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A VAPOR PRESSURE CHART
FOR METALS

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ABSTRACT

The plot of $\log p$ -vs- $1/T$ data for 52 metallic or refractory elements yields a family of straight lines which converge within a small region near 10,000 atmospheres and 10,000° C. (This is similar to the Cox chart for organic liquids.)

Establishing an approximate convergence point permits useful estimation of the entire $\log p$ vs $\frac{1}{T}$ line up to 10,000° C. for a metal, provided a single value of the vapor pressure is known at any temperature. Only Zn, Cd, Hg and Cs deviate substantially from the convergent line pattern of all the elements studied.

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I. DISCUSSION

The Clausius-Clapeyron equation represents the change in equilibrium pressure with the temperature for any phase equilibrium in a single-component system.

$$\frac{dp}{dT} = \frac{\lambda}{T\Delta v} \quad \dots (1)$$

where λ = latent heat of phase change

Δ = volume change accompanying the phase change.

Neglecting the volume of liquid in comparison with that of the vapor and assuming that the vapor is an ideal gas, Eq. (1) becomes,

$$\frac{d \ln p}{dT} = \frac{\lambda}{RT^2} \quad \dots (2)$$

Assuming that λ is independent of temperature and integrating we have

$$\ln p = \frac{-\lambda}{RT} + \text{Constant} \quad \dots (3)$$

or as an empirical equation

$$\log p = -\frac{A}{T} + B \quad \dots (4)$$

By plotting the experimental data given in Table I it becomes apparent that the vapor pressure curves converge within a small area. By picking the center of this area as a point of convergence it is possible to construct a chart such as Fig. 1 which gives straight line values for the vapor pressure of the metals as a function of temperature. The point of convergence is

roughly at 10,000 atmospheres and 10,000° C.

Not all metals have vapor pressure-temperature curves of the proper slope to converge at the selected point although the divergence is not more than $\pm 50^\circ$ C. for a given vapor pressure on a line drawn through the convergence point and the boiling point of the metal. The metals which deviate the most from the slope predicted by the chart are Zn, Cd, Hg, and Cs. It will be noted that these are among the most volatile of all the elements listed.

It is possible from Fig. 1 to estimate vapor pressure at any temperature for a metal where only one vapor pressure value is known. It should be noted that the values of the boiling points listed in Ref. 2 for the more refractory metals are in many cases too high according to the chart (assuming that the low pressure data is more accurate than the determination of the boiling points). Al, Ga, Ge, ^{AND} In have recorded boiling points about 100° C. too high; Th, Nb, Sn, Mo, and W 300 to 500° C. too high; and Ta has a recorded boiling point which is 1100° C. too high according to the chart. However, the temperature scale becomes very condensed at higher temperatures (1200 to 10,000° C.) and the accuracy to be expected in plotting and reading temperatures is ± 50 to 100° C.

The constants A and B in Eq. (4) determined from Fig. 1 are given in Table II. For comparison, the same constants are listed as given in the literature. The values of A (representing the slope of the vapor pressure curve) taken from Fig. 1 and from the literature are in good agreement

except for Ba and Sb. The values of B, representing the intercept of the vapor pressure curve at $1/T = 0$, do not agree as closely.

II. CONCLUSIONS

Although the observed vapor pressure data for a few metals does not fit exactly the values predicted in Fig. 1 there is a close enough correlation for most metals to give the chart some utility in estimating vapor pressures of metals.

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TABLE I

VAPOR PRESSURES OF METALS

Metal	Temperatures (in °C) at Which The Vapor Pressures are						Boiling Point °C 760 mm (a)	Boiling Point °C (From Fig. 1)	Melting Point °C (a)
	0.001 mm (a)	0.01 mm (a)	0.1 mm (a)	1.0 mm (a)	10 mm (a)	100 mm (a)			
Li	439	514	607	725	890	1084	1367	1330	179
Na	238	291	356	437	548	696	914	880	98
K	161	207	265	338	443	581	779	730	64
Rb	123	165	217	283	387	519	679	640	38.5
Cs	110	153	207	277	387	515	690		29
Cu	1141	1273	1432	1628	1879 (c)	2207 (c)	2595	2610	1083
Ag	936	1047	1184	1353	1575 (c)	1865 (c)	2212	2240	961
Au	1316	1465	1646	1867	2154 (c)	2521 (c)	2966	2900	1063
Be	1130	1246	1395	1582			2507	2550	1284
Mg	383	443	515	605	702	909	1126	1130	651
Ca	528	605	700	817	983 (c)	1207 (c)	1482	1480	810
Sr	475	549	639	750	898 (c)	1111 (c)	1384	1380	771
Ba	625	721	840	961	1049 (c)	1301 (c)	1638	1670	717
Zn	292	343	405	487 (b)	593	736	907	940	419
Cd	220	264	321	394 (b)	484	611	765		321
Hg	18	48	82	126	184	261	361	360	-40
B	1239	1355	1489	1648			2527	2700	2000
Al	889	996	1123	1279	1487	1749	2327	2200	660
Sc	1282	1423	1595	1804			2727	2800	1397
Y	1494	1649	1833	2056			3227		1477
La	1242	1381	1549	1754			2727		887
Ce	1190	1305	1439	1599			2527		785
Ga	965	1093	1248	1443	1541 (c)	1784 (c)	2427	2300	30
In	840	952	1088	1260	1466	1756	2167	2080	157
Tl	527	606	702	821	983	1196	1457	1450	304
C	2471	2681	2926	3214	3946 (c)	4373 (c)	4552	4500	
Si	1223	1343	1485	1670	1888 (c)	2083 (c)	2477	2730	1410
Ti	1384	1546	1742	1965			3127	3000	1727
Zr	1816	2001	2212	2459			3577	3700	2127
Th	1999	2196	2431	2715			4227	3900	1827
Ge	1112	1251	1421	1635			2707	2600	959
Sn	1042	1189	1373	1609	1703	1968	2727	2330	232
Pb	625	718	832	975	1167	1417	1737	1700	328
V	1725	1888	2079	2207			3527	3500	1697
Cr	2539						5127	4600	2500
Ta	2820						6027	4900	2996
Sb	595	678	779	904	1033	1223	1617	1620	630
Bi	609	698	802	934	1136 (c)	1271 (c)	1627	1650	271
Cr	1090	1205	1342	1504			2222	2510	1900
Mo	2295	2533		3102 (c)	3535 (c)	4109 (c)	4804	4300	2622
W	3016	3309		3990 (c)	4507 (c)	5168 (c)	5677	5100	3382
U	1730	1898	2098	2338			3527	3500	1132
Mn	878	980	1103	1251	1505 (c)	1792 (c)	2097	2130	1244
Fe	1310	1447	1602	1783	2039 (c)	2360 (c)	2727	2850	1535
Co	1494	1649	1833	2056			3097	3160	1478
Ni	1371	1510	1679	1884	2507 (c)	2364 (c)	2837	3000	1455
Ru	2230	2431	2666	2946			4227	4250	2427
Rh	1971	2149	2358	2607			3877	3850	1967
Pd	1405	1566	1759	2000			3167	3100	1555
Os	2451	2667	2920	3221			4627	4500	2697
Ir	2340	2556	2811	3118			4527	4400	2454
Pt	1904	2090	2313	2582	3146 (c)	3714 (c)	3827	3800	1774

a. From Ref. 1

b. From Ref. 2

c. From Ref. 3

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TABLE II

CONSTANTS FOR VAPOR PRESSURE

EQUATION $\log p = \frac{A}{T} + B$

Element	A	A	B	B
	From Fig. 1	From Ref. 4	From Fig. 1	From Ref. 4
W	49300	42,000	11.8	9.84
Ta	45100	39,800	11.3	6.98
Nb	39200		11.0	
C	37700		10.7	
Os	37000		10.7	
Ir	35400		10.4	
Mo	34700	34,000	10.3	10.88
Ru	33300		10.2	
Th	29400		10.0	
Rh	29100		9.9	
Pt	27900	27,900	9.7	15.70
Zr	26300		9.5	
U	25000		9.34	
V	25000		9.34	
Co	21400		9.15	
Pd	20000		9.12	
Ti	19700		9.00	
Ni	19700	12,100	9.00	7.87
Au	18900	19,400	8.82	12.50
Fe	18700	19,300	8.80	9.00
Sc	18200	19,300	8.70	
Si	17900	18,000	8.60	12.83
B	17200	17,100	8.60	12.31
Cu	16600	17,700	8.50	13.51
Ge	16300		8.45	
Be	16000	17,300	8.40	9.22
Cr	15700	17,800	8.37	10.37
Sn	14400	17,400	8.28	9.28
Ga	14000	16,300	8.26	14.12
Ag	13700	14,550	8.25	10.13
Al	13300	16,450	8.23	12.36
Mn	12900	13,260	8.20	8.63
In	12600	12,200	8.18	8.03
Pb	10000	10,300	8.11	11.43
Ba	9900	350,000	8.00	15.77
Bi	9600	10,000	7.95	12.70
Sb	9500	614	7.95	-26.30
Ca	8650	9,500	7.80	11.91
Tl	8450	9,300	7.75	11.10
Sr	8100		7.67	
Li	7750	8,860	7.65	12.50
Mg	6680	7,610	7.50	11.6
Zn	5640	6,670	7.38	12.0
Na	5370	5,700	7.36	11.33
K	4570	4,770	7.30	11.6
Rb	4250	4,280	7.28	11.34
Hg	2760	3,328	7.20	10.5