The harsh truth about terraforming

I enjoyed reading Charles Day's column on the subject of terraforming in the July 2021 issue of PHYSICS TODAY (page 8). I was only a year old in 1942, so I missed seeing Jack Williamson's story that introduced the term when it was published. I also missed it in the mid 1950s when I read many of the back issues of *Astounding Science-Fiction*.

My first introduction to the concept was from reading *Sands of Mars* by Arthur C. Clarke, first published in 1951, although I don't believe he actually used the term "terraforming." He describes selectively breeding native plants that extract oxygen from the Martian soil to release it into the atmosphere—a precursor of the biological approach in Kim Stanley Robinson's Mars trilogy—and turning Phobos into a second sun to warm the planet.

On a more serious note, it seems to me that the very concept of terraforming represents a striking display of human hubris. Today we are struggling to safeguard the health of Earth's critical ecosystems from the unintended consequences of the artificial environment we have built. Given our limited success so far and significant chance of failure, the idea that we could create a viable, self-sustaining environment on another planet anytime soon seems pretty far-fetched. The reality is that a planetary ecosystem is many orders of magnitude more complex than what we are currently able to deal with. The time will likely come when our capabilities will have reached that level, but for the moment, terraforming appears destined to remain in the realm of science fiction and, apparently, board games.

MARS'S SURFACE as captured by NASA's *Curiosity* rover. The image's white balance has been adjusted to show how the surface of Mars would look under Earth's skylight. Terraforming Mars has been the subject of several works of science fiction, such as *Sands of Mars* by Arthur C. Clarke. (Courtesy of NASA/JPL-Caltech/MSSS.)

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More on Arrhenius plots

Axel Lorke's Quick Study in the May 2021 issue of PHYSICS TODAY (page 66) describes Svante Arrhenius's illustrious career and provides important insight into Arrhenius's quantitative description of thermally induced processes. Lorke describes the broad power of the famous Arrhenius relationship $a = A\exp(-E_a/k_BT)$, where k_B is the Boltzmann constant and T is absolute temperature, to capture complex physics with temperature-dependent measurements aimed at the extraction of a single parameter, the activation energy E_a. Presenting an example from thermodynamics and another from kinetics, he shows how E_a connects closely to independently determined quantities such as a semiconductor's bandgap energy and the UV-induced gelation energy of proteins.

The Quick Study focuses on the slope of logarithmic plots of rates and other temperature-dependent quantities versus inverse temperature $1/T$. In kinetics, the prefactor A of the exponential also provides important physical information. It may be obtained by extrapolating an Arrhenius line like that of figure 3 in Lorke's Quick Study to yield an intercept at the