ENERGY SPECTRUM OF He I AND H^- IN A STRONG MAGNETIC FIELD

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The energy spectrum of He I is calculated by a variational method for magnetic fields B in the range $0-3 \times 10^{11}$ gauss. Improved results for the electron affinity of H^- are also presented.

The binding energy of H^- in magnetic fields B in the range $0-3 \times 10^9$ G has been calculated using a variational method [1]. We now apply the same technique to a calculation of the energy spectrum and the binding energy of the ground state of He I. B values $\leqslant 10^7$ G were considered in [2] but, as we shall see, B does not have a pronounced effect below $\sim 10^8$ G.

Our notation and method of calculation follows that of [1]. At $B = 0$, we calculate the energies of the five lowest levels and obtain results which agree with Pekeris et al. [3, 4] to within 1%. This accuracy was achieved by the use of 24 Slater orbital terms in the sum over the index Γ. For the largest B values ($\sim 3 \times 10^{11}$ G) reported here, we use 125 terms, with a maximum L of nine.

Fig. 1 gives the energies of some of the lowest states of He I as a function of B. The lowest energy state goes from the singlet, even-parity state $\gamma = (000+)$ to the triplet, odd-parity state $\gamma = (-1\ -1\ 1-)$ at $B \approx 1.7 \times 10^9$ G.

The binding energy of the ground-state of He I is given by

$$I(\text{He I}) = -E(\text{He I}) - I(\text{He II}), \qquad (2)$$

where E(He I) is the ground-state energy of He I and I(He II) is the binding energy for He II in the ground state [5].

The results for I(He I) are presented in fig. 2. It decreases with increasing B to $B \approx 1.7 \times 10^9$ G, where the lowest-energy state now corresponds to both electrons having their spins opposite to the direction of the B field. From $B = 1.7 \times 10^9$ G to $B = 3 \times 10^{11}$ G,

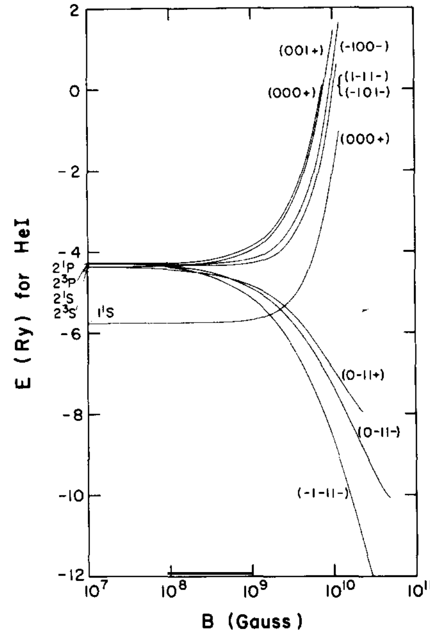

Fig. 1. Energy levels of He I as a function of the magnetic field strength B.

I increases with increasing B. Then the curve tends to turn-over because it became computationally prohibitive to obtain convergent results. Inspection of figs. 1 and 2 will show where other bound states of He I occur.

In addition, we have now achieved greater accuracy for the H^- energy levels at the higher B values (10^9 G–3.3×10^9 G). The greatest improvement ($\sim 5\%$) occurs for the lowest -energy $(-1\ -1\ 1-)$ state at $B = 3.3 \times 10^9$ G, where we now obtain a value -1.9 Ry, compared to the previous result -1.8 Ry. This leads to a greater percentage change in $I(H^-)$

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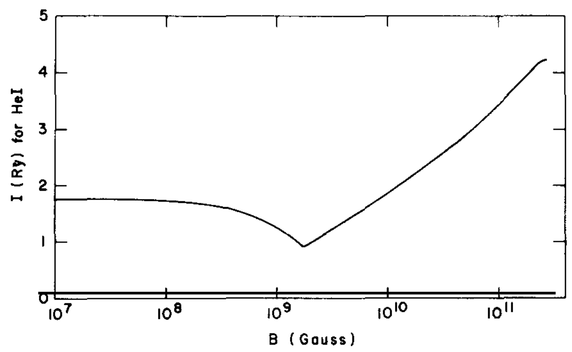

Fig. 2. Binding energy of He I as a function of B.

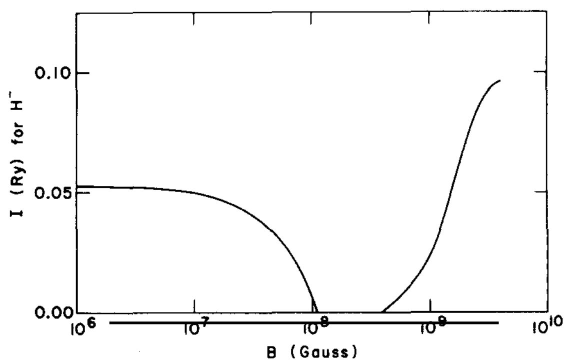

Fig. 3. Electron affinity of H^- as a function of B.

which is obtained from the difference of two quantities, $-E(H^-)$ and $I(H)$, both of which are relatively large but whose difference is relatively small. Fig. 3 gives $I(H^-)$. As before [1], we note that H^- is unbound for an intermediate range of B values. However, in this region there is a "quasi-bound" singlet state – "quasi" in the sense that it is embedded in the "continuum" of the system consisting of a single-electron atom with spin down and a "free" (from the Coulomb but not from the magnetic field) electron with spin down. In the other B regions for H^- (and also for He I) this "quasi-bound" state is lower than the triplet bound state (because of the large energy of $2\hbar\omega_L$ released in flipping the electron spin). Further details may be found in ref. [6].

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