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63RD EDITION

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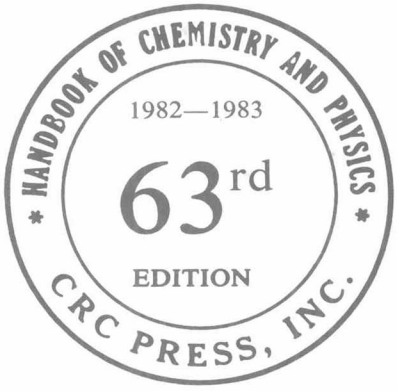
A Ready-Reference Book of Chemical and Physical Data



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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 physiochemical 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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The Publishers and Editors will be grateful to readers of this Handbook who will call their attention to errors that may be discovered. Suggestions for improvement are also welcome.

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MISCELLANEOUS MATHEMATICAL CONSTANTS

π CONSTANTS

π = 3.14159 26535 89793 23846 26433 83279 50288 41971 69399 37511
$1/\pi$ = 0.31830 98861 83790 67153 77675 26745 02872 40689 19291 48091
π^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^e AND e^π CONSTANTS

π^e = 22.45915 77183 61045 47342 71522
e^π = 23.14069 26327 79269 00572 90864
$e^{-\pi}$ = 0.04321 39182 63772 24977 44177
$e^{1/2\pi}$ = 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
$\sqrt[3]{2}$ = 1.25992 10498 94873 16476 72106 07278 22835 05702 51464 70151
$\log_e 2$ = 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
$\sqrt[3]{3}$ = 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 γ = 0.57721 56649 01532 86061
$\log_e \gamma$ = −0.54953 93129 81644 82234
Golden Ratio ϕ = 1.61803 39887 49894 84820 45868 34365 63811 77203 09180

EXPONENTIAL FUNCTIONS

x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}
0.00	1.0000	0.00000	1.000000
0.01	1.0101	.00434	0.990050
0.02	1.0202	.00869	.980199
0.03	1.0305	.01303	.970446
0.04	1.0408	.01737	.960789
0.05	1.0513	0.02171	0.951229
0.06	1.0618	.02606	.941765
0.07	1.0725	.03040	.932394
0.08	1.0833	.03474	.923116
0.09	1.0942	.03909	.913931
0.10	1.1052	0.04343	0.904837
0.11	1.1163	.04777	.895834
0.12	1.1275	.05212	.886920
0.13	1.1388	.05646	.878095
0.14	1.1503	.06080	.869358
0.15	1.1618	0.06514	0.860708
0.16	1.1735	.06949	.852144
0.17	1.1853	.07383	.843665
0.18	1.1972	.07817	.835270
0.19	1.2092	.08252	.826959
0.20	1.2214	0.08686	0.818731
0.21	1.2337	.09120	.810584
0.22	1.2461	.09554	.802519
0.23	1.2586	.09989	.794534
0.24	1.2712	.10423	.786628
0.25	1.2840	0.10857	0.778801
0.26	1.2969	.11292	.771052
0.27	1.3100	.11726	.763379
0.28	1.3231	.12160	.755784
0.29	1.3364	.12595	.748264
0.30	1.3499	0.13029	0.740818
0.31	1.3634	.13463	.733447
0.32	1.3771	.13897	.726149
0.33	1.3910	.14332	.718924
0.34	1.4049	.14766	.711770
0.35	1.4191	0.15200	0.704688
0.36	1.4333	.15635	.697676
0.37	1.4477	.16069	.690734
0.38	1.4623	.16503	.683861
0.39	1.4770	.16937	.677057
0.40	1.4918	0.17372	0.670320
0.41	1.5068	.17806	.663650
0.42	1.5220	.18240	.657047
0.43	1.5373	.18675	.650509
0.44	1.5527	.19109	.644036
0.45	1.5683	0.19543	0.637628
0.46	1.5841	.19978	.631284
0.47	1.6000	.20412	.625002
0.48	1.6161	.20846	.618783
0.49	1.6323	.21280	.612626
0.50	1.6487	0.21715	0.606531

x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}
0.50	1.6487	0.21715	0.606531
0.51	1.6653	.22149	.600496
0.52	1.6820	.22583	.594521
0.53	1.6989	.23018	.588605
0.54	1.7160	.23452	.582748
0.55	1.7333	0.23886	0.576950
0.56	1.7507	.24320	.571209
0.57	1.7683	.24755	.565525
0.58	1.7860	.25189	.559898
0.59	1.8040	.25623	.554327
0.60	1.8221	0.26058	0.548812
0.61	1.8404	.26492	.543351
0.62	1.8589	.26926	.537944
0.63	1.8776	.27361	.532592
0.64	1.8965	.27795	.527292
0.65	1.9155	0.28229	0.522046
0.66	1.9348	.28663	.516851
0.67	1.9542	.29098	.511709
0.68	1.9739	.29532	.506617
0.69	1.9937	.29966	.501576
0.70	2.0138	0.30401	0.496585
0.71	2.0340	.30835	.491644
0.72	2.0544	.31269	.486752
0.73	2.0751	.31703	.481909
0.74	2.0959	.32138	.477114
0.75	2.1170	0.32572	0.472367
0.76	2.1383	.33006	.467666
0.77	2.1598	.33441	.463013
0.78	2.1815	.33875	.458406
0.79	2.2034	.34309	.453845
0.80	2.2255	0.34744	0.449329
0.81	2.2479	.35178	.444858
0.82	2.2705	.35612	.440432
0.83	2.2933	.36046	.436049
0.84	2.3164	.36481	.431711
0.85	2.3396	0.36915	0.427415
0.86	2.3632	.37349	.423162
0.87	2.3869	.37784	.418952
0.88	2.4109	.38218	.414783
0.89	2.4351	.38652	.410656
0.90	2.4596	0.39087	0.406570
0.91	2.4843	.39521	.402524
0.92	2.5093	.39955	.398519
0.93	2.5345	.40389	.394554
0.94	2.5600	.40824	.390628
0.95	2.5857	0.41258	0.386741
0.96	2.6117	.41692	.382893
0.97	2.6379	.42127	.379083
0.98	2.6645	.42561	.375311
0.99	2.6912	.42995	.371577
1.00	2.7183	0.43429	0.367879

EXPONENTIAL FUNCTIONS (Continued)

x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}
1.00	2.7183	0.43429	0.367879
1.01	2.7456	.43864	.364219
1.02	2.7732	.44298	.360595
1.03	2.8011	.44732	.357007
1.04	2.8292	.45167	.353455
1.05	2.8577	0.45601	0.349938
1.06	2.8864	.46035	.346456
1.07	2.9154	.46470	.343009
1.08	2.9447	.46904	.339596
1.09	2.9743	.47338	.336216
1.10	3.0042	0.47772	0.332871
1.11	3.0344	.48207	.329559
1.12	3.0649	.48641	.326280
1.13	3.0957	.49075	.323033
1.14	3.1268	.49510	.319819
1.15	3.1582	0.49944	0.316637
1.16	3.1899	.50378	.313486
1.17	3.2220	.50812	.310367
1.18	3.2544	.51247	.307279
1.19	3.2871	.51681	.304221
1.20	3.3201	0.52115	0.301194
1.21	3.3535	.52550	.298197
1.22	3.3872	.52984	.295230
1.23	3.4212	.53418	.292293
1.24	3.4556	.53853	.289384
1.25	3.4903	0.54287	0.286505
1.26	3.5254	.54721	.283654
1.27	3.5609	.55155	.280832
1.28	3.5966	.55590	.278037
1.29	3.6328	.56024	.275271
1.30	3.6693	0.56458	0.272532
1.31	3.7062	.56893	.269820
1.32	3.7434	.57327	.267135
1.33	3.7810	.57761	.264477
1.34	3.8190	.58195	.261846
1.35	3.8574	0.58630	0.259240
1.36	3.8962	.59064	.256661
1.37	3.9354	.59498	.254107
1.38	3.9749	.59933	.251579
1.39	4.0149	.60367	.249075
1.40	4.0552	0.60801	0.246597
1.41	4.0960	.61236	.244143
1.42	4.1371	.61670	.241714
1.43	4.1787	.62104	.239309
1.44	4.2207	.62538	.236928
1.45	4.2631	0.62973	0.234570
1.46	4.3060	.63407	.232236
1.47	4.3492	.63841	.229925
1.48	4.3929	.64276	.227638
1.49	4.4371	.64710	.225373
1.50	4.4817	0.65144	0.223130

x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}
1.50	4.4817	0.65144	0.223130
1.51	4.5267	.65578	.220910
1.52	4.5722	.66013	.218712
1.53	4.6182	.66447	.216536
1.54	4.6646	.66881	.214381
1.55	4.7115	0.67316	0.212248
1.56	4.7588	.67750	.210136
1.57	4.8066	.68184	.208045
1.58	4.8550	.68619	.205975
1.59	4.9037	.69053	.203926
1.60	4.9530	0.69487	0.201897
1.61	5.0028	.69921	.199888
1.62	5.0531	.70356	.197899
1.63	5.1039	.70790	.195930
1.64	5.1552	.71224	.193980
1.65	5.2070	0.71659	0.192050
1.66	5.2593	.72093	.190139
1.67	5.3122	.72527	.188247
1.68	5.3656	.72961	.186374
1.69	5.4195	.73396	.184520
1.70	5.4739	0.73830	0.182684
1.71	5.5290	.74264	.180866
1.72	5.5845	.74699	.179066
1.73	5.6407	.75133	.177284
1.74	5.6973	.75567	.175520
1.75	5.7546	0.76002	0.173774
1.76	5.8124	.76436	.172045
1.77	5.8709	.76870	.170333
1.78	5.9299	.77304	.168638
1.79	5.9895	.77739	.166960
1.80	6.0496	0.78173	0.165299
1.81	6.1104	.78607	.163654
1.82	6.1719	.79042	.162026
1.83	6.2339	.79476	.160414
1.84	6.2965	.79910	.158817
1.85	6.3598	0.80344	0.157237
1.86	6.4237	.80779	.155673
1.87	6.4883	.81213	.154124
1.88	6.5535	.81647	.152590
1.89	6.6194	.82082	.151072
1.90	6.6859	0.82516	0.149569
1.91	6.7531	.82950	.148080
1.92	6.8210	.83385	.146607
1.93	6.8895	.83819	.145148
1.94	6.9588	.84253	.143704
1.95	7.0287	0.84687	0.142274
1.96	7.0993	.85122	.140858
1.97	7.1707	.85556	.139457
1.98	7.2427	.85990	.138069
1.99	7.3155	.86425	.136695
2.00	7.3891	0.86859	0.135335

EXPONENTIAL FUNCTIONS (Continued)

x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}
2.00	7.3891	0.86859	0.135335
2.01	7.4633	.87293	.133989
2.02	7.5383	.87727	.132655
2.03	7.6141	.88162	.131336
2.04	7.6906	.88596	.130029
2.05	7.7679	0.89030	0.128735
2.06	7.8460	.89465	.127454
2.07	7.9248	.89899	.126186
2.08	8.0045	.90333	.124930
2.09	8.0849	.90768	.123687
2.10	8.1662	0.91202	0.122456
2.11	8.2482	.91636	.121238
2.12	8.3311	.92070	.120032
2.13	8.4149	.92505	.118837
2.14	8.4994	.92939	.117655
2.15	8.5849	0.93373	0.116484
2.16	8.6711	.93808	.115325
2.17	8.7583	.94242	.114178
2.18	8.8463	.94676	.113042
2.19	8.9352	.95110	.111917
2.20	9.0250	0.95545	0.110803
2.21	9.1157	.95979	.109701
2.22	9.2073	.96413	.108609
2.23	9.2999	.96848	.107528
2.24	9.3933	.97282	.106459
2.25	9.4877	0.97716	0.105399
2.26	9.5831	.98151	.104350
2.27	9.6794	.98585	.103312
2.28	9.7767	.99019	.102284
2.29	9.8749	.99453	.101266
2.30	9.9742	0.99888	0.100259
2.31	10.074	1.00322	.099261
2.32	10.176	1.00756	.098274
2.33	10.278	1.01191	.097296
2.34	10.381	1.01625	.096328
2.35	10.486	1.02059	0.095369
2.36	10.591	1.02493	.094420
2.37	10.697	1.02928	.093481
2.38	10.805	1.03362	.092551
2.39	10.913	1.03796	.091630
2.40	11.023	1.04231	0.090718
2.41	11.134	1.04665	.089815
2.42	11.246	1.05099	.088922
2.43	11.359	1.05534	.088037
2.44	11.473	1.05968	.087161
2.45	11.588	1.06402	0.086294
2.46	11.705	1.06836	.085435
2.47	11.822	1.07271	.084585
2.48	11.941	1.07705	.083743
2.49	12.061	1.08139	.082910
2.50	12.182	1.08574	0.082085

x	e^x	$\text{Log}_{10}(e^x)$	e^{-x}
2.50	12.182	1.08574	0.082085
2.51	12.305	1.09008	.081268
2.52	12.429	1.09442	.080460
2.53	12.554	1.09877	.079659
2.54	12.680	1.10311	.078866
2.55	12.807	1.10745	0.078082
2.56	12.936	1.11179	.077305
2.57	13.066	1.11614	.076536
2.58	13.197	1.12048	.075774
2.59	13.330	1.12482	.075020
2.60	13.464	1.12917	0.074274
2.61	13.599	1.13351	.073535
2.62	13.736	1.13785	.072803
2.63	13.874	1.14219	.072078
2.64	14.013	1.14654	.071361
2.65	14.154	1.15088	0.070651
2.66	14.296	1.15522	.069948
2.67	14.440	1.15957	.069252
2.68	14.585	1.16391	.068563
2.69	14.732	1.16825	.067881
2.70	14.880	1.17260	0.067206
2.71	15.029	1.17694	.066537
2.72	15.180	1.18128	.065875
2.73	15.333	1.18562	.065219
2.74	15.487	1.18997	.064570
2.75	15.643	1.19431	0.063928
2.76	15.800	1.19865	.063292
2.77	15.959	1.20300	.062662
2.78	16.119	1.20734	.062039
2.79	16.281	1.21168	.061421
2.80	16.445	1.21602	0.060810
2.81	16.610	1.22037	.060205
2.82	16.777	1.22471	.059606
2.83	16.945	1.22905	.059013
2.84	17.116	1.23340	.058426
2.85	17.288	1.23774	0.057844
2.86	17.462	1.24208	.057269
2.87	17.637	1.24643	.056699
2.88	17.814	1.25077	.056135
2.89	17.993	1.25511	.055576
2.90	18.174	1.25945	0.055023
2.91	18.357	1.26380	.054476
2.92	18.541	1.26814	.053934
2.93	18.728	1.27248	.053397
2.94	18.916	1.27683	.052866
2.95	19.106	1.28117	0.052340
2.96	19.298	1.28551	.051819
2.97	19.492	1.28985	.051303
2.98	19.688	1.29420	.050793
2.99	19.886	1.29854	.050287
3.00	20.086	1.30288	0.049787