MOMENTUM TRANSFER TO HELIUM-3 AND HELIUM-4-MICRODROPLETS IN HEAVY ATOM COLLISIONS

J. Gspann, H. Vollmar

To cite this version:

J. Gspann, H. Vollmar. MOMENTUM TRANSFER TO HELIUM-3 AND HELIUM-4-MICRODROPLETS IN HEAVY ATOM COLLISIONS. Journal de Physique Colloques, 1978, 39 (C6), pp.C6-330-C6-331. <10.1051/jphyscol:19786146>. <jpa-00217554>

HAL Id: jpa-00217554
https://hal.archives-ouvertes.fr/jpa-00217554

Submitted on 1 Jan 1978

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
MOMENTUM TRANSFER TO HELIUM-3 AND HELIUM-4-MICRODROPLETS IN HEAVY ATOM COLLISIONS

J. Gspann and H. Vollmar

Institut für Kernverfahrenstechnik der Universität und des Kernforschungszentrums Karlsruhe, Postfach 38 40, 7600 Karlsruhe, GERMANY.

Résumé.- La déflexion des faisceaux de micro-gouttes d'hélium par des jets croisés de xénon ou de gaz carbonique est étudiée. On observe que les gouttes de moins de quelques $10^4$ atomes d'hélium-4 ou $10^5$ atomes d'hélium-3 retiennent moins que la moitié du courant d'impulsion des collisions à une vitesse relative d'environ 400 m/s. L'augmentation de taille des gouttes ou la réduction de vitesse élèvent le transfert d'impulsion, à l'exception d'un minimum à environ 110 m/s qui ne fut observé qu'avec des gouttes d'hélium-4.

Abstract.—The deflection of beams of helium microdroplets by crossed jets of xenon or carbon dioxide shows that droplets of less than some $10^4$ atoms of $^4$He or $10^5$ atoms of $^3$He retain less than half of the momentum flux impinging at about 400 m/s relative speed. Increasing the cluster size or lowering the relative speed raise the momentum transfer, except for a minimum at about 110 m/s occurring only with $^4$He-microdroplets.

INTRODUCTION.—Microdroplets of $^4$He flying through high vacuum in sharply bounded beams of uniform speed have been investigated earlier by measuring the extinction of a crossed beam of cesium atoms /1/ /2/. This paper reports on measurements of the deflection of $^3$He- and $^4$He-microdroplets by crossed free jets of xenon or carbon dioxide. As the molecular mean free path in the cross-jets is always large compared to the droplet diameters the drag force acting on a droplets arises from successive independent collisions with the heavy atoms, or molecules, of the cross-jet.

EXPERIMENTAL.—As shown schematically in figure 1, a beam of microdroplets extracted from a partly condensing nozzle flow of precooled gas is intersected by a free jet the relative velocity of which can be changed by varying orientation or temperature of the cross-jet nozzle. In order to obtain very low mean relative velocities an additional set-up is used which shields the microdroplet beam from those parts of the cross-jet otherwise intersecting the beam at angles larger than $15^\circ$, leading thereby to larger relative velocities.

Molecular intensities are measured with a movable stagnation pressure ion gage which for determining droplet sizes and velocities is replaced by an improved version of a time-of-flight mass analyzer described earlier /3/.

RESULTS.—In the following, the results of the deflection experiments are presented in terms of the observed drag coefficients of the microdroplets in the free molecular cross-jet flow field. The drag coefficient is defined as usual:

$$C_D = \frac{2F}{(\rho v_{rel}^2 A)}$$

Therein, $F$ denotes the drag force leading to the measured angle of deflection, $\rho$ is the cross-jet mass density, $v_{rel}$ the relative flow velocity and $A$ the cross sectional area of a spherical droplet of the corresponding bulk density.

Figure 2 shows measured drag coefficients of microdroplets of $^3$He and $^4$He, and of $N_2$-clusters.
for comparison, as a function of the number \( N \) of atoms or molecules per droplet or cluster. (The more general term "cluster" is used with any substance except helium as only the latter may not solidify from evaporation cooling.)

Fig. 2: Drag coefficients \( C_D \) of \(^3\)He- and \(^4\)He-microdroplets and of \( N_2^- \) clusters as a function of the number \( N \) of atoms or molecules per cluster. Black symbols: \( \text{CO}_2 \) cross-jet; empty symbols: \( \text{Xe} \) cross-jet; \( \beta = 90^\circ \); \( \alpha = 2.5^\circ \).

For the measurements a cross-jet intersection at right angles is chosen while the mass flux is adjusted to yield an angle of focussed deflection \( \alpha \) of \( 2.5^\circ \). With \( \text{CO}_2 \) cross-jets, drag coefficients of nitrogen clusters of about 3 are found to be practically size-independent over 2 orders of magnitude of \( N \). The drag coefficients of helium microdroplets, on the other hand, are found to be smaller than 2, increasing droplet size. The data obtained with a \( \text{Xe} \) cross-jet are somewhat below those of the \( \text{CO}_2 \) jet but otherwise confirm the trends of the latter.

Lowering the mean relative velocity of the \( \text{Xe} \) cross-jet leads to increasing drag coefficients of helium microdroplets, as shown by the black dots in figure 3. Empty circles pertain to non-focussed small angle deflection using the special cross-jet set-up with partly shielded microdroplet beam.

DISCUSSION.— A drag coefficient of 2 means that all the intercepted momentum flux, but only that, is transferred to the microdroplet or cluster. Larger values, as observed with \( N_2^- \) clusters, usually arise from reflection or reevaporation of the impinging particles, but may also arise from backward directed vaporization of cluster material. Values below 2, as observed with helium microdroplets at relative velocities of about 400 m/s, are rather unusual. They point to deep penetration of the heavy particles impinging at supersonic speeds, leading eventually to helium expulsion at the backside of the droplet the recoil of which compensates part of the impact momentum. The available amount of energy can be estimated to be at least compatible with the observed losses of cluster material during deflection.

Fig. 3: Drag coefficients \( C_D \) of \(^3\)He- and \(^4\)He-microdroplets of \( N \) atoms as a function of the mean relative velocity of a \( \text{Xe} \) cross-jet. Empty circles: data obtained with skimming of crossed flow of larger than \( 15^\circ \) angle of intersection; black dots: without skimming.

Lowering the mean relative velocity apparently results in decreasing depth of penetration and hence increasing effect of backward vaporization, or perhaps splashing, the recoil of which adds to the impact momentum. Tentatively, the low velocity minimum of the drag coefficients of \(^4\)He-microdroplets may be ascribed to an intermediate maximum of penetration due to the impossibility of creating phonons in superfluid \(^4\)He at velocities below that of first sound.

References

/1/ Becker, E.W., Gspann, J., and Krieg, G., proceedings of the 14th Int. Conference on Low Temperature Physics, Otaniemi 1975, Volume 4, 426