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Comparative Analysis of Ion-Specific Effects on the Electrophysical and Rheological Properties of DNA Aqueous Solutions with LiCl, NaCl, and KCls

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DNA is a strong polyanionic polyelectrolyte with the properties, which are largely governed by interactions with charged ions (counterions) in aqueous solution. Alkali metal cations differ substantially in ionic radius, charge density, and hydration enthalpy, which in turn determine how strongly they bind to the phosphate backbone, reorganize the surrounding hydration shell, and affect macroscopic transport and hydrodynamic properties of the solution [1,2].

This work presents a comparative analysis of the electrical conductivity and viscosity of aqueous high-molecular-weight DNA solutions in the presence of LiCl, NaCl, and KCl across a common range of salt concentrations and temperatures. Rather than treating each system in isolation, the ionic series $Li^+ \rightarrow Na^+ \rightarrow K^+$ is examined as a single trend, allowing the relative contributions of cation size and hydration strength to charge transport and DNA conformational behavior to be disentangled. Comparison of the conductivity and viscosity responses reveals systematic, ion-specific deviations that correlate with the strength of cation–phosphate binding and the degree of ion dehydration upon association with DNA. The concentration- and temperature-dependence of these deviations further indicates how the balance between electrostatic screening and hydration-shell re-structuring shifts along the Li^+–Na^+–K^+ series.

These comparative trends provide a more direct route to identifying the mechanisms underlying ion-specific effects in DNA–electrolyte systems than analysis of individual salts alone, and contribute to a more general understanding of counterion selectivity in polyelectrolyte solutions.

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[2]. Perepelytsya, S., Piatnytskyi, D., Bubon, T., Cibotariu, N., Laaksonen, A., & Mocci, F. (2026). Ions as architects of DNA nanostructures: Mechanisms, simulations, and technological frontiers. Small Structures, 7, e202500786. https://doi.org/10.1002/sstr.202500786

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