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ON THE POSSIBILITY OF FORMATION OF A NUCLEAR URANIUM LATTICE AT VERY HIGH TEMPERATURES

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At very high temperatures, U metal can be considered to consist of almost completely ionized nuclei, surrounded by a gas of electrons. Under these circumstances, there will be strong Coulomb forces between adjacent U nuclei, and as Maria G. Mayer has pointed out, a tendency for the nuclei to form a lattice.

We have attempted to estimate the possibility of occurence of this phenomenon by two simple, very rough calculations. In both cases, we have compared U with a number of other metals, since the lattices formed by most metals are cubical, and thus, of a simple nature.

First, we have considered as a criterion for melting the ratio of the amplitude of vibration r of the atoms at the melting temperature of the metal to the lattice spacing a. For the U, we have looked at two cases. In the first case, the U atoms have an energy of 5 kev and normal density. For this case, the net charge on the U nucleus was considered to be 88. In the second case the U is compressed 15-fold and the nuclei, with an effective charge of 16, are considered to have an energy of 1 kev. The average frequencies of vibration for the metal lattices are calculated from the Debye temperatures Θ of these metals, and the amplitude of vibration computed at the melting temperatures. The comparison is shown in Table I.

TABLE I

Substance	Θ	T melt.	r/a
W	310° K	3643° K	.069
Au	190	1336	.081
Al	390	933	.091
Ag	215	1233	.093
Pb	88	600	.095
Cu	315	1356	.098
Ca	230	1083	.098
Ni	370	1728	.100
Mo	379	2893	.112
Fe	395	1808	.118
K	100	335	.133
Na	159	371	.143
U, 5 kev, density 19			.418
U, 1 kev, density 15 x 19			.656

We note that, since the amplitudes of the U vibrations are, in both cases, relatively greater than those of any of the other metals at their melting points, the U will have, by this criterion, a greater tendency to form a liquid.

The second criterion for melting compares the energy of the atom or nucleus (kT) with the work required to remove it completely from the lattice, to leave a hole in its former place, and to attach the nucleus at the surface of the lattice. In the case of U, this work was considered to be given by the energy required to remove the U nucleus from its surrounding uniformly distributed electron gas. Attaching the nucleus at the surface does not liberate energy in the limiting case of high electron

temperatures. This is so because the electrons are distributed in the lattice with uniform density and the energy gained from their interaction with the newly attached nucleus is balanced by their decreased interaction with the other nuclei. In the case of the other metals, this work was taken as the energy of vaporization, (energy of removal = 2 x energy of vaporization; energy on the surface = energy of vaporization; the difference has to be taken) and was compared with kT at the melting point.

This comparison is shown in Table II.

TABLE II

metal	energy of vaporization - H	kT/H
Pb	3.20×10^{-12} ergs/atom	.0270
Al	4.73	.0273
Na	1.81	.0283
Au	6.25	.0294
K	1.53	.0302
Cu	5.70	.0328
Ni	6.80	.0350
Ag	4.80	.0354
W	14.1	.0356
Fe	6.75	.0370
Mo	10.8	.0370
Ca	2.99	.0501
U, 5 kev, density 19	1.02×10^{-7}	.0785
U, 1 kev, density 15 x 19	.083	.193

The ratio of energy to work of removal is seen to be greater, in both cases, for the U than for the other metals at their melting points. Again, this indicates that the U will not form a lattice under the conditions we have considered. However, the margin of safety, according to the above calculations, is not very large, so that further investigations using better criteria for melting seem to be called for.

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