13. pH SCALE FOR AQUEOUS SOLUTIONS

Values of pH For Primary Standard Reference Solutions

Primary ref. standard	Temperature (°C)															
	0	5	10	15	20	25	30	35	37	40	50	60	70	80	90	95
Saturated (at 25°C) potassium hydrogentartrate	—	—	—	—	—	3.557	3.552	3.549	3.548	3.547	3.549	3.560	3.580	3.610	3.650	3.674
0.1 mol kg^{-1} Potassium dihydrogencitrate	3.863	3.840	3.820	3.802	3.788	3.776	3.766	3.759	3.756	3.754	3.749	—	—	—	—	—
0.025 mol kg^{-1} Disodium hydrogenphosphate + 0.025 mol kg^{-1} potassium dihydrogen phosphate	6.984	6.951	6.923	6.900	6.881	6.865	6.853	6.844	6.841	6.838	6.833	6.836	6.845	6.859	6.876	6.886
0.03043 mol kg^{-1} Disodium hydrogenphosphate + 0.008695 mol kg^{-1} potassium dihydrogen phosphate	7.534	7.500	7.472	7.448	7.429	7.413	7.400	7.389	7.386	7.380	7.367	—	—	—	—	—
0.01 mol kg^{-1} Disodium tetraborate	9.464	9.395	9.332	9.276	9.225	9.180	9.139	9.102	9.088	9.068	9.011	8.962	8.921	8.884	8.850	8.833
0.025 mol kg^{-1} Sodium hydrogencarbonate + 0.025 mol kg^{-1} sodium carbonate	10.317	10.245	10.179	10.118	10.062	10.012	9.966	9.926	9.910	9.889	9.828	—	—	—	—	—

Note: Based on an uncertainty of $\pm$ 0.2 mV in determined $(E - E^{\theta})$, the uncertainty is $\pm$ 0.003 in pH in the range 0–50°C.

pH Values of Operational Reference Solutions

Operational standard ref. solution	Temperature (°C)														
	0	5	10	15	20	25	30	37	40	50	60	70	80	90	95
0.1 mol kg^{-1} Potassium tetroxalate[a]	—	—	—	—	1.475	1.479	1.483	1.490	1.493	1.503	1.513	1.52	1.53	1.53	1.53
0.05 mol kg^{-1} Potassium tetroxalate[a]	—	—	1.638	1.642	1.644	1.646	1.648	1.649	1.650	1.653	1.660	1.671	1.689	1.72	1.73
0.05 mol kg^{-1} Sodium hydrogendiglycolate[b]	—	3.466	3.470	3.476	3.484	3.492	3.502	3.519	3.527	3.558	3.595	—	—	—	—
Saturated (at 25°C) Potassium hydrogen-tartrate	—	—	—	—	—	3.556	3.549	3.544	3.542	3.544	3.553	3.570	3.596	3.627	3.649
0.05 mol kg^{-1} Potassium hydrogenphthalate (RVS)	4.000	3.998	3.997	3.998	4.000	4.005	4.011	4.022	4.027	4.050	4.080	4.115	4.159	4.21	4.24
0.1 mol dm^{-3} Acetic acid + 0.1 mol dm^{-3} sodium acetate	4.664	4.657	4.652	4.647	4.645	4.644	4.643	4.647	4.650	4.663	4.684	4.713	4.75	4.80	4.83
0.01 mol dm^{-3} Acetic acid + 0.1 mol dm^{-3} sodium acetate	4.729	4.722	4.717	4.714	4.712	4.713	4.715	4.722	4.726	4.743	4.768	4.800	4.839	4.88	4.91
0.02 mol kg^{-1} Piperazine phosphate[c]	—	6.477	6.419	6.364	6.310	6.259	6.209	6.143	6.116	6.030	5.952	—	—	—	—
0.025 mol kg^{-1} Disodium hydrogen-phosphate + 0.025 mol kg^{-1} potassium dihydrogen phosphate	6.961	6.935	6.912	6.891	6.873	6.857	6.843	6.828	6.823	6.814	6.817	6.830	6.85	6.90	6.92
0.03043 mol kg^{-1} Disodium hydrogen-phosphate + 0.008695 mol kg^{-1} potassium disodium phosphate	7.506	7.482	7.460	7.441	7.423	7.406	7.390	7.369	—	—	—	—	—	—	—
0.04 mol kg^{-1} Disodium hydrogen-phosphate + 0.01 mol kg^{-1} potassium dihydrogen phosphate	—	7.512	7.488	7.466	7.445	7.428	7.414	7.404	—	—	—	—	—	—	—
0.05 mol kg^{-1} Tris hydrochloride + 0.01667 mol kg^{-1} Tris[d]	8.399	8.238	8.083	7.933	7.788	7.648	7.513	7.332	7.257	7.018	6.794	—	—	—	—
0.05 mol kg^{-1} Disodium tetraborate ($Na_2B_4O_7$)	9.475	9.409	9.347	9.288	9.233	9.182	9.134	9.074	9.051	8.983	8.932	8.898	8.88	8.84	8.89
0.01 mol kg^{-1} Disodium tetraborate ($Na_2B_4O_7$)	9.451	9.388	9.329	9.275	9.225	9.179	9.138	9.086	9.066	9.009	8.965	8.932	8.91	8.90	8.89
0.025 mol kg^{-1} Sodium hydrogencarbonate + 0.025 mol kg^{-1} sodium carbonate	10.273	10.212	10.154	10.098	10.045	9.995	9.948	9.889	9.866	9.800	9.753	9.728	9.725	9.75	9.77
Saturated (at 20°C) calcium hydroxide	13.360	13.159	12.965	12.780	12.602	12.431	12.267	12.049	11.959	11.678	11.423	11.192	10.984	10.80	10.71

Note: Uncertainty is $\pm$ 0.003 in pH between 0 and 60°C rising to $\pm$ 0.01 above 70°C.

[a]Potassium trihydrogen dioxalate ($KH_3C_4O_8$).

[b]Sodium hydrogen 2,2′-oxydiethanoate.

[c]$C_4H_{10}N_2 \cdot H_3PO_4$.

[d]2-Amino-2(hydroxymethyl)-1,3 propanediol or tris(hydroxymethyl)aminomethane.

Useful Data on Some Standard Buffer Solutions

	Molecular formula	Molarity (mol kg^{-1})	Relative molar mass	Density at 20°C (g cm^{-3})	Molarity at 20°C (mol l^{-1})	Mass of 1 l at 20°C (g)	Mass tolerance for ± 0.001 pH[a] (g)	Mass tolerance expressed as a percentage (%)
Potassium tetraoxalate	$KH_3C_4O_8 \cdot 2H_2O$	0.1	254.1913	1.0091	0.09875	25.1017	0.07	0.27
Potassium tetraoxalate	$KH_3C_4O_8 \cdot 2H_2O$	0.05	254.1913	1.0038	0.04965	12.6202	0.034	0.26
Disodium hydrogen orthophosphate	Na_2HPO_4	0.025	141.9588	1.0038	0.02492	3.5379	0.02	0.56
Potassium dihydrogen orthophosphate	KH_2PO_4	0.025	136.0852			3.3912	0.02	0.58
Disodium tetraborate	$Na_2B_4O_7 \cdot 10H_2O$	0.05	381.367	1.0075	0.04985	19.0117	0.9	4.73
Disodium tetraborate	$Na_2B_4O_7 \cdot 10H_2O$	0.01	381.367	1.0001	0.009981	3.8064	0.19	0.49
Sodium carbonate	Na_2CO_3	0.025	105.9887	1.0021	0.02494	2.6428	0.017	0.064
Sodium hydrogencarbonate	$NaHCO_3$	0.025	84.0069			2.0947	0.013	0.62

[a]Calculated from known dilution value of solution.
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14. PROPERTIES OF PARTICLES, ELEMENTS AND NUCLIDES

Properties of Some Particles

Name	Symbol[a]	Spin I	Charge number z	Rest mass		Magnetic moment μ/μ_N	Meanlife τ/s
				m/u	mc^2/MeV		
Photon	γ	1	0	0	0		
Neutrino	ν_e	1/2	0	0	0		
Electron[b]	e	1/2	−1	$5.485\,799\,03\,(13) \times 10^{-4}$	0.510 999 06 (15)	1.001 159 652 193 (10)[c]	
Muon	$\mu^{\pm}$	1/2	±1	0.113 428 913 (17)	105.658 389 (34)	1.001 165 923 (8)[d]	$2.197\,3\,(4) \times 10^{-6}$
Pion	$\pi^{\pm}$	1	±1	0.149 832 3 (8)	139.5679 (7)		$2.6030\,(24) \times 10^{-8}$
Pion	π^0	1	0	0.144 9008 (9)	134.9743 (8)		$8.4\,(6) \times 10^{-17}$
Proton	p	1/2	1	1.007 276 470 (12)	938.272 31 (28)	2.792 847 386 (63)	
Neutron	n	1/2	0	1.008 664 904 (14)	939.565 63 (28)	−1.913 042 75 (45)	889.1 (21)
Deuteron	d	1	1	2.013 553 214 (24)	1875.613 39 (53)	0.857 437 6 (1)	
Triton	t	1/2	1	3.015 500 71 (4)	2808.921 78 (85)	2.978 960 (1)	
Helion	h	1/2	2	3.014 932 23 (4)	2808.392 25 (85)	−2.127 624 (1)	
α-Particle	α	0	2	4.001 506 170 (50)	3727.380 3 (11)	0	

[a]The Particle Data Group recommends the use of italic symbols for particles and this has been adopted by many physicists.
[b]The electron as β-particle is sometimes denoted by β.
[c]The value is given in Bohr magnetons μ/μ_B, $\mu_B = e\hbar/2m_e$.
[d]The value is given as μ/μ_μ, where $\mu_\mu = e\hbar/2m_\mu$.
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In nuclear physics and chemistry the masses of particles are often quoted as their energy equivalents (usually in mega electronvolts). The unified atomic mass unit corresponds to 931.494 32 (28) MeV.

Atom-like pairs of a positive particle and an electron are sometimes sufficiently stable to be treated as individual entities with special names.