Q $\qquad$ $aA + bB \rightleftharpoons cC + dD$

Reaction Quotient $\qquad$ Reactants $\qquad$ Products

$$Q = \frac{\text{Products}}{\text{Reactants}} = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

When measured at equilibrium

(when $\text{Rate}_{\text{forward}} = \text{Rate}_{\text{Reverse}}$)

$$Q_{eq} = K = \frac{[C]_{eq}^c\,[D]_{eq}^d}{[A]_{eq}^a\,[B]_{eq}^b}$$

Temperature dependant

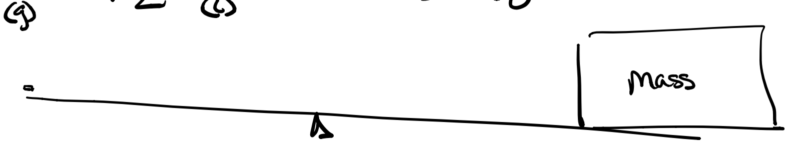
K = equilibrium Constant

$$HCl_{(g)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$$

$$K = \frac{[H_3O^+][Cl^-]}{[HCl][H_2O]} = 1\times10^7 >>> 1$$

[ ] = concentration mols/L

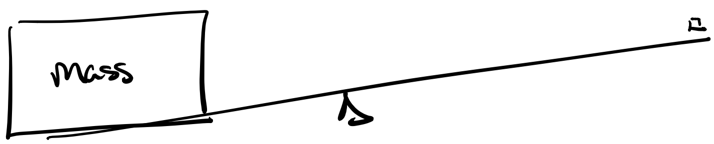
$$HCl_{(g)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)} \qquad K = 1\times10^7$$



$$HC_2H_3O_{2(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + C_2H_3O^-_{2(aq)}$$

$$K = \frac{[H_3O^+][C_2H_3O_2^-]}{[HC_2H_3O_2][H_2O]} = 1.8 \times 10^{-5} <<< 1$$

$$HC_2H_3O_{2(l)} + H_2O_{(l)} \longleftarrow H_3O^+_{(aq)} + C_2H_3O^-_{2(aq)}$$



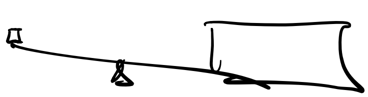
Strong Acid

Dissociates Completely

	K
HCl	1×10^{7}
HNO_3	$1 \times 10^{1.3}$
H_2SO_4	1×10^{9}

> 1

$$H\text{-}Acid + H_2O \rightarrow H_3O^{\oplus} + Acid^{\ominus}$$



Weak Acid

Dissociate only a little

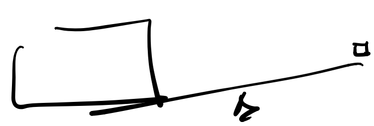
	K
$HC_2H_3O_2$	1.8×10^{-5}
H_2CO_3	4.3×10^{-7}

< 1

Molecular side

Ionic side

$$H\text{-}Acid + H_2O \rightarrow H_3O^{\oplus} + Acid^{\ominus}$$



La Chatelier's Principle

- When an equilibrium is stressed (thrown out of equilibrium by adding, subtraction reagents, or changing temp or pressure) The equilibrium will re-establish by shifting to Counteract the stress.

$\uparrow$ increased = Stress

$$\uparrow HNO_3 + \uparrow H_2O \rightleftharpoons \downarrow H_3O^+ + NO_3^-$$

Stress — Add NO_3^- to the mixture

$$K = \frac{[H_3O^+][NO_3^-]\uparrow}{[HNO_3][H_2O]} = 2 \times 10^1$$

$\downarrow \quad \uparrow$

out of equilibium $\quad Q = \dfrac{\downarrow [H_3O^+]\,\left[NO_3^-\right]}{\uparrow [HNO_3][H_2O]\uparrow}$

$$\uparrow HNO_3 + H_2O\downarrow \rightleftharpoons H_3O^+\uparrow + NO_3^-\uparrow$$

Stress Add HNO_3

Shift is towards products

Adding a reactant → Shift towards products

Add a product → Shift towards reactants

Remove a product → Shift towards products

$$\downarrow HNO_3 + \downarrow H_2O \rightleftharpoons \uparrow H_3O^+ + NO_3^- \downarrow$$ Take some away

Remove a reactant → Shift towards reactants

Special Equilibrium

$$H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$$

Acid Base

$$2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

$$K = \frac{[H_3O^+][OH^-]}{[H_2O]^2}$$

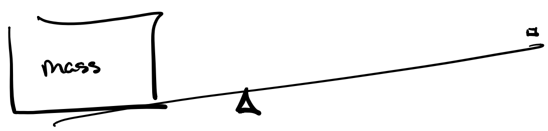
$$K[H_2O]^2 = [H_3O^+][OH^-] = K_w = 1 \times 10^{-14} \text{ moles}^2/L^2$$

at 25°C

K_w = Equilibrium Constant of water

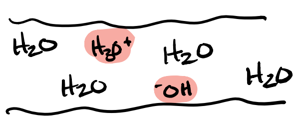
$= 1 \times 10^{-14}$

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

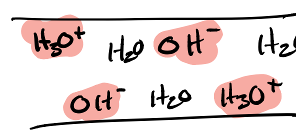


$= 1 \times 10^{-14} <<< 1$

As temp increases K_w increases



25°C



>100°C

At 25°C

$K_w = 1 \times 10^{-14}$ $\quad [H_3O^+] = [OH^-]$

$$[H_3O^+] = \frac{1 \times 10^{-14}}{2} = 1 \times 10^{-7}$$

$$[OH^-] = 1 \times 10^{-7}$$

$$(1 \times 10^{-7}) \times (1 \times 10^{-7}) = 1 \times 10^{(-7 + -7)} = 1 \times 10^{-14}$$

$$A^x \times A^y = A^{x+y}$$

$$2H_2O \rightarrow 1\,H_3O^+ + 1\,OH^-$$

$$[H_3O^+] = [OH^-]$$

$$K_w = [H_3O^+][OH^-] = 1\times10^{-14}$$

$$2[H_3O^+] = 1\times10^{-14}$$

$$[H_3O^+] = \frac{1\times10^{-14}}{2} = 1\times10^{-7}$$

New function $p = -\log$

$$p(x) = -\log x$$

$$pH = p[H_3O^+] = -\log[H_3O^+]$$

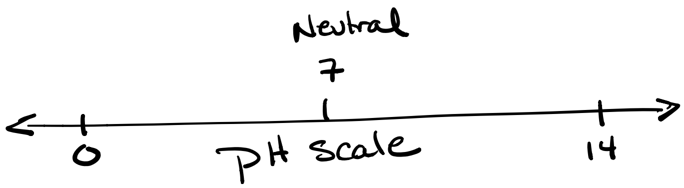
in pure H_2O @ 25°C $[H_3O^+] = 1\times10^{-7}$

$$pH = -\log[H_3O^+] = -\log 1\times10^{-7}$$

$$\log x = 10^{?} = x$$

$$-\log 1\times10^{-7} = -(-7) = 7$$

pH at 25°C of pure H_2O = 7



$[H_3O^+] = [OH^-]$ @ pH 7

$$[H_3O^+][OH^-] = 1\times10^{-14}$$

	pH	$[H_3O^+] \times$	$[OH^-] = 1\times10^{-14}$	pOH
		more H_3O^+		
Acidic	3	1×10^{-3} ×	1×10^{-11}	11
more H_3O^+	4	1×10^{-4} ×	1×10^{-10}	10
	5	1×10^{-5}	1×10^{-9}	9
	6	1×10^{-6}	1×10^{-8}	8
equal	7	1×10^{-7}	1×10^{-7}	7
	8	1×10^{-8}	1×10^{-6}	6
more OH^-	9	1×10^{-9}	1×10^{-5}	5
Basic	10	1×10^{-10}	1×10^{-4}	4
more Base	11	1×10^{-11}	1×10^{-3}	3
	12	1×10^{-12}	1×10^{-2}	2
	13	1×10^{-13}	1×10^{-1}	1
	14	1×10^{-14}	1×10^{0}	0
			more OH^-	

What is the pH of an aqueous solution with a hydronium ion concentration of 6.723×10^{-3} moles/L?

$$[H_3O^+] = 6.723 \times 10^{-3} \text{ mols/L}$$

$$pH = -\log[H_3O^+] = -\log 6.723 \times 10^{-3}$$

4

$$= \underbrace{2}_{\text{power of 10}}.\underbrace{1724}_{\text{mantissa carries the sig figs}}36889$$

power of 10

mantissa carries the sig figs

(−) log(6.723 EE (−) 3) =

(±) (±)

$$pH = 2.1724 \quad (4 \text{ sig figs})$$

7 8 9

4 5 6

1 2 3

0 . (−)

(−) log(6.723 [2nd] EE (−) 3) =

What is the pH of 0.023 M HNO_3 solution?

$$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$$

$$0.023\,M \longrightarrow 0.023\,M$$

Because it is a strong acid

$$[HNO_3] = [H_3O^+] = 0.023\ \text{Mols/L}$$

$$pH = -\log[H_3O^+] = -\log(0.02\overset{2}{3})$$

$$= -\log(2.3 \times 10^{-2})$$

$$pH \approx 2$$

$$pH = 1.638\,27$$

$$\boxed{pH = 1.64}$$ 2 SF

What is $[H_3O^+]$ of a solution with a pH of 3.26?

$$pH = -\log[H_3O^+] \qquad pH = 3.26$$

Inverse functions $\quad [H_3O^+] = 10^{-pH}$

$$[H_3O^+] = 10^{-3.26} = 10 \wedge (-) 3.26 = 0.00054954 0874$$

$$\boxed{[H_3O^+] = 0.00055\ \text{moles/L} = 5.5 \times 10^{-4}\ \text{moles/L}}$$

$$[H_3O^+][OH^-] = 1\times10^{-14}$$

$$pH + pOH = 14$$

derivation

$$-\log\left([H_3O^+][OH^-]\right) = -\log 1\times10^{-14}$$

$$\log(AB) = \log A + \log B$$

$$-\log[H_3O^+] + -\log[OH^-] = -\log 1\times10^{-14}$$

$$pH \quad + \quad pOH = 14$$

Road Map

$$\begin{tikzcd}
[H_3O^+] \arrow[d, shift right, "-\log[H_3O^+]"'] & \times & [OH^-] \arrow[d, shift right, "-\log[OH^-]"'] & = & 1\times10^{-14} \\
pH \arrow[u, shift right, "10^{-pH}"'] & + & pOH \arrow[u, shift right, "10^{-pOH}"'] & = & 14
\end{tikzcd}$$

What is the pH of a solution with a hydroxide ion concentration of 0.692 moles/L ?

Route A

0.692 moles/L

$$\begin{tikzcd}[column sep=small]
{[H_3O^+]} \arrow[d, shift right, "-\log[H_3O^+]"'] & \times & {[OH^-]} \arrow[d, shift right, "-\log[OH^-]"'] \arrow[ll, bend right, "\text{Route A}"'] & = & 1\times10^{-14} \\
pH \arrow[u, shift right, "10^{-pH}"'] & + & pOH \arrow[u, shift right, "10^{-pOH}"'] & = & 14
\end{tikzcd}$$

Route B

?

Route A

$$[OH^-][H_3O^+] = 1\times10^{-14}$$

$$[H_3O^+] = \frac{1\times10^{-14}}{[OH^-]}$$

$$[H_3O^+] = \frac{1\times10^{-14}\ \text{moles}^2/L^2}{0.692\ \text{moles}/L}$$

$$pH = -\log[H_3O^+]$$

$$[H_3O^+] = 1.44|50867\times10^{-14}$$

$$pH = -\log[H_3O^+] = -\log(1.4450867\times10^{-14})$$

$$pH = 13.840|06$$

$$\boxed{pH = 13.840}$$

$pH = [H^+] = [H_3O^+]$

hydrogen ion   hydronium ion in water

pH measured for aqueous things

pH is usually the pH of a resulting aqueous solution

$HC_2H_3O_{2(l)}$ pH no meaning

Glacial Acetic Acid

$HC_2H_3O_{2(aq)}$ $pH = \sim 4.5$

$$HC_2H_3O_{(l)} + H_2O \rightleftharpoons H_3O^+ + C_2H_3O_2^-$$

pH