SCATTERING OF MESIC ATOMS ON MOLECULAR HYDROGEN TARGETS AT LOW ENERGIES

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When studying muonic catalysis kinetics the total cross section data for mesic hydrogen isotope scattering on hydrogen molecules are needed. The consistent accounting of molecular structure and electronic shell of the target was accomplished in /1—4/. The scattering by molecules of the deuterium-tritium mixture was investigated in /1,2/, by H_2 molecules — in /3,4/. We have calculated elastic and inelastic scattering cross sections on rotational levels of the target. No vibration degrees of freedom were taken into account as we had confined ourselves to the collision energy interval $0<\varepsilon<$ <0.15 eV (vibrational quantum of H_2 equals 0.533 eV). The H_2 gas was regarded as a nonequilibrium mixture of two different gases — parahydrogen (spin 0) and orthohydrogen (spin 1) — with statistical weights of 1 and 3. The thermodynamic equilibrium was assumed to be set in each gas separately. We neglected the changing of spin states because of the weakness of the spin-dependent interaction (proton exchange in the $p\mu+H_2$ scattering results in the non-spin flip since the $p\mu$-atom is expected to be in the lower hyperfine state separated from the upper one by the energy split of 0.183 eV). As the total nuclear spin of the molecule determines its rotation spectrum (even rotational quantum numbers J correspond to the parahydrogen, odd J — to the orthohydrogen) the even-even or odd-odd rotational transitions are only possible due to the collision.

The method of Fermi's pseudopotential was used for describing interaction between a mesic atom and molecule nuclei. The amplitudes of elastic scattering by nucleus are needed for pseudopotential construction. These are available in /5,6/. The interaction of a mesic atom with a molecular electronic shell was taken into account according to the perturbation theory.

Table 1 shows energy dependence of cross sections $\sigma_{JJ'}$ for elastic and inelastic scattering on different rotational levels of H_2. We have considered only levels with a marked population at room temperature. The quantity $\sigma_{JJ'}$ refers to scattering accompanied by the rotational $J\to J'$ transition in the target.

Table 1

Cross sections $\sigma_{JJ'}(10^{-20}$ cm^2) for scattering of $p\mu$-atom by H_2-molecule

Collision energy, eV	Parahydrogen					Orthohydrogen	
	σ_{00}	σ_{02}	σ_{20}	σ_{22}	σ_{24}	σ_{11}	σ_{13}
0.01	87		1.9	87		88	
0.02	51		1.7	52		52	
0.04	27		1.6	28		29	
0.10	12	5.3	1.6	14		15	2.1
0.15	9.3	7.0	1.4	12	2.8	12	4.2

Table 2 gives the total cross section $\sigma^{mol} = \sum_{JJ'} g_J \sigma_{JJ'}$ summed over all rotational states with account of their statistical weight and population at temperature T=300 K against collision energy ε. The last column in Table 2 relates to thermalized mesic atoms. The values of $<\sigma^{mol}>$ are calculated by averaging of σ^{mol} over ε accepting the Maxwellian relative velocity distribution. The former are almost twice as much as the latter taken at ε=0.04 eV in consequence of rapid increase of the cross sections with ε decreasing. For the $p\mu+H_2$ collision the value $<\sigma^{mol}>$ is an order of magnitude larger than the last experimental result /7/.

Table 2

Total cross sections (in units of 10^{-20} cm^2) for mesic atom scattering in H_2 gas at T=300 K

Collision	ε=0.01	0.02	0.04	0.10	0.15 eV	$<\sigma^{mol}>$
$p\mu+H_2$	88	52	29	17	16	52
$d\mu+H_2$	124	66	34	16	11	73
$t\mu+H_2$	180	97	51	26	18	110

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