Earth, and that the required rate of increase is in remarkable agreement with the previously calculated rate of decrease of the Earth's radius (*Proc. R. Soc. op cit.*; 1965).

Small as the rate of decrease may seem, it yet gives a change in the Earth's angular velocity comparable to that produced by the tidal couples, but of opposite sign and therefore accelerative as required. Lyttleton shows that while a similar but much smaller acceleration could also be produced by separation of iron into the core, such draining down is generally regarded as having occurred largely, if not entirely, early in the Earth's history, and even under the most favourable assumptions as to the present rate, it could not nearly account for the observed discrepancy. It would seem that unless the adherents of the iron core hypothesis can produce a comparably satisfactory alternative explanation for this discrepancy emerging from the standard Jeffreys tidal theory, Lyttleton has struck a telling blow for the phase-change hypothesis for the nature of the core. □

Beaded bubbles

from Robert W. Cahn

An infinite monocrystalline element containing a second element in solid solution, not liable to any phase transformation, tends to a spatially uniform distribution of the dissolved element, and diffusion will persist until that stable terminal state is attained. That cautious opening sentence incorporates several provisos: if the solid consists of distinct crystal grains or, being less than infinite, is bounded by free surfaces, complications ensue. In general, solutes tend to segregate either to or away from free surfaces or grain boundaries; improved methods of microanalysis have allowed a considerable body of experimental information to be assembled concerning this process of 'Gibbsian' segregation (J. H. Westbrook, in *Interfaces Conference, Melbourne 1969* (ed. Gifkins, R. C., 283 (Butterworth, 1969); E. D. Hondros, *ibid*, page 77). Hondros's extensive experimental work has led him to the conclusion that solutes with a small equilibrium bulk solubility (usually associated with very different solvent and solute atomic sizes) are particularly apt to segregate to interfaces and surfaces, thereby relieving lattice strain in the solvent. As Westbrook points out, surface segregation is not restricted to external surfaces; it can apply equally to internal pores, such as are found in imperfectly sintered powder compacts. Westbrook emphasises the role of the binding energy that holds vacancies and solute atoms together; if this is high, any excess vacancies diffusing to a pore must drag solute atoms along with them.

Materials scientists responsible for the design of nuclear fuel elements are currently much concerned with pores —'voids' is the preferred term—in neutron-irradiated metals and ceramics. During irradiation (especially of the metal used to encapsulate the fuel) interstitial atoms and vacancies are formed in equal numbers and diffuse away to 'sinks', predominantly dislocations and grain boundaries. These sinks attract interstitial atoms more effectively than vacancies and the surplus vacancies then assemble to form small voids, visible in the electron microscope. The voids cause swelling of the material, a disease which must be kept within strict bounds for safety reasons. The principal strategy for minimising swelling is to choose suitable base metals and to maximise the concentration of effective sinks for interstitials and vacancies alike. Now, another strategy has been identified.

Some years ago, P. R. Okamoto and H. Wiedersich of the Argonne National Laboratory (*J. nucl. Mater.* **53**, 336; 1974) observed indications that solute elements segregate to radiation-induced voids in a stainless steel. The evidence was indirect—micrographic features indicating pronounced lattice distortion alleged to accompany the segregation—and it was not possible to identify the segregating species. The investigators suggested that it was interstitial solute atoms generated by the irradiation which segregate and lead to the high lattice distortion observed in the electron microscope. Thus Hondros's view that segregation acts to reduce lattice strains is not always in accord with observation.

The whole matter has now been clarified by an elegant set of experiments published by K. Farrell, J. Bentley and D. N. Braski of Oak Ridge National Laboratory (*Scripta Met.* **11**, 243; 1977). They irradiated aluminium foils to very high neutron doses, enough to generate about 0.4 atomic % silicon by $^{27}Al \rightarrow (n,\gamma) \rightarrow {}^{28}Al \rightarrow {}^{28}Si + e$. When the foils were thinned and examined by scanning transmission electron microscopy (STEM), they were seen to contain not only ordinary voids and silicon precipitates, as expected, but also some anomalous voids sitting on the surface of the foil or extending beyond the foil edge. In fact, these voids, bounded by a dark margin, were inhabiting empty space. Very detailed electron microprobe experiments using the ultrafine STEM beam proved that these free-standing voids were coated with shells (4–11 nm thick) of (possibly amorphous) silicon. The aluminium surrounding them had been dissolved away during the thinning process, leaving hollow silicon spheres standing clear of the foils. Silicon has a small solubility in aluminium, and meets Hondros's criterion for ready Gibbsian segregation.

Farrell, Bentley and Braski point out that this substantial Gibbsian segregation offers the hope of influencing the growth rate of voids, especially in their early stages. The segregated solute must alter the specific surface energy at the void walls and thus affect the efficacy of the void in attracting vacancies—and hence must alter the swelling rate too. If Okamoto and Wiedersich are right in presuming that radiogenic interstitial solutes are peculiarly prone to Gibbsian segregation, then it may be possible to design alloys with initial solutes which, after radiation-induced transmutation, segregate to the incipient voids and inhibit their further growth. That would be an elegant way of setting one consequence of irradiation to neutralise another. □

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The plasmapause revisited

from Michael J. Rycroft

Within the charged particle environment of the Earth, which encompasses the ionosphere and magnetosphere, the plasmapause is a physically significant boundary. The plasmapause marks the boundary between the cool, relatively dense plasma of terrestrial origin and the hot, tenuous plasma of both terrestrial and solar wind origin which resides in the outer magnetosphere. This demarcation feature is aligned along lines of force of the Earth's magnetic field; the feet of these field lines touch the Earth's surface at near 60° magnetic latitude. They extend out into space, crossing the equatorial plane at a geocentric radial distance of ~ 4 Earth radii. Such field lines are termed $L \sim 4$ field lines, using the parameter L introduced by McIlwain as a coordinate to order observations of the van Allen radiation belt electrons.

The existence of the plasmapause was discovered independently by two different scientists almost 20 years ago.

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