Robert Boyle 1680

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

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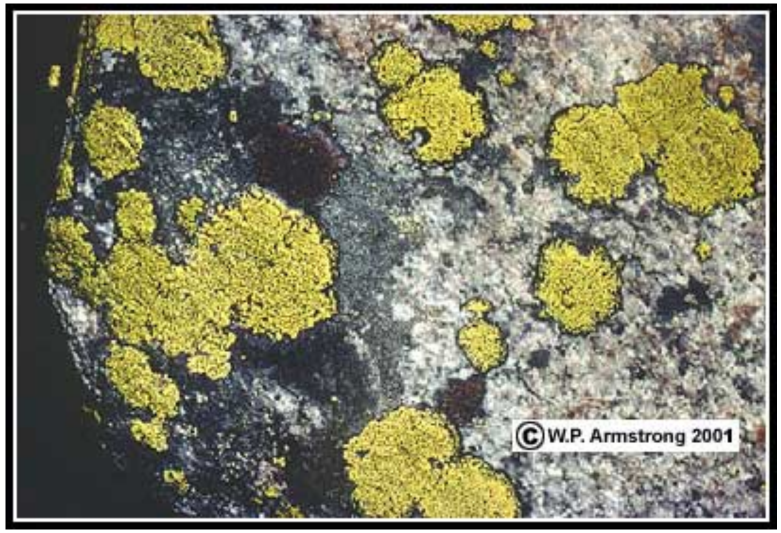
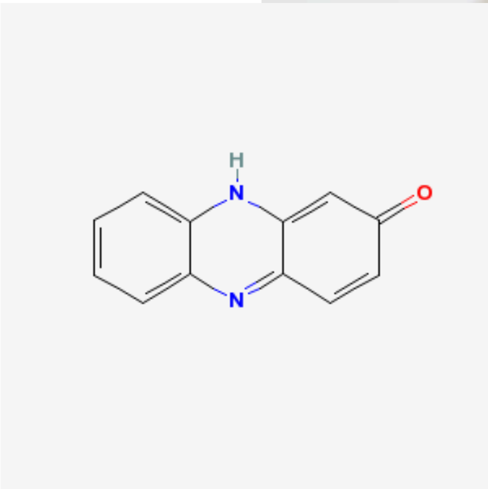
Chrozophora tinctoria

Roccella tinctoria also 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

$$X + :Y \rightarrow X:Y$$

acid base

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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)*

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Acid base reaction (most common)

HCl + NaOH

$$H^+ + :\ddot{O}H^- \longrightarrow H_2O$$

acid base product

$\Delta G << 0 \approx - 57$ KJ/mol

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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

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Acids and bases of biomedical interest

ACIDS			
HCll	hydrochloric ac.	Strong	gastric jouce
HNO_3	nitric ac.	strong	caustic
H_2SO_4	sulphoric ac.	strong	caustic
H_2SO_3	sulphoric ac.	strong	caustic
H_3PO_4	phosphoric ac.	weak	biological buffer
H_3BO_3	boric ac.	weak	external disinfectant
H_2CO_3	carbonic ac.	weak	biological buffer
HCOOH	formic ac.	weak	
CH_3COOH	acetic ac.	weak	vinegar
BASES (HYDROXIDES)			
NaOH	sodium hydroxide	strong	caustic
KOH	potassium hydroxide	caustic	
$Ca(OH)_2$	calcium hydroxide	caustic	
$Mg(OH)_2$	magnesium hydroxide	strong	caustic
$Al(OH)_3$	aluminum hydroxide	strong	caustic
$NH_3.H_2O$	ammonia	weak	
NH_4OH	ammonium hydroxide		

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

Acid				base
HCl	$\longrightarrow$	H^+	$+$	Cl^-
$HCOOH$	$\rightleftharpoons$	H^+	$+$	$HCOO^-$
NH_4^+	$\rightleftharpoons$	H^+	$+$	NH_3

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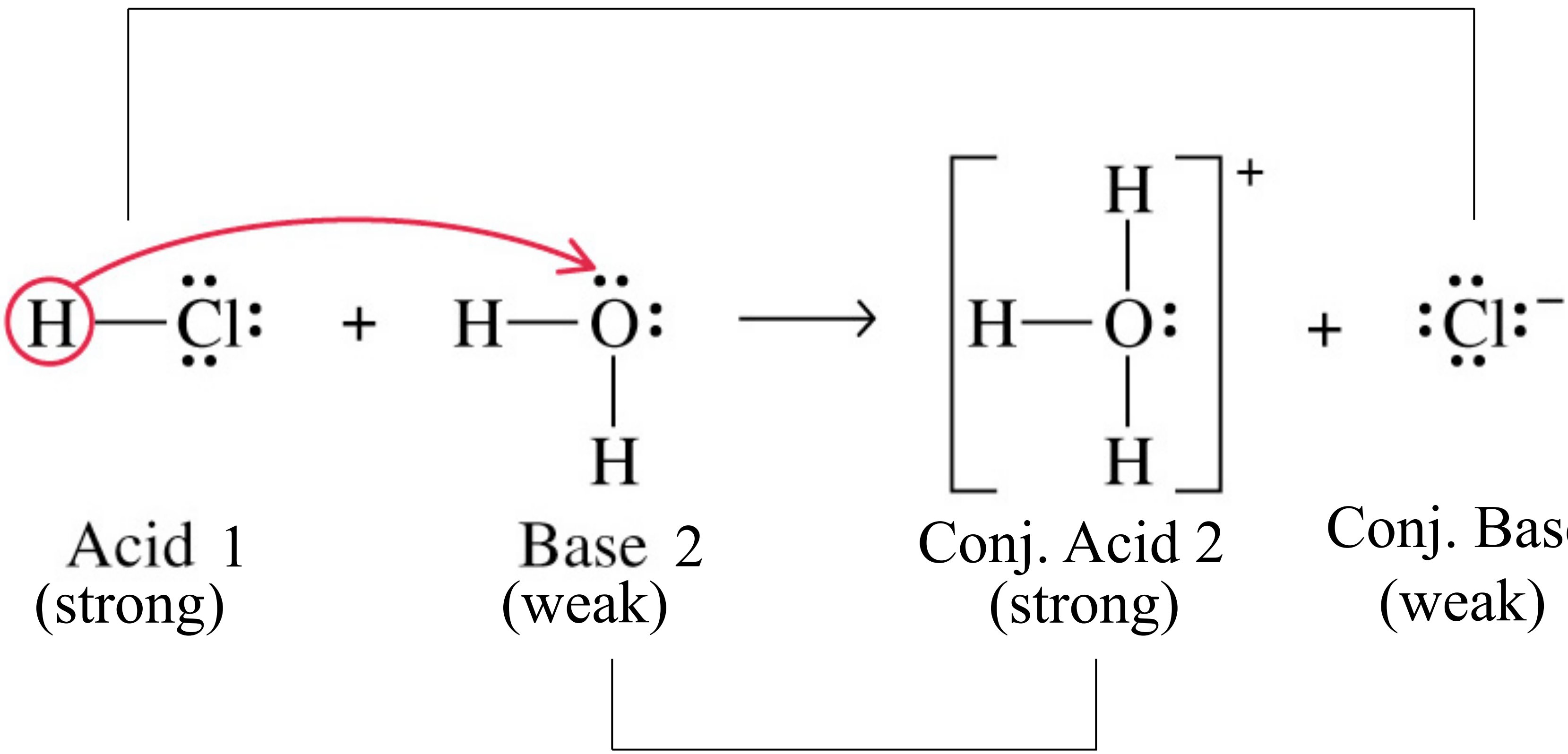
Acid-base reaction

Conjugated couple 1

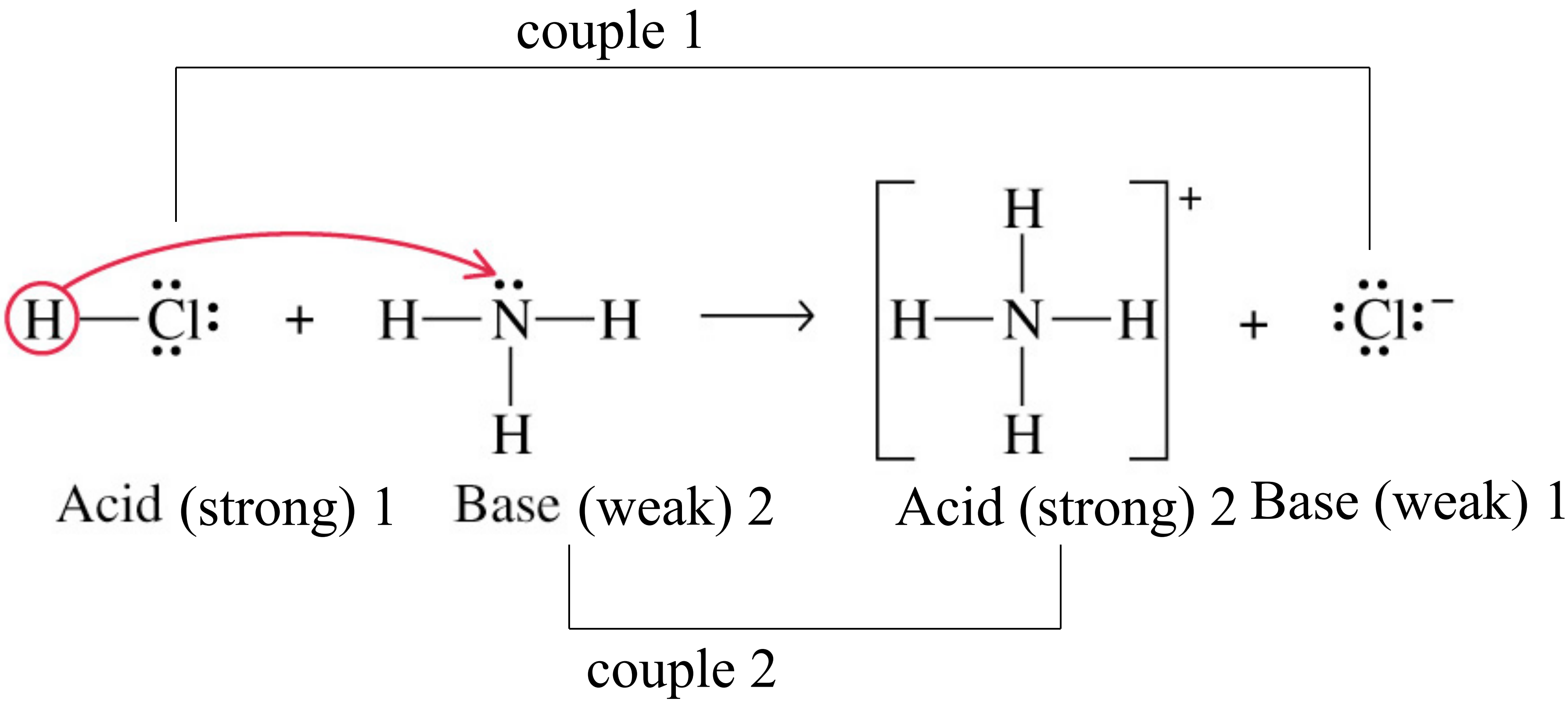


Conjugated couple 2

After H+ donation, the acid turns into the conjugated base while the base turns into the conjugated acid

The cojugated species have opposite strength !

Acid-base Reaction → between cojugated couples



remember
Conjugated species have opposite strength!

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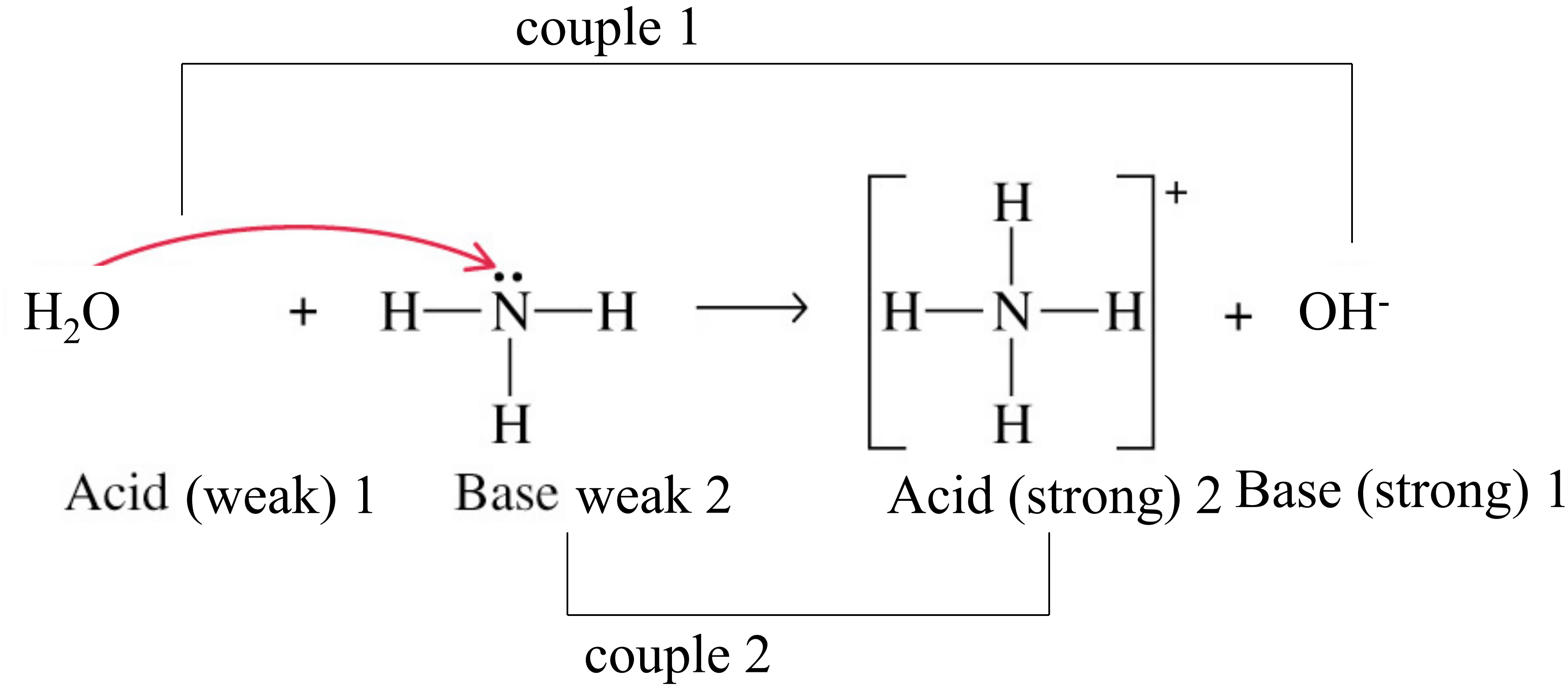
H_2O as an acid *(donating H+)*



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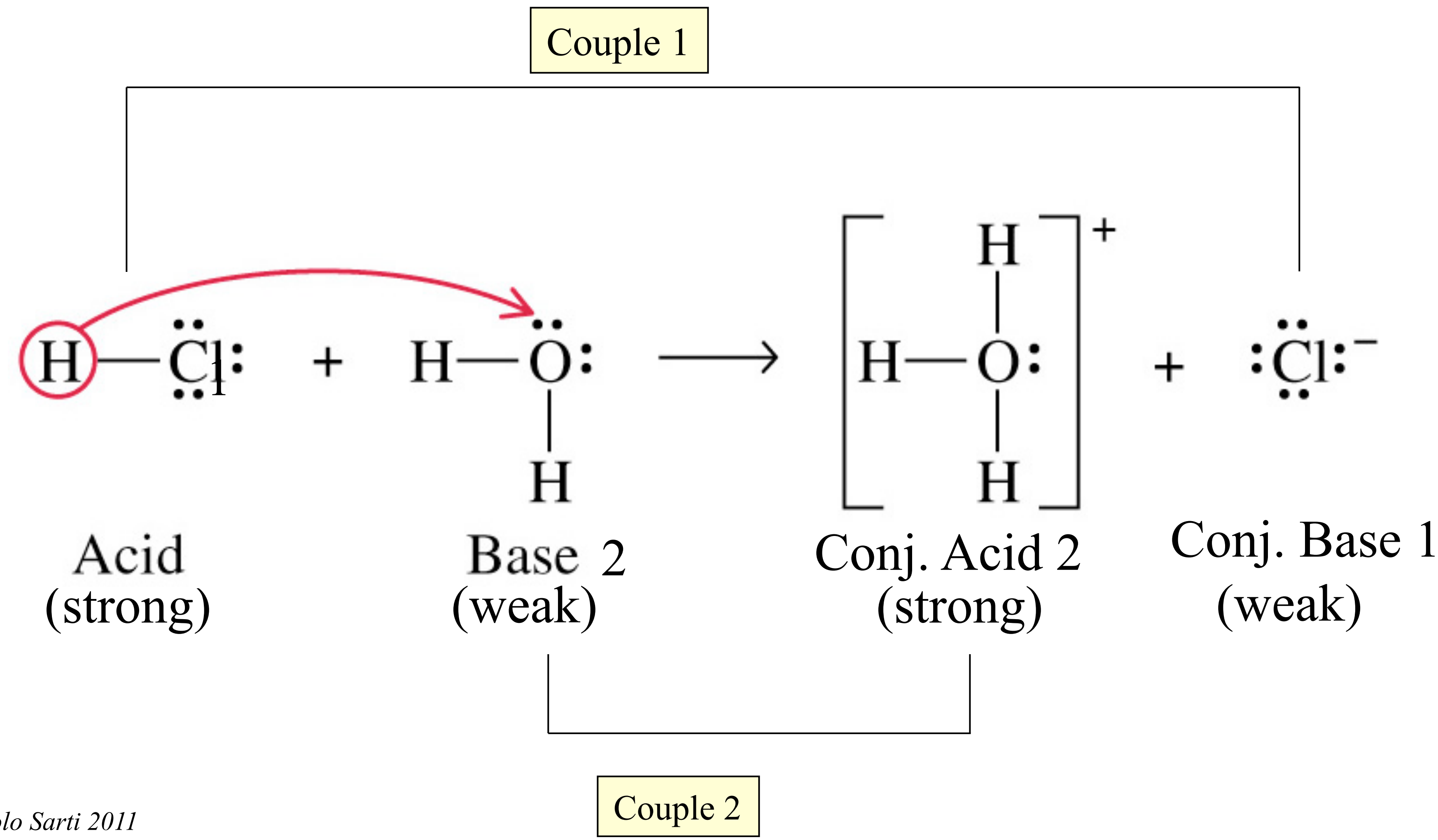
H_2O as a base *(accepting H+)*



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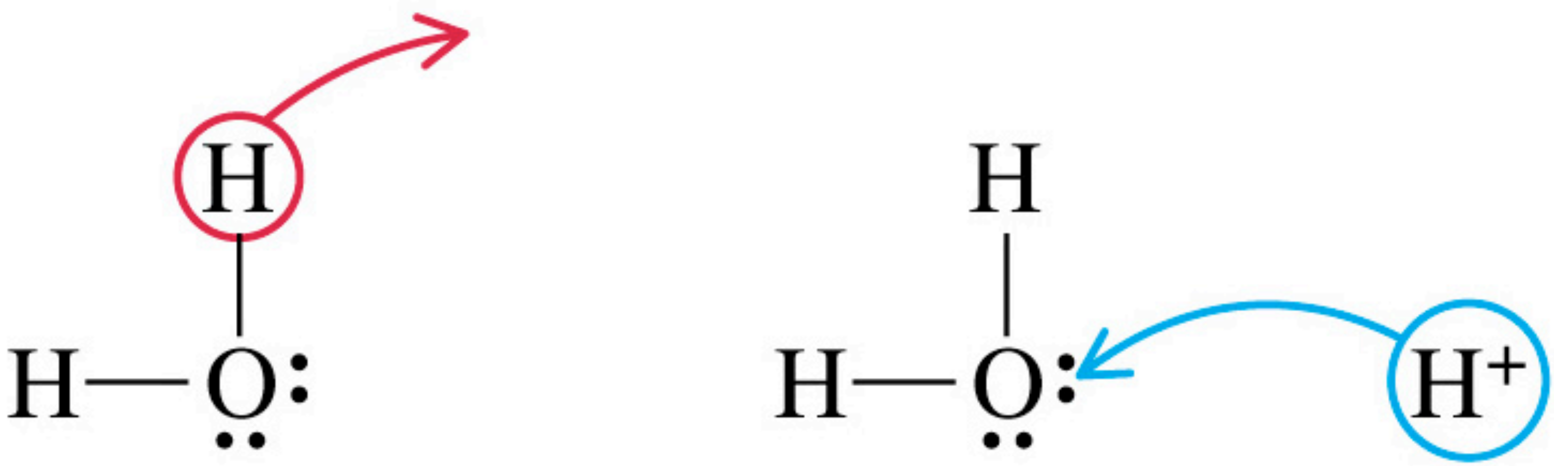
The water molecule is "amphoteric"



H_2O as an acid $\qquad$ H_2O as a base

Water auto-protolysis

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

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

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H_2O
dissociation equilibrium

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

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

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continuing

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

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

$[H_2O] = 55.\bar{5}$ *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) $B^- + H_2O \rightleftharpoons BH + OH^-$

These are 2 equilibria

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

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

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$[H_2O] \approx$ costant!

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

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

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

Ka is the dissociation constant of a weak acid

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

$$Keq = \frac{[BH]\ [OH^-]}{[B^-]\ [H_2O]}$$

$$\underbrace{Keq/[H_2O]}_{constant} = \frac{[BH]\ [OH^-]}{[B^-]} = Kb$$

Kb is the association constant of a weak base!

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Examples

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

$$Keq = \frac{[HCOO^-]\ [H_3O^+]}{[HCOOH]\ [H_2O]}$$

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

Ka, HCOOH = 1.8×10^{-4}

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

$$Keq = \frac{[NH_4^+]\ [OH^-]}{[NH_3]\ [H_2O]}$$

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

H+ association of a weak base!

Kb, NH_3 = 1.8×10^{-5}

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

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

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

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

Thus K_a e K_b are inversely related

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

BUT

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BUT pay attention to approximations !

$$B + H_2O \rightleftharpoons HB^+ + OH^-$$

K_{eq} → $K_b = \frac{[HB^+][OH^-]}{[B]}$ $[OH^-] = \frac{K_w}{[H^+]}$ *in* H_2O $Kw = [H^+]\,[OH^-]$

$$K_b = \frac{[HB^+]K_w}{[B][H^+]} = \frac{K_w}{K_a}$$

Thus Kb and Ka are inversely related…!

$K_b \propto 1/K_a$ → $K_b = K_w/K_a$ and

$K_a \propto 1/K_b$ → $K_a = K_w/K_b$

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

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

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

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CONCLUDING:

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

How large ?

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Conjugated couple

Relative strength

$K_b = K_w/K_a$

Acid strength increases ↑ — Base strength increases ↓

	ACID	BASE		Ka
Strong (100% ionized in H_2O)	HCl	Cl^-	Negligible	Very high
Strong (100% ionized in H_2O)	H_2SO_4	HSO_4^-	Negligible	Very high
Strong (100% ionized in H_2O)	HNO_3	NO_3^-	Negligible	20
	$H_3O^+(aq)$	H_2O		
Weak	HSO_4^-	SO_4^{2-}	Weak	$1.2\ 10^{-2}$
Weak	H_3PO_4	$H_2PO_4^-$	Weak	$7.5\ 10^{-3}$
Weak	HF	F^-	Weak	$6.7\ 10^{-4}$
Weak	$HC_2H_3O_2$	$C_2H_3O_2^-$	Weak	$1.8\ 10^{-5}$
Weak	H_2CO_3	HCO_3^-	Weak	$4.3\ 10^{-7}$
Weak	H_2S	HS^-	Weak	$1.0\ 10^{-7}$
Weak	$H_2PO_4^-$	HPO_4^{2-}	Weak	$6.2\ 10^{-8}$
Weak	NH_4^+	NH_3	Weak	
Weak	HCO_3^-	CO_3^{2-}	Weak	
Weak	HPO_4^{2-}	PO_4^{3-}	Weak	
	H_2O	OH^-		
Negligible	OH^-	O^{2-}	Strong (100% protonated in H_2O)	
Negligible	H_2	H^-	Strong (100% protonated in H_2O)	
Negligible	CH_4	CH_3^-	Strong (100% protonated in H_2O)	

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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}

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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)

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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) *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

Ka increases

pKa Decreases

Stronger Acid

Weak Acid

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

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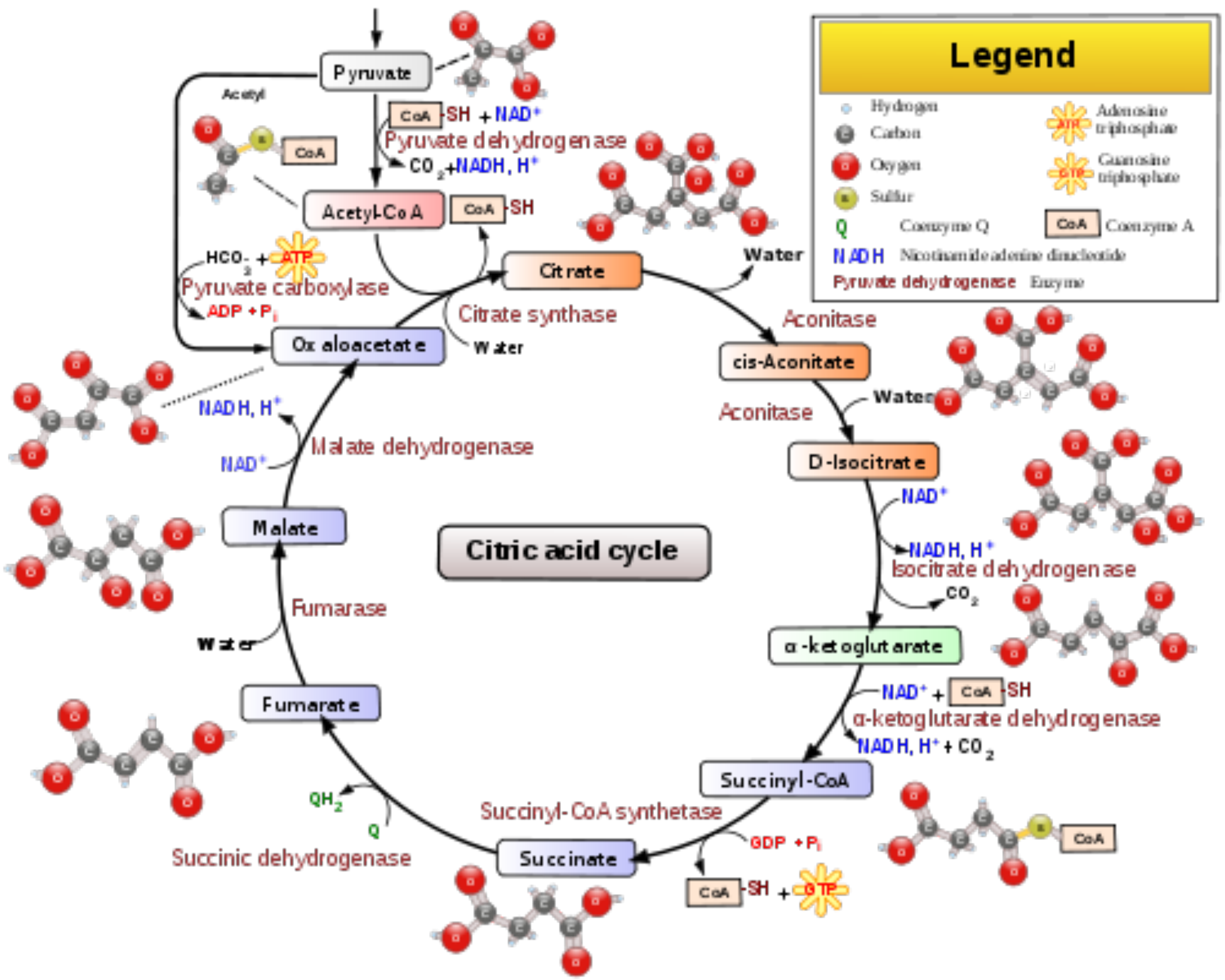
Krebs cycle



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Remember relationship between Ka and α ?

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

Weak electrolytes

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

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

$(1 - \alpha)$ C	αC	αC

At equilibrium

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

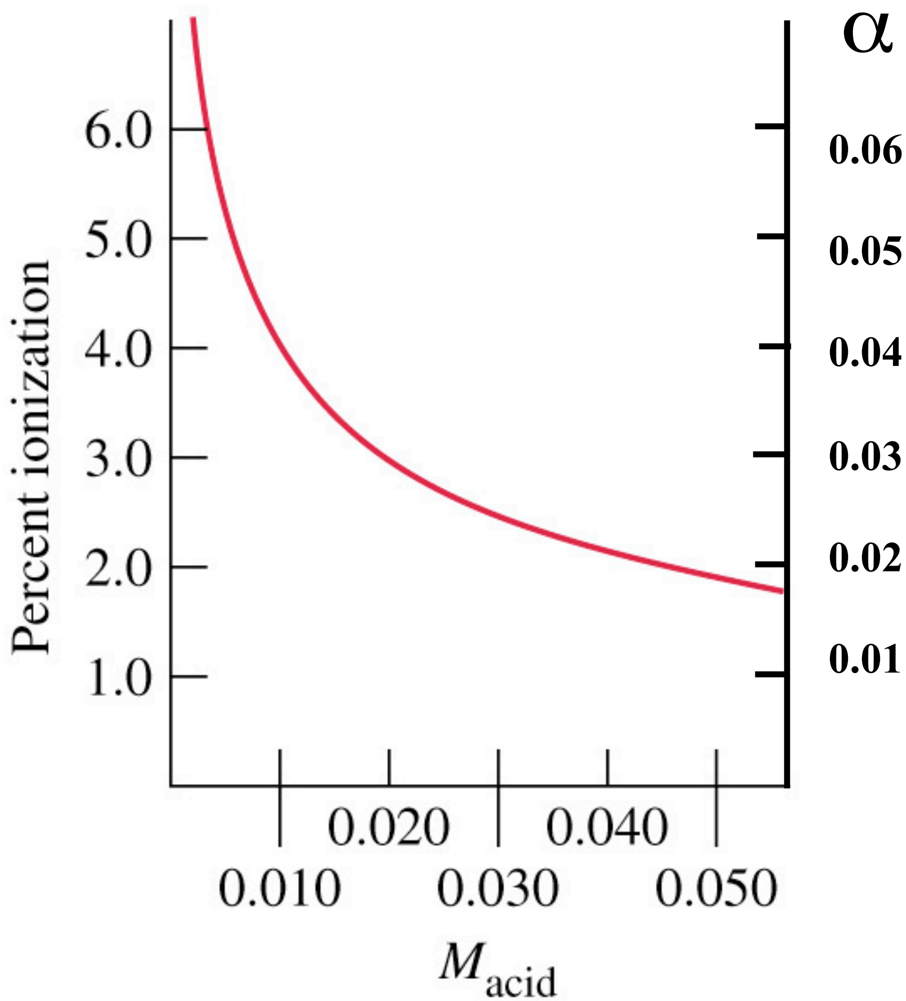
if α
is small…

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

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)

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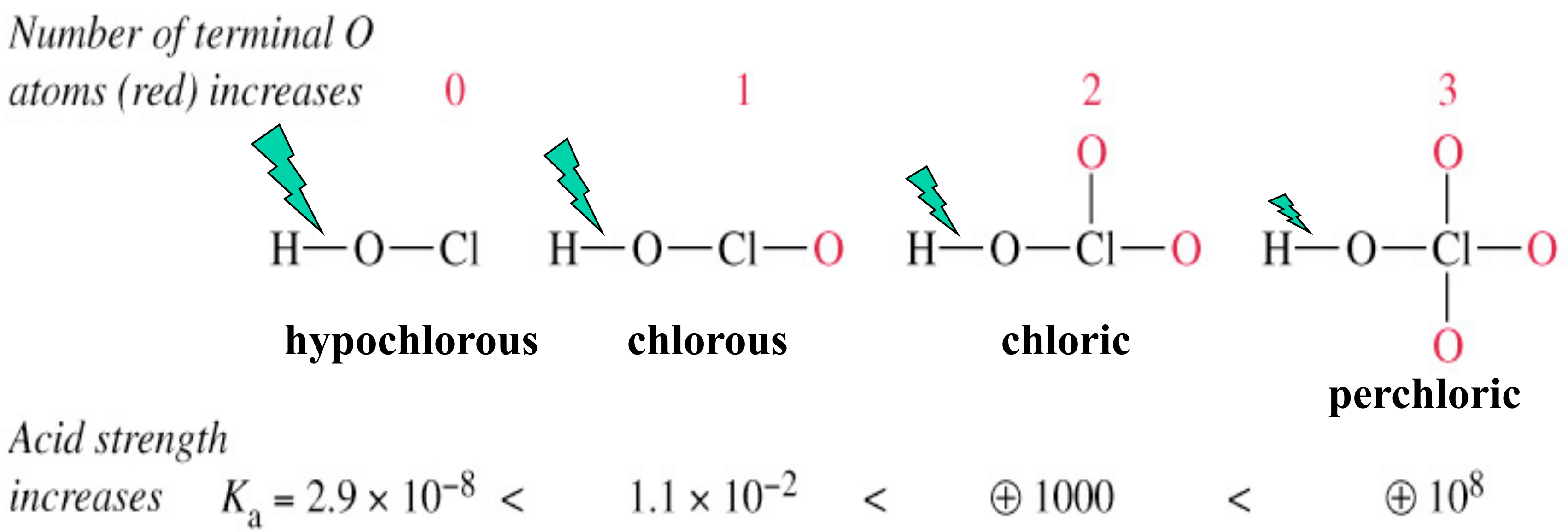
Ex.

Strenght of hydro-chloro acids



Bond energy !

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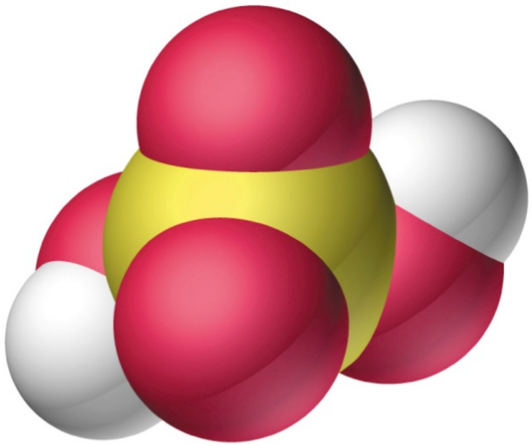
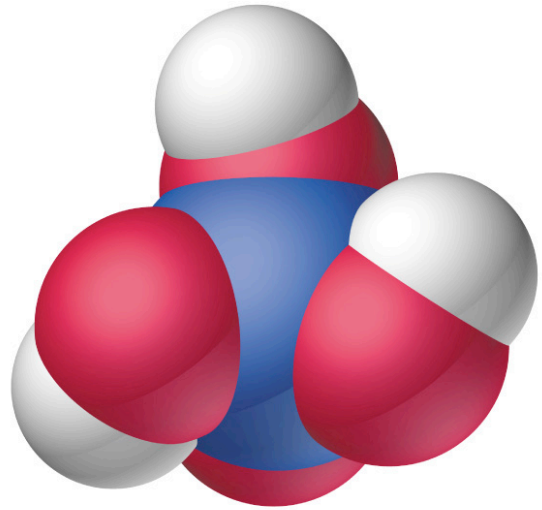


Sulfuric acid

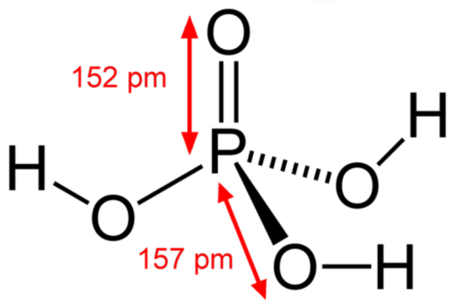
H_2SO_4

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

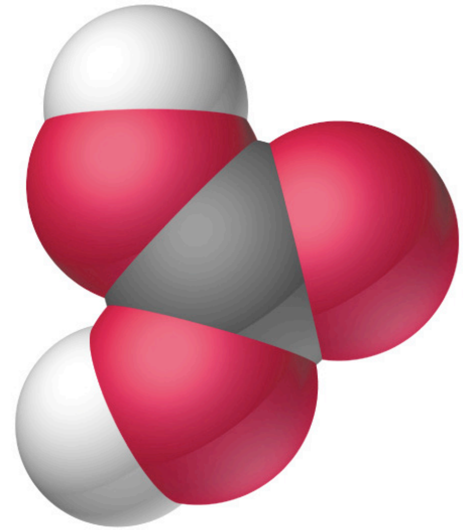
H_3PO_4



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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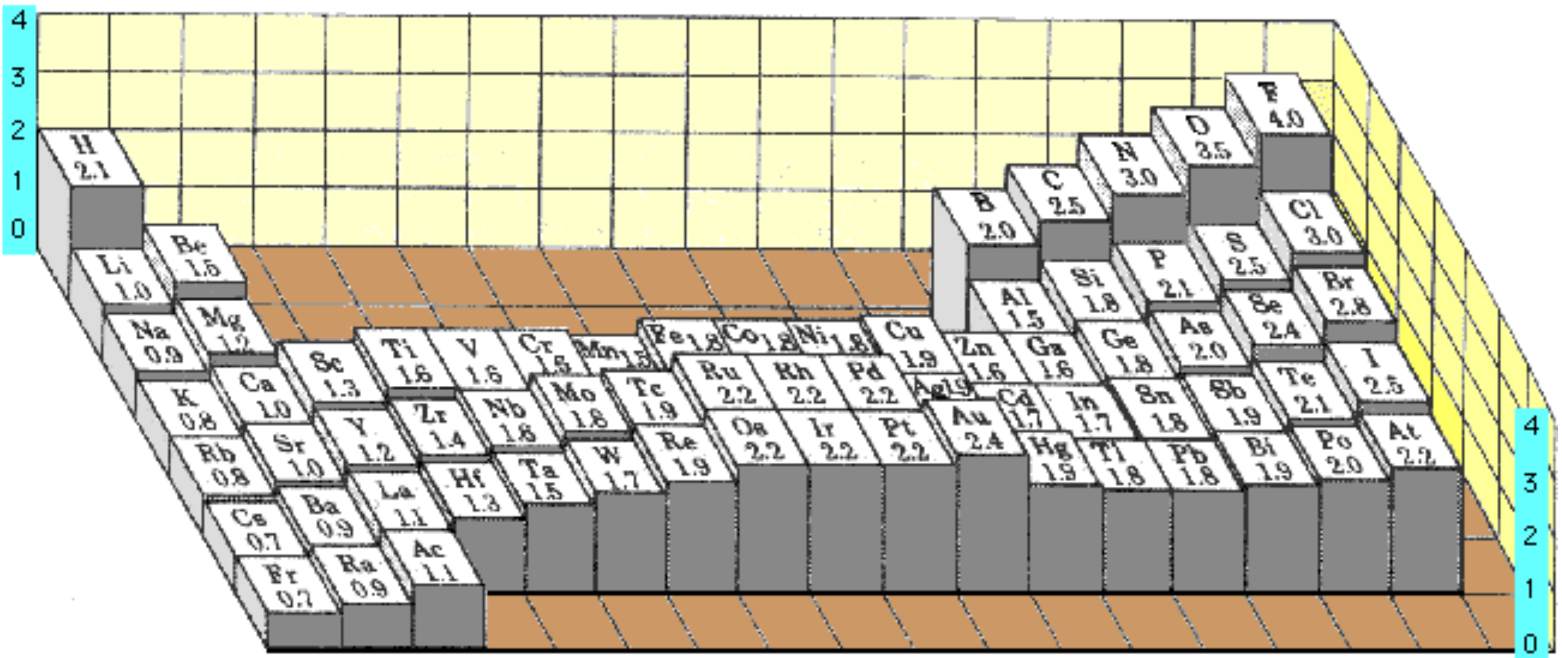
Electronegativity → $f(E_i, A_e)$

Distribution of electronegativity



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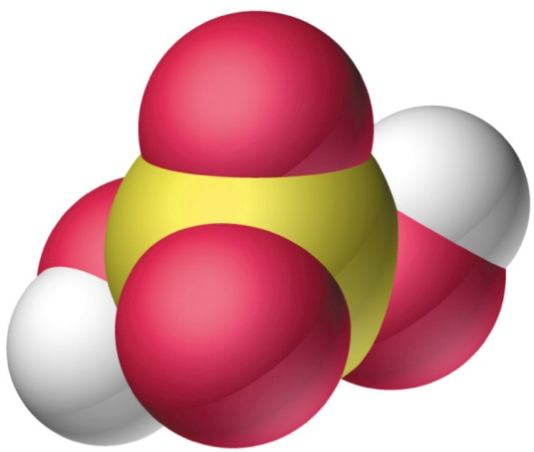
polyfunctional acids

strength

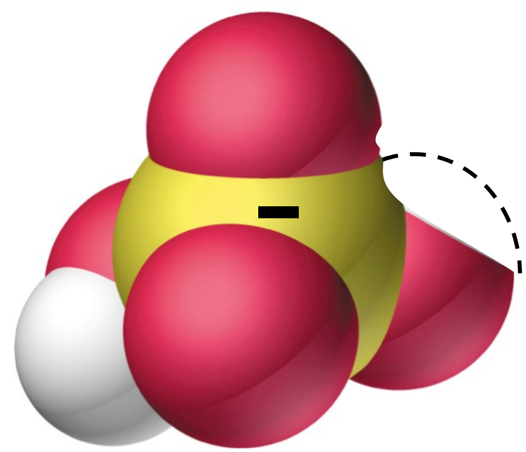
$H_2SO_4 \longrightarrow HSO_4^- + H^+$ $K_{a1} = \infty$

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



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

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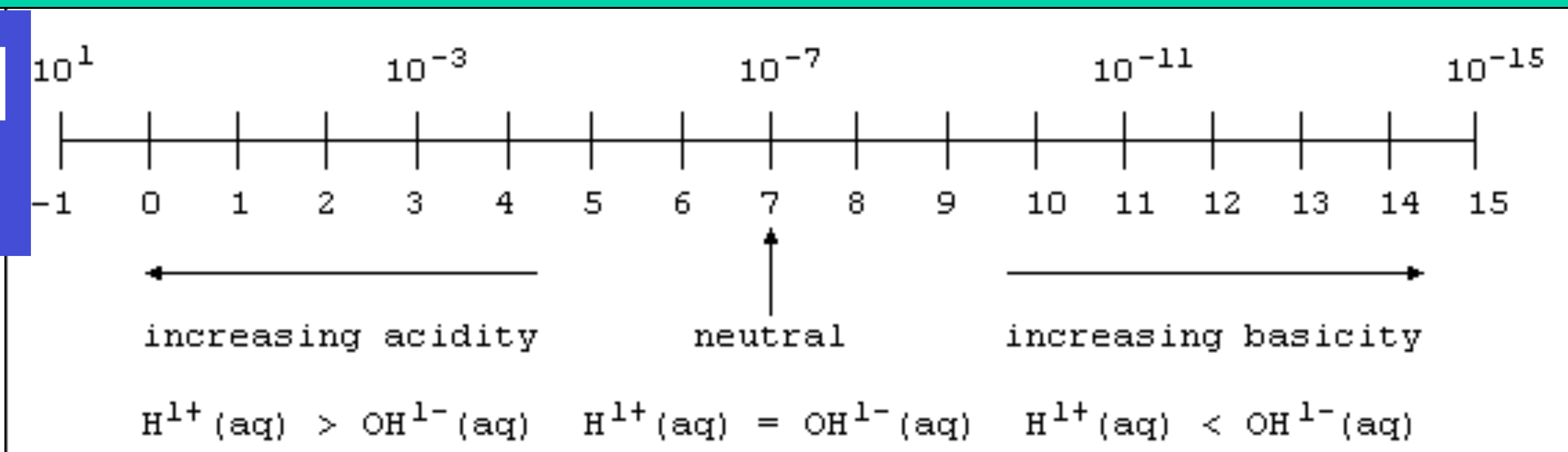
$[H^+]$ to pH conversion

$[H^+]$

pH



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

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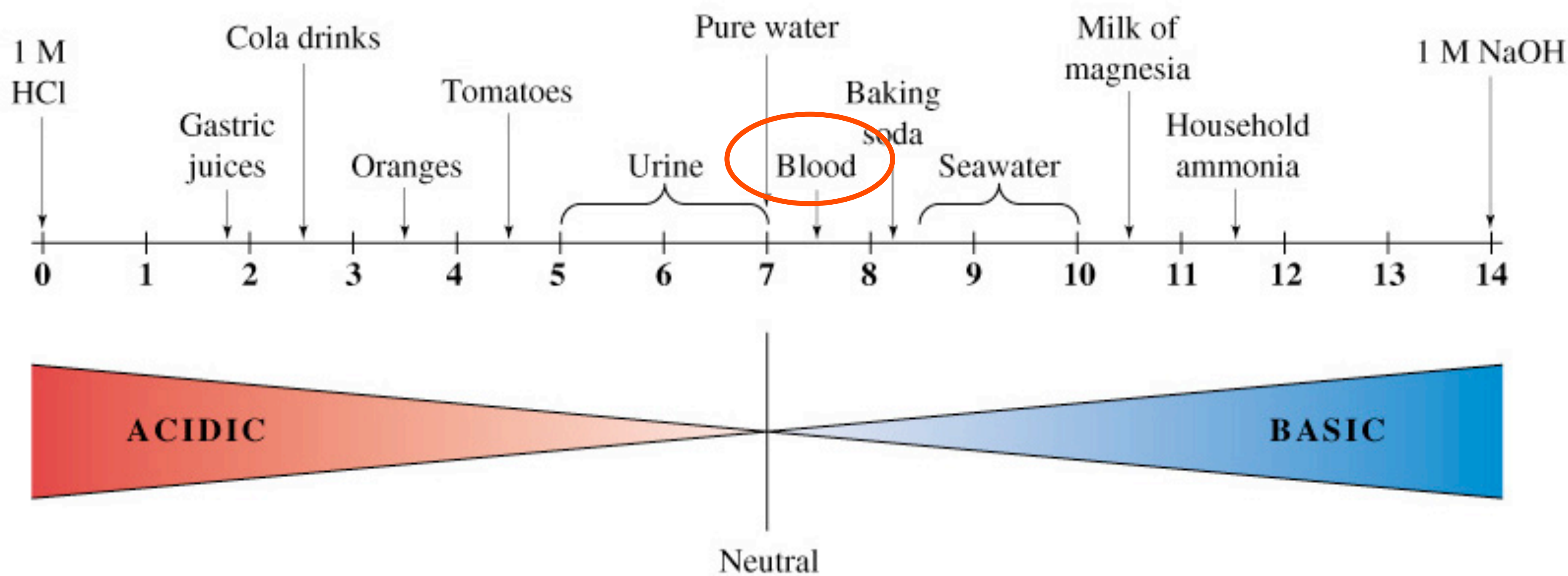
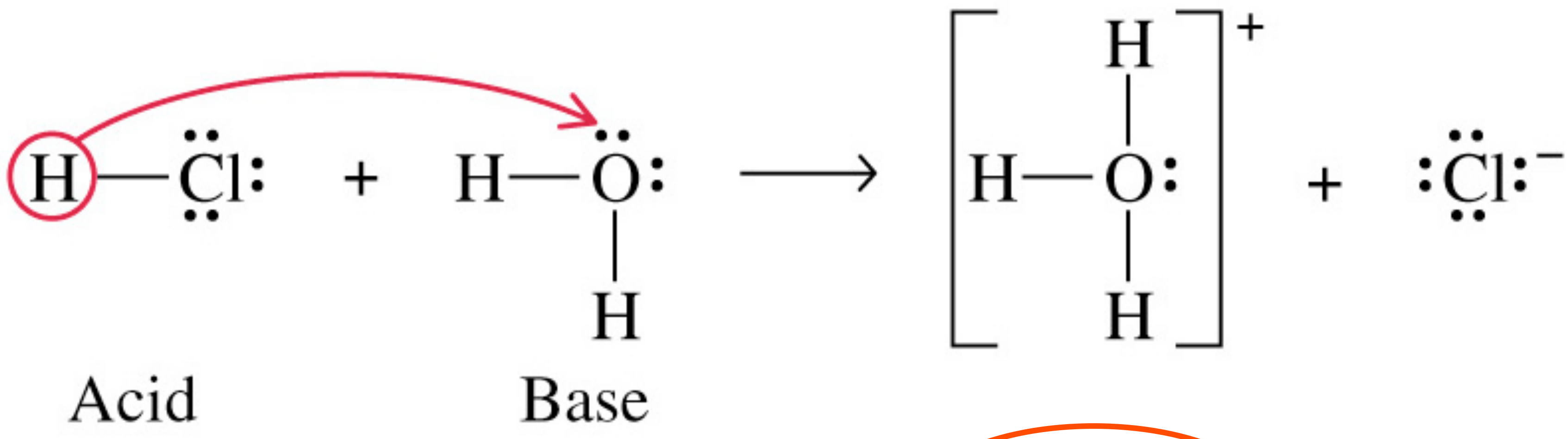
Biological fluids



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

$$pH + pOH = 14$$



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

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

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

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

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

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.

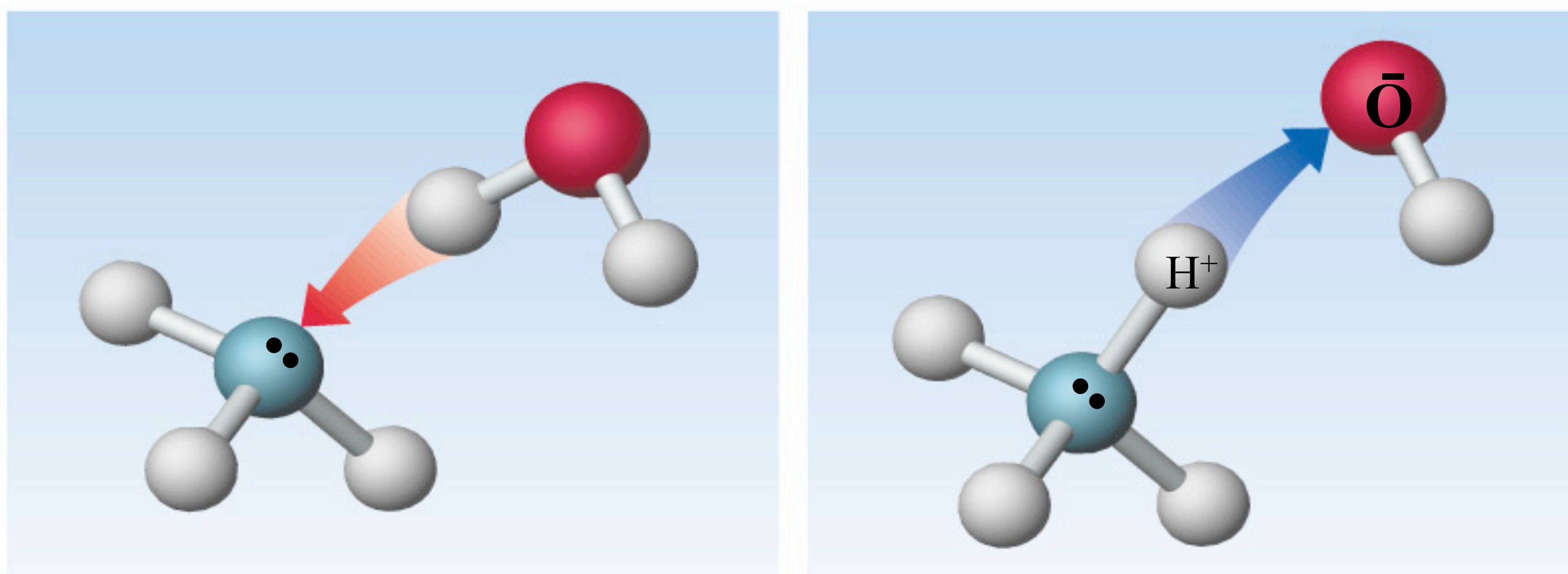
Another 1.8*1027 would be oxygen, which has 8 protons, 8 neutrons and 8 electrons.

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.

Acid-base conjugated couples



NH_3	+	H_2O	$\rightleftharpoons$	NH_4^+	+	OH^-
Base(1)		Acid(2)		Acid(1)		Base(2)

couple 1

couple 2