deuterium.

The consequence is that fusion induced by cosmic-ray muons cannot be excluded as an explanation of the reports of radiation effects in palladium loaded electrochemically with deuterium, although the estimates of the rate of muon-induced fusion is much less than that required by the thermal observations of Fleischmann and Pons[10].

These developments emphasize the need for experimental data on the effects of negative muons in solids, especially metal deuterides and tritides, which are at present lacking in the open literature. Arrangements are in hand to investigate the reported palladium-deuterium effects with a muon source of greater flux than that of the natural cosmic ray radiation.

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SIR—In my theoretical investigations of the electronic structure of the H_2^+ molecule (*Phys. Lett.* **123**, 170; 1987), I have found that the two nuclei and the electron can form a collapsing quasi-molecule — a compound system whose dimensions decrease with time to zero. (The extreme case is when the electron is at the centre-point between the two nuclei.) In general, in collapsing molecules like these, the repulsive Coulomb interaction of the nuclei and the gas-kinetic pressure of the electron are less than the attractive Coulomb forces between the two nuclei and the electron. The closest approach of the two nuclei depends on the initial state of the electron, its binding energy and the mean value of the kinetic energy in particular.

The probability of the tunnelling effect is therefore identical with the probability of formation of a collapsing quasi-molecule. Thus it is clear that the electrons present in the matter are responsible for the Coulomb-barrier tunnelling, and that the process which has been observed depends on quasi-molecular systems.

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SIR—Reports of the experiments by Fleischmann and Pons contain a paradox — that, if fusion reactions do occur in them, either too much energy is liberated or too few neutrons are detected. I wish to suggest a possible explanation.

I start from the hypothesis that the palladium contains regions where the density of deuterons is sufficiently great for d-d fusion to occur by one of the reactions leading either to ^{3}H and a proton or to ^{3}He and a neutron. The product particles will be produced within a region where the density of other particles is very great. The mean free paths of the particles will then be very small, and it appears reasonable to assume that even though these high-density regions will be geometrically small, they will be so optically large that even the most penetrating particles, such as neutrons, will remain trapped inside them. In this situation, the particles produced by fusion reactions will undergo multiple scattering collisions until a new reaction occurs.

Several such reactions are possible, including fusion reactions of deuterons with ^{3}H and ^{3}He (yielding ^{4}He and a neutron or proton respectively) and the radiative capture of protons or neutrons by deuterons. These reactions are exothermic, releasing large amounts of energy.

It is crucial that these processes can also form multiplicative chains, especially if the γ-ray photons released by radiative capture reactions yield further energetic neutrons and protons by the photodisintegration of deuterons. The reaction chains will come to an end only when reactive particles escape from high-density regions to those where the density is insufficient to sustain them.

The main products of these reaction chains will be α-particles, but the reactive particles such as neutrons and ^{3}H will only infrequently be released to the environment.

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Pulsar formation

SIR—Lindley[1] states that the report[2,3] of a half-millisecond pulsar in the remnant of supernova 1987A "has surprised everybody and could, if confirmed, stand theory on its head". He has apparently overlooked several papers (refs 4 and 5, for example) suggesting that pulsars may form directly as rapidly rotating neutron stars "in original spin" with weak magnetic fields, without the need for "resurrection" after birth as a slow rotator followed by subsequent decay of the magnetic field and spin-up by accretion of matter from a companion star[6].

Even before the discovery of millisecond pulsars, we discussed[7] the question of why collapsed stars rotate so slowly, and pointed out that if there was significant mass ejection during the formation of a neutron star, and if it had a strong magnetic field, it was likely to be born spinning slowly. We argued, furthermore, that if the progenitor giant core of the neutron star has a strong magnetic field, it is likely to have been rotating relatively slowly, as the magnetic field would have enhanced transfer of angular momentum from it to the envelope during earlier evolutionary phases. We concluded that if weak-field neutron stars could form at all, they would be born spinning fast. If the optical emission from the half-millisecond pulsar arises from incoherent synchrotron radiation at the light cylinder, and scaling by the optical luminosity and magnetic field of the Crab pulsar, it follows that the half-millisecond pulsar indeed has a weak magnetic field of $B \sim 10^8$ gauss.

With the discovery of six millisecond pulsars (with periods $\leq$12 ms), of which four are in binary star systems, several authors concluded that 'resurrection' was required to account for their observed properties. A key requirement for the 'resurrection' model is that the magnetic field of neutron stars must decay on a timescale of a few million years. But arguments against significant neutron-star magnetic-field decay have been proposed (for example, ref. 8). Futhermore, calculations by Sang and Chanmugam[9] showed that there are serious difficulties with all models so far proposed for field decay. In addition, there is no satisfactory detailed model that explains how single millisecond pulsars can be formed from binary star systems. Even in the case of PSR1957 + 20, where there is evidence of matter evaporating from the companion, the spin-down rate indicates insufficient energy loss from the pulsar to evaporate the entire companion star. When combined with all the difficulties of the 'resurrection' model, the discovery of the half-millisecond pulsar seems to provide substantial further support for the view that at least some millisecond pulsars can be born "in original spin".

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