INTRODUCTION

Certain aqueous metal cations have been demonstrated to facilitate the abiotic formation of linear RNA oligomers through condensation of activated nucleotide monomers. Such RNA may have played a key role in the emergence of life. However, the significance of concentration and the extent to which metal cations can impact polymerization remain largely unknown. These include common ions, such as Na+, Ca++, and Mg++, which were also likely abundant early in Earth’s history. Here we investigate the relationship between concentration and the length of the resulting RNA products.

EXPERIMENTAL METHODS

All experiments were performed using imidazole-activated adenosine 5’-monophosphate (ImpA). Of the canonical nucleotides, ImpA consistently yields the longest oligomers and allows for the most sensitive detection of variation in polymerization. Metal cations were supplied by dissolving the appropriate chloride salts in deionized water. Experiments were left undisturbed for ~3 days before analysis.

RESULTS

Figure 2 Average maximum observed linear RNA oligomer lengths plotted at each concentration (M) of aqueous metal cation tested. Metals can be categorized into one of two groups. The first group (A) results in higher oligomer lengths as concentration increases across the entire concentration range. The second group (B) exhibits local maxima in length at concentrations far from saturation. Triplicates of each experiment were tested and analyzed via MALDI-TOF MS. Error bars indicate the range of observed maxima.

DISCUSSION

The results presented in Figure 2 highlight the strong dependence of oligomer length on aqueous metal concentration in solution, and illustrate the differences between metal species. These data suggest that highly saline waters may be suitable prebiotic environments for the synthesis of RNA. Such waters exist today as brines in evaporite forming environments, which were also likely present on both the early Earth and Mars. The mechanism behind the polymerization observed in these experiments is elusive. However, the data shown in Figure 3 suggest that the extent of polymerization is partially dependent on the charge densities of the ions in solution. The remaining variables contributing to the observed phenomena continue to be investigated.

FIGURE 1

(A) ~0.5 mg of ImpA are weighed into an RNase-free microcentrifuge tube. (B) Deionized water is added to dissolve the nucleotide. (C) The appropriate volume of concentrated metal chloride solution is added to the nucleotide solution to reach the desired concentration. The total volume of each experiment is 100 microliters.

FIGURE 2

Maximum observed linear RNA oligomer lengths for each metal across the range of experiment concentrations. Charge density was calculated using 6-fold coordination effective ionic radii reported by Shannon (1976).