

pH of any acid/base solution

Chemical calculators | Downloads | Prices | Buy | **Lectures** | FAQ

pH calculation

- [Table of contents](#)
- [pH definition](#)
- [pH scale](#)
- [pH meter & pH electrode](#)
- [Arrhenius theory](#)
- [Water ion product](#)
- [Acid base equilibrium](#)
- [Brønsted-Lowry theory](#)
- [Polyprotic constants](#)
- [Other constants types](#)
- [General case](#)
- **[Acid/base solution](#)**
- [Strong acid/base](#)
- [Weak acid/base](#)
- [Polyprotic acid/base](#)
- [Polyprotic simplified](#)
- [Salts in general](#)
- [Amphiprotic salt](#)
- [Salts simplified](#)
- [More on the salt pH](#)
- [pH of buffers](#)
- [Buffer capacity](#)
- [Acid-base titration curve](#)
- [Ionic strength and activities](#)
- [Newton method](#)
- [Symbols used](#)
- [Disclaimer](#)

pH questions

- [Table of contents](#)

pH calculation lectures » pH of any acid/base solution

What is pH of solution of a monoprotic acid? Let's try the general approach described in the general case section. Equilibrium in solution is described by the set of the following equations:

$$K_w = [H^+][OH^-] \quad (6.1)$$

$$[H^+] = [OH^-] + [A^-] \quad (6.2)$$

$$K_a = \frac{[H^+][A^-]}{[HA]} \quad (6.3)$$

$$[A^-] + [HA] = C_a \quad (6.4)$$

6.1 and 6.3 describe equilibrium, 6.2 is a charge balance - solution must be neutral, 6.4 is a mass balance and reflects the fact, that sum of concentrations of all acid forms present in the solution must be identical to the concentration of acid added.

Combining 6.1 and 6.2 we get

$$[H^+] - \frac{K_w}{[H^+]} - [A^-] = 0 \quad (6.5)$$

From 6.4

$$[HA] = C_a - [A^-] \quad (6.6)$$

Substituting 6.6 into 6.3 yields

$$K_a = \frac{[H^+][A^-]}{C_a - [A^-]} \quad (6.7)$$

We solve 6.7 for $[A^-]$ and substitute it into 6.5:

$$[H^+] - \frac{K_w}{[H^+]} - \frac{C_a K_a}{[H^+] + K_a} = 0 \quad (6.8)$$

Which - when expanded - gives third degree equation for $[H^+]$:

$$[H^+]^3 + K_a [H^+]^2 - (C_a K_a + K_w) [H^+] - K_a K_w = 0 \quad (6.9)$$

This equation describes any solution of any monoprotic acid (just remember the concentration/activity thing described in the [ionic strength and activities](#) section). To calculate pH we need to know C_a and K_a and the final result will be correct regardless of their values - doesn't matter if acid is strong or weak, or if it is concentrated or diluted (neglecting activity calculations). This is the ultimate equation for pH calculation of monoprotic acid solution.

And what about bases? Using exactly the same method as above we can get equation for $[OH^-]$:

$$[OH^-]^3 + K_b [OH^-]^2 - (C_b K_b + K_w) [OH^-] - K_b K_w = 0 \quad (6.10)$$

which is almost identical with 6.9. We can also use conjugate K_a definition and solve directly for $[H^+]$:

$$[H^+]^3 + (C_b + K_a) [H^+]^2 - K_w [H^+] - K_a K_w = 0 \quad (6.11)$$

See also pH calculation for salt section for more interesting information.

Equations in this form are unusable for hand calculations. There are two things that can be done. We can try to simplify the equations (see [strong acid/base](#) and [weak acid/base](#) sections), or we can use numerical method to find polynomial root - see [Newton method](#) section.

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