Quantum entanglement for doubly-excited resonance states of the helium atom\textsuperscript{1} Y.-C. LIN, T.K. FANG, Fu Jen Catholic University, Y.K. HO, Institute of Atomic and Molecular Sciences — It is well known that quantum entanglement is relevant to quantum information, quantum computation, quantum teleportation, and quantum cryptography. In our present work, quantum entanglement for doubly-excited resonance states are quantified by calculating the linear entropy ($S_L$) and von Neumann entropy ($S_{vN}$) for such states. The linear entropy is defined as $S_L = 1 - Tr \left( \rho_{\text{red}}^2 \right)$ and the von Neumann entropy as $S_{vN} = -Tr \left( \rho_{\text{red}} \log_2 \rho_{\text{red}} \right)$, where $\rho_{\text{red}}$ is the reduced density matrix, and $Tr$ denotes the trace of the matrix. In our previous works, we calculated the linear entropy for the bound states of the helium atom in free space [1]. Here, we employ the projection operator method [2] to calculate the energies and wave functions of doubly-excited resonance states in the helium atom. Using the projection operators $P$ and $Q$ with $P \psi = (1 - Q) \psi$, we can evaluate the eigenvalues of $\langle QHQ | \rangle = \varepsilon_{\text{res}} \langle QQ | \rangle$, and such eigenvalues $\varepsilon_{\text{res}}$ approximate the resonance energies. Once the wave functions for the resonance states are obtained, we can use them to calculate the von Neumann and linear entropies of the doubly-excited resonance states. In the present work, we investigate the $^13S_e^e$, $^13P_o^o$, $^13D_e^e$, and $^13F_o^o$ resonance series in the helium atom lying below the $\text{He}^+ (N=2)$ threshold. Our results indicate that different series will have different behaviors for their entropies. The detail of our findings will be presented at the meeting.

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