We identify a new kind of elementary excitations in the superconducting state of a doped Mott insulator, called spin-rotons. They will play a central role in deciding the superconducting transition temperature, resulting in a simple $T_c$ formula: $T_c = \frac{E_g}{\gamma k_B}$ with $\gamma \approx 6$ and $E_g$ as the characteristic energy scale of the spin-rotons. We show that the singlet ($S=0$) and triplet ($S=1$) rotons are degenerate in energy, hinting the spin-charge separation, which can be probed by $A_{1g}$ Raman scattering and neutron scattering, respectively, and are in excellent agreement with the high-$T_c$ cuprates.