

# THERMODYNAMIC PROPERTIES OF CHLORINE

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## ABSTRACT

Using the reduced temperature-entropy and reduced temperature-enthalpy data of argon as a function of pressure and the principle of corresponding states, a temperature-entropy-enthalpy diagram for chlorine up to a pressure of 2200 atmospheres and a temperature up to 1500°K is presented. The evaluated values agree within 1 per cent with the available literature data. The data on enthalpy, entropy and volume is presented in tabular form.

## INTRODUCTION

An extensive literature survey revealed that the thermodynamic properties of chlorine are available only in a limited range of temperature and pressure. The previous investigations (summarized well by Kapoor and Martin<sup>7</sup>) include those of Hulme<sup>4</sup>, Hulme-Tillman<sup>5</sup>, Kapoor and Martin<sup>7</sup>, Pellaton<sup>9</sup> and Ziegler<sup>12</sup>. These authors have contributed either to experimental study or calculation of the thermodynamic properties of chlorine. Kapoor and Martin have utilized the Martin-Hou<sup>8</sup> equation of state and have calculated the thermodynamic properties up to a pressure of 95 atmospheres and a temperature of 550°K. This is the maximum temperature and pressure range investigated so far. The present work was undertaken with the following objectives in view.

- (i) to cover a wider range of temperature and pressure so as to cover the area of interest both in research and industrial application,
- (ii) to test the validity of the proposed law of corresponding states<sup>1</sup>, and
- (iii) to present data for the starting material in the chlorinated organic compounds series, the evaluation of the thermodynamic properties of which this laboratory has undertaken.

## PRESENT WORK

The present investigation has utilized the data on isothermal changes of enthalpy and entropy with pressure of argon and the principle of the law of corresponding states. This principle states that the departure of any property from that of the reference substance at the same reduced properties is the same. The reference substance chosen for various reasons<sup>1</sup>, is argon. The

properties of argon have been evaluated<sup>2</sup> for pressures up to 5000 atmospheres and for temperatures up to 600°K. The investigation of Achuta Ramayya and Kuloor<sup>1</sup> has revealed that the percentage deviation of

$$(\Delta S)_{T_r} \Big]_{P_r=0.05}^{P_r}$$

from argon values for various substances conforms (especially above  $T_r = 1.2$ ) well with the above stated principle of corresponding states. In the present work, the values of enthalpy and entropy were calculated using the relations,

$$(\Delta S)_{T_r} = (\Delta S)_{T_r} \Big]_{P_r=0.05}^{P_r} + (\Delta S)_{T_r} \Big]_{P_r=0}^{P_r=0.05} \quad [1]$$

$$(\Delta H)_{T_r} = (\Delta H)_{T_r} \Big]_{P_r=0.05}^{P_r} + (\Delta H)_{T_r} \Big]_{P_r=0}^{P_r=0.05} \quad [2]$$

So the procedure is

(i) evaluate the property at  $T$  and  $P = 0.05 P_c$  for the substance (chlorine) in question.

(ii) add the value of that property from  $P = 0.05 P_c$  and the desired pressure  $P$  evaluated at  $T$  using the argon diagram or data.

The  $0.05 P_c$  datum line for chlorine was evaluated in the following way. The ideal gas constant pressure heat capacity data of Potter<sup>10</sup> obtained from spectroscopic data in the temperature range of 300-1500°K was fitted to the equation,

$$C_p^\circ = a + bT + cT^2 + dT^3 + eT^4 \quad [3]$$

where

$$\begin{aligned} a &= 5.924545453 \\ b &= 1.16402316 \times 10^{-2} \\ c &= -1.785920995 \times 10^{-5} \\ d &= 1.242251082 \times 10^{-8} \\ e &= -3.172077922 \times 10^{-12} \end{aligned}$$

The maximum error of the calculated values using Equation [3] was 0.75 per cent. The basic reference point was taken as  $S = 0$ ,  $H = 0$  for crystal at absolute zero of temperature. At lower temperatures over the range of 200-553°K, the specific heat data  $C_p^\circ$  of ideal gas is fitted by Kapoor and Martin<sup>7</sup> to the quadratic relation

$$C_p^\circ = \alpha + \beta T + \gamma T^2 \quad [4]$$

where

$$\begin{aligned} \alpha &= 5.701272 \times 10^{-2} \\ \beta &= 7.294438 \times 10^{-4} \\ \gamma &= -3.675117 \times 10^{-8} \end{aligned}$$

Next Equation [4] and Giauque-Powell<sup>3</sup> data on entropy of chlorine at the normal boiling point together with Berthelot's correction for pressure were utilised to evaluate the entropy value at  $T_r = 0.8$  and  $P_r = 0.05$ . Using this entropy value and Equation [3] (as it covers a range of temperature of 300-1500 °K), the entropy equation at  $P_r = 0.05$  was obtained,

$$\begin{aligned} \int ds &= S_{T, 0.05} \\ &= a \ln T + bT + cT^2/2 + dT^3/3 + eT^5/5 \\ &\quad + \left( [\text{Berthelot's correction}] \right)_{P_r=0}^{P_r=0.05} + C \end{aligned} \quad [5]$$

where  $C$  is the constant of integration.

The constant of integration was evaluated using the entropy value at  $T_r = 0.8$  and  $P_r = 0.05$ . Thus the entropy equation at  $P_r = 0.05 P_c$  was obtained. The values got from Equation [5] at  $P_r = 0.05$  and various  $T_r$  values are compared with those of Kapoor and Martin. The maximum deviation was about 0.3 per cent. Table I also shows values evaluated at different  $P_r$  values using Equation [1] and argon values. A comparison with the values of Kapoor and Martin was made and the deviations are shown in Table I. The maximum and average deviations are around 0.5 and 0.3 per cent respectively.

TABLE I

Comparison of calculated entropy(S) and enthalpy(H) values with literature values<sup>1</sup>

$T_r$	$P_r$ range	No. of points	Per cent average deviation		Per cent maximum deviation	
			S	H	S	H
0.8	0.05 - 0.2	3	0.23	0.12	0.43	0.13
0.9	0.05 - 0.3	4	0.10	0.11	0.13	0.20
1.0	0.05 - 0.8	7	0.10	0.12	0.28	0.23
1.1	0.05 - 1.2	9	0.10	0.20	0.26	0.67
1.2	0.05 - 1.2	9	0.24	0.27	0.49	0.50
1.3	0.05 - 1.2	9	0.30	0.40	0.44	0.70

The values of entropy were then evaluated in the region of  $T_r = 0.8$  to 3.4 and  $P_r = 0.05$  to 30. using Equation [1] and argon values. The values are presented both in graphical, as Figure I\* and tabular form, as Table III.

\* 80 cm x 100 cm diagram can be obtained from the authors

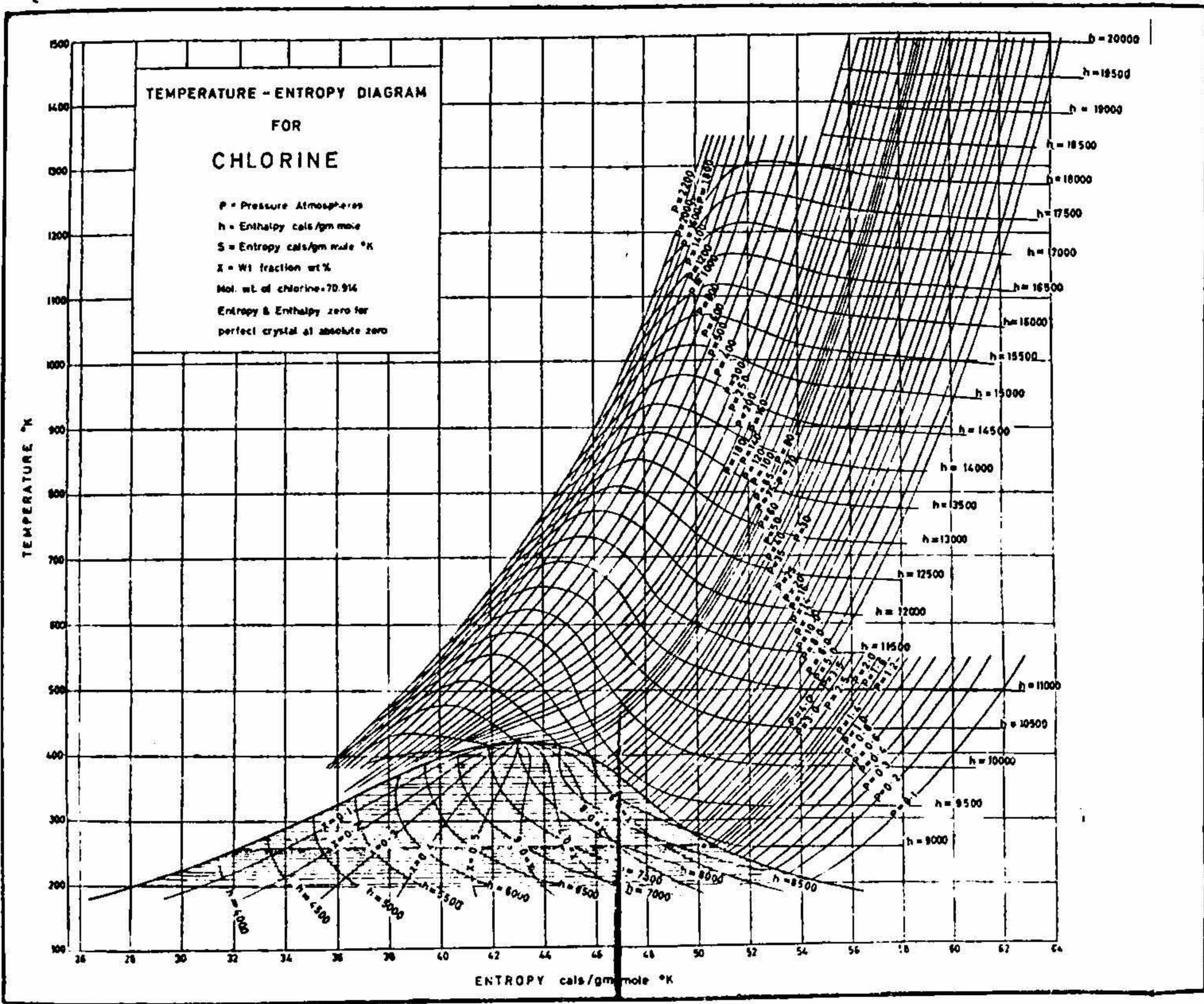


FIG. 1

TABLE II  
Properties of Saturated Liquid and Vapour

Temp. °K	Vapour pressure (atm.)	$V_l$ cc/mole	$V_g$ cc/mole	$S_l$ Cals./gm. mole °K	$\Delta S_v$ Cals./gm. mole °K	$S_g$ Cals./gm. mole °K	$H_l$ Cals./gm. mole	$\Delta H_v$ Cals./gm. mole	$H_g$ Cals./gm. mole
185	0.0410	41.707830	365217.4	26.33	30.09	56.42	3124.18	5383.60	8507.78
190	0.0615	42.028770	257644.2	27.20	28.10	55.30	3309.35	5239.80	8549.15
200	0.1200	42.648540	133691.7	28.08	26.22	54.30	3384.20	5196.46	8580.67
210	0.2290	43.294860	75256.92	28.89	24.52	53.41	3549.67	5141.30	8690.98
220	0.3940	43.994310	45216.60	29.65	23.00	52.65	3711.20	5050.70	8761.89
230	0.6600	44.702610	28402.20	30.37	21.61	51.98	3878.63	4954.17	8832.81
240	1.0520	45.428620	18856.52	31.08	20.32	51.40	4046.07	4857.65	8903.72
250	1.5900	46.234310	12754.43	31.75	19.10	50.85	4211.54	4759.16	8970.70
260	2.3000	47.097550	8933.440	32.40	17.95	50.35	4369.13	4664.69	9033.73
270	3.2400	47.978450	6498.660	33.02	16.92	49.94	4530.65	4566.11	9096.77
280	3.4900	48.956840	4803.160	33.61	15.92	49.53	4696.12	4447.92	9144.04
290	6.1000	50.023714	3630.040	34.19	14.99	49.18	4861.59	4337.61	9199.20
300	7.9500	51.156995	2793.360	34.75	14.11	48.86	5023.12	4231.24	9254.36
310	10.230	52.334540	2186.880	35.28	13.26	48.54	5204.34	4101.23	9305.57
320	13.100	53.653750	1735.336	35.82	12.40	48.22	5377.69	3967.28	9044.97
330	16.500	55.092490	1385.613	36.37	11.55	47.92	5554.98	3821.51	9376.49
340	20.300	56.699450	1115.573	36.91	10.74	47.65	5732.26	3656.04	9388.31
350	24.700	58.479050	903.0830	37.45	9.890	47.34	5917.43	3488.60	9406.03
360	29.950	60.847430	734.4190	37.97	9.090	47.06	6118.35	3277.83	9396.18
370	35.800	62.994460	597.1860	38.54	8.200	46.74	6338.97	3037.51	9376.48
380	42.250	65.894070	486.0710	39.14	7.240	46.38	6575.36	2757.79	9333.15
390	50.250	69.501970	387.1304	39.75	5.730	45.48	6827.50	2438.67	9266.17
395	54.450	71.914620	344.4110	40.09	5.660	45.75	6965.39	2241.69	9207.08
400	58.800	74.637150	301.9130	40.45	5.040	45.50	7103.28	2028.95	9132.22
405	63.450	78.178650	262.5140	40.88	4.310	45.19	7272.69	1776.80	9049.49
410	68.400	83.225290	221.7870	41.33	3.420	44.75	7489.37	1414.35	8903.72
415	73.650	93.938340	170.2130	41.96	2.080	44.04	7784.84	862.800	8647.64
417.16	76.100	123.77500	123.7750	42.96	0.000	42.96	8185.51	0.00000	8185.51

Thermodynamic Properties of Chlorine

TABLE  
Properties of

T °K	P. Atms. →	0	1	10	20	30	40	60
260	V		20877.17					
	H	9100.0	9065.30					
	S		52.06					
280	V		22600.06					
	H	9270.0	9240.2					
	S		52.64					
300	V		24280.91					
	H	9432.0	9406.1					
	S		53.25					
320	V		25966.42					
	H	9605.0	9582.4					
	S		53.73					
340	V		27644.33	2559.67	1138.25	.....	.....	.....
	H	9775.0	9755.0	9584.0	9390.0	.....	.....	.....
	S		54.23	49.47	47.70	.....	.....	.....
360	V		29316.27	2747.46	1270.79	.....	.....	.....
	H	9929.0	9881.3	9761.0	9581.0	.....	.....	.....
	S		54.69	50.01	48.23	.....	.....	.....
380	V		30983.46	2931.28	1378.33	832.74	541.372	.....
	H	10090.0	10074.0	9936.0	9784.0	9641.0	9400.0	.....
	S		55.14	50.54	48.87	47.72	46.59	.....
400	V		32646.84	3112.80	1481.57	912.88	621.149	.....
	H	10262.0	10247.0	10109.0	9974.0	9832.0	9642.0	.....
	S		55.61	51.05	49.40	48.35	47.37	.....
420	V		34307.11	3293.94	1579.77	990.01	691.838	370.474
	H	10432.0	10419.2	10289.0	10164.0	10034.0	9884.0	9524.0
	S		55.99	51.51	49.89	48.95	48.00	46.46
440	V		35964.82	3472.46	1664.38	1061.20	753.666	435.05
	H	10601.0	10589.4	10486.0	10356.0	10236.0	10009.0	9820.0
	S		56.39	51.95	50.36	49.43	48.57	47.13
460	V		37620.41	3649.93	1758.91	1130.08	811.042	487.85
	H	10772.0	10761.4	10648.0	10544.0	10434.0	10328.0	10085.0
	S		56.78	52.37	50.82	49.86	49.04	47.74

III

superheated vapour

100	200	300	600	1000	1400	1800	2200
59.01	57.61	56.04	53.333	50.540	48.882		
6160.0	6180.0	6210.0	6300.0	6451.0	6839.0		
37.54	37.14	36.88	36.11	35.56	35.00		
62.85	60.02	58.29	54.748	51.605	49.597	48.114	46.96
6455.0	6470.0	6460.0	6520.0	6684.0	7034.0	7962.0	8268.0
38.54	38.05	37.74	36.96	36.29	35.70	35.26	34.95
66.69	63.11	61.10	56.04	52.373	50.348	48.602	47.468
6825.0	6775.0	6745.0	6780.0	6920.0	7250.0	8204.0	8490.0
39.58	38.96	38.57	37.77	36.91	36.32	35.90	35.59
73.42	66.51	63.546	57.349	53.246	51.116	49.336	47.956
7290.0	7100.0	7045.0	7040.0	7156.0	7480.0	9429.0	8709.0
40.70	39.86	39.40	38.40	37.52	36.95	36.51	36.20
87.11	71.23	66.34	58.571	54.119	51.989	49.929	48.410
7845.0	7460.0	7355.0	7315.0	7396.0	7732.0	8652.0	8932.0
41.87	40.66	40.12	39.05	38.13	37.51	37.06	36.71
139.14	77.163	69.31	60.317	54.992	52.722	50.627	48.969
8765.0	7850.0	7670.0	7600.0	7628.0	7976.0	8882.0	9150.0
44.31	41.38	40.81	39.67	38.73	38.07	37.61	37.21
201.56	85.54	73.32	62.324	55.865	53.351	51.361	49.528
9400.0	8240.0	8020.0	7895.0	7868.0	8222.0	9109.0	9380.0
45.47	42.08	41.47	40.97	39.30	38.61	38.14	37.72

TABLE  
Properties

T °K	P. Atms. →	0	1	10	20	30	40	60
480	V		39274.22	3824.37	1851.14	1197.06	865.998	534.664
	H	10940.0	10930.4	10824.0	10736.0	10628.0	10540.0	10320.0
	S		57.15	52.77	51.23	50.27	49.47	48.32
500	V		40926.54	3998.90	1943.04	1261.44	917.979	574.378
	H	11108.0	11099.2	11004.0	10928.0	10828.0	10740.0	10552.0
	S		57.54	53.17	51.59	50.65	49.89	48.81
520	V		42577.58	4171.66	2035.27	1324.70	966.432	611.22
	H	11282.0	11273.90	11180.0	11114.0	11022.0	10957.0	10779.0
	S		57.87	53.48	51.94	51.01	50.26	49.22
540	V		44227.54	4342.74	2126.84	1388.06	1016.89	648.785
	H	11453.0	11445.60	11360.0	11298.0	11220.0	11146.0	10958.0
	S		58.25	53.78	52.27	51.35	50.59	49.61
560	V		45876.57	4514.15	2217.2	1449.58	1067.19	684.586
	H	11637.0	11630.10	11540.0	11480.0	11412.0	11343.0	11210.0
	S		58.64	54.07	52.50	51.68	50.92	49.98
580	V		47524.78	4683.46	2224.91	1511.66	1115.66	718.629
	H	11818.0	11811.60	11718.0	11666.0	11605.0	11541.0	11437.0
	S		59.01	54.35	52.86	51.97	51.23	50.33
600	V		49172.30	4854.27	2391.96	1572.81	1162.38	752.76
	H	11991.0	11985.1	11897.0	11847.0	11792.0	11732.0	11664.0
	S		59.29	54.63	53.15	52.24	51.52	50.67
640	V		52465.57	5191.69	2566.38	1693.42	1255.62	819.227
	H	12343.0	12337.9	12257.0	12219.0	12168.0	12120.0	12020.0
	S		59.86	55.17	53.72	52.83	52.14	51.32
680	V		55756.93	5528.18	2739.62	1811.54	1346.65	882.52
	H	12694.0	12689.6	12616.0	12580.0	12538.0	12486.0	12400.0
	S		60.41	55.70	54.25	53.39	52.72	51.89
720	V		59046.81	5864.55	2911.70	1928.73	1436.80	945.268
	H	13048.0	13044.1	12977.0	12939.0	12896.0	12858.0	12774.0
	S		60.90	56.20	54.77	53.89	53.27	52.42
760	V		62335.5	6199.62	3083.13	2045.02	1526.13	1007.75
	H	13397.0	13393.6	13236.0	13297.0	13274.0	13238.0	13146.0
	S		61.38	56.70	55.27	54.42	53.77	52.94



III—(contd)

superheated vapour

100	200	300	600	1000	1400	1800	2200
248.13	95.84	78.385	64.594	57.00	53.979	52.024	50.069
9815.0	8640.0	8345.0	8165.0	8141.0	8450.0	9364.0	9630.0
46.24	42.84	42.15	40.89	39.87	39.17	38.69	38.24
287.19	108.06	83.62	66.689	58.134	54.608	52.408	50.662
10115.0	9000.0	8645.0	8435.0	8396.0	8659.0	9584.0	9860.0
46.93	43.74	42.83	41.47	40.45	39.70	38.60	38.77
321.29	122.20	89.558	69.045	59.356	55.481	53.072	51.273
10386.0	9274.0	8925.0	8640.0	8584.0	8846.0	9742.0	9984.0
47.55	44.60	43.45	42.00	40.92	40.21	39.69	39.19
350.93	137.74	97.24	71.664	60.578	56.304	53.770	51.954
10650.0	9598.0	9160.0	8810.0	8762.0	9026.0	9868.0	10080.0
48.08	45.42	44.05	42.50	41.36	40.68	40.16	39.74
377.02	152.40	104.92	74.37	61.975	57.279	54.503	52.618
10908.0	10040.0	9500.0	9085.0	9016.0	9280.0	10148.0	10279.0
48.53	46.10	44.67	43.01	41.82	41.17	40.63	40.15
401.956	172.852	115.04	77.512	63.546	58.379	55.376	53.246
11172.0	10430.0	10190.0	9550.0	9428.0	9670.0	10534.0	10797.0
48.95	46.67	45.27	43.49	42.26	41.57	41.07	40.56
425.37	186.098	123.426	80.306	65.816	59.706	56.214	54.014
11462.0	10908.0	10300.0	9875.0	9766.0	10012.0	10864.0	11124.0
49.35	47.19	45.86	43.97	42.67	41.97	41.47	40.92
458.767	213.26	141.23	86.94	69.22	62.115	57.960	55.585
11818.0	11282.0	10860.0	10366.0	10260.0	10536.0	11331.0	11608.0
50.10	48.12	46.80	44.85	43.54	42.79	42.24	41.67
511.767	239.20	157.992	93.40	72.80	64.454	59.810	57.244
12222.0	11772.0	11402.0	11919.0	10821.0	11024.0	11776.0	12106.0
50.73	48.87	47.59	45.63	44.38	43.49	42.98	42.52
551.206	263.49	173.69	100.208	76.99	67.108	62.01	59.01
12624.0	12245.0	11896.0	11421.0	11339.0	11552.0	12358.0	12720.0
51.28	49.43	48.29	46.34	45.05	44.23	43.78	42.97
592.43	286.27	189.58	107.365	81.353	70.459	64.419	60.648
13008.0	12666.0	12364.0	11924.0	11836.0	12150.0	12870.0	13126.0
51.79	49.55	48.97	47.04	45.76	45.00	44.54	43.97

TABLE  
Properties of

T°K	P. Atms. →	0	1	10	20	30	40	60
800	V		65623.2	6534.12	3253.93	2160.32	1613.84	1067.36
	H	13748.0	13745.0	13694.0	13658.0	13628.0	13600.0	13540.0
	S		61.85	57.15	55.74	54.89	54.25	53.44
850	V		69731.9	6950.88	3465.15	2303.24	1721.85	1141.60
	H	14199.0	14196.0	14138.0	14108.0	14086.0	14038.0	13990.0
	S		62.38	57.20	56.29	55.44	54.82	54.02
900	V		73839.46	7366.40	3674.19	2444.88	1830.22	1215.40
	H	14631.0	14628.8	14582.0	14548.0	14519.0	14480.0	14460.0
	S		62.87	58.24	56.82	55.96	55.35	54.55
950	V		77946.34	7781.02	3883.53	2586.14	1937.46	1288.53
	H	15085.0	15083.1	15048.0	15020.0	14996.0	14972.0	14922.0
	S		63.36	58.72	57.32	56.44	55.84	55.06
1000	V		82052.6	8195.39	4093.26	2726.79	2043.64	1360.87
	H	15539.0	15537.4	15489.0	15470.0	15446.0	15423.0	15385.0
	S		63.82	59.16	57.78	56.92	56.32	55.53
1100	V		90263.74	9022.24	4510.98	3007.71	2256.19	1504.62
	H	16432.0	16430.8	16399.0	16387.0	16380.0	16365.0	16335.0
	S		64.68	60.01	58.65	57.79	57.21	56.41
1200	V		98473.5	9849.14	4927.18	3287.08	2466.79	1646.33
	H	17343.0	17342.1	17299.0	17287.0	17280.0	17265.0	17248.0
	S		65.47	60.80	59.44	58.59	58.00	57.21
1300	V		106682.3	10674.5	5341.62	3563.96	2676.09	1787.61
	H	18247.0	18246.3	18213.0	18190.0	18176.0	18171.0	18160.0
	S		66.20	61.55	60.14	59.69	58.96	57.93
1400	V		114890.4	11488.77	5756.47	3841.82	2884.81	1928.00
	H	19159.0	19158.6	19137.0	19132.0	19127.0	19122.0	19111.0
	S		66.88	62.20	60.82	60.00	59.44	58.62
1500	V		123097.9	12312.04	6170.67	4119.07	3093.33	2067.76
	H	20067.0	20066.7	20049.0	20047.0	20045.0	20043.0	20039.0
	S		67.50	62.84	61.44	60.62	60.06	59.25

III—(concl'd.)

superheated vapour

100	200	300	600	1000	1400	1800	2200
631.42	308.195	205.0	114.7	85.543	73.742	66.758	62.342
13417.0	13088.0	12834.0	12442.0	12410.0	12820.0	13566.0	13772.0
52.29	50.62	49.54	47.69	46.43	45.66	45.17	44.65
678.35	334.57	223.12	123.51	90.693	77.163	69.604	64.471
13704.0	13602.0	13392.0	13038.0	13277.0	13592.0	14292.0	14285.0
52.87	51.25	50.21	48.41	47.23	46.44	45.91	45.44
724.45	359.85	241.56	132.33	95.494	80.445	72.345	66.567
14366.0	14120.0	13940.0	13625.0	13721.0	13960.0	14748.0	15002.0
53.43	51.82	50.81	49.07	47.92	47.14	46.60	46.14
770.94	384.69	258.56	141.059	100.295	83.815	74.719	68.713
14832.0	14660.0	14476.0	14204.0	14194.0	14564.0	15213.0	15499.0
53.94	52.34	51.36	49.71	48.55	47.79	47.24	46.79
815.29	408.71	275.42	149.49	104.92	87.149	76.884	70.861
15304.0	15119.0	14970.0	14745.0	14756.0	15094.0	15805.0	16008.0
54.42	52.85	51.90	50.29	49.14	48.39	47.82	47.39
903.82	455.36	308.26	167.245	114.348	92.875	82.401	75.10
16272.0	16100.0	16016.0	15873.0	15861.0	16172.0	16868.0	17058.0
55.33	53.79	52.89	51.32	50.16	49.54	48.85	48.39
990.95	500.84	339.54	181.894	145.249	98.724	87.289	78.909
17119.0	17081.0	17020.0	16860.0	16918.0	17213.0	17880.0	18087.0
56.16	54.65	53.76	52.23	51.09	50.34	49.76	49.29
1077.37	546.42	370.15	196.49	154.501	104.921	91.828	82.750
18136.0	18048.0	18000.0	17910.0	17963.0	18245.0	18879.0	19061.0
56.93	55.44	54.56	53.04	51.92	51.16	50.59	50.11
1163.35	590.98	400.11	-----	-----	-----	-----	-----
19088.0	19045.0	19010.0	-----	-----	-----	-----	-----
57.63	56.24	55.34	-----	-----	-----	-----	-----
1248.53	634.48	429.76	-----	-----	-----	-----	-----
20031.0	19994.0	20005.0	-----	-----	-----	-----	-----
58.26	56.76	56.00	-----	-----	-----	-----	-----

TABLE IV  
Comparison of the values of  $(H^* - H)/T_c$  for chlorine

	Kapoor and Martin	Present work	Lydersen, Greenkorn and Hougen
$T_r = 0.80$			
$P_r = 0.10$	0.3853	0.3524	0.38
$P_r = 0.20$	0.7054	0.6827	.....
$T_r = 0.90$			
$P_r = 0.10$	0.3038	0.3153	0.30
$P_r = 0.20$	0.5580	0.5873	0.64
$P_r = 0.30$	0.8434	0.8879	1.00
$P_r = 0.40$	0.1743	1.1420	1.48
$T_r = 0.10$			
$P_r = 0.10$	0.2784	0.2805	0.23
$P_r = 0.20$	0.4822	0.4985	0.48
$P_r = 0.30$	0.7172	0.7367	0.74
$P_r = 0.40$	0.9618	1.0001	1.00
$P_r = 0.50$	1.2280	1.2804	1.32
$P_r = 0.60$	1.5410	1.5932	1.66
$P_r = 0.70$	1.8995	1.9303	2.08
$P_r = 0.80$	2.3599	2.3217	2.63
$T_r = 1.1$			
$P_r = 0.10$	0.2530	0.2438	0.16
$P_r = 0.20$	0.4316	0.4256	0.36
$P_r = 0.30$	0.6271	0.6206	0.53
$P_r = 0.40$	0.8213	0.8157	0.74
$P_r = 0.50$	0.9340	1.0267	0.97
$P_r = 0.60$	1.2602	1.2430	1.20
$P_r = 0.70$	1.5048	1.4765	1.45
$P_r = 0.80$	1.7758	1.7220	1.76
$P_r = 0.90$	2.0371	2.9741	2.11
$P_r = 1.00$	2.3585	2.1997	2.42
$P_r = 1.10$	2.6726	2.5315	2.79
$P_r = 1.20$	2.9388	2.9163	3.12

TABLE IV—(concl'd)  
Comparison of the values of  $(H^* - H)/T_c$  for chlorine

	Kapoor and Martin	Present work	Lydersen, Greenkorn and Hougen
$T_r = 1.2$			
$P_r = 0.10$	0.2378	0.2133	0.13
$P_r = 0.20$	0.3937	0.3619	0.27
$P_r = 0.30$	0.5591	0.5039	0.40
$P_r = 0.40$	0.7246	0.6791	0.56
$P_r = 0.50$	0.8133	0.8370	0.75
$P_r = 0.60$	1.0725	1.0015	0.93
$P_r = 0.70$	1.2618	1.1873	1.13
$P_r = 0.80$	1.4536	1.3751	1.33
$P_r = 0.90$	1.6622	1.5536	1.56
$P_r = 1.00$	1.8685	1.7436	1.78
$P_r = 1.10$	2.0795	1.9689	2.02
$P_r = 1.20$	2.3097	2.1560	2.25
$T_r = 1.3$			
$P_r = 0.10$	0.2299	0.1908	0.11
$P_r = 0.20$	0.3630	0.3156	0.21
$P_r = 0.30$	0.5141	0.4483	0.32
$P_r = 0.40$	0.6532	0.5690	0.42
$P_r = 0.50$	0.7299	0.6990	0.60
$P_r = 0.60$	0.9385	0.8424	0.73
$P_r = 0.70$	1.0968	0.9790	0.92
$P_r = 0.80$	1.2647	1.1422	1.06
$P_r = 0.90$	1.4229	1.2497	1.21
$P_r = 1.00$	1.5788	1.4063	1.40
$P_r = 1.10$	1.7467	1.5576	1.58
$P_r = 1.20$	1.9146	1.7739	1.74

TABLE V

Comparison of the calculated values of volume of chlorine with literature<sup>7</sup> values

Pressure atmospheres	Temperature °K	No. of points	Average per cent deviation	Maximum per cent deviation
5	340 – 540	11	0.076	0.271
10	380 – 540	9	0.233	0.344
20	380 – 540	9	0.313	0.742
40	420 – 540	7	0.874	2.178
60	420 – 540	7	0.791	1.939
75	420 – 540	7	1.269	3.782
90	420 – 540	5	0.731	1.157
	Overall maximum % Deviation		=	3.78
	Overall average % Deviation		=	0.54

The enthalpy values were also evaluated similar to the entropy values. The constant of integration was evaluated similarly using the experimental value of Grauque and Powell<sup>3</sup> at the normal boiling point. Table I shows the deviation from the values of Kapoor and Martin. The average and maximum deviations are 0.4% and 0.7% respectively. Table II shows the values of enthalpy in the region of  $T_r = 0.8$  to 3.4 and  $P_r = 0.05$  to 30. Table IV shows a comparison of the enthalpy departure from ideal gas of the present work with those of Kapoor and Martin and of Lydersen, Greenkorn and Hougen (values corresponding to  $Z_c = 0.27$ ). It can be seen from Table IV that the proposed law of corresponding states is better than the three parameter law used by Lydersen *et al.* The deviations decrease above  $T_r = 1.2$ , possibly because the effect of  $Z_c$  above such temperatures is negligible. This also shows that  $Z_c$  may not be the ideal parameter to characterize inter-molecular effects.

#### MOLAL SPECIFIC VOLUME

In the region of available data in the literature, the compressibilities of chlorine calculated using the compressibilities of argon and the law of corresponding states in the form  $Z = f(P_r, T_r)$  showed good agreement with the literature values. Table V shows such a comparison with the values tabulated by Kapoor and Martin<sup>7</sup>. The values of volume of chlorine therefore, were calculated using argon compressibility values and tabulated in Table III.

## NOMENCLATURE

$a, b, c, d, e,$	= constants in Equation [3]
$C_p^\circ$	= ideal gas specific heat at constant pressure, cal./gram mole $^\circ K$
$C_v^\circ$	= ideal gas specific heat at constant volume, cal./gram mole $^\circ K$
$H$	= enthalpy, cal./gram mole
$S$	= entropy, cal./gram mole $^\circ K$
$P$	= pressure, atm.,
$T$	= temperature, $^\circ K$
$V$	= volume, cc./gram mole
$\alpha, \beta, \gamma$	= constants in Equation [4]
$\Delta H_v$	= enthalpy of vaporisation, cal./gram mole
$\Delta S_v$	= entropy of vaporisation, cal./gram mole $^\circ K$
$l$	refers to liquid
$g$	refers to gas or vapour

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