On the Specific Heat of Iron-Carbon System at High Temperatures, and the Heat Changes Accompanying Those of Phase(1).

By

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CONTENTS.

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(1) The **335**th report of the Research Institute for Iron, Steel and Other Metals.

Synopsis.

The heat content of 19 kinds of iron-carbon alloys ranging from 0.07 to 5.07% carbon were measured at each of different high temperatures up to beyond the melting point by the method of mixture, and their mean and true specific heats were deduced therefrom. From the relation of the heat of peritectic reaction and carbon concentration, a value of 14.7 calories was given as the heat of reaction per gram of the specimen in 0.13% carbon, and the heat of solution of γ-crystal below 0.13% carbon into δ-crystal decreases with the rise of temperature. The heat content and specific heat of cementite at high temperatures were found by extrapolation of the present results, and the heat of A_0 transformation of cementite was estimated to be 9.35 calories. The heat of fusion of δ-crystal to melt into the liquid of the corresponding carbon concentration is 64.90 calories per gram of δ-crystal in 0.07% carbon, and 65.31 calories for that in 0.03% carbon. The heat of fusion of γ-crystal on the solidus to melt into the liquid of the corresponding carbon concentration is 57.80 calories per gram of γ-crystal in 1.70% carbon, and 67.19 calories for that in 0.13% carbon. As the latent heat of fusion of eutectic alloy was found to be 60.91 calories per gram. The heat of transformation of α- into γ-iron at the A_3 transformation point was calculated to be 5.59 calories per gram for pure iron and 16.60 calories at 720° for eutectoid steel, respectively.

The heat of solution of cementite into γ-crystal of 0.90% carbon is 11.15

calories per gram at 720°, and decreases with the rise of temperature and carbon concentration of γ-crystal. The latent heat of fusion was obtained as the limiting value of the heat of fusion, and the former is always somewhat less than the latter. The latent heat of fusion of cementite was found to be 65.0 calories per gram, the melting temperature being estimated to be 1600°. The heat of mixture of any two liquids or solids in the iron-carbon system is proportional to the product of their quantities a and b, and inversely proportional to the sum of these quantities, being always endothermic reaction. So the heat of mixture H_1 in these cases will be given as follows;

$$H_1 = K\frac{ab}{a+b}$$

where $$K = f(t)(C_1 - C_2)^2.$$

The proportional constant K is a function of temperature and the square of the difference of carbon concentrations C_1 and C_2 of two liquids or solids.

§ I. Introduction.

As to the specific heat of carbon steel at high temperatures, A. Meuthen(2), N. Yamada(3) and the present writer(4) already published their results of experiments. Recently, R. Averdieck(5), and H. Esser and W. Grass(6) newly determined the heat of A_1 transformation by their experiments. On the other hand, P. Oberhoffer and W. Grosse(7) and the present writer(8) measured the specific heat of pure iron at high temperatures. In carbon steel, however, the measurements carried out by N. Yamada, A. Meuthen, H. Esser and W. Grass, and R. Averdieck were limited to several hundred degrees of temperature; in the former case of the present writer, the measurement was made up to a little above 1000°, the maximum carbon content being 2.81 percent. The heat of A_0, A_1, A_2 and A_3 transformations in carbon steel, that of the A_4 transformation and the heat of fusion in pure

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(2) Ferrum, 10 Jahrg, (1912), 1.

(3) Sci. Rep., **10** (1922), 453.

(4) Rep. Res. Inst. I. G. S. W., **5** (1925), No. 2; Kinzoku-no-kenkyu, **3** (1926), 225; Sci. Rep., **15** (1926), 331.

(5) Dr. Ing. Diss. Tech. Hoch. Aschen, (1932).

(6) Stahl u. Eisen, **53** (1932), 92.

(7) Stahl u. Eisen, **47** (1927), 576.

(8) Rep. Res. Inst. I. G. S. W., **9** (1929), No. 3; Kinzoku-no-kenkyu, **5** (1928), 184, 479; Sci. Rep., **18** (1929), 91.

iron were previously reported by the present writer(9), but no publication on the specific heat, the heat of fusion and that of mixture of iron-carbon system in the range of temperatures up to liquid iron has never been published. These constants being, however, very important in the operation of the manufacture of steel, the present writer newly determined the specific heat of these steels and calculated them at high temperatures in the range above mentioned. From the results thus obtained, he determined the equilibrium diagram of iron-carbon system, and obtained therefrom the heat required for the peritectic and eutectic reactions. He also obtained the heat of the A_0, A_1 and A_2 transformations of hyper-eutectic cast iron of 4.81% carbon. From the observed results, he also obtained by extrapolation the specific heat of cementite at high temperatures, its heat of solution as well as that of fusion, the latent heat of fusion of cementite at high temperatures. Moreover, from these results, he intended to determine the relation existing among these heat quantities in iron-carbon system.

§ II. Specimens and Method of Experiments.

The specimens used in the present experiment were prepared by alloying electrolytic iron manufactured by the Institute of Physical and Chemical Research, Tokyo, with sugar charcoal. The specimens which contained various concentrations of carbon, were made into the form of a short cylinder, 10～12 mm in diameter and 13～15 mm in length.

The method and the apparatus in this experiment were exactly the same as those used in the writer's previous experiment(10). In the measurement at very high temperatures, especially in semi-molten or molten state, the temperature was very slowly reduced from 5°～10° above the required point, and after keeping it constant at this point for about 20 minutes, the specimen was let fall into the calorimeter.

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(9) Rep. Res. Inst. I. G. S. W., **6** (1926), No. 5 ; **7** (1927), No. 9. Kinzoku-no-kenkyu, **3** (1926), 385, 527 ; Sci. Rep., **16** (1927), 775, 1009.

(10) Rep. Res. Inst. I. G. S. W., l. c.

The water in the calorimeter was 500 grams and its water equivalent was found to be 16.5 grams. The rise of temperature of water in the calorimeter was read by a Beckmann thermometer, and the temperature-time curve extending before and after the fall of the specimen in water was obtained, from which the true rise of temperature including the loss of heat by radiation was deduced as usual. The specimens were thoroughly polished before each experiment, all other particulars being the same as in the previous experiment. It may be safely assumed that the inside of the specimen was uniformly heated(11) in view of the size of the specimen and of the time kept constant. The range of temperatures, in which the specific heat of carbon steels was measured, is above 900°, and the specific heat below this range is found in my former paper(12). 19 kinds of specimen were used, their chemical analysis being shown below :—

Chemical Analysis of Specimens of
Iron-Carbon Alloys.

Sp. No.	C (%)	Si (%)	Mn (%)	P (%)	S (%)	Cu (%)
1	0.07	0.034	0.030	0.012	0.017	0.06
2	0.11	0.027	0.042	0.019	0.028	0.05
3	0.13	0.022	0.034	0.013	0.023	0.04
4	0.19	0.034	0.040	0.017	0.031	0.22
5	0.30	0.019	0.038	0.020	0.024	0.04
6	0.41	0.043	0.210	0.002	0.024	0.20
7	0.61	0.101	0.069	0.040	0.023	0.08
8	0.77	0.100	0.075	0.023	0.041	0.21
9	1.05	0.050	0.060	0.023	0.006	0.03
10	1.33	0.107	0.077	0.025	0.041	0.049
11	1.57	0.047	0.070	0.027	0.011	0.03
12	1.85	0.065	0.080	0.015	0.010	0.05
13	2.40	0.040	0.070	0.012	0.020	0.01
14	2.90	0.060	0.020	0.016	0.070	0.01
15	3.00	0.070	0.050	0.011	0.020	0.30
16	3.50	0.060	0.060	0.012	0.020	0.01
17	4.30	0.090	0.080	0.021	0.037	0.02
18	4.81	0.040	0.040	0.003	0.018	0.05
19	5.07	0.098	—	0.018	0.045	0.005

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(11) Sci. Rep., l. c.

(12) Sci. Rep., **14** (1926), 331.

All these specimens, after they were subjected to the calorimetric measurement, were examined under a microscope, but no graphitization could be detected.

The following is the formula used in the calculation of the mean specific heat of the specimen:

$$C=\frac{(w+W)(t_2-t_0)}{m(t_1-t_2)},$$

where

C = Mean specific heat of the specimen,
w = Water equivalent of the calorimeter,
W = Mass of water in the calorimeter,
m = Mass of the specimen,
t_0 = Initial temperature of water in the calorimeter,
t_1 = Temperature of the specimen heated,
t_2 = Temperature of water in the calorimeter raised by the heated specimen.

§ III. Results of Experiments.

The results of experiments are given in the following Table 1, each being the mean of two or three independent observations.

Table 1.

No. 1 (0.07% C).

$t_1=900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.368	24.442	3.074	875.6	147.502	0.1639	11.0622
22.416	24.895	2.479	875.1	147.722	0.1641	8.9164
				Mean 147.612	0.1640	

$t_1=1000°$,

Initial temp. (t_0)	Final temp. (t_2)	t_2-t_0	t_1-t_2	Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
23.234	24.723	1.242	975.3	161.02	0.1610	8.1941
23.310	26.720	3.410	973.3	161.23	0.1612	11.2254
				Mean 161.13	0.1611	

$t_1=1100^\circ$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.456	25.966	3.510	1074.0	177.803	0.1616	10.1452
22.610	24.742	2.132	1075.3	177.682	0.1615	6.3371

Mean 177.743 0.1616

$t_1=1200^\circ$,

23.103	26.482	3.379	1173.5	194.821	0.1624	9.1612
23.006	25.995	2.989	1174.0	194.787	0.1623	8.1012

Mean 194.804 0.1623

$t_1=1300^\circ$,

23.204	27.945	4.741	1272.1	211.835	0.1630	11.8150
23.107	26.717	3.610	1273.3	212.064	0.1631	8.9765

Mean 211.950 0.1630

$t_1=1400^\circ$,

23.306	27.665	4.359	1372.3	229.465	0.1639	10.0107
23.314	27.616	4.302	1372.4	229.632	0.1640	9.8711

Mean 229.549 0.1640

$t_1=1450^\circ$,

20.311	24.097	3.786	1425.9	238.363	0.1644	8.3412
21.663	25.657	3.994	1424.3	238.240	0.1643	8.8145

Mean 238.302 0.1644

$t_1=1480^\circ$,

19.446	23.341	3.895	1456.7	245.921	0.1662	8.3116
20.041	23.295	3.254	1456.7	245.720	0.1667	6.9216

Mean 245.321 0.1664

$t_1=1500^\circ$,

18.922	24.449	5.527	1475.6	256.582	0.1711	11.3112
19.214	22.936	3.722	1477.1	256.391	0.1709	7.6144
20.333	24.785	4.452	1475.2	256.771	0.1712	9.1055

Mean 256.582 0.1711

$t_1=1515°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
18.623	23.896	5.273	1491.1	282.062	0.1862	9.8112
19.442	25.071	5.629	1489.9	281.145	0.1856	10.5155
20.313	23.777	3.464	1491.2	283.012	0.1868	6.4233

Mean 282.073 0.1862

$t_1=1540°$,

23.55	28.028	4.478	1512.0	321.806	0.2090	7.3211
20.02	23.980	3.960	1516.0	322.336	0.2093	6.4455

Mean 322.071 0.2091

$t_1=1570°$,

20.10	24.854	4.754	1545.2	326.775	0.2081	7.6356
19.44	23.712	4.272	1546.3	328.713	0.2094	6.8155

Mean 327.734 0.2088

No. 2 (0.11% C).

$t_1=900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.763	25.268	3.505	874.7	147.674	0.1641	12.6132
20.317	23.114	2.797	876.9	147.368	0.1637	10.0656

Mean 147.521 0.1639

$t_1=1000°$,

22.168	25.626	3.458	974.4	161.571	0.1616	11.3452
22.081	25.590	3.509	974.4	161.312	0.1613	11.5311

Mean 161.442 0.1615

$t_1=1100°$,

21.682	25.166	3.504	1074.8	177.004	0.1609	10.4631
22.313	24.780	2.467	1075.2	177.861	0.1617	7.9625

Mean 177.433 0.1613

$t_1=1200°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
23.334	27.259	3.925	1172.7	194.312	0.1619	10.6744
22.675	25.981	3.306	1174.0	194.522	0.1621	8.9712

Mean 194.417 0.1620

$t_1=1300°$,

22.246	26.197	3.951	1273.8	211.204	0.1625	9.8613
22.103	25.384	3.281	1274.6	212.251	0.1633	8.1426

Mean 211.728 0.1629

$t_1=1400°$,

26.074	30.000	3.926	1370.0	229.012	0.1636	9.0483
23.010	27.445	4.435	1372.6	230.812	0.1649	10.1219
23.246	26.585	3.339	1373.4	229.642	0.1640	7.6542

Mean 229.822 0.1645

$t_1=1450°$,

24.473	28.878	4.405	1421.1	239.011	0.1648	9.7133
23.105	27.026	3.921	1423.0	238.804	0.1647	8.6417

Mean 238.907 0.1648

$t_1=1480°$,

23.353	27.873	4.520	1452.1	244.901	0.1655	9.7167
22.168	25.847	3.679	1454.2	245.103	0.1656	7.8915

Mean 245.002 0.1655

$t_1=1490°$,

21.351	25.983	4.632	1464.0	255.870	0.1717	9.5156
19.644	23.698	4.054	1466.3	256.003	0.1718	8.3121
20.612	24.202	3.590	1465.8	257.261	0.1727	7.3261

Mean 256.378 0.1721

$t_1=1500°$,

20.121	25.303	5.182	1474.7	270.999	0.1807	10.0461
23.011	26.930	3.919	1473.1	272.340	0.1816	7.5677
19.657	23.980	4.323	1476.0	272.031	0.1814	8.3411

Mean 271.790 0.1812

$t_1 = 1510°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.336	25.093	4.757	1487.9	289.502	0.1917	8.6311
19.691	23.157	3.466	1486.8	290.200	0.1922	6 2650

Mean 289.851 0.1920

$t_1 = 1540°$,

19.134	21.976	2.842	1518.0	322.031	0.2091	4.625
19.818	24.591	4.773	1515.4	320.713	0.2083	7.8113

Mean 321.372 0.2087

$t_1 = 1570°$,

20.516	24.968	4.452	1545.0	327.510	0.2086	7.1344
20.136	23.613	3.477	1546.4	326.650	0.2081	5.5811

Mean 327.080 0.2083

No. 3 (0.13% C).

$t_1 = 900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.011	25.274	3.263	874.7	147.516	0.1639	11.7552
19.981	22.690	2.709	877.3	147.188	0.1635	9.7534

Mean 147.352 0.1637

$t_1 = 1000°$,

23.104	26.246	3.142	973.8	160.812	0.1608	10.3633
24.412	26.733	2.321	973.3	161.321	0.1613	7.6348

Mean 161.067 0.1611

$t_1 = 1100°$,

23.143	27.010	3.867	1073.0	177.741	0 1616	11.5187
22.479	26.064	3.585	1073.9	177.943	0.1618	10.6567

Mean 177.842 0.1617

$t_1=1200°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
23.366	27.464	4.098	1172.5	194.520	0.1621	11.1367
23 102	26.034	2.932	1174.0	194.243	0.1619	7.9681

Mean 194.332 0.1620

$t_1=1300°$,

22.518	26.551	4.033	1273.5	211.691	0.1628	10.0456
21.558	25.139	3.581	1274.9	211.591	0.1628	8.9127

Mean 211.641 0.1628

$t_1=1400°$,

24.637	28.500	3.863	1371.5	230.051	0.1643	8.8544
24.019	28.825	4.806	1371.2	229.653	0.1640	11.0366

Mean 229.852 0.1642

$t_1=1460°$,

22.669	26.744	4.075	1433.3	240.522	0.1647	8.9144
23.107	26.480	3.373	1433.5	240.911	0.1650	7.3655

Mean 240.717 0.1649

$t_1=1487°$,

23,715	28.096	4.381	1458.9	260.214	0.1750	8.8633
24.212	27.735	3.523	1459.3	258.433	0,1738	7.1744

Mean 259.324 0.1744

$t_1=1490°$,

24.313	28.943	4.630	1461.1	263.811	0.1771	9.2455
22.616	26.998	4.382	1463.0	262.815	0.1764	8.7710
20.110	24.103	3.993	1465.9	263.307	0.1767	7.9613

Mean 263.311 0.1767

$t_1=1500°$,

19.760	25.200	5.440	1474.8	274.100	0.1827	10.4161
21.065	24.752	3.687	1475.3	275.140	0.1834	7.0367

Mean 274.620 0.1831

$t_1=1510°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.612	25.398	4.786	1484.6	300.715	0.1992	8.3611
20.618	25.274	4.656	1484.7	301.321	0.1996	8.1167
21.716	25.793	4.077	1484.2	300.133	0.1988	7.1375
			Mean	300.723	0.1992	

$t_1=1540°$,

20.618	25.412	4.794	1514.6	320.533	0.2081	7.8542
19.231	23.403	4.172	1516.6	321.095	0.2085	6.8153
			Mean	320.764	0.2083	

$t_1=1570°$,

20.106	25.080	4.974	1544.9	326.330	0.2079	8.0011
19.912	24.207	4.295	1545.8	326.650	0.2081	6.8971
			Mean	326.490	0.2080	

No. 4 (0.19 % C).

$t_1=900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.637	25.724	3.087	874.3	146.757	0.1631	11.1817
21.561	24.050	2.489	876.0	146.911	0.1632	8.9931
			Mean	146.834	0.1632	

$t_1=1000°$,

22.261	26.045	3.784	974.0	160.302	0.1603	12.5181
21.478	24.644	3.166	975.4	160.716	0.1607	10.4312
			Mean	160.509	0.1605	

$t_1=1100°$,

24.162	28.117	3.995	1071.9	177.411	0.1613	11.8165
22.415	25.840	3.425	1074.2	177.802	0.1616	10.1896
			Mean	177.607	0.1615	

$t_1 = 1200°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
24.233	28.557	4.324	1171.4	194.120	0.1618	11.7852
21.625	25.562	3.937	1174.4	194.542	0.1621	10.6828

Mean 194.311 0.1619

$t_1 = 1300°$,

19.367	24.243	4.876	1275.8	211.832	0.1630	12.1140
19.512	23.067	3.555	1276.9	212.272	0.1633	8.8063

Mean 212.052 0.1631

$t_1 = 1400°$,

24.471	28.853	4.382	1371.2	229.301	0.1638	10.0781
23.673	27.500	3.827	1372.5	230.101	0.1644	8.7615

Mean 229.651 0.1641

$t_1 = 1450°$,

24.123	28.037	3.914	1422.0	238.762	0.1647	8.6333
23.124	26.666	3.542	1423.3	238.544	0.1645	7.8122

Mean 238.653 0.1646

$t_1 = 1470°$,

24.312	28.454	4.142	1441.6	245.155	0.1668	8 8982
22 677	26.168	3.491	1443.8	244.301	0.1662	7.8976
21.461	24 642	3.181	1445.4	245.307	0.1669	6.8111

Mean 244.921 0.1666

$t_1 = 1480°$,

19.471	23.383	3.912	1456.6	252.011	0.1703	8.1465
20.468	24.262	3.794	1455.7	253.912	0.1716	7.8461
22.134	25.245	3.111	1454.8	252.830	0.1708	6.4657

Mean 252.818 0.1709

$t_1 = 1490°$,

21.306	25.598	4.292	1464.4	277.077	0.1860	8.1414
19.882	23.857	3.975	1466.1	277.041	0.1859	7.5313
21.478	24.891	3.413	1465.1	277.335	0.1861	6.4639

Mean 277.151 0.1860

$t_1=1500°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
19.775	24.234	3.459	1475.8	291.812	0.1945	8.0216
21.634	25.188	3.554	1474.9	293.206	0.1955	6.3681
20.464	24.263	3.799	1475.7	292.542	0.1950	6.8177

Mean 292.520 0.1950

$t_1=1520°$,

20.057	24.661	4.604	1495.3	315.673	0.2077	7.6577
21.717	25.867	4.150	1494.1	316.471	0.2082	6.8910

Mean 316.072 0.2079

$t_1=1540°$,

19.768	24.409	4.641	1515.6	319.421	0.2074	7.6255
19.658	23.381	3.723	1516.6	320.085	0.2079	6.1003

Mean 319.753 0.2076

$t_1=1560°$,

18.661	23.047	4.486	1537.0	323.700	0.2075	7.1034
19.313	22.809	3.496	1537.2	323.909	0.2076	5.658
20.107	24.812	4.705	1535.2	323.521	0.2074	7.6333

Mean 323.710 0.2075

No. 5 (0.30% C).

$t_1=900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.108	25.243	3.135	874.8	145.717	0.1619	11.4314
23.355	26.280	2.925	873.7	146.031	0.1623	10.6565

Mean 145.874 0.1621

$t_1=1100°$,

19.216	23.003	3.787	1077.0	176.211	0.1602	11.3361
20.658	23.743	3.085	1076.3	176.713	0.1607	9.2168

Mean 176.462 0.1604

$t_1=1200°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.134	24.336	4.202	1175.7	193.200	0.1610	11.4654
20.678	24.877	4.199	1175.1	192.320	0.1603	11.5160

Mean 192.760 0.1606

$t_1=1300°$,

23.132	27.937	4.805	1272.1	210.301	0.1618	12.0591
19.416	23.567	4.151	1276.4	211.141	0.1624	10.3412

Mean 210.721 0.1621

$t_1=1400°$,

23.108	27.613	4.505	1372.4	229.105	0.1637	10.3610
23.406	27.192	3.786	1372.8	229.841	0.1642	8.6755

Mean 229.473 0.1639

$t_1=1440°$,

24.046	27.927	3.881	1412.1	240.021	0.1667	8.5157
25.104	28.401	3.297	1411.6	240.043	0.1667	7.2364

Mean 240.032 0.1667

$t_1=1460°$,

23.335	27.192	3.857	1432.8	250.610	0.1717	8.1010
22.617	26.272	3.655	1433.7	251.801	0.1725	7.6347
22.314	25.571	3.257	1434.4	251.233	0.1721	6.8155

Mean 251.215 0.1721

$t_1=1480°$,

23.216	27.533	4.317	1452.5	271.663	0.1836	8.3631
19.868	23.443	3.575	1456.6	271.442	0.1834	6.9124
20.117	23.027	2.910	1457.0	271.984	0.1838	5.6133

Mean 271.663 0.1836

$t_1=1487°$,

23.061	27.798	4.737	1459.2	294.620	0.1981	8.4632
20.662	24.884	4.222	1462.1	295.240	0.1986	7.5116

Mean 294.930 0.1983

$t_1=1490°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal.	M.S.H.	Weight
		t_2-t_0	t_1-t_2	$q(t_1-0)$	(t_1-t_2)	(gram)
19.313	23.926	4.613	1466.1	300.663	0.2018	8.0531
20.626	24.987	4.361	1465.0	300.106	0.2014	7.6345
21.611	26.106	4.495	1463.9	300.380	0.2016	7.8677

Mean 300.383 0.2016

$t_1=1520°$,

22.314	27.334	5.020	1492.7	313.020	0.2059	8.4356
19.952	23.620	3.668	1496.4	313.628	0.2063	6.1367

Mean 313.324 0.2061

$t_1=1560°$,

19.866	24.772	4.906	1535.2	320.511	0.2055	8.0341
19.773	24.477	4.704	1535.5	321.153	0.2059	7.6850

Mean 320.832 0.2057

No. 6 (0.41 % C).

$t_1=900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal.	M.S.H.	Weight
		t_2-t_0	t_1-t_2	$q(t_1-0)$	(t_1-t_2)	(gram)
21.714	25.107	3.393	874.9	144.412	0.1605	12.4812
20.681	23.344	2.663	876.7	144.814	0.1609	9.7523

Mean 144.613 0.1607

$t_1=1100°$,

20.311	24.093	3.782	1075.9	174.922	0.1590	11.4166
20.373	23.728	3.355	1076.3	175.946	0.1600	10.0674

Mean 175.434 0.1595

$t_1=1200°$,

19.359	23.547	4.188	1176.5	191.524	0.1596	11.5216
20.813	24.070	3.257	1175.9	192.516	0.1604	8.9167

Mean 192.020 0.1600

$t_1=1300^\circ$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.367	26.532	4.165	1273.5	210.824	0.1622	10.4160
19.063	22.613	3.550	1277.4	208.934	0.1607	8.9321
19.818	22.095	2.277	1277.9	209.915	0.1615	5.6992

Mean 209.891 0.1615

$t_1=1370^\circ$,

20.106	24.924	4.818	1345.1	222.610	0.1625	11.3850
21.321	25.940	4.619	1344.1	223.154	0.1629	10.8965

Mean 222.882 0.1627

$t_1=1420^\circ$,

21.346	25.976	4.630	1394.0	238.516	0.1680	10.2124
22.477	26.273	3.796	1393.7	238.926	0.1683	8.3611

Mean 238.721 0.1681

$t_1=1450^\circ$,

19.216	23.543	4.327	1426.5	253.418	0.1748	8.9641
19.265	22.856	3.591	1427.1	253.752	0.1750	7.4263
20.369	23.705	3.336	1426.3	253.120	0.1746	6.9199

Mean 253.430 0.1748

$t_1=1470^\circ$,

21.346	25.971	4.625	1444.0	275.234	0.1872	8.8351
22.617	26.513	3.896	1443.5	274.434	0.1867	7.4670

Mean 274.834 0.1870

$t_1=1500^\circ$,

21.060	25.311	4.251	1474.7	308.201	0.2055	7.2461
21.515	25.206	3.691	1474.8	307.505	0.2050	6.3055

Mean 307.853 0.2052

$t_1=1560^\circ$,

20.319	23.317	2.998	1536.7	319.308	0.2047	4.9230
19.188	23.814	4.626	1536.2	318.633	0.2043	7.6152
20.566	25.351	4.785	1534.7	318.762	0.2043	7.8811

Mean 318.901 0.2044

No. 7 (0.61% C).

$t_1 = 900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
19.413	22.967	3.554	877.0	144.331	0.1604	13.0488
19.671	22.690	3.019	877.3	144.591	0.1607	11.0615

Mean 144.461 0.1606

$t_1 = 1000°$,

19.813	23.553	3.740	976.4	157.512	0.1575	12.5611
21.417	24.900	3.483	975.1	157.952	0.1580	11.6750

Mean 157.732 0.1578

$t_1 = 1100°$,

21.660	25.416	3.756	1074.6	177.233	0.1611	11.2034
23.651	26.989	3.338	1073.0	176.365	0.1603	10.0216

Mean 176.800 0.1607

$t_1 = 1200°$,

19.984	24.166	4.182	1175.8	191.102	0.1593	11.5361
21.066	24.323	3.257	1175.7	191.524	0.1596	8.9665

Mean 191.313 0.1594

$t_1 = 1300°$,

19.265	23.498	4.233	1276.5	208.914	0.1607	10.6581
20.414	23.852	3.438	1276.2	209.570	0.1612	8.6322

Mean 209.242 0.1610

$t_1 = 1350°$,

20.636	25.105	4.469	1324.9	219.942	0.1629	10.6930
21.558	25.298	3.740	1324.7	220.706	0.1635	8.9190

Mean 220.324 0.1632

$t_1 = 1400°$,

19.818	22.988	3.170	1377.0	238.415	0.1703	6.9812
23.616	27.667	4.051	1372.3	238.865	0.1706	8.9365

Mean 238.640 0.1705

$t_1=1450°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.551	26.666	4.115	1423.3	271.841	0.1875	7.9652
19.468	22.748	3.280	1427.3	272.261	0.1878	6.3211

Mean 272.051 0.1876

$t_1=1460°$,

19.312	24.053	4.741	1436.0	282.502	0.1935	8.8130
20.181	24.236	4.055	1435.8	281.601	0.1929	7.5622
20.714	24.032	3.318	1436.0	282.293	0.1934	6.1723

Mean 282.132 0.1932

$t_1=1500°$,

21.470	26.184	4.714	1473.8	304.533	0.2030	8.1366
19.312	23.398	4.086	1476.6	303.795	0.2025	7.0565

Mean 304.164 0.2028

$t_1=1560°$,

21.432	26.294	4.862	1533.7	315.122	0.2020	8.1056
22.036	25.987	3.951	1534.0	316.466	0.2028	6.5577

Mean 315.794 0.2024

No. 8 (0.77% C).

$t_1=900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
19.912	23.485	3.573	876.5	140.752	0.1564	13.4614
22.031	24.403	2.372	875.6	141.301	0.1570	8.9133
21.508	24.267	2.759	875.7	140.713	0.1563	10.4125

Mean 140.922 0.1566

$t_1=1000°$,

20.612	24.337	3.725	975.7	155.557	0.1556	12.6717
20.817	23.946	3.129	976.1	156.211	0.1562	10.6002
19.715	22.358	2.643	977.6	156.304	0.1563	8.9346

Mean 156.024 0.1560

$t_1=1100°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.416	24.790	4.374	1075.2	172.205	0.1566	13.4171
21.659	25.141	3.482	1074.9	172.495	0.1568	10.6715
			Mean	172.350	0.1567	

$t_1=1200°$,

21.446	25.899	4.453	1174.1	187.910	0.1566	12.5112
19.846	24.532	4.667	1175.5	188.796	0.1573	13.0630
			Mean	188.353	0.1570	

$t_1=1250°$,

21.334	25.879	3.545	1224.1	197.105	0.1577	12.1622
22.136	25.737	3.601	1224.3	197.537	0.1580	9.6134
			Mean	197.341	0.1579	

$t_1=1320°$,

19.817	24.415	4.598	1295.6	214.823	0.1627	11.2631
20.368	23.877	3.509	1296.1	215.605	0.1633	8.5613
			Mean	215.214	0.1630	

$t_1=1350°$,

19.606	24.434	4.828	1325.6	224.511	0.1663	11.3122
19.904	24.506	4.602	1325.5	223.802	0.1658	10.8164
22.033	25.749	3.716	1324.3	224.485	0.1663	8.7155
			Mean	224.266	0.1661	

$t_1=1400°$,

20.318	25.356	5.038	1374.6	245.133	0.1751	10.8116
21.926	25.740	3.814	1374.3	245.737	0.1755	8.1657
			Mean	245.435	0.1753	

$t_1=1430°$,

20.031	24.716	4.685	1405.3	263.455	0.1842	9.3468
22.313	26.092	3.779	1403.9	262.793	0.1838	7.5651
19.366	23.450	4.084	1406.6	263.508	0.1843	8.1388
			Mean	263.252	0.1841	

$t_1=1470^\circ$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.365	25.652	4.287	1444.4	295.230	0.2008	7.6335
20.677	24.201	3.524	1445.8	296.021	0.2014	6.2511

Mean 295.621 0.2011

$t_1=1500^\circ$,

22.621	27.376	4.755	1472.6	301.033	0.2007	8.3106
19.477	23.667	4.190	1476.3	300.646	0.2004	7.3133
20.315	23.745	3.430	1476.3	302.011	0.2013	5.9607

Mean 301.230 0.2008

$t_1=1540^\circ$,

21.451	24.960	3.509	1515.0	308.811	0.2005	5.9658
23.617	27.672	4.055	1512.3	308.433	0.2003	6.9144

Mean 308.622 0.2004

No. 9 (1.05% C).

$t_1=800^\circ$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.413	23.565	3.152	776.4	124.085	0.1551	13.5182
20.212	22.704	2.492	777.3	124.537	0.1557	10.6344

Mean 124.311 0.1554

$t_1=850^\circ$,

21.607	24.652	3.045	825.3	133.511	0.1571	12.1303
20.451	23.105	2.654	826.9	133.024	0.1565	10.5910
20.812	23.677	2.865	826.3	133.383	0.1569	11.4135

Mean 133.306 0.1568

$t_1=900^\circ$,

20.519	23.840	3.321	876.2	142.515	0.1584	12.3622
20.874	23.590	2.716	876.4	143.409	0.1593	10.0466
21.036	24.157	3.121	875.8	143.106	0.1590	11.5751

Mean 143.012 0.1589

$t_1=950°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.467	25.086	3.619	924.9	149.794	0.1577	12.8162
22.712	25.500	2.788	924.5	149.612	0.1575	9.8913

Mean 149.703 0.1576

$t_1=1000°$,

22.312	26.045	3.733	974.0	157.168	0.1572	12.5971
21.162	24.105	2.943	975.9	157.496	0.1575	9.8911

Mean 157.332 0.1574

$t_1=1100°$,

19.873	23.912	4.039	1076.1	172.441	0.1568	12.3677
20.715	23.622	2.907	1076.4	172.101	0.1565	8.9155
20.166	23.470	3.304	1076.5	172.538	0.1569	10.1070

Mean 172.360 0.1567

$t_1=1170°$,

22.365	26.135	3.770	1143.9	184.102	0.1574	10.8183
19.875	24.540	4.665	1145.5	183.610	0.1569	13.4051

Mean 183.856 0.1572

$t_1=1200°$,

21.132	25.578	4.446	1174.4	188.317	0.1569	12.4618
20.337	24.229	3.892	1175.8	188.671	0.1572	10.8755

Mean 188.494 0.1571

$t_1=1250°$,

20.659	25.245	4.586	1224.8	201.109	0.1609	12.0210
19.910	23.743	3.833	1226.3	201.067	0.1609	10.0366

Mean 201.088 0.1609

$t_1=1300°$,

18.944	23.330	4.386	1276.7	217.284	0.1671	10.6161
20.316	23.854	3.538	1276.2	217.634	0.1674	8.5533
24.618	27.689	3.071	1272.3	217.105	0.1670	7.4652

Mean 217.341 0.1672

$t_1=1350°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
19.216	23.626	4.410	1326.4	235.802	0.1747	9.8322
23.652	27.280	3.628	1322.7	236.000	0.1748	8.1044
			Mean	235.901	0.1747	

$t_1=1400°$,

19.313	24.065	4.752	1375.9	258.637	0.1847	9.6552
20.306	24.307	4.001	1375.7	258.312	0.1845	8.1411
21.215	24.629	3.414	1375.4	258.911	0.1849	6.9323
			Mean	258.820	0.1847	

$t_1=1430°$,

26.516	31.146	4.630	1398.9	283.162	0.1980	8.6331
19.818	23.568	3.750	1406.4	283.300	0.1981	6.9515
			Mean	283.232	0.1981	

$t_1=1450°$,

20.363	24.847	4.484	1425.2	289.764	0.1998	8.1322
19.218	23.029	3.811	1427.0	289.902	0.1999	6.8991
			Mean	289.833	0.1999	

$t_1=1500°$,

20.803	25.406	4.603	1474.6	299.046	0.1994	8.0867
18.921	22.684	3.763	1477.3	299.356	0.1996	6.5920
			Mean	299.201	0.1995	

$t_1=1540°$,

21.312	25.678	4.366	1514.3	306.203	0.1988	7.4891
22.569	26.345	3.776	1513.7	306.745	0.1992	6.4689
			Mean	306.474	0.1990	

No. 10. (1.33% C).

$t_1=800°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.485	23.560	3.075	776.4	125.163	0.1565	13.0711
20.901	23.339	2.438	776.7	124.977	0.1562	10.3819
			Mean	125.070	0.1564	

t_1=900°,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.366	23.680	3.314	876.3	141.095	0.1568	12.4611
19.832	22.448	2.616	877.6	140.529	0.1561	9.8651
			Mean	140.812	0.1565	

t_1=950°,

20.368	23.621	3.253	926.4	150.301	0.1582	11.4635
19.857	23.467	3.610	926.6	148.995	0.1568	12.8341
20.416	23.373	2.957	926.6	149.003	0.1568	10.5103
			Mean	149.433	0.1573	

t_1=1000°,

19.816	23.248	3.432	976.6	150.738	0.1507	12.0411
18.635	21.625	2.990	978.4	150.188	0.1502	10.5087
			Mean	150.463	0.1505	

t_1=1050°,

20.371	24.504	4.133	1025.5	166.755	0.1588	13.1066
19.817	22.833	3.016	1027.2	167.075	0.1591	9.5313
			Mean	166.915	0.1590	

t_1=1100°,

19.316	23.467	4.151	1076.5	174.311	0.1585	12.5680
20.567	23.970	3.403	1076.0	174.109	0.1583	10.3213
			Mean	174.210	0.1584	

t_1=1150°,

19.463	23.397	3.934	1126.6	181.342	0.1577	11.4361
20.713	24.067	3.354	1125.9	181.856	0.1581	9.7322
19.914	23.550	3.636	1126.5	181.701	0.1580	10.5514
			Mean	181.633	0.1579	

t_1=1200°,

19.215	23.282	4.057	1176.7	193.589	0.1613	11.0655
20.316	24.018	3.702	1176.0	193.953	0.1616	10.0606
21.133	25.578	4.445	1174.4	193.770	0.1615	12.1050
			Mean	193.771	0.1615	

$t_1=1250°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.596	25.344	4.748	1224.7	207.533	0.1660	12.0615
19.568	24.042	4.474	1226.0	207.225	0.1658	11.3688

Mean 207.430 0.1659

$t_1=1300°$,

19.513	23.974	4.461	1276.0	225.368	0.1734	10.4155
22.618	26.411	3.793	1273.6	225.695	0.1736	8.8611
19.319	22.594	3.275	1277.4	225.530	0.1735	7.6322

Mean 225.531 0.1735

$t_1=1350°$,

20.068	25.432	5.364	1324.6	245.211	0.1816	11.5161
20.612	25.434	4.822	1324.6	245.820	0.1821	10.3255
20.323	24.110	3.787	1325.9	245.862	0.1821	8.1012

Mean 245.631 0.1820

$t_1=1400°$,

22.138	26.930	4.792	1373.1	270.729	0.1934	9.3215
19.069	23.251	4.182	1376.8	271.031	0.1936	8.1042

Mean 270.880 0.1935

$t_1=1450°$,

22.414	26.997	4.583	1423.0	290.199	0.2001	8.3122
22.389	26.867	4.478	1423.1	290.827	0.2006	8.1034

Mean 290.563 0.2004

$t_1=1500°$,

19.185	23.388	4.204	1476.6	299.597	0.1997	7.3612
20.312	23.722	3.410	1476.3	299.827	0.1998	5.9690

Mean 299.712 0.1998

$t_1=1540°$,

20.673	25.263	4.590	1514.7	306.948	0.1993	7.8516
19.325	23.030	3.705	1517.0	307.676	0.1998	6.3133

Mean 307.312 0.1996

No. 11 (1.57% C).

$t_1=800°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
19.691	22.871	3.180	777.1	125.614	0.1570	13.4622
20.553	22.936	2.383	777.1	125.908	0.1574	10.0616

Mean 125.761 0.1572

$t_1=900°$,

19.317	22.820	3.503	877.2	141.264	0.1570	13.1362
20.716	23.511	2.795	876.5	140.722	0.1564	10.5186
21.702	24.062	2.360	875.9	141.293	0.1570	8.8617

Mean 141.093 0.1568

$t_1=1000°$,

19.688	23.448	3.760	976.6	157.433	0.1574	12.6344
20.415	23.339	2.924	976.7	157.579	0.1576	9.8111

Mean 157.506 0.1575

$t_1=1050°$,

19.622	22.379	2.757	1027.6	166.582	0.1586	8.7536
21.364	24.546	3.182	1025.5	166.122	0.1582	10.1301

Mean 166.352 0.1584

$t_1=1080°$,

20.963	25.321	4.358	1054.7	172.902	0.1601	13.3316
19.867	23.387	3.520	1056.6	172.730	0.1599	10.7580

Mean 172.816 0.1600

$t_1=1100°$,

19.910	22.803	2.893	1077.2	175.895	0.1599	8.6755
19.367	22.735	3.368	1077.3	175.711	0.1597	10.1096
19.555	23.634	4.079	1076.4	175.983	0.1600	12.2357

Mean 175.863 0.1599

$t_1=1120°$,

21.315	25.757	4.442	1094.2	178.605	0.1595	13.1466
19.932	22.946	3.014	1097.1	178.311	0.1592	8.9135
20.456	23.943	3.487	1096.1	178.614	0.1595	10.3021

Mean 178.510 0.1594

$t_1=1130°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.465	25.608	4.143	1104.4	180.412	0.1597	12.1340
20.734	24.624	3.890	1105.4	179.893	0.1592	11.4166
19.836	22.730	2.894	1107.3	179.731	0.1591	8.4871

Mean 180.012 0.1593

$t_1=1180°$,

19.326	23.868	4.542	1156.1	192.902	0.1635	12.4110
20.069	23.112	3.043	1156.9	192.775	0.1634	8.3174

Mean 192.831 0.1634

$t_1=1250°$,

19.417	24.307	4.890	1225.7	214.035	0.1712	12 0351
20.066	23.670	3.604	1226.3	214.125	0.1713	8.8610

Mean 214.080 0.1713

$t_1=1300°$,

21.132	25.201	5.069	1273.8	232.947	0.1792	11.4711
19.681	22.774	3.093	1277.2	233.704	0.1798	6.9566
20.976	23.339	2.363	1276.7	233.017	0.1792	5.3327

Mean 233.182 0.1794

$t_1=1350°$,

19.126	24.287	5.161	1325.7	254.336	0.1884	10.6717
19.363	23.595	4.232	1326.4	254.711	0.1887	8.7351
19.518	23.491	3.971	1326.5	254.174	0.1883	8.2162

Mean 254.291 0.1885

$t_1=1420°$,

21.608	26.394	4.786	1393.6	285.236	0.2009	8.8312
19.216	23.218	4.002	1396.8	285.312	0.2009	7.3657

Mean 285.274 0.2009

$t_1=1450°$,

21.608	26.436	4.828	1423.6	290.892	0.2006	8.7312
18.659	22.888	4.229	1427.1	290.755	0.2005	7.6324
20.311	23.567	3.256	1426.4	290.861	0.2006	5.8777

Mean 290.836 0.2006

$t_1=1500°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.312	24.409	4.097	1475.6	300.117	0.2001	7.1672
19.515	22.564	3.049	1477.4	300.423	0.2003	5.3213

Mean 300.270 0.2002

No. 12 (1.85% C).

$t_1=600°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.241	23.204	1.963	576.8	83.912	0.1399	12.5671
22.068	23.886	1.818	576.1	83.721	0.1395	11.6815

Mean 83.817 0.1397

$t_1=700°$,

20.167	22.634	2.467	677.4	102.956	0.1471	12.7897
22.075	24.128	2.053	675.9	102.876	0.1470	10.6765

Mean 102.916 0.1470

$t_1=800°$,

21.654	24.800	3.146	775.2	124.818	0.1560	13.4344
21.453	23.827	2.374	776.2	124.984	0.1562	10.1128

Mean 124.901 0.1561

$t_1=900°$,

21.262	24.381	3.119	875.6	140.751	0.1564	11.7655
22.168	24.916	2.748	875.1	141.153	0.1568	10.3401

Mean 140.952 0.1566

$t_1=1000°$,

23.361	27.365	4.004	972.6	157.312	0.1573	13.5167
25.100	28.095	2.995	971.9	157.568	0.1576	10.1011

Mean 157.440 0.1574

$t_1=1100°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.898 19.655	26.260 23.153	4.362 3.498	1073.7 1076.9	174.418 174.108	0.1586 0.1583	13.2344 10.5987

Mean 174.263 0.1584

$t_1=1150°$,

21.336 19.467 20.108	26.066 22.679 23.964	4.730 3.212 3.856	1123.9 1127.3 1176.0	189.127 188.765 189.111	0.1645 0.1641 0.1644	13.2161 8.9651 10.7566

Mean 189.001 0.1644

$t_1=1200°$,

21.343 19.714	25.853 23.630	4.510 3.916	1174.2 1176.4	204.333 204.669	0.1703 0.1706	11.6513 10.0811

Mean 204.501 0.1704

$t_1=1300°$,

21.162 20.465 20.066	25.759 24.212 23.805	4.597 3.747 3.739	1274.2 1275.8 1276.2	241.503 241.022 241.537	0.1858 0.1854 0.1858	10.0303 8.1822 8.1443

Mean 241.354 0.1857

$t_1=1350°$,

21.501 21.464	25.709 26.101	4.208 4.637	1324.2 1323.9	264.801 265.005	0.1962 0.1963	8.3663 9.2155

Mean 264.903 0.1962

$t_1=1400°$,

19.981 20.478	24.347 24.159	4.366 3.681	1375.7 1375.8	282.148 281.714	0.2015 0.2012	8.1332 6.8669

Mean 281.931 0.2014

$t_1=1500°$,

20.367 19.168	24.176 22.502	3.809 3.334	1475.8 1477.5	300.414 300.686	0.2003 0.2005	6.6562 5.8133

Mean 300.550 0.2004

No. 13 (2.40% C).

$t_1=600°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.268	23.218	1.950	576.8	84.401	0.1407	12.4155
22.010	23.706	1.696	576.3	84.342	0.1406	10.8122

Mean 84.372 0.1406

$t_1=700°$,

21.465	23.914	2.449	676.1	103.302	0.1476	12.6791
20.368	22.428	2.060	677.6	103.184	0.1474	10.6544

Mean 103.243 0.1475

$t_1=800°$,

20.194	24.134	3.220	775.9	124.918	0.1562	13.7260
21.011	23.505	2.494	776.5	124.644	0.1558	10.6477

Mean 124.781 0.1560

$t_1=900°$,

22.634	26.177	3.543	873.8	140.515	0.1561	13.4122
19.925	22.307	2.382	877.7	140.707	0.1563	8.9655

Mean 140.611 0.1562

$t_1=1000°$,

22.475	25.555	3.080	974.5	156.890	0.1569	10.4056
21.334	24.432	3.098	975.6	157.050	0.1571	10.4422

Mean 156.970 0.1570

$t_1=1100°$,

27.504	30.359	2.855	1069.6	173.410	0.1577	8.7444
20.223	23.917	3.694	1076.1	173.896	0.1581	11.2151

Mean 173.653 0.1579

$t_1=1150°$,

24.425	27.378	2.953	1122.6	201.010	0.1748	7.7725
22.086	25.452	3.366	1124.6	201.236	0.1750	8.8344

Mean 201.123 0.1749

$t_1=1200°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal.	M.S.H.	Weight
		t_2-t_0	t_1-t_2	$q(t_1-0)$	(t_1-t_2)	(gram)
20.811	24.025	3.214	1176.0	217.608	0.1813	7.7855
22.634	26.280	3.646	1173.7	217.718	0.1814	8.8424
19.436	22.178	2.742	1177.8	217.426	0.1812	6.6361
			Mean	217.584	0.1813	

$t_1=1250°$,

21.666	25.319	3.653	1224.7	235.766	0.1886	8.1677
19.814	22.809	2.995	1227.2	235.836	0.1887	6.6812
			Mean	235.801	0.1886	

$t_1=1300°$,

20.656	24.761	4.105	1275.2	256.899	0.1976	8.4126
19.337	22.532	3.195	1277.5	257.141	0.1978	6.5311
			Mean	257.020	0.1977	

$t_1=1350°$,

23.347	26.864	3.517	1323.1	273.914	0.2029	6.7655
20.066	23.161	3.095	1326.8	274.194	0.2031	5.9313
			Mean	274.054	0.2030	

$t_1=1400°$,

20.583	25.126	4.543	1374.9	283.013	0.2022	8.4427
19.676	23.385	3.709	1376.6	283.413	0.2024	6.8750
			Mean	283.213	0.2023	

$t_1=1450°$,

21.374	25.473	4.099	1424.5	292.634	0.2018	7.3642
20.867	24.465	3.598	1425.5	292.448	0.2017	6.4631
			Mean	292.541	0.2018	

No. 14 (2.90% C).

$t_1=600°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal.	M.S.H.	Weight
		t_2-t_0	t_1-t_2	$q(t_1-0)$	(t_1-t_2)	(gram)
21.216	23.135	1.919	576.9	85.078	0.1418	12.1144
20.137	21.853	1.716	578.2	85.021	0.1417	10.8165
			Mean	85.050	0.1418	

$t_1=700°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.026	24.309	2.283	675.7	103.921	0.1485	11.7533
19.981	21.981	2.000	678.0	104.105	0.1487	10.2466

Mean 104.013 0.1486

$t_1=800°$,

24.446	27.309	2.863	772.7	125.010	0.1563	12.2467
22.237	24.731	2.494	775.3	125.350	0.1567	10.6034

Mean 125.180 0.1565

$t_1=900°$,

23.464	26.503	3.039	873.5	140.939	0.1566	11.4747
22.890	25.258	2.368	874.7	140.763	0.1564	8.9416

Mean 140.851 0.1565

$t_1=1000°$,

22.426	26.463	4.037	973.5	156.633	0.1566	13.6732
24.647	27.648	3.001	972.4	156.833	0.1568	10.1633

Mean 156.733 0.1567

$t_1=1100°$,

22.467	26.570	4.103	1073.4	173.001	0.1573	12.5531
26.842	29.398	2.556	1070.6	173.613	0.1578	7.8132

Mean 173.312 0.1576

$t_1=1150°$,

23.414	27.999	4.585	1122.0	212.631	0.1849	11.4161
22.686	26.049	3.363	1124.0	212.983	0.1852	8.3450
20.810	23.924	3.114	1126.1	212.918	0.1852	7.7143

Mean 212.844 0.1851

$t_1=1200°$,

23.444	27.820	4.376	1172.2	229.878	0.1916	10.0661
25.661	28.255	2.594	1171.8	230.130	0.1918	5.9632
21.479	25.307	3.828	1174.7	230.412	0.1920	8.7657

Mean 230.140 0.1918

$t_1=1250°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
24.678	29.099	4.421	1220.9	249.711	0.1998	9.3614
22.777	25.598	2.821	1224.4	248.866	0.1991	5.9766
23.358	26.659	3.301	1223.3	249.716	0.1998	6.9775
			Mean	249.431	0.1996	

$t_1=1300°$,

22.626	26.989	4.363	1273.0	266.330	0.2049	8.6411
21.645	24.587	2.942	1275.4	266.472	0.2050	5.8116
			Mean	266.401	0.2049	

$t_1=1400°$,

23.745	28.153	4.408	1371.9	284.311	0.2031	8.1717
23.101	26.422	3.321	1373.6	284.469	0.2032	6.1464
			Mean	284.390	0.2031	

$t_1=1500°$,

20.416	24.780	4.264	1475.2	302.288	0.2015	7.5811
22.681	25.759	3.078	1474.2	302.654	0.2018	5.3446
			Mean	302.471	0.2017	

No. 15 (3.00% C).

$t_1=600°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.268	24.072	1.804	576.0	85.010	0.1417	11.4166
22.104	23.831	1.727	576·2	85.096	0.1418	10.9175
			Mean	85.053	0.1418	

$t_1=700°$,

21.268	23.530	2.262	676.5	103.950	0.1485	11.6711
21.427	23.484	2.067	676.5	104.062	0.1487	10.6176
			Mean	104.006	0.1486	

$t_1=800°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
25.424	28.834	3.410	771.2	125.010	0.1563	14.6142
24.375	26.871	2.496	773.1	125.432	0.1568	10.6366

Mean 125.221 0.1565

$t_1=900°$,

22.641	26.534	3.893	873.5	139.810	0.1553	14.8196
24.321	27.178	2.857	872.8	140.058	0.1556	10.8641

Mean 139.934 0.1555

$t_1=1000°$,

26.364	27.510	4.146	972.5	156.781	0.1568	14.0444
26.412	29.481	3.069	970.5	157.039	0.1570	10.4012

Mean 156.910 0.1564

$t_1=1100°$,

21.617	25.798	4.181	1074.2	173.166	0.1574	12.7716
26.446	30.121	3.675	1069.9	173.736	0.1579	11.2334

Mean 173.451 0.1577

$t_1=1150°$,

21.646	25.591	3.945	1124.4	214.311	0.1864	9.7233
22.472	24.657	2.185	1125.3	214.898	0.1868	5.3669
23.436	26.202	2.766	1123.8	214.477	0.1865	6.8166

Mean 214.562 0.1866

$t_1=1200°$,

21.324	25.226	3.902	1174.8	232.287	0.1936	8.8633
22.647	25.959	3.312	1174.0	231.716	0.1931	7.5467
19.962	22.419	2.457	1177.6	232.456	0.1937	5.5622

Mean 232.153 0.1935

$t_1=1250°$,

20.891	25.751	4.860	1224.3	252.115	0.2017	10.1667
20.277	23.039	2.762	1227.0	252.178	0.2017	5.7623
22.424	26.374	3.950	1223.6	252.760	0.2022	8.2465

Mean 252.351 0.2019

$t_1=1300°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
23.235 24.126	27.094 26.882	3.859 2.756	1272.9 1273.1	266.632 266.912	0.2051 0.2053	7.6347 5.4466

Mean 266.772 0.2052

$t_1=1400°$,

23.423 22.789	27.681 25.482	4.258 2.693	1372.3 1374.5	284.588 284.860	0.2033 0.2035	7.8838 4.9735

Mean 284.724 0.2034

$t_1=1500°$,

24.863 23.347	29.268 26.714	4.405 3.367	1470.7 1473.3	302.591 302.909	0.2017 0.2019	7.6678 5.8458

Mean 302.750 0.2018

No. 16 (3.50% C).

$t_1=600°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.467 22.518	23.447 24.151	1.980 1.633	576.6 577.9	85.720 85.902	0.1429 0.1432	12.4179 10.2324

Mean 85.811 0.1430

$t_1=700°$,

22.417 23.121	24.702 25.139	2.285 2.018	675.3 674.9	104.652 104.853	0.1495 0.1498	11.6914 10.3134

Mean 104.753 0.1497

$t_1=800°$,

25.582 23.682	28.805 26.303	3.223 2.621	771.2 773.7	125.003 125.401	0.1563 0.1568	13.8165 11.1637

Mean 125.202 0.1565

$t_1=900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.412	24.783	3.371	875.2	140.821	0.1565	12.7133
19.382	21.758	2.376	878.2	141.045	0.1567	8.9166

Mean 140.933 0.1566

$t_1=1000°$,

18.915	22.233	3.318	977.8	157.060	0.1571	11.1611
19.824	22.734	2.910	977.3	157.440	0.1574	9.7688

Mean 157.250 0.1573

$t_1=1100°$,

19.411	22.252	2.841	1077.8	173.901	0.1581	8.6133
21.471	24.059	2.588	1075.9	173.661	0.1579	7.8683

Mean 173.781 0.1580

$t_1=1150°$,

23.517	27.717	4.200	1122.3	226.751	0.1972	9.8033
20.617	23.775	3.158	1126.2	226.133	0.1966	7.3651

Mean 226.442 0.1969

$t_1=1200°$,

24.413	28.472	4.059	1171.5	245.011	0.2042	8.7643
22.636	25.780	3.144	1174.2	245.595	0.2047	6.7564

Mean 245.303 0.2044

$t_1=1300°$,

23.267	27.052	3.785	1275.0	267.508	0.2058	7.4641
21.415	24.627	3.212	1275.4	267.894	0.2061	6.3133

Mean 267.701 0.2059

$t_1=1400°$,

22.603	26.294	3.691	1373.7	285.007	0.2036	6.8166
23.415	26.747	3.332	1373.3	285.613	0.2040	6.1436

Mean 285.310 0.2038

No. 17 (4.30% C).

t_1=500°,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.201	21.779	1.578	478.2	68.615	0.1372	12.4177
20.417	21.664	1.247	478.3	68.315	0.1366	9.8551
			Mean	68.465	0.1369	

t_1=600°,

19.871	21.689	1.818	578.3	86.722	0.1445	11.2362
20.643	22.280	1.637	577.7	86.886	0.1448	10.1044
			Mean	86.804	0.1447	

t_1=700°,

21.126	23.200	2.074	676.8	105.861	0.1512	10.4658
19.722	21.448	1.726	678.6	106.063	0.1515	8.6717
			Mean	105.962	0.1514	

t_1=800°,

23.616	26.996	3.380	773.0	125.306	0.1566	14.4176
22.425	24.839	2.414	755.2	125.596	0.1570	10.2455
			Mean	125.451	0.1568	

t_1=900°,

21.417	25.243	3.826	874.8	141.013	0.1567	14.4167
22.978	25.077	2.099	874.9	141.489	0.1572	7.8819
19.785	22.166	2.381	877.8	141.887	0.1577	8.8875
			Mean	141.463	0.1572	

t_1=1000°,

23.244	27.023	3.779	973.0	157.781	0.1578	12.7155
21.641	25.053	3.412	975.0	157.903	0.1579	11.4485
			Mean	157.842	0.1578	

t_1=1100°,

20.818	24.487	3.669	1075.5	174.512	0.1587	11.1047
22.121	25.084	2.963	1074.9	174.297	0.1585	8.9855
19.766	22.226	2.460	1077.8	174.931	0.1590	7.4144
			Mean	174.580	0.1587	

$t_1 = 1150°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
21.422	25.403	3.981	1124.6	242.110	0.2105	8.6857
22.113	26.896	4.783	1123.1	242.913	0.2112	10.4144
19.344	22.365	3.021	1127.6	242.511	0.2109	6.5611

Mean 242.511 0.2109

$t_1 = 1170°$,

22.255	27.686	5.431	1142.3	245.890	0.2100	11.6851
24.386	28.890	4.504	1141.1	245.459	0.2098	9.7183
21.646	26.465	4.819	1143.5	246.870	0.2110	10.3156

Mean 246.073 0.2103

$t_1 = 1200°$,

21.506	26.134	4.628	1173.9	250.848	0.2090	9.7411
24.246	28.420	4.174	1171.6	251.945	0.2100	8.7655
22.036	25.045	3.009	1175.0	251.413	0.2095	6.3131

Mean 251.402 0.2095

$t_1 = 1300°$,

21.468	25.379	3.911	1274.6	269.033	0.2070	7.6571
22.046	24.830	2.784	1275.2	269.710	0.2075	5.4355
20.027	22.493	2.466	1277.5	268.911	0.2069	4.8193

Mean 269.218 0.2071

$t_1 = 1400°$,

22.446	27.294	4.848	1372.7	287.724	0.2055	8.8755
24.512	27.854	3.342	1372.2	287.144	0.2051	6.1344

Mean 287.434 0.2053

No. 18 (4.81% C).

$t_1 = 100°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
22.168	22.402	0.234	77.6	13.445	0.1345	11.5871
20.196	20.458	0.262	79.5	13.426	0.1343	12.6917

Mean 13.436 0.1344

$t_1=140°$,

Initial temp.	Final temp.	Difference		Total cal.	M.S.H.	Weight
(t_0)	(t_2)	t_2-t_0	t_1-t_2	$q(t_1-0)$	(t_1-t_2)	(gram)
25.417	25.801	0.284	114.2	18.320	0.1309	13.2611
26.132	26.446	0.314	113.6	18.312	0.1308	10.9123
			Mean	18.316	0.1308	

$t_1=180°$,

24.818	25.351	0.533	154.7	24.353	0.1535	13.1461
26.414	26.870	0.454	153.1	24.437	0.1358	11.2677
			Mean	24.395	0.1355	

$t_1=200°$,

27.104	27.752	0.648	172.3	28.413	0.1421	13.6812
24.377	24.916	0.539	175.1	28.491	0.1425	11.1556
			Mean	28.452	0.1423	

$t_1=220°$,

26.617	27.353	0.736	192.7	32.205	0.1464	13.4715
24.315	24.906	0.736	195.1	32.345	0.1470	10.6481
			Mean	32.275	0.1467	

$t_1=240°$,

24.131	24.849	0.718	215.2	35.316	0.1472	11.7194
23.515	24.170	0.655	215.8	35.546	0.1481	10.5781
			Mean	35.431	0.1477	

$t_1=260°$,

23.714	24.514	0.800	235.5	38.623	0.1486	11.8191
25.911	26.623	0.712	233.4	38.727	0.1490	10.5775
			Mean	38.675	0.1488	

$t_1=280°$,

23.617	24.458	0.841	255.5	40.866	0.1460	11.6455
24.648	25.592	0.944	254.4	40.884	0.1460	13.1312
			Mean	40.875	0.1460	

$t_1=300°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
27.711 26.786	28.461 27.338	0.750 0.552	271.5 272.7	43.595 43.755	0.1453 0.1459	9.8210 7.1647

Mean 43.675 0.1456

$t_1=400°$,

29.024 28.987	29.929 29.864	0.905 0.877	370.1 370.1	56.834 56.916	0.1421 0.1423	8.8880 8.6018

Mean 56.875 0.1422

$t_1=500°$,

29.228 29.529	30.477 30.617	1.249 1.088	469.5 469.4	69.950 69.025	0.1399 0.1381	9.8210 8.6720

Mean 69.488 0.1390

$t_1=600°$,

22.417 22.333	24.431 24.044	2.014 1.711	575.6 576.0	86.933 86.688	0.1449 0.1445	12.4775 10.6178

Mean 86.811 0.1447

$t_1=700°$,

26.531 24.448	28.783 26.171	2.252 1.723	671.2 673.8	106.925 106.122	0.1528 0.1516	11.3465 8.7111

Mean 106.524 0.1522

$t_1=730°$,

25.412 23.636	28.628 26.067	3.216 2.431	701.4 703.9	114.021 114.682	0.1562 0.1571	15.1618 11.3617

Mean 114.352 0.1567

$t_1=740°$,

24.143 22.618	27.259 25.292	3.116 2.674	712.7 714.7	115.893 116.107	0.1566 0.1569	14.4162 12.3175

Mean 116.000 0.1568

$t_1=760°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
26.714	30.166	3.452	729.8	118.758	0.1563	15.6344
24.313	27.209	2.896	732.8	118.382	0.1558	13.1044
			Mean	118.570	0.1560	

$t_1=800°$,

23.514	26.733	3.219	773.3	126.334	0.1580	13.6145
23.678	26.247	2.569	773.8	126.046	0.1576	10.8822
			Mean	126.160	0.1577	

$t_1=900°$,

24.668	28.064	3.396	871.9	142.103	0.1579	12.7425
24.549	27.661	3.112	872.3	142.321	0.1581	11.6511
			Mean	142.212	0.1580	

$t_1=1000°$,

25.313	29.110	3.797	970.9	158.812	0.1588	12.7195
22.516	25.774	3.258	974.2	158.970	0.1590	10.8644
			Mean	158.891	0.1589	

$t_1=1100°$,

26.611	29.544	2.933	1070.5	175.583	0.1596	8.8674
24.310	27.455	3.145	1072.6	175.757	0.1598	9.4786
			Mean	175.670	0.1597	

$t_1=1150°$,

25.552	30.265	4.715	1119.7	231.036	0.2009	10.8211
23.981	27.239	3.258	1122.8	230.611	0.2005	7.4733
21.477	25.055	3.578	1125.0	230.972	0.2009	8.1795
			Mean	230.873	0.2008	

$t_1=1200°$,

22.867	27.478	4.609	1172.5	245.701	0.2048	9.9164
24.682	27.879	3.197	1172.1	245.104	0.2043	6.8975
21.564	25.178	3.614	1174.8	245.317	0.2044	7.7717
			Mean	245.374	0.2045	

$t_1 = 1300°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
20.603	25.505	4.902	1274.5	270.766	0.2083	9.5381
20.587	24.582	3.995	1275.4	270.856	0.2084	7.7652

Mean 270.811 0.2083

$t_1 = 1400°$,

19.947	24.580	4.633	1375.4	288.304	0.2059	8.4477
21.336	25.056	3.720	1374.9	288.536	0.2061	6.7811

Mean 288.420 0.2060

$t_1 = 1500°$,

22.316	26.582	4.266	1473.4	306.007	0.2040	7.3310
20.755	24.696	3.941	1475.3	306.397	0.2043	6.7553

Mean 306.202 0.2041

No. 19 (5.07 % C).

$t_1 = 900°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference		Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
		t_2-t_0	t_1-t_2			
16.832	19.181	2.349	880.8	141.471	0.1572	8.7614
16.514	18.807	2.293	881.2	141.791	0.1576	8.5311

Mean 141.631 0.1574

$t_1 = 1000°$,

19.211	22.549	3.338	977.5	158.211	0.1582	11.1477
19.430	22.455	3.025	977.6	158.735	0.1587	10.0691

Mean 158.473 0.1585

$t_1 = 1100°$,

16.143	20.525	4.382	1079.5	175.108	0.1592	13.1711
16.812	19.736	2.924	1080.3	175.903	0.1599	8.7433
15.171	18.546	3.375	1081.5	175.495	0.1595	10.1048

Mean 175.502 0.1596

$t_1=1150°$,

Initial temp. (t_0)	Final temp. (t_2)	Difference t_2-t_0	Difference t_1-t_2	Total cal. $q(t_1-0)$	M.S.H. (t_1-t_2)	Weight (gram)
15.341	20.355	5.014	1129.7	224.268	0.1950	11.7556
18.614	22.012	2.398	1128.0	225.173	0.1958	7.9471
16.371	20.795	4.424	1129.2	224.869	0.1955	10.3475
			Mean	224.770	0.1955	

$t_1=1200°$,

16.314	22.032	5.718	1178.0	237.415	0.1979	12.6710
16.632	20.304	3.672	1179.7	237.972	0.1983	8.1080
17.565	20.946	3.381	1179.1	237.725	0.1981	7.4775
			Mean	237.704	0.1981	

$t_1=1250°$,

16.814	22.206	5.392	1227.8	252.948	0.2024	11.2100
16.217	19.886	3.669	1230.1	252.166	0.2017	7.6371
17.518	20.871	3.353	1229.1	252.569	0.2021	6.9724
			Mean	522.561	0.2021	

$t_1=1350°$,

16.147	20.990	4.843	1329.0	279.108	0.2068	9.1040
16.817	19.950	3.133	1330.1	280.211	0.2076	5.8622
15.765	18.609	2.844	1331.4	280.300	0.2076	5.3144
			Mean	279.873	0.2073	

$t_1=1400°$,

16.354	20.993	4.639	1379.0	286.612	0.2047	8.4871
17.103	20.638	3.535	1379.4	288.104	0.2058	6.4325
16.827	20.729	3.902	1379.3	287.934	0.2057	7.1044
			Mean	287.550	0.2054	

$t_1=1500°$,

16.217	21.513	5.296	1478.5	306.104	0.2041	9.0655
15.564	18.900	3.336	1481.1	307.206	0.2048	5.6812
16.101	19.802	3.701	1480.2	306.289	0.2042	6.3241
			Mean	306.533	0.2044	

Each specimen thus measured contains also a certain amount of martensite corresponding to the temperature heated and its carbon percentage. Therefore, in order to obtain true results corresponding to the equilibrium diagram of iron-carbon system, these numerical data must be corrected for the heat of transformation martensite → pearlite.

As to the heat of transformation from martensite to pearlite, Prof. K. Honda(13) first made the measurement with 0.8% carbon steel. Afterwards, the present writer(14) obtained the heats of transformation, austenite → martensite and martensite → pearlite, with four kinds of carbon steels of 0.28, 0.61, 0.79 and 1.57 percent carbon by the same method. By adopting these values he made the correction by means of the iron-carbon diagram, and obtained the true specific heat at each temperature from the difference in the corrected heat content before and after the observed points. The corrected numerical values are shown in Table 2.

Table 2.

No. 1 (0.07% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	147.612	148.51	0.1650	0.159
1000	161.13	161.83	0.1618	0.161
1100	177.743	178.44	0.1622	0.164
1200	194.804	195.50	0.1629	0.167
1300	211.950	212.65	0.1636	0.171
1400	299.549	230.25	0.1645	0.177
1450	238.302	239.00	0.1648	——
1480	246.321	247.02	0.1669	——
1500	256.582	257.60	0.1717	——
1515	282.073	283.51	0.1871	——
1540	322.070	323.17	0.2099	0.192_6
1570	327.734	328.83	0.2095	0.192_6

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(13) Sci. Rep., 8 (1919), 197.

(14) Sci. Rep., l. c.

No. 2 (0.11% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	147.521	148.62	0.1651	0.159
1000	161.442	162.54	0.1625	0.160
1100	177.433	178.53	0.1623	0.163
1200	194.417	195.52	0.1629	0.166
1300	211.728	212.83	0.1637	0.171
1400	229.822	230.92	0.1649	0.175
1450	238.907	240.01	0.1655	——
1480	245.002	246.10	0.1663	——
1490	256.378	259.72	0.1743	——
1500	271.790	269.55	0.1797	——
1510	289.851	291.02	0.1927	——
1540	321.372	323.17	0.2099	0.192_5
1570	327.080	328.88	0.2095	0.192_5

No. 3 (0.13% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	147.352	148.75	0.1653	0.159
1000	161.067	162.47	0.1625	0.160
1100	177.842	179.24	0.1630	0.163
1200	194.332	195.73	0.1631	0.166
1300	211.641	213.04	0.1639	0.171
1400	229.852	231.25	0.1652	0.175
1460	240.717	242.12	0.1658	——
1487	259.324	261.72	0.1760	——
1490	263.311	265.00	0.1779	——
1500	274.620	276.46	0.1843	——
1510	300.723	302.57	0.2004	——
1540	320.764	323.16	0.2098	0.192_4
1570	326.490	328.89	0.2095	0.192_4

No. 4 (0.19% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	146.834	148.83	0.1654	0.158
1000	160.509	162.51	0.1625	0.159
1100	177.607	179.61	0.1633	0.162
1200	194.311	196.31	0.1636	0.165

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
1300	212.052	214.05	0.1647	0.170
1400	229.651	231.65	0.1655	0.175
1450	238.653	240.65	0.1660	——
1470	244.921	247.01	0.1680	——
1480	252.818	255.32	0.1725	——
1490	277.151	280.33	0.1881	——
1500	292.520	295.80	0.1972	——
1520	316.072	319.27	0.2101	0.192_2
1540	319.753	322.95	0.2087	0.192_2
1560	323.710	326.91	0.2096	0.192_2

No. 5 (0.30% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	145.874	149.17	0.1657	0.157
1100	176.462	179.76	0.1634	0.161
1200	192.760	196.06	0.1634	0.164
1300	210.721	214.02	0.1646	0.169
1400	229.473	232.77	0.1663	0.175
1440	240.032	243.46	0.1691	——
1460	251.215	255.27	0.1748	——
1480	271.663	276.34	0.1867	——
1487	294.930	299.64	0.2015	——
1490	300.383	306.53	0.2057	——
1520	313.324	319.47	0.2102	0.191_9
1560	320.832	326.98	0.2093	0.191_9

No. 6 (0.41% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	144.613	149.21	0.1658	0.156
1000	175.434	180.03	0.1637	0.160
1200	192.020	196.62	0.1639	0.165
1300	209.891	214.49	0.1650	0.171
1370	222.882	227.48	0.1660	0.176
1420	238.721	243.30	0.1713	——
1450	253.430	259.33	0.1789	——
1470	274.853	281.59	0.1916	——
1500	307.853	315.15	0.2101	0.191_5
1560	318.901	326.20	0.2091	0.191_5

No. 7 (0.61% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	144.461	149.36	0.1660	0.153
1000	157.732	164.63	0.1646	0.155
1100	176.800	180.46	0.1641	0.158
1200	191.313	198.11	0.1651	0.163
1300	209.242	216.04	0.1662	0.170
1350	220.324	226.87	0.1681	——
1400	238.640	244.80	0.1749	——
1450	272.051	279.85	0.1930	——
1460	282.132	292.54	0.2004	——
1500	304.164	315.06	0.2100	0.191
1560	315.794	326.20	0.2091	0.191

No. 8 (0.77% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	140.922	149.62	0.1662	0.152
1000	156.024	164.72	0.1647	0.155
1100	171.850	181.05	0.1646	0.158
1200	188.353	197.55	0.1646	0.165
1250	197.341	206.53	0.1652	0.167
1320	215.214	222.31	0.1684	——
1350	224.266	231.16	0.1712	——
1400	245.435	252.90	0.1806	——
1430	263.252	273.03	0.1909	——
1470	295.621	309.42	0.2105	0.190_5
1500	301.230	315.03	0.2100	0.190_5
1540	308.622	322.42	0.2094	0.190_5

No. 9 (1.05% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
800	124.311	133.92	0.1674	0.180
850	133.306	143.95	0.1694	0.212
900	143.010	152.98	0.1700	0.150
950	149.703	159.60	0.1648	0.152
1000	157.332	167.23	0.1672	0.155
1100	172.360	182.21	0.1657	0.160
1170	183.856	193.72	0.1656	0.164

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
1200	188.494	198.41	0.1653	0.165
1250	201.067	211.23	0.1690	—
1300	217.341	225.90	0.1738	—
1350	235.901	243.94	0.1807	—
1400	258.820	268.65	0.1919	—
1430	283.232	296.77	0.2075	—
1450	289.833	305.53	0.2107	0.189_6
1500	299.201	314.90	0.2099	0.189_6
1540	306.474	322.17	0.2092	0.189_6

No. 10 (1.33% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
800	125.070	133.91	0.1674	0.147
900	140.812	149.68	0.1663	0.175
950	149.433	158.85	0.1672	0.198
1000	160.112	169.51	0.1695	0.227
1050	166.915	176.31	0.1679	0.156
1100	174.210	183.52	0.1668	0.159
1150	181.633	191.03	0.1661	0.162
1200	193.771	203.45	0.1695	—
1250	207.430	217.52	0.1740	—
1300	225.531	234.50	0.1804	—
1350	245.631	254.79	0.1887	—
1400	270.880	283.10	0.2022	—
1450	290.563	305.46	0.2107	0.188_8
1500	299.712	314.61	0.2097	0.188_8
1540	307.312	322.21	0.2092	0.188_8

No. 11 (1.57% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
800	125.761	133.90	0.1674	0.145
900	141.093	149.41	0.1660	0.157
1000	157.506	166.25	0.1663	0.181
1050	166.352	175.37	0.1670	0.196
1080	172.816	181.55	0.1681	0.209
1100	175.863	184.65	0.1679	0.158
1120	178.510	187.48	0.1674	0.169
1130	180.012	188.99	0.1672	0.161

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
1180	192.831	202.21	0.1714	——
1250	214.080	224.12	0.1793	——
1300	233.182	242.53	0.1866	——
1350	254.291	264.45	0.1959	——
1420	285.274	299.47	0.2109	0.188_1
1450	290.836	305.03	0.2104	0.188_1
1500	300.270	314.47	0.2097	0.188_1

No. 12 (1.85% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
600	83.817	83.817	0.1397	——
700	102.916	102.916	0.1470	——
800	124.901	133.40	0.1668	0.152
900	140.952	149.42	0.1660	0.156
1000	157.440	165.91	0.1659	0.162
1100	174.263	182.67	0.1661	0.171
1150	189.001	197.83	0.1720	——
1200	204.501	213.89	0.1782	——
1300	241.354	251.15	0.1932	——
1350	264.903	276.20	0.2046	——
1400	281.931	295.43	0.2110	0.187_3
1500	300.550	314.05	0.2094	0.187_3

No. 13 (2.40% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
600	84.372	84.372	0.1406	——
700	103.243	103.243	0.1475	——
800	124.781	132.33	0.1654	0.153
900	140.611	148.12	0.1646	0.157
1000	156.970	164.48	0.1645	0.163
1100	173.653	181.10	0.1646	0.171
1150	201.123	209.51	0.1822	——
1200	217.584	226.64	0.1889	——
1250	235.801	245.62	0.1965	——
1300	257.020	267.67	0.2059	——
1350	274.054	285.95	0.2118	0.185_7
1400	283.213	295.11	0.2108	0.185_7
1450	292.541	304.44	0.2100	0.185_7

No. 14 (2.90% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
600	85.050	85.050	0.1418	——
700	104.013	104.013	0.1486	——
800	125.180	131.85	0.1648	0.154
900	140.851	147.25	0.1636	0.158
1000	156.733	163.37	0.1634	0.163
1100	173.312	179.90	0.1636	0.170
1150	212.844	220.83	0.1920	——
1200	230.140	238.90	0.1991	——
1250	249.431	259.11	0.2073	——
1300	266.401	276.90	0.2130	0.184_2
1400	284.390	294.89	0.2106	0.184_2
1500	302.471	312.97	0.2087	0.184_2

No. 15 (3.00% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
600	85.053	85.053	0.1418	——
700	104.006	104.006	0.1486	——
800	125.221	131.72	0.1647	0.154
900	139.934	146.40	0.1627	0.158
1000	156.910	163.37	0.1634	0.163
1100	173.451	179.87	0.1635	0.170
1150	214.562	222.47	0.1935	——
1200	232.153	241.05	0.2009	——
1250	252.351	262.00	0.2096	——
1300	266.772	276.97	0.2131	0.183_9
1400	284.724	294.92	0.2107	0.183_9
1500	302.750	312.95	0.2086	0.183_9

No. 16 (3.50% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
600	85.811	85.811	0.1430	——
700	104.753	104.753	0.1497	——
800	125.202	130.82	0.1635	0.155
900	140.933	146.51	0.1628	0.159
1000	157.250	162.83	0.1628	0.163
1100	173.781	179.32	0.1630	0.169
1150	226.442	233.96	0.2034	——
1200	245.303	253.81	0.2115	——
1250	258.864	267.66	0.2141	0.182_5
1300	267.701	276.50	0.2127	0.182_5
1400	285.310	294.11	0.2101	0.182_5

No. 17 (4.30% C),

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
500	68.465	68.465	0.1369	—
600	86.804	86.804	0.1447	—
700	105.962	105.962	0.1514	—
800	125.451	129.65	0.1621	0.157
900	141.463	145.65	0.1618	0.160
1000	157.842	162.03	0.1620	0.164
1100	174.580	178.74	0.1625	0.169
1150	242.511	249.11	0.2161	0.180_1
1170	246.073	252.67	0.2160	0.180_1
1200	251.402	258.00	0.2150	0.180_1
1300	269.218	275.82	0.2122	0.180_1
1400	287.434	294.03	0.2100	0.180_1

No. 18 (4.81% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
100	13.436	13.436	0.1344	—
140	18.316	18.316	0.1308	0.134
180	24.395	24.395	0.1355	0.173
200	28.452	28.452	0.1423	0.197
220	32.275	32.275	0.1467	0.199
240	35.431	35.431	0.1476	0.160
260	38.675	38.675	0.1488	0.127
280	40.875	40.875	0.1460	0.125
300	43.675	43.675	0.1456	0.127
400	56.875	56.875	0.1422	0.145
500	69.488	69.488	0.1390	0.160
600	86.811	86.811	0.1447	0.183
700	106.524	106.524	0.1522	0.205
730	114.352	117.310	0.1567	0.138
740	116.000	118.452	0.1568	0.151
760	118.570	121.634	0.1560	0.177
800	126.160	129.10	0.1614	0.158
900	142.212	145.13	0.1613	0.161
1000	158.891	161.80	0.1618	0.164
1100	175.670	178.56	0.1623	0.168
1150	230.873	236.00	0.2052	—
1200	245.374	250.49	0.2087	—
1300	270.811	276.01	0.2123	0.178_7
1400	288.420	293.62	0.2097	0.178_7
1500	306.202	311.40	0.2076	0.178_7

No. 19 (5.07% C).

Temp. (°C)	Obs. (Cal.)	Cor. (Cal.)	Cor. M.S.H.	T.S.H.
900	141.631	144.57	0.1606	0.161
1000	158.473	161.40	0.1614	0.164
1100	175.502	178.53	0.1623	0.168
1150	224.770	229.30	0.1994	——
1200	237.704	242.20	0.2018	——
1250	252.561	257.00	0.2056	——
1350	279.873	284.47	0.2107	0.177_9
1400	287.550	293.45	0.2096	0.177_9
1500	306.533	311.13	0.2074	0.177_9

According to the result of recent investigations, no inconsiderable amount of austenite remains untransformed in steels of high carbon content, and therefore the correction above made is not quite sufficient. This amount of the austenite depends naturally on the carbon content of the specimens and quenching temperature; but if it is known, the correction due to the retained austenite can be made exactly. As it is, however, not the case at present, this correction is left for a future occasion; but it can be concluded that the correction is atmost of the order of one percent in the case of mean specific heat and is much smaller in the case of true specific heat.

(1) Heat Content and Specific Heat.

The relation between the corrected heat content of one gram of the specimen and the temperature heated is shown in Fig. 1. While, the mean specific heat at each temperature is shown in Figs. 2 and 3, and true specific heat in Fig. 4. The heat content of cementite at each temperature is obtained by extrapolation from the curve of heat content to carbon concentration at the same temperature and is included in Fig. 1.

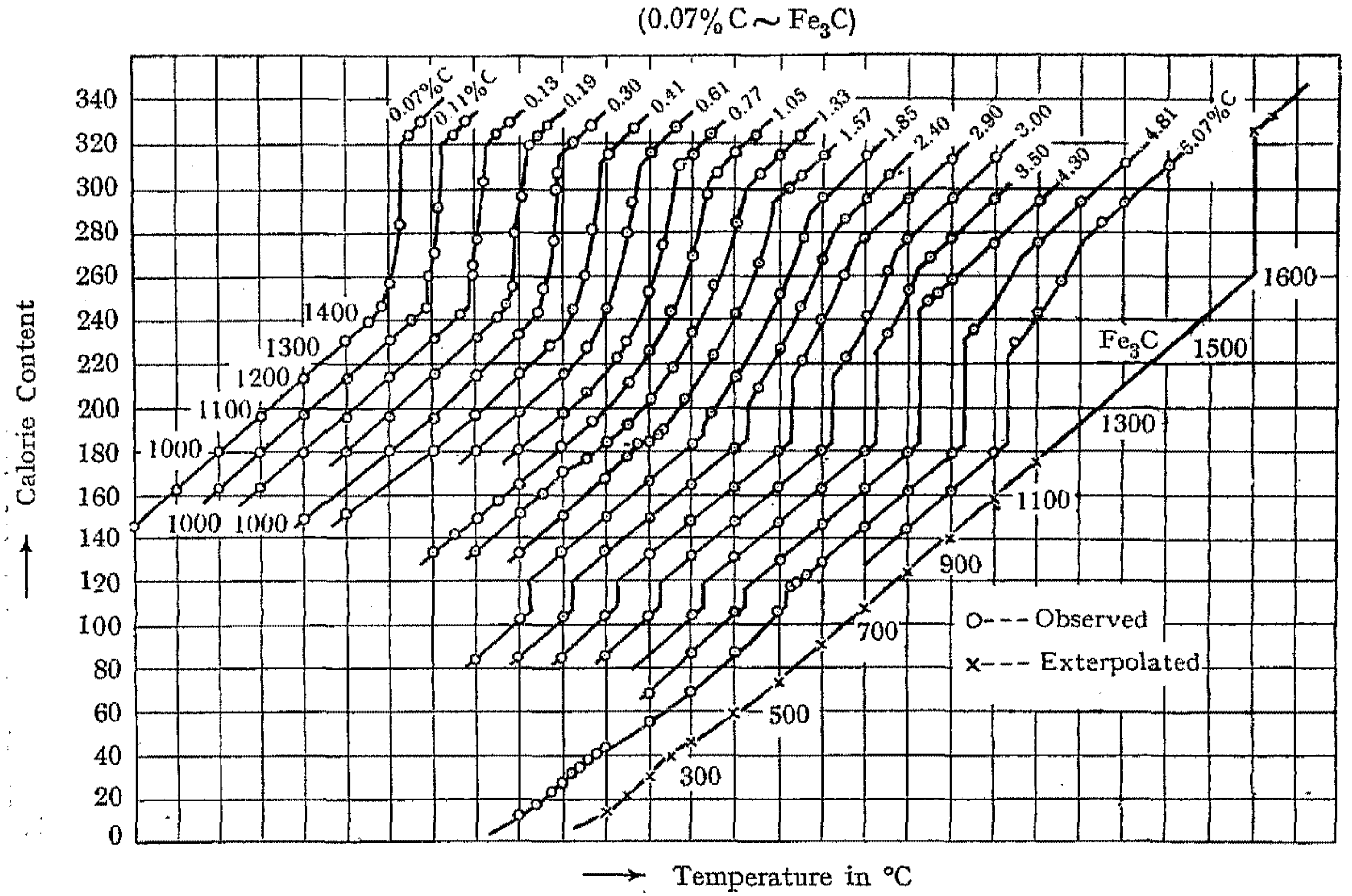
(0.07% C ~ Fe_3C)
Calorie Content
Temperature in °C
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
0.07% C
0.11% C
0.13
0.19
0.30
0.41
0.61
0.77
1.05
1.33
1.57
1.85
2.40
2.90
3.00
3.50
4.30
4.81
5.07% C
1000
1100
1200
1300
1400
1000
1000
300
500
700
900
1100
1300
1500
1600
Fe_3C
o--- Observed
x--- Exterpolated

Fig. 1.

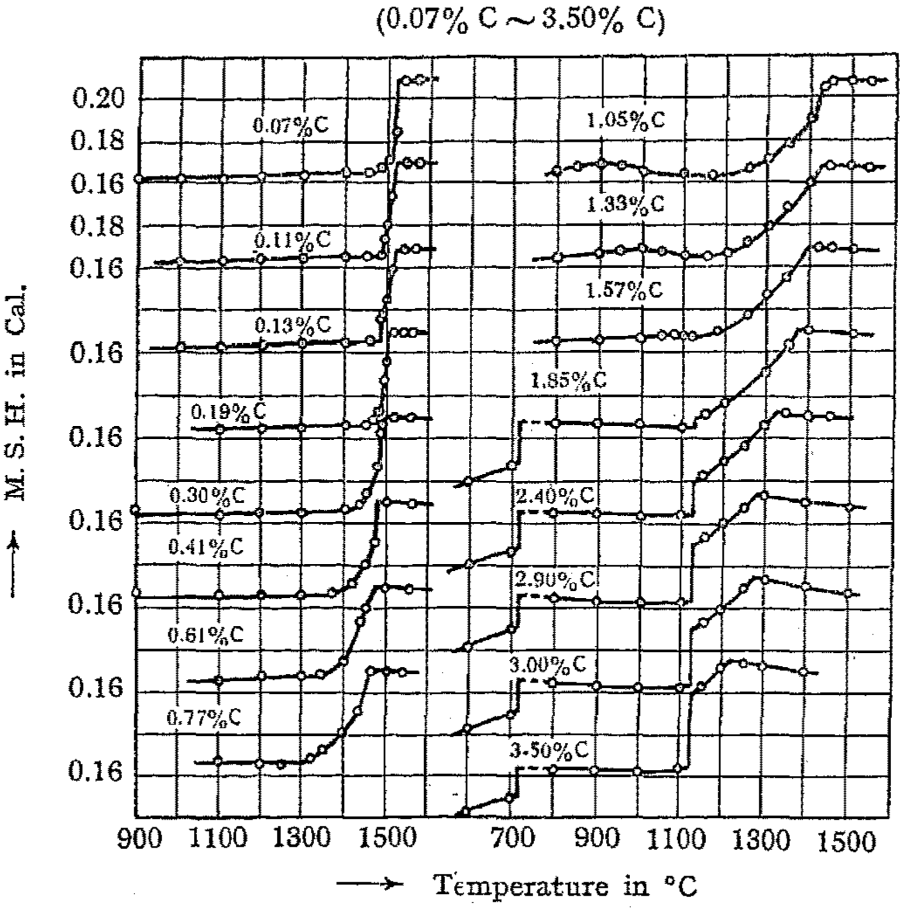
(0.07% C ~ 3.50% C)
0.20
0.18
0.16
0.18
0.16
0.16
0.16
0.16
0.16
0.16
0.16
→ M. S. H. in Cal.
0.07%C
0.11%C
0.13%C
0.19%C
0.30%C
0.41%C
0.61%C
0.77%C
1.05%C
1.33%C
1.57%C
1.85%C
2.40%C
2.90%C
3.00%C
3.50%C
900
1100
1300
1500
700
900
1100
1300
1500
→ Temperature in °C

Fig. 2.

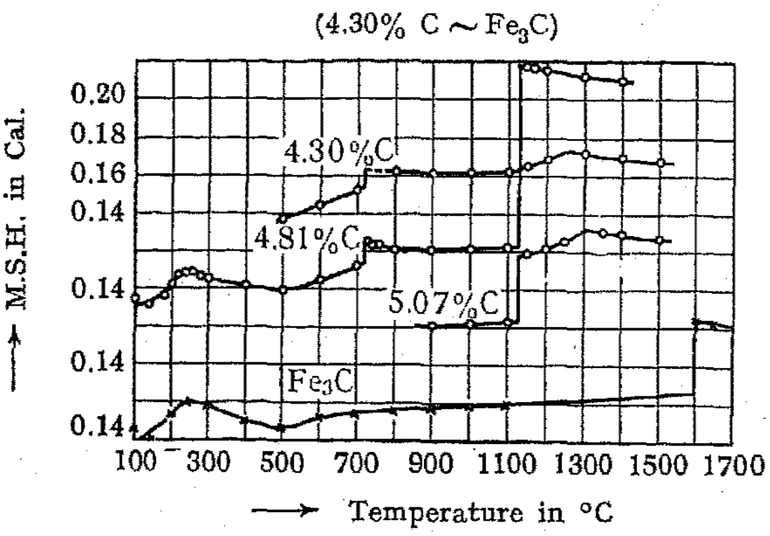
(4.30% C ~ Fe$_3$C)
0.20
0.18
0.16
0.14
0.14
0.14
0.14
→ M.S.H. in Cal.
4.30%C
4.81%C
5.07%C
Fe$_3$C
100
300
500
700
900
1100
1300
1500
1700
→ Temperature in °C

Fig. 3.

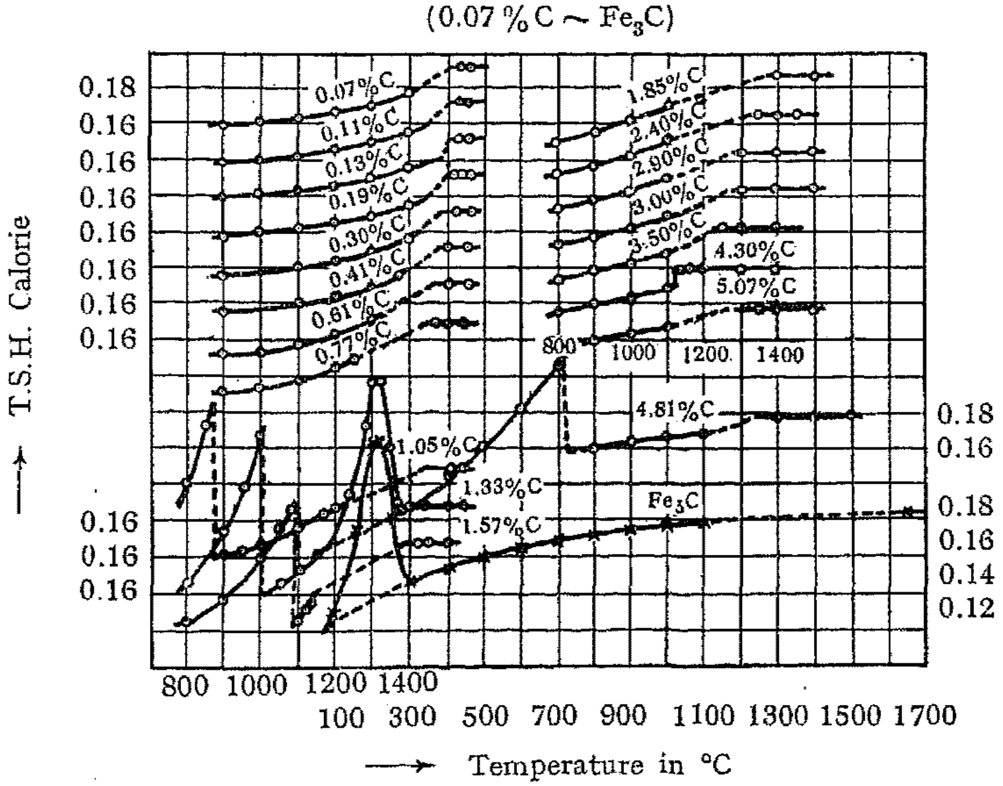

Fig. 4.

Thus the heat content continuously increases with the rise of temperature and shows abrupt changes in the solidifying range and at A_1 point, but the A_3 line and the solubility curve of cementite may only be recognized by a change in the course of the heat content temperature curves in crossing these lines.

The mean specific heats of carbon steels gradually increase with the rise of temperature up to the A_1 point, where it shows an abnormal increase. It shows also an abrupt increase at peritectic point, and in the range where solidus and liquidus phases coexist, that is, in the range of temperatures enclosed between the liquidus and solidus curves, the increase of the mean specific heat is comparatively large, but after the complete melting, the specific heat rather decreases.

As seen from Fig. 4, the true specific heat of a carbon steel gradually increases with the rise of temperature and attains a constant value(15) after melting, this value decreasing with the increase of carbon content,

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(15) K. Honda, Phil. Mag., **45** (1923), 189.

that is, from 0.192 of 0.07% carbon to 0.178 of 5.07% carbon. Therefore the true specific heat of a carbon alloy should be 0.173_3 in a 6.67% carbon concentration, i. e the true specific heat of molten cementite will be 0.173_3. In hyper-eutectoid steel, the true specific heat abruptly decreases at A_1 point, but afterwards, it increases gradually. The true specific heat of a 4.81% carbon cast iron shows an abnormal change of A_0 point(16) and afterwards it increases with the rise of temperature, till it abruptly decreases at the A_1 point; then it gradually increases, and after melting it takes almost a constant value.

It was found by extrapolation that the mean and true specific heats of cementite have an abnormal change corresponding to the A_0 transformation, but show naturally no such change at the A_1 transformation point.

(2) Diagram of Iron-Carbon System determined by the Heat Centent Temperature Relation.

(a) Solubility Curve.

In the range between the A_1 line and the solubility curve of cementite, steel consists of two phases, i. e. austenite and cementite; but above it, it consists solely of austenite independent of temperature and of carbon concentration. Hence it is to be concluded that the heat content temperature curve of steel changes its course and the true specific heat shows an abrupt change, in crossing the solubility curve. As seen in the case of 1.05~1.57% carbon steels (Fig. 5), the heat content temperature curve has each one break, at which it is divided into two nearly straight parts, this break point being the solubility temperature of cementite.

In the determination of the solubility curve of cementite in the iron-carbon system, P. Soldan(17) and I. Iitaka(18) used the electric resis-

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(16) Sci. Rep., l. c.

(17) Jour. Iron and Steel Inst., 7 (1916), 195.

(18) Sci. Rep., 7 (1918), 167.

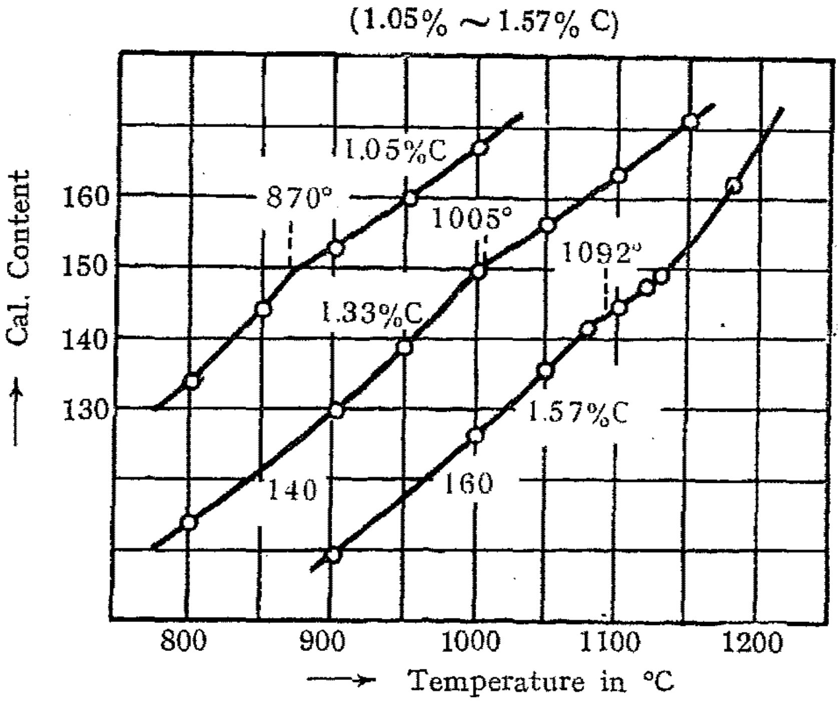

Fig 5.

tance method, while S. Konno(19) and T. Satô(20) used a differential dilatometric method, and K. Honda and H. Endo(21) the thermomagnetic analysis. All these previous determinations have been found almost in agreement with that of the present writer. Table 3 shows a comparison of the solubility temperatures by the above mentioned investigators :

Table 3.

	C (%)	1.05	1.33	1.57	Methods
Solubility Temperature	Writer	870°	1005°	1092°	Calorimetric determination
	Honda-Endo	868°	1010°	1098°	Thermomagnetic determination
	Sato	854°	984°	1087°	Thermal analysis

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(19) Sci. Rep., **12** (1923), 127.

(20) Kinzoku-no-kenkyu, **6** (1929), 53.

(21) Sci. Rep., **16** (1923), 235, 627 ; Kinzoku-no-kenkyu, **3** (1926), 492.

(b) Solidus and Eutectic Temperature.

Many investigators(22) have already made the determination of the solidus curve of the iron carbon system, but their methods of experiments seem to be somewhat unsatisfactory. Recently S. Kaya(23) made a measurement of electric resistance of steel and determined the solidus curve based on the fact that the temperature coefficients of steel changes discontinuously at the solidus point; while K. Honda and H. Endo(24) determined the solidus from the position of a break in the magnetic susceptibility temperature curve. Below the solidus, steels all consist of a solid solution, but above it, they are made up of a mixture of liquid and solid, their proportion varying with temperature. Hence in reaching the solidus point, the heat content temperature curve will change its course abruptly, as seen from Fig. 1. This break point can be obtained as the point of intersection of two portions of the same curve. The following table contains the result thus obtained from Fig. 1.

Table 4.

C (%)	0.13	0.19	0.30	0.41	0.61	0.77	1.05	1.33	1.57
Writer	1487°	1462°	1427°	1393°	1335°	1290°	1220°	1163°	1140°
S. Kaya	—	1460°	1426°	1394°	1330°	1280°	1213°	1168°	1142°
K. Honda and H. Endo	—	—	1428°	1393°	1332°	1288°	1220°	1173°	1141°

We see that the values given in the above three rows, though slightly differ from each other, almost agree with each other. A point on the solidus curve is a temperature at which, during cooling, the gamma

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(22) Carpenter and Keeling, Jour. Iron and Steel Inst., **1** (1904), 224; Gustowsky, Metallurgie, (1909), 731; Asahara, Sci. Rep. of the Inst. Phys. and Chem. Res. Lab. Tokyo, **2** (1924), 420.

(23) Sci. Rep., **14** (1925), 529.

(24) Sci. Rep., **16** (1927), 235.

crystal, that is, austenite ends to precipitate from a mixture of austenite and liquid, and a point on the solubility curve is a temperature at which, during cooling, cementite begins to preciptitate from austenite. Therefore the point of intersection of these two curves is the temperature at which austenite and cementite begin to precipitate from the mixture of austenite and liquid. Thus the present writer obtained 1130° as the point of intersection of these curves at the carbon concentration of 1.70 percent. Thus the eutectic temperature is found to be 1130°.

(c) Liquidus and Peritectic Line.

As to the liquidus of the iron-carbon system, Kohlschütter, Frank and Ehlens(25) already reported their experimental results. Later, R. Ruer and P. Goerens(26) carried out also a determination of the liquidus and the peritectic line. As these measurements are to be made at very high temperatures, it is very difficult to obtain a suitable refractory materials for the container and the protecting tube for the thermocouple, and therefore very few previous investigations are satisfactory. The present writer used a special high refractory magnesia tube made by the Imperial Steel Works and measured the heat content at short intervals of temperature. As the specimen has a few changes of state at high temperatures, the heat content curve will show the corresponding changes at these temperatures.

By referring to the result of Ruer and Goerens, the heat content temperature curve in the vicinity of the peritectic line was obtained and the temperatures at which the specimen changes its state were determined, as is shown in Fig. 6; the result obtained in this way is given in Table 5.

From the above results, the equilibrium diagram of the iron-carbon system, Fig. 7, is obtained.

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(25) Ann. d. Chem., **400** (1913), 268; O. Ruff and W. Bormann, Zeit. Anorg. Chem., **88** (1914), 397.

(26) Ferrum, **14** (1917), 161.

Table 5.

C (%)	Liquidus	Peritectic line	$\delta+\gamma$-iron $\rightarrow \gamma$-iron	Solidus
0.07	1522°	1487°	1445°	
0.11	1517	1487 (?)	1475 (?)	
0.13	1513	1487		1487°
0.19	1506	1487		1462
0.30	1495	1487°		1427
0.41	1487			1393
0.61	1475			1335
0.77	1463			1290
1.05	1440			1220
1.33	1418			1163
1.57	1394			1140
1.85	1370			1130
2.40	1327			1130
2.90	1280			1130
3.00	1270			1130
3.50	1220			1130
4.30	1130			1130
4.81	1255			1130
5.07	1310°			1130°

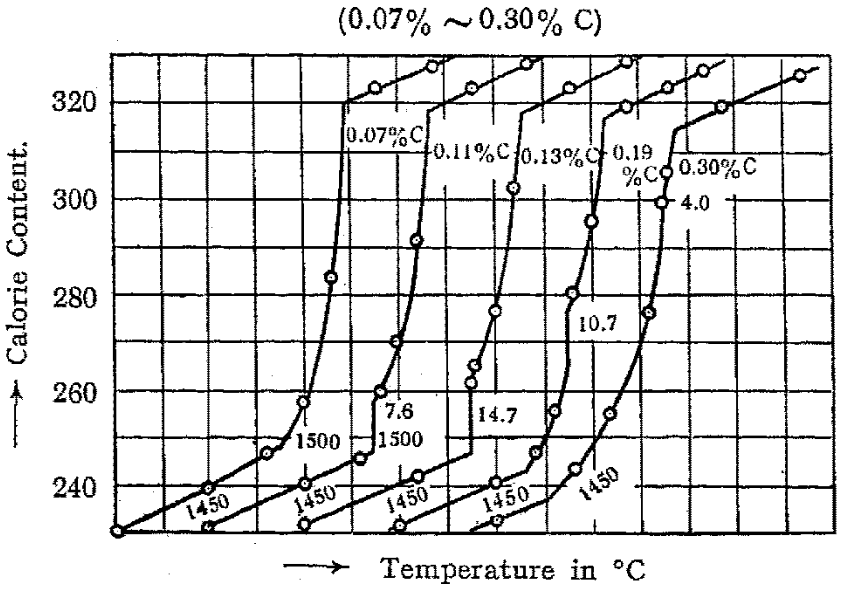

Fig. 6.

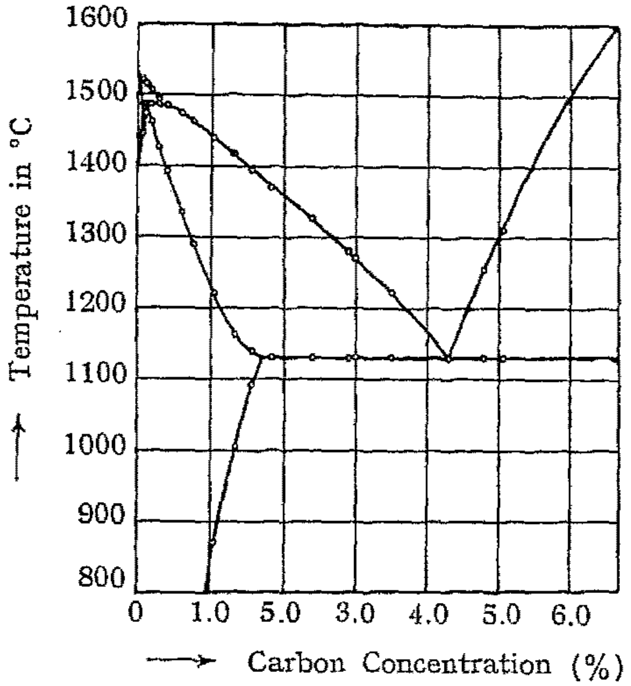

Fig. 7.

(3) Heat of Reaction.

(a) Heat of Peritectic Reaction.

The heat required for the peritectic reaction at 1487° may be obtained from the difference in heat content before and after this temperature. That is, from the heat content curves given in Fig. 6, the heat of peritectic reaction at 1487° is obtained as follows:—

Table 6.

Heat of Peritectic Reaction.

C (%)	0.07	0.11	0.13	0.19	0.30
Calories	0.0	9.6	14.7	10.7	4.0

The relation between the heat of peritectic reaction and the carbon concentration is shown in Fig. 8.

From this result, we see that the heat of peritectic reaction begins from 0.07% carbon, reaches a maximum value 14.7 calories at 0.13% carbon and ends at 0.36% carbon. Thus unit mass of the specimen of 0.13% carbon consisting of liquid and delta crystal evolves during cooling 14.7 calories of heat in order to change the mixture at the peritectic temperature into gamma crystal and during heating, it absorbes the same quantity of heat at the same point.

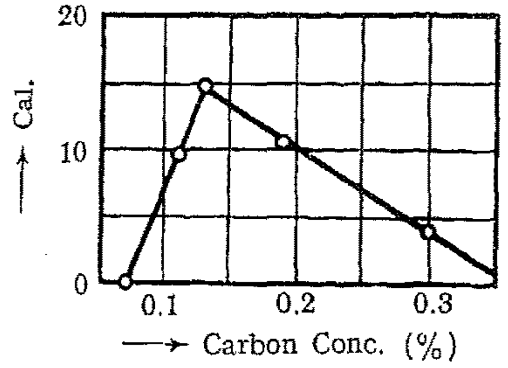

Fig. 8.

(b) Heat of Eutectic Reaction.

From the heat content temperature curves shown in Fig. 1, the heat of the eutectic reaction at the eutectic point, i. e. 1130°, is obtained for different iron-carbon alloys as follows :—

Table 7.
Heat of Eutectic Reaction.

C (%)	1.85	2.40	2.90	3.00	3.50	4.30	4.81	5.07
Calories	3.5	16.7	29.0	30.8	42.6	61.2	47.2	41.0

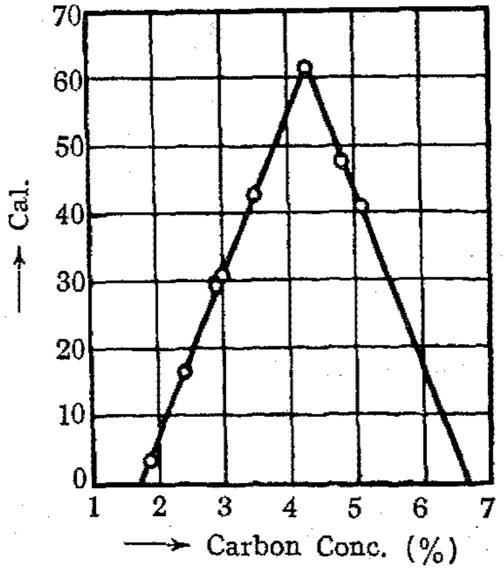

Fig. 9.

The relation between this heat and the carbon concentration is graphically shown in Fig. 9.

From the result, we see that the heat of the eutectic reaction of the iron-carbon system begins at 1.70% carbon, and reaches the maximum value of 60.9 calories at the eutectic concentration, i. e. 4.30% carbon. This is the latent heat of fusion of the eutectic alloy.

The straight line connecting

the points representing the heat of reaction for the eutectic concentration with those points corresponding to 4.81 and 5.07% carbon cast iron almost passes through the 6.67% carbon concentration; this shows the vanishing of the heat of eutectic reaction. The above maximum value of the heat of eutectic reaction is very near to Schmidt's 59 calories,(27) which was obtained by the specimen of 4.35% carbon concentration ; but when it is compared with the writer's previous result of 46.63 calories for the specimen of 4.31% carbon, a considerable difference exists between these two. As the eutectic temperature in this case is so high as 1169°, this difference is probably due to that of manganese and silicon(28) contained in these specimens.

(4) Heat of Fusion of Iron-Carbon System.

In pure state iron melts at a definite temperature, but if the carbon content in iron increases, it does not melt at a single temperature, but in a certain range of temperatures, and so the heat of fusion cannot be simply obtained from the heat content before and after the fusion. The present writer undertook, therefore, to calculate the heat of fusion of iron-carbon system by combining the experimental results with the theoretical consideration.

In Fig. 10, let us consider a specimen of a concentration M; when its temperature rises to M_1, the eutectic point, the quantities of liquid and solid phases are respectively $\frac{AM_1}{AE}$ and $\frac{M_1E}{AE}$ grams, assuming the total mass of the

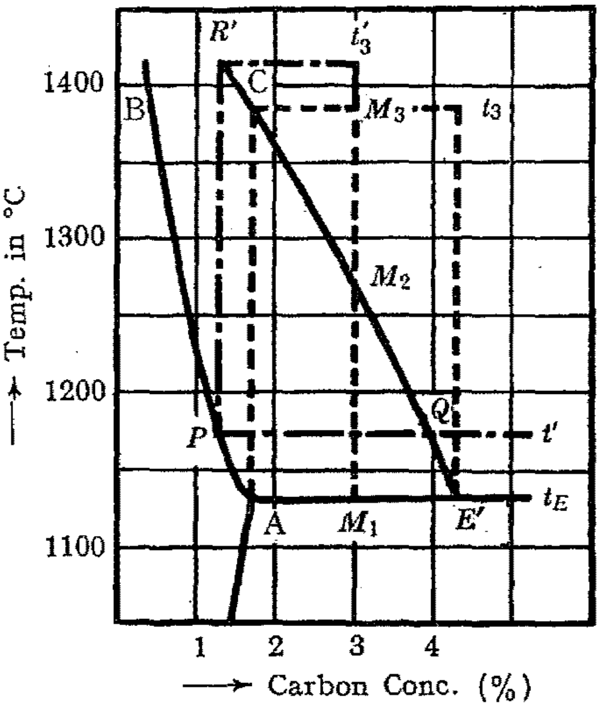

Fig. 10.

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(27) Metall., 7 (1910), 164.

(28) K. Honda and T. Murakami, Sci. Rep., 13 (1924), 1. H. Sawamura, Mem. Kyoto Imp. Uni., 4 (1926), No. 4. T. Kikuta, Kinzoku-no-kenkyu, 3 (1926), 185.

specimen to be one gram.

The heat content of the specimen at this temperature can be obtained from the experimental result; let us denote this heat by h_1. When the temperature rises further to M_3 point, the specimen consists wholly of liquid M. If we denote the heat content of this liquid by h_3, the total heat absorbed in the course of this change is h_3-h_1.

Now, assume that $\frac{M_1E}{AE}$ grams of the solid of composition A and $\frac{AM_1}{AE}$ grams of the liquid are raised to t_3° and then mixed. If Q_3 be the heat to be absorbed during this process and $\bar{S}_A$, S_E be the specific heats of the solid and liquid phases respectively, then the following formula is obtained:—

$$h_3-h_1=\bar{S}_A(t_3-t_E)\frac{M_1E}{AE}+S_E(t_3-t_E)\frac{AM_1}{AE}+Q_3$$

that is,

$$Q_3=h_3-h_1-(t_3-t_E)\left(\bar{S}_A\frac{M_1E}{AE}+S_E\frac{AM_1}{AE}\right).$$

Q_3 is the heat to be absorbed when the solid of composition A at t_3° melts into the liquid of composition E and forms a uniform liquid M_3. Hence if Q_E be the heat required for the formation of a uniform liquid at the eutectic temperature from the two co-existing phases and S_M be the specific heat of the liquid, then the following relation will be obtained:—

$$Q_E=h_3-h_1-S_M(t_3-t_E).$$

Here, since h_3, h_1 and S_M are the values known from our observation, Q_E can be obtained.

(a) Heat of Fusion, Heat of Solution and Latent Heat of Fusion of Gamma Iron.

Now, from the above equation we can get the heat of fusion of gamma iron by using the observed results as follows:-

$A = 1.70\%$ C, $E = 4.30\%$ C, $t_E = 1130°$, $t_3 = 1390°$.

M_i	1.85 %	2.40 %	2.90 %	3.00 %	3.50 %
Quantity of solid $\frac{M_iE}{AE}$	$\frac{24.5}{26} = 0.941$	$\frac{19}{26} = 0.730$	$\frac{14}{26} = 0.538$	$\frac{13}{26} = 0.500$	$\frac{8}{26} = 0.308$
S_M	0.187_3	0.185_7	0.184_2	0.183_9	0.182_5
h_3	294.6_6	293.9_8	293.5_5	293.5_0	293.0
h_1	191.6_5	203.5_4	214.5_7	216.7_9	227.7_3
$h_3 - h_1$	103.0_1	90.4_4	78.9_8	76.7_1	65.2_7
$S_M(t_3 - t_E)$	48.70	48.28	47.89	47.81	47.45
Q_E	54.31	42.16	31.09	28.90	17.82

Now Q_E is the heat to be absorbed when solid austenite and the liquid of composition E, which are in equilibrium with each other at the eutectic temperature, change into a uniform liquid M_i, but at the eutectic point, this liquid M_i does not really exist, so that Q_E is merely a theoretical quantity. When, however, carbon concentration gradually decreases and M_i approaches the concentration A, the extreme value of Q_E represents the heat that the solid austenite itself melts, i. e. it is the latent heat of fusion of austenite. From the results shown in the above table, we get **Fig. 11.** From this, we see that the value of Q_E is not exactly proportional to the quantity of solid mass $M_iE : AE$, and depends more or less upon the relative quantities of solid mass and the liquid.

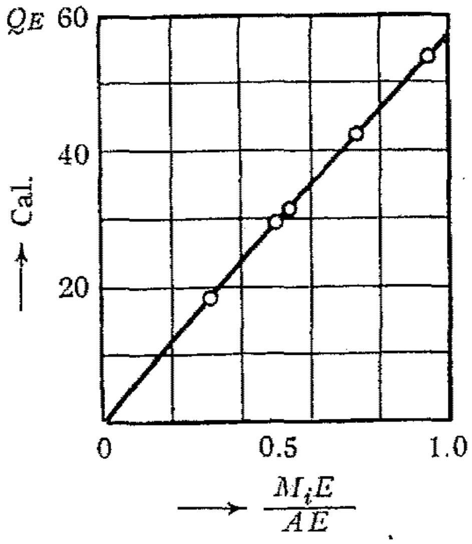

Fig. 11.

The heat to be required when one gram of the solid austenite melts into the liquid of one gram of eutectic carbon concentration, can be obtained by doubling Q_E corresponding to 0.5 of $M_1E : AE$ in Fig. 11.[*] That is,

$$Q_s = 28.90 \times 2 = 57.80 \text{ calories.}$$

Again, if the above calculation is applied to two points, such as *P* and *Q* in Fig. 10, the heat of fusion per gram of austenite of composition *P*, when it melts into the same quantity of liquid *Q* at t'°, can be obtained. The result thus obtained is given in Table 8.

Table 8.

Comp. of Solvent C(%)	0.13	0.19	0.30	0.41	0.61	0.77	1.05	1.33	1.57	1.70
Comp. of Solute C(%)	0.36	0.75	1.20	1.59	2.29	2.75	3.50	4.02	4.17	4.30
t'	1487°	1460°	1428°	1395°	1336°	1290°	1222°	1163°	1140°	1130°
Heat of fusion Q_s	67.19	66.75	66.04	65.27	63.91	62.84	61.07	59.29	58.29	57.80

These results will be graphically shown in Figs. 12 and 13.

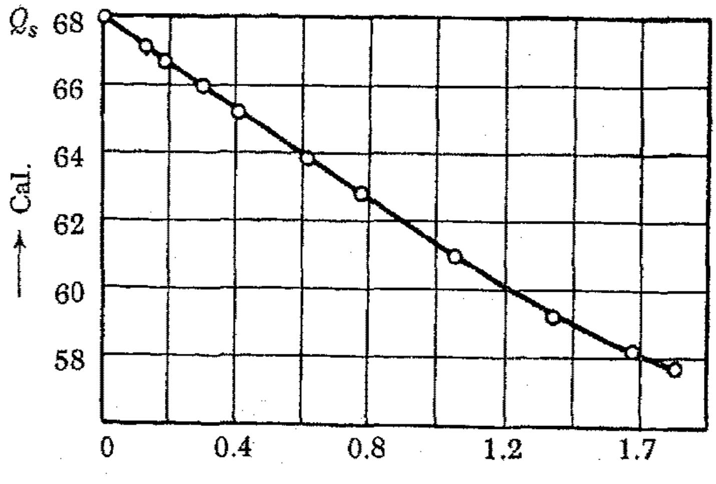

Fig. 12.

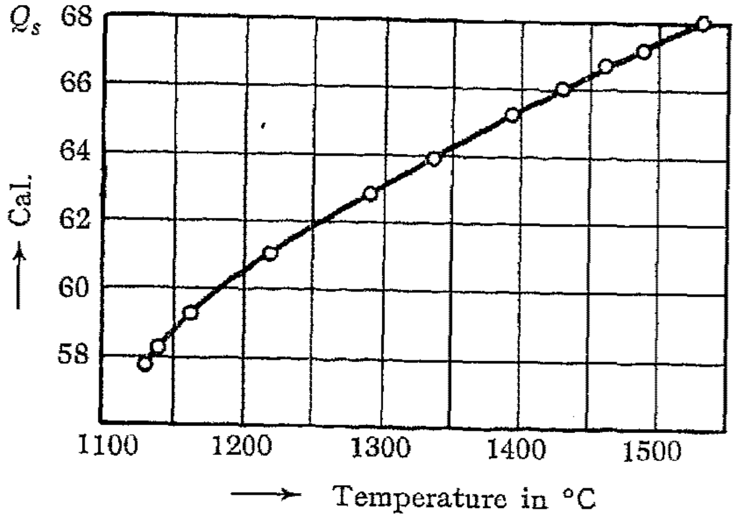

Fig. 13.

From this relation, it will be seen that, with the increase of carbon concentration, the heat of fusion gradually diminishes and with the rise of temperature, it increases steadily. From Fig. 12, we get the value of 68.0 calories as the latent heat of fusion of pure iron, provided it had no A_4 transformation. The heat of A_4 transformation in pure iron at 1530° can be calculated from its true specific heat as follows,

$$1.86+(1530-1400)\,(0.185-0.181)=2.38.$$

So, if we assume that pure iron has no A_4 transformation at all, the latent heat of fusion will be

$$65.65+2.38=68.03 \text{ calories per gram,}$$

the observed value being 65.65. The value agrees satisfactorily with the above result, 68.0 calories.

The values of Q_E in the forgoing page are the heat of fusion of austenite of each carbon concentration, when the austenite melts into the liquid of the corresponding carbon concentration ; but if we take the extreme value of $M_1E : AE=1$ in Fig. 11, we get the latent heat of fusion of austenite itself. The heat of fusion of austenite of each carbon concentration Q_l obtained in this way is given in Table 9.

Table 9.

Latent Heat of Fusion of Austenite and Its Carbon Concentration.

Carbon conc. of austenite (%)	0.13	0.19	0.30	0.41	0.61	0.77	1.05	1.33	1.57	1.70
Temperature	1487°	1460°	1428°	1393°	1336°	1290°	1220°	1163°	1140°	1130°
Q_l (Calorie)	67.19	66.72	66.01	65.22	63.86	62.76	60.94	59.20	58.20	57.70

These results are graphically shown in Figs. 14 and 15.

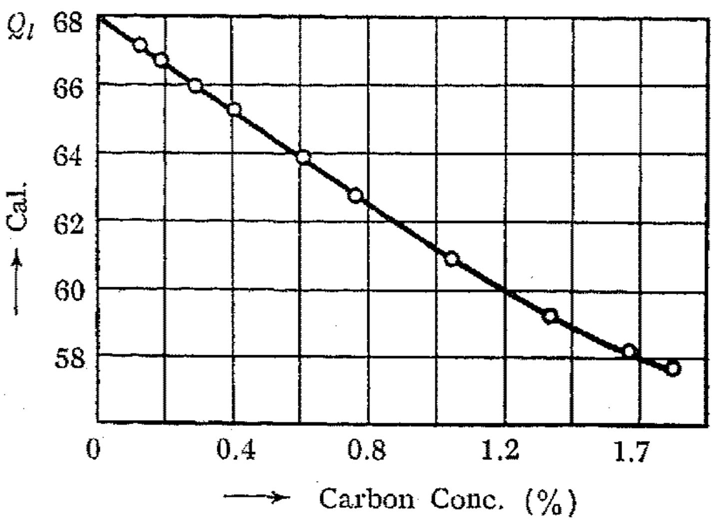

Fig. 14.

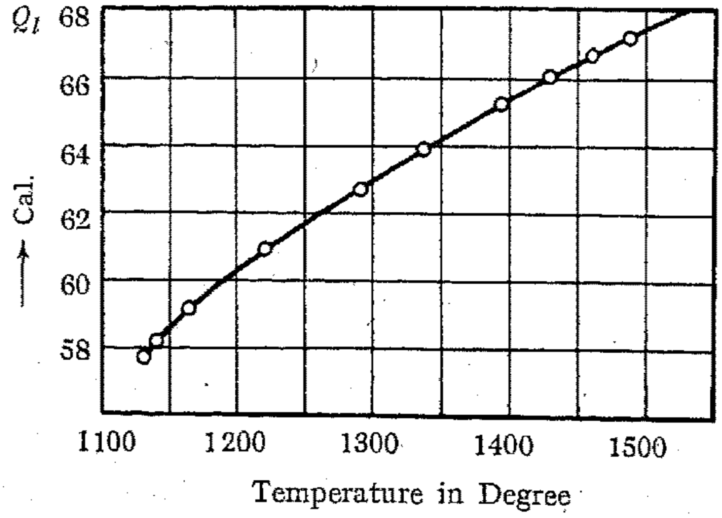

Fig. 15.

From Tables 8 and 9, it will be seen that the relation of the latent heat of fusion to the carbon concentration or to the temperature is quite the same as in the case of the heat of fusion.

Next, by referring to the solubility line of gamma into delta iron in the diagram previously obtained, the heat required for one gram of gamma iron to be solved into one gram of delta iron of the corresponding carbon concentration may be obtained by a similar calculation as before, and the result is given in Table 10.

Table 10.

Heat of Solution of Gamma into Delta Iron.

Composition of Solute C(%)	0.00	0.05	0.07	0.11	0.13
Composition of Solvent C(%)	0.00	0.03	0.04	0.06	0.07
t'	1400°	1433°	1447°	1474°	1487°
Q_s (Cal.)	1.86	1.26	1.04	0.56	0.32

The heat of transformation from gamma to delta iron, i. e. 1.86 calories,(29) is the value obtained experimentally by the present writer. The relation of the heat of solution to the carbon concentration of solute or to the temperature is graphically shown in Fig. 16.

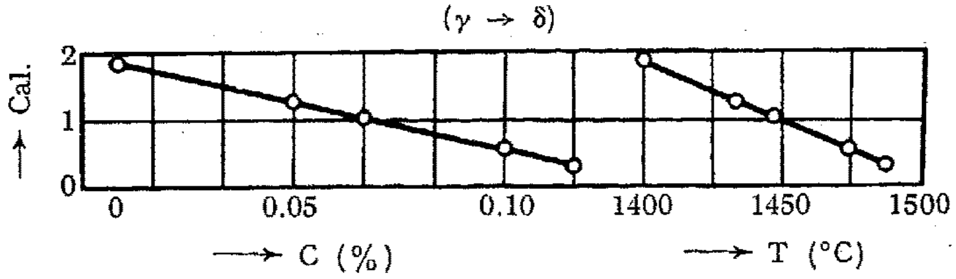

Fig. 16.

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(29) S. Umino, l. c.

This shows that with the increase of carbon concentration, or with the rise of temperature, the heat of solution of gamma iron into delta iron decreases.

(b) Heat of Fuion and Latent Heat of Fusion of Delta Iron.

The same calculation used in obtaining the heat of fusion of gamma iron may also be applied to the case of delta iron and the liquid. The heat of fusion of delta iron thus obtained is given below :

$$A=0.07\ \%\text{C},\quad E=0.36\ \%\text{C},\quad t_E=1487^\circ,\quad t_3=522^\circ.$$

M_i	0.11 %	0.13 %	0.19 %	0.30 %
Quantity of delta iron	$\frac{25}{29}=0.861$	$\frac{23}{29}=0.794$	$\frac{17}{29}=0.585$	$\frac{6}{29}=0.207$
S_M	0.192_5	0.192_4	0.192_2	0.191_9
h_3	319.8_2	319.8_1	319.7_8	319.7_0
h_1	257.2_3	261.5_8	275.0_9	299.5_4
h_3-h_1	62.5	58.2	44.6	20.1
$S_M(t_3-t_E)$	6.74	6.73	6.73	6.72
Q_E	55.85	51.50	37.96	13.44

The heat of fusion Q_E is almost proportional to the quantity of solid mass of delta iron, as is shown in Fig. 17. The end value of the heat of fusion of delta iron, 64.8 calories, is the latent heat of fusion per gram of delta iron of 0.07% carbon itself. The heat to be required when one gram of the solid delta iron melts into the liquid of the same quantity of the corresponding carbon concentration can be obtained by doubling Q_E corresponding to 0.5 of the quantity of delta iron in Fig. 17. Thus we get

$$Q_s = 32.45 \times 2 = 64.90 \quad \text{calories.}$$

Next, in order to see the change in the heat of fusion of delta iron due to the decrease of its carbon concentration, the writer obtained by interpolation the heat of fusion of the specimens of 0.03 and 0.05% carbon from those of 0.07% carbon and pure iron, which the writer obtained in his experiment. The result of the calculation is given in Table 11.

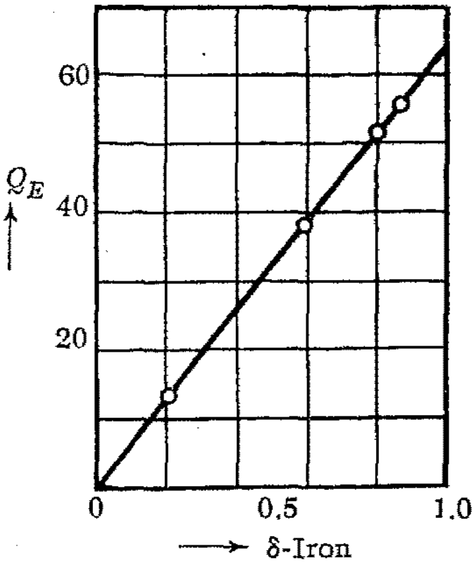

Fig. 17.

Table 11.

Heat of Fusion of Delta Iron and Its Carbon Concentration.

Composition of Solute C(%)	0.0	0.03	0.05	0.07
Composition of Solvent C(%)	0.0	0.16	0.26	0.36
t'	1530°	1511°	1498°	1487°
Q_S (Cal.)	65.65	65.31	65.10	64.90

This relation is shown in Fig. 18;

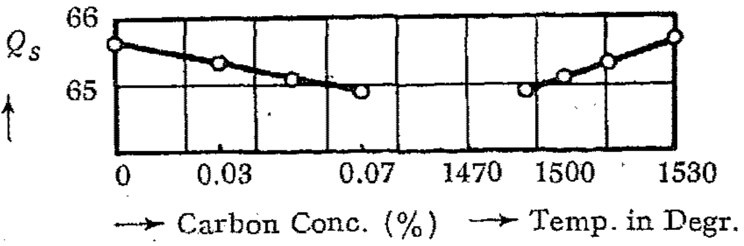

Fig. 18.

This shows that the heat of fusion of delta iron decreases with the increasing carbon concentration, and increases with the temperature.

Next, the end value of the heat of fusion of delta iron in Fig. 17

is the latent heat of fusion of delta iron itself, and this value can be obtained by extrapolation. A similar calculation has been applied for delta iron of lower carbon concentrations with the results given in Table 12.

Table 12.

Latent Heat of Fusion of Delta Iron and Its Carbon Concentration.

Carbon Conc. of Delta Iron C(%)	0.00	0.03	0.05	0.07
Temperature	1530°	1511°	1498°	1487°
Q_l (Calorie)	65.65	65.30	65.07	64.84

From this result, it will be seen that these values of latent heat of fusion of delta iron is almost the same as the heat of fusion. The melting temperature of delta iron falls with increasing carbon concentration, while the latent heat of fusion slightly decreases.

(c) Latent Heat of Fusion and Carbon Concentration of Gamma and Delta Irons at a given Temperature.

The latent heat of fusion of gamma and delta irons so far obtained being a function of temperature and carbon concentration, the writer tried to obtain by calculation the change of the latent heat of fusion in these two phases, when it is reduced to the same temperature.

If $\varDelta Q_l$ denotes the change of the latent heat of fusion due to the change of temperature $\varDelta t°$, we get by Kirchhoff's equation(30)

$$\varDelta Q_l = \varDelta t \Sigma S.$$

If the latent heat of fusion of delta or gamma iron at $t'°$ is to be reduced to that at 1530° and the mean values of the true specific

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(30) Pogg. Ann., **103** (1858), 454.

heats of liquid and solid are respectively S_M and $\bar{S}_s$, the above equation becomes

$$\begin{aligned} \varDelta Q_l &= (1530-t')\Sigma S \\ &= (1530-t')\,(S_l-\bar{S}_s). \end{aligned}$$

Table 13 contains the results of calculation for $\varDelta Q_l$ together with the values of t', $\bar{S}_s$, S_l and Q_l; here as the latent heat of fusion Q_l at t'°, the values estimated from the values in Tables 9 and 11 are taken.

Table 13.

Latent Heat of Fusion at 1530°.

C(%)		t'	S_l	$\bar{S}_s$	$\varDelta Q_l$	Q_l	$Q_l+\varDelta Q_l$
δ-iron	0.03	1511°	0.192_7	$0{\cdot}182_2$	0.20	65.30	65.50
	0.05	1498	0.192_6	0.182_0	0.34	65.06	65.40
	0.07	1487	0.192_6	0.181_9	0.46	64.84	65.30
γ-iron	0.13	1487	0.192_4	0.181_5	0.47	67.19	67.66
	0.19	1460	0.192_2	0.181_2	0.77	66.72	67.49
	0.30	1428	0.191_9	0.180_3	1.18	66.01	67.19
	0.41	1393	0.191_5	0.179_3	1.67	65.22	66.89
	0.61	1336	0.190_9	0.178_1	2.48	63.88	66.36
	0.77	1290	0.190_5	0.177_4	3.13	62.76	65.89
	1.05	1220	0.189_6	0.176_2	4.16	60.94	65.10
	1.33	1163	0.188_8	0.174_8	5.14	59.19	64.33
	1.57	1140	0.188_1	0.174_3	5.42	58.20	63.62
	1.70	1130°	0.187_7	0.173_8	5.54	57.70	63.24

The relation between the latent heat of fusion and the carbon concentration at 1530° is graphically shown in Fig. 19, in which, it will be seen that the latent heat of fusion of delta or gamma iron decreases with the increase of carbon concentration.

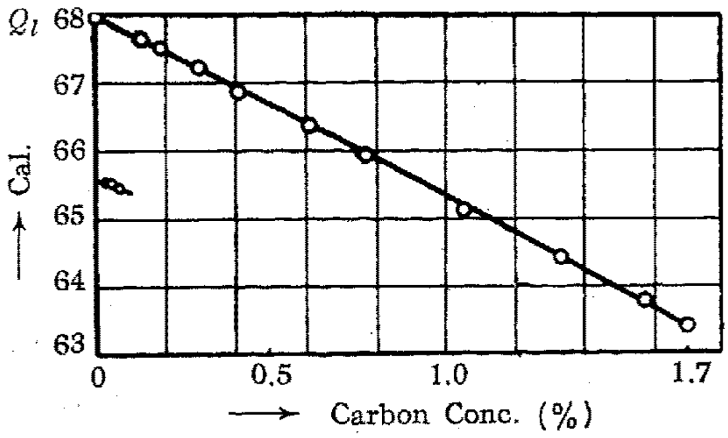

Fig. 19.

The latent heat of fusion of gamma iron of zero carbon at 1530° may be obtained by the extrapolation of the above curve. It is 68.0 calories per gram of gamma iron ; this is about 2.4 calories larger than that of delta iron of the same carbon concentration.

Again, the latent heat of fusion at 1130° can be obtained by the same calculation as follows ;

$$\Delta Q_l=(t'-t_2)\ (\bar{S}_1-S_2).$$

Here $\bar{S}_1$ represents the mean value of the true specific heat of solid at $t'\sim 1130°$ and S_2 that of liquid respectively. The calculated values of the latent heat of fusion at 1130° are given in Table 14.

Table 14.

Latent Heat of Fusion at 1130°.

C(%)		t'	S_2	$\bar{S}_1$	$-\Delta Q_l$	Q_l	$Q_l-\Delta Q_l$
δ-iron	0.03	1511°	0.192_7	0.172_8	7·58	65.30	57.72
	0.05	1498	0.192_6	0.172_6	7.36	65.06	57.70
	0.07	1487	0.192_5	0.172_5	7.14	64.84	57.70
γ-iron	0.13	1487	0.192_4	0.172_3	7.17	67.19	60.02
	0.19	1460	0.192_2	0.171_7	6.75	66.72	59.97
	0.30	1428	0.191_9	0.171_2	6.18	66.01	59.83
	0.41	1393	0.191_5	0.170_3	5.56	65.22	59.66
	0.61	1336	0.190_9	0.169_2	4.48	63.88	59.40
	0.77	1290	0.190_5	0.168_0	3.60	62.76	59.16
	1.05	1220	0.189_6	0.165_1	2.20	60.94	58.74
	1.33	1163	0.188_8	0.162_1	0.89	59.19	58.30
	1.57	1140	0.188_1	0.161_5	0.27	58.20	57.93
	1.70	1130°	$0·187_7$	0.161	0	57.70	57.70

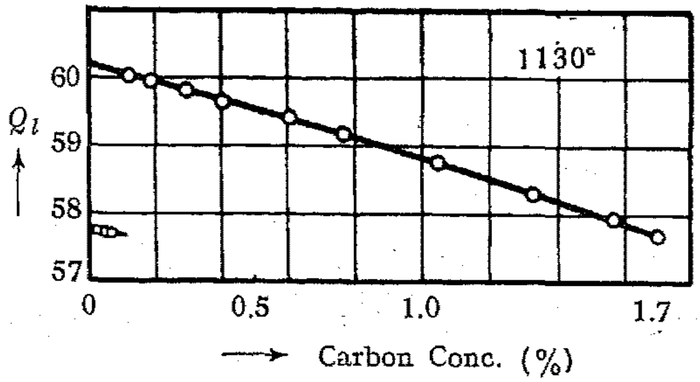

Fig. 20.

Here, as the latent heat of fusion Q_l at t'°, the values estimated from the values in Tables 9 and 11 were taken as before. The relation between the latent heat of fusion and carbon concentration is given in Fig. 20.

The above figure shows that the latent heat of fusion of delta and gamma iron at 1130° decreases with the increase of carbon concentration just as the same at 1530°, and the latent heat of fusion of gamma iron becomes 57.7 calories per gram for a 1.70% carbon.

The latent heat of fusion of pure gamma iron at 1130° is found to be 60.2 calories per gram by the extrapolation of the curve in Fig. 20. This is 1.60 calories larger than that of delta iron of the same carbon concentration.

(d) Heat of Solution of Gamma Iron to Delta Iron at a given Temperature.

The heat of solution of gamma iron into delta iron is also a function of temperature and carbon content; so it will be convenient to reduce the heat to the A_4 point in pure iron, i. e. to 1400°, by using the same relation as before, i. e.

$$\varDelta Q_S=(t_1-t_2)\,(\bar{S}'_s+\bar{S}''_s-2\bar{S}_s).$$

Here the $\bar{S}'_s$ and $\bar{S}''_s$ are the mean values of the specific heat of solute and solvent in the range of temperatures $t_1 \sim t_2^0$, assuming that the total amount of specimens is two grams, and $\bar{S}_s$ is the mean specific heat, when the two parts are mutually dissolved and become a homogeneous solid. The results of calculation are shown in Table 15; here Q_s are the values given in Table 10.

Table 15.

Heat of Solution at 1400°.

Comp. of Solute C(%)	t_1	t_2	$\bar{S}'_s$	$\bar{S}''_s$	$2\bar{S}_s$	$-\varDelta Q_s$	Q_s	$Q_s-\varDelta Q_s$
0.05	1433°	1400°	0.176_4	0.185_4	0.364_8	0.10	1.26	1.16
0.07	1447	1400	0.176_6	0.185_6	0.365_2	0.14	1.04	0.90
0.11	1474	1400	0.176_9	0.185_8	0.365_7	0.22	0.56	0.34
0.13	1487°	1400°	0.177_1	0.186_0	0.366_1	0.26	0.32	0.06

This table shows that at 1400°, the heat of solution decreases with the increase of carbon concentration and almost vanishes at 0.13% carbon, and that the line drawn through the mean position of these points intersects the axis of pure iron at 1.86 calories, as is seen from Fig. 21.

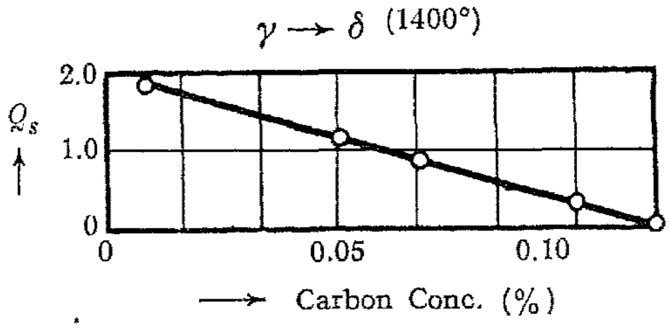

Fig. 21.

In the same way, the heat of solution at the peritectic temperature, 1487°, will be obtained, as is seen in Table 16.

Table 16.

Heat of Solution at the Peritectic Temperature 1487°.

Comp. of Solute C(%)	t_1	t_2	$\bar{S}_s'$	$\bar{S}_s''$	$2\bar{S}_s$	ΔQ_s	Q_s	$Q_s+\Delta Q_s$
0.00	1400°	1487°	0.177_7	0.185_0	0.366_7	0.35	1.86	2.21
0.05	1433	1487	0.178_2	0.185_6	0.368	0.22	1.26	1.48
0.07	1447	1487	0.178_4	0.186_1	0.368_5	0.16	1.04	1.20
0.11	1474	1487	0.179_0	0.186_7	0.370_2	0.05	0.56	0.61
0.13	1487°	1487°	0.179_2	0.187_0	0.371_2	0	0.32	0.32

This relation is shown in Fig. 22.

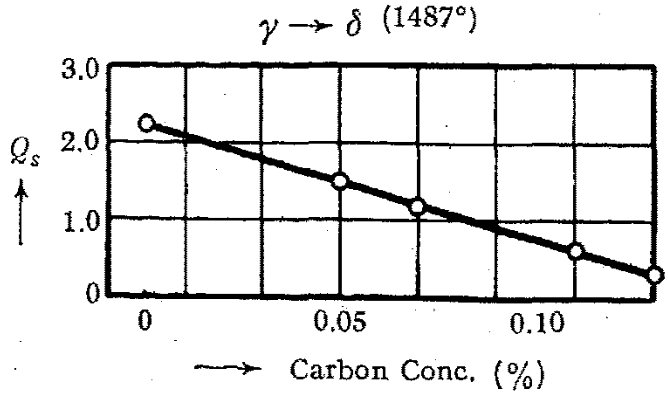

Fig. 22.

In this case also, the heat of solution decreases with the increase of carbon concentration as in the case of 1400°.

(e) Heat of Fusion and Carbon Concentration of Gamma and Delta Iron at a given Temperature.

The heat of fusion of gamma and delta iron at temperatures 1530° and 1130° can be calculated from Tables 8 and 10 by the following formula. If we take ΔQ_s as the variation of the heat of fusion, it becomes

$$\Delta Q_s = (t_1 - t_2)\,(2\bar{S}_M - \bar{S}'_M - \bar{S}'_s).$$

Here, $\bar{S}'_M$ and $\bar{S}'_s$ are the mean values of the specific heat of solvent and solute, i. e., melt and delta or gamma iron in the range of temperatures $t_1 \sim t_2$, and $\bar{S}_M$ is the mean specific heat, when two parts are mixed and form a uniform liquid. The results thus calculated are given in Table 17.

Table 17.

Heat of Fusion at 1530°.

	Comp. of Solute C(%)	t_1	t_2	$2\bar{S}_M$	$\bar{S}'_M$	$\bar{S}'_s$	ΔQ_s	Q_s	$Q_s - \Delta Q_s$
δ-iron	0.03	1530°	1511°	0.385_0	0.192_2	0.182_2	0.17	65.31	65.48
	0.05	1530	1498	0.384_6	0.192_0	0.182_0	0.33	65.10	65.43
	0.07	1530	1487	0.384_4	0.191_7	0.181_9	0.46	64.90	65.36
γ-iron	0.13	1530	1487	0.384_1	0.191_7	0.181_5	0.47	67.19	67,66
	0.19	1530	1460	0.383_0	0.190_6	$0,181_2$	0.79	66.75	67.54
	0.30	1530	1428	0.381_2	0.189_3	0.180_3	1.18	66,04	67.22
	0.41	1530	1393	0.379_5	0.188_0	0.179_3	1.67	65.27	66.94
	0.61	1530	1336	0.376_9	0.186_1	0.178_1	2.46	63.91	66.37
	0.77	1530	1290	0.375_3	0.184_7	0.177_4	3.17	62.84	66.01
	1.05	1530	1220	0.372_2	0.182_5	0.176_2	4.18	61.07	65.25
	1.33	1530	1163	0.369_7	0.180_9	0.174_8	5.14	59·29	64.43
	1.57	1530	1140	0.368_8	0.180_4	0.174_3	5.48	58.29	63.77
	1.70	1530°	1130°	0.367_9	0.180_1	0.173_8	5.60	57.80	63.40

Heat of Fusion at 1130°.

Comp. of Solute C (%)		t_1	t_2	$2\bar{S}_M$	$\bar{S}'_M$	$\bar{S}'_s$	$\varDelta Q_s$	Q_s	$Q_s-\varDelta Q_s$
δ-iron	0.03	1130°	1511°	0.385_0	0.192_2	0.174_8	6.86	65.31	58.45
	0.05	1130	1498	0.384_6	0.192_0	0.174_4	6.70	65.10	58.38
	0.07	1130	1487	0.384_3	0.191_7	0.174_1	6.60	64.90	58.30
γ-iron	0.13	1130	1487	0.384_1	$0\ 191_7$	0.172_4	7.14	67.19	60.05
	0.19	1130	1460	0.383_0	0.190_6	0.171_7	6.75	66.75	59.92
	0.30	1130	1428	0.381_2	0.189_3	0.171_2	6.19	66.04	59.85
	0.41	1130	1393	0.379_5	0.188_0	0.170_3	5.57	65.27	59.70
	0.61	1130	1336	0.376_9	0.186_1	0.169_0	4.51	63.91	59.40
	0.77	1130	1290	0.375_3	0.184_7	0.167_8	3.65	62.84	59.19
	1.05	1130	1220	0.372_2	0.182_5	0.164_3	2.28	61.07	58.79
	1.33	1130	1163	0.369_7	0.180_9	0.162_0	0.88	59.29	58.41
	1.57	1130	1140	0.368_8	0.180_4	0.161_9	0.27	58.29	58.02
	1.70	1130°	1130°	0.367_9	0.180_1	0.161_0	0	57.80	57.80

The relation of the heat of solution to the carbon concentration of solute at these temperatures is similar to that of the latent heat of fusion to the carbon concentration.

(5) Heat of Transformation.

(a) Heat of A_0 Transformation.

Fig. 23 shows the heat content temperature relation in the visinity of the A_0 point of the specimen of 4.81% carbon concentration, and the true specific heat at each temperature was obtained from the observed

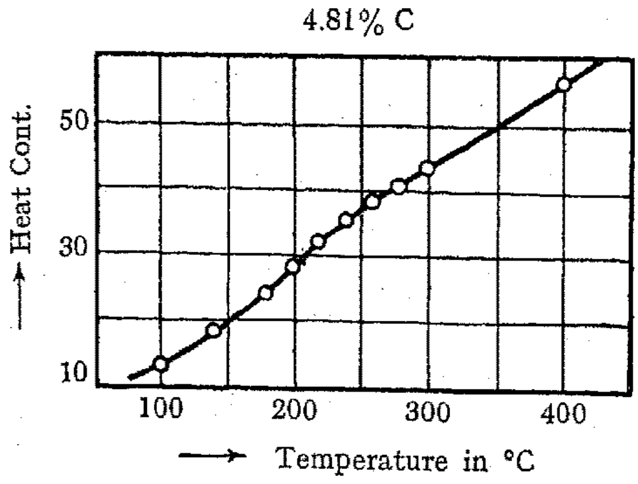

Fig. 23.

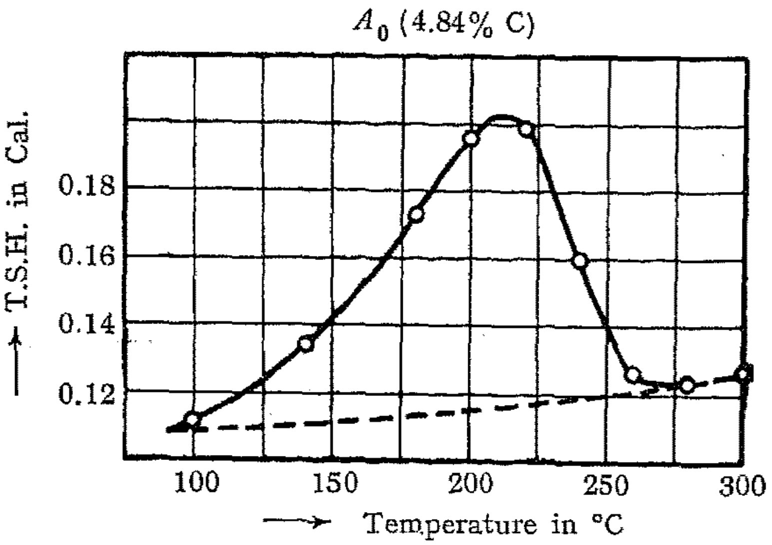

Fig. 24.

data. From the true specific heat temperature curve thus obtained⁽³¹⁾, the area enclosed between the curve and the dotted line, as shown in Fig. 24, was measured; this quantity is the heat of the A_0 or magnetic transformation⁽³²⁾ of the specimen, and amounts to 6.75 calories per unit mass of the specimen. It is also the heat of transformation of cementite per gram of the specimen of 4.81% carbon, and therefore the same heat per gram of cementite becomes 9.35 calories. This value agrees satisfactorily with the writer's previous result obtained with specimens of 0.57, 0.94 and 1.16% carbon.

(b) Heat of A_1 and A_2 Transformations.

The writer's previous experiment on the A_1 transformation was made with specimens up to 2.84% carbon concentration and that of the A_2 transformation with specimens up to 0.77% carbon concentration. In the present experiment the writer measured the heat of A_1 and A_2 transformations with a specimen of 4.81% carbon concentration, and compared it with those previously obtained. As for the heat of the A_1 transformation, the writer obtained 5.2 calories from the difference in heat content before and after 720° as shown in Fig. 25. This value

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(31) S. Umino, Kinzoku-no-kenkyu, **3** (1926), 288; Sci. Rep., **16** (1927), 593.

(32) K. Honda and H. Takagi, Sci. Rep., **2** (1913), 204; K. Honda and T. Murakami, Sci. Rep., **6** (1917), 23; K. Honda, Sci. Rep., **5** (1916), 28.

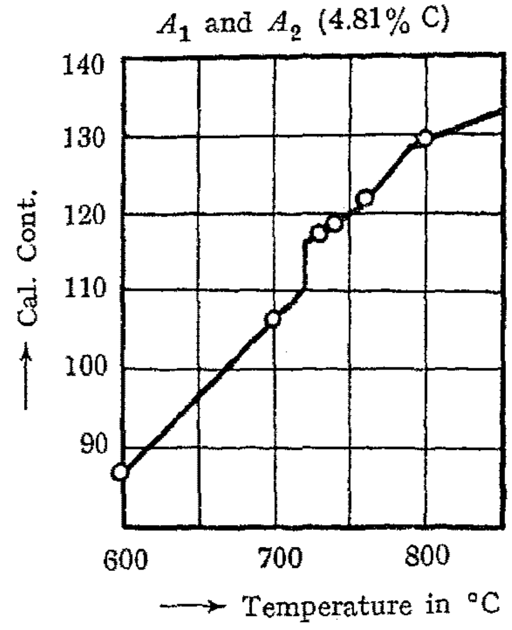

Fig. 25.

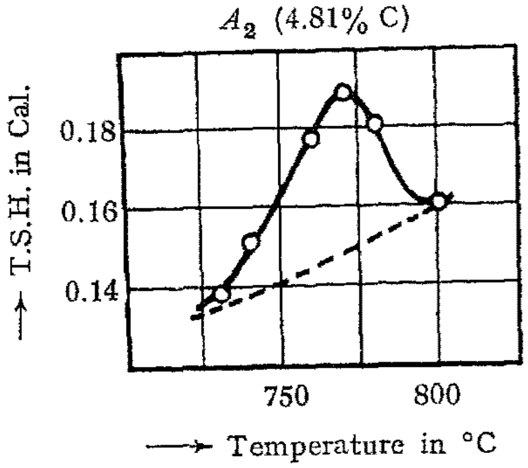

Fig. 26.

stands in harmony with the previous ones and shows that the heat of transformation should vanish at a 6.67% carbon concentration.

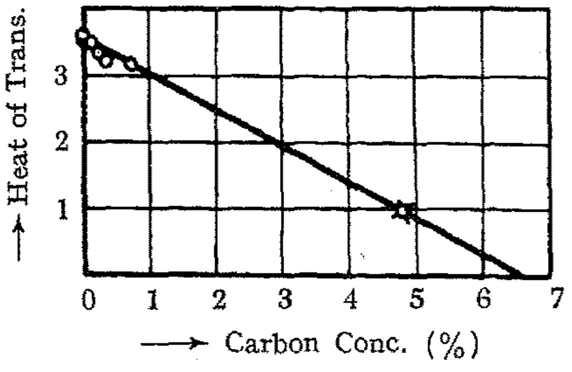

Fig. 27.

For the heat of the A_2 transformation, a quantity of 1.04 calories was obtained by measuring the area enclosed between the true specific heat temperature curve and dotted line as shown in Fig. 26. For the easiness of comparison with the previous ones, this value is graphically shown in Fig. 27, together with the previous results; the line intersects with the axis of concentration at 6.67 percent of carbon, showing that the A_2 transformation vanishes at this concentration.

(c) Heat of A_3 Transformation.

The heat of transformation of alpha into gamma phase in iron containing different percentages of carbon can be obtained by the same calculation as in the case of fusion heat of gamma iron, using the present and his previous results(33). In the case of temperature below 800°, the heat content was taken under the assumption that the specimen has no magnetic transformation. The heat of solution of alpha into gamma iron thus obtained is given below :

$A=0.0\%C$, $E=0.90\%C$, $t_E=720°$, $t_3=920°$.

M_i	0.11	0.19	0.30	0.41	0.61	0.77
Quantity of alpha iron	0.878	0.790	0.667	0.545	0.3225	0.1445
S_γ	0.157	0.156	0.155	0.154	0.152_4	0.151
h_3	151.6	151.8	152.1	152.4	152.9	153.2
h_1	105.7	107.4	110.0	112.5	117.0	120.6
h_3-h_1	45.9	44.4	42.1	39.9	35.9	32.6
$S_\gamma (t_3-t_E)$	31.3	31.2	31.0	30.8	30.5	30.2
Q_E	14.6	13.2	11.1	9.1	5.4	2.4

The relation between the heat of solution Q_E and the quantity of alpha iron is shown in Fig. 28. In this case also, as in the previous case, Q_E is almost proportional to the quantity of alpha iron. As the heat of transformation Q_{A_3}, we get 16.6 calories from the figure. The heat Q_s to be required when one gram of alpha iron dissolves into the same mass of gamma iron of the corresponding carbon concentration can be obtained by doubling Q_E corresponding to the quantity 0.5 of alpha iron.

That is, $Q_s=8.37\times2=16.74$.

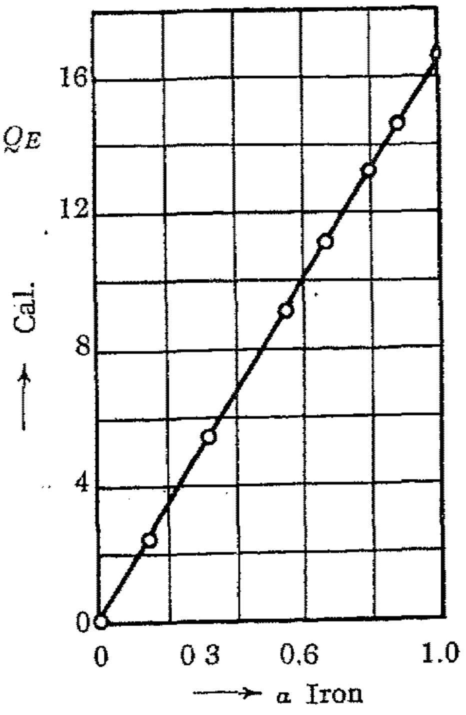

Fig. 28.

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(33) Sci. Rep., **18** (1929), 91. Sci. Rep., **16** (1927), 1009.

Thus if we find the heat of transformation per gram of alpha into gamma iron along the solubility curve, i. e., the heat of the A_3 transformation, the results given in Table 18 are obtained.

Table 18.

Heat of Transformation Q_{A_3} from Alpha to Gamma Iron.

Temp.	920°	884°	861°	833°	808°	769°	740°	720°
Q_{A_3}(Cal.)	5.59	7.00	8.00	9.30	10.50	12.90	14.90	16.60

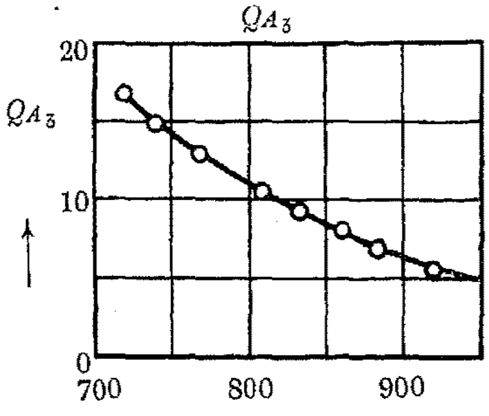

Fig 29.

The relation between Q_{A_3} and the temperature is graphically shown in Fig. 29. Here, 5.59 calories at zero carbon concentration extrapolated from others coincide with the previous experimental result. The heat of transformation of alpha to gamma iron decreases with temperature, and therefore if $\varDelta Q_t$ denotes the decrease of the heat per degree, it becomes

$$\varDelta Q_t = \frac{16.60-5.60}{920-720} = 0.055\ ;$$

that is 0.055 calories per gram is obtained.

Next, the results of calculation for the heat Q_s are given in Table 19.

Table 19.

Heat of Solution Q_s of Alpha to Gamma Iron of Corresponding Carbon Concentrations.

C (%)	0.0	0.11	0.19	0.30	0.41	0.61	0.77	0.90
Temperature	920°	884°	861°	833°	808°	769°	740°	720°
Q_s (Calorie)	5.59	7.00	8.00	9.32	10.53	12.96	15.00	16.74

The relation between the heat Q_s and temperature, and that between Q_s and carbon concentration are graphically shown in Figs. 30 and 31.

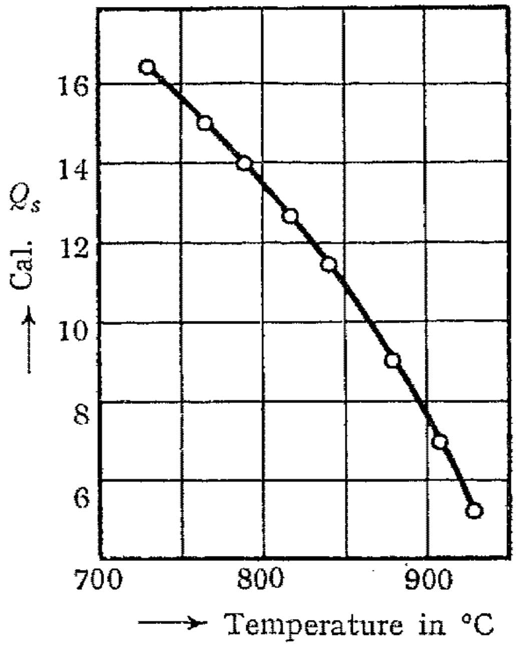

Fig. 30.

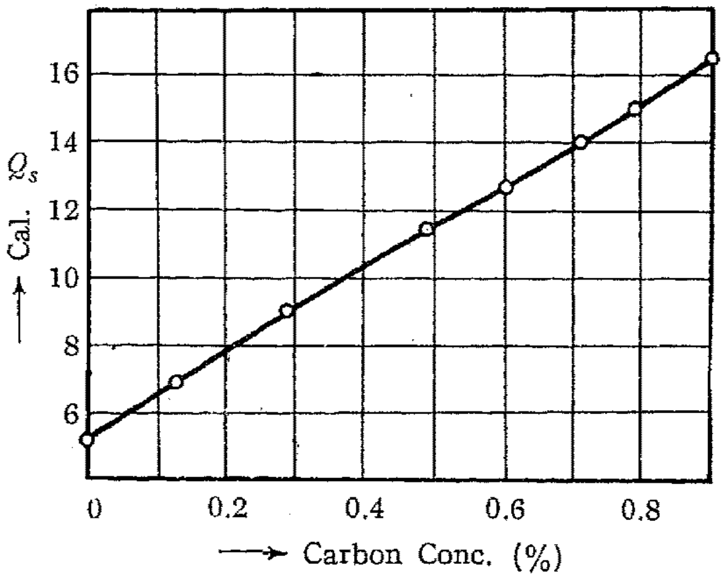

Fig. 31.

From the above result, it will be seen that the heat to be required when one gram of alpha iron dissolves into the same quantity of gamma iron of the corresponding carbon concentration is somewhat larger than the heat of transformation of one gram of alpha to gamma iron. This increase of heat is a function of temperature as well as its carbon concentration. Reduced to the same temperature of 720°, the heat variation can be given by

$$\Delta Q_S = (t' - 720)(\bar{S}_\gamma + \bar{S}_\alpha - 2\bar{S}_S),$$

where, $\bar{S}_\gamma$ and $\bar{S}_\alpha$ are the mean values of the true specific heats of two solids at the temperature range of $t' \sim 720°$ respectively, and $\bar{S}_s$ is that after the mutual dissolution. The results thus calculated are given in Table 20. The relation between the heat of solution and carbon concentration is graphically shown in Fig. 32.

Table 20.

Heat of Solution Q_s of Alpha into Gamma Iron of Corresponding Carbon Concentration at 720°.

C(%)	t'	$\bar{S}_\gamma$	$\bar{S}_\alpha$	$2\bar{S}_s$	$\varDelta Q_s$	Q_s	$Q_s+\varDelta Q_s$
0.0	920°	0.158	0.185	0.288	11.0	5.59	16.59
0.11	884	0.158	0.185	0.284_6	9.60	7·00	16.60
0.19	861	0.158	0.185	0·282	8.61	8.00	16.61
0.30	833	0.157_6	0.135	0.278	7.30	9.30	16.62
0.41	808	0.157	0.185	0.272_6	6.10	10.50	16.63
0.61	769	0.157_2	0.185	0.267	3.69	12.90	16.65
0.77	740	0.156	0.185	0.256	1.70	14.90	16.70
0.90	720°	0.156	0.185	0.249	0	16.60	16.74

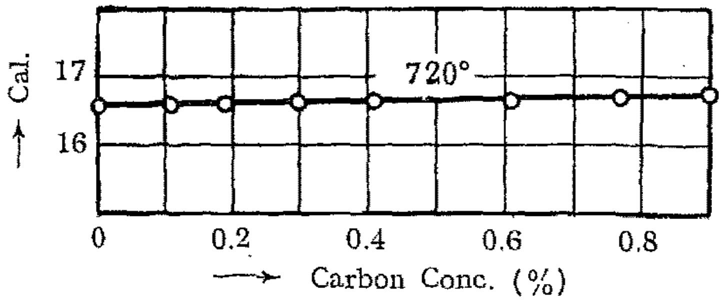

Fig. 32.

(6) Specific Heat, Heat of Fusion, Heat of Solution, and Latent Heat of Fusion of Cementite.

(a) Specific Heat and Latent Heat of Fusion of Cementite.

The specific heat of cementite cannot be measured directly, but its value at a given temperature is obtained by extrapolation of the specific heat carbon concentration curve at this temperature, which is constructed from the observed values of the specific heat of steels and cast irons of different carbon concentrations. So the value of the specific heat of cementite is more accurate, as the range of carbon concentration is wider. In the writer's previous paper, the range of temperature investigated was limited to 900° and the carbon content to 2.84 percent; but in the present case, both of them were extended to 1600° and 5.07 percent carbon respectively.

From the curves of the heat content, the mean specific heat and the true specific heat, plotted against carbon concentration at each of different temperatures, these three quantities for cementite were obtained by extrapolation. The accuracy of these values is very great, because at a given temperature, the variation of the heat content of these specimens with carbon content is very slight and moreover these curves are straight for high carbon specimens. For example, the same curves after melting are shown in Fig. 33. Table 21 contains the results obtained in the above way.

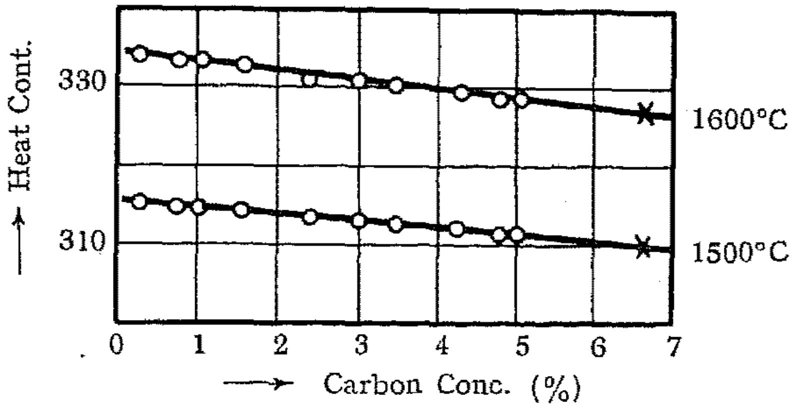

Fig. 33.

Table 21.

Heat Content and Specific Heat of Cementite.

Temperature	Heat content	Mean specific heat	True specific heat
100°	14.5	0.1450	0.119
150	21.0	0.1400	0.165
200	30.7	0.1535	0.215
250	40.1	0.1605	0.172
300	47.0	0.1567	0.138
400	59.9	0.1498	0.144
500	73.0	0.1460	0.150
600	91.5	0.1525	0.156
700	108.0	0.1543	0.159
800	124.8	0.1560	0.161
900	141.3	0.1570	0.164
1000	158.5	0.1585	0.166
1100	175.0	0.1591	0.167
1600	326.8	0.2043	0.173
1650°	335.3	0.2032	0.173

For the melting point of cementite, a value 1600° is obtained from the heat content concentration curves. The relation between the heat content and the temperature, or that between the specific heat and the temperature, is seen from Figs. 1~4.

The latent heat of fusion of cementite was found to be 65.0 calories per gram of the specimen from the difference in heat content above and below its melting point. Its value at 1530°, that is Q_{l1530}, can be obtained by the following formula:

$$Q_{l1530}=Q_{l1600}-(1600-1530)(0.173_3-0.172_3)$$
$$=65.0-0.07=64.93.$$

That is, Q_{l1530} is 64.93 calories, which is larger by 1.5 calories than the latent heat of fusion of a gamma crystal of 1.70% carbon, and is 0.72 calories less than the value 65.65 calories for pure delta iron at the same temperature.

(b) Heat of Solution of Cementite.

The heat of solution of cementite in austenite, that is, the heat of solution along the solubility curve of cementite may be obtained as in the case of the heat of fusion of gamma iron. In the case of solid gamma iron, the true specific heat is a function of temperature. The true specific heat at t_E° cannot be found directly, but it may be found from extrapolation of the true specific heat of the specimen M_i at high temperatures or that of other specimens. Now, if we take the temperature 720° as t_E°, and $\bar{S}_\gamma$ as the mean value of true specific heat of solid gamma iron, the following result is obtained:

$$A=6.67\,\%\mathrm{C},\ E=0.90\,\%\mathrm{C},\ t_E=720^\circ,\ t_3=1130^\circ.$$

M_i	1.05% C	1.33% C	1.57% C
Quantity of Cementite	0.0260	0.0745	0.1161

$\bar{S}_\gamma$	0.153	0.152	0.151
h_3	187.2	188.2	188.9
h_1	124.1_7	125.1	125.8_5
h_3-h_1	3.03	3.09	3.05
$\bar{S}_\gamma\ (t_3-t_E)$	62.75	63.32	61.91
Q_E	0.28	0.77	1.14
For one gram of Cementite	10.76	10.34	9.82

The relation between the heat of solution per gram of cementite and the carbon concentration is graphically shown in Fig. 34.

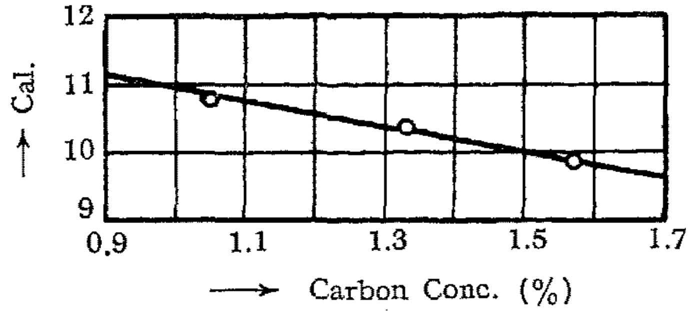

Fig. 34.

From the result, it will be seen that the heat of solution per gram of cementite at the temperature 720°, i. e., A_1 transformation point, depends upon the position of M_i. The heat of solution decreases linearly with the increasing carbon concentration, and at 0 and 0.9% carbon concentration the heats become 12.9 and 11.2 calories respectively. These heats depend upon the quantities of gamme iron as well as carbon concentration. Therefore, the relation between the quantity of gamma iron and the heat of solution to be given in Fig. 38 is shown in Table 22 and in Fig. 35.

Table 22.

C (%)	Fe_3C	0.9	Heat of Solution (720°)	Heat of Solution (1130°)
1.05	1 gr.	37.45 gr.	10.86	12.38
1.33	1	12.43	10.30	11.76
1.57	1	7.61	9.86	11.19

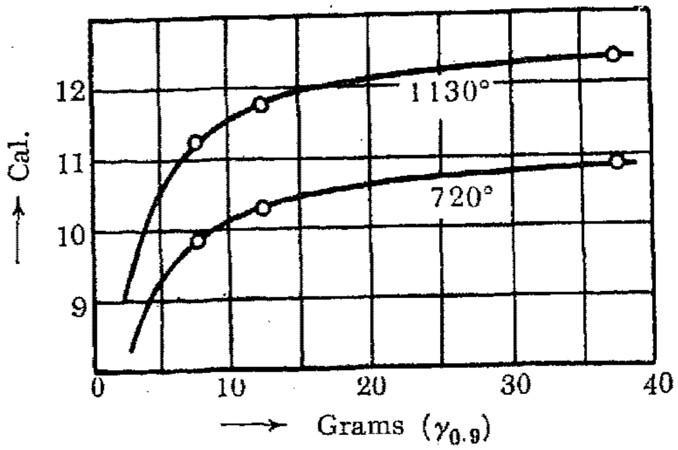

Fig. 35.

From this figure, it may be seen that the heat of solution per gram of cementite increases with the quantity of solvent, i. e. gamma iron of 0.9% carbon concentration. By a similar calculation, the heat of solution of cementite along the solubility curve will be obtained, and the results are shown in Table 23. From a thermodynamical calculation based on the equilibrium diagram of iron-carbon system, F. Korber and W. Öelsen⁽³⁴⁾ reported 30.2 calories as the heat of solution per gram of cementite to dissolve into gamma solid solution, but this value is very large as compared with that of the present writer.

Table 23.

Carbon (%)	0.90	1.05	1.33	1.57
Temperature	720°	870°	1005°	1092°
Heat of Solution (Cal.)	11.15	11.16	10.56	9.86

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(34) Arch. Eisenhütenwes., May, (1932), 5691.

The relations of the heat of solution to carbon concentration and to temperature are graphically shown in Figs. 36 and 37.

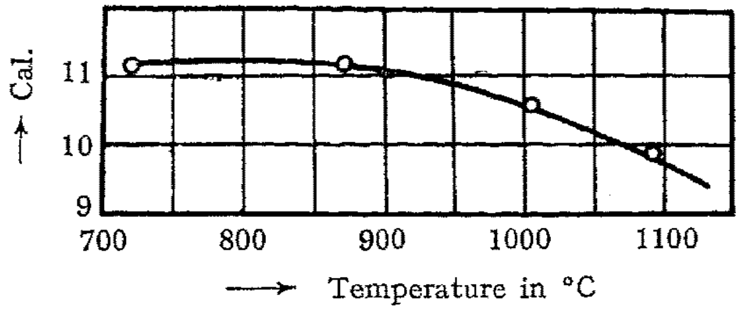

Fig. 36.

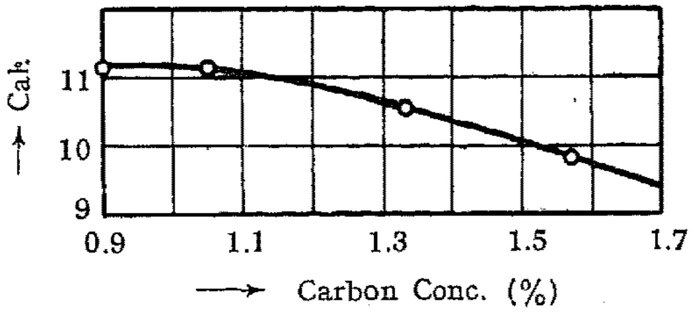

Fig. 37.

From the result, it may be seen that the heat of solution decreases gradually with the rise of temperature as well as the increasing carbon concentration, and that at 1130° it becomes 9.4 calories at the point of 1.7 percent carbon concentration. As mentioned above, the heat of solution of cementite is a function of temperature as well as carbon concentration, and the heat at a temperature of 1130° can be calculated as before; the results are given in Table 24. Here, $\bar{S}_c$ and $\bar{S}_\gamma$ are the mean values of the true specific heats of cementite and gamma iron of 0.9% carbon concentration at the temperature range of $t_1^\circ \sim t_2^\circ$, and $\bar{S}_s$ is that in the case, when the two parts are mixed and form a homogeneous solid. The specific heat of a specimen of 0.9 percent carbon concentration was obtained by extrapolation from other cases.

Table 24.

Heat of Solution at 1130°.

C(%)	t_1	t_2	$\bar{S}_c$	$\bar{S}_\gamma$	$2\bar{S}_s$	$\Delta Q'_l$	Q'_l	$Q'_l+\Delta Q'_l$
0.90	1130°	720°	0.164	0.149_8	0.310	1.56	11.15	12.71
1.05	1130	870	0.165	0.150_7	0.311	1.22	11.16	12.38
1.33	1130	1005	0.166_5	0.157_1	0.314	1.20	10.56	11.76
1.57	1130°	1092°	0.167	0.184	0.317	1.33	9.86	11.19

Heat of Solution at 720°.

0.90	720°	720°	0.159	0.130_8	0.289	0	11.15	11.15
1.05	870	720	0.160_8	0.131_4	0.290_1	0.32	11.16	10.84
1.33	1005	720	0.162_5	0.132_4	0.294	0.25	10.56	10.31
1.57	1092°	720°	0.163_5	0.135_6	0.297	0	9.86	9.86

The relation is graphically shown in Fig. 38.

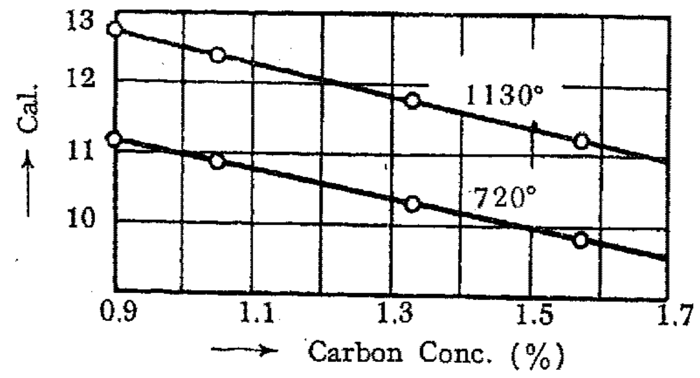

Fig. 38.

(c) Heat of Fusion of Cementite along the Liquidus.

Just in the same way as in the case of the heat of fusion of gamma crystal, the present writer calculated the heat of fusion of cementite in the case of hyper-eutectic cast iron as follows :

$A = 6.67\%$ C, $E = 4.30\%$ C, $t_E = 1130°$, $t_3 = 1600°$.

M_i	4.81% C	5.07% C
Quantity of cementite	$\frac{10.2}{47.4} \doteq 0.215$	$\frac{15.4}{47.4} = 0.325$
S_M	0.178_7	0.177_9
h_3	329.2_0	328.9_8
h_1	231.5_1	224.6_7
$h_3 - h_1$	97.6_9	104.3_1
$S_M\ (t_3 - t_E)$	83.99	83.6_1
Q_E	13.70	20.70

If we calculate the latent heat of fusion of cementite at 1130° from its true specific heat, we will obtain the value

$$65.0 - (1600 - 1130)(0.173_8 - 1.070_3) = 63.59.$$

The relation of Q_E and the quantity of cementite will be given in Fig. 39. From this figure, it will be seen that the heat to be required when cementite melts into the liquid of the corresponding carbon concentration depends upon the relative quantities of cementite and the liquid. Accordingly, the heat produced when one gram of cementite melts into the same quantity of liquid can be obtained by doubling Q_E which corresponds to 0.5 of the quantity of cementite in Fig. 39. Thus we get

$$31.84 \times 2 = 63.68 \quad \text{calories.}$$

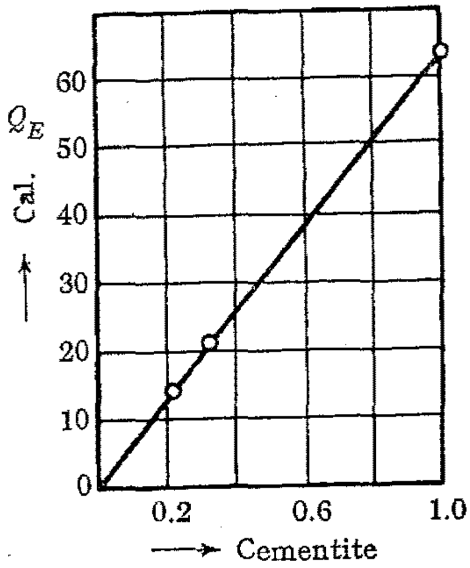

Fig. 39.

The heat of fusion per gram of cementite along the liquidus of the hyper-eutectic cast iron, when one gram of cementite melts into the same quantity of the liquid of the corresponding carbon concentration, can be obtained in the same way as before; the results are given in Table 25 and in Fig. 40.

Table 25.

Heat of Fusion of Cementite and Carbon Concentration.

Carbon (%)	Temperature	Heat of Fusion (Cal.), Q_s
4.30	1130°	63.68
4.81	1255°	64.05
5.07	1310°	64.16

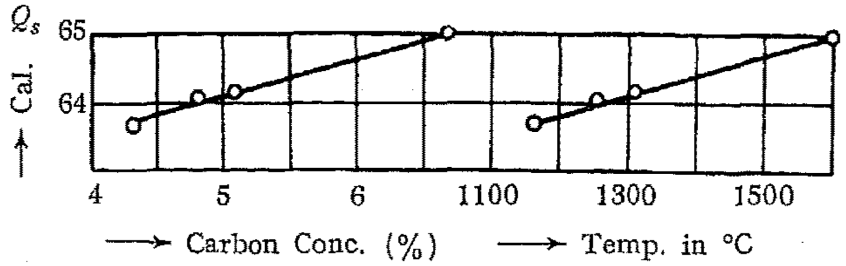

Fig. 40.

Thus we see that the heat of fusion increases with the rise of temperature or of carbon concentration, and from the extrapolation of these curves, we get 65.0 calories per gram at 6.67% carbon concentration, the melting temperature being 1600°. It is also important to know the heat of fusion at a given temperature, for example, at 1600° and 1130°. As before the variation of heat ΔQ_s by temperature change can be given by

$$\Delta Q_s = (t_1 - t_2)\,(2S_M - \bar{S}'_M - \bar{S}'_s).$$

Here, S'_M and S'_s are the mean value of true specific heats of liquid and cementite at the temperature range of $t_1^\circ \sim t_2^\circ$, and S_M is that of melt when the two parts are mixed and forms a uniform liquid. The results of calculation are given in Table 26.

Table 26.

Heat of Fusion of Cementite at 1600°.

Comp. of Solvent C(%)	t_1°	t_2°	$2\bar{S}_M$	$\bar{S}'_M$	$\bar{S}'_s$	ΔQ_s	Q_s	$Q_s+\Delta Q_s$
4.30	1600°	1130°	0.353_4	0.180_1	0.170_3	1.41	63.68	65.09
4.81	1600	1255	0.351_9	0.178_6	0.170_3	1.02	64.05	65.07
5.07	1600°	1310°	0.352_0	0.177_9	0.171	0.89	64.16	65.05

Heat of Fusion of Cementite at 1130°.

4.30	1130°	1130°	0.353_4	0.180_1	0.168_2	0.00	63.68	63.68
4.81	1130	1255	0.351_9	0.178_6	0.169_8	0.44	64.05	63.61
5.07	1130	1310	0.352_0	0.177_9	0.171_0	0.56	64.16	63.60
6.67	1130°	1600°	0.346_6	0.173_3	0.170_3	1.41	65.0	63.59

The relation between the heat and the carbon concentration of solvent is graphically shown in Fig. 41. It will be seen that the heat of fusion decreases slightly with the increase of carbon concentration at each of two temperatures 1600° and 1130°, and increases by a constant amount with the rise of temperature, independent of carbon concentration.

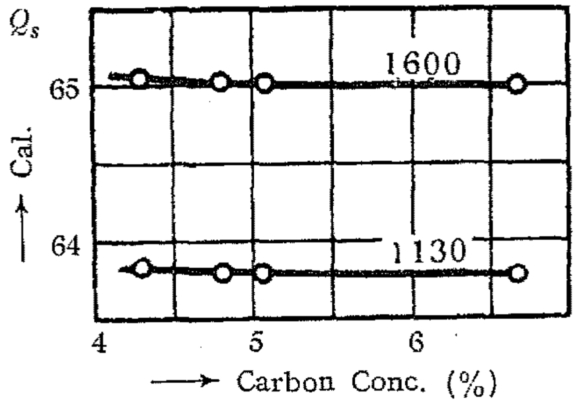

Fig. 41.

(7) Heat of Mixture of Melts in Iron-Carbon System.

On the heat of mixture of molten metals many reports have been already made by many investigators(35), but no publication on the heat of mixture in the case of iron-carbon system has ever been appeared.

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(35) A. Magnus and M. Manheimer, Zeits. Phys. Chem., **121** (1926), 267; G. N. Lewis and M. Randal, J. A. C. S., **43** (1921), 233; M. Kawakami, Sci. Rep., **16** (1927), 915.

The present writer intended to calculate this heat of mixture for iron-carbon system from his experimental results.

(a) Heat of Mixture of Gamma Iron.

The heat of fusion of one gram of gamma iron, which has been calculated in the previous article, is the sum of the latent heat of fusion itself and the heat of mixture of it to one gram of the liquid of the corresponding carbon concentration at that temperature. Hence, if Q_s, Q_l and H be the heat of fusion to the corresponding liquid, the latent heat of fusion and the heat of mixture respectively, the following equation will be obtained :

$$Q_s = Q_l + H.$$

Here, since Q_s and Q_l can be known as before, we can obtain the value of H.

The following table contains the values of Q_s and Q_l given in Table 14 and 17, and also H :

Table 27.

Heat of Mixture of Gamma Iron at 1130°.

C (%)	Q_s	Q_l	H
0.13	60.05	60.02	0.01
0.19	59.92	59.97	0.01
0.30	59.85	59.83	0.01
0.41	59.70	59.66	0.02
0.61	59.40	59.40	0.02
0.77	59.19	59.16	0.03
1.05	58.79	58.74	0.05
1.33	58.41	58.30	0.07
1.57	58.02	57.93	0.09
1.70	57.80	57.70	0.10

Here, H has been calculated from the mean values of Q_s and Q_l. The relations of Q_s and Q_l to carbon concentrations are graphically shown in Fig. 42.

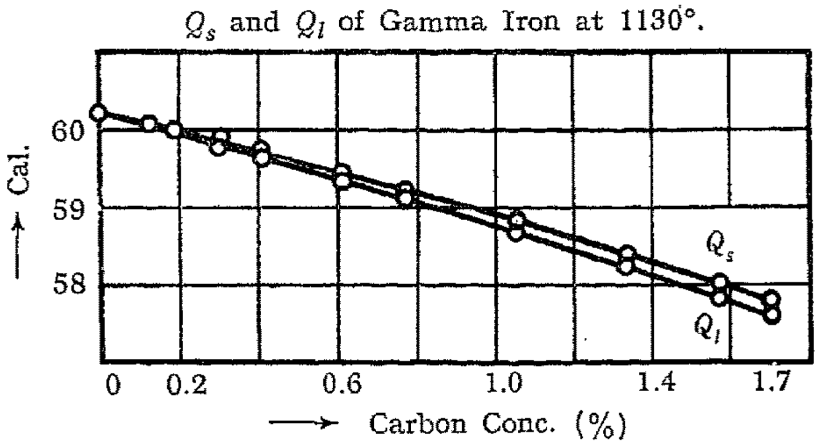


Fig. 42.

It will be seen that the heat of mixture H is very small and slightly increases with carbon concentration of gamma iron, as is shown in Fig. 43.

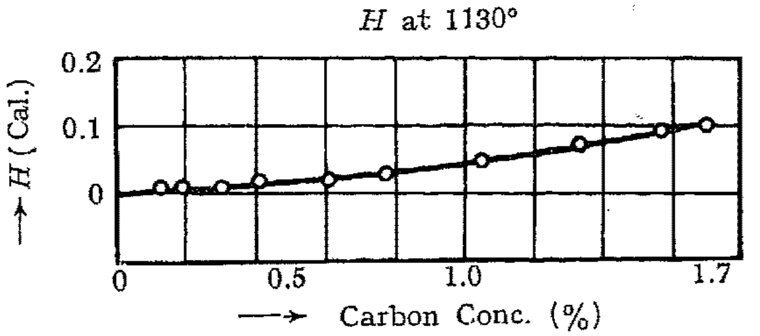


Fig. 43.

Thus we see that the heat of mixture will vanish in pure iron and the latent heat of fusion of pure gamma iron is 60.2 calories per gram.

In the previous calculation of the heat of fusion of gamma iron, the heat Q_s with which one gram of austenite of 1.70% carbon melts into the same quantity of the liquid of the corresponding carbon concentration, is not exactly equal to the heat of fusion of solid austenite itself; this fact indicates that the heat is required when liquid austenite mixes with the liquid of the corresponding carbon concentration. If we denote by α, β $(\alpha+\beta=1)$ the relative quantities of solid austenite and the liquid and by H_1 the difference of $\alpha(Q_s-Q_l)$; Q_l being 57.72 calories, then we have the relation shown in the following table, which contains the result of calculation for steels of different carbon contents:

Table 28.

M_i	$Q_E = aQ_s$	aQ_l	H_1	$\alpha\ \beta$	$K = \frac{H_1}{\alpha\ \beta}$
1.85	54.31	54.30	0.01	0.055	0.18
2.40	42.16	42.12	0.04	0.197	0.20
2.90	31.09	31.04	0.05	0.249	0.20
3.00	28.90	28.85	0.05	0.250	0.20
3.50	17.82	17.77	0.05	0.213	0.23

Mean $K=0.20$

From this table, it will be seen that H_1 is proportional to the product of the relative quantities of solid austenite and the liquid ; therefore if K be the proportional constant, we have $H_1 = K\alpha\beta$.

The heat of mixture H_m, when the total mass of the specimen is m,

$$H_m = K\alpha\beta\ m = 0.20\alpha\beta\ m.$$

If a and b represent the quantities of the two phases, the above equation becomes

$$H_m = K\frac{a}{a+b}\frac{b}{a+b}(a+b) = K\frac{ab}{a+b}.$$

Here the proportional constant depends upon the concentration and the temperature of two liquids. Since the heat of mixture given in Fig. 43 is the heat to be required, when one gram of each of two liquids mixes with each other, the same figure represents the relation of the half value of the constant K to the carbon concentration of gamma iron.

Q_l shown in Fig. 42 is the latent heat of fusion of gamma crystal of different concentrations ranging from 0 to 1.70% carbon at the eutectic temperature, but the latent heats of fusion of γ-crystals of pure iron and of a specimen containing 1.70% carbon are 60.20 and 57.70 calories respectively. Hence if the heat of mixture were absent, the latent heat of gamma crystals should fall on the line Q_l' connecting these two points. The relation between Q_l and Q_l' is shown in Fig. 44.

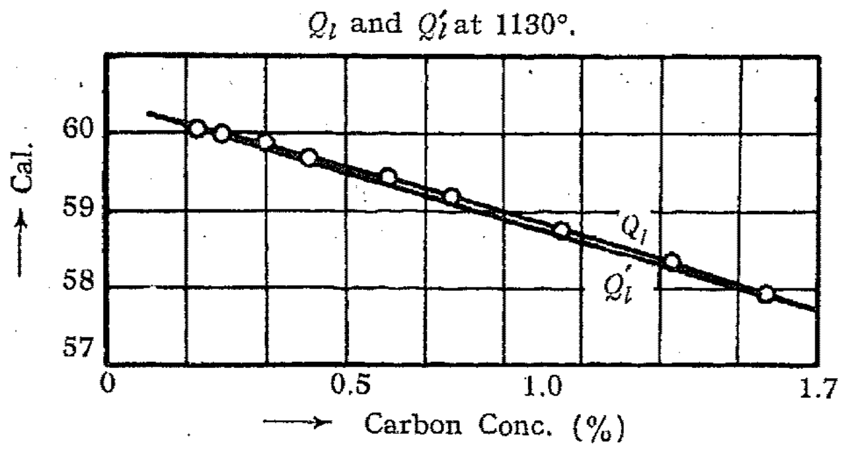


Fig. 44.

Thus the difference between Q_l and Q_l' is the heat of mixture required when the liquid of pure iron of a grams mixes with that of $(1-a)$ grams of 1.70% carbon concentration. Now, if H_1, α and β be the heat of mixture and the relative quantities of two parts respectively, the numerical relation among them is given in Table 29.

Table 29.

C (%)	Q_l	Q_l'	H_1	$\alpha\ \beta$	$K=\frac{H_1}{\alpha\ \beta}$
0.00	60.21	60.21	——	——	——
0.13	60.02	60.01	0.01	0.071	0.14
0.19	59.97	59.95	0.02	0.099	0.20
0.30	59.83	59.80	0.03	0.145	0.21
0.41	59.66	59.62	0.04	0.183	0.22
0.61	59.40	59.34	0.06	0.231	0.26
0.77	59.16	59.10	0.06	0.248	0.24
1.05	58.74	58.69	0.05	0.236	0.21
1.33	58.30	58.26	0.04	0.171	0.23
1.57	57.93	57.91	0.02	0.069	0.29
1.70	57.70	57.70	0	——	——

Mean $K=0.22$

Here, as the values of Q_l the mean values in the curve was taken; thus if equal quantities of two liquids are mixed and form a homogeneous liquid of one gram, the heat of mixture becomes

$$H_1=0.22\alpha\beta=0.55 \text{ calories.}$$

Next, consider the heat of mixture to be required when the liquid austenite of 1.70% carbon concentration mixes with liquid cementite. The latent heat of fusion of cementite is 63.59 calories per gram as shown in Table 26, and also that of austenite of 1.70% carbon is 57.70 calories per gram at the same temperature as shown in Fig. 11 and Table 9. Therefore, the values of Q_l' can be obtained as before, and consequently H_1 is known, as is shown in Table 30 and in Fig. 45.

Table 30.

Heat of Mixture of Cementite and Austenite at 1130°.

C (%)	Q_l	Q_l'	H_1	$\alpha\beta$	$K=\frac{H_1}{\alpha\beta}$
1.70	57.70	57.70	0.00	——	——
1.85	57.89	57.87	0.02	0.029	0.69
2.40	58.59	58.53	0.06	0.121	0.50
2.90	59.20	59.11	0.09	0.184	0.49
3.00	59.32	59.23	0.09	0.194	0.46
3.50	59.94	59.83	0.11	0.231	0.48
4.30	60.91	60.79	0.12	0.249	0.48
4.81	61.51	61.39	0.12	0.234	0.51
5.07	61.80	61.69	0.11	0.218	0.50
6.67	63.59	63.59	0.00		

Mean $K=0.51$

Q_l and Q_l' at 1130°.

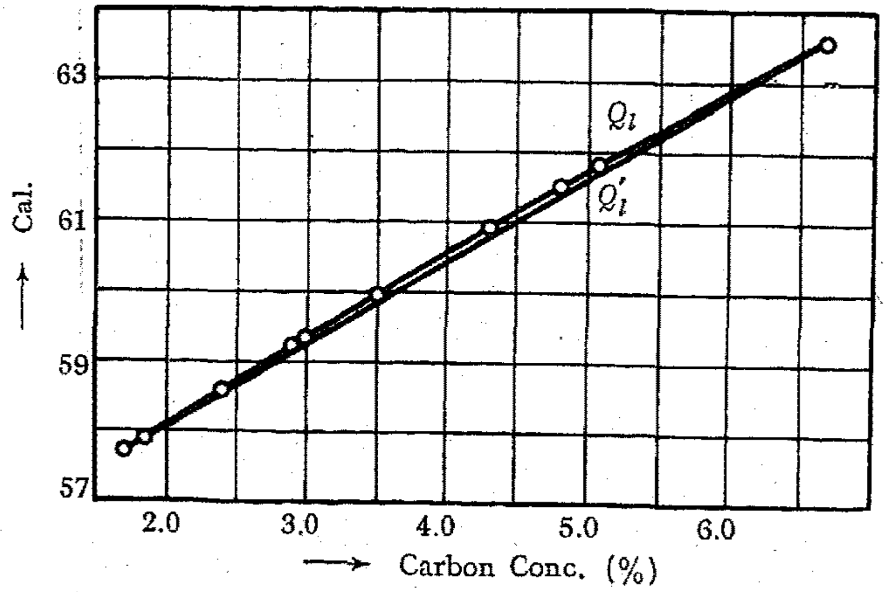


Fig. 45.

Thus the heat of mixture is proportional to the product $\alpha\beta$, the proportional constant K being 0.51 ; hence

$$H_1=0.51\,\alpha\beta, \quad \text{or} \quad H_m=0.51\,\alpha\beta\,m.$$

(b) Heat of Mixture of Melts at High Temperatures.

Since the heat of mixture of two liquids is a function of temperature, the present writer tried to obtain the heat of mixture at 1530° from that at the eutectic temperature. The heat of fusion Q_s at the eutectic temperature required when one gram of gamma iron melts into the same quantity of the liquid of the corresponding carbon concentration will be seen from Table 17, and the latent heat of fusion of gamma iron itself at the same temperature are already given in Table 13. The relation of these heats Q_s and Q_l to their carbon concentration is shown in Fig. 46.

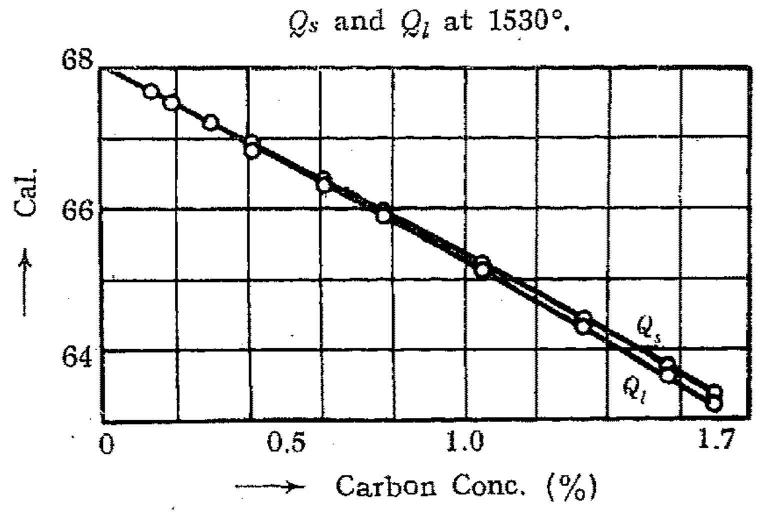


Fig. 46.

The difference between Q_s and Q_l is the heat of mixture required, when one gram of liquid austenite mixes with the same quantity of liquid of the corresponding carbon concentration. If we find the values of Q_s and Q_l from each of the mean curves shown in Fig. 46 and take their difference, the results in Table 31 are obtained.

Table 31.

Heat of Mixture of Liquids at 1530°.

C (%)	Q_s (Cal.)	Q_l (Cal.)	H_1
0.13	67.67	67.66	0.01
0.19	67.52	67.50	0.02
0.30	67.23	67.20	0.03
0.41	66.94	66.90	0.04
0.61	66.40	66.35	0.05
0.77	65.97	65.90	0.07
1.05	65.21	65.11	0.10
1.33	64.44	64.32	0.12
1.57	63.77	63.62	0.15
1.70	63.40	63.24	0.16

The relation between the heat of mixture and the carbon concentration is graphically shown in Fig. 47.

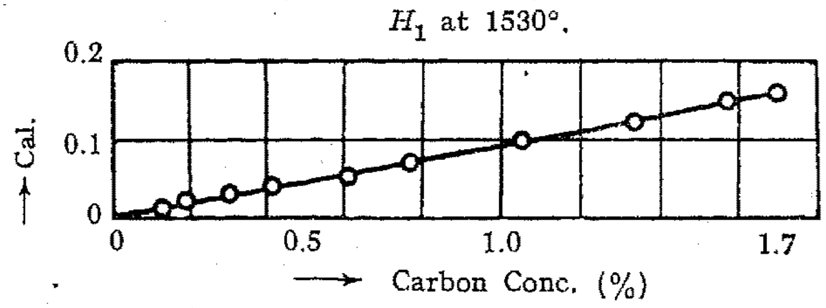


Fig. 47.

From this result, it will be seen that the heat of mixture is nearly proportional to carbon concentration, as in the case of eutectic temperature.

Next, we shall consider the heat of mixture to be absorbed when the liquid of pure iron mixes with the liquid of 1.70 percent carbon concentration at 1530°. The latent heats of fusion Q_l of gamma crystal of pure iron and that of 1.70% carbon concentration, at 1530°, are already known and have the values of 68.00 and 63.24 calories per gram respectively. Therefore, if the heat of mixture were absent, the latent heat of fusion of a gamma crystal in the range of 0 to 1.70% carbon concetration should fall on the line Q_l' connecting these two points. The relation between Q_l or Q_l' and carbon concentration is graphically shown in Fig. 48.

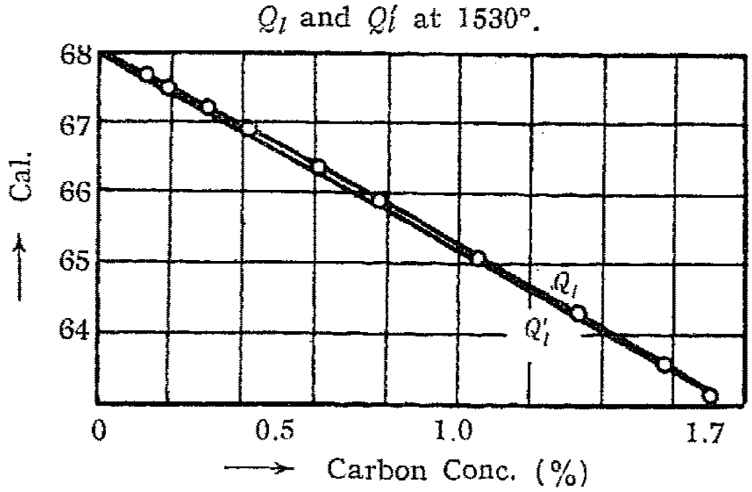


Fig. 48.

The difference between Q_l and Q_l' is the heat of mixture to be absorbed when at 1530° the liquid of pure iron mixes into the liquid of 1.70 percent carbon concentration in a definite proportion. Then, if H_1, α, β and K have the same meaning as before, the results given in Table 32 are obtained.

Table 32.

Heat of Mixture of liquid at 1530°.

C (%)	Q_l	Q_l'	H_1	$\alpha\ \beta$	$K=\dfrac{H_1}{\alpha\ \beta}$
0.13	67.66	67.64	0.02	0.071	0.28
0.19	67.50	67.47	0.03	0.099	0.28
0.30	67.20	67.15	0.05	0.145	0.35
0.41	66.90	66.84	0.06	0.183	0.33
0.61	66.35	66.28	0.07	0.231	0.30
0.77	65.90	65.82	0.08	0.248	0.32
1.05	65.11	65.03	0.08	0.236	0.34
1.33	64.32	64.26	0.06	0.171	0.35
1.57	63.60	63.60	0.02	0.069	0.29

Mean $K=0.32$

Thus the proportional constant K is greater by about 0.10 than in the case of eutectic temperature.

The latent heat of fusion of a given specimen above 1.70% carbon concentraion at 1530° can be obtained from the difference of heat content before and after the point, by extrapolating the heat content curve below the eutectic temperature up to 1530°, or may be calculated from the true specific heats at these temperatures as before. The heat thus calculated is given in Table 33. Here, S_1 and $\bar{S}_2$ are the mean values of true specific heats at these temperatures, and Q_l at the eutectic temperature was obtained from the curve Q_l given in the foregoing figure 45.

Table 33.

Latent Heat of Fusion Q_l at 1530°.

C (%)	t	S_1	$\bar{S}_2$	$\varDelta Q_l$	Q_l (1130°)	Q_l (1530°)
1.70	400	0.186_9	0.173_3	5.53	57.70	63.23
1.85	400	0.186_8	0.173_2	5.44	57.89	62.33
4.20	400	0.185_5	0.173_0	5.00	58.59	63.59
2.90	400	0.184_4	0.172_8	4.64	59.20	63.84
3.00	400	0.184_0	0.172_5	4.60	59.32	63.92
3.50	400	0.182_0	0.171_6	4.16	59.94	64.10
4.30	400	0.180_2	0.171_4	3.52	60.91	64.43
4.81	400	0.179_0	0.171_4	3.04	61.51	64.55
5.07	400	0.178_0	0.170_9	2.84	51.80	64.64
6.67	400	0.173_0	0.169_6	1.36	63.59	64.95

Also, the heat to be absorbed, when each of austenite and cementite melts separately and mixes together with each other at 1530°, can be calculated from the latent heats of two extreme menbers, i. e. 63.23 and 64.95 calories. From the straight line Q_l' connecting these two points and Q_l curve shown in Fig. 49, the heat of mixture can be obtained as before.

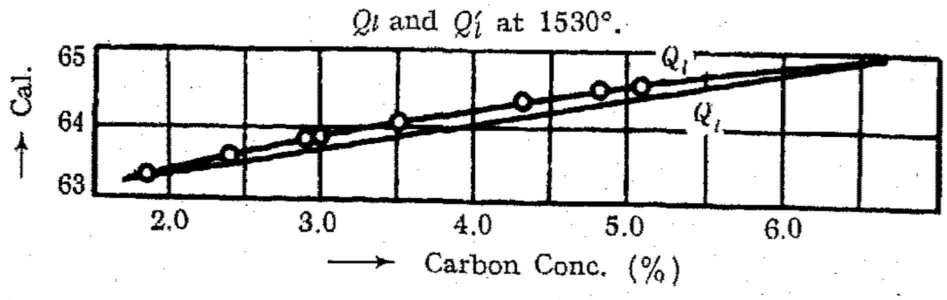


Fig. 49.

The following table contains the result of calculation together with the values of K:

Table 34.

Heat of Mixture and Its Proportional Constant at 1530°.

C (%)	Q_l	Q_l'	H_1	$\alpha\beta$	$K=\frac{H_1}{\alpha\beta}$
1.85	63.32	63.29	0.03	0.029	1.03
2.40	63.61	63.48	0.13	0.121	1.07
2.90	63.85	63.65	0.20	0.184	1.09
3.00	63.91	63.69	0.22	0.194	1.13
3.50	64.11	63.85	0.26	0.231	1.13
4.30	64.41	64.14	0.27	0.249	1.08
4.81	64.56	64.30	0.26	0.234	1.11
5.07	64.63	64.39	0.24	0.218	1.10

Mean $K=1.09$

Thus we see that H_1 and K are nearly doubled as compared with those at eutectic temperature given in Table 30. When the equal quantities of liquids are mixed and form a homogeneous liquid of one gram, the heat of mixture becomes

$$H_1=1.09\ \alpha\beta=0.27 \quad \text{calories.}$$

(c) **Heat of Mixture of Delta Iron.**

As the latent heat of fusion of delta iron of 0.07 percent of carbon, a value of 64.84 calories at the peritectic temperature was obtained from the curve shown in Fig. 17. In the same way, the latent heat of fusion in the case of 0.03 and 0.05 percent of carbon can be obtained and the result is given in Table 35 and Fig. 50.

Table 35.

Latent Heat of Fusion Q of Delta Iron.

C (%)	Temp. (°C)	Q_l
0.00	1530	65.65
0.03	1511	65.30
0.05	1498	65.06
0.07	1487	64.84

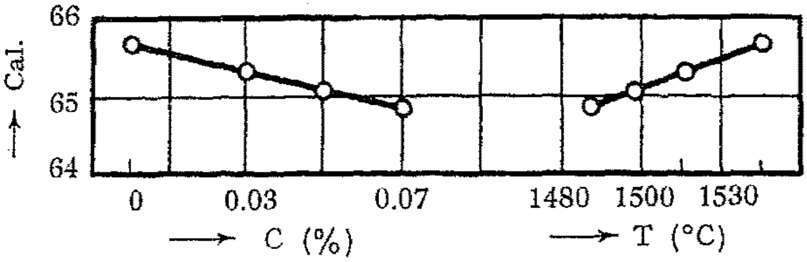


Fig. 50.

Thus with the increase of carbon concentration, the latent heat of fusion of delta iron decreases and with the rise of temperature it increases. If the same quantity is reduced to the peritectic temperature, the results given in Table 36 and graphically shown in Fig. 51 are obtained.

Table 36.

Latent Heat of Fusion Q_l of Delta Iron at 1487°.

C (%)	$\Delta t(t-1487)$	S_1	$\bar{S}_2$	ΔQ_l	Q_l (t)	Q_l (1487°)
0.00	43	0.192_8	0.181_5	0.49	65.65	65.16
0.03	24	0.192_7	0.180_4	0.27	65.30	65.03
0.05	11	0.192_6	0.180_2	0.14	65.06	64.92
0.07	0	0.192_5	0.180_0	0	64.84	64.84

The difference between Q_l and Q_s reduced to the same temperature is the heat of mixture to be required, when the liquid of one gram of delta iron mixes with that of the same quantity of the corresponding carbon concentration. The numerical data thus obtained are given in Table 37.

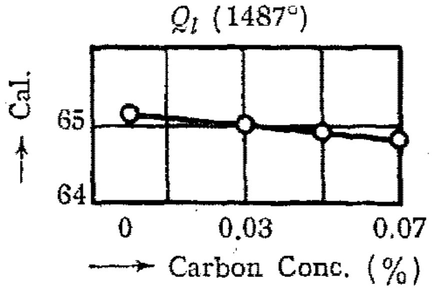


Fig. 51.

Table 37.

Heat of Mixture of Delta Iron at 1487°.

C (%)	Q_s	Q_l	H_1
0.00	65.15	65.15	0.00
0.03	65.05	65.03	0.02
0.05	64.96	64.92	0.04
0.07	64.90	64.84	0.06

It is seen that the heat of mixture is proportional to the carbon concentration of delta iron; this is also evident from Fig. 52.

We shall further consider the value of K in the case when the liquid of delta iron of 0.07 percent carbon mixes with that of the corresponding carbon concentration, the result of calculation is given in Table 38.

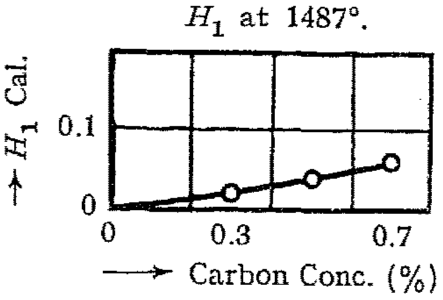


Fig. 52.

Table 38.

C (%)	$Q_E = aQ_s$	aQ_l	H_1	$a\ \beta$	$K = \frac{H_1}{a\ \beta}$
0.11	55.85	55.83	0.02	0.120	0.17
0.13	51.50	51.48	0.02	0.165	0.12
0.19	37.96	37.93	0.03	0.242	0.12
0.30	13.44	13.42	0.02	0.164	0.12

Mean $K = 0.13$

Next, the heat of mixture at 1530° is given in Table 39 and Fig. 53.

Table 39.
Heat of Mixture of Delta Iron at 1530°.

C (%)	Q_s (Cal.)	Q_l (Cal.)	H_1
0.00	65.65	65.65	0.00
0.03	65.55	65.52	0.03
0.05	65.46	65.40	0.06
0.07	65.37	65.28	0.09

Thus, it will be seen that the heat of mixture increases with carbon concentration.

(d) Heat of Mixture and Heat of Solution of Cementite.

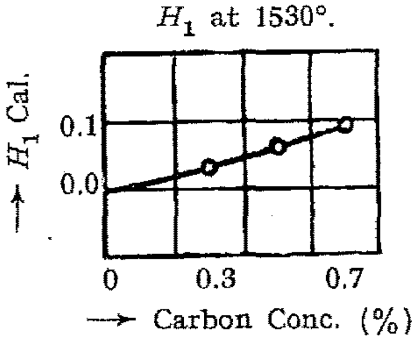


Fig. 53.

The heat of fusion Q_s per gram of cementite which dissolves into the liquid of one gram of the corresponding hyper-eutectic cast iron at the eutectic temperature can be obtained from Table 26, and the latent heat of fusion of cementite, Q_l, is 63.59 calories per gram. Then the difference between Q_s and Q_l is the heat of mixture; the result of calculation is given in Table 40.

Table 40.

Heat of Mixture of Cementite at 1130°.

C (%)	Q_s	Q_l	H_1
4.30	63.68	63.59	0.09
4.81	63.61	63.59	0.02
5.07	63.60	63.59	0.01
6.67	65.59	63.59	0.00

We have seen that the heat of mixture when one gram of liquid cementite mixes with the same quantity of gamma iron of 1.7% carbon concentration is 0.26 calories, thus the values in Table 40 together with this value are graphically shown in Fig. 54.

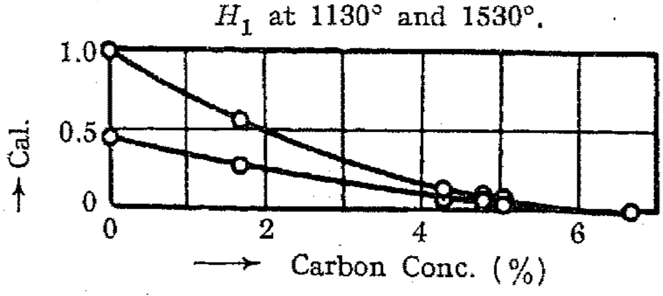


Fig. 54.

From this, it may be seen that the heat of mixture of pure iron is 0.48 calories and decreases with the increase of carbon concentration.

Table 41.

Heat of Mixture of Cementite at 1530°.

C (%)	Q_s (Cal.)	Q_l (Cal.)	H_1
1.70	65.50	64.95	0.55
4.30	65.06	64.95	0.11
4.81	65.04	64.95	0.09
5.07	65.02	64.95	0.07
6.67	64.95	64.95	0.00

Calculated in the same way, the heat of mixture at 1530° given in Table 41 and Fig. 54 is obtained. Thus, the heat of mixture decreases with the increase of carbon concentration. The proportional constant K in the case of mixture of the liquid of eutectic alloy and that of cementite can be obtained as before, as shown in Table 42.

Table 42.

C (%)	Q_E	aQ_l	H_1	$\alpha\ \beta$	$K=\dfrac{H_1}{\alpha\ \beta}$
4.81	13.70	13.67	0.03	0.169	0.18
5.07	20.70	20.67	0.03	0.219	0.14

Mean $K=0.16$

As we have already seen, the latent heats of fusion of pure iron, cementite and sustenite of 1.70% carbon at the eutectic temperature are 60.22, 63.59 and 57.70 calories, and those at 1530°, 68.00, 64.95 and 63.24 calories, respectively. If we find the relation between these values and carbon concentration, two triangles ABC and $A'B'C'$ are obtained as graphically shown in Fig. 55. Assuming that an iron-carbon alloy consists of a mixture of iron and cementite before melting, the latent heat of fusion will fall on the line AB or $A'B'$, if the heat of mixture be disregarded.

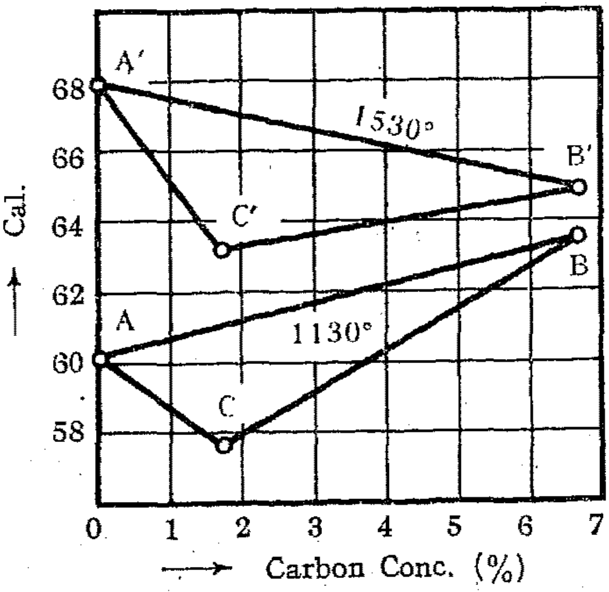


Fig. 55.

On the other hand if the specimen before melting is assumed to consist of iron and austenite of 1.70% carbon, or of this austenite and cementite, its latent heat of fusion will fall on the lines AC and $A'C'$ or BC and $B'C'$, if the heat of mixture be disregarded. Thus a specimen is supposed to have the latent heat of fusion of two kinds.

Correcting for their latent heat of fusion at these temperatures, by the heat of mixture given in the previous article, let us denote by Q_1 and Q_2 the latent heats corresponding to the curves AB and AC, and by γ_0, $\gamma_{1.7}$ and $C_{6.67}$ the latent heats of fusion of iron, austenite of 1.70% carbon and cementite, respectively. Then, for a given specimen the following equation will hold :

$$a\gamma_0 + b\gamma_{1.7} = Q_2,$$

$$c\gamma_0 + dC_{6.67} = Q_1.$$

Here, a, b, c and d are the quantities of each component in one gram, then the above equations become

$$\gamma_0(c-a) + d\,C_{6.67} - b\gamma_{1.7} = Q_1 - Q_2.$$

If Q be the heat to be required when one gram of cementite dissolves into gamma crystal of pure iron and forms a gamma crystal of 1.7% carbon, then we have

$$Q = \frac{Q_1 - Q_2}{d}.$$

From the curve given in Fig. 55, a, b, c, d and Q_1, Q_2, Q can be calculated; the numerical data are given in Table 43. Thus the heat required when one gram of cementite dissolves into gamma crystal of pure iron and forms a gamma crystal of 1.70% carbon, is 12.66 calories per gram at the eutectic temperature. Since this heat is that when one gram of cementite dissolves into 2.92 grams of gamma crystal of pure iron, the heat required when one gram of cementite dissolves into 2.92 grams of gamm crystal of 0.9% carbon concentration is 9.48 calories from the foregoing figure 35 at the same

Table 43.

Heat of Solution of Cementite into Pure Gamma Iron at 1130°.

C (%)	b ($\gamma_{1.7}$)	$(c-a)$ (γ_0)	d ($C_{6.67}$)	Q_1-Q_2	Q
0.05	0.294	0.219	0.075	0.95	12.66
1.00	0.588	0.437	0.151	1.91	12.65
1.50	0.882	0.657	0.225	2.85	12.66
1.70	1.000	0.745	0.255	3.22	12.64
2.00	0.937	0.700	0.237	3.00	12.66
3.00	0.738	0.550	0.188	2.38	12.66
4.00	0.537	0.399	0.138	1.75	12.68
5.00	0.336	0.249	0.087	1.11	12.75
6.00	0.134	0.099	0.035	0.44	12.56

Mean $Q = 12.66$

temperature, and the heat required when one gram of cementite dissolves into 2.92 grams of it is zero; hence the relation between these heats and carbon concentrations of their solvents will be as shown in Fig. 56. From this result, it will be seen that the heat required when one gram of cementite dissolves into 2.92 grams of

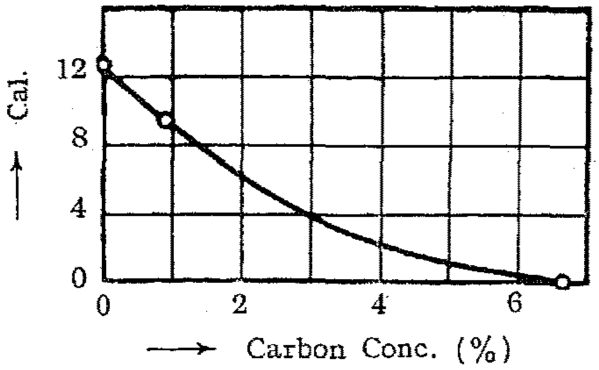


Fig. 56.

Table 44.

Heat of Solution of Cementite in Pure Iron at 1530°.

C (%)	b ($\gamma_{1.7}$)	$(c-a)$ (γ_0)	d ($C_{6.67}$)	Q_1-Q_2	Q
0.50	0.294	0.219	0.075	1.07	14.26
1.00	0.588	0.437	0.151	2.15	14.25
1.50	0.882	0.657	0.225	3.22	14.30
1.70	1.000	0.745	0.255	3.62	14.20
2.00	0.937	0.700	0.237	3.40	14.37
3.00	0.738	0.550	0.188	2.68	14.25
4.00	0.537	0.399	0.138	1.96	14.20
5.00	0.336	0.249	0.087	1.24	14.26
6.00	0.134	0.099	0.035	0.50	14.29

Mean $Q = 14.26$

gamma crystal decreases as the carbon concentration increases.

Next, we consider the same heat at 1530°. If we calculate Q from the triangle $A'B'C'$ and take its carbon concentration as before, the numerical data as given in Table 44 are obtained. Thus, the heat of solution increases by 1.60 calories per gram than that at the eutectic temperature.

Now, we consider the heat required to form gamma crystal of carbon concentration B by dissolving c grams of cementite into gamma crystal of carbon concentration A, which consists of a grams of pure iron and b grams of cementite. The sum of heats to be required when b and c grams of cementite dissolve separately into a grams of pure gamma crystal should be equal to the heat of solution of $(b+c)$ grams of cementite into a grams of pure gamma crystal. Therefore, if $K_{0.C}$ and $K_{A\cdot C}$ denote the proportional constants when cementite dissolves into pure gamma crystal and gamma crystal A respectively, the following holds good.:—

$$K_{\gamma_0\cdot C}\frac{ab}{a+b}+K_{A.C}\frac{(a+b)c}{a+b+c}=K_{\gamma_0\cdot C}\frac{a(b+c)}{a+b+c}\,.$$

Hence
$$K_{A.C}=K_{\gamma_0\cdot C}\left(\frac{a}{a+b}\right)^2$$

or,
$$K_{A.C}\frac{(a+b)c}{a+b+c}=K_{\gamma_0\cdot C}\frac{(a+b)c}{a+b+c}\left(\frac{a}{a+b}\right)^2,$$

whereas, from Table 43, we get,
$$K_{\gamma_0\cdot C}\frac{(a+b)c}{a+b+c}=12.66\,c\,.$$

Therefore,
$$K_{A.C}\frac{(a+b)c}{a+b+c}=12.66\,c\left(\frac{a}{a+b}\right)^2$$

Now, if we put
$$K_{A.C}\frac{(a+b)c}{a+b+c}=Q_{\gamma_A.C}\quad\text{and}\quad\left(\frac{a}{a+b}\right)^2=D^2,$$

D denoting the difference in the carbon concentrations, then the above equation becomes

$$Q_{\gamma_{A}.C}=QcD^2. \tag{4}$$

If we know the composition of the solvent, we can calculate D and therefore the value of $Q_{\gamma_{A}\cdot C}$ can be known.

(e) Constant K of the Heat of Mixture in Lquids.

As mentioned above, the heat of mixture in the liquids of iron carbon system is always endothermic reaction. Now, let us represent the liquids of gamma crystal of pure iron and 1.70% carbon, that of delta crystal of 0.07% carbon, and those of 0.36, 4.30, 6.67% carbon, by γ_0, $\gamma_{1.7}$, $\delta_{0.07}$, $C_{0.36}$, $C_{4.30}$ and $C_{6.67}$, respectively, and also the difference in carbon concentrations of two mixed liquids by D; then the proportional constant K can be calculated in terms of D in the following way :—

When two liquids A and B, which consist of iron and cementite in a given proportion, are mixed together, then denoting by $K_{A.B}$ and $K_{O.C}$ the proportional constants of the heat of mixture of liquids A and B, and of iron and cementite, respectively, the following equation exists :

$$K_{0.C}\left(\frac{ab}{a+b}+\frac{cd}{c+d}\right)+K_{A.B}\frac{(a+b)(c+d)}{(a+b)+(c+d)}$$

$$=K_{0.C}\frac{(a+c)(b+d)}{(a+c)+(b+d)}$$

where a, b and c, d denote the quantities of iron and cementite contained in each liquid. Thus the above equation will be written as follows :—

$$K_{A.B}\frac{(a+b)(c+d)}{(a+b+c+d)}=K_{0.C}\left\{\frac{(a+c)(b+d)}{(a+c+b+d)}-\frac{ab}{(a+b)}-\frac{cd}{(c+d)}\right\}.$$

That is,

$$K_{A.B}=\frac{K_{0.C}}{(a+b)(c+d)}\left\{\frac{ad(a+c)+bc(b+d)}{(a+b)}-\frac{cd(a+b+c+d)}{(c+d)}\right\}$$

$$=K_{0.C}\left\{\frac{bc-ad}{(a+b)(c+d)}\right\}^2=K_{0.C}\left\{\frac{b}{(a+b)}-\frac{d}{(c+d)}\right\}^2$$

So that,

$$K_{A.B}=\frac{K_{0.C}}{(0.0667)^2}\left\{\frac{0.0667\,b}{(a+b)}-\frac{0.0667\,d}{(c+d)}\right\}^2$$

Here, as the term in the bracket represents the difference D of carbon concentrations in the two liquids, we have

$$K_{A.B}=\frac{K_{0.C}}{(0.0667)^2}D^2$$

Table 45.

Proportional Constant for the Heat of Mixture at 1130° and 1530°.

Liquids		$\gamma_{1.70}$	$\gamma_{1.70}$	$\delta_{0.07}$	$C_{4.30}$	γ_0	γ_0
		$C_{4.30}$	$C_{6.67}$	$C_{0.36}$	$C_{6.67}$	$C_{6.67}$	1.70
$D\times10^{-2}$		2.60	4.97	0.29	2.37	6.67	1.70
K	1130°	0.20	0.51	0.13	0.16	0.86	0.22
	1530°	0.32	1.09	0.18	0.22	1.96	0.32

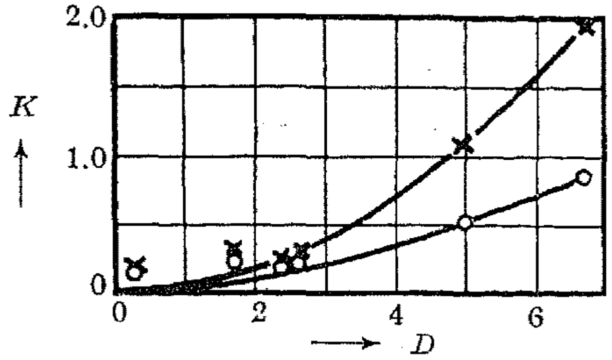
In the case of the liquids at temperatures 1130° and 1530°, the value of $K_{0.C}$ becomes 0.86 and 1.96 respectively, as has been already obtained. So the above equation will be written as follows:—

$$K_{A.B(1130^\circ)}=\frac{0.86}{(0.0667)^2}D^2=193\,D^2$$

and

$$K_{A.B(1530^\circ)}=\frac{1.96}{(0.0667)^2}D^2=440\,D^2$$

From these equations, we see that the proportional constant $K_{A.B}$



× (1530°) ; ∘ (1130°).

Fig. 57.

is proportional to the square of the difference of carbon concentrations in liquids *A* and *B*. The results of calculation of this comstant at 1130° and 1530° are given in Table 45, and the relation between *K* and *D* is graphically shown in two curves in Fig. 57.

(8) Heat of Mixture of Solids in Iron-Carbon System.

The present writer has also confirmed that the same law of mixture in liquids holds good for two solids. The heat of transformation, the heat of fusion or solution and the heat of reaction may be considered to be the heats required when a solid transforms into the other, a solid dissolves into solid or liquid, and a liquid reacts with a solid to form a uniform solid, respectively. Hence, the present writer intended to calculate these heats according to the law of mixture.

(a) Constant of the Heat of Solution of Cementite in Gamma Crystal of Pure Iron.

From the foregoing table 43, the constant of heat of solution was calculated and the result is given in Table 46.

Table 46.

Constant of the Heat of Solution at 1130°.

C (%)	b	$(c-a)\,d=\alpha\beta$	$(Q_1-Q_2)=H_1$	$\frac{H_1}{\alpha\beta}=K$
0.5	0.294	0.0164	0.95	17.03
1.0	0.588	0.0659	1.91	17.06
1.5	0.882	0.1476	2.85	17.04
1.7	1.000	0.1899	3.22	16.96
2.0	0.937	0.1658	3.00	16.95
3.0	0.738	0.1034	2.38	17.00
4.0	0.537	0.0550	1.75	17.08
5.0	0.336	0.0217	1.11	17.18
6.0	0.134	0.0035	0.44	16.85

Mean $K=17.02$

Thus, the heat of solution H_1, by which cementite dissolves into gamma crystal of pure iron, is proportional to the product $\alpha\beta$, and is given by the equation

$$H_m = K\,\frac{ab}{(a+b)^2}\,.$$

So, as in the case of liquid, the constant $K_{A\cdot B}$ of the heat of mixture of two gamma irons of respective carbon concentrations becomes

$$K_{A.B} = \frac{K_{0.C}}{(0.0667)^2}\,D^2 = \frac{17.02}{(0.00445)}\,D^2 = 3825\,D^2\,.$$

We shall next consider the heat of solution of cementite into gamma crystal of pure iron at A_1 point. The following table contains the latent heat of fusion Q_{γ_0} of pure gamma crystal, that of cementite $Q_{C6.67}$, that of gamma crystal of 1.7% carbon concentration $Q_{\gamma1.7}$, respectively.

Table 47.

Heat of Solution at 720°.

L.H.F.	t_1	t_2	S_1	$\bar{S}_2$	ΔQ_l	Q_l	$Q_l+\Delta Q_l$
$Q_{\gamma 0}$	1530°	720°	0.192_8	0.168_8	19.44	68.02	48.58
$Q_{C6\cdot 67}$	1600°	720°	0.173_3	0.160_3	11.44	65.0	53.56
$Q_{\gamma 1\cdot 7}$	1530°	720°	0.187_5	0.167_4	16.28	63.24	46.96

By drawing a triangle as in Fig. 55, the heat of solution of cementite at 720° has been obtained as before and the result is given in Table 48.

Table 48.

Heat of Solution of Cementite into Gamma Crystal of Pure Iron at 720°.

C (%)	b ($\gamma_{1.7}$)	$c-a$ (γ_0)	d (c)	(Q_1-Q_2)	Q
0.5	0.294	0.219	0.075	0.84	11.20
1.0	0.588	0.437	0.151	1.69	11.19

C (%)	$b\ (\gamma_{1.7})$	$c-a\ (\gamma_0)$	$d\ (c)$	(Q_1-Q_2)	Q
1.5	0.882	0.657	0.225	2.52	11.20
1.7	1.000	0.745	0.255	2.86	11.23
2.0	0.937	0.700	0.237	2.66	11.23
3.0	0.738	0.550	0.188	2.11	11.23
4.0	0.537	0.399	0.138	1.55	11.24
5.0	0.336	0.249	0.087	0.97	11.15
6.0	0.134	0.099	0.035	0.39	11.14

Mean $Q=11.21$

Thus, the heat of solution to be required when one gram of cementite dissolves into gamma crystal of pure iron at A_1 point to form a homogeneous gamma crystal of 1.7% carbon concentration becomes 11.21 calories. If we calculate the constant K as in Table 46, the result given in Table 49 is obtained.

Table 49.

Constant of Heat of Solution at 720°.

C (%)	b	$(a-c)\ d=\alpha\beta$	$(Q_1-Q_2)=H_1$	$\dfrac{H_1}{\alpha\ \beta}=K$
0.5	0.294	0.0164	0.84	15.05
1.0	0.588	0.0659	1.69	15.11
1.5	0.882	0.1476	2.53	15.05
1.7	1.000	0.1899	2.86	15.05
2.0	0.937	0.1658	2.66	15.04
3.0	0.738	0.1034	2.11	15.09
4.0	0.537	0.0550	1.55	15.14
5.0	0.336	0.0217	0.97	15.01
6.0	0.134	0.0035	0.39	14.94

Mean $K=15.05$

So the constant $K_{A.B}$ for the heat of solution at 720° becomes

$$K_{A.B}=\frac{15.05}{(0.0667)^2}D^2=3383D^2.$$

As given in Table 44, the heat of solution to be required when one gram of cementite dissolves into the gamma crystal of pure iron at 1530° is 14.26 calories, and consequently the value of K becomes

$$K_{1530^\circ}=19.18.$$

Therefore, the constant $K_{A \cdot B}$ at a temperature of 1530° can be written as follows:

$$K_{A.B} = \frac{19.18}{(0.0667)^2} D^2 = 4310\, D^2.$$

Thus, the constants of the heat of solution in the case of two given gamma crystals and also the heat at these temperatures, are collected in Table 50.

Table 50.

Heat of Solution of Cementite and Temperatures.

Temperature	720°	1130°	1530°
Q	11.21	12.66	14.26
$K_{\gamma.C}$	15.05	17.02	19.18
$K_{A.B}$	3383 D^2	3825 D^2	4310 D^2

The relation of the heat of solution of cementite to temperature is graphically shown in Fig. 58, and that of $K_{A \cdot B}$ to the temperature is shown in Fig. 59.

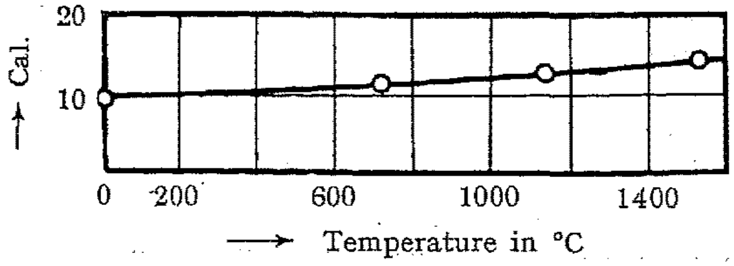


Fig. 58.

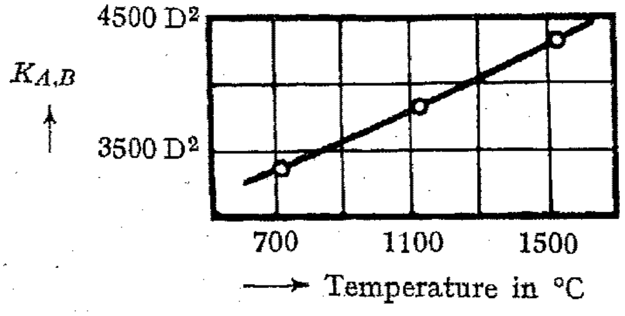


Fig. 59.

Finally, if we find the ratio of the constants for the heat of mixture in liquid and solid phases at the same temperature, the result given in Table 51 and Fig. 60 are obtained.

Table 51.

Comparison of Constants in the cases of Liquids and Solids.

Temp. (°C)	1000	1130	1300	1530
$K_{A.B}$ (Solids)	3680 D^2	3825 D^2	4030 D^2	4310 D^2
$K_{A.B}$ (Liquids)	113.7 D^2	193 D^2	298 D^2	440 D^2
Ratio	32.3	19.8	13.5	9.8

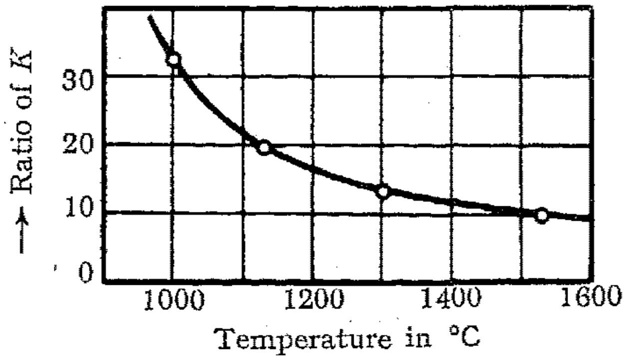


Fig. 60.

From this result, it will be seen that the constant $K_{A.B}$ in case of liquids is much less than that of solids.

(b) Heat of Solution of Cementite along the Solubility Curve.

The heat of solution of cementite has been already given in the foregoing tables 23 and 24; this heat is one required when cementite dissolves into the gamma crystal of the corresponding carbon concentration to form a uniform gamma crystal. The constant of the heat of solution in the case of cementite and gamma crystal of 0.9% of carbon at 720° and 1130° can be obtained from Table 50; thus

$$K_{720^\circ}=3383\times(0.0577)^2=11.25.$$
$$K_{1132^\circ}=3825\times(0.0577)^2=12.73.$$

From these quantities, the heat of solution of cementite h or the heat per gram of cementite H can be obtained; the result of calculation is given in Table 52, and is almost the same as that given in Table 24.

Table 52.

Heat of Solution of Cementite at 720°.

C (%)	Fe_3C	γ_0	K	h	H
0.9					11.25
1.05	0.0260	0.9740	11.25	0.284	10.94
1.33	0.0746	0.9254	11.25	0.776	10.41
1.57	0.1162	0.8838	11.25	1.154	9.93
1.70	0.1388	0.8612	11.25	1.344	9.68

The same Heat at 1130°.

C (%)	Fe_3C	γ_0	K	h	H
0.90					12.73
1.05	0.0260	0.9740	12.73	0.3218	12.37
1.33	0.0746	0.9254	12.73	0.8770	11.75
1.57	0.1162	0.8838	12.73	1 306	11.24
1.70	0.1388	0.8612	12.73	1.520	10.95

Fig. 61 shows the same result graphically; here H varies in a direct proportion to carbon concentration c and is given by the equation

$$H=Ac+B,$$

where $A=-1.93$ and $B=12.87$ at 720° and $A=-2.20$ and $B=14.70$ at 1130°. H will vanish at the concentration $C=-A/B$; with the above values of A and B, this ratio becomes 6.67, which as is to be expected, is the concentration of cementite.

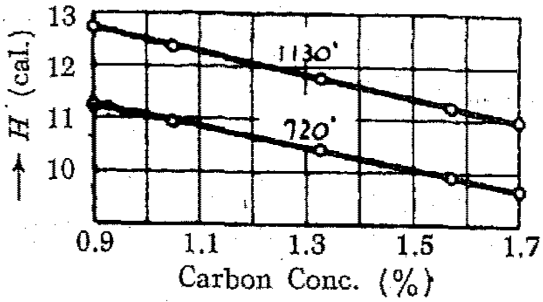


Fig. 61.

Next, we shall calculate the constant K of the heat of solution along the solubility line ; $K_{A.B}$ is obtained by Fig. 59, and K from it, as given in the table below :

Table 53.

Constant of Heat of Solution of Cementite along the Solubility Curve.

C (%)	Temp.	$K_{A.B}$	D^2	K
0.90	720°	$3383\,D^2$	$(0.0577)^2$	11.25
1.05	870	$3540\,D^2$	$(0.0562)^2$	11.16
1.33	1005	$3680\,D^2$	$(0.0534)^2$	10.49
1.57	1092	$3780\,D^2$	$(0.0510)^2$	9.83
1.70	1130°	$3825\,D^2$	$(0.0497)^2$	9.43

By this result, the heat of solution of cementite along the solubility line can be obtained.

(c) **Constant of the Heat of A_1 Transformation.**

The constant of the heat of A_1 transformation can also be calculated, as is given in Table 54.

Table 54.

Constant of the Heat of A_1 Transformation at 720°.

C (%)	a (Fe)	b (Fe_3C)	$\frac{ab}{a+b}$	Heat of A_1 Transf.	K	H
0.5	0.481	0.075	0.065	9.00	138.5	119.8
0.9	0.865	0.134_6	0.116_5	16.10	138.2	119.5
1.7	0.745	0.116_2	0.100_6	13.89	138.1	119.6
3.0	0.560	0.085_5	0.074	10.25	138.2	119.9
4.0	0.400	0.062	0.053_6	7.41	138.2	119.4
5.0	0.250	0.039	0.033_8	4.66	138.2	119.4
6.0	0.100	0.016	0.013_8	1.91	138.2	119.2

Mean $K=138.2$ $H=119.5$

Here, as the heat of A_1 transformation, the mean values of the observed results is taken, and H is the heat required when one gram of cementite dissolves into gamma crystal to form a uniform crystal of 0.9% carbon. Thus the mean values of K and H are 138.2 and 119.5 calories respectivelly.

Next, we shall consider the value of the heat of A_1 transformation at the eutectic temperature 1130°. Using the same notation as before, the heat of A_1 transformation of a sepcimen containing 0.9% carbon at 1130° can be calculated as follows :

$$\begin{aligned}&16.10+(1130-720)\ (\bar{S}_{\gamma 0\cdot 9}-a\bar{S}_{\alpha 0}-b\bar{S}_C)\\&=16.10+(1130-720)\ (0.157-0.167_1-0.022_1)\\&=2.90.\end{aligned}$$

So the heat required per gram of cementite becomes

$$2.90\div 0.1346=21.55 \text{ calories.}$$

Also, in the case of a specimen of 0.9% carbon concentraion, we get 1.70 calories from the interpolation of the data given in Table 43, and therefore the heat required when one gram of cementite dissolves into the gamma crystal of zero carbon is

$$1.70\div 0.1346=12.63 \text{ calories.}$$

The quantities of alpha and gamma crystals and the heat of solution of cementite in these two phases are summarised below :

Table 55.

Heat of Solution of Cementite at 1130°.

C (%)	α (grams)	γ_0 (grams)	Fe_3C (grams)	Calories
0.9	6.425	——	1.00	21.55
0.9	——	6.425	1.00	12.63

$\alpha \rightarrow \gamma_0=8.92$

This value of the difference is the heat of transformation from alpha to gamma crystal; if it is referred to one gram, it becomes 1.39 calories. This value nearly coincides with that obtained by extrapolation of the curve in Fig. 29.

In the same way the heat of A_1 transformation at 920° becomes

$$16.10+(920-720)\ (0.149-0.174_1-0.021_9)=6.70.$$

The heat of A_1 transformation at 720°, 920° and 1130° being thus obtained, the constant K is calculated and given in Table 56 and in Fig. 62.

Table 56.

Constant of Heat of the A_1 Transformation.

Temperature	α (Fe)	β (Fe_3C)	$\frac{\alpha\beta}{\alpha+\beta}$	A_1	K
720	0.8654	0.1346	0.1165	16.10	138
920	0.8654	0.1346	0.1165	6.70	58
1130	0.8654	0.1346	0.1165	2.94	25

The heat of transformation as well as its constant continuously decreases with the rise of temperature. Similarly we can obtained the same heat in other percentages of carbon at a given temperature, the numerical data of which are shown in Fig. 63.

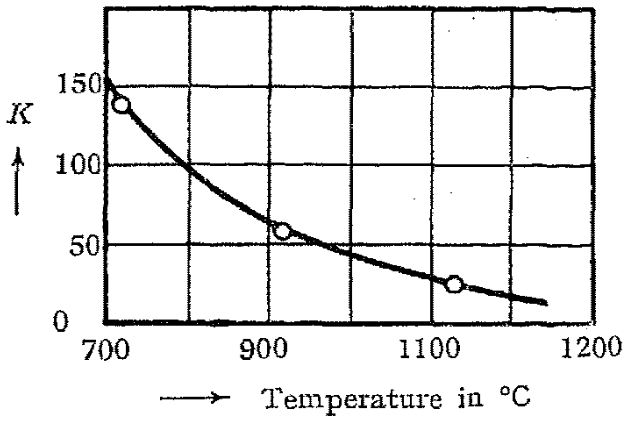


Fig. 62.

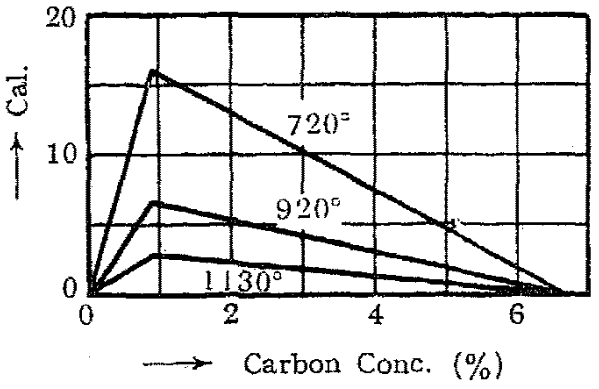


Fig. 63.

(d) Heat of Reaction as Heat of Mixture.

The heat of reaction at different carbon concentrations, when cementite and gamma crystal of 1.70% carbon mix together with each other to form a uniform liquid of 4.3% carbon concentration can be obtained from the heat of eutectic reaction given in Fig. 9; from these values the constant of the heat of reaction can be calculated. The result is given in Table 57. By using this constant, we can obtain the heat of reaction of a specimen of any carbon concentration. The same constant is equal to the heat of mixture, when two grams of each liquid mix together with each other.

Table 57.

Constant of the Heat of Reaction at 1130°.

C (%)	Q (Cal.)	$\alpha\beta$	K
2.0	7.0	0.029	243.4
3.0	30.6	0.125	243.5
4.0	53.9	0.221	243.3
4.3	60.8	0.250	243.4
5.0	42.9	0.176	243.2
6.0	17.1	0.070	243.0

Mean $K=243.3$

Next, we shall consider the latent heat of fusion at the eutectic point, of a specimen, for which it is assumed that cementite in the specimen dissolves into gamma crystal of 1.70% carbon to form a uniform gamma crystal. From the foregoing table 50, the constant in the case of mixture of cementite and gamma crystal of 1.70% carbon becomes

$$K=3825\times(0.050)^2=9.4 \text{ calories},$$

and in the case of a lower percentage of carbon than the above, it becomes

$$K=3825\times(0.017)^2=1.11 \text{ calories}.$$

Thus, if we calculate the heat of fusion of solids, the results tabulated in Table 58 are obtained.

Table 58.

Heat of Fusion in Solid at 1130°.

C (%)	$\alpha(\gamma_0)$ or $\alpha(Fe_3C)$	$\beta(\gamma_{1.7})$	H_1 (Cal.)	Q_l	$Q_m=Q_l-H_1$
0.5	0.706	0.294	0.23	59.47	59.24
1.0	0.412	0.588	0.27	58.74	58.47
3.0	0.261	0.738_5	1.82	59.25	57.43
4.3	0.523	0.477	2.35	60.79	58.44
5.5	0.765	0.235	1.70	62.19	60.49

Here, in the case of specimens of 0.5 and 1.0% carbon, α represents the quantity of gamma crystal in pure iron, and in the other case the quantity of cementite, and β is always that of the gamma crystal of 1.70% of carbon. Q_l represents the latent heat of fusion of the specimen and is obtained from Figs. 44 and 45 by interpolation of Q_l curves, and therefore the latent heat of fusion of the specimen consisting of gamma crystal of a uniform concentration will be Q_m.

In the same way, if we assume that a given specimen consists of cementite and gamma crystal of pure iron, the heat of solution between these two components can be calculated ; the results are given in Table 59.

Table 59.

Heat of Solution in Solid (γ_0+Fe_3C).

C (%)	α (γ_0)	β (Fe_3C)	$\alpha\beta$	$K(\gamma_0+Fe_3C)$	H_1 (Cal.)
0.5	0.925	0.075	0.069_3	17.02	1.18
1.0	0.850_5	0.149_5	0.127_1	17.02	2.16
1.7	0.745_5	0.254_5	0.189_9	17.02	3.23
2.5	0.625	0.375	0.234_3	17.02	3.90
3.0	0.541	0.459	0.248	17.02	4.22
4.3	0.356	0.644	0.229	17.02	3.90
5.0	0.252	0.748	0.188_5	17.02	3.21
6.0	0.100	0.900	0.090	17.02	1.53

The relation between Q_m and its carbon concentration given in Table 58 is graphically shown in Fig. 64. It will be seen in the

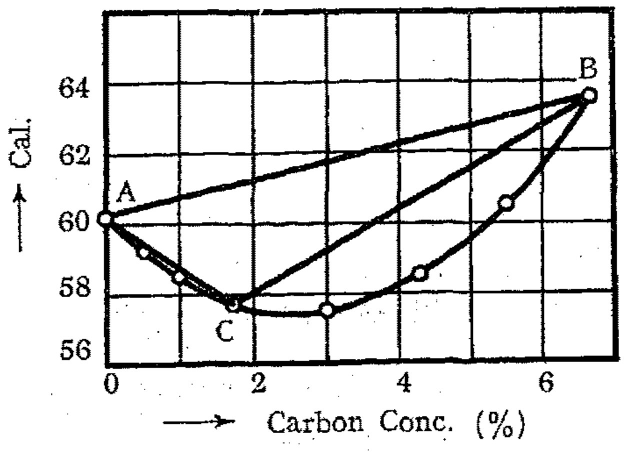


Fig. 64.

triangle *ABC* that the heat corresponding to the difference between the line *AC* and the curve *AC*, or that between the line *BC* and the curve *BC*, is H_1 given in Table 58, and the difference of heats between the line *AB* and the curve *ACB* is H_1 given in Table 59.

The constant of the heat of peritectic reaction can also be calculated as before; the results are given in Table 60. Here, H_p represents the heat of peritectic reaction. As already remarked, the peritectic reaction on heating is always endothermic. Knowing the value of *K*, the heat of reaction of a specimen of any concentration can be obtained by calculations.

Table 60.

Constant of Heat of Peritectic Reaction at 1487°.

C (%)	$a+b$ ($\gamma_{0\cdot 13}$)	a ($\gamma_{0\cdot 36\cdot}$)	b ($\delta_{0\cdot 07}$)	$\frac{a\ b}{a+b}$	H_p (Cal.)	K
0.09	0.333	0.069	0.264	0.0546	4.90	89.5
0.11	0.667	0.138	0.529	0.1092	9.75	89.4
0.13	1.000	0.207	0.793	0.1640	14.70	89.6
0.15	0.913	0.189	0.724	0.1495	13.40	89.6
0.20	0.695_5	0.143_5	0.552	0.1137	10.20	89.6
0.25	0.478	0.100	0.378	0.0791	7.06	89.2
0.30	0.261	0.054	0.207	0.0428	3.83	89.5

Mean $K=89.5$

Similarly the heat of reaction, when delta crystal of 0.07% carbon and gamma crystal of 0.36% carbon mix each other to form a uniform gamma crystal of 0.13% carbon, can be calculated. The latent heat of fusion of the gamma crystal of 0.36% carbon at the eutectic point is already given in Table 14, and therefore the same quantity at the peritectic temperature can be deduced. Since the value at 1130° is 59.75 calories, that at 1487° can be obtained as before:

$$59.75+(1487-1130)(0.191_7-0.172_7)=66.53.\ \text{calories.}$$

From this value, the heat evolved H_l, when different quantities of the liquid of the same concentration solidify, can be calculated. Then the difference H_p-H_l is the required heat of mixture of two solid phases, and the constant in this case can also be obtained, as given in Table 61.

Table 61.

Constant of the Heat of Mixture of $\delta_{0\cdot07}$ and $\gamma_{0\cdot36}$ at 1487°.

C (%)	a ($\gamma_{0.36}$)	$\frac{ab}{a+b}$	H_p-H_l	K
0.09	0.069	0.0547	4.90−4.59=0.31	5.68
0.11	0.138	0.1092	9.75−9.17=0.53	5.32
0.13	0.207	0.1640	14.70−13.77=0.93	5.67
0.15	0.187	0.1495	13.40−12.57=0.83	5.56
0.20	0.143_5	0.1137	10.20−9.55=0.65	5.71
0.25	0.100	0.0791	7.06−6.65=0.41	5.19
0.30	0.054	0.0428	3.83−3.59=0.24	5.61

$K=5.53$

By means of this constant, we can calculate the heat of transformation from delta crystal of 0.07% carbon to gamma crystal and the result is found to be 1.13 calories por gram.

(9) Space-Model representing the mutual relation of Heat Content, Temperature and Carbon Concentration.

Based on the observed results, the present writer tried to show the mutual relation of heat content, temperature and carbon concentration by a space model, for which he adopted Professer K. Honda's diagram of iron-carbon system(36), shown in Fig. 65. Thus on each point in the diagram, a line perpendicular to the plane of the diagram is erected and its length is taken as proportional to the heat content at that point; thus a surface showing the mutual relation of the heat content, temperature and carbon concentration is obtained as is shown in Fig. 66, the same relation in the vicinity of the peritectic reaction is also shown in another model, Fig. 67, in a magnified scale.

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(36) Sci. Rep., l. c.

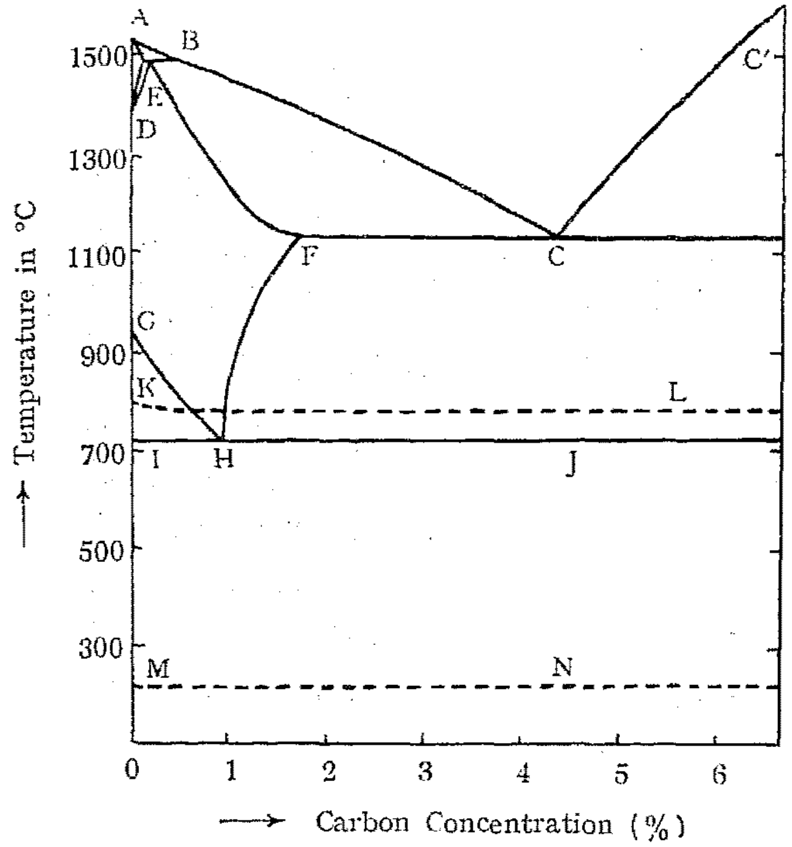
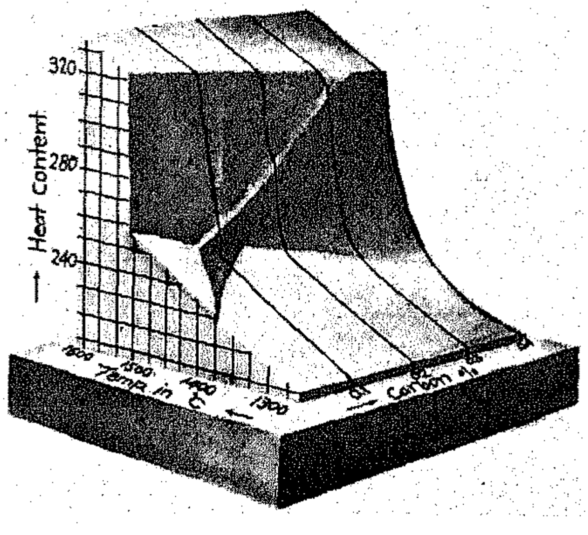
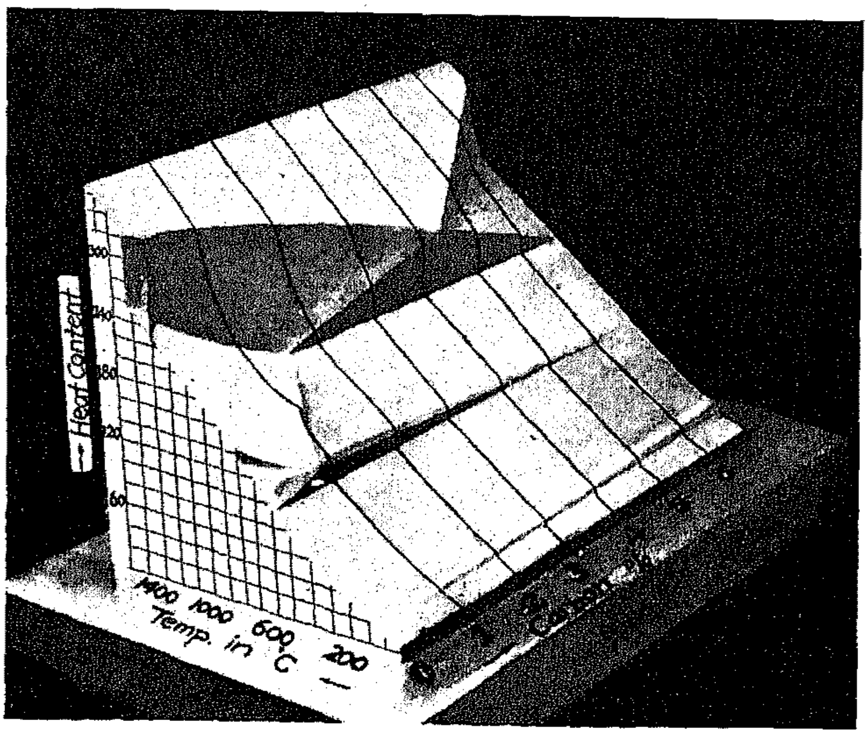


Fig. 65.



Space-Model of Heat Content, Temperature and Carbon Concentration.

Fig. 66.



Magnified Model showing a Portion of Peritectic Reaction.

Fig. 67.

It is seen from the space-model that all lines in iron-carbon diagram find the corresponding space lines in the model, and that along the lines of the diagram in which during heating an abrupt or continuous heat absorption is observed, the surface of the model shows an abrupt or continuous rise respectively; as an example of the first case, the heat content along the eutectic and A_1 lines and as that of the second case, the heat content along A_0, A_2, A_3 lines, etc., may be cited.

§ IV Summary of the Present Investigation.

1. Heat Content and Specific Heat.

(1) Heat contents of 19 kinds of alloys in iron-carbon system ranging from 0.07 to 5.07% carbon are measured by the method of mixture at different high temperatures up to beyond the melting

point of these alloys, and the heat content temperature relation has been obtained therefrom.

(2) The abrupt increase of the heat-content occurs at the peritectic, eutectic, A_1 and A_3 transformation points, but in other changes of state, the heat content shows a gradual change.

(3) The mean specific heat of different steels and cast irons increases with carbon content and also with the rise of temperature. It abruptly increases at eutectoid point and also in the coexisting range of solid and its melt, but after the fusion, it diminishes slowly.

(4) The true specific heat generally increases with the rise of temperature, but in crossing the solubility curve of cementite, an abnormal change is recognized. During fusion, it abruptly increases, and afterwards remains constant, but this value gradually decreases with the content of carbon.

(5) At A_0 and A_2 points, the true specific heat shows an abnormal change.

2. Heat of Reaction, Heat of Solution and Heat of Transformation.

(1) The heat of peritectic reaction has been obtained from the difference in heat content before and after the peritectic temperature, and the relation between the heat and the carbon concentration is also obtained. The heat of peritectic reaction of a specimen of 0.13% carbon concentration is 14.7 calories per gram.

(2) The heat of solution of gamma crystal below 0.13% carbon into delta crystal of the corresponding carbon concentration has been calculated ; its amount decreases with the rise of temperature.

(3) The heat of eutectic reaction has been obtained from the difference in heat content before and after the eutectic temperature, and the latent heat of fusion of eutectic alloy is found to be 60.9 calories per gram of the specimen.

(4) The heat of transformation and that of solution of alpha into gamma crystal at the A_3 transformation point have been obtained.

The former begins from 5.59 calories in pure iron and ends in 16.60 calories per gram in 0.9% carbon, and the latter from 5.59 calories to 16.74 calories in the same carbon concentration, respectively.

(5) From the mutual relation of heat content, temperature and carbon concentration for iron-carbon system, the heat content and specific heat of cementite at high temperatures can be obtained. The heat of A_0 transformation in cementite is found to be 9.35 calories per gram.

3. Heat of Fusion and Latent Heat of Fusion.

(1) The heat of fusion of gamma crystal on the solidus, when it melts into the liquid of the corresponding carbon concentration, is 57.8 calories per gram for gamma crystal of 1.70% carbon, and 67.2 calories for that of 0.13% carbon, respectively; it is a function of temperature and carbon concentration.

(2) The heat of fusion of delta crystal to melts into the liquid of the corresponding carbon concentration is 64.9 calories per gram for delta crystal of 0.07% carbon, and 65.3 calories for that of 0.03% carbon, respectively; it is also a function of temperature and carbon concentration.

(3) The latent heat of fusion itself has been obtained from the extreme value of the heat of fusion. This heat is slightly less in every case than that of fusion.

(4) From the mutual relation of the heat-content, temperature and carbon concentration, the latent heat of fusion of cementite has been obtained by extrapolation, and this heat becomes 65.0 calories per gram; its melting point is estimated to be 1600°.

4. Heat of Mixture.

(1) From the difference between the heat of fusion by which delta, gamma crystal or cementite melts into the liquid of the corresponding carbon concentration, and the latent heat of fusion itself at

the same temperature, the heat of mixture to be required, when they mix with each other, has been obtained.

(2) From the difference between the latent heats of fusion of pure gamma crystal and 1.7% carbon or cementite at a given temperature, the heat of solution, by which a solid dissolves into the other, or the heat of transformation or reaction can be obtained.

(3) If a and b be the quantities of two liquids or solids respectively, the heat of mixture H_m can be given by the following equation

$$H_m = K\frac{ab}{a+b},$$

where $$K = f(t)\,D^2.$$

The constant K is a function of temperature t and of the difference of carbon concentrations D in two materials.

(4) In the case of the mixture of two liquids, the constant K has always the following form:

$$K = f(t)\,D^2 = (0.6158t - 503)D^2\,;$$

but, in the case of solids, $f(t)$ is expressed by a quadratic function of temperature.

(5) The heat of mixture of two liquids or two solids is always endothermic reaction, except the case of solution of delta into gamma crystal.

In conclusion, the present writer wishes to express his cordial thanks to Professor K. Honda, the Principal of the Tôhoku Imperial University, for his kind guidance; he is also very grateful to Dr. T. Noda, the former Director of the Reserach Institute of the Imperial Government Steel Works, Mr. T. Kuroda, the former chief of the Fourth Department of the same Institute, Professor M. Ono of the Kyushu Imperial University, Mr. S. Kokubo, the Assistant Professor of the Research Institute for Iron, Steel and Other Metals, Tohoku Imperial University, Sendai, for their valuable advice. It should also be mentioned that the present work owes very much to the following assistants; Messers. T. Nakahata, Y. Okada, M. Seto, K. Ishii, S. Koga and T. Tsukada who cooperated in the experiments during several years with untiring efforts.

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