Acid and base strength

$$K_a \times K_b = \frac{a_{A^-} \times a_{H_3O^+}}{a_{HA}} \times \frac{a_{HA} \times a_{OH^-}}{a_{A^-}} = a_{H_3O^+} \times a_{OH^-} = K_w$$

conjugate base

$$\boxed{\Rightarrow pK_a + pK_b = pK_w}$$

As the strength of an acid decreases, the strength of its conjugate base increases and vice versa

$K_a > 1$, $pK_a < 0$: strong acid (HCl, HNO_3)
$K_b > 1$, $pK_b < 0$: strong base (O^{2-})

Table 8.1 *Acidity and basicity constants* at 25 °C*

Acid/base	K_b	pK_b	K_a	pK_a
Strongest weak acids				
Trichloroacetic acid, CCl_3COOH	3.3×10^{-14}	13.48	3.0×10^{-1}	0.52
Benzenesulfonic acid, $C_6H_5SO_3H$	5.0×10^{-14}	13.30	2×10^{-1}	0.70
Iodic acid, HIO_3	5.9×10^{-14}	13.23	1.7×10^{-1}	0.77
Sulfurous acid, H_2SO_3	6.3×10^{-13}	12.19	1.6×10^{-2}	1.81
Chlorous acid, $HClO_2$	1.0×10^{-12}	12.00	1.0×10^{-2}	2.00
Phosphoric acid, H_3PO_4	1.3×10^{-12}	11.88	7.6×10^{-3}	2.12
Chloroacetic acid, $CH_2ClCOOH$	7.1×10^{-12}	11.15	1.4×10^{-3}	2.85
Lactic acid, $CH_3CH(OH)COOH$	1.2×10^{-11}	10.92	8.4×10^{-4}	3.08
Nitrous acid, HNO_2	2.3×10^{-11}	10.63	4.3×10^{-4}	3.37
Hydrofluoric acid, HF	2.9×10^{-11}	10.55	3.5×10^{-4}	3.45
Formic acid, HCOOH	5.6×10^{-11}	10.25	1.8×10^{-4}	3.75
Benzoic acid, C_6H_5COOH	1.5×10^{-10}	9.81	6.5×10^{-5}	4.19
Acetic acid, CH_3COOH	5.6×10^{-10}	9.25	1.8×10^{-5}	4.75
Carbonic acid, H_2CO_3	2.3×10^{-8}	7.63	4.3×10^{-7}	6.37
Hypochlorous acid, HClO	3.3×10^{-7}	6.47	3.0×10^{-8}	7.53
Hypobromous acid, HBrO	5.0×10^{-6}	5.31	2.0×10^{-9}	8.69
Boric acid, $B(OH)_3$†	1.4×10^{-5}	4.86	7.2×10^{-10}	9.14
Hydrocyanic acid, HCN	2.0×10^{-5}	4.69	4.9×10^{-10}	9.31
Phenol, C_6H_5OH	7.7×10^{-5}	4.11	1.3×10^{-10}	9.98
Hypoiodous acid, HIO	4.3×10^{-4}	3.36	2.3×10^{-11}	10.64
Weakest weak acids				
Weakest weak bases				
Urea, $CO(NH_2)_2$	1.3×10^{-14}	13.90	7.7×10^{-1}	0.10
Aniline, $C_6H_5NH_2$	4.3×10^{-10}	9.37	2.3×10^{-5}	4.63
Pyridine, C_5H_5N	1.8×10^{-9}	8.75	5.6×10^{-6}	5.35
Hydroxylamine, NH_2OH	1.1×10^{-8}	7.97	9.1×10^{-7}	6.03
Nicotine, $C_{10}H_{11}N_2$	1.0×10^{-6}	5.98	1.0×10^{-8}	8.02
Morphine, $C_{17}H_{19}O_3N$	1.6×10^{-6}	5.79	6.3×10^{-9}	8.21
Hydrazine, NH_2NH_2	1.7×10^{-6}	5.77	5.9×10^{-9}	8.23
Ammonia, NH_3	1.8×10^{-5}	4.75	5.6×10^{-10}	9.25
Trimethylamine, $(CH_3)_3N$	6.5×10^{-5}	4.19	1.5×10^{-10}	9.81
Methylamine, CH_3NH_2	3.6×10^{-4}	3.44	2.8×10^{-11}	10.56
Dimethylamine, $(CH_3)_2NH$	5.4×10^{-4}	3.27	1.9×10^{-11}	10.73
Ethylamine, $C_2H_5NH_2$	6.5×10^{-4}	3.19	1.5×10^{-11}	10.81
Triethylamine, $(C_2H_5)_3N$	1.0×10^{-3}	2.99	1.0×10^{-11}	11.01
Strongest weak bases				

*Values for polyprotic acids—those capable of donating more than one proton—refer to the first deprotonation.
†The proton transfer equilibrium is $B(OH)_3(aq) + 2\,H_2O(l) \rightleftharpoons H_3O^+(aq) + B(OH)_4^-(aq)$.

Polyprotic acids

$H_2A(aq) + H_2O(aq) \rightleftharpoons HA^-(aq) + H_3O^+(aq) \Rightarrow K_{a1} = \dfrac{a_{HA^-} \times a_{H_3O^+}}{a_{H_2A}}$

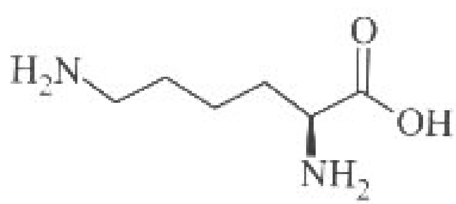
$HA^-(aq) + H_2O(aq) \rightleftharpoons A^{2-}(aq) + H_3O^+(aq) \Rightarrow K_{a2} = \dfrac{a_{A^{2-}} \times a_{H_3O^+}}{a_{HA^-}}$

E.g., H_2SO_4/HSO_4^-, $H_3PO_4/H_2PO_4^-/HPO_4^{2-}$

$K_{a1} \approx 10^5 \times K_{a2}$ $K_{a1} \approx 10^5 \times K_{a2}$

Amphiprotic (= accepting and donating H^+)

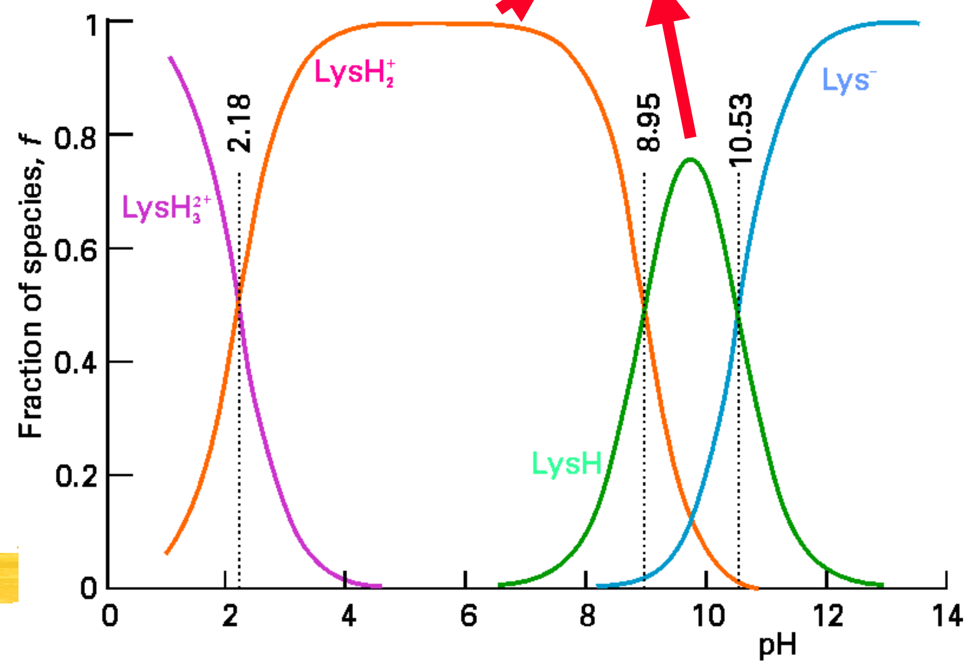
Aminoacids!



3 Lysine (Lys)

$\Rightarrow$ **zwitterionic!**

$\Rightarrow$ **Proteins are polyprotic acids!**



Problem:

What is the pH of an amphiprotic anion solution such as an amino acid, HSO_4^-, HPO_4^{2-}, or HCO_3^-?