

expect it to be even greater than of ^4He , if the same isotopic relations exist as between protium and deuterium (κ of $^1\text{H} = 480 \times 10^{-6}$ megabars vs. $D = 300 \times 10^{-6}$). The liquid atomic volumes of ^3He and ^4He , under their respective saturated vapour-pressure, at 1.2° and 1.6°K are known⁽²⁰⁾ and are as follows:

		^3He	^4He
Atomic volume, ($\text{cm}^3/\text{g atom}$) . . .	(α) 1.2°K	37.11	27.515
	(β) 1.6°K	37.77	27.504

Thus, the atomic volume of ^3He is by a factor of $1\frac{1}{3}$ greater than ^4He , an exceptional situation for isotopes. In solid form both ^3He and ^4He exist each in a body centered cubic (space group $-O_h^9$ or $I m\bar{3}m$, 2 atoms/cell, $d_0 = 1.0911 \cdot v_0^{\frac{1}{3}}$) and hexagonal close packed (D_6^4h or $C6/mmc$, 2 atoms/cell, $d_0 = 1.1224 \cdot v_0^{\frac{1}{3}}$) lattice and their atomic volumes and cell dimensions have been accurately measured.⁽²¹⁻²⁴⁾ They are correlated in Table 5.

TABLE 5.—PROPERTIES⁽²¹⁻²⁴⁾ OF SOLID ^3He AND ^4He

	^3He	^4He
Atomic volume of b.c.c., ($\text{cm}^3/\text{g atom}$)	20.060	20.928
Atomic volume of h.c.p., ($\text{cm}^3/\text{g atom}$)	20.060	20.737
Density, (g/cm^3)	}0.1504	0.1913
{ b.c.c.		0.1930
{ h.c.p.	0°	1.73°
Conditions for above { { atm.	98.5	29.01
a_0 of b.c.c., (Å)	4.054	4.111
a_0 of h.c.p., (Å)	3.612	3.655
c_0 of h.c.p., (Å)	5.898	5.954
c_0/a_0	1.633	1.629
Atomic weight ($^{12}\text{C} = 12.0000$)	3.01596	4.00259

Table 5 shows that both isotopes of solid helium have, in contrast to all other groups of the Periodic System, a substantially higher atomic volume (i.e., 20 and 21 $\text{cm}^3/\text{g atom}$) than their next homologue—neon (13.07 $\text{cm}^3/\text{g atom}$, see Table 1). It is this fact which is responsible for the "retrograde" or upper part of the curve of the solid noble gases in Fig. 2.

In conclusion, a few remarks regarding the reason for this singular behaviour of the noble gas family when compared to the families of *metals* in the Periodic System. First of all, there is a big difference in the nature of forces holding the atoms together in the lattice; in the case of noble gases—weak van der Waals forces, as against much stronger metallic bonding (see Table 6).

However, in both cases, the distances between atoms and the forces or energies holding them together describe the behavior of the solid; these are determined by the atomic volume (or v_0 , or a_0 and d_0) and the heat of sublimation of the solid at 0°K . The latter gives directly the energy required to separate the lattice atoms from each other and convert it to a gas.

⁽²⁰⁾ See K. R. ATKINS, *Liquid Helium*, Cambridge Univ. Press (1959).

⁽²¹⁾ A. F. SCHUCH and R. L. MILLS, *Advan. Cryogenic Eng.* **7**, 311 (1960).

⁽²²⁾ E. R. GRILLY and R. L. MILLS, *Ann. Phys.* **8**, 1 (1956).

⁽²³⁾ A. F. SCHUCH and R. L. MILLS, *Phys. Rev. (Letters)* **8**, 469 (1962).

⁽²⁴⁾ J. DONOHUE, *J. Amer. Chem. Soc.* **85**, 1238-40 (1963).