lished Fig. 1*a*, thereby not providing the supporting evidence of the ^{40}K (1.46-MeV) and ^{208}Tl (2.61-MeV) features which must be present in their spectra in order for their identification to be correct.

Therefore, although Fleischmann *et al.* may have observed a change in their γ-ray spectra that bears some relation to detector location, we conclude that it is unrelated to the 2.22-MeV neutron-capture γ-rays, and that it is also unrelated to the background $^{214}_{83}$Bi line (2.20 MeV; Fig. 1*a*), as has been suggested elsewhere[11]. We can offer no plausible explanation for the feature other than it is possibly an instrumental artefact, with no relation to a γ-ray interaction.

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Fusion in from the cold?

SIR—Recent experiments involving the loading of deuterium (D) into palladium[1] via a 0.1 M $LiOD/D_2O$ electrolyte may have created something not encountered in the absence of current flow. The voluminous body of older work on electrolytic D–Pd loading is based on thin wires or foils of high aspect ratio which allow only small voltage differentials. But the reported chemical potential across a thick deuterated palladium negative electrode could give rise to metastable solid phases alien to the existing equilibrium Pd–D phase diagram. The theoretical existence of palladium analogues to hydrogen-rich[2] compounds like Li_2ReH_9 is as tantalizing as the limit of solid solubility of D in Pd is finite. And beyond PdD_3 (by analogy to the known compound Li_3Pd) the thermodynamic distinction between the higher palladium deuterides and metallic deuterium grows dim. The mechanism of their formation might involve the intersection of high deuteron mobility grain boundaries with the Cottrell clouds of H and D that decorate dislocations in many transition metals.

A small mass of (mostly) deuterons transforming into molecular deuterium as they recapture electrons previously delocalized into the S- and D-bands of palladium could release roughly 1 MJ mol^{-1}. Apart from explaining the electrode meltdown and vaporization reports[1] (although this could be due to lithium's remarkable ability to lower the melting point of palladium), this could raise local temperatures to very high values.

Could the so-called 'cold fusion' environment in fact involve local temperatures of greater than 10^5 K generated by the detonation of deuteron clusters (R. G. Gordon, personal communication) or of a metallurgical precipitate, coarse or fine-grained, of a high D/Pd ratio intermetallic compound inside a deuterated palladium electrode? The energy of reassociation of electrons and deuterons is roughly 1 Rydberg (13.6 eV) minus the work-function of Pd (4.9 eV); to this must be added the roughly 4.7 eV liberated when two deuterium atoms pair. Obviously, these energies must be scaled down to compensate for the difference between reactions in free space and the solid state. Nevertheless, the 20 eV energy of formation of D_2 from deuterons could thus produce hot and highly compressed deuterium plasma bubbles of small (>0.01μm–<100μm) size. As to the objection that the surrounding cool metal will quench these bits of pale fire in a nanosecond or so, I believe it answers a serious question: how come the Fleischmann and Pons[1] claimed neutron yield is 9–14 orders of magnitude short of their claimed heat flux? At present, one can only speculate as to by how many orders of magnitude a reflected spherical shock front might raise the temperature and pressure of the D-plasma.

There is another ramification to the notion of nano-novas flashing out of per-deuteride grains decorating the grain boundaries of electrochemically overwrought palladium nagative electrodes. The explosion of such precipitated grains will, above a critical radius, generate cracks in the adjacent metal. It has been postulated (G. Chapline, personal communication) that the surfaces of such cracks, as they open, could host a field gradient or a propagating array of plasmons down whose wake field a deuteron could accelerate. This presumes that the bulk Pd–D system has reached 1:1 stoichiometry and thus been restored to long-range order; this condition is very far from the disorderly and anharmonic state of Pd–D during the early stages of electrolytic D-loading. In this model some thousands of unit cells of travel would suffice to yield keV deuterons. So the propitiated shade of Rutherford may yet countenance not-so-cold fusion.

It has been noted in a News and Views article in the 27 April issue[3] that neutrons have been observed when cracks are generated in crystals of lithium deuteride[4].

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1. Fleischmann, M. & Pons, S. *J. electoanalyt. Chem.* **261**, 301–308 (1989).
2. Shaw, B.L. *Inorganic Hydrides*, 99 (Pergamon, Oxford, 1967).
3. Cohen, J.S. & Davies, J.D. *Nature* **338**, 705–707 (1989).
4. Klyuev, V.A. *et al. Sov. tech. Phys. Lett.* **12**, 551 (1986).

Mössbauer cancer therapy doubts

SIR—Mills *et al.*[1] present data to support the view that a dose of 10^{-5} Gy of 14.4-keV X-rays can ablate a population of malignant cells containing ^{57}Fe(III) · bleomycin. They suggest that such a regime may have the potential for the low-dose sterilization of superficial human tumours.

This is unlikely on simple physical grounds, basically because only a small fraction of the exposed cells will have received any energy deposition at all. The proportion of cells that would receive one or more energy depositions, assuming the statistical independence of such events, is obtained from the Poisson distribution and is $(1 - e^{-n})$; here n, the average number of energy depositions occurring in the sensitive site, is given by D/z_{1F}, where D is the absorbed dose and z_{1F} is the so-called 'frequency-averaged specific energy per event' — or simply, the mean energy per unit mass deposited by single energy deposition events in the sensitive site in the cell[2]. This mean specific energy will be similar, irrespective of whether the photon is ultimately absorbed in a photoelectric event or in a Mössbauer absorption (it would be slightly larger in the latter case); it has been measured for 12-keV photons in a tissue-equivalent material in spherical sites of various volumes[3].

Appropriate volumes for consideration are those of typical human cell nuclei (100–1,000 μm^3)[4] or, perhaps more relevantly, the volume of nucleotides in the mammalian nucleus (~3 μm^3)[5]. For volumes of 250 and 3.5 μm^3, for which measurements have been made[3], the corresponding values of z_{1F} are 4×10^{-3} Gy and 0.14 Gy. These numbers yield a probability of about 2.5×10^{-3} that a 250 μm^3 volume of cell nuclei will be subject to at least one energy deposition, and a corresponding probability of 7×10^{-5} for a 3.5 μm^3 volume of nucleotides. Thus, only about 1 in 400 cells (250 μm^3 volume) or 1 in 14,000 cells (3.5 μm^3 volume) would receive any energy deposition at all if exposed to a dose of 10^{-5} Gy.

To sterilize even a small tumour containing about 10^8 cells requires an appropriately small probability (less than 10^{-9}) that any cell will receive no energy-deposition events. Thus, an average number of energy depositions per cell of

1. Mills, R.L. *et al. Nature* **336**, 787–789 (1988).
2. *Microdosimetry ICRU Rep.* 36 (ICRU, Bethesda, 1983).
3. Kliauga, P.J. & Dvorak, R. *Radiat. Res.* **73**, 1–20 (1978).
4. Altman, P.L. & Katz, D.D. (eds) *Cell Biology* (FASEB, Bethesda, 1976).
5. Brenner, D.J. *Radiat. Envir. Biophys.* **27**, 189 (1988).
6. Goodhead, D.T., Thacker, J. & Cox, R. *Phys. med. Biol.* **26**, 1115–1127 (1981).