

Potassium tempers earth's core

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The core of the earth, a region some 2900 km deep below, and commencing beyond the mantle zone, contains a third of the total mass of the planet, but forms hardly 14% of the volume. Studies of the seismic wave propagation through this core region, have revealed a solid central portion (about 5% by volume) and surrounding it, a liquid outer zone. In the early stages of our understanding of the earth's interior, scientists thought that the core may be a form of metallic silicate or even metallic hydrogen. But later experiments subjecting silicates to high pressures, disproved this view; also, theoretical calculations indicated that pressures of the order of 18 Mb, not prevalent in the core, are required to convert molecular hydrogen to metallic state, and this view was also dismissed. Based on geochemical abundances of elements in earth and the densities of the core, it has now been established that the core is essentially made up of iron. While these are the broad features of the core zone lying beyond the lower mantle, certain physical features of this region have generated considerable debate among scientists about possible presence of other chemical constituents here, besides iron. For example, seismological measurements show that the core is less dense than pure iron at the core temperature and pressure and this has given rise to speculations among earth scientists seeking to explain its implications on the chemistry of the core.

At the mantle/core transition zone, the density has been estimated to increase from 5.5 g/cc in the mantle zone to 10 g/cc in the core at a pressure of 1.35 million atmospheres. Also the mantle density at the mantle/core interface is found to be 10% higher than expected. This would suggest that the mantle material is soluble in the core and that there has been intermixing between these two adjacent regions¹. That some lighter constituents have dissolved into the core is also favoured by the proponents of the dynamo theory² of earth's magnetic field/electricity production, as this model requires a fairly high electrical resistance of core materials relative to pure iron for sustaining eddy current movements required. Incorporation of U, Th and K has also been attributed to sustain the convection currents through radiogenic heating of the

molten core. Considerable experimental work has been carried out since the 1960s on the solubility of elements at pressures and temperatures prevailing in the core and over the years elements such as K, Mg, C, H, S and O were proposed as the core constituents to explain its reduced density^{1,3}.

Under high pressures such as prevailing in the core region, chemical elements display characteristics that profoundly differ from those seen at ambient conditions. For example, elements that behave like insulators on the surface have been experimentally found to be good conductors of electricity while some others that do not react with certain group of elements are observed to combine with them, at core P and T conditions. Normally, the physical properties like electronic configuration, ionic radii and other parameters of alkali metals like K, Rb or Cs differ in comparison to those of the transition metals such as Fe, Ni or Co. These two groups do not have any chemical affinities and do not react with each other, but researchers have found changes in their size and electronic structure under high pressures and the former group of elements behaved like the latter transition metals and chemically they could combine. At Pennsylvania State University, John V. Badding along with his colleagues Laura J. Parker and Toshiyuki Atou have recently achieved one such unconventional union – that of K and Ni. They took elemental powders of K and Ni and subjected them to very high pressures of the order of 310,000 atmospheres (31 GPa) and above and temperature of about 2500 K, in a laser-heated diamond anvil⁴, an apparatus wherein the sample mixture is squeezed between a pair of gem quality diamonds (Figure 1). The authors collected X-ray diffraction patterns before and after laser heating and found

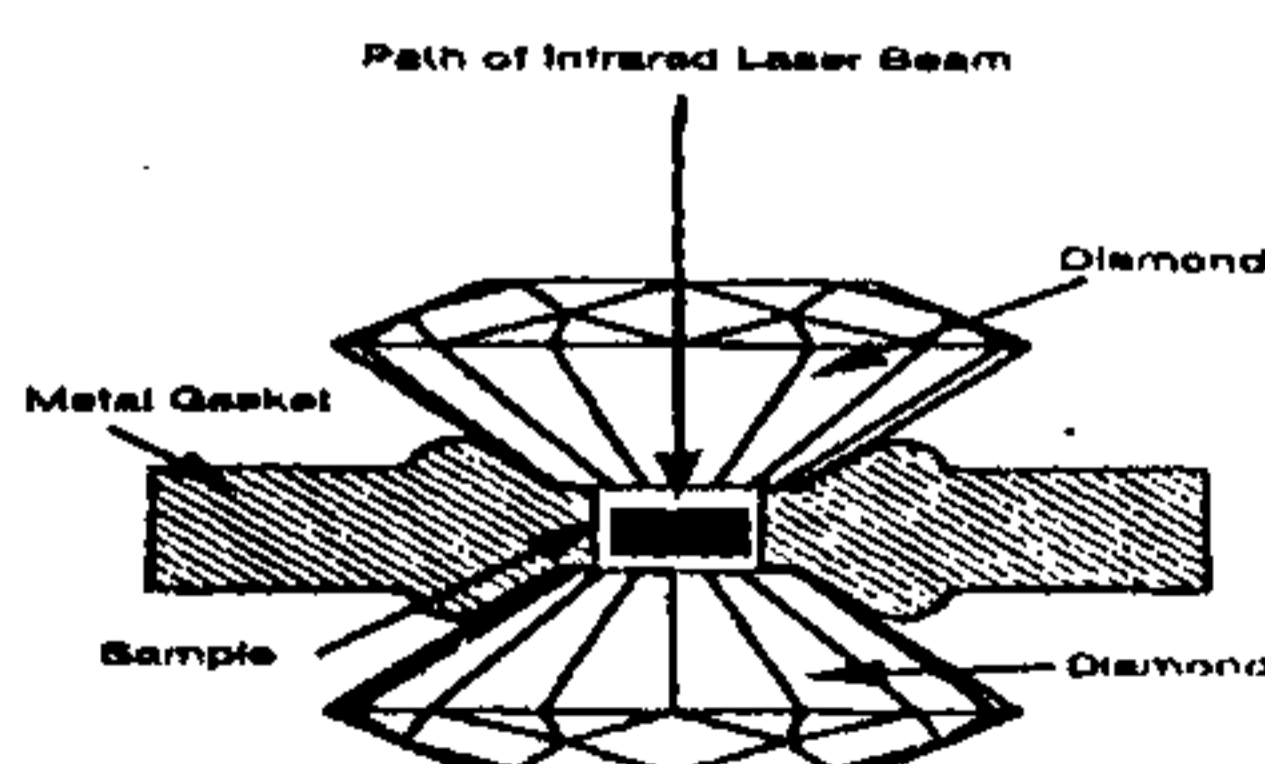


Figure 1. Diamond anvil for subjecting K and Ni to high pressures (up to 37 GPa) and temperatures (2500 K) by infrared laser from Nd-Y LIF laser.

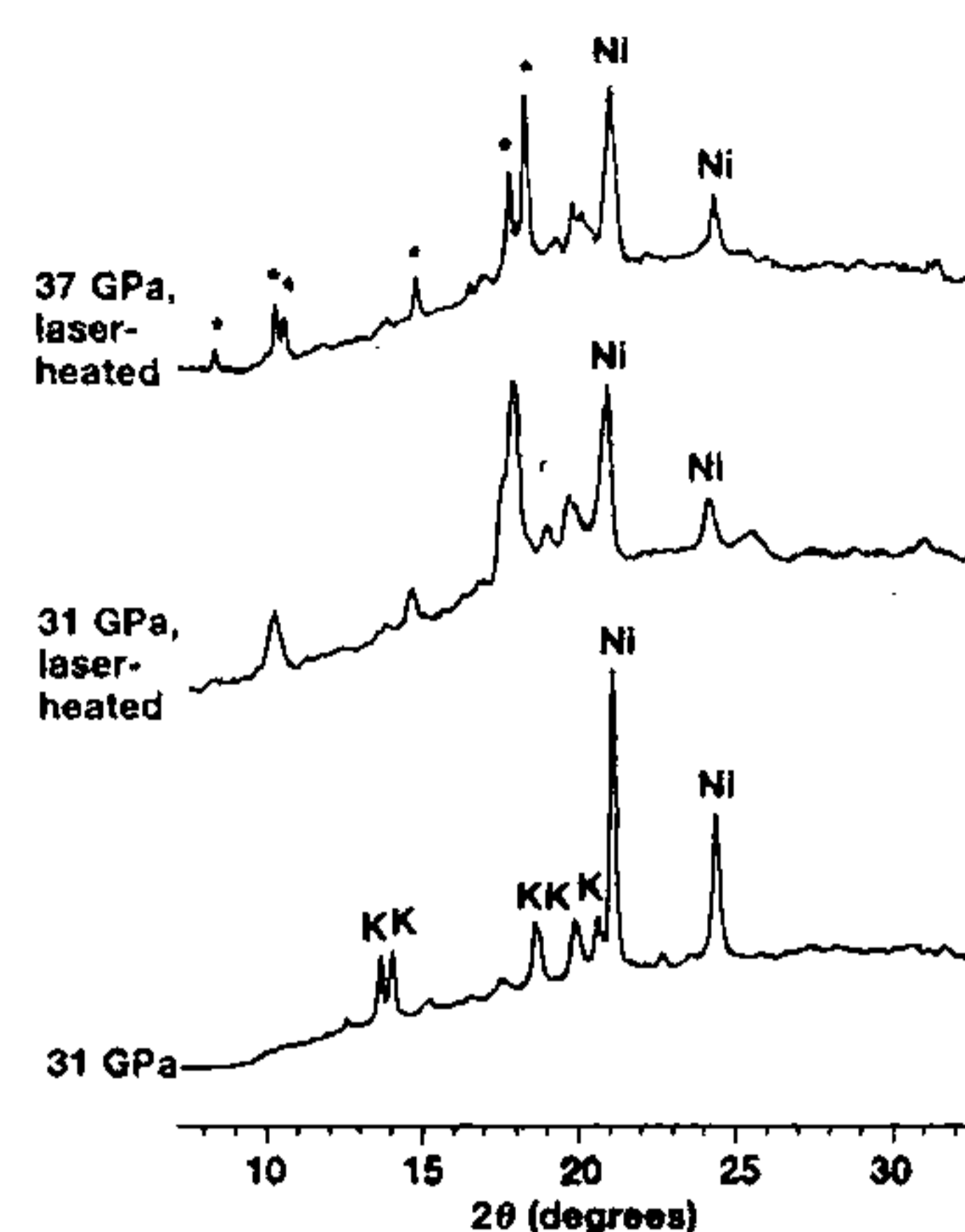


Figure 2. X-ray diffraction patterns of K-Ni mixture under pressure before and after laser heating, [after Parker *et al.*⁴].

that 'before laser heating the diffraction pattern of the sample was characteristic of a mixture of K [in the high pressure phase K(III)] and Ni. After laser heating, the diffraction lines due to K(III) completely disappeared and new diffraction lines appeared, indicative of reaction between K and Ni to form an inter-metallic compound.' Increase of the pressure up to 37 GPa combined with laser heating made the lines sharper and more intense (Figure 2).

The high pressure attained in this instrument could reduce the size of K atoms to a fifth of their ambient size and force an electronic structure analogous to the transition metals. The results have spurred Badding and co-workers to speculate that 'since charge densities of Fe and Ni are similar, despite the slightly lower electronegativity and work function of Fe', K and Fe should react under pressure prevailing in the core and the 'presence of K in the core becomes a viable hypothesis'. They feel that their results are 'important in understanding partitioning of trace elements between core and mantle, a key problem in mantle geochemistry and evolution of Earth'.

1. Rama Murthy, V., *Nature*, 1991, **253**, 303-306; *Nature*, 1991, **257**, 1284-1285.
2. Elasser, W. M., *Sci. Am.*, 1958, **198**, 44-48.
3. Jeanloz, R., *Annu. Rev. Earth Planet. Sci.*, 1990, **18**, 357.
4. Parker, L. J., Atou, T., Badding, J. V., *Science*, 1996, **273**, 95-97.

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