The first law of cosmochemistry

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The basic assumption that the Solar System started with a well defined initial isotopic composition is so fundamental to inferring Solar System evolution that it should be called “the first law of cosmochemistry”. However, the existence of very small isotopic heterogeneities in heavy elements like Ba and Nd in bulk samples of primitive meteorites suggests that this law may not be entirely correct when applied to the smallest scale isotopic variations. We have been conducting experiments with the ZBL laser at Sandia National Laboratory to understand the physical mixing processes that are important in leading to the isotopically well mixed nature of the Solar System. Our results suggest that this is due to Richtmyer-Meshkov instabilities producing shock-induced turbulent mixing both in our laser experiments as well as in the two major steps of pre-solar isotope mixing: (1) supernova explosions and (2) molecular cloud collapse. Within the Solar System this process also causes additional chemical and isotopic mixing, in particular during the giant impact stage of planetary formation. The observed mixing can be qualitatively explained by simple theoretical scaling relationships. The key to why this works can be found in the fact that Euler's equations remain scale invariant between micron and mm scale laser experiments to large-scale astrophysical phenomena such as supernova explosions. This has been called “Euler similarity” because it depends directly on Euler's equations. Therefore, such scaling is valid for all aspects of hydrodynamic instabilities including the Richtmyer-Meshkov and Rayleigh-Taylor instabilities, and their possible interaction with the Kelvin-Helmholtz instability.

Review of solutions to global warming, air pollution and energy security

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This study reviews and ranks major proposed energy-related solutions to global warming, particle and gas air pollution mortality, and energy security while considering impacts on water supply, land use, wildlife, resource availability, thermal pollution, water chemical pollution, and nuclear weapons risk. Nine electric power sources and two liquid fuel options were considered. The electricity sources included solar-photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, hydroelectric, wave, tidal, nuclear, and coal with carbon capture and storage (CCS) technology. The liquid fuel options included corn-ethanol (E85) and cellulosic E85. To place the electric and liquid fuel sources on an equal footing, their comparative impacts of powering new-technology vehicles, including battery-electric vehicles (BEVs), hydrogen fuel cell vehicles (HFCVs), and flex-fuel vehicles run on E85, were examined. Upon ranking and weighting twelve combinations of energy source-vehicle types with respect to 11 impact categories, four clear divisions, or tiers, emerged. Tier 1 (highest-ranked) included wind-BEVs and wind-HFCVs. Tier 2 included CSP-BEVs, geothermal-BEVs, PV-BEVs, tidal-BEVs, and wave-BEVs. Tier 3 included hydro-BEVs, nuclear-BEVs, and CCS-BEVs. Tier 4 included corn- and cellulosic-E85. Wind-BEVs ranked first in 7 out of 11 categories. Its land footprint is 2-6 orders of magnitude less than that of any other option, minimizing wildlife loss and maximizing carbon storage. Nuclear and coal-CCS emit 9-17 and 41-53 times more carbon, respectively, than wind, Cellulosic-E85 may cause the greatest average human mortality and nuclear-BEVs, the greatest upper-limit mortality risk. In sum, the use of wind, CSP, geothermal, tidal, PV, wave, and hydro to provide electricity for BEVs and HFCVs and, by extension, electricity, will result in the most benefit among the options considered. Coal-CCS and nuclear offer less benefit thus represent an opportunity cost loss, and the biofuel options provide no certain benefit and the greatest negative impacts.