Mechanism of solid-state fusion

SIR—Experiments by Derjaguin *et al.*[1,2] indicating that MeV neutrons were emitted during the destruction of heavy ice or monocrystals of LiD went almost unnoticed, whereas recent claims of 'cold fusion'[3,4] have attracted worldwide attention, ranging from highly enthusiastic confirmations to equally sceptical rejections. Here we wish to present some relevant considerations of mechanisms which could enhance nuclear interactions in the solid state.

A body of experimental evidence[5,6] suggests that hydrogen resides in transition metals as a simple 'lattice gas'. Although the rate for nuclear fusion of d + d in the lattice may be increased over the 'free' rate because of screening of the repulsive Coulomb potential by lattice electrons, the enhancement cannot be large enough[7] to explain the claims of refs 3 and 4. Likewise, single-neutron tunnelling at low energies (the Oppenheimer–Philips mechanism[8]) will not do the job, and an excited resonance state in ^{4}He (ref. 9), because under these conditions the tunnelling time is much longer than the lifetime of the resonant state.

Any enhancement of the fusion rate must then be 'chemical' in origin — the potential barrier between deuterons may change shape substantially, or deuterons may gain some unusual thermal activation.

An increase in the density and effective mass of lattice electrons can cause a decrease of the shielding radius and a corresponding increase in barrier penetrability. In addition, the combined effects of a redistribution of electrons and lattice deformation may produce a local minimum in the potential barrier. Under the right conditions, a quasi-stationary complex can form, and an effect known as resonance transparency may appear[10]. If such a complex has a vibrational frequency with an energy ~ 0.1 eV, the effective collision frequency of deuterons can be greater by as much as a factor of 10^9 over the simple 'lattice gas' value.

A considerable increase in the fusion rate would also come about if a single deuteron were able to acquire ~ 10 keV of energy. In a lattice in equilibrium such an energy transfer would not occur, but perhaps during the destruction of a lattice there might be significant localization of the destruction energy, which could be transferred to absorbed deuterons. A macroscopic version of this effect is found in the electrostatic acceleration of deuterium ions in cracks, which, as noted by Cohen and Davies in their recent News and Views article[11], is apparently responsible for the appearance of neutrons during the shock destruction of D_2O and LiD (refs 1 and 2).

This is then a problem in piconuclear (pressure-induced) reactions rather than in thermonuclear reactions. Common features may apply in the various experiments: high overvoltages and D compression in ref. 3, cold fusion in natural geophysical conditions in ref. 4, and high static pressures and shears in refs 1 and 2.

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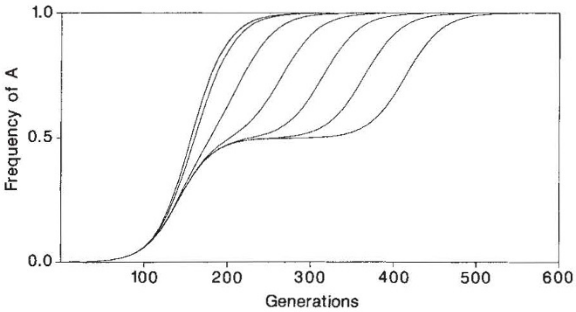
Sex in diploids

SIR—Kirkpatrick and Jenkins[1] suggest that the origin and maintenance of sex in diploids is related to the advantage conferred by genetic segregation. They contend that the segregation advantage gained by facilitating the fixation of advantageous mutations more than compensates for the twofold reproduction advantage of asexual reproduction. We point out here that the segregation advantage they discuss is present even when only a very small proportion of individuals in a population reproduce sexually.

To illustrate this, we have compared the pattern of increase in the frequency of a favourable allele in a population with only sexual reproduction to that in populations where there is a mixture of sexual and asexual reproduction[2]. As an example, the figure shows the change in allelic frequency of advantageous mutation A when there is a 10 per cent selective difference between homozygotes and the heterozygotes are exactly intermediate in fitness. Note first that the initial increase from 0.001 to nearly 0.5 occurs essentially at the same rate for all levels of sexual reproduction. Furthermore, even if there is only a very small amount of sexual reproduction, the continued increase of the advantageous allele from 0.5 to fixation is nearly as fast as that in a completely sexually reproducing population.



The change in frequency of advantageous mutation A for different amounts of sexual reproduction. For the curve on the far right the proportion of sexual reproduction is 10^{-7} (1 in 10 million individuals reproduce sexually). Successive curves to the left are for increasing amounts of sexual reproduction (10^{-6}, 10^{-5}, . . 10^{-1}). The curve for 10 per cent sexual reproduction is indistinguishable from 100 per cent sexual reproduction.

Kirkpatrick and Jenkins show that there is a plateau at a frequency of 0.5 for the heterozygous asexual population while it is waiting for the occurrence of a second mutation. We observe a temporary plateau at an allelic frequency of 0.5 only when the proportion of sexual reproduction is about 10^{-6} or smaller. This plateau, which is generally very short and in the most extreme case in the figure only doubles the time to fixation of the favourable mutant, occurs because the population consists of nearly 100% heterozygotes at the beginning of this period and is waiting for segregation to produce AA homozygotes (which it will at a rate about ¼ times the rate of sexual reproduction). We also find that the relative duration of this plateau is even shorter when the selective difference between the homozygotes is reduced.

A number of species have a small (but not zero) amount of sexual reproduction[2,3]. Perhaps this is a way in which a species can have both the segregation advantage discussed by Kirkpatrick and Jenkins and the twofold advantage of asexuality many others have noted. In other words, we see why some sexual reproduction should be favoured over complete asexual reproduction because of the segregation advantage, but it is not clear why a lot of sexual reproduction should be favoured over a little[4].

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