Table for PH Values Corresponding to Electromotive Forces determined in Quinhydrone Electrode Measurements. II.*

By

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In our previous publication[1], an investigation on the BIILMANN's Quinhydrone electrode for determination of hydrogen ion concentration was reported in regard to several points observed in our practice. This paper presents a table of PH values corresponding to electromotive forces determined by the use of quinhydrone electrode for both cases when it is employed in conjunction with the N/10 KCl calomel and the standard quinhydrone electrode.

In preparing the table, the calculations have been made for every two millivolts on the acid range up to PH 5, and for every millivolt above that up to the limit of application of the method, i. e. PH 8.5. Thus the somewhat tedious computations are avoided by using this table.

This table was prepared in appreciation of a similar table[2] on PH, H^+ and OH^- values, on the H_2 electrode, published by the University of California Press, and has been very useful. The authors hope that this table will be serviceable to the workers in this field.

Discussions on the Table:

Since the theoretical basis for the calculation of such table is so will known that it is obvious to state here in detail. However some factors involved in the calculation are noted below;

A. Formulae.

The formula II and III[1] without the temperature correction or in other words t=18, were used in our calculation respectively according to a chain employed in the measurement. That is,

1) A. ITANO and K. HOSODA, Journal of the Agr. Chem. Soc. (Japan) Vol. 2, No. 2, p. 13, 1926.

2) C. L. A. SMITH and D. R. HOAGLAND, Univ. of California, Publications in Physiology, 5, 4, p. 23—69, March, 1919.

* Published in the Journal of the Agricaltural Chemical Soc. of Japan II, 3, 23, March, 1926.

Formula II. $P_H = 6.35 - \frac{\pi}{0.0577}$

is used, for

$$\text{Hg}-\text{HgCl} \;\Big|\; \text{N/10 KCl} \;\Big|\; \text{Sat. KCl} \;\Big|\; \frac{\text{Unknown solution.}}{\text{saturated with quinhydrone.}} \;\Big|\; \text{Pt (blank)}$$

Formula III. $P_H = 2.04 + \frac{\pi}{0.0577}$

is used, for

$$\text{Pt (blank)} \;\Big|\; \begin{matrix}\text{Quinhydrone}\\ \text{HCl 0.01N}\\ \text{KCl 0.09N}\end{matrix} \;\Big|\; \text{Sat. KCl} \;\Big|\; \frac{\text{Unknown solution.}}{\text{saturated with quinhydrone.}} \;\Big|\; \text{Pt (blank)}$$

Since the thermodynamical factor, 0.0577 in the formulae is $\frac{RT}{nF}$ at 18°C, in the well known NERNST's formula our calculations hold correct for that temperature only. For other temperature, the correction should be applied by using the following multiplying factor for a particular working temperature unless the formulae with the temperature correction are used.

The multiplying factors given below, were calculated upon the following basis:

A. The NERNST equation for the calculation of hydrogen ion concentration,

$$\pi = \frac{RT}{nF} \ln \frac{1}{(C_H)} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \text{(A)}$$

is used, where

π = Difference of potential between the E. M. F. measured and the potential of the particular calomel electrode.

R = Gas constant in volt coulomb, (8.3129).

T = Absolute temperature, (273.09—18).

n = Valency of hydrogen, (1).

F = Faraday constant, (96494).

ln = Natural logarithum. $\ln \frac{1}{C_H} = \frac{1}{0.4343} \log_{10} \frac{1}{C_H}$

C_H = Concentration of hydrogen ion to be determined.

Substituting the numerical value in the above equation. (A), we have,

$$\pi = \frac{8.3129\ T}{96497 \times 0.4343} \log_{10} \frac{1}{C_H} \quad \ldots \ldots \ldots \ldots \ldots \text{(B)}$$

$$= 0.00019837 \times (273.09 + 18) \log_{10} \frac{1}{C_H}$$

$$= 0.0577 \log_{10} \frac{1}{C_H} = 0.0577\ P_H$$

or $P_H = \frac{\pi}{0.0577}$

As it will be seen from the equation B, the value $\frac{RT}{nF}$ changes with the

temperature, i. e. 0.00019837 per one degree. It was expressed in the SÖRENSEN's formula as $0.0577 + 0.0002\ (t - 18)$. Upon this basis, the following factors were calculated for convenience.

Also it should be noted that π, in the BIILMANN's equation, designates the potential measured in relation to the particular standard electrode used, and it is used in our table as such.

Table I.

Factors.

Temperature, °C.	Factors (Multiply).
15	1.011
16	1.007
17	1.003
18	1.000
19	0.997
20	0.993
21	0.990
22	0.986
23	0.983
24	0.980
25	0.976

For example:

A. At 15°C, if π was found to be 0.105, measured by the (Q — C) chain, then the value of π at 18°C will be

$$0.105 \times 1.011 = 0.106 +$$

The PH value for this, will be found in the table as **4.513.**

B. By the (Q — Qs) chain, if π was found to be 0.1414 at 15°C, then the value of π at 18°C will be

$$0.141 \times 1.011 = 0.142 -$$ or PH **4.518** will be found in the table.

Notes: Although the authors checked the figures, some errors might have been overlooked among so many of them, and we invite any suggestions or corrections to improve the table.

Table II.

PH Values Corresponding to Electromotive Forces, π.

Q = Quinhydrone electrode:
C = N/10 KCl calomel electrode:
Qs = Standard quinhydrone electrode:

Formula.	$PH = 6.35 - \frac{\pi}{0.0577}$		$PH = 2.04 + \frac{\pi}{0.0577}$	
Chain.	(Q – C)		(Q – Qs)	
	π	PH	π	PH
	0.366	0.007	−0.119	0.012
	0.364	0.042	−0.115	0.049
	0.362	0.077	−0.113	0.082
	0.360	0.111	−0.111	0.116
	0.358	0.146	−0·109	0.151
	0.356	0.181	−0.107	0.186
	0.354	0.215	−0.105	0.220
	0.352	0.249	−0.103	0.255
	0.350	0.293	−0.101	0.290
	0.348	0.319	−0.099	0.324
	0.346	0.354	−0.097	0.359
	0.344	0.388	−0.095	0.394
	0.342	0.423	−0.093	0.428
	0.340	0.458	−0.091	0.463
	0.338	0.492	−0.089	0.498
	0.336	0.527	−0.087	0.532
	0.334	0.561	−0.085	0.567
	0.332	0.596	−0.083	0.602
	0.330	0.631	−0.081	0.636
	0.328	0.665	−0.079	0.671
	0.326	0.700	−0.077	0.706
	0.324	0.735	−0.075	0.740
	0.322	0.769	−0.073	0.775
	0.320	0.804	−0.071	0.809
	0.318	0.839	−0.069	0.844
	0.316	0.873	−0.067	0.879
	0.314	0.908	−0.065	0.913
	0.312	0.943	−0.063	0.948
	0.310	0.977	−0.061	0.983
	0.308	1.011	−0.059	1.017
	0.306	1.049	−0.057	1.052
	0.304	1.081	−0.055	1.087
	0.302	1.116	−0.053	1.121
	0.300	1.151	−0.051	1.156
	0.298	1.185	−0.049	1.191
	0.296	1.220	−0.047	1.226

Chain.	(Q – C)		(Q – Qs)	
	π	PH	π	PH
	0.294	1.255	−0.045	1.260
	0.292	1.289	−0.043	1.295
	0.290	1.324	−0.041	1.329
	0.288	1.359	−0.039	1.364
	0.286	1.393	−0.037	1.399
	0.284	1.428	−0.035	1.433
	0.282	1.463	−0.033	1.468
	0.280	1.497	−0.031	1.503
	0.278	1.532	−0.029	1.537
	0.276	1.567	−0.027	1.572
	0.274	1.601	−0.025	1.607
	0.272	1.636	−0.023	1.641
	0.270	1.671	−0.021	1.676
	0.268	1.705	−0.019	1.711
	0.266	1.740	−0.017	1.745
	0.264	1.775	−0.015	1.780
	0.262	1.809	−0.013	1.815
	0.260	1.844	−0.011	1.849
	0.258	1.879	−0.009	1.884
	0.256	1.914	−0.007	1.919
	0.254	1.948	−0.005	1.953
	0.252	1.983	−0.003	1.988
	0.250	2.017	−0.001	2.023
	0.248	2.052	0.001	2.057
	0.246	2.087	0.003	2.092
	0.244	2.121	0.005	2.127
	0.242	2.156	0.007	2.161
	0.240	2.191	0.009	2.196
	0.238	2.225	0.011	2.231
	0.236	2.260	0.013	2.265
	0.234	2.295	0.015	2.300
	0.232	2.329	0.017	2.335
	0.230	2.364	0.019	2.369
	0.228	2.399	0.021	2.404
	0.226	2.433	0.023	2.439
	0.224	2.468	0.025	2.473
	0.222	2.503	0.027	2.508
	0.220	2.537	0.029	2.543
	0.218	2.572	0.031	2.577
	0.216	2.606	0.033	2.612
	0.214	2.641	0.035	2.647
	0.212	2.676	0.037	2.681
	0.210	2.711	0.039	2.716

Chain.	(Q − C)		(Q − Qs)	
	π	PH	π	PH
	0.208	2.745	0.041	2.751
	0.206	2.780	0.043	2.785
	0.204	2.815	0.045	2.820
	0.202	2.849	0.047	2.854
	0.200	2.884	0.049	2.889
	0.198	2.919	0.051	2.924
	0.196	2.953	0.053	2.959
	0.194	2.988	0.055	2.993
	0.192	3.023	0.057	3.028
	0.190	3.057	0.059	3.063
	0.188	3.092	0.061	3.097
	0.186	3.127	0.063	3.132
	0.184	3.161	0.065	3.167
	0.182	3.196	0.067	3.201
	0.180	3.231	0.069	3.236
	0.178	3.265	0.071	3.271
	0.176	3.300	0.073	3.305
	0 174	3.335	0.075	3.340
	0.172	3.370	0.077	3.374
	0.170	3.404	0.079	3.409
	0.168	3.439	0.081	3.444
	0.166	3.473	0.083	3.478
	0.164	3.508	0.085	3.513
	0.162	3.542	0.087	3.548
	0.160	3.577	0.089	3.582
	0.158	3.612	0.091	3.617
	0.156	3.616	0.093	3.652
	0.154	3.681	0.095	3.686
	0.152	3.716	0.097	3.721
	0.150	3.750	0.099	3.756
	0.148	3.785	0.101	3.790
	0.146	3.820	0.103	3.825
	0.144	3.854	0.105	3.860
	0.142	3.889	0.107	3.894
	0.140	3.924	0.109	3.929
	0.138	3.958	0.111	3.964
	0.136	3.993	0.113	3.998
	0.134	4.028	0.115	4.033
	0.132	4.062	0.117	4.068
	0.130	4.097	0.119	4.102
	0.128	4.132	0.121	4.137
	0.126	4.166	0.123	4.172
	0.124	4.201	0.125	4.206

Chain.	(Q − C)		(Q − Qs)	
	π	PH	π	PH
	0.122	4.236	0.127	4.241
	0.120	4.270	0.129	4.276
	0.118	4.305	0.131	4.310
	0.116	4.340	0.133	3.345
	0.114	4.374	0.135	4.380
	0.112	4.409	0.137	4.414
	0.110	4.444	0.139	4.449
	0.108	4.478	0.141	4.484
	0.106	4.513	0.143	4.518
	0.104	4.548	0.145	4.553
	0.102	4.582	0.147	4.588
	0.100	4.617	0.149	4.622
	0.098	4.652	0.151	4.657
	0.096	4.686	0.153	4.692
	0.094	4.721	0.155	4.726
	0.092	4.756	0.157	4.761
	0.090	4.790	0.159	4.796
	0.088	4.825	0.161	4.830
	0.086	4.860	0.163	4.865
	0.084	4.894	0.165	4.900
	0.083	4.929	0.167	4.934
	0.080	4.964	0.169	4.969
	0.078	4.998	0.171	5.004
	0.077	5.016	0.172	5.020
	0.076	5.033	0.173	5.038
	0.075	5.050	0.174	5.055
	0.074	5.068	0.175	5.073
	0.073	5.085	0.176	5.090
	0.072	5.102	0.177	5.108
	0.071	5.119	0.178	5.125
	0.070	5.137	0.179	5.142
	0.069	5.154	0.180	5.159
	0.068	5.172	0.181	5.177
	0.067	5.189	0.182	5·194
	0.066	5.206	0.183	5.212
	0.065	5.223	0.184	5.229
	0.064	5.241	0.185	5.246
	0.063	5.258	0.186	5.263
	0.062	5.276	0.187	5.281
	0.061	5.293	0.188	5.298
	0.060	5.310	0.189	5.316
	0.059	5.327	0.190	5.333
	0.058	5.345	0.191	5.350

Chain.	(Q − C)		(Q − Qs)	
	π	PH	π	PH
	0.057	5.362	0.192	5.367
	0.056	5.379	0.193	5.385
	0.055	5.397	0.194	5.402
	0.054	5.414	0.195	5.420
	0.053	5.431	0.196	5.437
	0.052	5.449	0.197	5.454
	0.051	5.466	0.198	5.471
	0.050	5.483	0.199	5.489
	0.049	5.501	0.200	5.506
	0.048	5.518	0.201	5.524
	0.047	5.536	0.202	5.541
	0.046	5.553	0.203	5.558
	0.045	5.570	0.204	5.575
	0.044	5.587	0.205	5.593
	0.043	5.605	0.206	5.610
	0.042	5.622	0.207	5.628
	0.041	5.639	0.208	5.645
	0.040	5.657	0.209	5.662
	0.039	5.674	0.210	5.679
	0.038	5.691	0.211	5.697
	0.037	5.709	0.212	5.714
	0.036	5.726	0.213	5.732
	0.035	5.743	0.214	5.749
	0.034	5.761	0.215	5.766
	0.033	5.778	0.216	5.784
	0.032	5.795	0.217	5.801
	0.031	5.813	0.218	5.818
	0.030	5.830	0.219	5.835
	0.029	5.847	0.220	5.853
	0.028	5.865	0.221	5.870
	0.027	5.882	0.222	5.887
	0.026	5.900	0.223	5.905
	0.025	5.917	0.224	5.922
	0.024	5.984	0.225	5.939
	0.023	5.951	0.226	5.957
	0.022	5.969	0.227	5.974
	0.021	5.986	0.228	5.991
	0.020	6.003	0.229	6.009
	0.019	6.021	0.230	6.026
	0.018	6.038	0.231	6.043
	0.017	6.055	0.232	6.061
	0.016	6.073	0.233	6.078
	0.015	6.090	0.234	6.095

Chain.	(Q − C)		(Q − Qs)	
	π	PH	π	PH
	0.014	6.107	0.235	6.113
	0.013	6.125	0.236	6.130
	0.012	6.142	0.237	6.147
	0.011	6 159	0.238	6.165
	0.010	6.177	0.239	6.182
	0.009	6.194	0.240	6.199
	0.008	6.211	0.241	6.217
	0.007	6.229	0.242	6.234
	0.006	6.246	0.243	6.251
	0.005	6.263	0.244	6 269
	0.004	6.281	0.245	6.286
	0.003	6.298	0.246	5.303
	0.002	6.315	0.247	6.321
	0.001	6.333	0.248	6.338
	0.000	6.350	0.249	6.355
	−0.001	6.367	0.250	6.373
	−0.002	6.385	0.251	6.390
	−0.003	6.402	0.252	6.407
	−0.004	6.419	0.253	6.425
	−0.005	6.437	0.254	6.442
	−0.006	6.454	0.255	6.459
	−0.007	6.471	0.256	6.476
	−0.008	6.489	0.257	6.497
	−0.009	6.506	0.258	6.511
	−0.010	6.523	0.259	6.529
	−0.011	6.541	0.260	6.546
	−0.012	6.558	0.261	6.563
	−0.013	6.575	0.262	6.581
	−0.014	6.593	0.263	6.598
	−0.015	6.610	0.264	6.615
	−0.016	6.627	0.265	6.633
	−0.017	6.645	0.266	6.650
	−0.018	6.662	0.267	6.667
	−0.019	6.679	0.268	6.685
	−0.020	6.697	0.269	6.702
	−0.021	6.714	0.270	6.719
	−0.022	6.731	0.271	6.737
	−0.023	6.749	0.272	6.754
	−0.024	6.766	0.273	6·772
	−0.025	6.783	0.274	6.789
	−0.026	6.800	0.275	6.806
	−0.027	6.818	0.276	6.823
	−0.028	6.835	0.277	6.841

Chain.	(Q − C)		(Q − Qs)	
	π	PH	π	PH
	−0.029	6.853	0.278	6.858
	−0.030	6.870	0.279	6.875
	−0.031	6.887	0.280	6.893
	−0.032	6.905	0.281	6.910
	−0.033	6.922	0.282	6.927
	−0.034	6.939	0.283	6.945
	−0.035	6.957	0.284	6.962
	−0.036	6.974	0.285	6.979
	−0.037	6.991	0.286	6.997
	−0.038	7.009	0.287	7.014
	−0.039	7.026	0.288	7.031
	−0.040	7.043	0.289	7.049
	−0.041	7.061	0.290	7.066
	−0.042	7.078	0.291	7.083
	−0.043	7.095	0.292	7.101
	−0.044	7.113	0.293	7.117
	−0.045	7.130	0.294	7.135
	−0.046	7.147	0.295	7.153
	−0.047	7.164	0.296	7.170
	−0.048	7.182	0.297	7.187
	−0.049	7.199	0.298	7.205
	−0.050	7.217	0.299	7.222
	−0.051	7.234	0.300	7.239
	−0.052	7.251	0.301	7.257
	−0.053	7.269	0.302	7.274
	−0.054	7.286	0.303	7.291
	−0.055	7.303	0.304	7.309
	−0.056	7.321	0.305	7.326
	−0.057	7.338	0.306	7.343
	−0.058	7.355	0.307	7.361
	−0.059	7.373	0.308	7.379
	−0.060	7.390	0.309	7.395
	−0.061	7.407	0.310	7.413
	−0.062	7.425	0.311	7.430
	−0.063	7.442	0.312	7.447
	−0.064	7.459	0.313	7.465
	−0.065	7.477	0.314	7.482
	−0.066	7.494	0.315	7.499
	−0.067	7.511	0.316	7.517
	−0.068	7.528	0.317	7.534
	−0.069	7.546	0.318	7.551
	−0.070	7.563	0.319	7.569
	−0.071	7.581	0.320	7.586

Chain.	(Q − C)		(Q − Qs)	
	π	PH	π	PH
	−0.072	7.598	0.321	7.603
	−0.073	7.615	0.322	7.621
	−0.074	7.632	0.323	7.638
	−0.075	7.650	0.324	7.655
	−0.076	7.667	0.325	7.673
	−0.077	7.684	0.326	7.690
	−0.078	7.702	0.327	7.707
	−0.079	7.719	0.328	7.722
	−0.080	7.736	0.329	7.742
	−0.081	7.754	0.330	7.759
	−0.082	7.771	0.331	7.777
	−0.083	7.788	0.332	7.794
	−0.084	7.806	0.333	7.811
	−0.085	7.823	0.334	7.830
	−0.086	7.804	0.335	7.846
	−0.087	7.858	0.336	7.863
	−0.088	7.875	0.337	7.881
	−0.089	7.862	0.338	7.898
	−0.090	7.910	0.339	7.915
	−0.091	7.927	0.340	7.932
	−0.092	7.944	0.341	7.950
	−0.093	7.962	0.342	7.964
	−0.094	7.979	0.343	7.985
	−0.095	7.996	0.344	8.002
	−0.096	8.014	0.345	8.019
	−0.097	8.031	0.346	8.036
	−0.098	8.048	0.347	8.054
	−0.099	8.066	0.348	8.071
	−0.100	8.083	0.349	8.089
	−0.101	8.100	0.350	8.106
	−0.102	8.118	0.351	8.123
	−0.103	8.135	0.352	8.141
	−0.104	8.152	0.353	8.158
	−0.105	9.170	0.354	8.175
	−0.106	8.187	0.355	8.193
	−0.107	8.204	0.356	8.209
	−0.108	8.222	0.357	8.227
	−0.109	8.239	0.358	8.244
	−0.110	8.256	0.359	8.262
	−0.111	8.274	0.360	8.279
	−0 112	8.291	0.361	8.296
	−0.113	8.308	0.362	8.313
	−0 114	8.326	0.363	8.331

Chain.	(Q − C)		(Q − Q_5)	
	π	PH	π	PH
	−0.115	8.343	0.364	8.348
	−0.116	8.360	0.365	8.366
	−0.117	8.378	0.366	8.383
	−0.118	8.395	0.367	8.400
	−0.119	8.412	0.368	8.418
	−0.120	8.430	0.369	8,435
	−0.121	8·448	0.370	8.452
	−0.122	8.464	0.371	8.470
	−0.123	8.482	0.372	8.487
	−0.124	8.499	0.373	8.504
	−0.125	8.516	0.374	8.522