FUSION WITH A MUON-DEUTERON SYSTEM

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References: Griffiths, David J. (2005), Introduction to Quantum Mechanics, 2nd Edition; Pearson Education - Problem 7.19.

When we examined the hydrogen molecule ion H_2^+ using the variational principle, we found that the lowest energy occurred when the protons were separated by $R = 2.4a$, where a is Bohr radius. It is this separation which causes the problem in attempting to achieve controlled nuclear fusion, since we need to get the two nuclei close enough for the short range nuclear force to overcome the electrical repulsion. A possible alternative is to use a deuteron molecule ion with the electron replaced by a muon, whose mass is 207 times the mass of the electron.

The only difference from the original calculation is in the masses of the particles. In this case, the Bohr radius is

$$a_\mu = \frac{4\pi\varepsilon_0\hbar^2}{\mu_{d\mu}e^2} \tag{1}$$

where $\mu_{d\mu}$ is the reduced mass of the muon and deuteron. Taking the deuteron mass to be twice that of the proton, which is in turn 1833 times the mass of the electron, so

$$\mu_{d\mu} = \frac{(207m_e)(2\times 1833m_e)}{207m_e + 2\times 1833m_e} = 196m_e \tag{2}$$

Therefore, the Bohr radius is reduced by a factor of 196, meaning that the two deuterons are separated by $R = 2.4a_\mu = 6.73\times 10^{-13}$ m. Having the two nuclei much closer together should make fusion easier to achieve.