÷20[5]	0.250 [5]	Zr^{90}(*p*, *n*)Nb^{90m}
SmO	A few *m* sec	—	—	—	—
HgO	42±5	0.37±0.02	—	—	—
	5±1	—	—	—	—
Ga	несколько *мсек*	—	—	—	—
Cd	47±10	0.28	45±10[6]	0,312±0,01 [6]	Cd (*p*, *n*) или Cd(*p*, 2*n*)