Robert Boyle 1680

“acids…substances able to turn to red the indicator paper and to react with bases being neutralised…”

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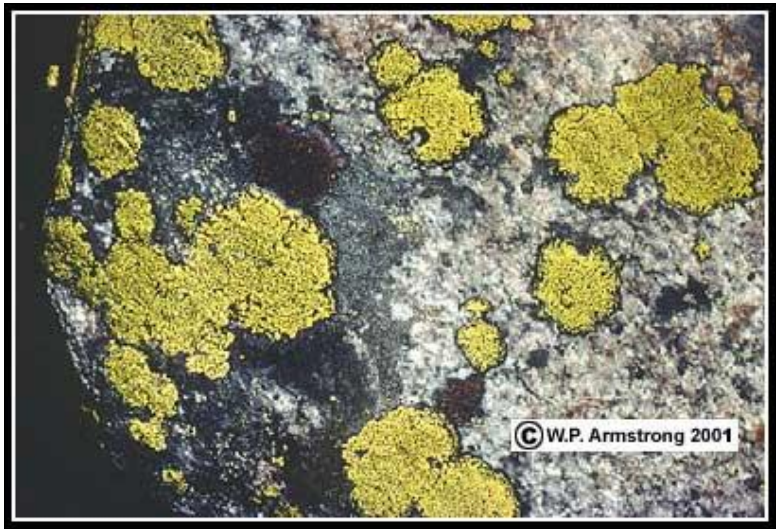
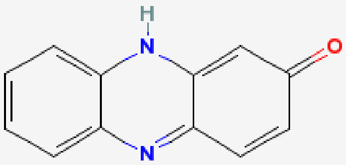
Chrozophora tinctoria

Roccella tinctoria so called *tornasole*





2-hydroxyphenazine

What do you notice in this structure ?!

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Acids & bases, definition

Arrhenius Theory (1883)

ACID: Produces H^+ in Water
BASE: Produces OH^- in Water

Bronsted/Lowry Theory (1923)
ACID: proton, H^+ DONOR
BASE: proton, H^+ ACCEPTOR

Lewis Theory (1938)
a more general acid base theory.
ACID: accepts pair of electrons for sharing
BASE: donates pair of electrons for sharing

$$\underset{\text{acid}}{X} + \underset{\text{base}}{:Y} \rightarrow X{:}Y$$

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OPERATIVE DEFINITIONS

generally,

- an acid donates one (or more) H^+ to an acceptor base

- An acid accepts one (or more) *lone pair(s)* form a donor base

----

- H^+ is a very efficient *lone pair* acceptor
- OH^- is avery efficient *lone pair(s)*3 of them) *donor*…!.

HCl is an acid, since it releases H^+ (accepting a *lone pair*)
NaOH is a base, since it releases OH^- (donating a *lone pair)*

Acid base reaction (most common)

$\mathrm{HCl} \quad + \quad \mathrm{NaOH}$

$\mathrm{H^+} \quad + \quad :\!\ddot{\underset{\cdot\cdot}{\mathrm{O}}}\mathrm{H^-} \quad \longrightarrow \quad \mathrm{H_2O}$

acid base product

$\Delta G < 0 \approx - 80\ \mathrm{KJ/mol}$

The calorie, again

1 cal raises by 1 °C (14.5 – 15.5) 1 g H_2O (p = 1 atm)

1 Kcal raises by 1 °C (14.5 – 15.5) 1 Kg H_2O (p = 1 atm)

100 Kcal raise from 0 to 100 °C 1Kg H_2O

1 cal ~ 4.18 joules

Acids e bases of biomedical interest

ACIDI

HCl	ac cloridrico	forte	succo gastrico
HNO_3	ac nitrico	forte	caustico
H_2SO_4	ac solforico	forte	caustico
H_2SO_3	ac solforoso	forte	caustico
H_3PO_4	ac fosforico	debole	tampone sangue e liquidi biologici
H_3BO_3	ac borico	debole	antisettico superficie
H_2CO_3	ac carbonico	debole	tampone sangue e liquidi biologici
HCOOH	ac formico	debole	capostipite ac carbossilici
CH_3COOH	ac acetico	debole	tampone laboratorio + *aceto*

BASI (IDROSSIDI)

NaOH	Id di sodio	forte	caustico (*soda*)
KOH	Id di potassio	forte	caustico (*potassa*)
$Ca(OH)_2$	Id di calcio	forte	caustico
$Mg(OH)_2$	Id di magnesio	forte	caustico
$Al(OH)_3$	Id di alluminio	forte	caustico
$NH_3.H_2O$	ammoniaca	debole	coadiuvante detersione superfici
NH_4OH	Id di ammonio		

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Acid-base conjugated couple *(Brönsted & Lowry)*

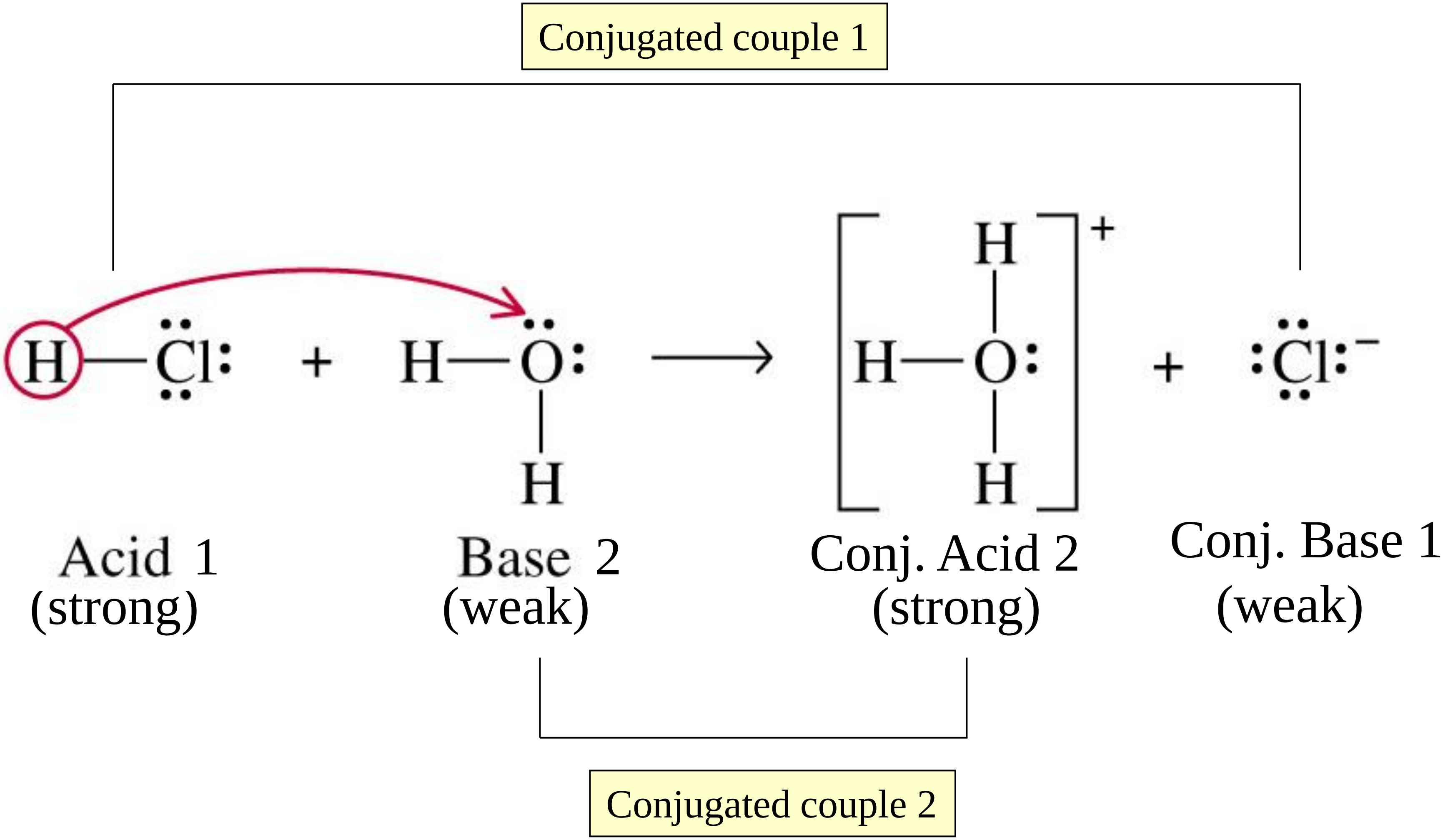
Acid base

$HCl \longrightarrow H^+ + Cl^-$

$HCOOH \rightleftarrows H^+ + HCOO^-$

$NH^{4+} \rightleftarrows H^+ + NH_3$

Acid-base reaction



Conjugated couple 1

Acid 1
(strong)

Base 2
(weak)

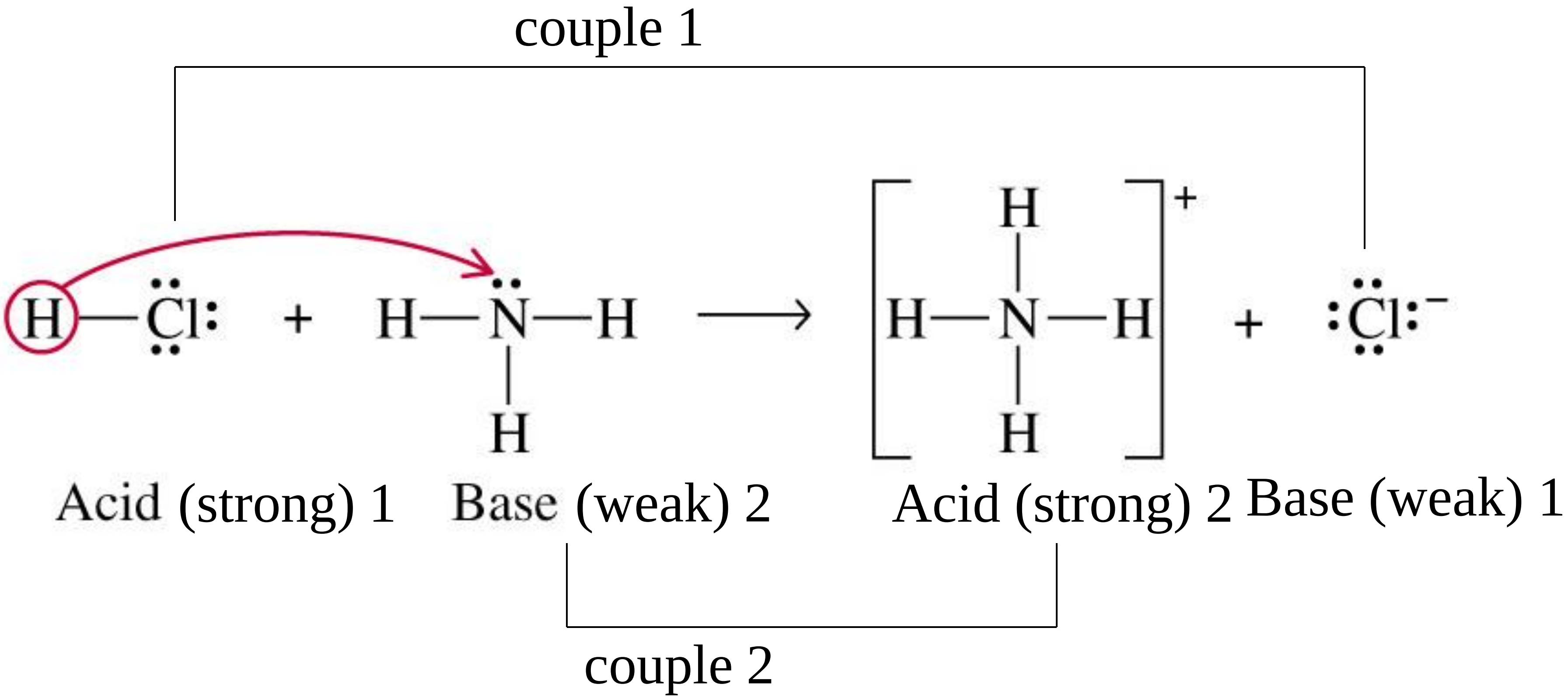
Conj. Acid 2
(strong)

Conj. Base 1
(weak)

Conjugated couple 2

After H+ donation, the acid turns to the conjugated base
while the base turns into the conjugated acid
The cojugated species have opposite strength !

Acid-base Reaction → between cojugated couples



couple 1

Acid (strong) 1 Base (weak) 2 Acid (strong) 2 Base (weak) 1

couple 2

remember

Conjugated species have opposite strength!

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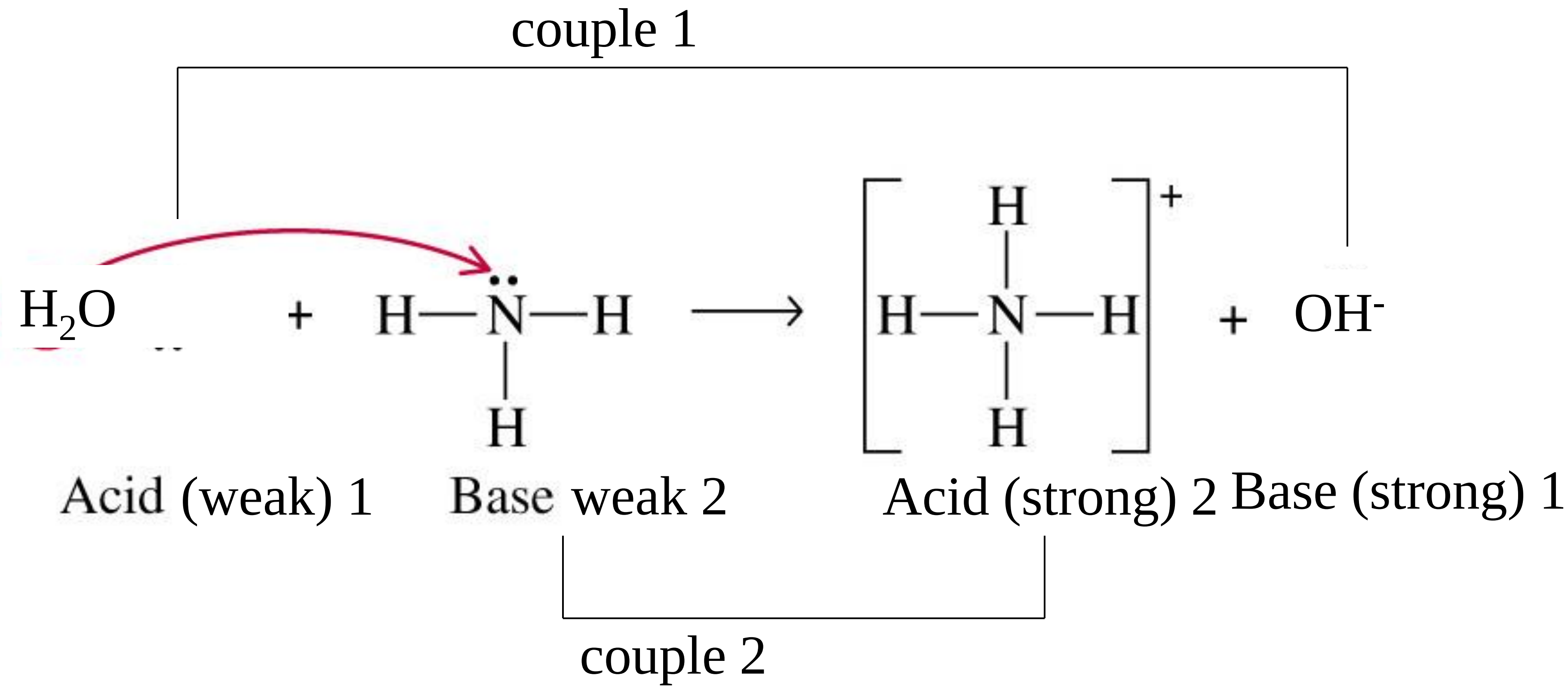
H_2O as an acid *(donating H+)*



couple 1

$H_2O + NH_3 \longrightarrow [NH_4]^+ + OH^-$

Acid (weak) 1

Base weak 2

Acid (strong) 2

Base (strong) 1

couple 2

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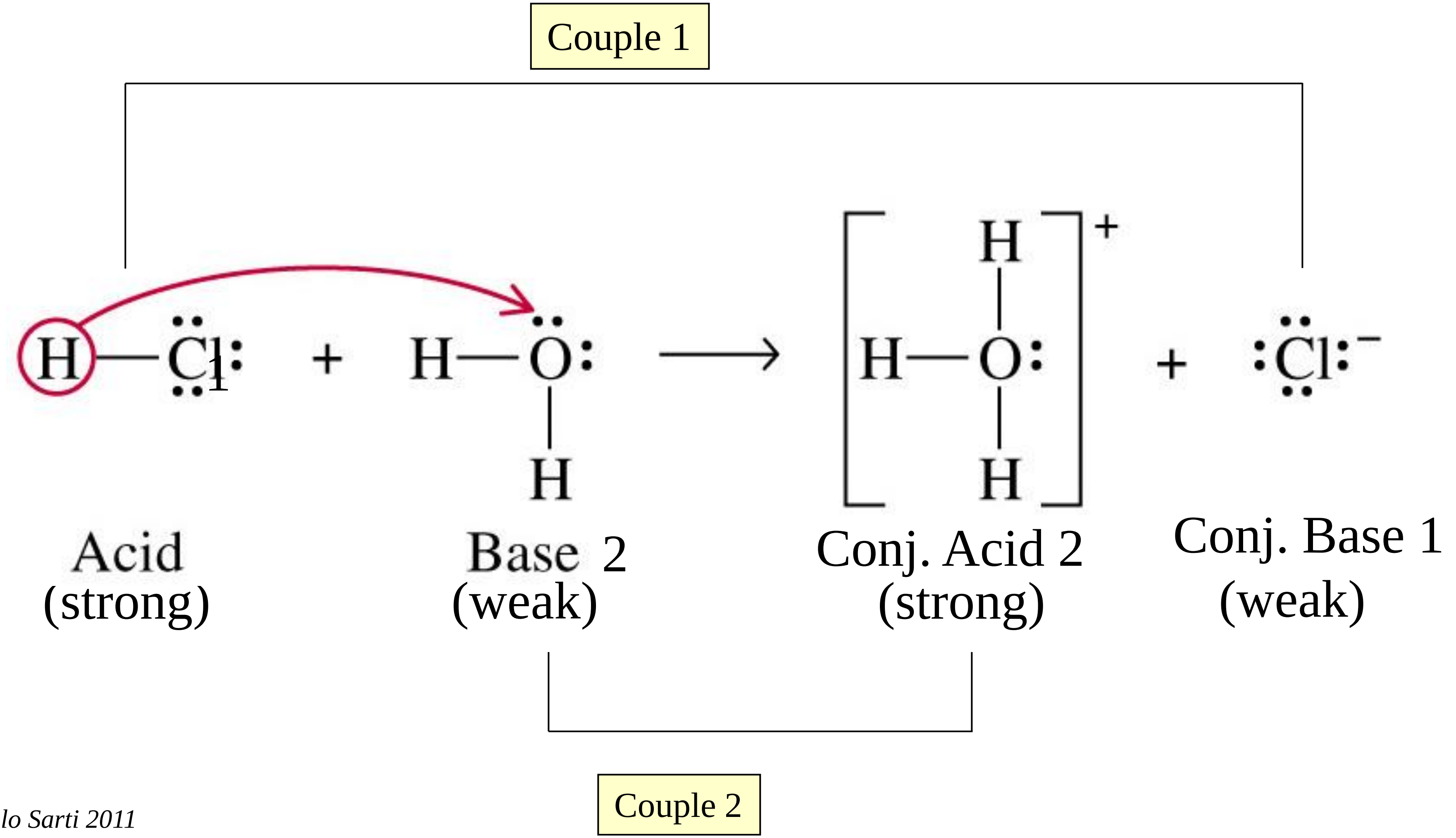
H_2O as a base *(accepting H+)*



Couple 1

Acid
(strong)

1

Base 2
(weak)

Conj. Acid 2
(strong)

Conj. Base 1
(weak)

Couple 2

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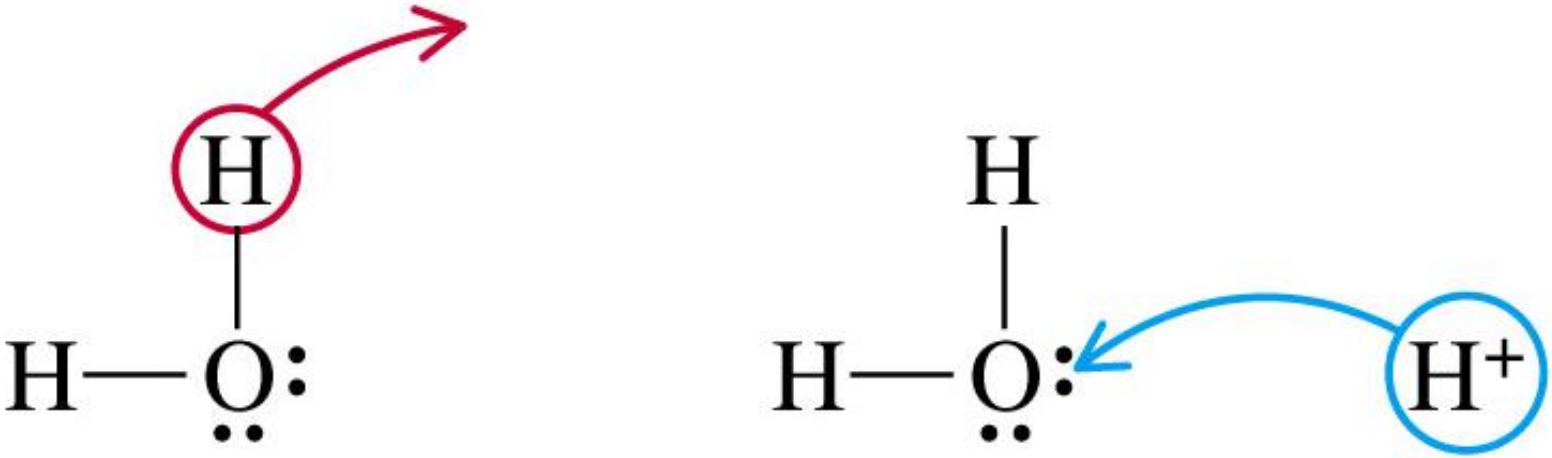
The water molecule is ambìvalent “amphoteric”



H_2O as an acid H_2O as a base

Water auto-protolysis

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

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

H_2O dissociation equilibrium

$$2\,H_2O \rightleftarrows H_3O^+ + OH^-$$

$$Keq = \frac{[H_3O^+]\;[OH^-]}{[H_2O\,]^2} = \frac{(10^{-7})\quad(10^{-7})}{(55.5)^{\,2}} = 3.2 \times 10^{-18}$$

To make it simpler!

$$H_2O \rightleftarrows H^+ + OH^-$$

$$Keq = \frac{[H^+]\;[OH^-]}{[H_2O\,]}$$

continuing

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

$$Keq = \frac{[H^+]\ [OH^-]}{[H_2O\ ]} = \frac{10^{-7}\ \ 10^{-7}}{55.5} = 1.8 \times 10^{-16}\ \text{M} \quad (T = 298\ °K)$$

$[H_2O] = 55.\bar{5}$ M, costant !!

$$K_{eq}\ \times\ [H_2O] = [H^+]\ [OH^-] = 10^{-14} = K_W$$ (*costant, at cost T*)

***ion product** of water*

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Cojugated (acid-base) couples *(Brönsted & Lowry)*

acid base

$$HCl \longrightarrow H^+ + Cl^-$$

$$HCOOH \rightleftharpoons H^+ + HCOO^-$$

$$NH^{4+} \rightleftharpoons H^+ + NH_3$$

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strength of an acid/base in H_2O

Defined by the tendency to donate/accept H^+

Es:

1) $AH + H_2O \rightleftharpoons A^- + H_3O^+$

2) $B^- + H_3O^+ \rightleftharpoons BH + H_2O$

These are 2 equilibria

$$Keq_1 = \frac{[A-]\ [H_3O^+]}{[AH]\ [H_2O]}$$

$$Keq_2 = \frac{[BH]\ [H_2O]}{[B^-]\ [H_3O^+]}$$

$[H_2O] \approx$ costant!

$$AH + H_2O \rightleftharpoons A^- + H_3O^+$$

$$Keq = \frac{[A^-]\ [H_3O^+]}{[AH]\ [H_2O]} \qquad \underbrace{Keq \times [H_2O]}_{constant} = \frac{[A^-]\ [H_3O^+]}{[AH]} = {\color{red}Ka}$$

Ka is the H^+ dissociation constant of a weak acid

$$B^- + H_3O^+ \rightleftharpoons BH + H_2O$$

$$Keq = \frac{[BH]\ [H_2O]}{[B^-]\ [H_3O^+]} \qquad \underbrace{Keq/[H_2O]}_{constant} = \frac{[BH]}{[B^-]\ [H_3O^+]} = {\color{red}Kb}$$

Kb is the H^+ association constant of a weak base!

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Examples

$$HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$$

$$Keq = \frac{[HCOO^-]\ [H_3O^+]}{[HCOOH]\ [H_2O]} \qquad \underbrace{Keq \times [H_2O]}_{constant} = \frac{[HCOO^-]\ [H_3O^+]}{[HCOOH]} = Ka$$

Ka, HCOOH = 1.8 x 10^{-4}

$$NH_3 + H_3O^+ \rightleftharpoons NH_4^+ + H_2O$$

$$Keq = \frac{[NH_4^+]\ [H_2O]}{[NH_3]\ [H_3O^+]} \qquad \underbrace{Keq/[H_2O]}_{constant} = \frac{[NH_4^+]}{[NH_3]\ [H_3O^+]} = Kb$$

H+ association of a weak base!

Kb, NH_3 = 1.8 x 10^{-5}

Let's figure out:
The same equilibrium read from left to right and vice-versa…!

$$AH \underset{off}{\overset{on}{\rightleftarrows}} A^- + H^+$$

$$Ka = \frac{[A^-]\ [H^+]}{[AH]} \qquad\qquad Kb = \frac{[AH]}{[A-]\ [H^+]}$$

Thus K_a e K_b must be inversely related

$K_a \propto 1/K_b$ $\qquad$ $K_b \propto 1/K_a$

⇓

More in detail

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Weak acid dissociates

$$HA + H_2O \rightleftharpoons A^- + H_3O^+$$

And specific equilibrium constant Ka is:

$$K_a = [A^-][H_3O^+] / [HA]$$

The conjugated base A^- reacts with water according to:

$$A^- + H_2O \rightleftharpoons HA + OH^-$$

And specific equilibrium constant Kb is:

$$K_b = [HA][OH^-] / [A^-]$$

Let's multiply the two constants and relative expressions:

$$Ka \times Kb = [A^-][H^+] / [HA] \times [HA][OH^-] / [A^-]$$

simplifying:

$$Ka \times Kb = \cancel{[A^-]}[H^+] / \cancel{[HA]} \times \cancel{[HA]}[OH^-] / \cancel{[A^-]}$$

Thus

$$Ka \times Kb = [H^+][OH^-] = K_w$$

The acid (H^+) dissociation!

$$AH + H_2O \rightleftharpoons A^- + H_3O^+$$

K_{eq} →

$$K_a = \frac{[A-]\ [H_3O^+]}{[AH]}$$

$$[H_3O^+] = \frac{K_w}{[OH^-]}$$

in H_2O $\quad Kw = [H_3O^+]\,[OH^-]$

$$K_a = \frac{[A^-]\quad K_w}{[AH]\ [OH^-]} = \frac{K_w}{K_b}$$

Thus in water, the strength of an acid is given by Ka = Kw/Kb i.e.:
the lower the Kb value of the conjugated base the larger is Ka, and *viceversa*

$$K_a \sim 1/K_b \quad \rightarrow \quad K_a = K_w/K_b$$

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The basic (H^+) association !

$$A^- + H_2O \rightleftharpoons AH + OH^-$$

K_{eq} →

$$K_b = \frac{[AH]\ [OH^-]}{[A^-]}$$

$$[OH^-] = \frac{K_w}{[H_3O^+]}$$

in $H_2O \quad Kw = [H_3O^+]\ [OH^-]$

$$K_b = \frac{[AH]\ K_w}{[A^-]\ [H_3O^+]} = \frac{K_w}{K_a}$$

Thus in water, the strength of a base is given by Kb = Kw/Ka i.e.:
the lower the Ka value of the conjugated acid the larger is Kb, and *viceversa*

$$K_b \sim 1/K_a \quad \rightarrow \quad K_b = K_w/K_a$$

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The strength of the hydroxides (inorganic strong bases) is commonly expressed as dissociation of OH^-

$$BOH \rightleftarrows B^+ + OH^-$$

$$K_b = \frac{[B^+][OH^-]}{\cancel{[BOH]}} \rightarrow \infty$$

CONCLUDING:

- The stronger the acid, the bigger K_a
- The stronger the base, the bigger K_b

How big ?!

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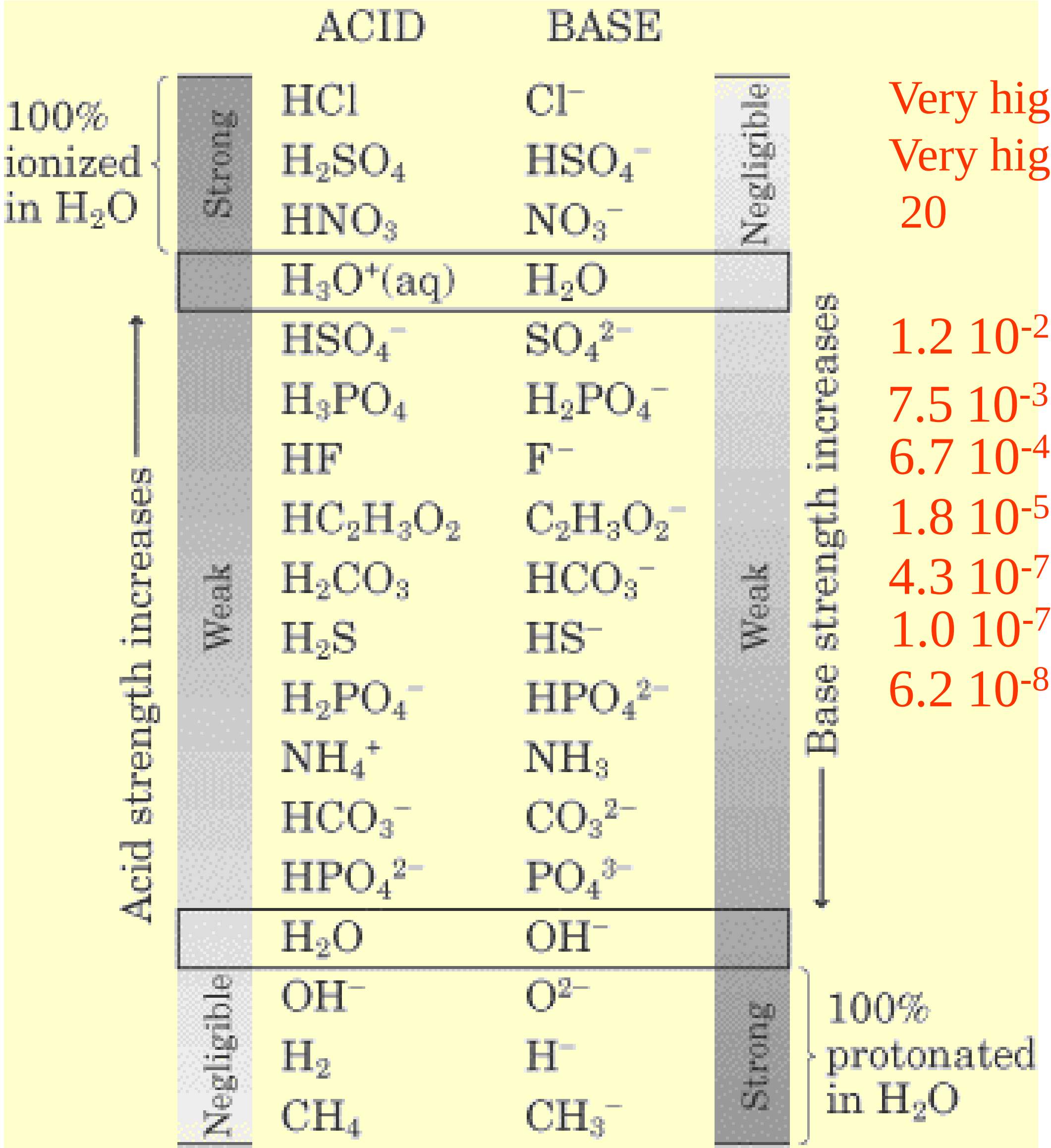
Conjugated couple

Relative strength



	ACID	BASE		Ka
Strong	HCl	Cl^-	Negligible	Very high
	H_2SO_4	HSO_4^-		Very high
	HNO_3	NO_3^-		20
	$H_3O^+(aq)$	H_2O		
Weak	HSO_4^-	SO_4^{2-}	Weak	$1.2\ 10^{-2}$
	H_3PO_4	$H_2PO_4^-$		$7.5\ 10^{-3}$
	HF	F^-		$6.7\ 10^{-4}$
	$HC_2H_3O_2$	$C_2H_3O_2^-$		$1.8\ 10^{-5}$
	H_2CO_3	HCO_3^-		$4.3\ 10^{-7}$
	H_2S	HS^-		$1.0\ 10^{-7}$
	$H_2PO_4^-$	HPO_4^{2-}		$6.2\ 10^{-8}$
	NH_4^+	NH_3		
	HCO_3^-	CO_3^{2-}		
	HPO_4^{2-}	PO_4^{3-}		
	H_2O	OH^-		
Negligible	OH^-	O^{2-}	Strong	
	H_2	H^-		
	CH_4	CH_3^-		

100% ionized in H_2O

Acid strength increases

Base strength increases

100% protonated in H_2O

Kb = Kw/Ka

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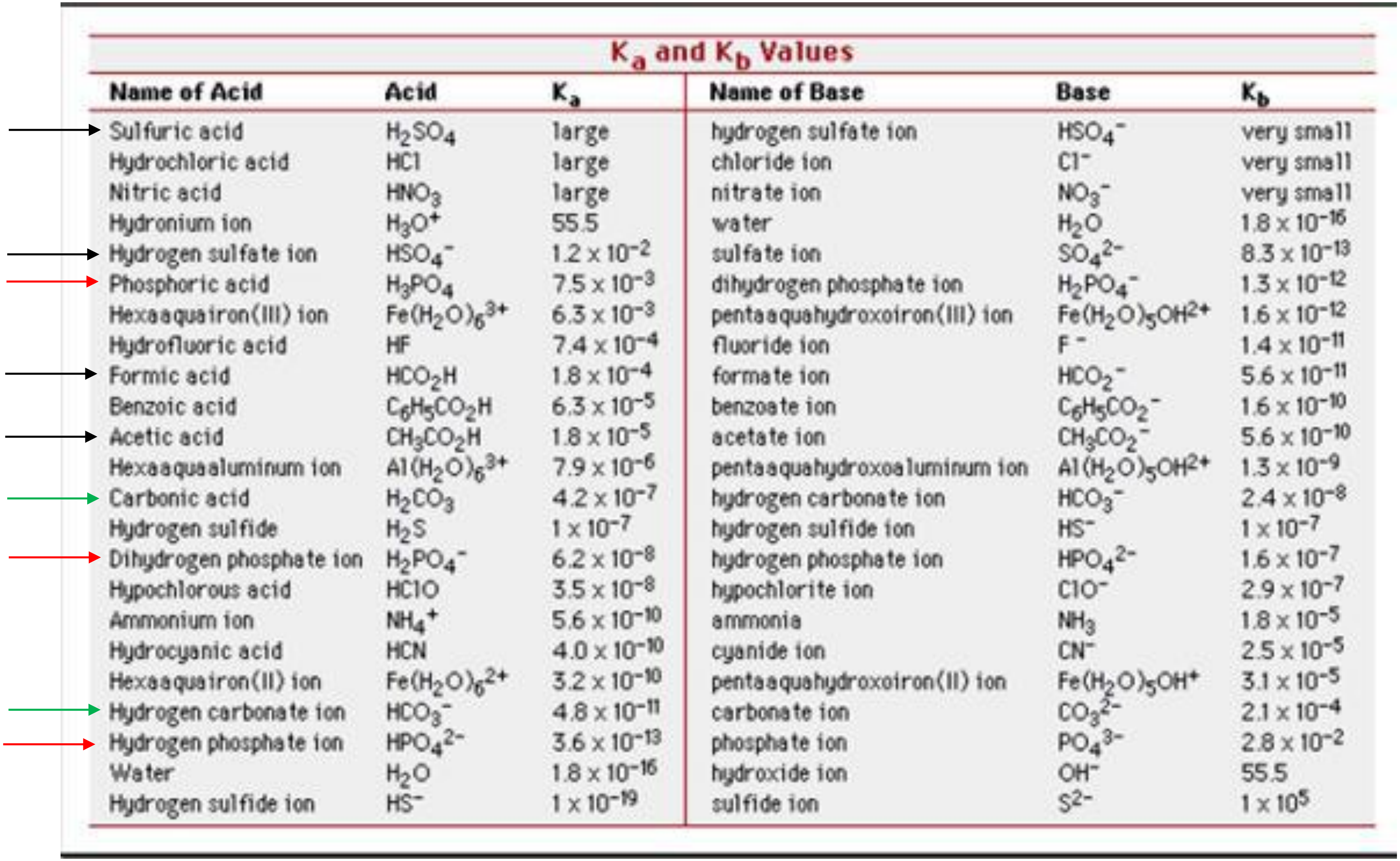
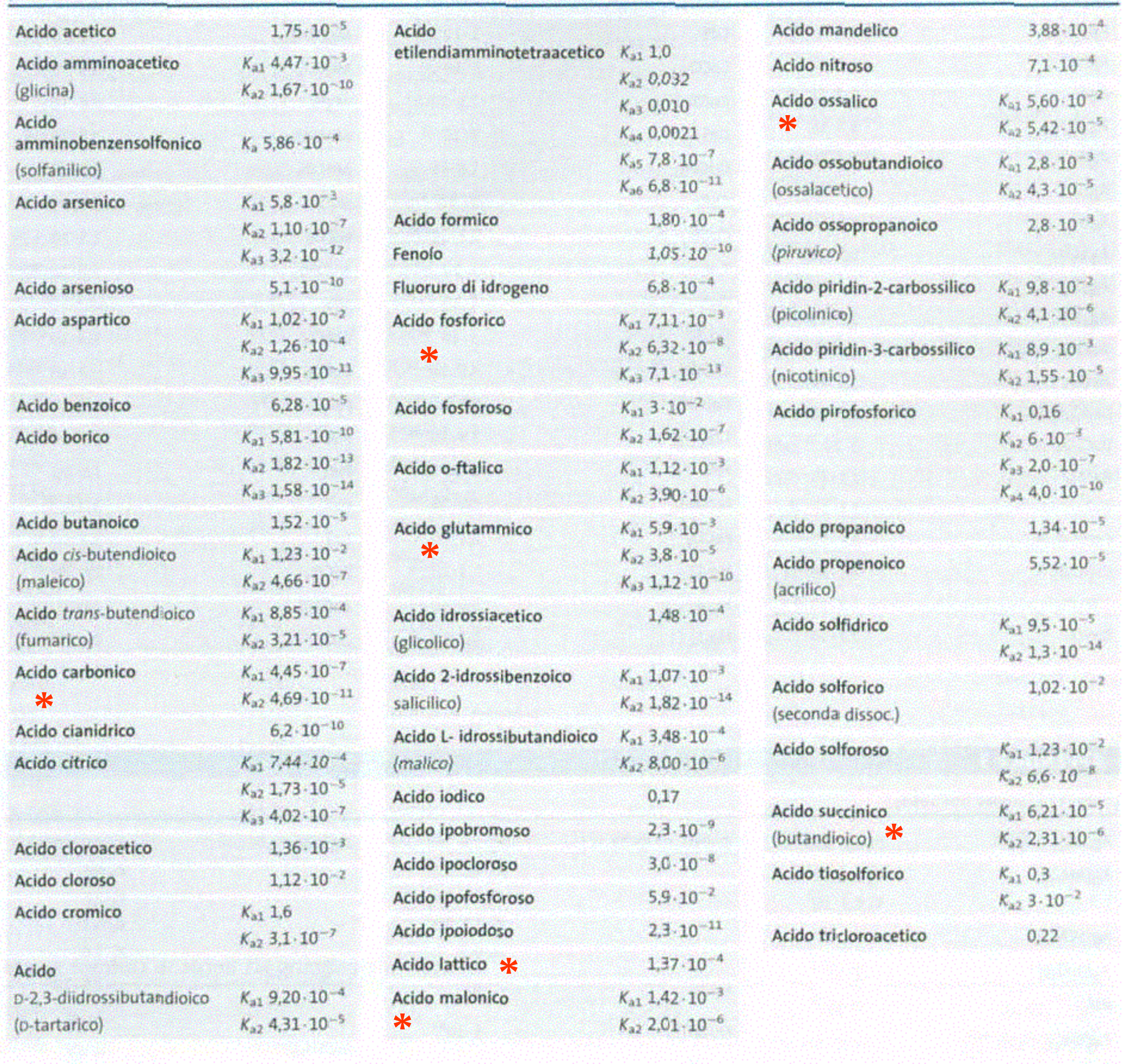


K_a and K_b Values

Name of Acid	Acid	K_a	Name of Base	Base	K_b
Sulfuric acid	H_2SO_4	large	hydrogen sulfate ion	HSO_4^-	very small
Hydrochloric acid	HCl	large	chloride ion	Cl^-	very small
Nitric acid	HNO_3	large	nitrate ion	NO_3^-	very small
Hydronium ion	H_3O^+	55.5	water	H_2O	1.8×10^{-16}
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}	sulfate ion	SO_4^{2-}	8.3×10^{-13}
Phosphoric acid	H_3PO_4	7.5×10^{-3}	dihydrogen phosphate ion	$H_2PO_4^-$	1.3×10^{-12}
Hexaaquairon(III) ion	$Fe(H_2O)_6^{3+}$	6.3×10^{-3}	pentaaquahydroxoiron(III) ion	$Fe(H_2O)_5OH^{2+}$	1.6×10^{-12}
Hydrofluoric acid	HF	7.4×10^{-4}	fluoride ion	F^-	1.4×10^{-11}
Formic acid	HCO_2H	1.8×10^{-4}	formate ion	HCO_2^-	5.6×10^{-11}
Benzoic acid	$C_6H_5CO_2H$	6.3×10^{-5}	benzoate ion	$C_6H_5CO_2^-$	1.6×10^{-10}
Acetic acid	CH_3CO_2H	1.8×10^{-5}	acetate ion	$CH_3CO_2^-$	5.6×10^{-10}
Hexaaquaaluminum ion	$Al(H_2O)_6^{3+}$	7.9×10^{-6}	pentaaquahydroxoaluminum ion	$Al(H_2O)_5OH^{2+}$	1.3×10^{-9}
Carbonic acid	H_2CO_3	4.2×10^{-7}	hydrogen carbonate ion	HCO_3^-	2.4×10^{-8}
Hydrogen sulfide	H_2S	1×10^{-7}	hydrogen sulfide ion	HS^-	1×10^{-7}
Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}	hydrogen phosphate ion	HPO_4^{2-}	1.6×10^{-7}
Hypochlorous acid	$HClO$	3.5×10^{-8}	hypochlorite ion	ClO^-	2.9×10^{-7}
Ammonium ion	NH_4^+	5.6×10^{-10}	ammonia	NH_3	1.8×10^{-5}
Hydrocyanic acid	HCN	4.0×10^{-10}	cyanide ion	CN^-	2.5×10^{-5}
Hexaaquairon(II) ion	$Fe(H_2O)_6^{2+}$	3.2×10^{-10}	pentaaquahydroxoiron(II) ion	$Fe(H_2O)_5OH^+$	3.1×10^{-5}
Hydrogen carbonate ion	HCO_3^-	4.8×10^{-11}	carbonate ion	CO_3^{2-}	2.1×10^{-4}
Hydrogen phosphate ion	HPO_4^{2-}	3.6×10^{-13}	phosphate ion	PO_4^{3-}	2.8×10^{-2}
Water	H_2O	1.8×10^{-16}	hydroxide ion	OH^-	55.5
Hydrogen sulfide ion	HS^-	1×10^{-19}	sulfide ion	S^{2-}	1×10^{5}



Acido acetico	$1{,}75 \cdot 10^{-5}$
Acido amminoacetico (glicina)	$K_{a1}\ 4{,}47 \cdot 10^{-3}$ $K_{a2}\ 1{,}67 \cdot 10^{-10}$
Acido amminobenzensolfonico (solfanilico)	$K_{a}\ 5{,}86 \cdot 10^{-4}$
Acido arsenico	$K_{a1}\ 5{,}8 \cdot 10^{-3}$ $K_{a2}\ 1{,}10 \cdot 10^{-7}$ $K_{a3}\ 3{,}2 \cdot 10^{-12}$
Acido arsenioso	$5{,}1 \cdot 10^{-10}$
Acido aspartico	$K_{a1}\ 1{,}02 \cdot 10^{-2}$ $K_{a2}\ 1{,}26 \cdot 10^{-4}$ $K_{a3}\ 9{,}95 \cdot 10^{-11}$
Acido benzoico	$6{,}28 \cdot 10^{-5}$
Acido borico	$K_{a1}\ 5{,}81 \cdot 10^{-10}$ $K_{a2}\ 1{,}82 \cdot 10^{-13}$ $K_{a3}\ 1{,}58 \cdot 10^{-14}$
Acido butanoico	$1{,}52 \cdot 10^{-5}$
Acido *cis*-butendioico (maleico)	$K_{a1}\ 1{,}23 \cdot 10^{-2}$ $K_{a2}\ 4{,}66 \cdot 10^{-7}$
Acido *trans*-butendioico (fumarico)	$K_{a1}\ 8{,}85 \cdot 10^{-4}$ $K_{a2}\ 3{,}21 \cdot 10^{-5}$
Acido carbonico *	$K_{a1}\ 4{,}45 \cdot 10^{-7}$ $K_{a2}\ 4{,}69 \cdot 10^{-11}$
Acido cianidrico	$6{,}2 \cdot 10^{-10}$
Acido citrico	$K_{a1}\ 7{,}44 \cdot 10^{-4}$ $K_{a2}\ 1{,}73 \cdot 10^{-5}$ $K_{a3}\ 4{,}02 \cdot 10^{-7}$
Acido cloroacetico	$1{,}36 \cdot 10^{-3}$
Acido cloroso	$1{,}12 \cdot 10^{-2}$
Acido cromico	$K_{a1}\ 1{,}6$ $K_{a2}\ 3{,}1 \cdot 10^{-7}$
Acido D-2,3-diidrossibutandioico (D-tartarico)	$K_{a1}\ 9{,}20 \cdot 10^{-4}$ $K_{a2}\ 4{,}31 \cdot 10^{-5}$
Acido etilendiamminotetraacetico	$K_{a1}\ 1{,}0$ $K_{a2}\ 0{,}032$ $K_{a3}\ 0{,}010$ $K_{a4}\ 0{,}0021$ $K_{a5}\ 7{,}8 \cdot 10^{-7}$ $K_{a6}\ 6{,}8 \cdot 10^{-11}$
Acido formico	$1{,}80 \cdot 10^{-4}$
Fenolo	$1{,}05 \cdot 10^{-10}$
Fluoruro di idrogeno	$6{,}8 \cdot 10^{-4}$
Acido fosforico *	$K_{a1}\ 7{,}11 \cdot 10^{-3}$ $K_{a2}\ 6{,}32 \cdot 10^{-8}$ $K_{a3}\ 7{,}1 \cdot 10^{-13}$
Acido fosforoso	$K_{a1}\ 3 \cdot 10^{-2}$ $K_{a2}\ 1{,}62 \cdot 10^{-7}$
Acido o-ftalico	$K_{a1}\ 1{,}12 \cdot 10^{-3}$ $K_{a2}\ 3{,}90 \cdot 10^{-6}$
Acido glutammico *	$K_{a1}\ 5{,}9 \cdot 10^{-3}$ $K_{a2}\ 3{,}8 \cdot 10^{-5}$ $K_{a3}\ 1{,}12 \cdot 10^{-10}$
Acido idrossiacetico (glicolico)	$1{,}48 \cdot 10^{-4}$
Acido 2-idrossibenzoico salicilico)	$K_{a1}\ 1{,}07 \cdot 10^{-3}$ $K_{a2}\ 1{,}82 \cdot 10^{-14}$
Acido L- idrossibutandioico *(malico)*	$K_{a1}\ 3{,}48 \cdot 10^{-4}$ $K_{a2}\ 8{,}00 \cdot 10^{-6}$
Acido iodico	$0{,}17$
Acido ipobromoso	$2{,}3 \cdot 10^{-9}$
Acido ipocloroso	$3{,}0 \cdot 10^{-8}$
Acido ipofosforoso	$5{,}9 \cdot 10^{-2}$
Acido ipoiodoso	$2{,}3 \cdot 10^{-11}$
Acido lattico *	$1{,}37 \cdot 10^{-4}$
Acido malonico *	$K_{a1}\ 1{,}42 \cdot 10^{-3}$ $K_{a2}\ 2{,}01 \cdot 10^{-6}$
Acido mandelico	$3{,}88 \cdot 10^{-4}$
Acido nitroso	$7{,}1 \cdot 10^{-4}$
Acido ossalico *	$K_{a1}\ 5{,}60 \cdot 10^{-2}$ $K_{a2}\ 5{,}42 \cdot 10^{-5}$
Acido ossobutandioico (ossalacetico)	$K_{a1}\ 2{,}8 \cdot 10^{-3}$ $K_{a2}\ 4{,}3 \cdot 10^{-5}$
Acido ossopropanoico *(piruvico)*	$2{,}8 \cdot 10^{-3}$
Acido piridin-2-carbossilico (picolinico)	$K_{a1}\ 9{,}8 \cdot 10^{-2}$ $K_{a2}\ 4{,}1 \cdot 10^{-6}$
Acido piridin-3-carbossilico (nicotinico)	$K_{a1}\ 8{,}9 \cdot 10^{-3}$ $K_{a2}\ 1{,}55 \cdot 10^{-5}$
Acido pirofosforico	$K_{a1}\ 0{,}16$ $K_{a2}\ 6 \cdot 10^{-3}$ $K_{a3}\ 2{,}0 \cdot 10^{-7}$ $K_{a4}\ 4{,}0 \cdot 10^{-10}$
Acido propanoico	$1{,}34 \cdot 10^{-5}$
Acido propenoico (acrilico)	$5{,}52 \cdot 10^{-5}$
Acido solfidrico	$K_{a1}\ 9{,}5 \cdot 10^{-5}$ $K_{a2}\ 1{,}3 \cdot 10^{-14}$
Acido solforico (seconda dissoc.)	$1{,}02 \cdot 10^{-2}$
Acido solforoso	$K_{a1}\ 1{,}23 \cdot 10^{-2}$ $K_{a2}\ 6{,}6 \cdot 10^{-8}$
Acido succinico (butandioico) *	$K_{a1}\ 6{,}21 \cdot 10^{-5}$ $K_{a2}\ 2{,}31 \cdot 10^{-6}$
Acido tiosolforico	$K_{a1}\ 0{,}3$ $K_{a2}\ 3 \cdot 10^{-2}$
Acido tricloroacetico	$0{,}22$

Thus

The stronger the acid:

- the higher its Ka (H^+ dissociation)

The stronger the base:

- the higher its Kb value (H+ association)
- the lower the Ka value (of the conjugated acid)
- the higher the efficiency to dissociate OH- (hydroxides only)

Ka or Kb values can be numbers *difficult to handle*, e.g. rather small (10^{-x}) whose, again, small variations induce big effects !

This is why it was introduced the notation **p**;
p = colog (-log x = log 1/x) *to base = 10*
of Ka or Kb

if [Ka] = 10^{-5}
pKa = 5
-log 10^{-5}, log $1/10^{-5}$ = log 10^{5} = 5

The weaker the acid:
- The lower its Ka value &
- The higher its pKa value

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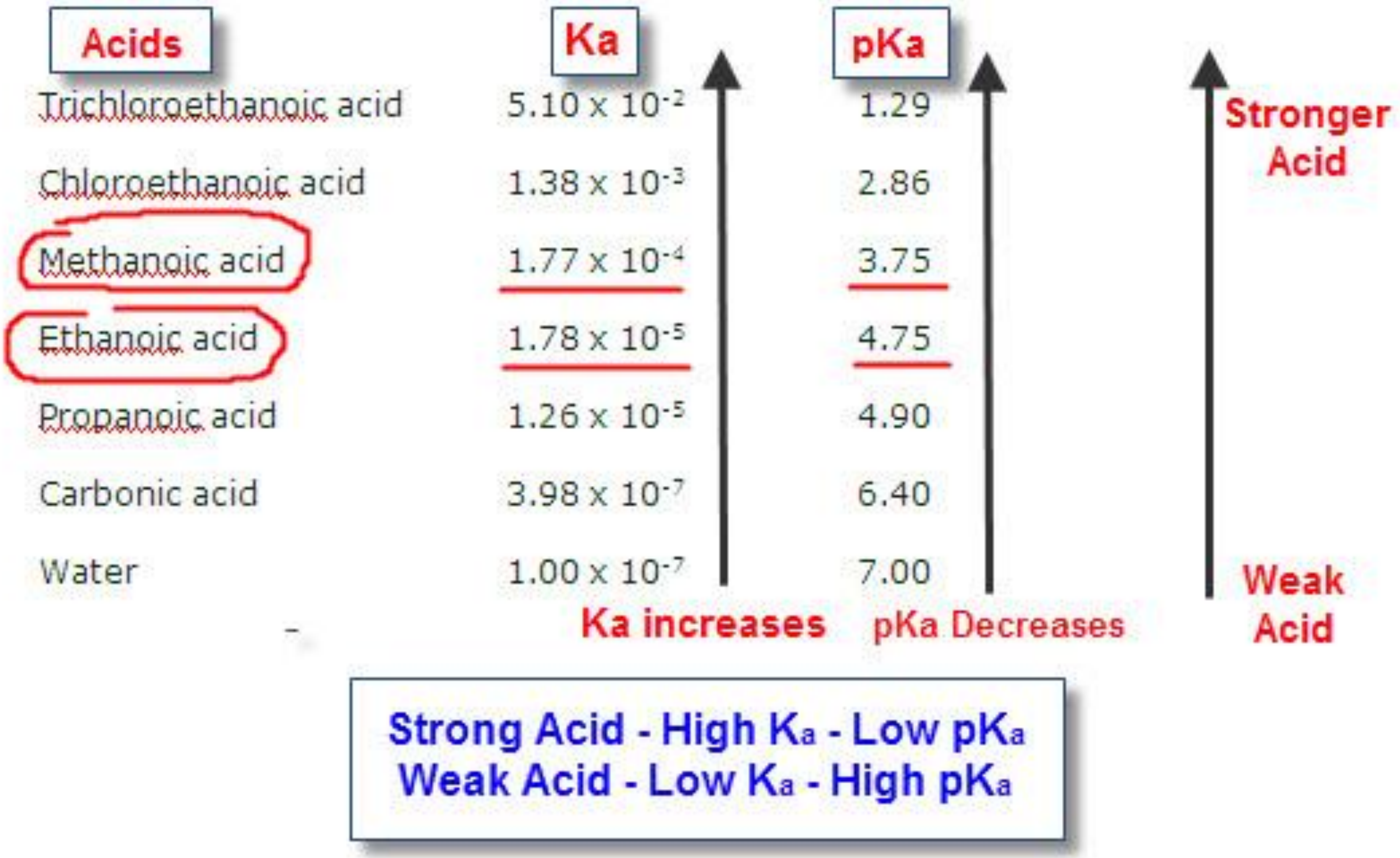
Ka & pKa



Acids	Ka	pKa
Trichloroethanoic acid	5.10×10^{-2}	1.29
Chloroethanoic acid	1.38×10^{-3}	2.86
Methanoic acid	1.77×10^{-4}	3.75
Ethanoic acid	1.78×10^{-5}	4.75
Propanoic acid	1.26×10^{-5}	4.90
Carbonic acid	3.98×10^{-7}	6.40
Water	1.00×10^{-7}	7.00

Strong Acid - High K_a - Low pK_a
Weak Acid - Low K_a - High pK_a

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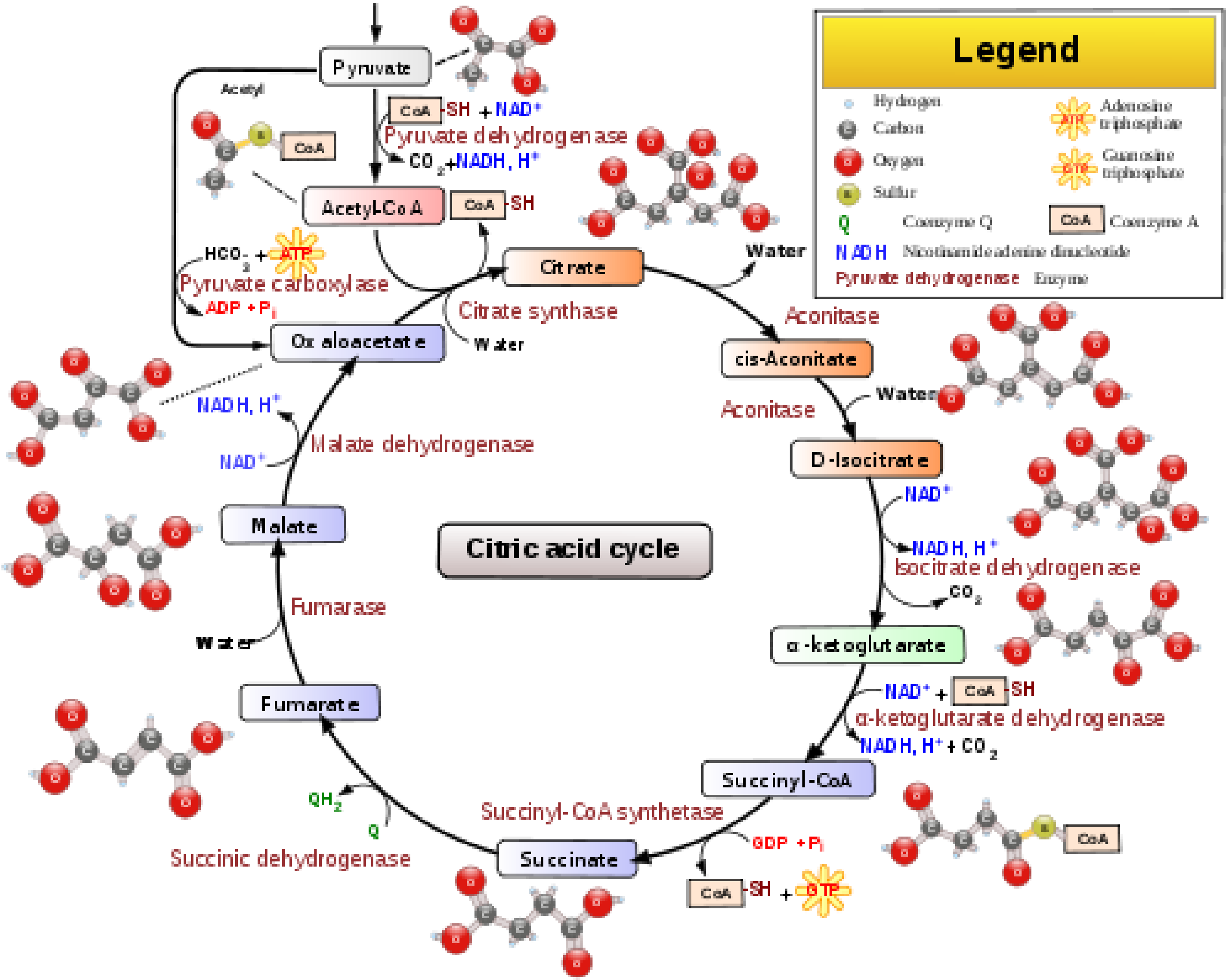
Krebs cycle



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Remember relationship between Ka and α ?

$$AH + H_2O \rightleftharpoons A^- + H_3O^+$$

Weak electrolytes

$$AB \rightleftharpoons A^+ + B^-$$

$$AH \rightleftharpoons A^- + H^+$$

$$(1-\alpha)\,C \qquad \alpha C \qquad \alpha C$$

At equilibrium

$$Ka = \frac{[A-]\ [H+]}{[AH]} = \frac{\alpha C \quad \alpha C}{(1-\alpha)C} = \frac{\alpha^2\ C}{(1-\alpha)} =$$

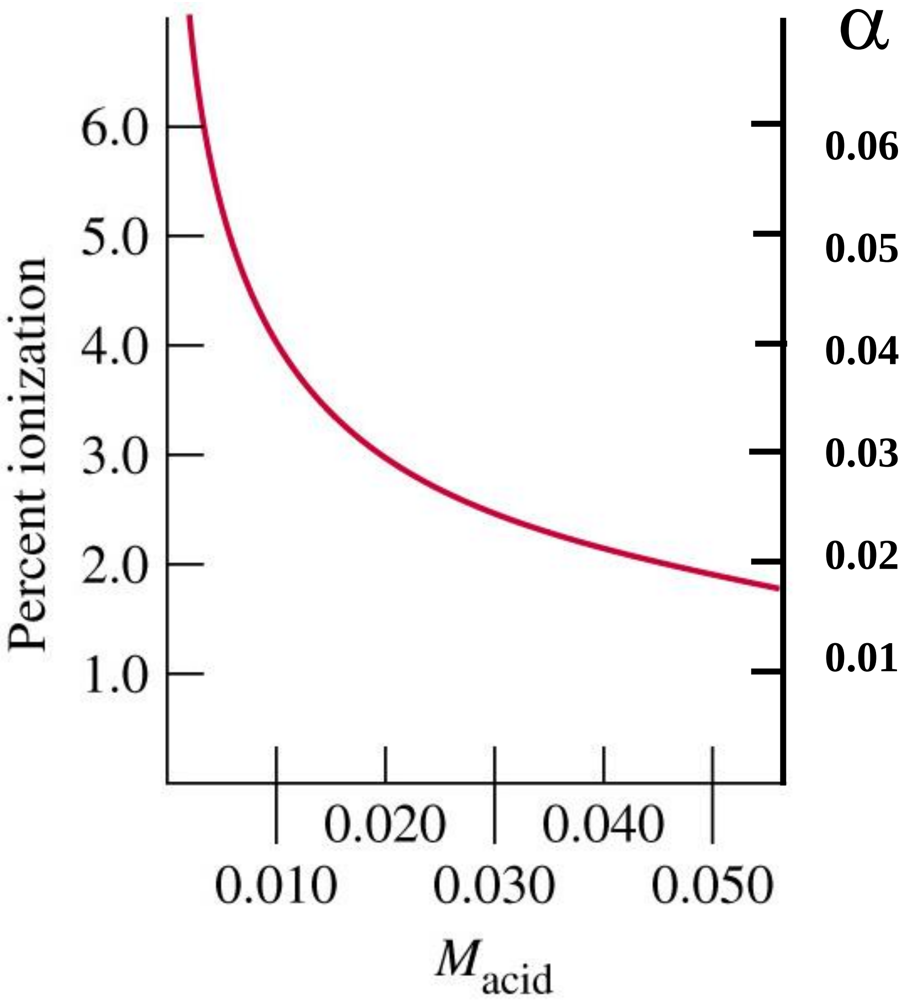
if α
is small…

$$\mathbf{Ka = \alpha^2\, C}$$

Ostwald dilution-law

What happens to α *upon diluting a solution of a weak electrolyte ?!*

Ostwald law



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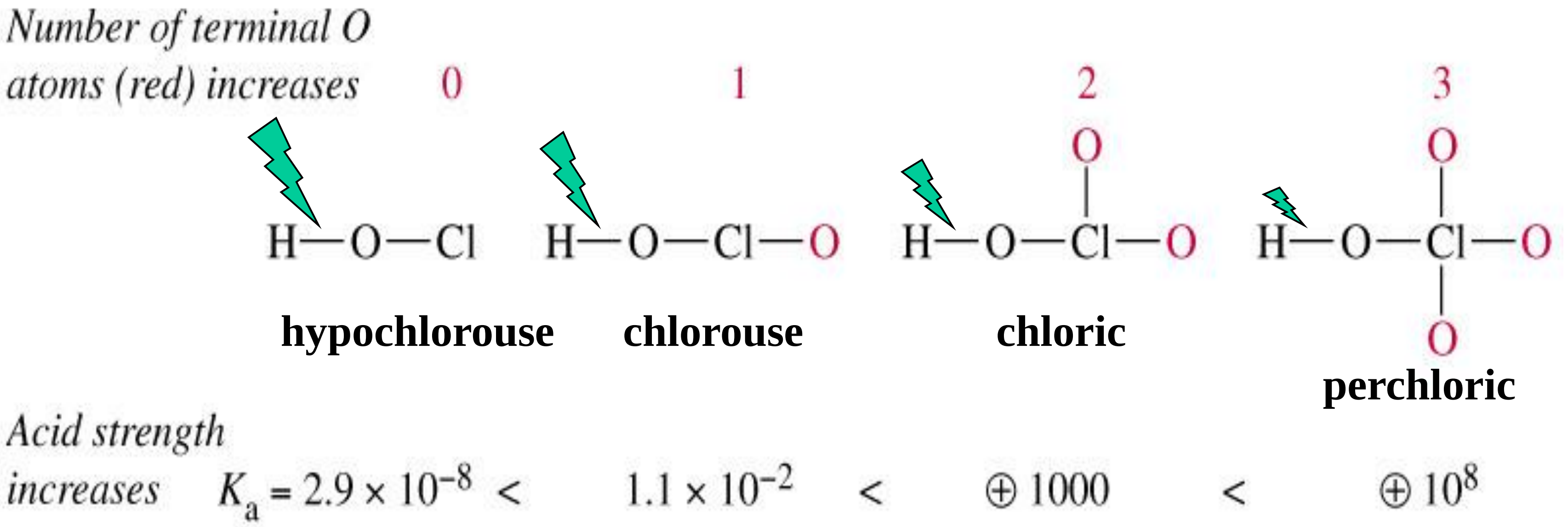
What is the molecular reason for different acid/base strength ?

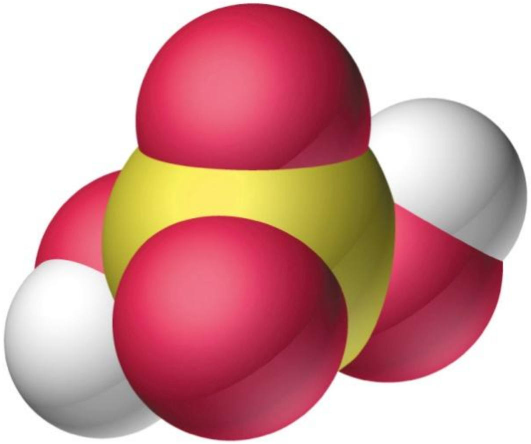
Different H+ bond energy (covalent etheropolar)
(electronegativity + inductive effects + charge distribution)

Ex.

Strenght of hydro-chloro acids



Bond energy !

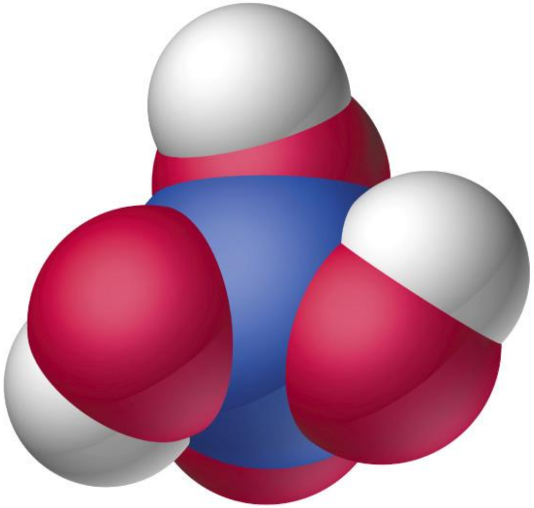


Sulfuric acid

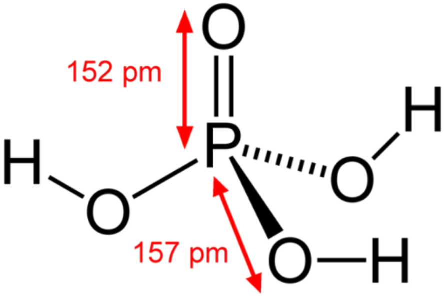
H_2SO_4

$K_{a1} = \infty$
$K_{a2} = 10^{-2}$

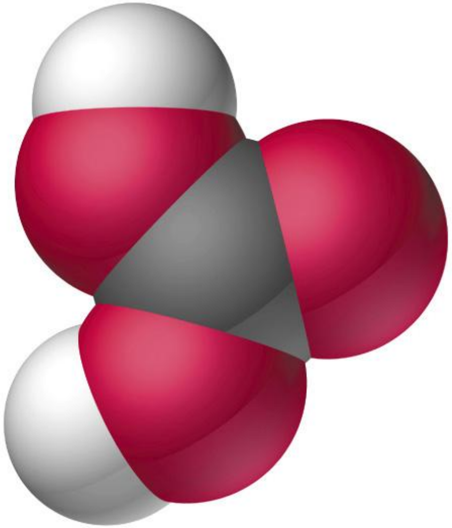
H_3PO_4



Phosphoric acid



$K_{a1} = 10^{-3}$
$K_{a2} = 10^{-8}$
$K_{a3} = 10^{-13}$



Carbonic acid

H_2CO_3

$K_{a1} = 10^{-7}$
$K_{a2} = 10^{-11}$

Poly-functional acids (*poly*-protic)

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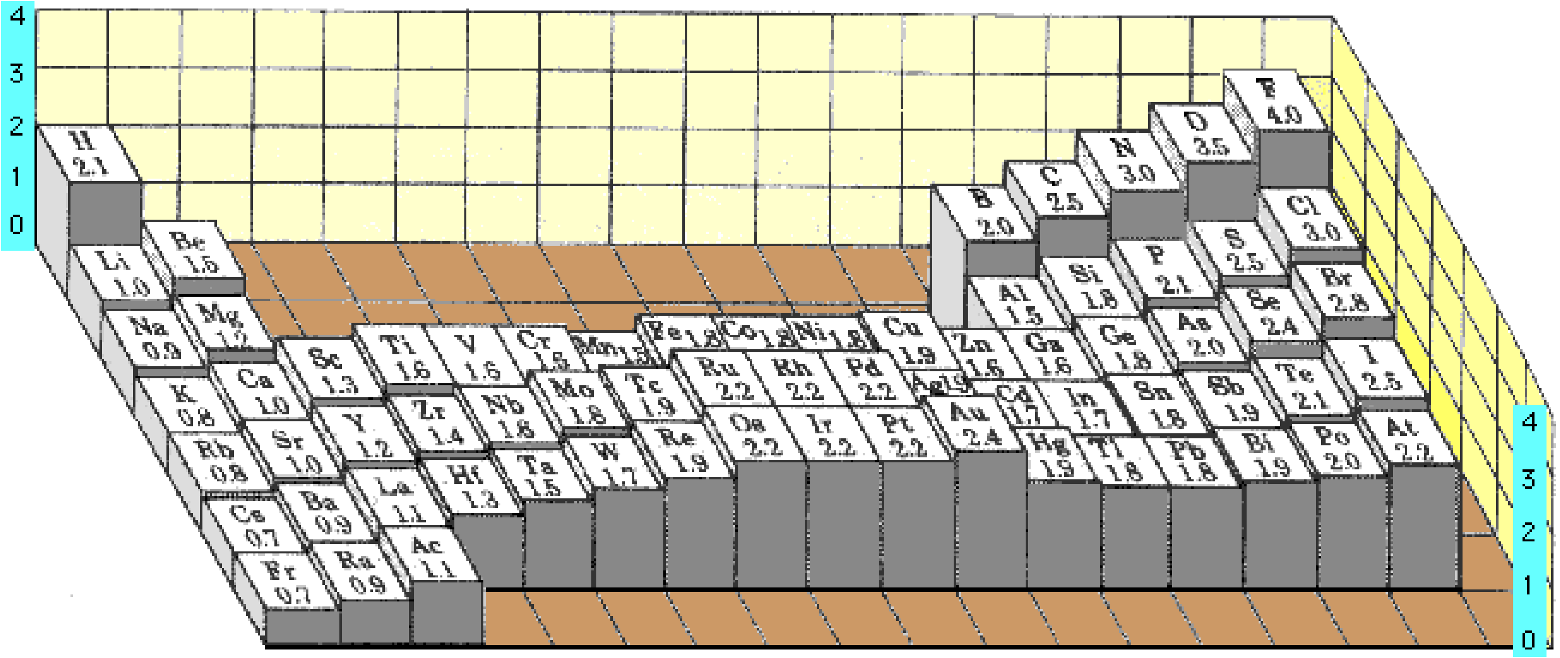
Electronegativity → $f(E_i, A_e)$

Distribution of electronegativity



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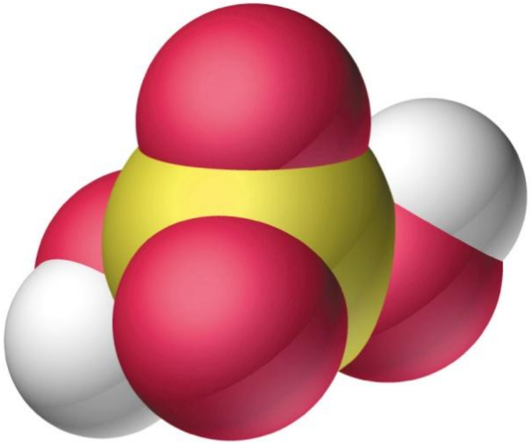
polyfunctional acids

strength

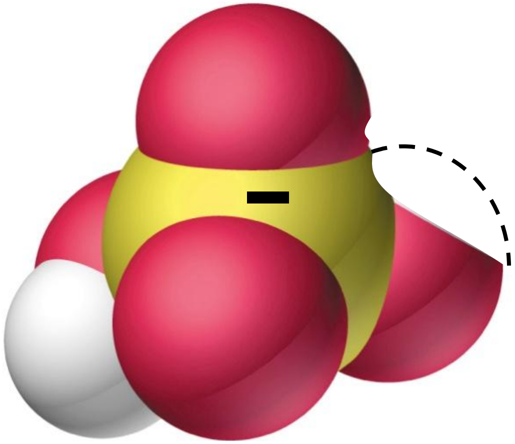
$H_2SO_4 \longrightarrow HSO_4^- + H^+$ $K_{a1} = \infty$

$HSO_4^- \rightleftharpoons SO_4^{2-} + H^+$ $K_{a2} = 10^{-2}$



H_2SO_4

electroneutral



HSO_4^-

negatively charged

$[H^+]$ in biological fluids is described by
very small numbers (10^{-x})
whose even smaller variations produce big effects !

Then **pH**
i.e. colog (-log x = log 1/x) to base 10
of $[H^+]$

$[H^+] = 10^{-7}$ M ?
The $\log 1/10^{-7} = \log 10^{7} = 7$
pH = 7 *(neutral pH!)*

Ex.s: $[H+] = 2{,}5119 \times 10^{-8}$ → pH 7.6

$[H^+] = 3{,}9810 \times 10^{-8}$ → pH 7.4

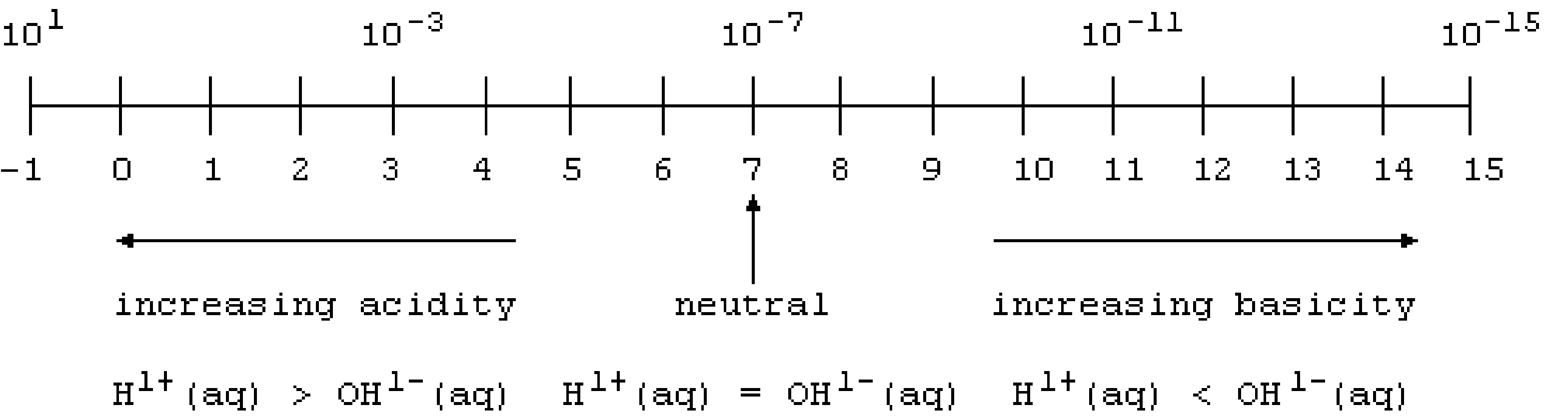
$[H^+] = 5{,}0118 \times 10^{-8}$ → pH 7.3

$[H^+] = 6{,}3095 \times 10^{-8}$ → pH 7.2
$[H+] = 3{,}1623 \times 10^{-7}$ → pH 6.5

$[H^+]$ to pH conversion

$[H^+]$

pH



$$[H^+]\ \mathrm{x}\ [OH^-] \quad = \text{cost} = 10^{-14}$$

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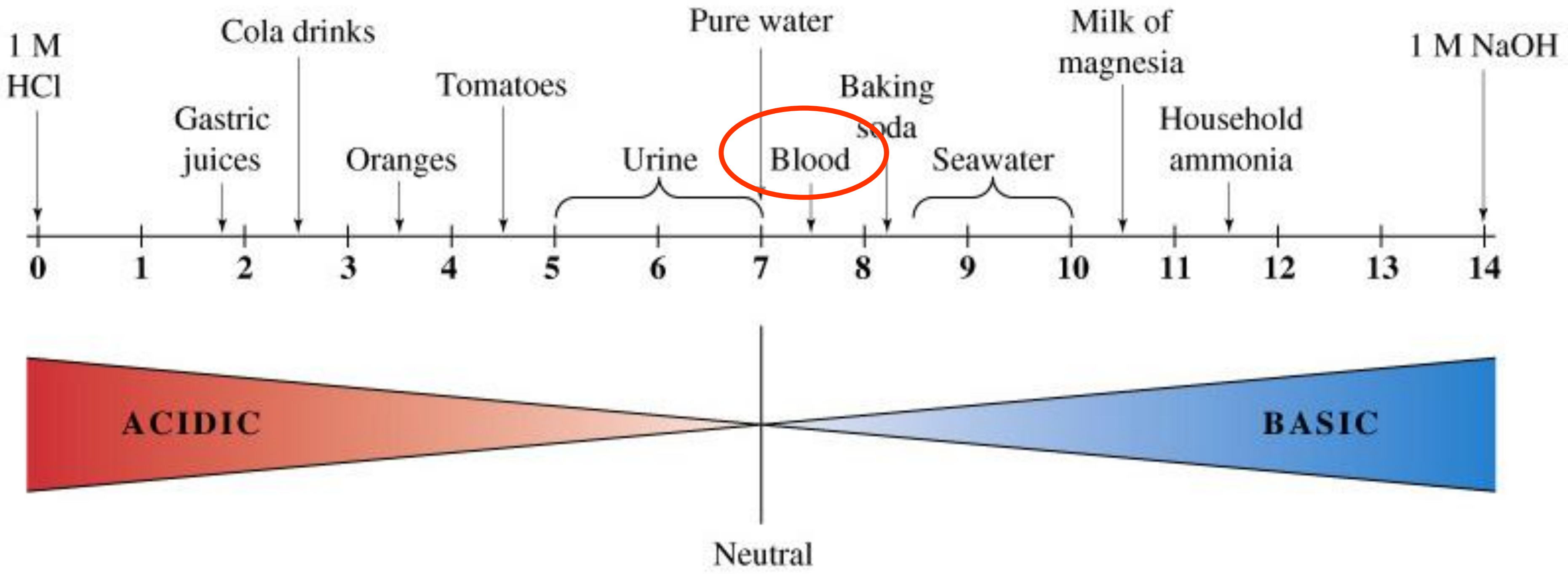
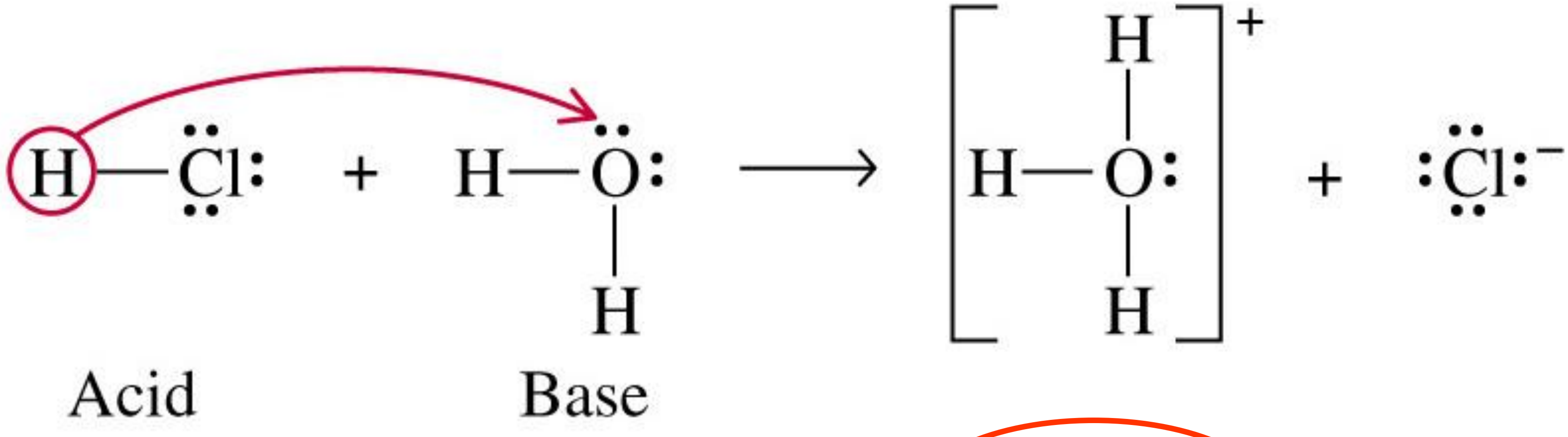
Biological fluids



$$[H^+] \times [OH^-] = \text{cost} = 10^{-14}$$

$$pH + pOH = 14$$



0.1 M 55.5 M 0.1 M 0.1 M

$$pH = \log 1/0.1 = 1.0$$

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pH of a weak acid solution

$$AH \rightleftharpoons A^- + H^+$$

$$Ka = \frac{[A^-]\ [H_3O^+]}{[AH]} = \frac{[H^+]^2}{[AH]}$$

$$[H^+]^2 = Ka\ [AH]$$

$$\boxed{[H^+] = \sqrt{Ka \times Ca}}$$

How many atoms are in the human body?

A 70 kg body would have approximately $7*10^{27}$ atoms.

That is, 7 followed by 27 zeros:

7,000,000,000,000,000,000,000,000,000

Of that, $4.7*10^{27}$ would be hydrogen atoms, which have one proton and one electron each.

Another $1.8*10^{27}$ would be oxygen, which has 8 protons, 8 neutrons and 8 electrons.

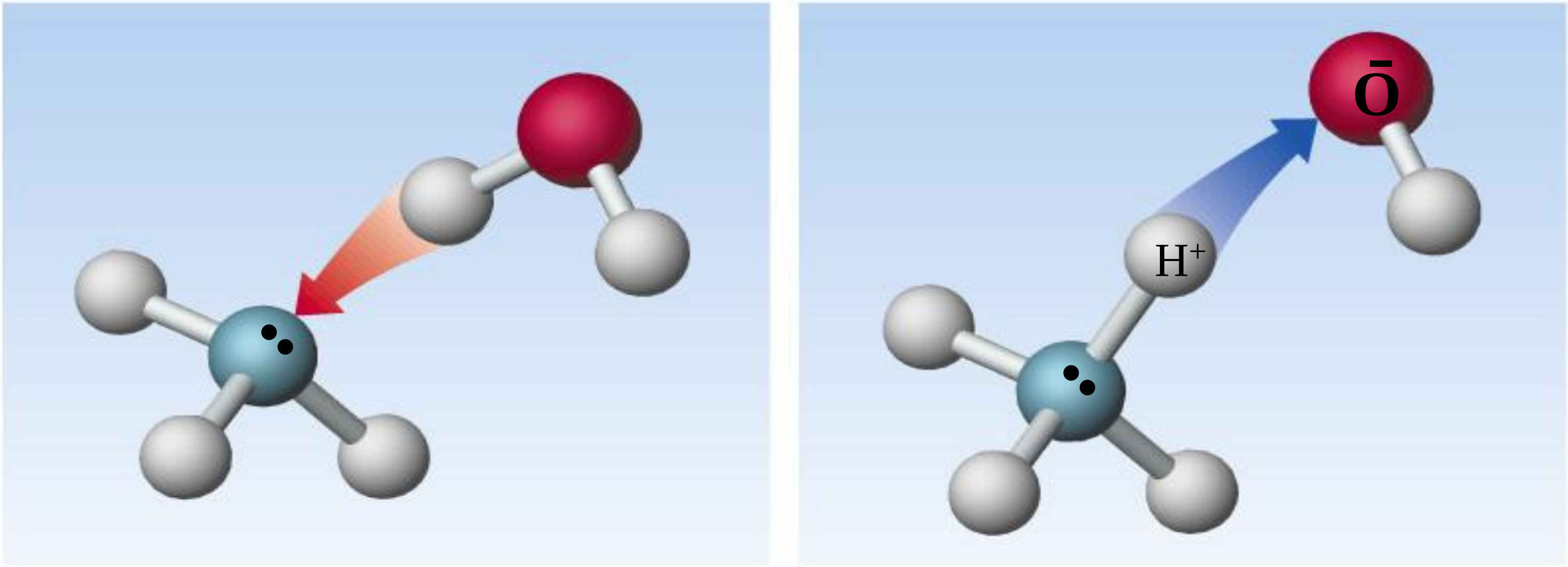
There are 7.0*1026
carbon

atoms, which have 6 protons, 6 neutrons and 6 electrons. Now, let's add that all up:

	Protons	**Neutrons**	**Electrons**
Hydrogen	$4.7*10^{27}$	0	$4.7*10^{27}$
Oxygen	$1.4*10^{28}$	$1.4*10^{28}$	$1.4*10^{28}$
Carbon	$4.2*10^{27}$	$4.2*10^{27}$	$4.2*10^{27}$
Total	$2.3*10^{28}$	$1.8*10^{28}$	$2.3*10^{28}$

Well, you'll have to agree that really is a whole bunch.

Ancòra: coppie coniugate acido - base



$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

Base(1) Acid(2) Acid(1) Base(2)

coppia 1

coppia 2