and in general this quantity determined whether Ⓑ was considered to be an estimated value. For the elements white phosphorus, scandium, arsenic, selenium, rubidium, strontium, cesium, and thulium the heat of fusion is known experimentally but the shear modulus is not.

27. Entropies of Fusion and Vaporization

Entropy of Fusion. The entropy of fusion, ΔS_f, is defined as

$$\Delta S_f = \Delta H_f / T_m, \tag{27.1}$$

where ΔH_f is the heat of fusion (Table X) and T_m is the melting point in degrees Kelvin (Table IX). Richard's rule states that the entropy of fusion is approximately equal to a constant (2.0 e.u.). Often the approximation is given as $\Delta S_f \simeq R$, where R is the gas constant. Generally this rule is used to estimate the heat of fusion of an element from the known melting point. Kelley,[54] however, used a value of 2.3 e.u. for estimating heats of fusion; and Stull and Sinke[53] used two values, 2.3 e.u. for elements which crystallize as close-packed structures (face-centered cubic and hexagonal) and 1.9 e.u. for elements which exhibit body-centered cubic structures. These results suggest that Richard's rule may not be a valid approximation, and therefore the ΔS_f values were calculated for all the known elements.

The entropies of fusion are shown in Table XXIII. The ΔS_f values vary from a minimum 0.47 e.u. for white phosphorus to a maximum of 7.13 e.u. for silicon. This is a very wide variation of values for a quantity which is supposed to be constant. However, if the values are grouped according to the crystal structure of the phase just prior to melting, several interesting things are seen. The entropy of fusion for 26 body-centered cubic metals is 1.76 ±0.34 e.u.; for 9 face-centered cubic metals, 2.28 ±0.23 e.u.; for 5 hexagonal close-packed metals, 2.33 ±0.23; or, for 14 metals with a close-packed structure (face-centered cubic and hexagonal) 2.29 ±0.23; for 3 elements which have the diamond structure, 6.50 +0.63; for 3 elements which have the $A7$ arsenic structure, 5.36 ±0.71; and 2 elements which have the $A8$ selenium structure, 4.22 ±1.57. Thus one notes that ΔS_f has a strong crystal-structure dependence and, therefore, Richard's rule is a poor approximation.

The variation of the entropy of fusion for the elements is shown in Fig. 29. Because of the sparsity of data for the transition metals (groups IVA, VA, VIIA, and VIIIA) it is not clear that there is a group dependence in this portion of the diagram. A group dependence is noted, however, near both ends of the plot shown in Fig. 29.

Table XXIII. Entropies of Fusion and Vaporization

Element	ΔS_f (e.u./g-at)	ΔS_v (e.u./g-at)
3 Li	1.58	21.5
4 Be	2.26	22.1
5 B	(2.29)[a]	29.6
6 C(g)	6.10	42.1
11 Na	1.68	20.5
12 Mg	2.32	22.2
13 Al	2.74	30.4
14 Si	7.13	34.1
15 P(w)	0.47	136.
16 S(m)	0.86	90.4
19 K	1.65	18.8
20 Ca	1.86	20.3
21 Sc	2.04	19.8
22 Ti	(1.76)[a]	28.6
23 V	(1.76)[a]	30.7
24 Cr	1.62	28.6
25 Mn	2.31	22.3
26 Fe	2.03	26.6
27 Co	2.10	28.4
28 Ni	2.44	29.7
29 Cu	2.30	25.9
30 Zn	2.55	23.4
31 Ga	4.41	24.3
32 Ge	6.28	25.6
33 As	6.07	32.6
34 Se	2.65	48.5
37 Rb	1.80	18.6
38 Sr	2.10	20.2
39 Y	1.54	24.3
40 Zr	(1.76)[a]	29.9
41 Nb	(1.76)[a]	34.2
42 Mo	2.30	24.1
43 Tc	(2.29)[a]	(25.5)[a]
44 Ru	(2.29)[a]	33.7
45 Rh	(2.29)[a]	30.0
46 Pd	2.25	27.1
47 Ag	2.25	24.7
48 Cd	2.49	23.0
49 In	1.82	23.9
50 Sn	3.39	25.2
51 Sb	5.25	28.5
52 Te	5.78	37.0
55 Cs	1.68	17.0
56 Ba	1.83	19.3