Supersymmetry identifies molecular Stark states whose eigenproperties can be obtained analytically

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We made use of supersymmetric (SUSY) quantum mechanics to find a condition under which the Stark effect problem for a polar and polarizable closed-shell diatomic molecule subject to collinear electrostatic and nonresonant radiative fields becomes exactly solvable. The condition, $\Delta \omega = \frac{\omega^2}{4 (m+1)^2}$, connects values of the dimensionless parameters ω and $\Delta \omega$ that characterize the strengths of the permanent and induced dipole interactions of the molecule with the respective fields. The exact solutions are obtained for the $|\tilde{J}=m,m;\omega,\Delta \omega>$ family of "stretched" states. The field-free and strong-field limits of the combined-fields problem were found to exhibit supersymmetry and shape-invariance, which is indeed the reason why they are analytically solvable. By making use of the analytic form of the $|\tilde{J}=m,m;\omega,\Delta \omega>$ wavefunctions, we obtained simple formulae for the expectation values of the space-fixed electric dipole moment, the alignment cosine, the angular momentum squared, and derived a "sum rule" which combines the above expectation values into a formula for the eigenenergy. The analytic expressions for the characteristics of the strongly oriented and aligned states provide a direct access to the values of the interaction parameters required for creating such states in the laboratory.

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