Combinatorics for spontaneous assembly With four nucleotides, we have 4100 possible combinations. But organic molecules exist in two varieties: left- and right-handed ones. For each nucleotide, the handedness (chirality) must match, so we have a multiplier of 2100. Between nucleotides, the right type of bond must form, too. If we assume a very generous 50% chance for that to happen, which is much higher even with amino acid catalysts present, we have another factor of 0.50-99 = 299. We must therefore synthesize 4100 . 2100 . 299 ? 10120 candidates for a single successful RNA replicator, which still ignores the specifics from the nucleotide geometries. With 1080 protons in the universe, the spontaneous assembly of an RNA-like molecule by purely classical biochemical means is cosmically improbable, let alone biochemically.

Combinatorics for the assembly ratchet For a tetramer there are 44 sequences with 24 chirality combinations and 23 bonds, or 32,768 possibilities. Out of these there are about 10 or so viable polymers to assemble gradually. These viable tetramers have the right canonical bonds, the right ends, and they have not hydrolysed prior to assembly into functional RNA chains. With only 10 viable polymers there are 1025 possibilities. The total number of possibilities is therefore on the order of 1029. This is still a massive filter, but much more feasible than the all-at-once assembly, for which it is unlikely that intermediate steps are even viable and therefore selected. On that order of magnitude, nature must run more than ten billion experiments in parallel, which is doable, even classically. Interestingly enough, that still far surpasses the number of both active and inactive hydrothermal vents by several orders of magnitude, and therefore bumps into the same combinatorial problem. In fact, classical assembly fails because most intermediate polymers are non-viable "dead ends." Quantum search avoids this via superposition: it simultaneously evaluates the stability across configurations before committing to a physical structure.