50 YEARS AGO

The Chemistry and Mode of Action of Plant Growth Substances — This volume is a collection of the full texts of papers contributed at the third International Conference on Plant Growth Substances... Since much of the data have appeared, or will be appearing, in botanical or chemical journals, the value of such a publication is left in some doubt... The great advantage of such meetings is that it allows scientists to 'stick out their necks'. The prospect of appearing in print is likely to inhibit this completely. The book is nevertheless an excellent technical production, and will doubtless be of great interest to all workers in the auxin field.

From *Nature* 30 March 1957.

100 YEARS AGO

In reference to the weight-judging competition, Mr Galton says that "the average competitor was probably as well fitted for making a just estimate of the dressed weight of the ox as the average voter is of judging the merits of most political issues on which he votes." These competitions are very popular in Cornwall; but I do not think that Mr Galton at all realises how large a percentage of the voters—the great majority, I should suspect—are butchers, farmers, or men otherwise occupied with cattle... I am afraid that the vast majority of such competitors know far more of their business, are far better trained, and are better fitted to form a judgment, than are the majority of voters of any party, and of either the uneducated or the so-called "educated" classes. I heartily wish that the case were otherwise. **F. H. Perry-Coste**

I inferred that many non-experts were among the competitors... It would be of service in future competitions if a line headed "Occupation" were inserted in the cards, after those for the address. **Francis Galton**

From *Nature* 28 March 1907.

50 & 100 YEARS AGO

acting through other receptors. These two unresolved issues might provide the basis for more immediate future investigations on this complex but tractable animal communication system. ■

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SOLID-STATE PHYSICS

Vacillating valence

Robert C. Albers and Jian-Xin Zhu

Electrons in one particular solid phase of plutonium are complex characters: while bound to atoms, in a quantum-mechanical mixture of two different valence states, they also roam freely throughout the crystal.

Plutonium is the most puzzling element of the generally bizarre actinides, the group of metals that, together with the lanthanides, nestles below the standard periodic table. It is extremely sensitive to added impurities, and comes in six distinct solid phases below its melting point of just over 900 kelvin. In particular, its δ phase at 600 K is characterized by a hugely increased volume per atom, around 25% greater than that of its room-temperature (300 K) α phase[1].

On page 513 of this issue[2], Shim, Haule and Kotliar explain the odd behaviour of the δ phase in terms of an underlying instability in its electronic structure. Electrons in a solid can be either atomic — strongly bound and localized deep in the core of an atom — or metallic, delocalized and overlapping with the electrons of neighbouring atoms to form bonding or itinerant states. But the electrons in the outermost ($5f$) orbitals of plutonium's δ phase, which should be metallic, actually show qualities of both atomic and metallic electrons[3]. Shim *et al.* investigate this split personality in detail, and show that it arises from a mixture of two different atomic valence states. Previous work focused mainly on the metallic aspects of these electrons; this work allows us to penetrate the complexity of electronic states on the boundary of localization.

The dilemma of the dual nature of the δ phase $5f$ electrons is reminiscent of the early days of quantum mechanics, when controversy raged as to whether electrons were particles or waves. Eventually, it was decided that they were both. The $5f$ duality similarly has a quantum-mechanical origin, but this time it is in the 'correlated electron' problem. Electrons have the same negative charge and so repel each other electrostatically. In simple, crystalline metals, this effect is weak, and the effect of all other electrons on one individual electron can be calculated using an averaged effective repulsive potential.

This 'self-consistent mean-field approximation' predicts itinerant electronic states, and provides generally accurate predictions of a metal's bonding, phase stability, equation of state, and so on. But where electrons are more strongly localized (atomic), the approximation starts to fail. New approaches must take into account not only how electron wavefunctions dance round each other in a correlated fashion so as to lower the total energy of the system, but also phenomena, such as the Pauli repulsion between two electrons of the same spin, that affect the metal's magnetic properties.

Calculating these correlation effects is fiendishly complex. It means ascertaining the detailed motion of every relevant electron — in a solid, some 10^{23} per cubic centimetre! An approximation is needed, and Shim *et al.*[2] use a promising approach called dynamical mean-field theory[4]. This technique makes the reasonable assumption that electronic correlations are strongest between electrons on the same atoms. Such an assumption makes it well suited to exploring the $5f$ electrons in δ-plutonium, whose wavefunctions only weakly overlap those of neighbouring atoms owing to the phase's lower atomic density.

An important test of any model of plutonium's electronic structure is whether it quenches magnetic tendencies. Localized electrons often have large quantum-mechanical 'exchange energies', which cause the alignment of electron