H Atom Sticking to He and He Films

Attention has been drawn by new data to the fundamental problem of the sticking coefficient $s(T)$ at temperature T approaching zero [1]. In the case of H impinging on a He surface, s was found to deviate substantially from the expected $T^{1/2}$ dependence, even in the regime $T=10^{-4}$ K. Interestingly, similar behavior was predicted in one of several calculations of Goldman [2], the case of an assumed potential which we call $V_{\rm I}$; see Fig. 1. In this Comment, we describe calculations leading to the following conclusions: Goldman's potential is too attractive at long range. When this is corrected, the resulting s values are orders of magnitude smaller than experiment [1]; this is true of any plausible potential required to be consistent with the measured binding energy [3]. To explain the s data, therefore, one must invoke a source of a strong long-range attraction. This may be the substrate if the He is actually a film. Finally, we note that there is an important factor [4] enhancing s due to a wave-function correction beyond the Born approximation; this has not previously been taken into account.

The first step we took was to modify $V_{\rm I}$ by replacing its dispersion coefficient C_g with the theoretical coefficient C which is smaller by a factor of 4, and incorporating the effect of retardation [5]. The new potential is

$$V_{\rm II}=V_{\rm I}f(z)-Ch(z)\frac{1-f(z)}{1+z/l},$$

where $h(z)=z^3/(z^6+z_0^6)$ and we have turned off the Goldman dispersion with a Fermi-type function $f=1/\{1+\exp[(z-b)/a]\}$ at a conservatively large distance $b=25$ Å; $a=4$, $z_0=3.8$, and $l=200$ Å. As seen in Fig. 1, the values of s computed (from the formula of Ref. [2], with the wave-function correction of Ref. [4]) with $V_{\rm II}$ are orders of magnitude smaller than those calculated with $V_{\rm I}$, due to the extreme sensitivity of the wave function to the long-range behavior. After much tinkering with alternative short-range potentials, we have concluded that the s data are not compatible with the known binding energy and asymptotic behavior of V. We have therefore addressed the effects of the substrate, since the He actually exists as a film of thickness d [6,7]. The potential considered is similar to $V_{\rm II}$, apart from the effect of the substrate:

$$V_{\rm III}=\frac{\mu_0}{e^{\beta z}+1}-\frac{C_s x^{-3}}{1+x/l}-f(z)h(z)C_g$$
$$-C[1-f(z)][h(z)-x^{-3}],$$

where $x=z+d$ and C_s is the substrate dispersion coefficient; $\mu_0=37$ K and $\beta=0.587$ Å^{-1}, similar to values in $V_{\rm I}$. As seen in Fig. 1, the resulting s values are quite compatible with the data. This conclusion depends on the actual d and C_s values in the experiment, which are not known at present.

We conclude that the theory of sticking, as revised by Boheim, Brenig, and Stutski [4], can explain the high-s data if one assumes "appropriate" substrate parameters. This situation illustrates that these experiments are invaluable probes of generally elusive long-range forces.

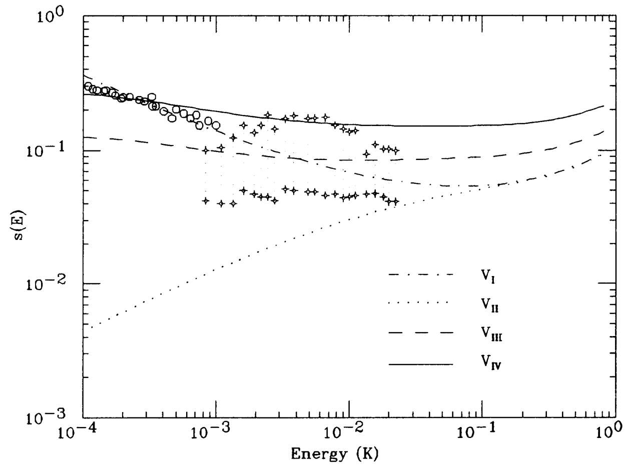

FIG. 1. Sticking coefficient computed from the formulas of Refs. [2] and [4] vs atom energy for potentials discussed in the text. The $V_{\rm IV}$ case differs from $V_{\rm III}$ only in its use of the wave-function correction of Ref. [4]; both use $C_s=5000$ K Å^3 and $d=50$ Å.

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