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THE DYNAMICS OF ADATOM DIFFUSION ON W(211)(1)

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Over the last two decades, observations of individual metal atoms with the field ion microscope have yielded considerable quantitative information about diffusion on metal surfaces. The temperature dependence of the observed diffusivities D can generally be represented in terms of the activation energy $E_A$ by $D = D_0 \exp[-E_A/kT]$. The prefactor $D_0$ is dependent upon the dynamics of the jump process; it is related to the entropy of activation $S_A$ and the jump length $\ell$ through $D = v\ell^2 \exp[S_A/kT]$, where $v$ is an attempt frequency.

For the simplest model of surface diffusion, in which atoms carry out a random walk between nearest-neighbor sites, $D_0$ should be on the order of $10^{-3}$ cm$^2$/sec. This is not what has been found in independent experiments in several different laboratories. On W(211), for example, prefactors varying over more than five orders of magnitude have been reported, suggesting significant differences in the details of the jump processes. To explore the dependence of prefactor $D_0$ upon the chemical identity of the adatoms we have carried out extensive observations on the diffusion of single atoms Re, W, Mo, Ir, and Rh on W(211) /1/. All measurements have been done on the same crystal sample, with special care to establish a reliable temperature scale. The results below are surprising:

<table>
<thead>
<tr>
<th></th>
<th>Re</th>
<th>W</th>
<th>Mo</th>
<th>Ir</th>
<th>Rh</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_A$ (kcal/mol)</td>
<td>19.2±.5</td>
<td>19.0±.6</td>
<td>16.4±.5</td>
<td>15.4±.4</td>
<td>12.4±.4</td>
</tr>
<tr>
<td>$D_0 \times 10^3$ (cm$^2$/sec)</td>
<td>0.73</td>
<td>7.7</td>
<td>2.0</td>
<td>0.61</td>
<td>3.3</td>
</tr>
</tbody>
</table>

The prefactors for all the atoms studied are much the same, within the statistical errors, and are close to the expected value of $10^{-3}$ cm$^2$/sec. From the magnitude of the measured $D_0$ values it appears that for the atoms Re through Rh, diffusion takes place by nearest-neighbor jumping, a mechanism that has been confirmed by independent observations. The activation energy for diffusion of the atoms studied on W(211) correlates with the heat of sublimation $\Delta H_v$ of the atoms from their own crystal, amounting to $\sim 1\Delta H_v$.

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REFERENCES