Degree of Dissociation at the Polarized Hydrogen Source ◊

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The beam formation at the Munich Stern-Gerlach atomic-beam source for the production of a thermal beam of polarized hydrogen atoms has been consistently described by comparing beam absorption - measured under various conditions - with beam-transport calculations [1,2]. The resulting degree of dissociation α=80 % at 2.0 mbar l /sec of gas-throughput is slightly higher than at the MADISON dissociator [3] and in significant discrepancy to the value of $\alpha < 50$ % of ref. [4] for the HERMES dissociator.

To check our estimate independently we modified a quadrupole-mass-spectrometer (QMS: Leybold Quadruvac 200) to crossed beam geometry cutting two aligned holes into the anode cage for the ion formation, each of them 4mm×4mm in size. They allow the atomic beam to pass the QMS in free clearance. Two apertures of 3 mm in diameter collimate the beam additionally. A moveable shutter in front of the collimator enables the subtraction of the background due to the residual gas in the vacuum chamber. A translatory mechanism allows to position the QMS on beam-axis. The operation of the QMS was verified by comparison with an unmodified QMS and an ionisation gauge.

The degree of dissociation α is generally definded as the ratio of the atomic flux out of the dissociator Φ^0_{at} by twice the total molecular flux into the dissociator Φ^0_{mol}:

$$\alpha = \frac{\Phi^0_{at}}{2\Phi^0_{mol}} \approx \frac{\Phi_{at}}{\Phi_{at} + 2\Phi_{mol}} \approx 1 - \frac{\Phi_{mol}}{\Phi^{off}_{mol}} \qquad (1)$$

with the atomic and molecular fluxes $\Phi_{at,mol}$ of the dissociated beam and the molecular fluxes Φ^{off}_{mol} with dissociator off, all measured at the position of the QMS. The summed flux $\Phi_{at} + 2\Phi_{mol}$ is approximately constant at constant gas inlet but varying α. As the QMS was placed at a distance of 238 mm from the nozzle we assume that the composition of the flux stays constant over distance. Eq. 1 defines two independent methods to determine the degree of dissociation. Using the first method α is determined via comparison of the atomic and molecular flux components of the dissociated flux, and by the second method via the comparison of the molecular flux components from dissociated and undissociated beam. The QMS measures particle densities n with efficiencies ϵ. They are related to the respective fluxes Φ by $\Phi = (n/\epsilon)vA$, with the velocities v of the atoms or molecules and the area A of the collimating system. The two different degrees of dissociation α_κ and α_{mol} are then:

$$\alpha_\kappa := \frac{n_{at}}{n_{at} + \kappa n_{mol}} \quad with \quad \kappa := 2\frac{v_{mol}\epsilon_{at}}{v_{at}\epsilon_{mol}} \qquad (2)$$

$$\alpha_{mol} := 1 - \frac{n^{on}_{mol}}{n^{off}_{mol}} \qquad (3)$$

The unknown factor κ can be determined from the summed densitiy $n_{at} + \kappa n_{mol}$, which is independent on α at low gas fluxes up to 0.5 mbar l/sec, where differences between atomic and molecular fluxes in beam-absorption or beam-formation are negligible. Fig. 2 shows a plot of molecular against atomic deuterium densities at a gas throughput of 0.2 mbar l /sec, where α has been varied by changing the dissociator power. The slope of the linear fit gives the calibration factor κ = 1.59 for deuterium (κ = 1.24 for hydrogen).

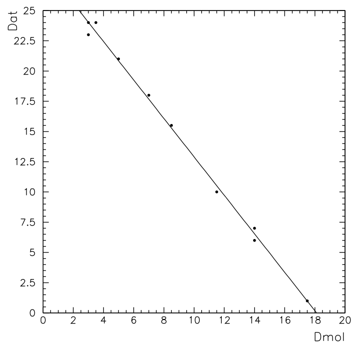

Fig. 1: Measured molecular against atomic particle densities for deuterium in arbitrary units. The linear fit through the data points justifies the assumption of unchanged beam formation and negligible beam-absorption between atomic and molecular hydrogen.

Table 1 compares the measured degrees of dissociation as a function of gas-throughput. The values for α_κ and α_{mol} agree for hydrogen and deuterium.

	hydrogen		deuterium	
$\Phi_0[mbl/sec]$	α_κ	α_{mol}	α_κ	α_{mol}
0.2	0.80	0.80	0.81	0.79
0.5	-	-	0.77	0.77
0.8	0.82	0.80	-	-
1.3	0.78	0.79	0.80	0.78

Table 1: Measured degrees of dissociation as a function of the gas-throughput Φ_0: α_κ denotes the degree of dissociation determined via the calibration factor κ, α_{mol} is determined from molecular densities only. The estimated error is 5 %. So far fluxes were limited to 1.3 mbl/sec. Larger fluxes will be investigated after the repair of the turbomolecular pump in chamber 1.

The performance of the atomic beam in the Munich ABS is largely understood. It is limited by scattering of the atomic beam on residual gas, particularly in the regions of limited pumping in the sixtupole magnets.

References

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