THURSDAY, MARCH 12, 2026 AP CHEMISTRY

CH. 16 ACID - BASE EQUILIBRIA

OLD DEFINITION: ACIDS INCL. H^+ ION (ARRHENIUS)
BASES INCL. OH^- ION

THIS IS REALLY ONLY VALID IN AQUEOUS SOLUTION.

A MORE GENERAL DEFINITION IS

ACIDS DONATE A PROTON (H^+)
BASES ACCEPT A PROTON ($X\!: \curvearrowright H^+$)
LONE PAIR BINDS H^+

$HCl + H_2O \longrightarrow \underset{\text{HYDRONIUM}}{H_3O^+} + Cl^-$ (HCl DONATES A PROTON TO H_2O)

SO H_2O IS A BASE

CONJUGATE ACID-BASE PAIRS

HA = GENERIC WEAK ACID
HX = GENERIC ACID (STRONG ACID)
H^+ = PROTON
A^- AND X^- ANION OF THE ACID, A.K.A., THE CONJUGATE BASE OF THE ACID.

B = GENERIC WEAK BASE
MOH = STRONG BASES ARE METAL HYDROXIDES

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

A^- IS THE CONJUGATE BASE OF THE ACID, HA

WEAK ACID DISSOCIATION EQUILIBRIUM $K_{eq} = K_a$

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

BH^+ IS THE CONJ. ACID OF THE BASE, B.

WEAK BASE HYDROLIZATION EQUILIBRIUM $K_{eq} = K_b$

$$HA + B \rightleftharpoons HB^+ + A^-$$

WEAK ACID REACTING WITH A WEAK BASE K_{eq} (IS RELATED TO K_a FOR HA AND HB^+)

CONJ. PAIRS

ACID	BASE
HA	A^-
HB^+	B

ACID-BASE EQUILIBRIA OR HOW WE CALC. $[H^+]$ OR $[OH^-]$ AND pH.

ACID DISSOCIATION

WHAT REALLY HAPPENS WITH WEAK ACIDS IN AQ. SOLN:

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

OUR HELPFUL SIMPLIFICATION

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

$$K_a = \frac{[H^+]'[A^-]'}{[HA]'}$$

K_a IS THE ACID DISSOCIATION CONSTANT (LOOK UP VALUES IN CH. 16 AND IN APPENDIX D)

BASE HYDROLYSIS

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

$$K_b = \frac{[BH^+][OH^-]'}{[B]'}$$

OR

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

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

NOTE: K_a FOR HA AND K_b FOR A^- ARE NOT THE INVERSE OF EACH OTHER

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AUTOIONIZATION OF WATER (16.3)

H_2O IS BOTH AN ACID AND A BASE.

IT IS AMPHIPROTIC: H_2O CAN BOTH DONATE AND ACCEPT A PROTON.

$$\underset{\text{ACID}}{H_2O} + \underset{\text{BASE}}{H_2O} \rightleftharpoons H_3O^+ + OH^-$$

ACCEPTS H^+

ACID DONATES H^+

SIMPLIFY

$$H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + OH^-_{(aq)} \quad K_w = [H^+][OH^-]$$

$K_w = 1.0 \times 10^{-14}$ AT 25°C

K_w IS CALLED THE ION-PRODUCT CONSTANT.

USING IT WE CAN CALC. THAT 2 OUT OF EVERY 1×10^9 WATER MOLECULES IS IONIZED IN PURE WATER AT 25°C AT ANY GIVEN TIME).

IN PURE WATER, $[H^+]_{eq} = [OH^-]_{eq} = 1.0 \times 10^{-7}\,M$

ADDING ACID TO FORM A SOLN INCR. $[H^+]$ AND DECR. $[OH^-]$

ADDING BASE DECR. $[H^+]$ AND INCR. $[OH^-]$.

THE PRODUCT $[H^+][OH^-]$ STILL EQUALS 1.0×10^{-14}

THIS IS THE BASIS OF THE pH SCALE. pH = POWER OF HYDROGEN

$$\boxed{pH = -\log_{10}[H^+] \quad \text{so} \quad 10^{-pH} = [H^+]}$$

pH IS AN EXPONENT (OR POWER)

THE pH SCALE IS LOGARITHMIC — EVERY UNIT UP OR DOWN IS A DIFFERENCE IN CONC. OF H^+ BY A FACTOR OF <u>TEN</u>.

pH	$[H^+]$
8	$1.0 \times 10^{-8} M$
7	$1.0 \times 10^{-7} M$
6	$1.0 \times 10^{-6} M$

FOR EVERY $[H^+]$ THERE IS A CORRESPONDING $[OH^-]$.

$$K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$$

FOR EX.

$$(1.0 \times 10^{-8} M)\, x = 1.0 \times 10^{-14} \qquad \frac{10^{-14}}{10^{-8}}$$

$$x = [OH^-] = 1.0 \times 10^{-6} M$$

ACIDITY FOR $pH < 7$

ALKALINITY FOR $pH > 7$
OR BASICITY

pH IS NEUTRAL AT $pH = 7$

FOR ALKALINE SOLNS WE MAY PREFER TO TALK ABOUT $[OH^-]$ RATHER THAN $[H^+]$.

SO: $pOH = -\log[OH^-]$

FOR EX. HOW ARE pH AND pOH RELATED?

$[H^+] = 1.0 \times 10^{-8} M \quad pH = 8$
$[OH^-] = 1.0 \times 10^{-6} M \quad pOH = 6$

$[H^+] = 1.0 \times 10^{-4} M \quad pH = 4$
$[OH^-] = 1.0 \times 10^{-10} M \quad pOH = 10$

FOR ANY SOLN, $\boxed{pH + pOH = 14}$

TO CALC pH OF BASIC SOLUTIONS, FIND pOH AND $14 - pOH = pH$

WHY IS THIS TRUE?

DERIVATION $K_w = [H^+][OH^-]$

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

$$pK_w = -\log([H^+][OH^-]) = -(\log[H^+] + \log[OH^-])$$

$$pK_w = -\log[H^+] - \log[OH^-]$$

$$\boxed{pK_w = pH + pOH} \qquad pK_w = 14$$

SIGNIFICANT FIGURES WITH LOGARITHMS:

$[H^+] = 1.72 \times 10^{-4}\,M$ $\quad pH = \underset{\substack{\downarrow \\ \text{EXPONENT}}}{3}.\underbrace{76447155 3}_{\text{SIG. FIGS.}}$

$\text{3 s.f.} \rightarrow pH = 3.\underline{764}$

ONLY DIGITS AFTER THE DECIMAL COUNT

$10^{-3.8}$

$10^{-3.76}$

$10^{-3.764}$

$10^{-3.7644}$

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HOW IS pH MEASURED?

① INDICATORS INCL. pH PAPER. INDICATORS ARE MOLECULES WHICH CHANGE COLOR ACCORDING TO THE pH OF THEIR ENVIRONMENT, WHICH DETERMINES THEIR STRUCTURE BY ADDING OR TAKING AWAY H^+.

② ELECTRONIC pH METERS MEASURE VOLTAGE ACROSS A GLASS H^+-PERMEABLE MEMBRANE.

RELATIVE ACID STRENGTH

STRENGTH IS NOT THE SAME AS CONCENTRATION (THINK COFFEE — MR K'S VS. DUNKIN).

FOR ACIDS, STRENGTH REFERS TO A QUANTITATIVE MEASURE OF THE ACID'S EXTENT OF DISSOCIATION IN AQUEOUS SOLN.

STRONG ACIDS

$\underbrace{HNO_3 \quad H_2SO_4 \quad HCl}_{\text{COMMON IN LABS}} \quad HBr \quad HI$ (NOT HF)

$HClO_3 \quad HClO_4$

COMPLETE DISSOCIATION

	HX	$\rightleftharpoons$	H^+	+	X^-
i	1M		0		0
e	0		1M		1M

AT EQUIL $[H^+]_{eq} = [X^-]_{eq} = [HX]_0$

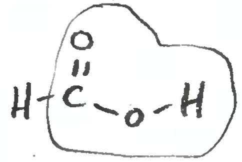
$K_a > 10^9$ (FOR EX.)

WEAK ACIDS

ARE CHARACTERIZED BY AN INCOMPLETE DISSOCIATION INTO IONS IN AQUEOUS SOLN.

FOR EX. HF HCN $HClO_2$ HClO ORGANIC ACIDS

HCOOH FORMIC



$H-\overset{O}{\overset{\|}{C}}-O-H$

CARBOXYLIC ACID GROUP

CH_3COOH ACETIC

DISSOCIATION IS PARTIAL

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

	HA	H^+	A^-
i	1M	0	0
c	−x	+x	+x
e	1−x	x	x

$$K_a = \frac{[H^+]^1[A^-]^1}{[HA]^1} < 1$$

(REACTANTS ARE FAVORED)

K_a WEAK ACID DISSOCIATION EQUIL. CONSTANT

$x < 1M$ IN OUR EXAMPLE

16.5 STRONG ACIDS AND BASES

FOR A STRONG ACID, HX, $[H^+]_{eq} = [HX]_0$

so for $[HCl] = 0.1M$, $[H^+]_{eq} = 0.1M$ so $pH = -\log 0.1 = 1.0$

(THINGS GET WEIRD FOR DIPROTIC OR POLYPROTIC ACIDS LIKE H_2SO_4).

BE CAREFUL, THOUGH, WITH VERY LOW CONC. IF THEY ARE TOO LOW, THE AUTODISSOCIATION OF WATER WILL BE MORE IMPORTANT.

For ex. $[HCl] = 7.3 \times 10^{-10} M$

$$-\log[H^+] = -\log 7.3\times10^{-10} = 9.14 \quad (!?)$$

$H_2O \rightleftharpoons H^+ + OH^-$ $K_w = 1.0\times10^{-14}$ so $[H^+] = 1.0\times10^{-7}M$

so pH = 7.0 NOT 9.14 (PAY ATTENTION AND DON'T FORGET WATER DOES ITS OWN THING)

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STRONG BASES ARE METAL HYDROXIDES.

FOR SOLUBLE HYDROXIDES $[OH^-]_{eq} = [XOH]_0$

JUST CALC $pOH = -\log[OH^-]$

$14 - pOH = pH$

SOLUBLE HYDROXIDES Li^+, Na^+, K^+, Rb^+, Cs^+, Ca^{2+}, Ba^{2+}, (Sr^{2+})

FOR INSOLUBLE HYDROXIDES — THEY DON'T AFFECT pH. THEY STILL REACT WITH ACIDS, THOUGH!

SOME ANIONS ARE EVEN MORE BASIC THAN OH^-

O^{2-} AND H^-

OXIDE HYDRIDE

BUT OH^- IS THE MOST BASIC ION THAT CAN EXIST IN AQUEOUS SOLUTION. SO THESE IONS REACT WITH H_2O TO MAKE OH^-.

$$Na_2O_{(s)} \xrightarrow{H_2O} 2Na^+_{(aq)} + O^{-2}_{(aq)}$$

$$O^{-2}_{(aq)} + H_2O_{(l)} \rightarrow 2OH^-_{(aq)}$$

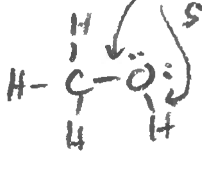
$$NaH_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + H^-_{(aq)}$$

$$H^-_{(aq)} + H_2O_{(l)} \rightarrow OH^-_{(aq)} + H_{2(g)}$$

THE $-\ddot{O}-H$ STRUCTURE IS NOT ALWAYS BASIC!

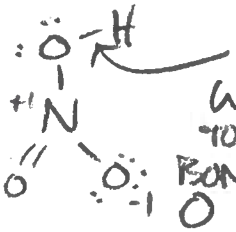
A SUBSTANCE WITH OH IN ITS FORMULA OR STRUCTURE IS ONLY BASIC IF THE OH IS BONDED TO A METAL ION. (OR NH_4^+).

ALCOHOLS ARE NOT BASIC:



BONDS ARE TOO STRONG TO ALLOW OH^- OR H^+ TO DISSOCIATE

OXYACIDS ARE ACIDIC



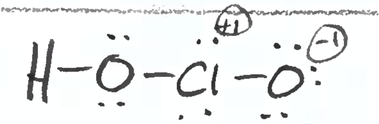
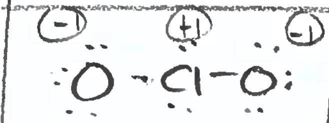
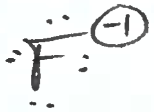
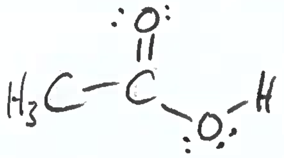
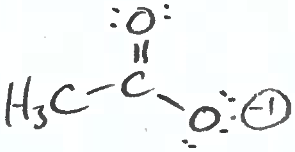
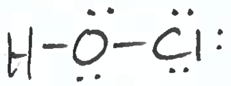
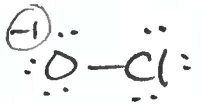
THIS BOND IS POLARIZED AND WEAKENED DUE TO N AND BONDED O ATOMS

16.6 WEAK ACIDS

$$HA \rightleftharpoons H^+ + A^- \quad K_a = \frac{[H^+][A^-]}{[HA]} \left(< 1 \text{ BY DEFINITION}\right)$$

WEAK ACIDS VARY IN RELATIVE STRENGTH AND WE CAN ORGANIZE THEM ON A SPECTRUM USING K_a VALUES (FIND K_a VALUES IN APPENDIX D IN YOUR BOOK).

SPECTRUM OF ACID STRENGTH

ACID FORMULA WITH K_a	ACID STRUCTURE	CONJUGATE BASE STRUC.	CONJ. BASE FORMULA & K_b
1.0×10^{-2} $HClO_2$ CHLOROUS			ClO_2^- 1.0×10^{-12}
6.8×10^{-4} HF HYDROFLUORIC			F^- 1.5×10^{-11}
1.8×10^{-5} CH_3COOH ACETIC			CH_3COO^- 5.6×10^{-10}
3.0×10^{-8} HClO HYPOCHLOROUS			ClO^- 3.3×10^{-7}

↑ ACID STRENGTH INCR. GOING UP

BASE STRENGTH INCR. GOING DOWN ↓

THE LARGER THE VALUE OF K_a IS, THE STRONGER THE ACID IS.

THE STRONGER A WEAK ACID IS, THE WEAKER ITS CONJ. BASE IS.

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FOR STRONG ACIDS, WE CAN SAFELY IGNORE THEIR CONJ. BASES WITH RESPECT TO pH.

SALTS OF WEAK ACIDS ARE BASIC:

$$HA + NaOH \rightarrow H_2O + \underset{\text{SALT}}{\boxed{NaA}}$$

$$NaA \xrightarrow{H_2O} Na^+ + A^-$$

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

SALTS OF STRONG ACIDS ARE NEUTRAL

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

$$HCl + NaOH \rightarrow H_2O + NaCl$$

$$NaCl \rightarrow Na^+ + Cl^-$$

AND Cl^- DOES NOT REACT WITH H_2O TO MAKE OH^-

HOW TO CALC. pH FOR A WEAK ACID SOLUTION:

	HA ⇌	H^+ +	A^-
i	0.4M	0	0
c	$-x$	$+x$	$+x$
e	$0.4-x$	x	x

$$K_a = \frac{[H^+][A^-]}{[HA]} = 1.8\times10^{-5}$$

$$\frac{(x)(x)}{(0.4-x)} \Rightarrow \frac{x^2}{0.4} = 1.8\times10^{-5}$$

ASSUMING $(0.4-x) \cong 0.4$

$$x^2 = 1.8\times10^{-5} \cdot 0.4$$

$$x = 2.68\times10^{-3}M = [H^+]$$

$$pH = -\log 2.68\times10^{-3}$$

$$\boxed{2.57}$$

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GROUP X

WE JUSTIFY THE ASSUMPTION THAT $[HA]_{eq} \approx [HA]_0$
OR $[HA]_0 - x \approx [HA]_0$
WITH THE IDEA OF PERCENT IONIZATION.

$$\boxed{\text{PERCENT IONIZATION} = \frac{[H^+]_{eq}}{[HA]_0} \times 100\%}$$

THIS QUANTIFIES THE EXTENT OF DISSOCIATION. IF IT IS LESS THAN 5% THEN THE ASSUMPTION IS CONSIDERED VALID.

WE ASSUMED THAT $0.4 - x \approx 0.4$

$$\frac{[H^+]}{[HA]} \quad \frac{2.68 \times 10^{-3}}{0.4} \times 100\% = 0.67\%$$

WE CHOSE 5% AS THE CUT-OFF B/C K_a ARE CORRECT ONLY WITH ABOUT 5%.

IF P.I. > 5% THEN YOU HAVE TO DO THE QUADRATIC.

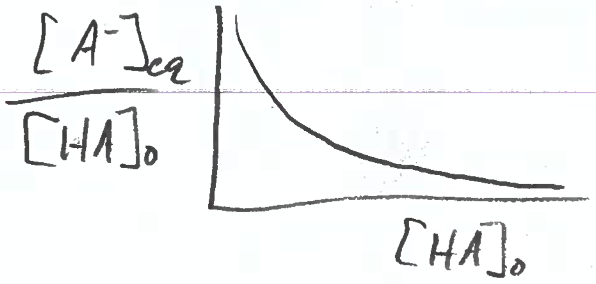
$$\left(\frac{x^2}{0.4 - x} = K_a \text{ IS A QUADRATIC}\right)$$

RANDOM FACTS ABOUT WEAK ACIDS

① RATE OF RXN WITH A WEAK ACID IS SLOWER THAN FOR A STRONG ACID OF THE SAME CONCENTRATION. THIS IS DUE TO THE LOWER CONC. OF H^+ FOR WEAK ACIDS.
RATE = $k[H^+]$

② PERCENT IONIZATION OF A WEAK ACID DECR. AS $[HA]_0$ INCR.

IT'S AN INVERSE PROPORTION.



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POLYPROTIC ACIDS

i.e., ACIDS WITH 2 OR MORE PROTONS TO DONATE

FOR EX. H_2SO_3 H_2SO_4 H_2CO_3 H_3PO_4 ETC.

WE THINK OF THESE ACIDS GIVING UP EACH PROTON IN SUCCESSION:

$$H_2SO_3 \rightleftharpoons H^+ + HSO_3^- \quad K_{a1} = 1.7\times10^{-2}$$

$$HSO_3^- \rightleftharpoons H^+ + SO_3^{2-} \quad K_{a2} = 6.4\times10^{-8}$$

FOR EVERY POLYPROTIC ACID, EACH SUCCESSIVE K_a IS MUCH SMALLER THAN THE PREVIOUS ONE. MOSTLY, K_{a2} IS MORE THAN 1000 TIMES SMALLER THAN K_{a1}, FOR EXAMPLE. BECAUSE OF THIS, WE TAKE $[H^+]_{eq}$ AS $[H^+]_0$ FOR ANY CALC. FOR K_{a2} (OR K_{a3}).

FOR EX. 16.14 pg 695

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

FOR $P_{CO_2} = 0.1\,atm$ YOU GET $[H_2CO_3] = 3.7\times10^{-3}\,M$

OUR TASK: CALC. pH, $[HCO_3^-]_{eq}$, AND $[CO_3^{2-}]_{eq}$

$$\begin{array}{lccc} & H_2CO_3 & \rightleftharpoons H^+ & + HCO_3^- \\ i & 3.7\times10^{-3} & 0 & 0 \\ c & -x & +x & +x \\ e & 3.7\times10^{-3}-x & x & x \end{array} \quad K_{a1} = 4.3\times10^{-7}$$

$$K_{a1} = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$$

$$4.3\times10^{-7} = \frac{x^2}{3.7\times10^{-3}}$$

ASSUMING $3.7\times10^{-3} - x \approx 3.7\times10^{-3}$

$$x = [H^+]_{eq} = [HCO_3^-]_{eq} = \boxed{4.0\times10^{-5}\,M}$$

$$\downarrow$$

$$pH = -\log 4\times10^{-5} = \boxed{4.40}$$

$$\begin{array}{lccc} & HCO_3^- & \rightleftharpoons H^+ & + CO_3^{2-} \\ i & 4.0\times10^{-5} & 4.0\times10^{-5} & 0 \\ c & -x & +x & +x \\ e & 4.0\times10^{-5}-x & 4\times10^{-5}+x & x \end{array}$$

$$K_{a2} = \frac{[H^+][CO_3^{2-}]}{[HCO_3^-]} = 5.6\times10^{-11}$$

$$\frac{(4\times10^{-5}-x)(x)}{(4\times10^{-5}+x)} = 5.6\times10^{-11}$$

$$\frac{\cancel{(4\times10^{-5})}x}{\cancel{4\times10^{-5}}} = x = 5.6\times10^{-11}$$

$$[CO_3^{2-}]_{eq} = 5.6\times10^{-11}\,M$$

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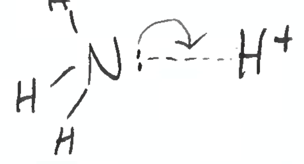
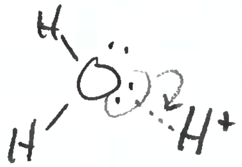
16.7 WEAK BASES

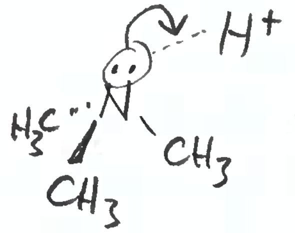
TYPES: ① CONJUGATE BASE OF A WEAK ACID
(AS A SOLUBLE SALT NaA, $NaC_2H_3O_2$, $NaCN$)

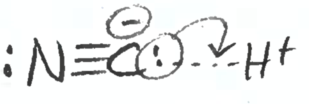
② AMINES, WHICH ARE NITROGEN-CONTAINING ORGANIC MOLECULES SIMILAR TO NH_3.
($CH_3\ddot{N}H_2$,  , $CH_3\ddot{N}HCH_3$)

STRUCTURALLY, WEAK BASES ALL HAVE A LONE PAIR OF ELECTRONS ON AN ATOM WHICH CAN "ACCEPT" A PROTON.









LET'S CALC. A pH!

0.2M $NaC_2H_3O_2$ – WHAT IS THE pH?

($NaC_2H_3O_2 \rightarrow Na^+ + C_2H_3O_2^-$ — IT'S A STRONG ELECTROLYTE)

	$C_2H_3O_2^-$	$+ H_2O \rightleftharpoons$	$HC_2H_3O_2$	$+ OH^-$
i	0.2	N/A	∅	∅
c	$-x$	/	$+x$	$+x$
e	$0.2-x$	/	x	x

$$K_b = \frac{[HC_2H_3O_2][OH^-]}{[C_2H_3O_2^-]}$$

$K_a = 1.8\times10^{-5}$ FOR $HC_2H_3O_2$

$$5.6\times10^{-10}\left(=\frac{(x)(x)}{(0.2-x)}\right) \quad \text{ASSUME } 0.2-x \approx 0.2 \quad \frac{x^2}{0.2}$$

$$\boxed{\text{GIVEN: } K_w = K_a\cdot K_b}$$

$K_a\cdot K_b = 1\times10^{-14}$

$K_b = \frac{10^{-14}}{K_a}$

$K_b = 5.6\times10^{-10}$

$x = 1.1\times10^{-5}M = [OH^-]$

$pOH = -\log 1.1\times10^{-5} = 4.98$

$pH = 14 - 4.98 = \boxed{9.02}$

W 2026-03-18 AP CHEM

OFTEN, INSTEAD OF K_a VALUES, A REF. WORK WILL LIST pK_a VALUES.

$pK_a = -\log K_a$ FOR WEAK BASES, $pK_b = -\log K_b$

16.8 HOW DOES K_a FOR A WEAK ACID RELATE TO K_b FOR ITS CONJUGATE BASE?

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

$$A^- + H_2O \rightleftharpoons HA + OH^- \quad K_b = \frac{[HA][OH^-]}{[A^-]}$$

+

IN ANY SOLUTION OF HA OR NaA OR A SOLN CONTAINING BOTH THESE TWO EQUILIBRIA BOTH APPLY.

ADD THESE CHEM. EQNS.

$$\cancel{HA} + \cancel{A^-} + H_2O \rightleftharpoons H^+ + \cancel{A^-} + \cancel{HA} + OH^-$$

$$\boxed{H_2O \rightleftharpoons H^+ + OH^-}$$

WHEN YOU ADD CHEM EQNS, YOU MULTIPLY THE K_{eq} VALUES

$$K_{eq} = K_a \cdot K_b$$

$$\boxed{K_w = K_a \cdot K_b}$$

K_a & K_b FOR A GIVEN MOLECULE ARE INVERSELY PROPORTIONAL

$-\log$

$$pK_w = 14 = pK_a + pK_b$$

$$\left(\begin{array}{l} 10^{-pK_a} = K_a \\ 10^{-pK_b} = K_b \end{array}\right)$$

SEE ALSO pg 8 OF THESE NOTES: <u>SPECTRUM OF ACID/BASE STRENGTH</u>

	K_a	pK_a	pK_b	K_b	
STRONG ACID	10^9	-9	23	10^{-23}	← THE "CONJ. BASE" OF A STRONG ACID IS NOT BASIC IN AQ. SOLN.
PRETTY STRONG WEAK ACID	10^{-1}	1	13	10^{-13}	EXTREMELY WEAK, WEAK BASE
	10^{-5}	5	9	10^{-9}	
	10^{-10}	10	4	10^{-4}	
NOT REALLY ACIDIC ANYMORE	10^{-15}	15	-1	10^{1}	

↓ STRONG BASES (eg NaOH)

16.9 ACID - BASE PROPERTIES OF SALTS

ACID + BASE → WATER + SALT

TYPES OF SALTS

I. STRONG ACID + STRONG BASE

FOR EX. $HCl + NaOH \rightarrow H_2O + \boxed{NaCl}$

NOT ACIDIC OR BASIC

II. WEAK ACID + STRONG BASE

FOR EX. $HC_2H_3O_2 + NaOH \rightarrow H_2O + \boxed{NaC_2H_3O_2}$

BASIC B/C THE SOLUBLE SALT HAS AN ANION WHICH IS THE CONJ BASE OF A WEAK ACID.

III. STRONG ACID + WEAK BASE

FOR. EX. $HCl + NH_3 \rightarrow \boxed{NH_4Cl}$

ACIDIC B/C THE SOL. SALT HAS A CATION WHICH IS THE CONJ. ACID OF A WEAK BASE

IV. WEAK ACID + WEAK BASE

FOR EX. $HC_2H_3O_2 + NH_3 \rightleftharpoons \boxed{NH_4C_2H_3O_2}$

BOTH ACIDIC AND BASIC!
DEPENDING ON REL. STRENGTH OF THE WEAK ACIDS THIS EQUIL. MAY LIE MORE TO THE LEFT IF THE CONJ ACID ON THE RIGHT IS STRONGER, OR VICE VERSA
(TO CALC. pH YOU SOLVE THIS EQUIL. FIRST THEN USE $HA \rightleftharpoons H^+ + A^-$ FOR EITHER ONE WITH SOME NON-ZERO $[HA]_0$ AND $[A^-]_0$)

W 2026-03-18 AP CHEM

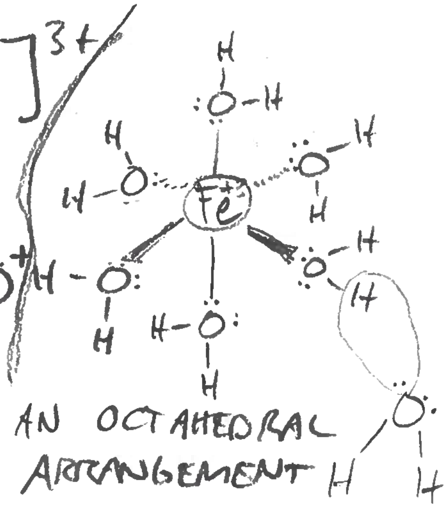
SALTS OF SOME METALS CAN AFFECT pH EVEN WITHOUT A WEAK ACID LIKE THE ONES WE'VE DISCUSSED. THIS IS POSSIBLE B/C THE LARGE POSITIVE CHARGE AND SMALL SIZE OF SOME IONS TURNS THEM INTO WEAK ACIDS DUE TO THE FORMATION OF COMPLEX IONS WITH WATER MOLECULE LIGANDS.

$$Fe^{3+} + 6H_2O \rightleftharpoons [Fe(H_2O)_6]^{3+}$$

$(FeCl_3)$

$$\underbrace{[Fe(H_2O)_6]^{+3}}_{} + H_2O \rightleftharpoons \underbrace{[Fe(H_2O)_5OH]^{2+}}_{} + H_3O^+$$

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



AN OCTAHEDRAL ARRANGEMENT

Fe^{3+} $K_a = 6.3 \times 10^{-3}$

Fe^{2+} $K_a = 3.2 \times 10^{-10}$

THE LARGER THE CHARGE, THE GREATER THE e^- WITHDRAWING EFFECT ON THE O—H BOND, AND THE STRONGER WE EXPECT THE ACID TO BE.

16.10 ACID-BASE BEHAVIOR AND CHEMICAL STRUCTURE

ACID STRENGTH DEPENDS ON ...

① ...THE POLARITY OF THE H—X BOND (USUALLY H—O). THE MORE POLAR THIS BOND IS, THE STRONGER THE ACID IS.

② ...THE STRENGTH OF THE H-X BOND. THE WEAKER THE BOND IS, THE STRONGER THE ACID IS.

③ ...THE STABILITY OF THE CONJUGATE BASE. THE MORE STABLE IT IS WITHOUT THE H^+, THE STRONGER THE ACID WAS.

COMPARING BINARY ACID STRENGTH: FIG. 16.18 pg 706

K_a —

CH_4 NOT ACIDIC/BASIC	NH_3 $K_b = 1.8 \times 10^{-5}$	H_2O $K_a = 1.8 \times 10^{-16}$	HF $K_a = 6.8 \times 10^{-4}$
SiH_4 NOT ACIDIC/BASIC	PH_3 $K_b = 4 \times 10^{-28}$	H_2S $K_a = 9.5 \times 10^{-8}$	HCl
		H_2Se $K_a = 1.3 \times 10^{-4}$	HBr
			HI

← BOND POLARITY

↖ WEAK ACID DUE TO HIGH BOND STRENGTH (DESPITE IT'S HIGH POLARITY)

↑ BOND LENGTH OR STRENGTH

STRONG ACIDS B/C THEIR BONDS ARE SO LONG/WEAK

OXYACIDS

$H{-}O{-}XO_n$

$n = 0, 1, 2, 3$

$X =$ NON-METAL (IF X IS A METAL, THEN THIS MIGHT A HYDROXIDE COMPOUND)

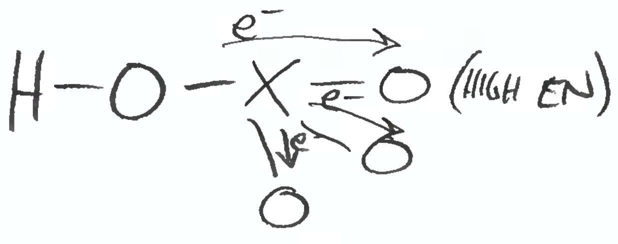
STRENGTH OF OXYACIDS DEPENDS ON

① THE ELECTRONEGATIVITY OF X. THE LARGER THE EN OF X IS, THE STRONGER THE ACID IS. (FOR THE SAME NUMBER OF OXYGEN ATOMS).

FOR EX	$HClO$	$HBrO$	HIO
K_a	3.0×10^{-8}	2.5×10^{-9}	2.3×10^{-11}

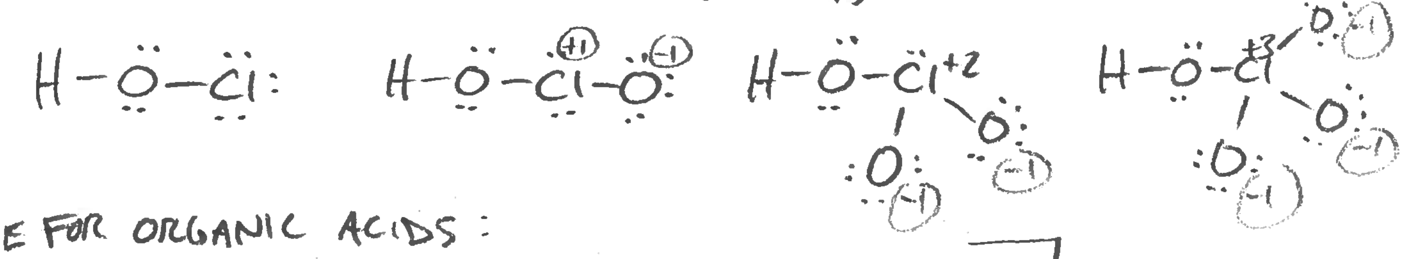
→ EN DECR.

② THE NUMBER OF OXYGEN ATOMS BONDED TO X. MORE OXYGENS MEANS GREATER ACID STRENGTH BECAUSE THEY WITHDRAW e^- DENSITY FROM THE O–H BOND, WEAKENING IT.



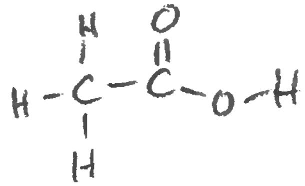
W 2026-03-18 AP CHEM

FOR EX	$HClO$	$HClO_2$	$HClO_3$	$HClO_4$
K_a	3.0×10^{-8}	1.1×10^{-2}	1.0×10^{-1} (STRONG)	STRONG



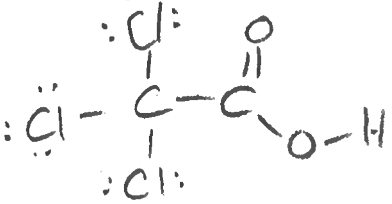
ASIDE FOR ORGANIC ACIDS:

ACETIC ACID



1.8×10^{-5}

TRICHLOROACETIC ACID



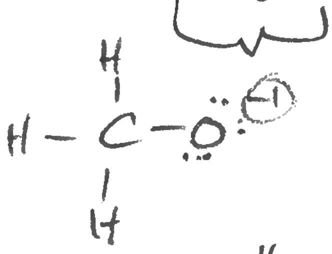
2.2×10^{-1}

OTHER ATOMS BESIDES OXY. CAN WITHDRAW e^- DENSITY

STABILITY OF THE CONJUGATE BASE

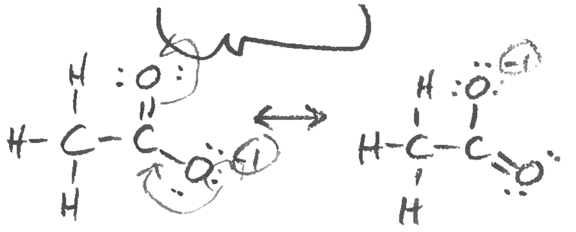
COMPARE ACIDITY OF CH_3OH TO CH_3COOH

$CH_3OH \rightleftharpoons CH_3O^- + H^+$



THE -1 CHARGE IS "STUCK" ON JUST ONE OXYGEN ATOM.

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$



RESONANCE SHOWS US THAT THE -1 CHARGE IS SPREAD OUT. THIS IS MORE STABLE AND IS WHY HCH_3COO IS AN ACID AND CH_3OH IS NOT.

AN EXERCISE FOR THE READER: COMPARE STABILITY OF THE CONJ BASES OF $HClO$, $HClO_2$, $HClO_3$, AND $HClO_4$ BASED ON RESONANCE.