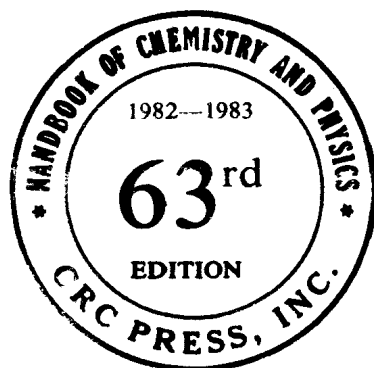


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A Ready-Reference Book of Chemical and Physical Data



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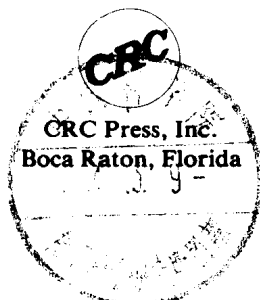
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In collaboration with a large number of professional chemists and physicists whose assistance is acknowledged in the list of general collaborators and in connection with the particular tables or sections involved.



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PREFACE

This is the 63rd Edition of the *Handbook of Chemistry and Physics* published over the past 69 years. It was the intent of the publisher to revise the book annually. However, there was no possibility of doing so during the years of World Wars I and II; there were simply more urgent matters than the revision of reference books. Nevertheless, this 63rd Edition, just as the 1st Edition of 1913, has been prepared to assist primarily those who are utilizing physical methods for investigations and research and for uniformly reporting results of such investigations and research. This current edition reflects the continuing efforts by the publisher and the editor to address educational institutions' and industries' concerns and needs for information and data in support of chemistry, physics and closely related sciences.

For the past few years the *Handbook of Chemistry and Physics* has contained considerable information concerning symbols, units and nomenclature in physics. This is being continued in the present edition and is being supplemented by extensive information on symbols and terminology for physicochemical quantities and units. All of the appropriate information is approved by the International Union of Pure and Applied Physics or the International Union of Pure and Applied Chemistry. Use of this information will permit scientists and others to report their results in a consistent and internationally approved form.

In mid-1981 the National Bureau of Standards essentially completed its multi-year effort of revising NBS Circular 500, by F. D. Rossini, D. D. Wagman, W. H. Evans, S. Levine and I. Jaffe. D. D. Wagman was in charge of the group which carried out the revision. The revised data were published over a period of years in the NBS Technical Note 270 series. Availability of the entire NBS TN-270 series permitted the editors of the *Handbook of Chemistry and Physics* to update the enthalpy, entropy, Gibbs free energy of formation, and heat capacity for many compounds and ions listed in the *Handbook*. Thus there has been a complete revision and updating of that section of the *Handbook* containing thermodynamic properties of inorganic compounds. These revised data have all been calculated from a uniform reference base. The number of compounds and ions for which data is presented in the *Handbook* is only a fraction of those contained in the complete NBS TN-270. However, the quantity should be more than sufficient to meet most of the needs of investigators.

A major addition to this edition of the *Handbook* is the Formula Index for the 15,000 compounds listed in the organic table. Addition of this index will reduce significantly the time necessary to locate certain compounds within the table.

In keeping with the growing importance of outer space, new information on our solar system and on cosmic radiation has been included in this edition. In addition, with the advent of better information, the data and charts on the U.S. standard atmosphere have been revised and added to this edition.

In a sense the *Handbook of Chemistry and Physics* is a cooperative one, depending in part upon its Contributors and Collaborators as well as upon suggestions from users of the *Handbook*. The help and guidance are appreciated.

R. C. Weast
March, 1982

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522 Uuq	523 Uuq	524 Uuq	525 Uuq	526 Uuq	527 Uuq	528 Uuq	529 Uuq	530 Uuq	531 Uuq	532 Uuq	533 Uuq	534 Uuq	535 Uuq	536 Uuq	537 Uuq	538 Uuq	539 Uuq	540 Uuq
550 Uuq	551 Uuq	552 Uuq	553 Uuq	554 Uuq	555 Uuq	556 Uuq	557 Uuq	558 Uuq	559 Uuq	560 Uuq	561 Uuq	562 Uuq	563 Uuq	564 Uuq	565 Uuq	566 Uuq	567 Uuq	568 Uuq
578 Uuq	579 Uuq	580 Uuq	581 Uuq	582 Uuq	583 Uuq	584 Uuq	585 Uuq	586 Uuq	587 Uuq	588 Uuq	589 Uuq	590 Uuq	591 Uuq	592 Uuq	593 Uuq	594 Uuq	595 Uuq	596 Uuq
606 Uuq	607 Uuq	608 Uuq	609 Uuq	610 Uuq	611 Uuq	612 Uuq	613 Uuq	614 Uuq	615 Uuq	616 Uuq	617 Uuq	618 Uuq	619 Uuq	620 Uuq	621 Uuq	622 Uuq	623 Uuq	624 Uuq
626 Uuq	627 Uuq	628 Uuq	629 Uuq	630 Uuq	631 Uuq	632 Uuq	633 Uuq	634 Uuq	635 Uuq	636 Uuq	637 Uuq	638 Uuq	639 Uuq	640 Uuq	641 Uuq	642 Uuq	643 Uuq	644 Uuq
646 Uuq	647 Uuq	648 Uuq	649 Uuq	650 Uuq	651 Uuq	652 Uuq	653 Uuq	654 Uuq	655 Uuq	656 Uuq	657 Uuq	658 Uuq	659 Uuq	660 Uuq	661 Uuq	662 Uuq	663 Uuq	664 Uuq
670 Uuq	671 Uuq	672 Uuq	673 Uuq	674 Uuq	675 Uuq	676 Uuq	677 Uuq	678 Uuq	679 Uuq	680 Uuq	681 Uuq	682 Uuq	683 Uuq	684 Uuq	685 Uuq	686 Uuq	687 Uuq	688 Uuq
686 Uuq	687 Uuq	688 Uuq	689 Uuq	690 Uuq	691 Uuq	692 Uuq	693 Uuq	694 Uuq	695 Uuq	696 Uuq	697 Uuq	698 Uuq	699 Uuq	700 Uuq	701 Uuq	702 Uuq	703 Uuq	704 Uuq
706 Uuq	707 Uuq	708 Uuq	709 Uuq	710 Uuq	711 Uuq	712 Uuq	713 Uuq	714 Uuq	715 Uuq	716 Uuq	717 Uuq	718 Uuq	719 Uuq	720 Uuq	721 Uuq	722 Uuq	723 Uuq	724 Uuq
726 Uuq	727 Uuq	728 Uuq	729 Uuq	730 Uuq	731 Uuq	732 Uuq	733 Uuq	734 Uuq	735 Uuq	736 Uuq	737 Uuq	738 Uuq	739 Uuq	740 Uuq	741 Uuq	742 Uuq	743 Uuq	744 Uuq
746 Uuq	747 Uuq	748 Uuq	749 Uuq	750 Uuq	751 Uuq	752 Uuq	753 Uuq	754 Uuq	755 Uuq	756 Uuq	757 Uuq	758 Uuq	759 Uuq	760 Uuq	761 Uuq	762 Uuq	763 Uuq	764 Uuq
766 Uuq	767 Uuq	768 Uuq	769 Uuq	770 Uuq	771 Uuq	772 Uuq	773 Uuq	774 Uuq	775 Uuq	776 Uuq	777 Uuq	778 Uuq	779 Uuq	780 Uuq	781 Uuq	782 Uuq	783 Uuq	784 Uuq
786 Uuq	787 Uuq	788 Uuq	789 Uuq	790 Uuq	791 Uuq	792 Uuq	793 Uuq	794 Uuq	795 Uuq	796 Uuq	797 Uuq	798 Uuq	799 Uuq	800 Uuq	801 Uuq	802 Uuq	803 Uuq	804 Uuq
806 Uuq	807 Uuq	808 Uuq	809 Uuq	810 Uuq	811 Uuq	812 Uuq	813 Uuq	814 Uuq	815 Uuq	816 Uuq	817 Uuq	818 Uuq	819 Uuq	820 Uuq	821 Uuq	822 Uuq	823 Uuq	824 Uuq
826 Uuq	827 Uuq	828 Uuq	829 Uuq	830 Uuq	831 Uuq	832 Uuq	833 Uuq	834 Uuq	835 Uuq	836 Uuq	837 Uuq	838 Uuq	839 Uuq	840 Uuq	841 Uuq	842 Uuq	843 Uuq	844 Uuq
846 Uuq	847 Uuq	848 Uuq	849 Uuq	850 Uuq	851 Uuq	852 Uuq	853 Uuq	854 Uuq	855 Uuq	856 Uuq	857 Uuq	858 Uuq	859 Uuq	860 Uuq	861 Uuq	862 Uuq	863 Uuq	864 Uuq
866 Uuq	867 Uuq	868 Uuq	869 Uuq	870 Uuq	871 Uuq	872 Uuq	873 Uuq	874 Uuq	875 Uuq	876 Uuq	877 Uuq	878 Uuq	879 Uuq	880 Uuq	881 Uuq	882 Uuq	883 Uuq	884 Uuq
886 Uuq	887 Uuq	888 Uuq	889 Uuq	890 Uuq	891 Uuq	892 Uuq	893 Uuq	894 Uuq	895 Uuq	896 Uuq	897 Uuq	898 Uuq	899 Uuq	900 Uuq	901 Uuq	902 Uuq	903 Uuq	904 Uuq
906 Uuq	907 Uuq	908 Uuq	909 Uuq	910 Uuq	911 Uuq	912 Uuq	913 Uuq	914 Uuq	915 Uuq	916 Uuq	917 Uuq	918 Uuq	919 Uuq	920 Uuq	921 Uuq	922 Uuq	923 Uuq	924 Uuq
926 Uuq	927 Uuq	928 Uuq	929 Uuq	930 Uuq	931 Uuq	932 Uuq	933 Uuq	934 Uuq	935 Uuq	936 Uuq	937 Uuq	938 Uuq	939 Uuq	940 Uuq	941 Uuq	942 Uuq	943 Uuq	944 Uuq
946 Uuq	947 Uuq	948 Uuq	949 Uuq	950 Uuq	951 Uuq	952 Uuq	953 Uuq	954 Uuq	955 Uuq	956 Uuq	957 Uuq	958 Uuq	959 Uuq	960 Uuq	961 Uuq	962 Uuq	963 Uuq	964 Uuq
966 Uuq	967 Uuq	968 Uuq	969 Uuq	970 Uuq	971 Uuq	972 Uuq	973 Uuq	974 Uuq	975 Uuq	976 Uuq	977 Uuq	978 Uuq	979 Uuq	980 Uuq	981 Uuq	982 Uuq	983 Uuq	984 Uuq
986 Uuq	987 Uuq	988 Uuq	989 Uuq	990 Uuq	991 Uuq	992 Uuq	993 Uuq	994 Uuq	995 Uuq	996 Uuq	997 Uuq	998 Uuq	999 Uuq	1000 Uuq	1001 Uuq	1002 Uuq	1003 Uuq	1004 Uuq
1006 Uuq	1007 Uuq	1008 Uuq	1009 Uuq	1010 Uuq	1011 Uuq	1012 Uuq	1013 Uuq	1014 Uuq	1015 Uuq	1016 Uuq	1017 Uuq	1018 Uuq	1019 Uuq	1020 Uuq	1021 Uuq	1022 Uuq	1023 Uuq	1024 Uuq
1026 Uuq	1027 Uuq	1028 Uuq	1029 Uuq	1030 Uuq	1031 Uuq	1032 Uuq	1033 Uuq	1034 Uuq	1035 Uuq	1036 Uuq	1037 Uuq	1038 Uuq	1039 Uuq	1040 Uuq	1041 Uuq	1042 Uuq	1043 Uuq	1044 Uuq
1046 Uuq	1047 Uuq	1048 Uuq	1049 Uuq	1050 Uuq	1051 Uuq	1052 Uuq	1053 Uuq	1054 Uuq	1055 Uuq	1056 Uuq	1057 Uuq	1058 Uuq	1059 Uuq	1060 Uuq	1061 Uuq	1062 Uuq	1063 Uuq	1064 Uuq
1066 Uuq	1067 Uuq	1068 Uuq	1069 Uuq	1070 Uuq	1071 Uuq	1072 Uuq	1073 Uuq	1074 Uuq	1075 Uuq	1076 Uuq	1077 Uuq	1078 Uuq	1079 Uuq	1080 Uuq	1081 Uuq	1082 Uuq	1083 Uuq	1084 Uuq
1086 Uuq	1087 Uuq	1088 Uuq	1089 Uuq	1090 Uuq	1091 Uuq	1092 Uuq	1093 Uuq	1094 Uuq	1095 Uuq	1096 Uuq	1097 Uuq	1098 Uuq	1099 Uuq	1100 Uuq	1101 Uuq	1102 Uuq	1103 Uuq	1104 Uuq
1106 Uuq	1107 Uuq	1108 Uuq	1109 Uuq	1110 Uuq	1111 Uuq	1112 Uuq	1113 Uuq	1114 Uuq	1115 Uuq	1116 Uuq	1117 Uuq	1118 Uuq	1119 Uuq	1120 Uuq	1121 Uuq	1122 Uuq	1123 Uuq	1124 Uuq
1126 Uuq	1127 Uuq	1128 Uuq	1129 Uuq	1130 Uuq	1131 Uuq	1132 Uuq	1133 Uuq	1										

Numbers in parentheses are mass numbers of most stable isotope of that element

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MISCELLANEOUS MATHEMATICAL CONSTANTS

π CONSTANTS

$\pi =$ 3.14159 26535 89793 23846 26433 83279 50288 41971 69399 37511
 $1/\pi =$ 0.31830 98861 83790 67153 77675 26745 02872 40689 19291 48091
 $\pi^2 =$ 9.86960 44010 89358 61883 44909 99876 15113 53136 99407 24079
 $\log_e \pi =$ 1.14472 98858 49400 17414 34273 51353 05871 16472 94812 91531
 $\log_{10} \pi =$ 0.49714 98726 94133 85435 12682 88290 89887 36516 78324 38044
 $\log_{10} \sqrt{2\pi} =$ 0.39908 99341 79057 52478 25035 91507 69595 02099 34102 92128

CONSTANTS INVOLVING e

$e =$ 2.71828 18284 59045 23536 02874 71352 66249 77572 47093 69996
 $1/e =$ 0.36787 94411 71442 32159 55237 70161 46086 74458 11131 03177
 $e^2 =$ 7.38905 60989 30650 22723 04274 60575 00781 31803 15570 55185
 $M = \log_{10} e =$ 0.43429 44819 03251 82765 11289 18916 60508 22943 97005 80367
 $1/M = \log_e 10 =$ 2.30258 50929 94045 68401 79914 54684 36420 76011 01488 62877
 $\log_{10} M =$ 9.63778 43113 00536 78912 29674 98645 -10

π^n AND e^n CONSTANTS

$\pi^n =$ 22.45915 77183 61045 47342 71522
 $e^n =$ 23.14069 26327 79269 00572 90864
 $e^{-n} =$ 0.04321 39182 63772 24977 44177
 $e^{1/2} =$ 4.81047 73809 65351 65547 30357
 $i^i = e^{-1/2} \pi =$ 0.20787 95763 50761 90854 69556

NUMERICAL CONSTANTS

$\sqrt{2} =$ 1.41421 35623 73095 04880 16887 24209 69807 85696 71875 37695
 $^3\sqrt{2} =$ 1.25992 10498 94873 16476 72106 07278 22835 05702 51464 70151
 $\log_2 =$ 0.69314 71805 59945 30941 72321 21458 17656 80755 00134 36026
 $\log_{10} 2 =$ 0.30102 99956 63981 19521 37388 94724 49302 67681 89881 46211
 $\sqrt{3} =$ 1.73205 08075 68877 29352 74463 41505 87236 69428 05253 81039
 $^3\sqrt{3} =$ 1.44224 95703 07408 38232 16383 10780 10958 83918 69253 49935
 $\log_e 3 =$ 1.09861 22886 68109 69139 52452 36922 52570 46474 90557 82275
 $\log_{10} 3 =$ 0.47712 12547 19662 43729 50279 03255 11530 92001 28864 19070

OTHER CONSTANTS

Euler's Constant $\gamma =$ 0.57721 56649 01532 86061
 $\log_e \gamma =$ -0.54953 93129 81644 82234
 Golden Ratio $\phi =$ 1.61803 39887 49894 84820 45868 34365 63811 77203 09180

EXPONENTIAL FUNCTIONS

x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}	x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}
0.00	1.0000	0.00000	1.000000	0.50	1.6487	0.21715	0.606531
0.01	1.0101	.00434	0.990050	0.51	1.6653	.22149	.600496
0.02	1.0202	.00869	.980199	0.52	1.6820	.22583	.594521
0.03	1.0305	.01303	.970446	0.53	1.6989	.23018	.588605
0.04	1.0408	.01737	.960789	0.54	1.7160	.23452	.582748
0.05	1.0513	0.02171	0.951229	0.55	1.7333	0.23886	0.576950
0.06	1.0618	.02606	.941765	0.56	1.7507	.24320	.571209
0.07	1.0725	.03040	.932394	0.57	1.7683	.24755	.565525
0.08	1.0833	.03474	.923116	0.58	1.7860	.25189	.559898
0.09	1.0942	.03909	.913931	0.59	1.8040	.25623	.554327
0.10	1.1052	0.04343	0.904837	0.60	1.8221	0.26058	0.548812
0.11	1.1163	.04777	.895834	0.61	1.8404	.26492	.543351
0.12	1.1275	.05212	.886920	0.62	1.8589	.26926	.537944
0.13	1.1388	.05646	.878095	0.63	1.8776	.27361	.532592
0.14	1.1503	.06080	.869358	0.64	1.8965	.27795	.527292
0.15	1.1618	0.06514	0.860708	0.65	1.9155	0.28229	0.522046
0.16	1.1735	.06949	.852144	0.66	1.9348	.28663	.516851
0.17	1.1853	.07383	.843665	0.67	1.9542	.29098	.511709
0.18	1.1972	.07817	.835270	0.68	1.9739	.29532	.506617
0.19	1.2092	.08252	.826959	0.69	1.9937	.29966	.501576
0.20	1.2214	0.08686	0.818731	0.70	2.0138	0.30401	0.496585
0.21	1.2337	.09120	.810584	0.71	2.0340	.30835	.491644
0.22	1.2461	.09554	.802519	0.72	2.0544	.31269	.486752
0.23	1.2586	.09989	.794534	0.73	2.0751	.31703	.481909
0.24	1.2712	.10423	.786628	0.74	2.0959	.32138	.477114
0.25	1.2840	0.10857	0.778801	0.75	2.1170	0.32572	0.472367
0.26	1.2969	.11292	.771052	0.76	2.1383	.33006	.467666
0.27	1.3100	.11726	.763379	0.77	2.1598	.33441	.463013
0.28	1.3231	.12160	.755784	0.78	2.1815	.33875	.458406
0.29	1.3364	.12595	.748264	0.79	2.2034	.34309	.453845
0.30	1.3499	0.13029	0.740818	0.80	2.2255	0.34744	0.449329
0.31	1.3634	.13463	.733447	0.81	2.2479	.35178	.444858
0.32	1.3771	.13897	.726149	0.82	2.2705	.35612	.440432
0.33	1.3910	.14332	.718924	0.83	2.2933	.36046	.436049
0.34	1.4049	.14766	.711770	0.84	2.3164	.36481	.431711
0.35	1.4191	0.15200	0.704688	0.85	2.3396	0.36915	0.427415
0.36	1.4333	.15635	.697676	0.86	2.3632	.37349	.423162
0.37	1.4477	.16069	.690734	0.87	2.3869	.37784	.418952
0.38	1.4623	.16503	.683861	0.88	2.4109	.38218	.414783
0.39	1.4770	.16937	.677057	0.89	2.4351	.38652	.410656
0.40	1.4918	0.17372	0.670320	0.90	2.4596	0.39087	0.406570
0.41	1.5068	.17806	.663650	0.91	2.4843	.39521	.402524
0.42	1.5220	.18240	.657047	0.92	2.5093	.39955	.398519
0.43	1.5373	.18675	.650509	0.93	2.5345	.40389	.394554
0.44	1.5527	.19109	.644036	0.94	2.5600	.40824	.390628
0.45	1.5683	0.19543	0.637628	0.95	2.5857	0.41258	0.386741
0.46	1.5841	.19978	.631284	0.96	2.6117	.41692	.382893
0.47	1.6000	.20412	.625002	0.97	2.6379	.42127	.379083
0.48	1.6161	.20846	.618783	0.98	2.6645	.42561	.375311
0.49	1.6323	.21280	.612626	0.99	2.6912	.42995	.371577
0.50	1.6487	0.21715	0.606531	1.00	2.7183	0.43429	0.367879

EXPONENTIAL FUNCTIONS (Continued)

x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}	x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}
1.00	2.7183	0.43429	0.367879	1.50	4.4817	0.65144	0.223130
1.01	2.7456	.43864	.364219	1.51	4.5267	.65578	.220910
1.02	2.7732	.44298	.360595	1.52	4.5722	.66013	.218712
1.03	2.8011	.44732	.357007	1.53	4.6182	.66447	.216536
1.04	2.8292	.45167	.353455	1.54	4.6646	.66881	.214381
1.05	2.8577	0.45601	0.349938	1.55	4.7115	0.67316	0.212248
1.06	2.8864	.46035	.346456	1.56	4.7588	.67750	.210136
1.07	2.9154	.46470	.343009	1.57	4.8066	.68184	.208045
1.08	2.9447	.46904	.339596	1.58	4.8550	.68619	.205975
1.09	2.9743	.47338	.336216	1.59	4.9037	.69053	.203926
1.10	3.0042	0.47772	0.332871	1.60	4.9530	0.69487	0.201897
1.11	3.0344	.48207	.329559	1.61	5.0028	.69921	.199888
1.12	3.0649	.48641	.326280	1.62	5.0531	.70356	.197899
1.13	3.0957	.49075	.323033	1.63	5.1039	.70790	.195930
1.14	3.1268	.49510	.319819	1.64	5.1552	.71224	.193989
1.15	3.1582	0.49944	0.316637	1.65	5.2070	0.71659	0.192059
1.16	3.1899	.50378	.313486	1.66	5.2593	.72093	.190133
1.17	3.2220	.50812	.310367	1.67	5.3122	.72527	.188247
1.18	3.2544	.51247	.307279	1.68	5.3656	.72961	.186374
1.19	3.2871	.51681	.304221	1.69	5.4195	.73396	.184520
1.20	3.3201	0.52115	0.301194	1.70	5.4739	0.73830	0.182684
1.21	3.3535	.52550	.298197	1.71	5.5290	.74264	.180866
1.22	3.3872	.52984	.295230	1.72	5.5845	.74699	.179066
1.23	3.4212	.53418	.292293	1.73	5.6407	.75133	.177284
1.24	3.4556	.53853	.289384	1.74	5.6973	.75567	.175520
1.25	3.4903	0.54287	0.286505	1.75	5.7546	0.76002	0.173774
1.26	3.5254	.54721	.283654	1.76	5.8124	.76436	.172045
1.27	3.5609	.55155	.280832	1.77	5.8709	.76870	.170333
1.28	3.5966	.55590	.278037	1.78	5.9299	.77304	.168638
1.29	3.6328	.56024	.275271	1.79	5.9895	.77739	.166960
1.30	3.6693	0.56458	0.272532	1.80	6.0496	0.78173	0.165299
1.31	3.7062	.56893	.269820	1.81	6.1104	.78607	.163654
1.32	3.7434	.57327	.267135	1.82	6.1719	.79042	.162026
1.33	3.7810	.57761	.264477	1.83	6.2339	.79476	.160414
1.34	3.8190	.58195	.261846	1.84	6.2965	.79910	.158817
1.35	3.8574	0.58630	0.259240	1.85	6.3598	0.80344	0.157237
1.36	3.8962	.59064	.256661	1.86	6.4237	.80779	.155673
1.37	3.9354	.59498	.254107	1.87	6.4883	.81213	.154124
1.38	3.9749	.59933	.251579	1.88	6.5535	.81647	.152590
1.39	4.0149	.60367	.249075	1.89	6.6194	.82082	.151072
1.40	4.0552	0.60801	0.246597	1.90	6.6859	0.82516	0.149569
1.41	4.0960	.61236	.244143	1.91	6.7531	.82950	.148080
1.42	4.1371	.61670	.241714	1.92	6.8210	.83385	.146607
1.43	4.1787	.62104	.239309	1.93	6.8895	.83819	.145148
1.44	4.2207	.62538	.236928	1.94	6.9588	.84253	.143704
1.45	4.2631	0.62973	0.234570	1.95	7.0287	0.84687	0.142274
1.46	4.3060	.63407	.232236	1.96	7.0993	.85122	.140858
1.47	4.3492	.63841	.229925	1.97	7.1707	.85556	.139457
1.48	4.3929	.64276	.227638	1.98	7.2427	.85990	.138069
1.49	4.4371	.64710	.225373	1.99	7.3155	.86425	.136695
1.50	4.4817	0.65144	0.223130	2.00	7.3891	0.86859	0.135335