

**Sali**

# La definizione di acido e base di Brønsted-Lowry

(1923)

Un acido è un **donatore di protoni**, qualsiasi specie che dona uno **ione  $H^+$** .

- Un acido deve contenere H nella sua formula.

Una base è un **accettore di protoni**, qualsiasi specie che accetta uno ione  **$H^+$** .

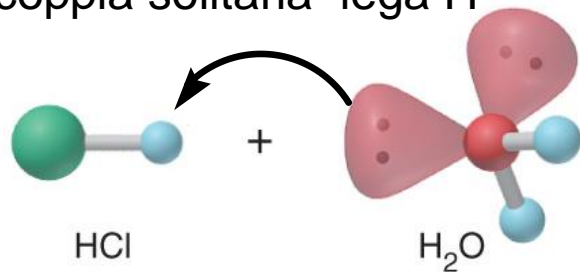
- Una base deve contenere una **coppia solitaria di elettroni** per legare  $H^+$ .

Una reazione acido-base è un **processo di trasferimento protonico**.



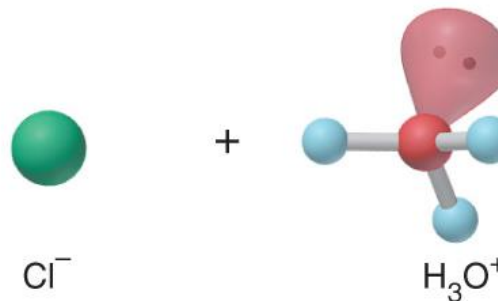
# Reazione acido-base di Brønsted-Lowry

La coppia solitaria lega  $H^+$



HCl

H<sub>2</sub>O



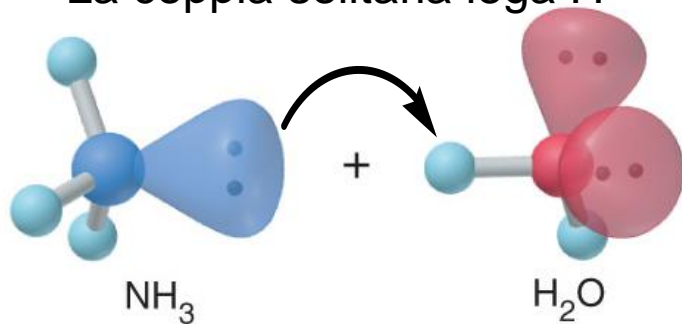
Cl<sup>-</sup>

H<sub>3</sub>O<sup>+</sup>

(acido, donatore di  $H^+$ )

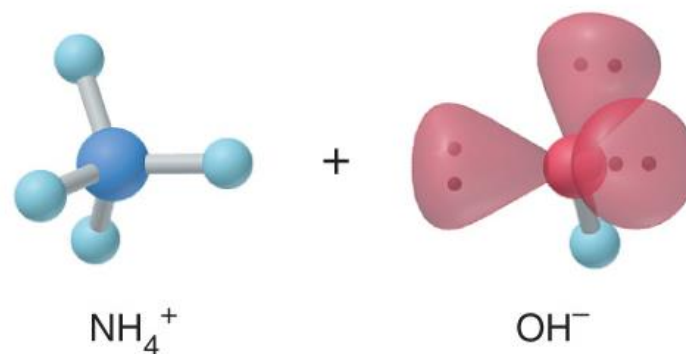
(base, accettore di  $H^+$ )

La coppia solitaria lega  $H^+$



NH<sub>3</sub>

H<sub>2</sub>O



NH<sub>4</sub><sup>+</sup>

OH<sup>-</sup>

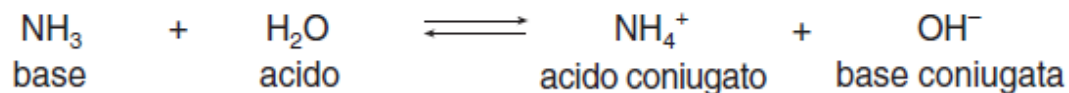
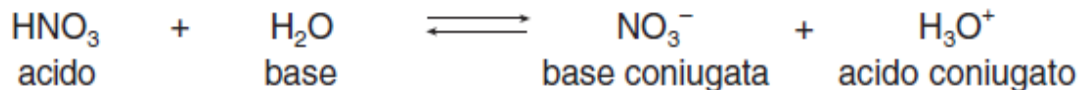
(base, accettore di  $H^+$ )

(acido, donatore di  $H^+$ )

# Sostanze Anfotere

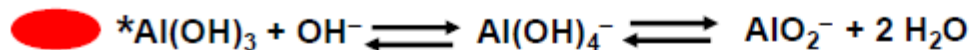
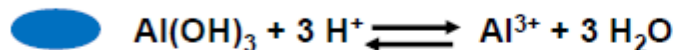
Una *sostanza anfotera* è una specie chimica che si comporta da base in presenza di acidi e da acido in presenza di basi.

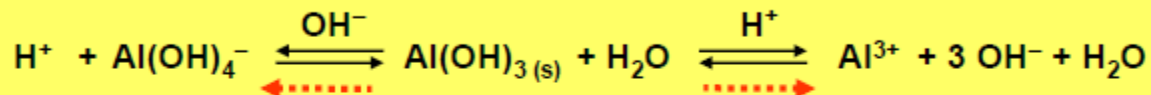
L'H<sub>2</sub>O è un anfotero, si ha infatti:



## IDROSSIDI ANFOTERI

Gli idrossidi di alcuni metalli (Al<sup>3+</sup>, Cr<sup>3+</sup>, Zn<sup>2+</sup>, Ag<sup>+</sup>, Pb<sup>2+</sup>), oltre a sciogliersi in ambiente acido, si sciolgono anche in un eccesso di alcali, legando altri ioni ossidrilici e formando i corrispondenti idrossometallati. Questi idrossidi si comportano sia da **basi** che da **acidi**.

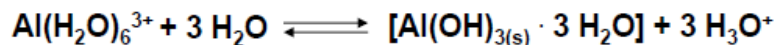




## CAUSE DELL'ANFOTERISMO

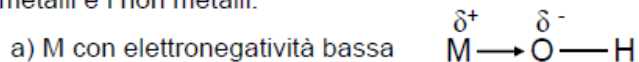
### Elevata densità di carica

Cationi con piccolo raggio ed alta carica esercitano una elevata forza di attrazione sulle molecole circostanti.

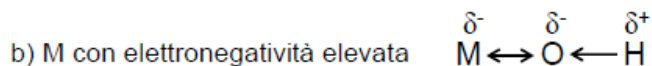


### Elettronegatività intermedia

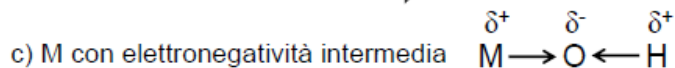
I metalli che formano ossidi e idrossidi anfoteri si trovano in una zona compresa tra i metalli e i non metalli.



Es. CeOH  $3,5 - 0,7 = 2,8 \Rightarrow$  base forte



Es. ClOH  $3,5 - 3 = 0,5 \Rightarrow$  acido forte



Es. AgOH  $3,5 - 1,8 = 1,7$  idrossido anfotero



## Coppie coniugate acido-base



H<sub>2</sub>S e HS<sup>-</sup> sono una **coppia coniugata acido-base**:

HS<sup>-</sup> è la **base coniugata** dell'acido H<sub>2</sub>S.

NH<sub>3</sub> e NH<sub>4</sub><sup>+</sup> sono una **coppia coniugata acido-base**:

NH<sub>4</sub><sup>+</sup> è l'**acido coniugato della** base NH<sub>3</sub>.

Avviene una reazione acido-base di Brønsted-Lowry quando *un acido* e una base reagiscono per formare la loro **base coniugata** e il loro **acido coniugato**, rispettivamente:



## K<sub>a</sub> e K<sub>b</sub> per una coppia coniugata acido-base



$$K_1 = \frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]} = K_a$$

$$K_2 = \frac{[\text{HA}][\text{OH}^-]}{[\text{A}^-]} = K_b$$

K<sub>w</sub>



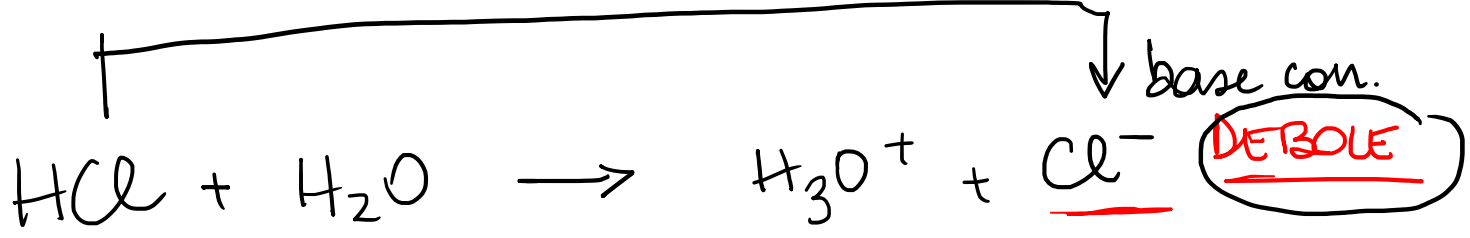
K<sub>c</sub> per la reazione complessiva = K<sub>1</sub> x K<sub>2</sub>, perciò:

$$\frac{[\text{H}_3\text{O}^+][\text{A}^-]}{[\text{HA}]} \times \frac{[\text{HA}][\text{OH}^-]}{[\text{A}^-]} = [\text{H}_3\text{O}^+][\text{OH}^-]$$

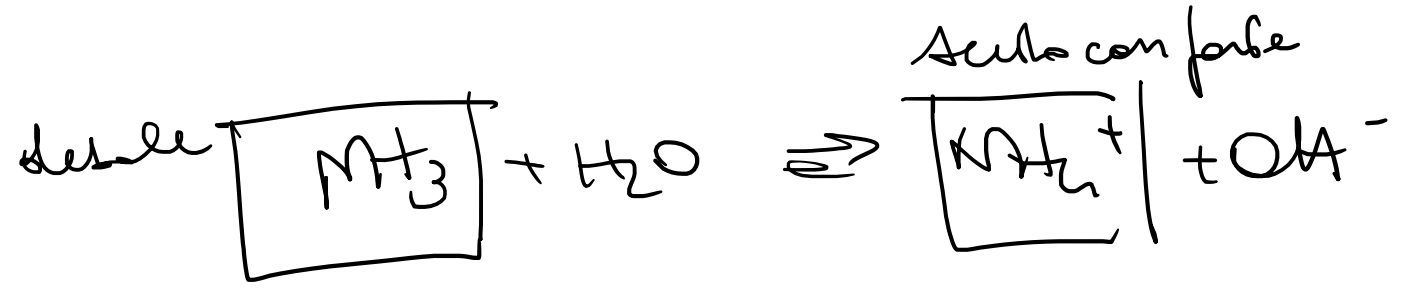
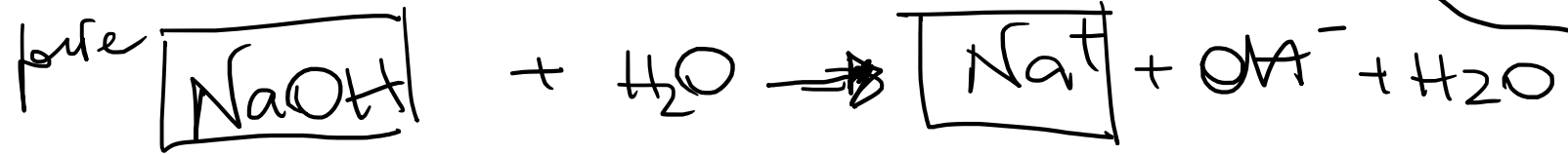
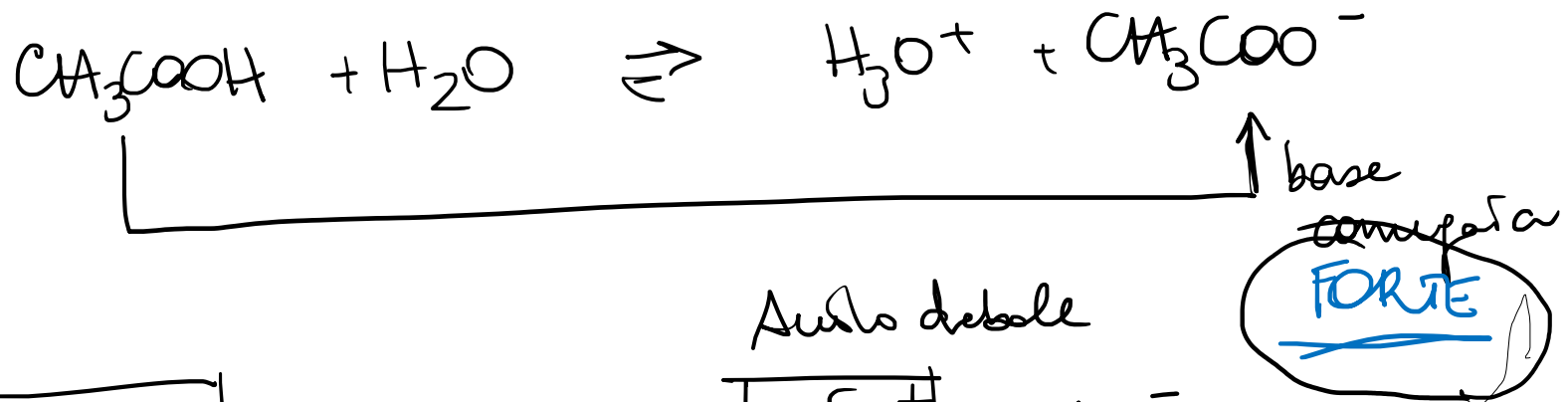
$$\boxed{K_a \times K_b = K_w}$$

Questa relazione è valida per qualsiasi **coppia coniugata acido-base**.

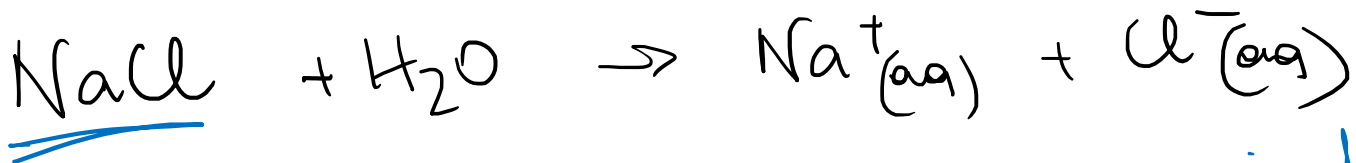
Acido  
FORTE



Acido  
debole



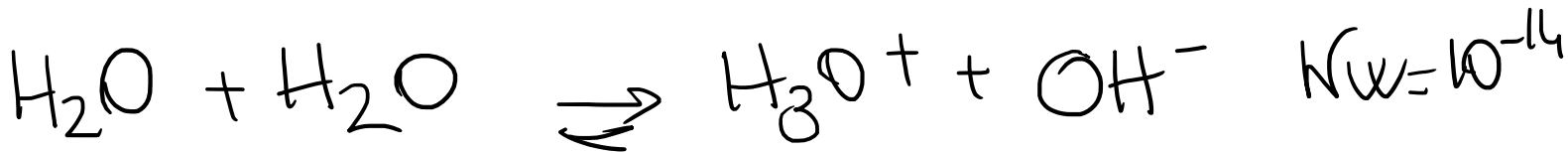
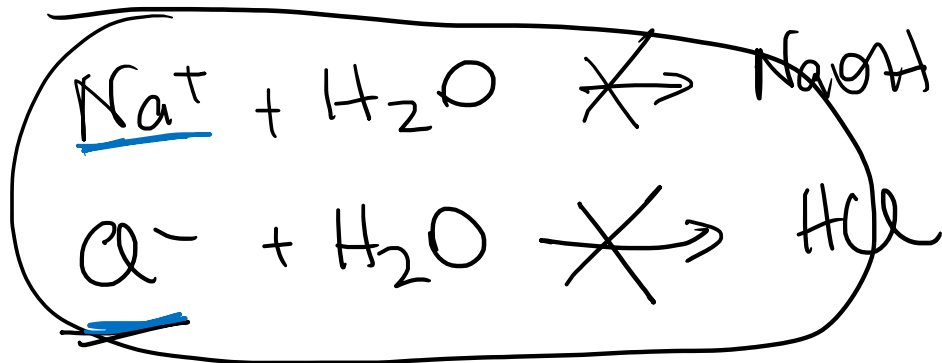




$$\boxed{\text{pH} = 7}$$

Perché?

SALI derivanti  
da acidi e  
basi forti

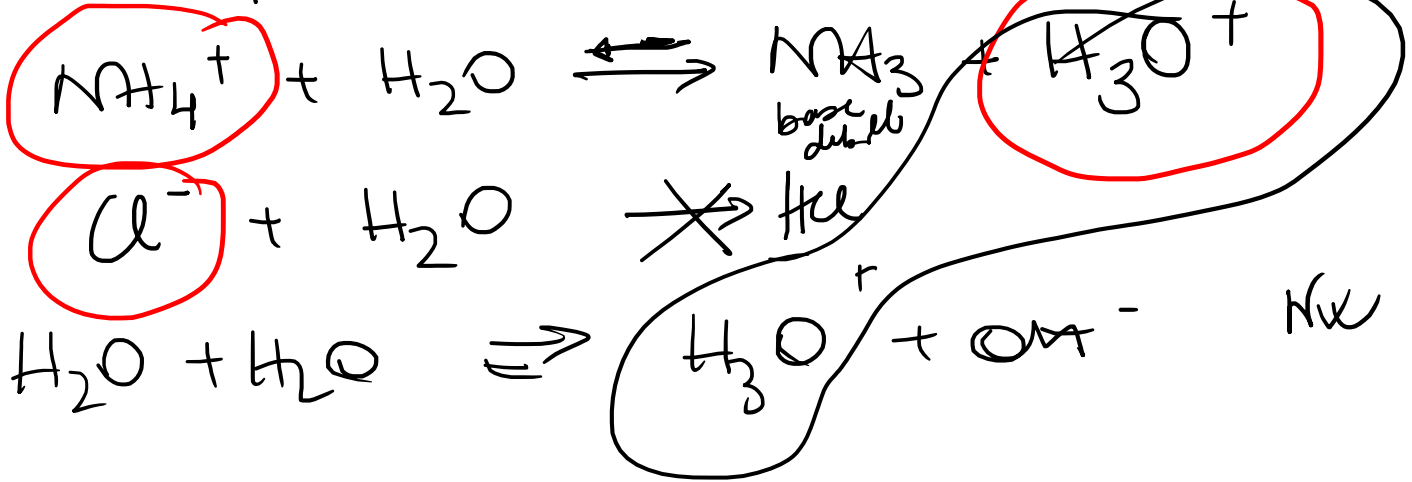


$$[\text{H}_3\text{O}^+] = [\text{OH}^-] = 10^{-7}$$

$$\boxed{\text{pH} = 7}$$



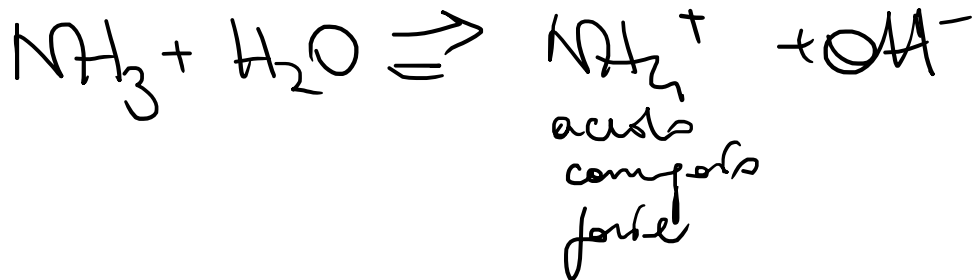
Acido Forte



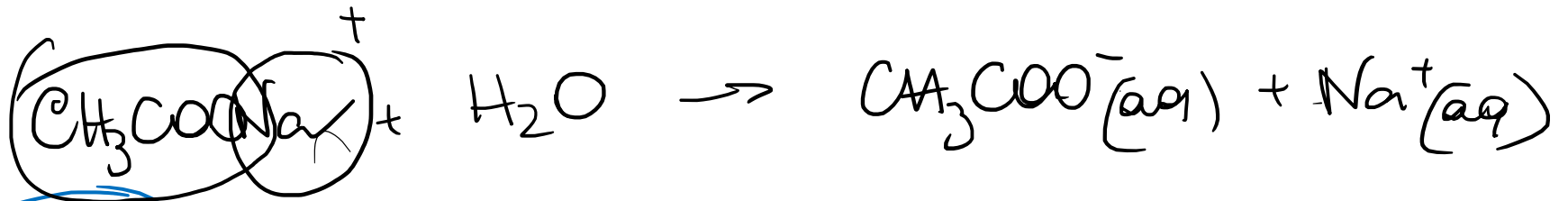
~~pH > 7~~

ANIONE DERIVA  
DA ACIDO FORTE

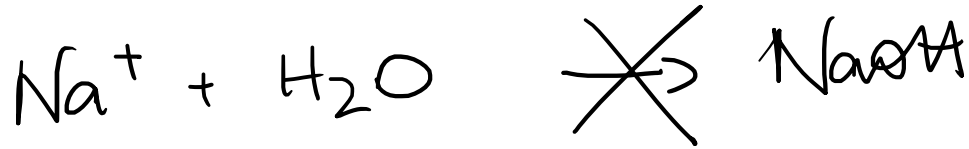
base debole



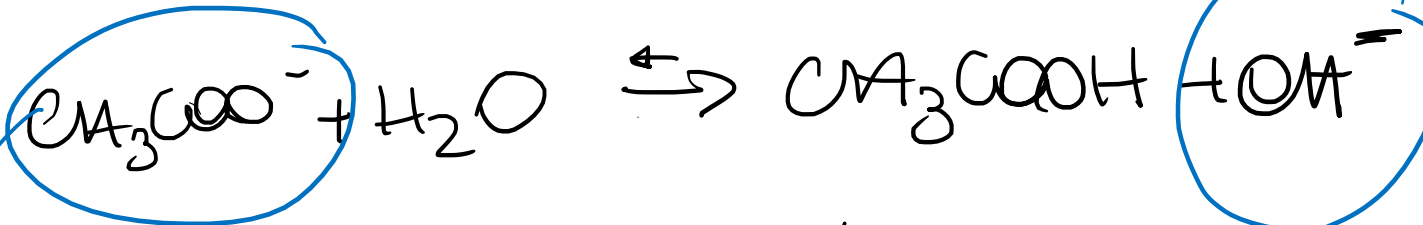
~~pH~~ ACIDO



$\text{pH} > 7$

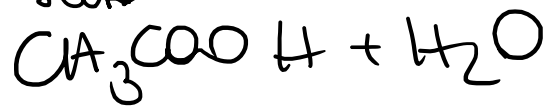


Basico



$\text{pH}$  BASICO

ácido  
débil

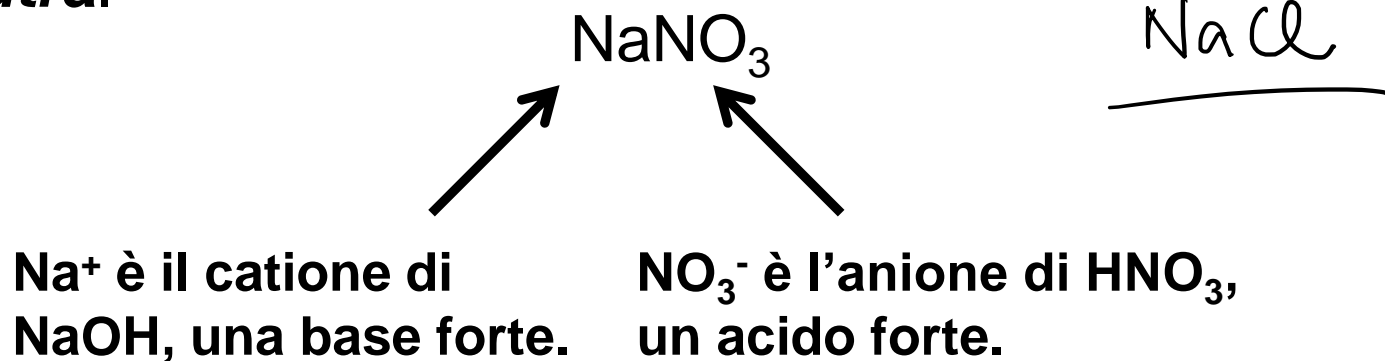


base con.  
fuerte



## Sali che producono soluzioni neutre

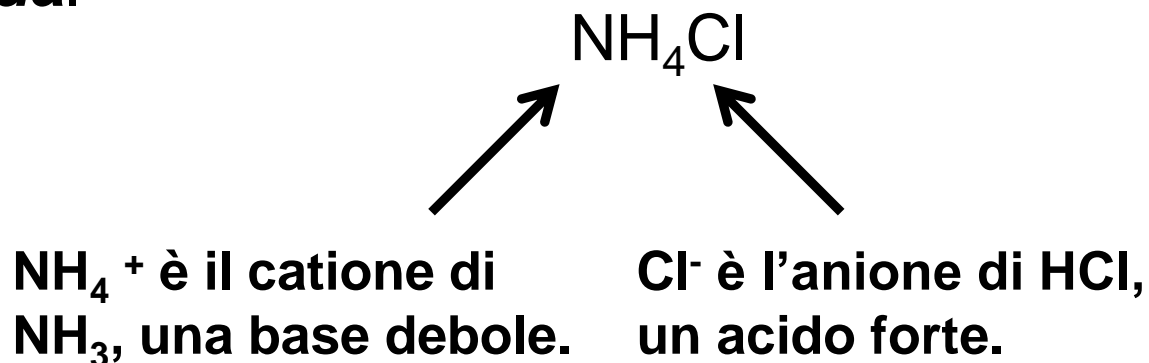
Un sale costituito dall'**anione** di un **acido forte** e dal **catione** di una **base forte** produce una soluzione **neutra**.



La soluzione di nitrato di sodio sarà neutra perché né  $\text{Na}^+$  né  $\text{NO}_3^-$  reagiranno con  $\text{H}_2\text{O}$ .

## Sali che producono soluzioni acide

Un sale costituito dall'**anione** di un **acido forte** e dal **catione** di una **base debole** produce una soluzione **acida**.



La soluzione di cloruro d'ammonio sarà **acida**, perché  $\text{NH}_4^+$  reagirà con  $\text{H}_2\text{O}$  per produrre  $\text{H}_3\text{O}^+$ :



## Sali che producono soluzioni basiche

Un sale costituito dall'**anione** di un **acido debole** e dal **catione** di una **base forte** produce una soluzione **basica**.

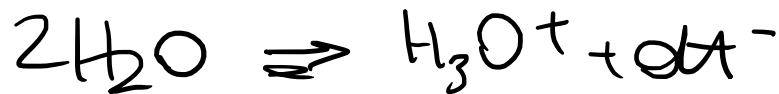
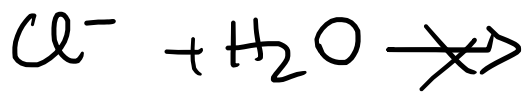
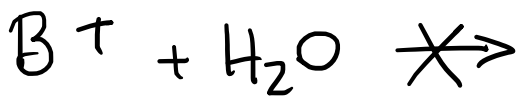
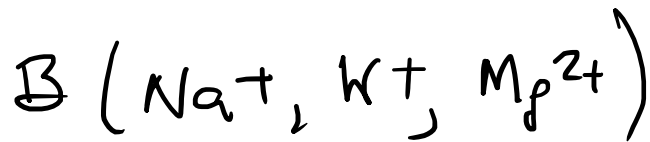
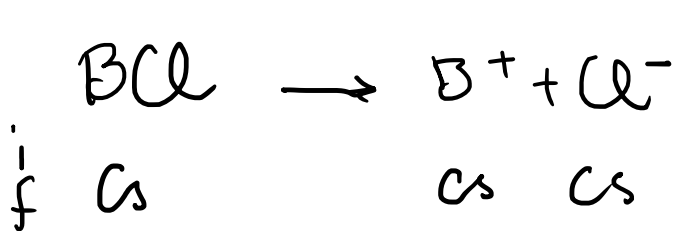


$\text{CH}_3\text{COO}^-$  è l'anione di  $\text{CH}_3\text{COOH}$ , un acido debole.

$\text{Na}^+$  è il catione di  $\text{NaOH}$ , una base forte.

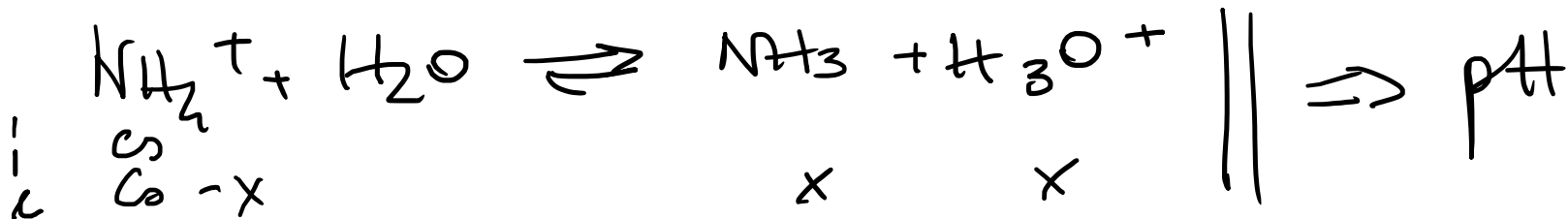
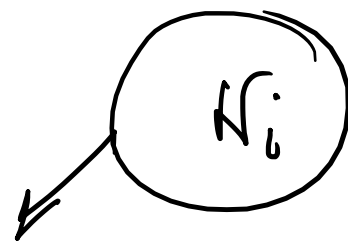
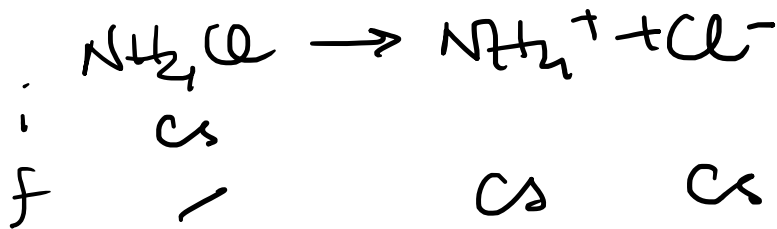
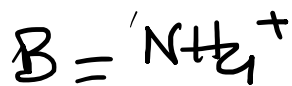
La soluzione di acetato di sodio sarà **basica**, perché  $\text{CH}_3\text{COO}^-$  reagirà con  $\text{H}_2\text{O}$  per produrre  $\text{OH}^-$ :





$$10^{-7} \quad 10^{-7}$$

$$\text{pH} = 7$$



$$K_i = \frac{\overbrace{[NH_3][H_3O^+][OH^-]}^{K_w}}{[NH_4^+][OH^-]} = \frac{K_w}{K_b}$$

$K_w = K_a = K_b$

$$K_i = \frac{K_w}{K_b} = \frac{x^2}{C_s - x}$$

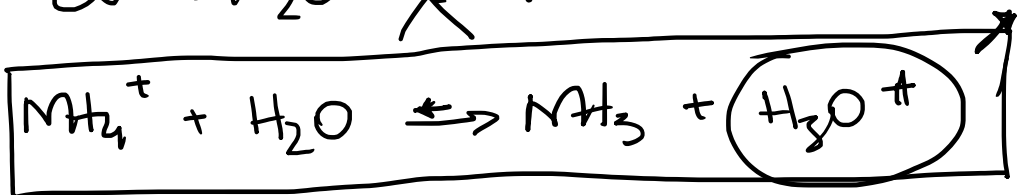
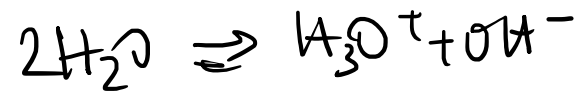
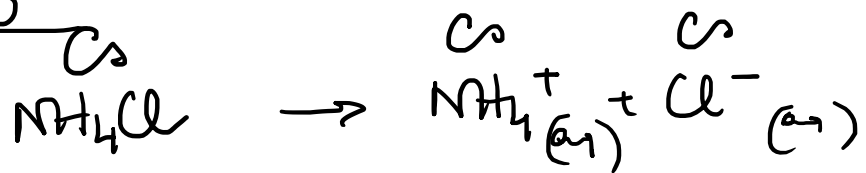
$x = [H_3O^+]$

$$K_i = \frac{K_w}{K_b} = \frac{[H_3O^+]^2}{C_s - [H_3O^+]} \Rightarrow K_i = \frac{K_w}{K_b} = \frac{[H_3O^+]^2}{C_s}$$

$$[H_3O^+] = \sqrt{\frac{K_w}{K_b} \cdot C_s}$$



SALF ACIDO

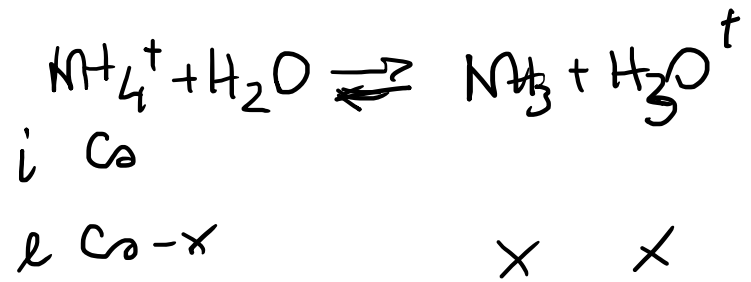


Acido

$\Delta/K_b$

$K_i = \frac{[\text{NH}_3][\text{H}_3\text{O}^+][\text{OH}^-]}{[\text{NH}_4^+][\text{OH}^-]}$

$= \frac{K_w}{K_b \text{NH}_3}$

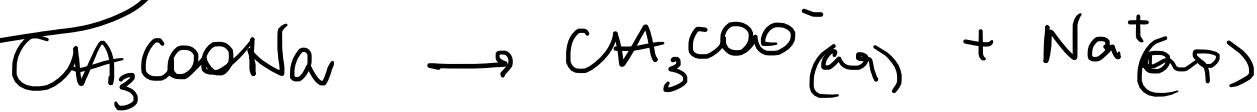


$K_i = \frac{K_w}{K_b} = \frac{x^2}{c_s}$

$x = [\text{H}_3\text{O}^+] \Rightarrow \frac{x^2}{c_s} = K_i = \frac{K_w}{K_b}$

$[\text{H}_3\text{O}^+] = \sqrt{\frac{K_w \cdot c_s}{K_b}}$

SALE BASICO



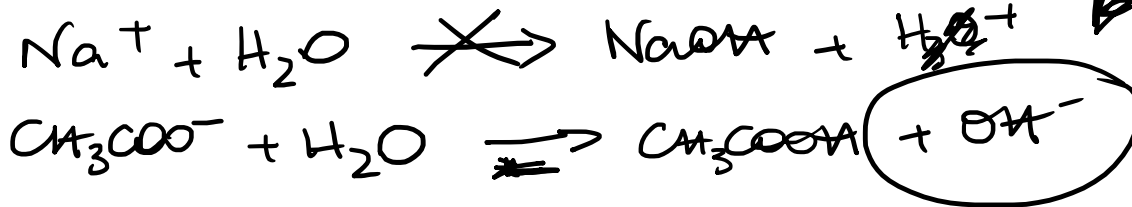
i Cs

f /

Cs

Cs

BASICO



i Cs

f Cs - x

$\Delta Ka$

$Kw$  x

x

$$x = [OH^-]$$

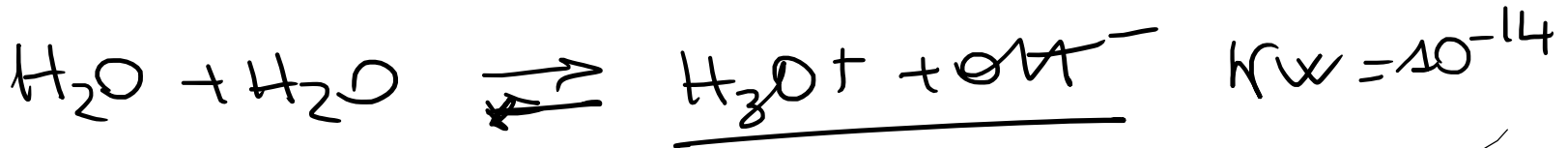
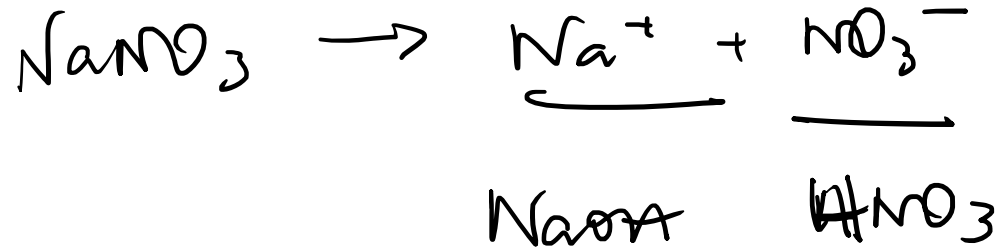
$$K_i = \frac{[CH_3COOH][OH^-] \cdot [H_3O^+]}{[CH_3COO^-][H_2O]} = \frac{Kw}{K_a [CH_3COOH]}$$

$$\frac{Kw}{K_a} = K_i = \frac{x^2}{Cs}$$

$$\frac{Kw}{K_a} = \frac{x^2}{Cs}$$

$$[OH^-] = \sqrt{\frac{Kw}{K_a} \cdot Cs}$$

SAM  
NEUTRAL

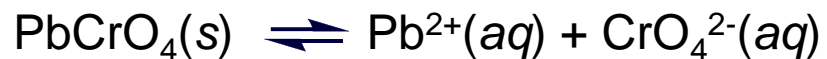
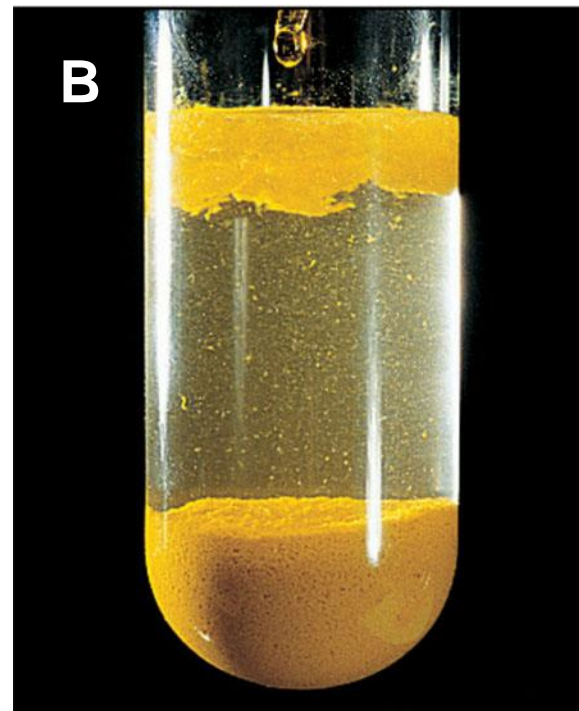
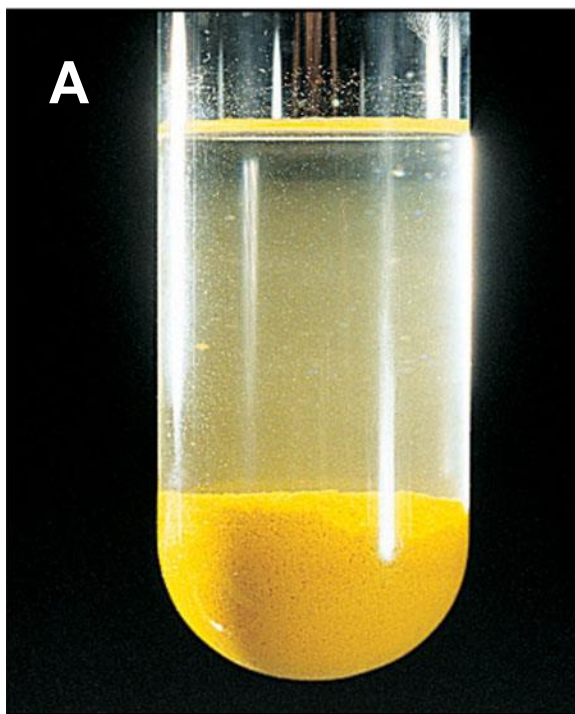


$$\text{pH} = 7$$

$$\underline{[\text{H}_3\text{O}^+] = [\text{OH}^-] = 10^{-7}}$$

# Soluzioni tampone

## Effetto ione comune



- A.** Il cromato di piombo(II), un sale poco solubile, forma una soluzione acquosa satura.
- B.** Quando si aggiunge una soluzione di  $\text{Na}_2\text{CrO}_4$ , la quantità di  $\text{PbCrO}_4(s)$  aumenta, indicando una minore solubilità in presenza dello ione a comune,  $\text{CrO}_4^{2-}$ .

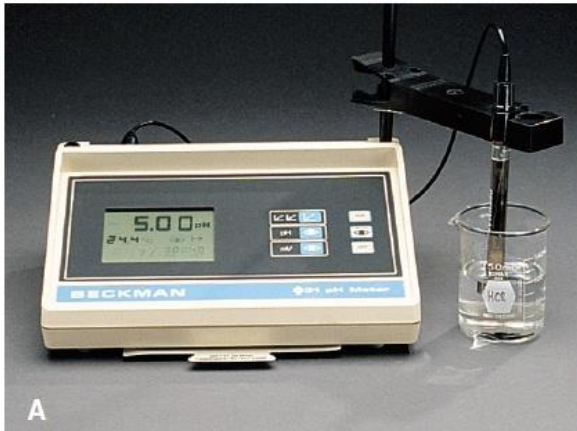
## Tamponi acido-base

Un tampone acido-base è una soluzione che diminuisce le variazioni in pH derivanti dall'aggiunta di un acido o di una base.

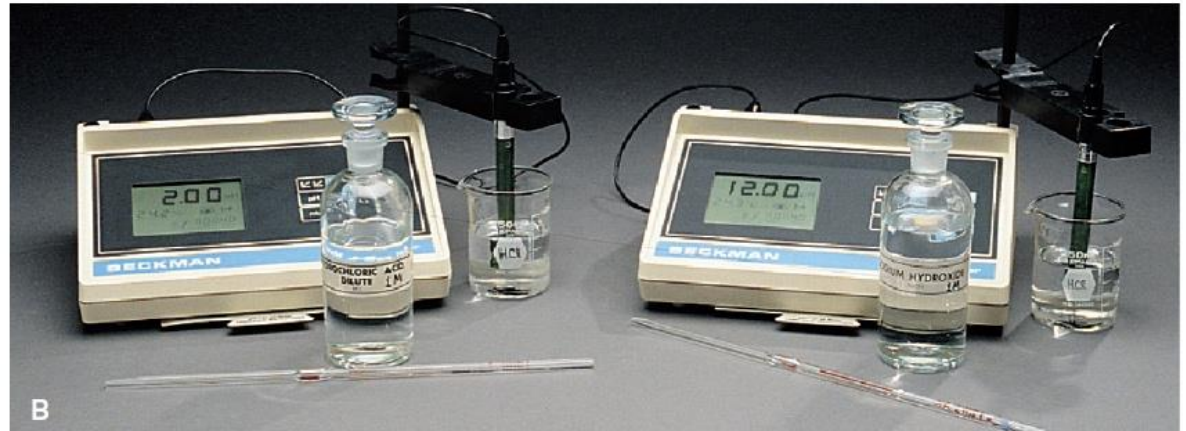
Un tampone acido-base normalmente è costituito da una soluzione contenente una **coppia coniugata acido-base** in cui entrambe le specie sono presenti in quantità apprezzabile.

Un tampone acido-base è perciò una soluzione di **un acido debole e della sua base coniugata**, o di una **base debole e del suo acido coniugato**.

# L'effetto dell'aggiunta di un acido o di una base a una soluzione non tamponata

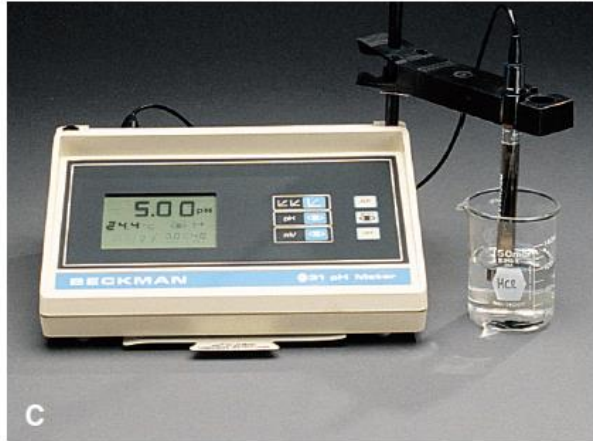


Un campione di 100 mL di una soluzione diluita di HCl viene portato a pH 5,00.



Dopo l'aggiunta di 1 mL di HCl 1 M (*a sinistra*) o di NaOH 1 M (*a destra*) si ha un'elevata variazione di pH.

# L'effetto dell'aggiunta di un acido o di una base a una soluzione tamponata

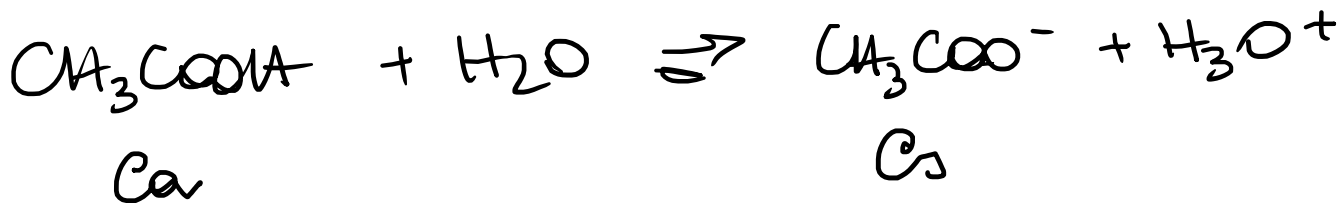
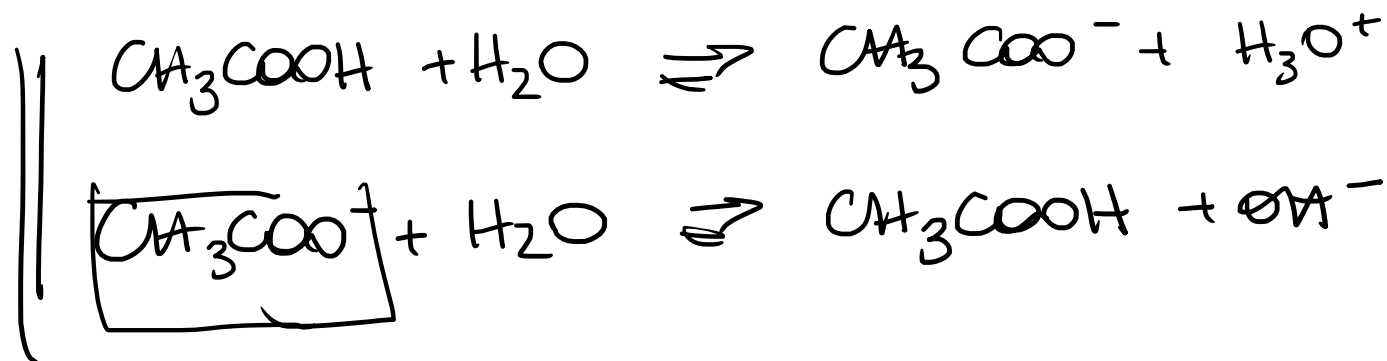
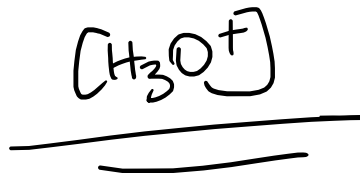
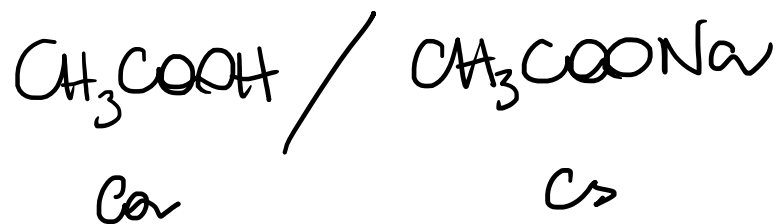


Si porta a pH 5,00 un campione di 100 mL di una soluzione tampone costituita mescolando  $\text{CH}_3\text{COOH}$  (un acido debole) 1 M con  $\text{CH}_3\text{COONa}$  (che produce la sua base coniugata,  $\text{CH}_3\text{COO}^-$ ) 1 M.

Dopo l'aggiunta di 1 mL di  $\text{HCl}$  1 M (a sinistra) o di  $\text{NaOH}$  1 M (a destra) la variazione di pH è trascurabile.



# TAMPONE ACIDA



$e$        $C_a - x$

$C_s + x$        $x$

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]} = \frac{(C_s + x)(x)}{C_a - x} \longrightarrow$$

$$K_a = \frac{(C_s - x)(x)}{C_a - x} = 1.8 \cdot 10^{-5}$$

TAMPONI  
non sono  
definiti.

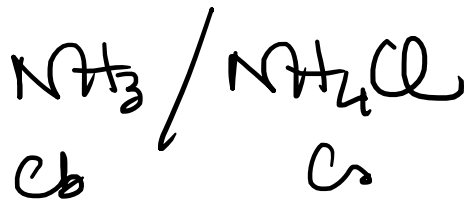
$$K_a = \frac{C_s (x)}{C_a}$$

$$x = [H_3O^+] = K_a \cdot \frac{C_a}{C_s}$$

$$pH = pK_a + \log \frac{C_s}{C_a}$$



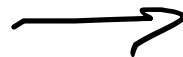
# TAMPONE BASICO



$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = \frac{(c_s + x)(x)}{c_b - x} = 1.76 \cdot 10^{-5}$$

$$x = [\text{OH}^-] \Rightarrow K_b = \frac{c_s \cdot x}{c_b}$$

$$[\text{OH}^-] = K_b \cdot \frac{c_b}{c_s}$$



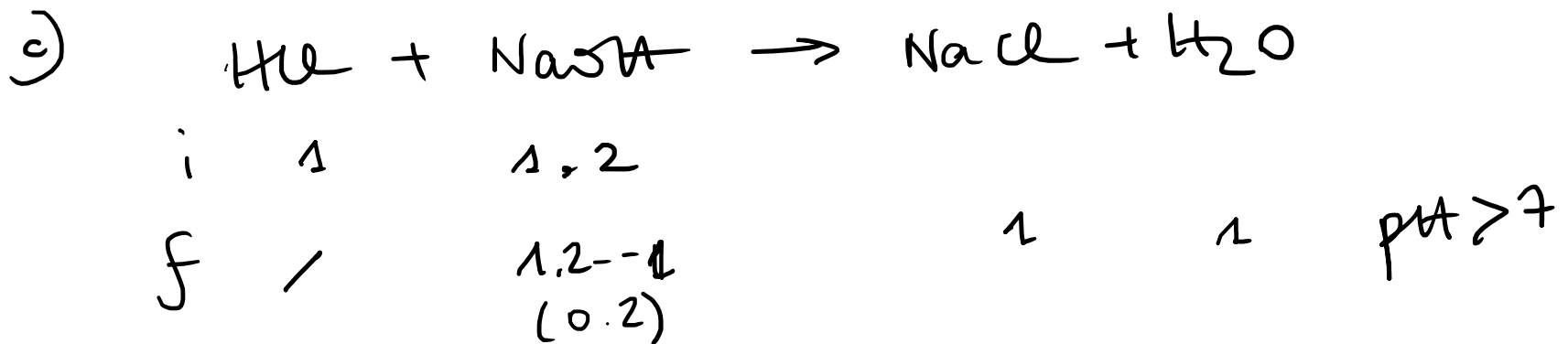
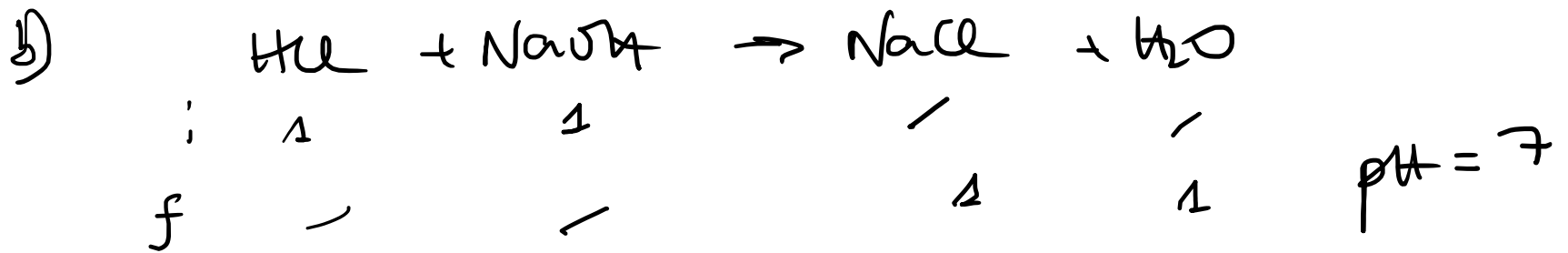
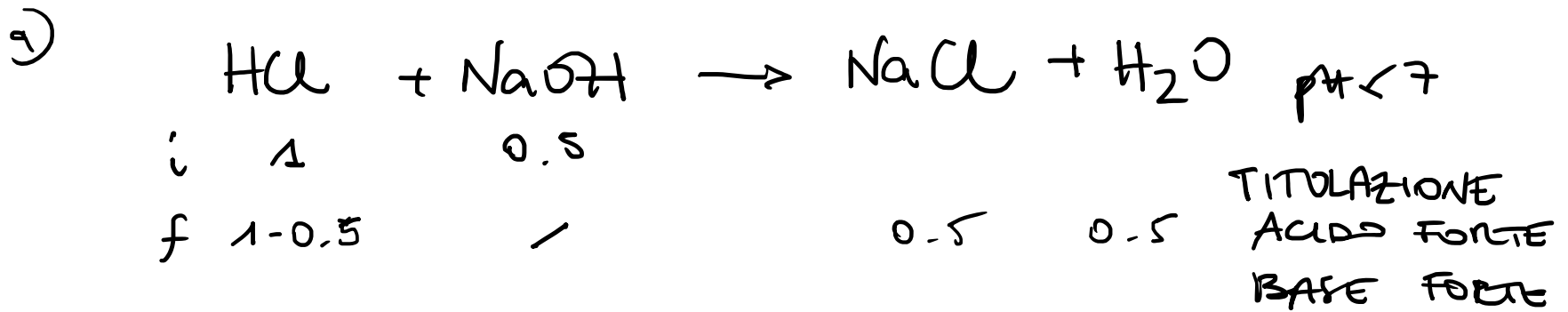
$$[A^-] = N_b \cdot \frac{C_b}{C_s}$$

$$pOH = pK_b + \log \frac{C_s}{C_b}$$

$$[H_3O^+] = N_a \cdot \frac{C_a}{C_s}$$
$$[OH^-] = N_b \cdot \frac{C_b}{C_s}$$

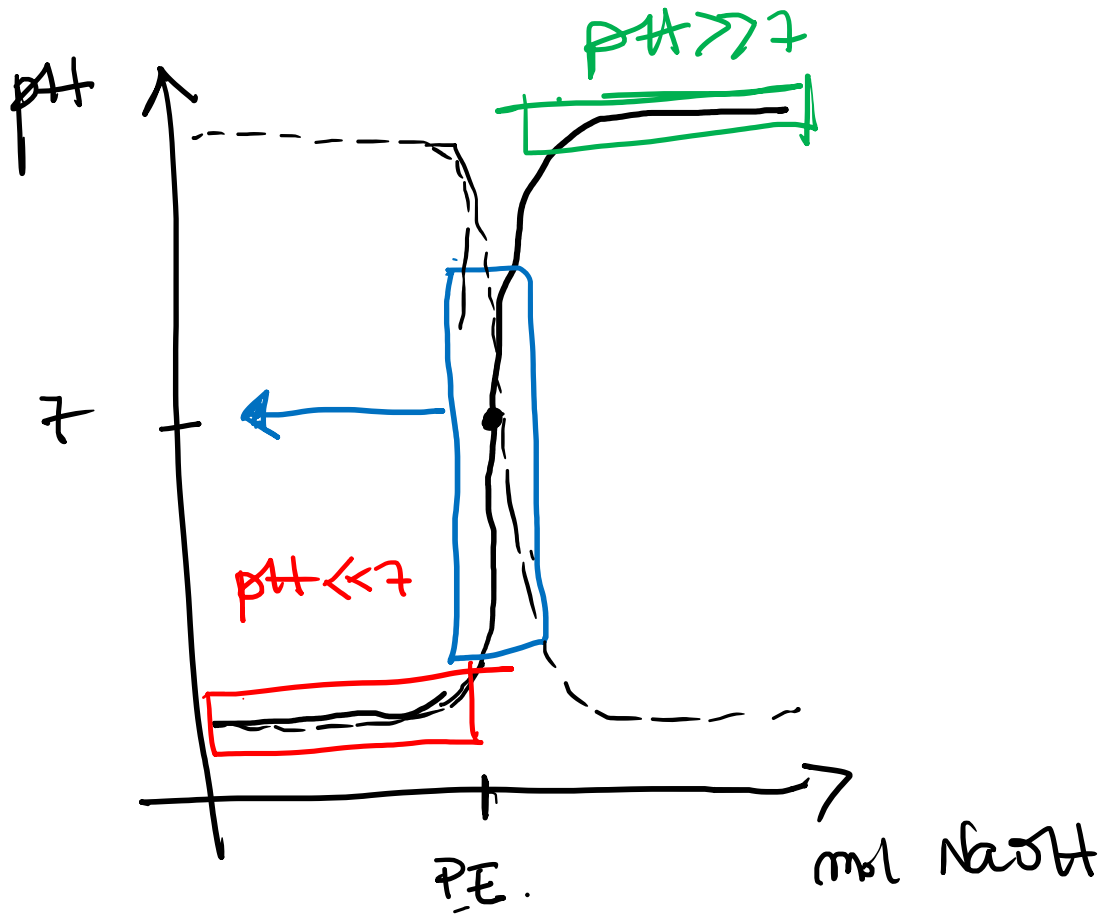
$$= N_a \cdot \frac{m_a}{\cancel{V_{tot}}}$$
$$= N_b \cdot \frac{m_b}{\cancel{V_{tot}}}$$
$$= N_b \cdot \frac{m_b}{m_s}$$

INDIPENDENTE dal VOLUME  
(dalla DILUIZIONE)



ACIDO FORTE + BASE FORTE

CURVA DI  
TITOLAZIONE





i 1 0.5

f 1-0.5

pH > 7

TAMPONE  
BASICO

0.5

$$[\text{OH}^-] = K_b \cdot \frac{C_b}{C_s} = K_b \cdot \frac{m_b}{m_s}$$

TITOL.  
0.5 BASE DEBILE  
ACIDO FORTE



i 1 1

f / /

1 1

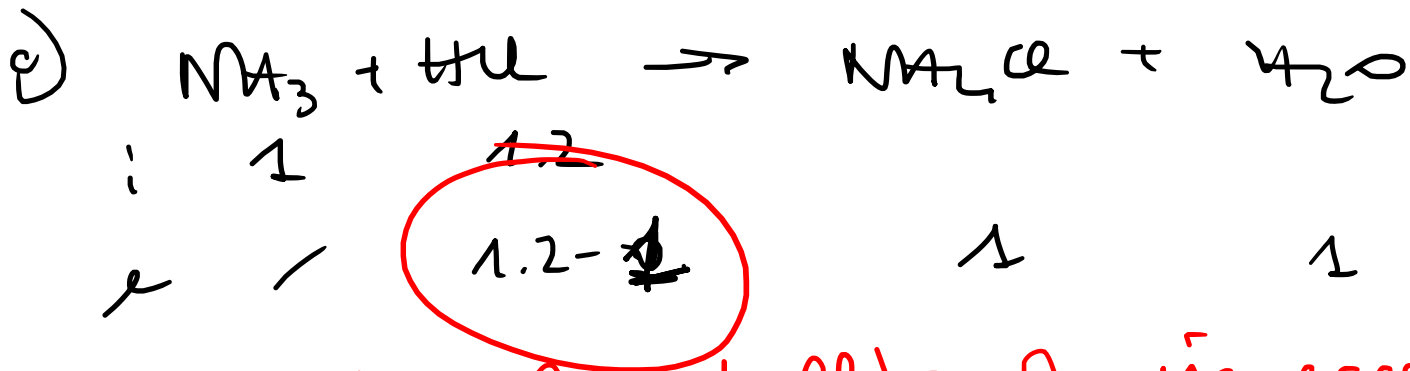
INDOLISI  
& ACIDE  
ACIDO



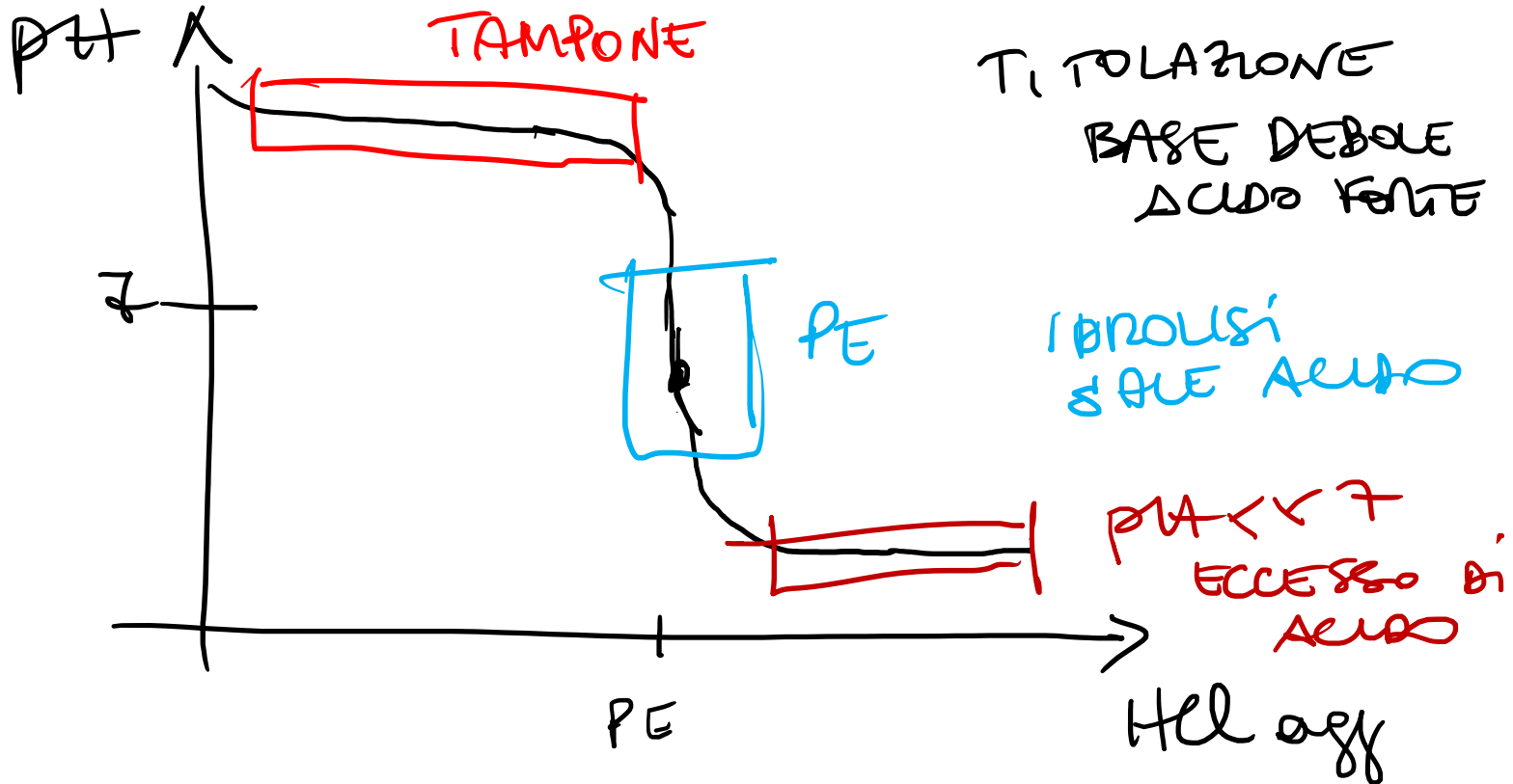
$$[\text{H}_3\text{O}^+] = \sqrt{\frac{K_a}{K_b} \cdot C_s}$$

$$pH < 7$$

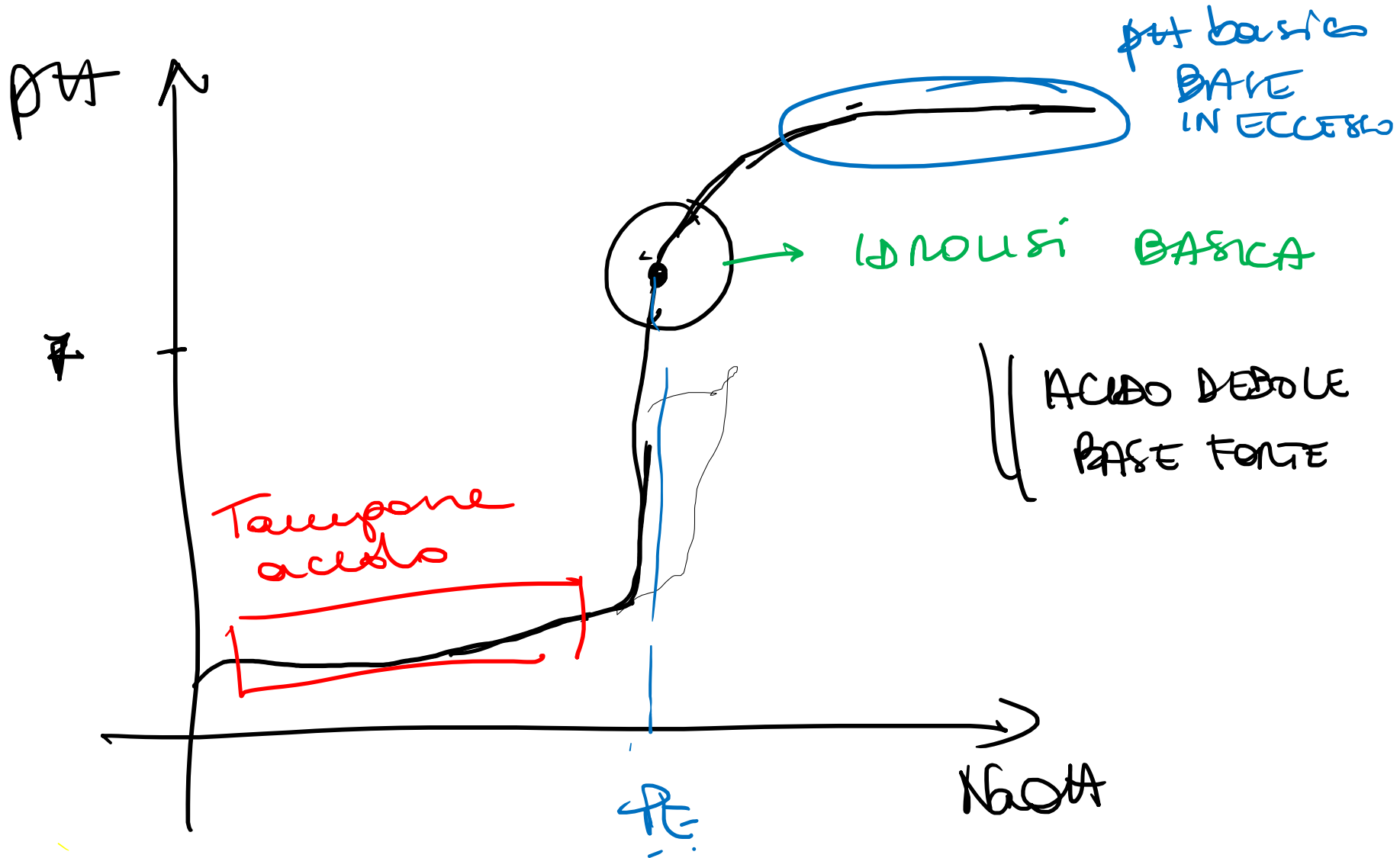
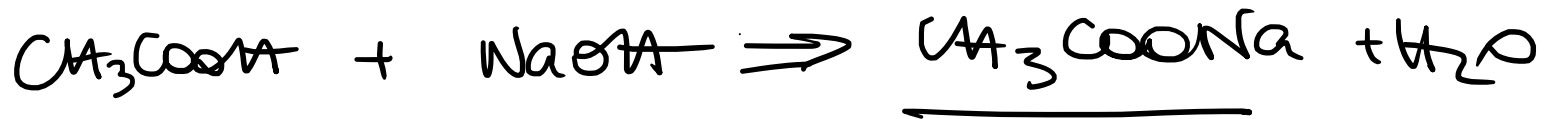
$$n_i = \frac{N_w}{K_b}$$



pH < 7 dipende dall'acido in eccesso







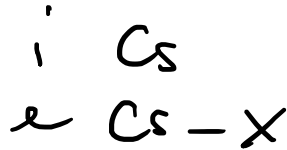
EX 1



pH = ?



0.100 M



x

Salt basic  
x

NaClO

$$K_a \text{HClO} = 2.95 \cdot 10^{-8}$$

$$x = [\text{OH}^-] \Rightarrow K_b = \frac{K_w}{K_a} = \frac{x^2}{C_s - x}$$

$$[\text{OH}^-] = \sqrt{\frac{K_w}{K_a} \cdot C_s} = \sqrt{\frac{10^{-14}}{2.95 \cdot 10^{-8}} \cdot 0.100} = 1.84 \cdot 10^{-4} \text{ M}$$

$$\text{pOH} = 3.735$$

$$\text{pH} = 14 - 3.735 = 10.265$$

(1)

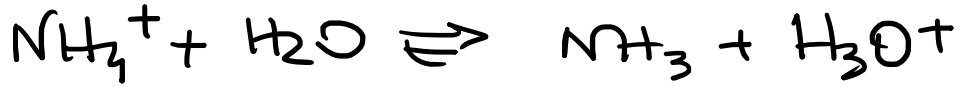
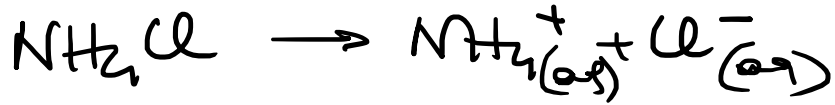
EX 2



$\text{pH} = 4.53$

$C_s = ?$

$K_b \text{NH}_3 = 1.79 \cdot 10^{-5}$



SALE ACID

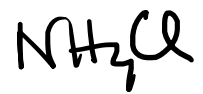
$C_s$	$x$	$x$	$x$
$C_s - x$	$x$	$x$	$x$

$$K_i = \frac{K_w}{K_b} = \frac{x^2}{C_s - x} = \frac{(10^{-4.53})^2}{C_s - 10^{-4.53}} = \frac{10^{-14}}{1.79 \cdot 10^{-5}} \quad x = [\text{H}_3\text{O}^+]$$

$[\text{H}_3\text{O}^+] = 10^{-4.53}$

$C_s = 1.56 \text{ M}$

EX3



$pH_i = 5.050$

$V_{H_2O} = ?$

$V_i = 0.5 L$

↓

$pH_f = 5.50$

$Nb_{NH_3} = 1.79 \cdot 10^{-5}$

$C_{si} \cdot V_i = C_{sf} \cdot V_f$

$N_i = \frac{N_{W}}{N_b}$

$= \frac{x^2}{C_{sf} - x}$

$= \frac{[H_3O^+]_f}{C_{sf} - [H_3O^+]_f}$

$= \frac{(10^{-5.50})^2}{C_{sf} - 10^{-5.50}}$

$C_{sf} = 0.0179 M$

(3)



$i \quad C_{sf}$

$2 \quad C_{sf} - x$

$x \quad (x)$

$[H_3O^+]_{imz} = 10^{-5.050}$

$N_i = \frac{N_{W}}{N_b} = \frac{(10^{-5.050})^2}{C_{si} - 10^{-5.050}}$

$C_{si} = 0.142 M$

$$C_{Si} \cdot V_i = C_{Sf} \cdot V_f$$

$$0.142 \frac{\text{mol}}{\text{L}} \cdot 0.5 \text{L} = 0.0179 \frac{\text{mol}}{\text{L}} \cdot V_f$$

$$V_f = 3.966 \text{L} = V_i + V_{\text{H}_2\text{O}}$$

$$V_{\text{H}_2\text{O}} = (3.966 - 0.5) \text{L} = \boxed{3.47 \text{L}}$$

(4)

ex 4

$\text{NH}_3$  0.200 M

50 mL

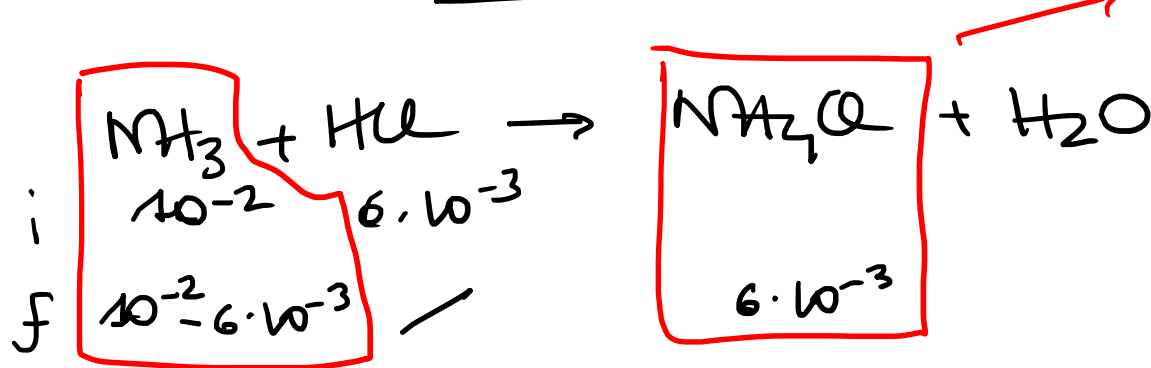
HCl 0.200 M

a) 30 mL

b) 50.1 mL

} pH = ?

TAMPONE  
BASICO



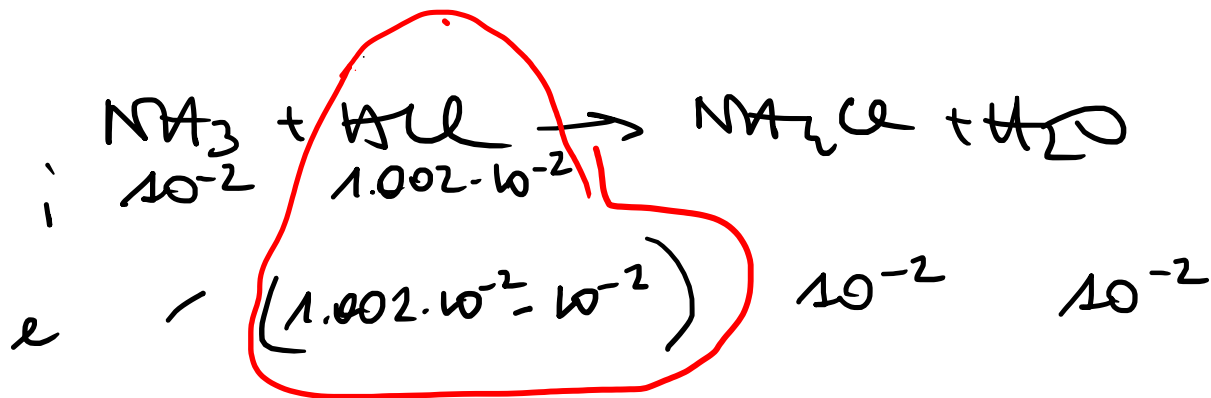
$$\text{mol NH}_3 = 0.05 \cancel{\text{L}} \cdot 0.200 \frac{\text{mol}}{\text{L}} = 10^{-2} \text{ mol NH}_3$$

$$\text{mol HCl} = 0.03 \cancel{\text{L}} \cdot 0.200 \frac{\text{mol}}{\text{L}} = 6 \cdot 10^{-3} \text{ mol HCl}$$

$$[\text{OH}^-] = K_b \cdot \frac{n_b}{n_s} = 1.79 \cdot 10^{-5} \cdot \frac{10^{-2} - 6 \cdot 10^{-3}}{6 \cdot 10^{-3}}$$

$$[\text{OH}^-] = 1.19 \cdot 10^{-5} \text{ M} \quad \text{pOH} = 4.92 \Rightarrow \boxed{\text{pH} = 9.08} \quad (5)$$

b)



$$\text{mol HCl} = 0.200 \frac{\text{mol}}{\text{L}} \cdot 0.0501 \text{ L} = 1.002 \cdot 10^{-2} \text{ mol}$$

$$\frac{2 \cdot 10^{-5} \text{ mol}}{0.05 \text{ L} + 0.0501 \text{ L}} = 2 \cdot 10^{-4} \text{ M} = [\text{H}_3\text{O}^+]$$

$$\boxed{\text{pH} = 3.70}$$

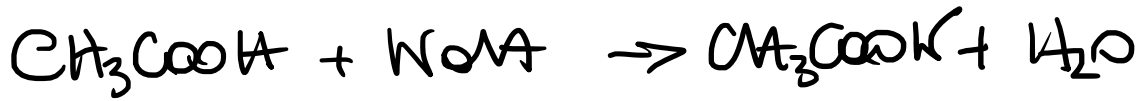
Ex 5

25 mL CH<sub>3</sub>COOH 0.1 M  
NaOH 0.1 M

pH<sub>init</sub> = ?  
K<sub>a</sub> = 1.8 · 10<sup>-5</sup>

pH = ?

- a) 15 mL NaOH
- b) 25 mL NaOH
- c) 35 mL NaOH



pH<sub>init</sub>



i    C<sub>0</sub>

x    C<sub>0</sub> - x

~~x~~    -    x

~~K<sub>a</sub>~~

$$K_a = 1.8 \cdot 10^{-5} = \frac{x^2}{C_0 - x}$$

$$\Rightarrow x = [\text{H}_3\text{O}^+] = \sqrt{K_a \cdot C_0}$$

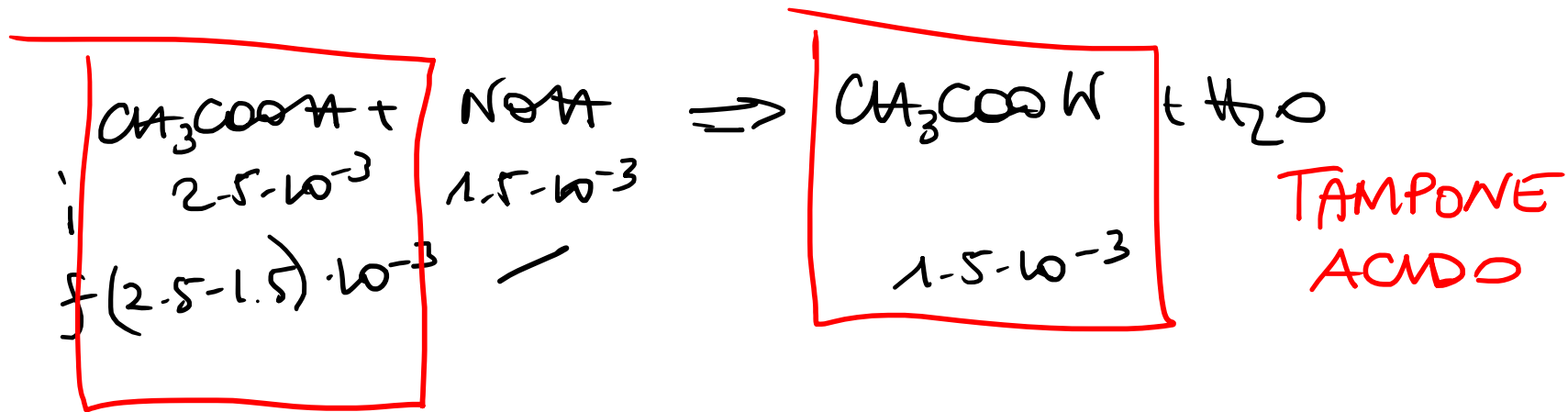
$$[\text{H}_3\text{O}^+] = \sqrt{1.8 \cdot 10^{-5} \cdot 0.1}$$

$$= 1.34 \cdot 10^{-3} \text{ M} \quad \boxed{\text{pH} = 2.88}$$

Ⓟ



a)



$$\text{mol CH}_3\text{COOH} = 0.1 \text{ mol/L} \cdot 0.025 \text{ L} = 2.5 \cdot 10^{-3} \text{ mol}$$

$$\text{mol NOH} = 0.1 \text{ mol/L} \cdot 0.015 \text{ L} = 1.5 \cdot 10^{-3} \text{ mol}$$

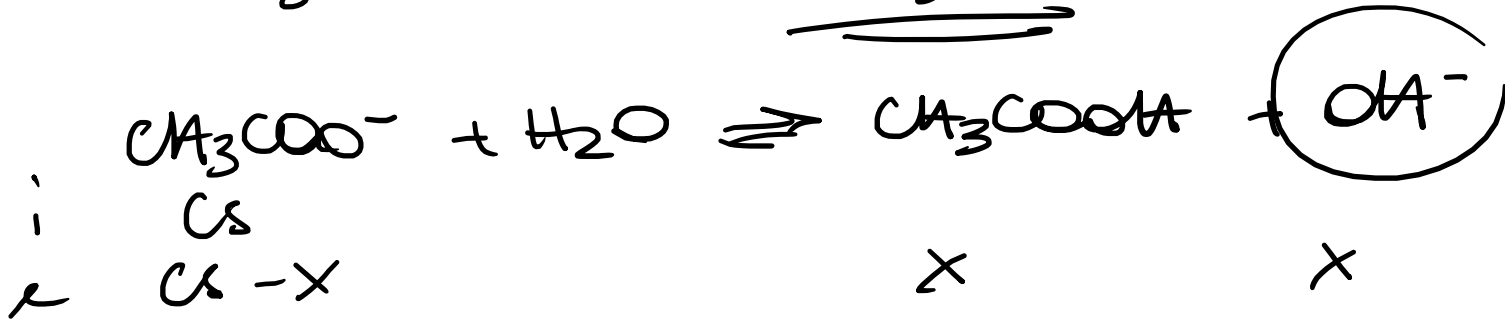
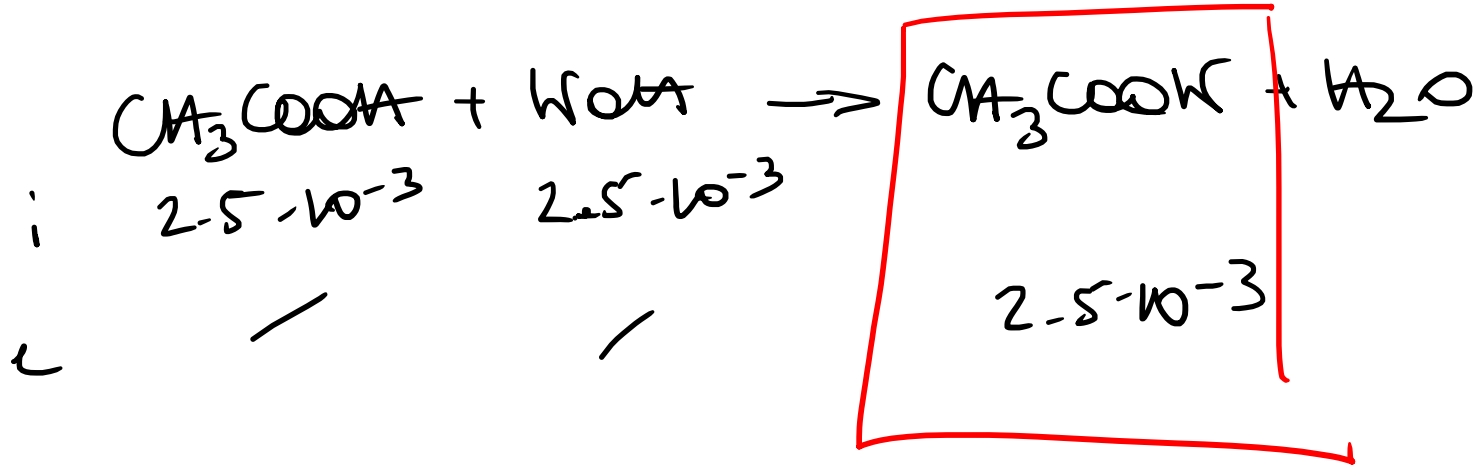
$$[\text{H}_3\text{O}^+] = K_a \cdot \frac{n_a}{m_s} = 1.8 \cdot 10^{-5} \cdot \frac{1 \cdot 10^{-3}}{1.5 \cdot 10^{-3}}$$

$$[\text{H}_3\text{O}^+] = 1.67 \cdot 10^{-5} \text{ M}$$

$$\boxed{\text{pH} = 4.93}$$

Ⓟ

b)

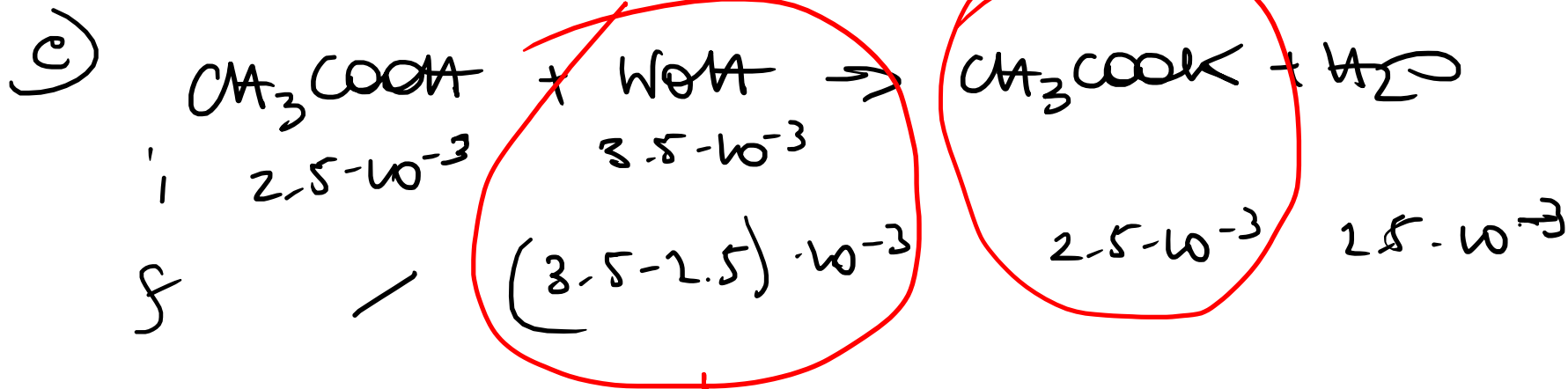


$$N_i = \frac{N_x}{N_a} = \frac{x^2}{C_s - x} = \frac{[\text{OH}^-]^2}{C_s}$$

$$\begin{aligned}
 C_s &= \frac{2.5 \cdot 10^{-3} \text{ mol}}{0.05 \text{ L}} \\
 C_s &= 0.05 \text{ M}
 \end{aligned}$$

$$[\text{OH}^-] = \sqrt{\frac{N_x}{N_a} \cdot 0.05} = 5.27 \cdot 10^{-6} \text{ M}$$

$$\begin{aligned}
 \text{pOH} &= 5.28 \\
 \text{pH} &= 8.72
 \end{aligned}$$



mol KOH =  $3.5 \cdot 10^{-3}$

$$[\text{OH}^-] = \frac{1 \cdot 10^{-3} \text{ mol}}{(0.025 + 0.035) \text{ L}} = 1.67 \cdot 10^{-2} \text{ M}$$

pOH = 1.28

pH = 12.22