NEW AUTOIONIZING LEVELS IN HELIUM*

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We recently reported the excitation of autoionizing states in helium by positive-ion bombardment and their subsequent observation as fine structure in the energy spectrum of the emitted electrons.[1] With somewhat increased resolution we have now observed additional levels in helium including parts of two series not previously reported.

The same apparatus was used as in the previous work except for the addition of an X-Y recorder to plot the data. Again, electrons ejected at a 160° angle with respect to the ion beam were observed. The helium pressure in the collision chamber was five to six microns. The bombarding ions were 75-keV H^+ or H_2^+.

In Fig. 1 are shown three runs at different recorder sensitivities. The peak at 62.15 eV can be identified as the $(2p^2)\,{}^1S$ level calculated theoretically by O'Malley and Geltman[2] but not previously observed. The peak at 63.65 eV is the $sp,23^+$ level observed by Madden and Codling.[3] The 64.46-eV $sp,24^+$ level is just detectable.

The energy scale could be determined by adding the ionization potential (24.58 eV) to the electron ejection energy measured by the analyzer. However, because of space charge and other effects the energies thus determined are uncertain by a few tenths of an eV. Therefore, the 63.65-eV value for the $sp,23^+$ level measured by Madden and Codling was used to calibrate the rest of the energy scale. The energies determined in this way are believed to be accurate to within about 0.05 eV.

The new series are the $(2sns)\,{}^1S$ and the $(2snp)$ ${}^3P$, the first terms of which have been previously reported by Simpson, Mielczarek, and Cooper[4] and by us.[1] Both series converge to the same limit as the $sp,2n$ series. This limit is given by Madden and Codling[3] as 65.397 eV. The $n=3$ terms in both series are combined in the single peak at 63.0 eV in Fig. 1. In Fig. 2 these two levels have just been resolved at 62.95 and 63.08 eV. An additional peak appearing as 62.78 eV is probably the $sp,23^-$ level reported by Madden and Codling.[3] The $(2s4s)\,{}^1S$ and $(2s4p)\,{}^3P$ states appear as a single unresolved peak in Fig. 1 at 64.22 eV, while the peak at 64.71 eV is probably the combination

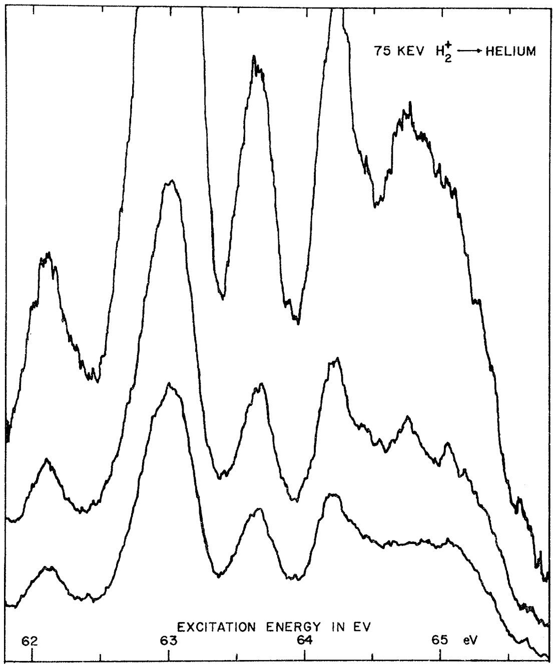

FIG. 1. Energy spectrum of electrons emitted from helium gas excited by 75-keV H_2^+ impact.

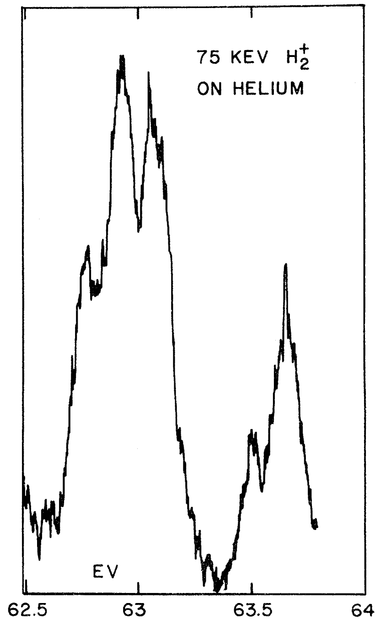

FIG. 2. Higher resolution energy spectrum of electrons emitted from helium gas excited by 75-keV H_2^+ impact.

Table I. Energies of terms of $(2sns)\,^1S$ series in helium.

n	$E_{\text{expt.}}$ (eV)	E_{calc}[a] (eV)	E_{calc}[b] (eV)
2	57.82	57.87	57.824
3	62.95	62.99	62.952
4	64.22	64.22	
5	64.71	64.70	

[a] See P. G. Burke, D. D. McVicar, and K. Smith, Phys. Rev. Letters 11, 559 (1963); P. G. Burke and D. D. McVicar, to be published.

[b] See reference 2.

Table II. Energies of terms of the $(2snp)\,^3P$ series in helium.

n	$E_{\text{expt.}}$ (eV)	E_{calc}[a] (eV)	E_{calc}[b] (eV)
2	58.34	58.36	58.296
3	63.08	63.14	63.141
4	64.22	64.26	64.320
5	64.71	64.71	

[a] See P. G. Burke, D. D. McVicar, and K. Smith, Phys. Rev. Letters 11, 559 (1963); P. G. Burke and D. D. McVicar, to be published.

[b] See reference 2.

of the $n = 5$ terms of both series. A summary of the measured and calculated values of the energies of the two series appears in Tables I and II.

Identification of the two series was aided by the fact that triplet levels are not excited by proton bombardment but show up strongly under H_2^+ bombardment. This is due to the fact that in order to conserve spin the triplet levels must be excited by a projectile bearing an electron to exchange with one in the target atom. With the proton beam the terms of the $(2snp)\,^3P$ series did not appear.

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[2] T. F. O'Malley and S. Geltman, Phys. Rev. 137, 1344 (1965).

[3] R. P. Madden and K. Codling, Astrophys. J. 141, 364 (1965).

[4] J. A. Simpson, S. R. Mielczarek, and J. Cooper, J. Opt. Soc. Am. 54, 269 (1964).

HARD-SQUARE LATTICE GAS*

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Exact statistical calculations of thermodynamic properties of two- or three-dimensional fluids with realistic interactions have never been obtained over the entire density range. Presented here are the results of rigorous calculations for a two-dimensional lattice model of a fluid of hard molecules, the system being of infinite length and relatively large finite width. The results provide strong evidence for the existence of a second-order phase transition for a system infinite in both directions.

The "hard-square lattice gas" investigated is illustrated in the inset of Fig. 1; the only forces present are the infinite repulsions corresponding to the nonzero area of the molecules. Mathematically, this is the Ising model with interaction $+\infty$ for two adjacent sites AA and interaction zero for two adjacent sites AB or BB. This is an extremely simple model of a fluid which yet retains the excluded-volume effect and reasonable lattice topology. Since the interactions are either zero or infinity, temperature enters into the problem in a trivial way, allowing attention to be focused on variable density.

Onsager[1] obtained the partition function for the two-dimensional Ising model of arbitrary size in vanishing field (in the original magnetic formulation). Yang and Lee[2] showed that for the ferromagnetic case (corresponding to attractions between neighboring molecules of area one) there can be only the one transition found by Onsager at zero field (or density one-half for the lattice gas). There has remained speculation about the existence of an antiferromagnetic transition at some nonvanishing field,