DIFFERENT LATTICE CONSTANTS OF SOLID NEON ISOTOPES

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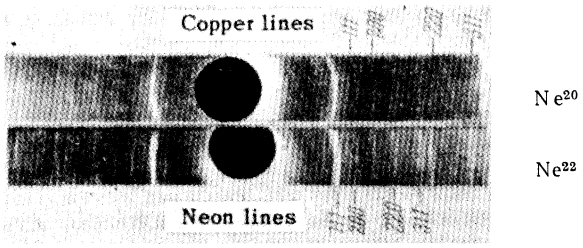
X-ray diffraction investigations of Ne^{20} and Ne^{22} were performed at 4.2° K. Both isotopes have face-centered cubic lattices, with the constants a = 4.471 ± 0.004 A and 4.455 ± 0.004 A, respectively. The relative difference in the molar volumes, $\Delta V/V = 1.1 \pm 0.5\%$, agrees satisfactorily with calculations taking into account the difference in zero-point vibration energy. The difference in the molar volumes of the neon isotopes is much greater than that for lithium isotopes, which, according to the literature, is negligible despite the larger relative mass difference of the latter. This is apparently associated with a difference in the nature of the binding forces in neon and lithium lattices.

WE have found only report[1] of an attempt to detect differences in the lattice constants of isotopes of elements heavier than helium. For the difference between the lattice constants of Li^6 and Li^7 Covington and Montgomery obtained 0.0015 kxu, which was close to the limit of their experimental accuracy. They considered the principal result of their work to be the direct confirmation of zero-point vibrations of lattice atoms, varying in energy for different isotope masses. This effect should evidently be more pronounced in inert gases, where different isotopes of the same element are not characterized by identical forces which result from free electrons, and which are the principal determinant of structure in metallic crystals. The different lattice constants of inert-gas isotopes or, equivalently, their different molar volumes in the solid phase, have been considered in several theoretical papers.[2-4] $\Delta V/V = 0.6\%$ has been obtained for neon at absolute zero.

We used x rays to study the structure of Ne^{20} (99% pure) and Ne^{22} (98% pure). Air impurities were removed by passing the neon through a coil cooled by liquid hydrogen, while helium contamination was eliminated by pumping from a vessel in which solid neon had been produced by liquid-helium cooling. Neon isotope samples were obtained in the form of polycrystalline layers deposited from the gaseous phase on a copper capillary tube that was cooled internally by liquid helium. The x-ray diffraction apparatus was described in reference 5. The figure shows typical x-ray diffraction patterns, including both neon lines and lines of the copper backing serving as standards.



We used CuKα and FeKα radiation from a Pines fine-focus x-ray tube, and a casette 40 mm in diameter. In the photometric study the separations of interference maxima were determined within ± 0.03 — 0.05 mm. The effective diameter of the cassette was determined within ± 0.05 mm by means of the standard lines. Corrections for sample thickness were introduced by the Kurdyumov procedure, taking account of characteristics associated with the use of a fine-focus tube.[6] Results obtained from the x-ray patterns are given in the table; the lattice constants are accurate to within ± 0.004 kxu.

The table shows that both neon isotopes have face-centered cubic lattices with constants differing by 0.016 kxu, which is one order of magnitude greater than in the case of lithium isotopes, despite a smaller relative mass difference. $\Delta V/V = 1.1 \pm 0.5\%$ for the relative difference in molar volumes was calculated from the lattice constants of the neon isotopes. The theoretical value $\Delta V/V = 0.6\%$ is within the range of experimental accuracy, but is considerably smaller than the mean value of $\Delta V/V$ obtained from the x-ray data.

The value a = 4.471 kxu obtained for the lattice constant of the lighter neon isotope, which constitutes ~ 91% of natural neon, improves the values

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Computations for Ne^{20} and Ne^{22} based on x-ray ($CuK\alpha$) diffraction patterns

hkl	Intensity for Ne^{22}		θ (Ne^{20})	θ (Ne^{22})	a (Ne^{20}), kxu	a (Ne^{22}), kxu
	computed	exper.				
(111)	100	100				
(200)	48	8				
(220)	27	21	29°06′	29°13,5′	4.470	4.459
(311)	25	20.5	34°48′	34°57′	4.472	4.456
(222)	6.4					
(400)	4.2					
(331)	7.0					
(420)	6.4	10.5	50°26.4′	50°38,3′	4.470	4.456
(422)	4.9	8	57°29′	57°53′	4.471	4.451
(333)(511)	6.0	10.5		63°55.5′		4.452
				Mean:	4.471	4.455

for the lattice constant of the natural mixture that are given in the literature: a = 4.52 kxu from x-ray diffraction[7] and 4.429 kxu from neutron diffraction.[8]

The neon line intensities in the x-ray patterns differ considerably from the calculated values. For $CuK\alpha$ and $FeK\alpha$ rays the (200) line intensities, compared with the (111) intensities, are much lower than the calculated values. With $FeK\alpha$ the (222) intensity was enhanced. This redistribution of the intensities is evidently associated with the fact that the neon layer deposited from the gaseous phase on the copper capillary tube has its [111] axis along capillary radii. It is interesting that the intensity ratio of identical x-ray interferences from the heavier and lighter isotopes [$I_{hkl}(Ne^{22})/I_{hkl}(Ne^{20})$] is greater, and increases more rapidly with the scattering angle, than could have been expected from the calculation of a thermal factor. The last lines that are distinctly visible in the x-ray patterns for the heavier isotope merge with the background in the case of the lighter isotope.

[1] E. J. Covington and D. J. Montgomery, J. Chem. Phys. **27**, 1030 (1957).

[2] J. H. Henkel, J. Chem. Phys. **23**, 681 (1955).

[3] I. J. Zucker, J. Chem. Phys. **25**, 915 (1956).

[4] T. F. Johns, Phil. Mag. **3**, 27 (1958).

[5] Kogan, Lazarev, and Bulatova, JETP **37**, 678 (1959), Soviet Phys. JETP **10**, 485 (1960).

[6] B. Ya. Pines, Острофокусные рентгеновские трубки (Fine-Focus X-ray Tubes), Gostekhizdat, 1955.

[7] Keesom, De Smedt, and Mooy, Comm. Phys. Univ. Leiden **18**, 203e (1930).

[8] D. G. Henshaw, Phys. Rev. **111**, 1470 (1958).

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