MANY-BODY THEORY OF POSITRON-ATOM INTERACTIONS

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Many-body theory is an attractive alternative to solving the Schrödinger equation for a system of interacting particles. It allows one to visualise the processes which take place and to consider the role of different mechanisms, without compromising the quantum-mechanical description of the system. The language of Feynman diagrams serves as a universal book-keeping tool for the contributions to the amplitudes of various processes, and is amenable to one's use of physical intuition.

Within the many-body theory formalism, the scattering of a positron by an atom is described by the Dyson equation,

$$H_0\psi(\mathbf{r}) + \int \Sigma_\varepsilon(\mathbf{r},\mathbf{r}')\psi(\mathbf{r}')d\mathbf{r}' = \varepsilon\psi(\mathbf{r}), \qquad (1)$$

where H_0 is Hamiltonian of the positron in the static field of the target (described at the Hartree-Fock level), $\psi(\mathbf{r})$ is the quasiparticle wavefunction of the positron, and $\Sigma_\varepsilon(\mathbf{r},\mathbf{r}')$ is the positron-target *correlation potential*, which depends on the positron energy ε. Although equation (1) has the form of a single-particle Schrödinger equation, the nonlocal potential Σ_ε accounts for all the many-body interactions. It can describe elastic and inelastic scattering. The positron wavefunction $\psi(\mathbf{r})$ can be used to determine the annihilation rate and gamma spectrum. (This also requires inclusion of nonlocal corrections to the *annihilation vertex*, similar to Σ_ε.)

Applied to the positron-atom interaction problem, many-body theory has provided a number of important insights into the physics of this interaction.

- Virtual positronium formation gives a large contribution to the positron-atom correlation potential [1, 2, 3].
- Strong positron-atom attraction gives rise to low-lying positron virtual states (e.g., in Ar, Kr and Xe [2, 5]), and positron binding to neutral atoms [4].
- Positron-atom virtual states are responsible for large values and strong energy dependence of positron annihilation rates on noble gases.
- Short-range electron-positron correlation effects enhance the annihilation rate several times, and have a weak dependence on positron energy [2, 5].
- The formalism can be extended to positron energies above the Ps formation threshold, to describe Ps formation and direct ionization [6].
- Virtual positronium formation and the short-range correlation effects can be accurately included by calculating the electron-positron vertex function [7].

Combined with modern age computer facilities, the many-body theory allows one to develop an accurate quantitative theory of positron-atom scattering, binding and annihilation [7].

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References

[1] M. Ya. Amusia, N. A. Cherepkov, L. V. Chernysheva and S. G. Shapiro, J. Phys. B **9**, L531 (1976).

[2] V. A. Dzuba, V. V. Flambaum, W. A. King, B. N. Miller, and O. P. Sushkov, Phys. Scr. **T46**, 248 (1993).

[3] G. F. Gribakin and W. A. King, J. Phys. B **27**, 2639 (1994).

[4] V. A. Dzuba, V. V. Flambaum, G. F. Gribakin and W. A. King, Phys. Rev. A **52**, 4541 (1995).

[5] V. A. Dzuba, V. V. Flambaum, G. F. Gribakin and W. A. King, J. Phys. B **29**, 3151 (1996).

[6] G. F. Gribakin and W. A. King, Can. J. Phys. **74**, 449 (1996).

[7] G. F. Gribakin and J. Ludlow, Phys. Rev. A **70**, 032720 (2004).