Neutral Water Is Not at pH 7 but at 6.81 at Body Temperature, Because Its Ionization Absorbs Heat

— the ionization absorbs **55.836** kJ/mol, so neutral pH falls to **7.445273** at **0** °C, **6.808385** at **37** °C and **6.014569** at **100** °C — blood at pH **7.40** is basic compared not with **7** but with **6.81** — [Paper 643]

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September 2026

— *From thinking to syncing.* —

Abstract

Water ionizes slightly into $\mathrm{H^+}$ and $\mathrm{OH^-}$, and equal concentrations of the two define neutrality. Neutral pH is half the negative common logarithm of the ion product K_w, and K_w moves with temperature.How neutral pH moves with temperature is counted from values in thermodynamic tables.No new theorem or law is claimed. First, neutral pH at 25 °C is nearly 7 but not exactly——from standard Gibbs energies of formation, the ionization has $\Delta G^\circ = 79.885$ kJ/mol, $K_w = 1.0110 \times 10^{-14}$, and neutral pH 6.997623. It is exactly 7.000000 only at 24.8552 °C (Section 2). **Second, and this is the core.The ionization absorbs heat, so warming lowers neutral pH——from standard enthalpies of formation, the ionization has $\Delta H^\circ = +55.836$ kJ/mol, and by the van 't Hoff equation neutral pH is 7.445273 at 0 °C, 6.808385 at 37 °C and 6.014569 at 100 °C** (Section 3). **Third, blood is basic compared with 6.81, not with 7——at body temperature, 37 °C, blood at pH 7.40 is 0.591615 above neutral, with $[\mathrm{OH^-}]$ 15.2486 times $[\mathrm{H^+}]$** (Section 4). **Fourth, in dilute acid, water's own ionization matters——at 25 °C, hydrochloric acid at 10^{-8} mol/L has pH 6.976036, not 8. What sets the middle of the pH scale is not the acid but the water** (Section 4). **Keywords**: neutral pH, ion product of water, van 't Hoff equation, enthalpy of ionization, acids and bases.

> **Scope of this paper (scope note)**: **No new theorem or law is claimed——that the ion product of water moves with temperature, the van 't Hoff equation, and the three definitions of acids and bases (Arrhenius, Brønsted 1923, Lewis 1923) are all known.It is an approximation——the enthalpy of ionization is taken as constant in temperature (the change in heat capacity is not included), so the values differ slightly from measured tables; they serve to show direction and size.Physiology is not discussed——only a representative blood pH of 7.40 is used.Relation to earlier papers**: **Paper 573 showed that the pH 5.6 line of acid rain belongs to the rain——here it is shown that neutral pH 7 belongs to water and temperature together.Paper 392 showed that the boiling point belongs to the substance and pressure together——in the same way, neutral pH belongs to water and temperature together.**What is added is **deriving neutral pH at each temperature from thermodynamic table values**, **finding by root-finding the temperature at which it is exactly 7**, and **placing the separator on the sign of the enthalpy of ionization**.

1. Notation and the Question

Setting: **water ionizes slightly, $\mathrm{H_2O} \rightleftharpoons \mathrm{H^+} + \mathrm{OH^-}$. With the ion product $K_w = [\mathrm{H^+}][\mathrm{OH^-}]$, $[\mathrm{H^+}] = [\mathrm{OH^-}]$ is called neutral, and neutral pH is $pK_w/2$.K_w is obtained from the standard Gibbs energy of ionization ΔG° as $K_w = \exp(-\Delta G^\circ / RT)$, and moved to other temperatures by the van 't Hoff equation**

$$\ln K_w(T) = \ln K_w(T_0) - \frac{\Delta H^\circ}{R}\left(\frac{1}{T} - \frac{1}{T_0}\right)$$

(with $T_0 = 298.15$ K and ΔH° taken as constant).

Question: **when is neutral pH 7, and what moves it?**

2. Neutral at 25 °C

Computation 2.1: **from the standard Gibbs energies of formation ($\mathrm{H_2O}$ -237.129, $\mathrm{OH^-}$ -157.244 kJ/mol, $\mathrm{H^+}$ 0), the ionization has $\Delta G^\circ = 79.885$ kJ/mol.At 25 °C, $K_w = 1.0110 \times 10^{-14}$, $pK_w = 13.995246$, and neutral pH is 6.997623.Root-finding for the temperature at which neutral pH is exactly 7.000000 gave 24.8552 °C.**

3. Moving with Temperature

Computation 3.1: **from the standard enthalpies of formation ($\mathrm{H_2O}$ -285.830, $\mathrm{OH^-}$ -229.994 kJ/mol), the ionization has $\Delta H^\circ = +55.836$ kJ/mol. Temperature was moved by the van 't Hoff equation.**

temperature	pK_w	neutral pH
0 °C	14.890546	7.445273
20 °C	14.162090	7.081045
25 °C	13.995246	6.997623
37 °C	13.616770	**6.808385**
60 °C	12.967567	6.483783
100 °C	12.029138	6.014569

Observation 3.2

this is the core: the ionization absorbs heat, so warming drives it further and lowers neutral pH.With $\Delta H°$ positive, K_w grows with temperature, and $[\mathrm{H^+}]$ and $[\mathrm{OH^-}]$ both grow. Both grow equally, so the water stays neutral, but the pH number moves away from 7——"neutral is pH 7" is a way of speaking that fits only water at 24.8552 °C.

4. Blood and Dilute Acid

Computation 4.1: at body temperature, 37 °C, blood at pH 7.40 is 0.591615 above neutral 6.808385, with $[\mathrm{OH^-}]/[\mathrm{H^+}] = 15.2486$.

Computation 4.2: for hydrochloric acid at 10^{-8} mol/L at 25 °C, including water's ionization, $[\mathrm{H^+}] = \{C + \sqrt{C^2 + 4K_w}\}/2$ gives pH 6.976036.Adding acid never makes the pH 8.

Observation 4.3

the middle of the pH scale is set by water itself.In dilute acid, more $\mathrm{H^+}$ comes from water's ionization than from the acid——and at body temperature the middle is 6.81, with blood 0.59 to the basic side of it.

5. Three Definitions

Observation 5.1

neutrality and pH live, among the three definitions of acids and bases, in the one about water.Arrhenius's definition calls an acid what releases H^+ in water; Brønsted's, what donates a proton in any solvent; Lewis's, what accepts an electron pair, with no proton needed. Each later definition contains the earlier——the number pH 7 appears only once both the solvent, water, and the temperature, 25 °C, are fixed.

6. The Separator

Observation 6.1

the separator is the sign of the enthalpy of ionization.Because the ionization absorbs heat (positive), warming lowers neutral pH; were it to release heat (negative), warming would raise it. With no heat exchanged, neutral pH would not move with temperature——neutral pH moves away from 7 because water's ionization is a reaction that absorbs heat.

Observation 6.2

beside Paper 573 and Paper 392.Paper 573 showed that the pH 5.6 line of acid rain belongs to the rain, and Paper 392 that the boiling point belongs to the substance and pressure together——in the same way, neutral pH 7 belongs to water and temperature together.

Observation 6.3

what is not said.The change in heat capacity is not included, and physiology is not discussed——what is shown is how neutral pH moves according to thermodynamic tables, and what sets the direction.

7. Roll Call and Closing

1. **neutral at 25 °C is 6.997623** (Computation 2.1): **nearly 7.**
2. **exactly 7 at 24.8552 °C** (Computation 2.1): **only there.**

3. **ionization at $+55.836$ kJ/mol** (Computation 3.1): **absorbs heat.**
4. **neutral at 37 °C is 6.808385** (Computation 3.1): **6.81 at body temperature.**
5. **6.014569 at 100 °C** (Computation 3.1): **warming lowers it.**
6. **warming moves the neutral number away from 7** (Observation 3.2): **the core.**
7. **blood 0.591615 above neutral** (Computation 4.1): **$[OH^-]$ 15.2486 times.**
8. **10^{-8} mol/L acid at 6.976036** (Computation 4.2): **not 8.**
9. **pH lives in water** (Observation 5.1): **three definitions.**
10. **neutral belongs to water and temperature** (Observation 6.2): **Paper 573 and Paper 392.**

Closing: **Neutral water means $[H^+] = [OH^-]$, not pH 7.From thermodynamic tables, neutral pH at 25 °C is 6.997623, and it is exactly 7 only at 24.8552 °C.The ionization absorbs 55.836 kJ/mol, so warming lowers neutral pH, to 6.808385 at body temperature and 6.014569 at 100 °C——blood at pH 7.40 is basic in comparison with this 6.81.The separator is the sign of the enthalpy of ionization.Placed among the earlier papers——like the boiling point of Paper 392, neutral pH belongs to water and temperature together.To be honest——it is an approximation without the change in heat capacity, and physiology is not entered.**

References

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