

① 2.2 g NH_4Cl $K_b = 1.8 \cdot 10^{-5}$
250 mL di NH_3 0.12 M

CALCOLO pH SOL. ORIGINALE

$$[\text{OH}^-] = \sqrt{K_b [\text{NH}_3]_0} = 0.0015 \text{ M}$$

$$\text{pOH} = 2.8 \quad \text{pH} = 14 - \text{pOH} = 11.2$$

CALCOLO pH SOL. TAMPONE

$$\text{pH} = \text{p}K_a + \log \frac{[\text{NH}_3]}{[\text{NH}_4^+]}$$

$$n_{\text{NH}_4\text{Cl}} = \frac{\text{MASSA}}{\text{PM}} = \frac{2.2}{53.40} = 0.041 \text{ mol}$$

$$n_{\text{NH}_4\text{Cl}} = n_{\text{NH}_4^+}$$

$$[\text{NH}_4^+] = \frac{\text{moli}}{\text{VOLUME}} = \frac{0.041}{0.250} = 0.164 \text{ M}$$

$$K_a = K_w / K_b = 5.56 \cdot 10^{-10}$$

$$pH = pK_a + \log \frac{[NH_3]}{[NH_4^+]}$$

$$= 9.25 - 0.14 = \underline{\underline{9.11}}$$

② 0.125 moli di NH_4Cl quindi NH_4^+
e 500 mL di NH_3 0.5 M
si IMMAGINA CHE IL VOLUME
RIMANGA COSTANTE

a)
$$pH = pK_a + \log \frac{[NH_3]}{[NH_4^+]}$$

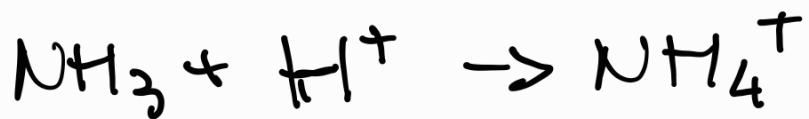
$$[NH_4^+] = \frac{0.125}{0.5} = 0.25 M$$

$$pH = pK_a + \log \frac{0.5}{0.25} = \underline{\underline{9.55}}$$

b) AGGIUNGO 0.01 moli di HCl



POI :



AUMENTA LA $[\text{NH}_4^+]$:

$$\text{moli NH}_4^+ = 0.125 + 0.01 = 0.135 \text{ mol}$$

$\swarrow$ $\downarrow$
 moli INIZIALI moli HCl

$$[\text{NH}_4^+] = \frac{0.135}{0.5} = 0.27 \text{ M}$$

NH_3 DIMINUISCE INVECE:

$$\begin{aligned} \text{moli INIZ. NH}_3 &= [\text{NH}_3] \cdot V \\ &= 0.5 \times 0.5 \\ &= 0.25 \text{ moli} \end{aligned}$$

$$\begin{aligned} \text{moli NH}_3 &= 0.25 - 0.01 \\ &\quad \downarrow \\ &\quad \text{moli di HCl} \\ &= 0.24 \text{ mol} \end{aligned}$$

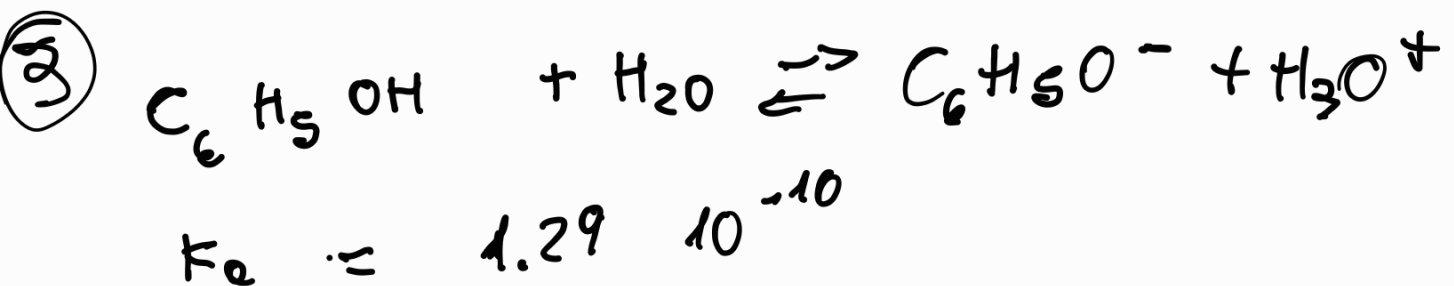
$$[\text{NH}_3] = \frac{\text{moli}}{\text{VOLUME}} = \frac{0.24}{0.5} = 0.48 \text{ M}$$

DA cui :

$$pH = pK_e + \log \frac{[NH_3]}{[NH_4^+]}$$

$$= 9.25 + \log \frac{0.48}{0.27}$$

$$= 9.50$$



$$K_e = 4.29 \cdot 10^{-10}$$

$$a) n_{FEN.} = \frac{MASSA}{PM} = \frac{0.515}{94} = 0.0055 \text{ mol}$$

$$[FEN.]_0 = \frac{n_{FEN.}}{V} = \frac{0.0055}{0.125}$$

$$= 0.0044 \text{ M}$$

QUINDI :

$$[H_3O^+] = \sqrt{K_e \cdot [FEN.]_0} = 2.4 \cdot 10^{-6} \text{ M}$$

$$pH = -\log [H_3O^+] = 5.6$$

b) PUNTO EQUIVALENTE

$$n_{\text{NaOH}} = n_{\text{FEN.}} \quad \text{PER DEFINIZIONE}$$

$$\text{QUINDI } n_{\text{NaOH}} = 0.0055 \text{ mol}$$

$$V_F = V_{\text{INIZIALE}} + V_{\text{NaOH}}$$

$$V_{\text{NaOH}} = \text{VOLUME TITOLANTE}$$

$$= \frac{n_{\text{NaOH}}}{[\text{NaOH}]} = \frac{0.0055}{0.123} = 44.7 \text{ mL}$$

$\searrow 0.123 \text{ M}$

$$V_F = V_{\text{INIZIALE}} + V_{\text{NaOH}}$$

$$= 123 + 44.7 = 169.7 \text{ mL}$$

DETERMINIAMO LE CONCENTRAZIONI:



$$n_{\text{Na}^+} = n_{\text{NaOH}} = 0.0055 \text{ mol}$$

$$[\text{Na}^+] = \frac{0.0055}{V_F} = \frac{0.0055}{169.7 \cdot 10^{-3}} = 0.032 \text{ M}$$



AL PUNTO EQ. L'ACIDO E' STATO CONVERTITO NELLA BASE CONIUGATA NaOH E' STATO CONSUMATO TUTTO QUINDI



$$K_b = K_w / K_a = 7.75 \cdot 10^{-5}$$

$$\begin{aligned} M_{\text{C}_6\text{H}_5\text{O}^-} &= M_{\text{C}_6\text{H}_5\text{OH}} \text{ INIZIALI} \\ &= M_{\text{Na}^+} = 0.0055 \text{ mol/l} \end{aligned}$$

$$\begin{aligned} [\text{C}_6\text{H}_5\text{O}^-] &= \frac{0.0055}{V_F} \\ &= \frac{0.0055}{0.123} = 0.032 \text{ M} \end{aligned}$$

$$[\text{OH}^-] = \sqrt{K_b [\text{C}_6\text{H}_5\text{O}^-]_0} = 0.0016 \text{ M}$$

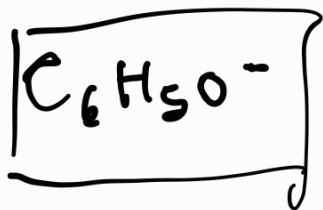


QUI BASTA RICORDARE

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

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

$$= 6.25 \cdot 10^{-12} \text{ M}$$



AVENDO USATO LA
FORMULA APPROSSIMATA

$$[C_6H_5O^-] \approx [C_6H_5O^-]_0$$

$$= 0.032 \text{ M}$$

VOLENDO

$$[C_6H_5O^-] = [C_6H_5O^-]_0 - [OH^-]$$

$$\approx 0.032 - 0.0016$$

$$\approx 0.0304 \text{ M}$$

c)

pH AL PUNTO EQUIVALENTE
VEDI $[H_3O^+]$ CALCOLATA
SOPRA E QUINDI

$$pH = -\log(6.25 \cdot 10^{-12})$$

$$\underline{\underline{= 11.2}}$$

④ 25 mL di NH_3
36.78 mL di HCl 0.0105 M

a) QUANTI MOLI DI HCl HO AGGIUNTO?

$n_{\text{HCl}} = n_{\text{NH}_3}$ AL PUNTO EQ.
PER DEFINIZIONE

$$\begin{aligned} n_{\text{HCl}} &= V_{\text{HCl}} \cdot [\text{HCl}] \\ &= 36.78 \cdot 10^{-3} \cdot 0.0105 \\ &= 0.000386 \text{ moli} \end{aligned}$$

$$n_{\text{NH}_3} = n_{\text{HCl}} = 0.000386 \text{ moli}$$

$$\begin{aligned} [\text{NH}_3]_{\text{INIZIALE}} &= \frac{n_{\text{NH}_3}}{V_{\text{INIZIALE}}} \\ &= \frac{0.000386}{25 \cdot 10^{-3}} \end{aligned}$$

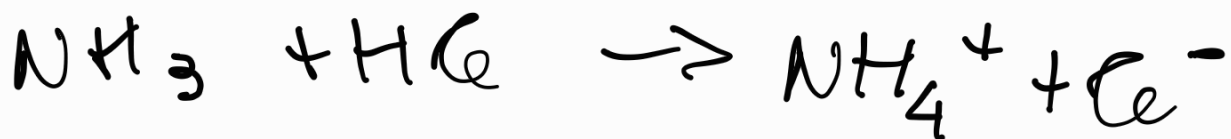
$$\approx \underline{\underline{0.0154 \text{ M}}}$$

b) AL PUNTO EQ. IL VOLUME
SARA' $V_{\text{INIZIALE}} + V_{\text{HCl}}$

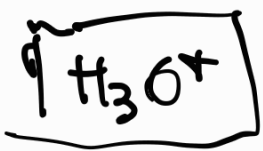
$$V_F = V_{\text{INIZIALE}} + V_{\text{HCl}}$$

$$= 25.0 + 36.78 = 61.78 \text{ mL}$$

AL PUNTO EQ. NH_3 TUTTO
CONVERTITO IN NH_4^+



pH ACIDO PERCHE' IDROLISI DI
 NH_4Cl



PRIMA DEVO CONOSCERE $[\text{NH}_4^+]$

$$M_{\text{NH}_4^+} = M_{\text{NH}_3} = 0.000386 \text{ mol/L}$$

$$[\text{NH}_4^+] = \frac{n_{\text{NH}_4^+}}{V_P} = \frac{0.000386}{61.78 \cdot 10^{-3}}$$

$$= 0.00625 \text{ M}$$

$$[\text{H}_3\text{O}^+] = \sqrt{K_a [\text{NH}_4^+]_0} = 1.86 \cdot 10^{-6} \text{ M}$$



EQUILIBRIO AUTO. H_2O

$$[\text{OH}^-] = K_w / [\text{H}_3\text{O}^+] = 5.38 \cdot 10^{-9} \text{ M}$$



LA CONSIDERO INVARIATA
VEDI SOPRA

$$[\text{NH}_4^+] = 0.00625 \text{ M}$$

e) AL PUNTO EQ.

$$\text{pH} = -\log ([\text{H}_3\text{O}^+])$$

$$= \underline{\underline{5.7}} \quad \text{DIPENDE DA } \text{NH}_4^+$$

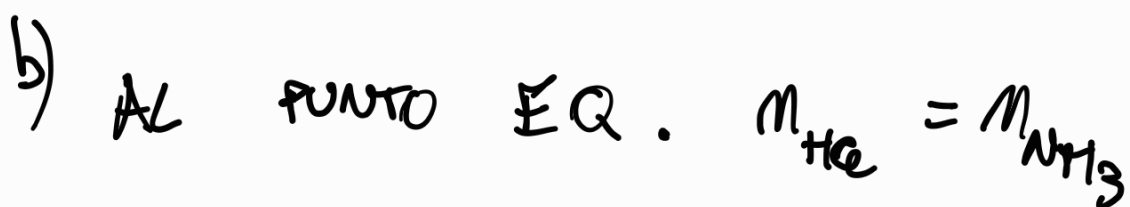
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$$K_b = 1.8 \cdot 10^{-5} \quad [\text{NH}_3]_0 = 0.10 \text{ M}$$

$$[\text{OH}^-] = \sqrt{K_b [\text{NH}_3]_0}$$
$$= 0.00134 \text{ M}$$

$$\text{pOH} = 2.87 \quad \text{pH} = 14 - \text{pOH} = \underline{\underline{11.13}}$$



$$K_a = K_w / K_b = 5.6 \cdot 10^{-10}$$



$$n_{\text{NH}_4^+} = n_{\text{NH}_3} = [\text{NH}_3] \cdot V_1 = 0.10 \cdot 25 \cdot 10^{-3}$$
$$= 0.0025 \text{ moli}$$

$$V_F = V_{\text{AL PUNTO EQ.}} = V_1 + V_{\text{HCl}}$$

VISTO CHE $[NH_3] = [HCl]$ OVVERO
CHE PER AVERE LE STESSA MOL, DEVO
AVER AGGIUNTO UN $V_{HCl} = V_1$
QUINDI ,

$$V_F = V_1 + V_{HCl} = 25 + 25 = 50 \text{ mL}$$

$$[NH_4^+] = \frac{n_{NH_4^+}}{V_F} = \frac{0.0025}{50 \cdot 10^{-3}} \\ = 0.05 \text{ M}$$

$$[H_3O^+] = \sqrt{K_a [NH_4^+]} = 5.3 \cdot 10^{-6} \text{ M}$$

$$\text{pH} = \underline{\underline{5.3}}$$

c) A META' TITOLAZIONE

$$n_{HCl} = n_{NH_3} / 2$$



QUINDI META' MOL DI $NH_3 \rightarrow NH_4^+$

$$\text{DA CUI } n_{NH_3} = n_{NH_4^+}$$

QUINDI :

$$\begin{aligned} \text{pH} &= \text{p}K_e + \log \frac{[\text{NH}_3]}{[\text{NH}_4^+]} \\ &= \text{p}K_e + \log \frac{n_{\text{NH}_3} / V_F}{n_{\text{NH}_4^+} / V_F} \\ &= \text{p}K_e + \log(1) = \text{p}K_e \\ &= 9.25 \end{aligned}$$

d) PUNTO EQ. $\text{pH} = 5.3$

ROSSO METILE

VERDE BROMO CRESOLO

e) CONSIDERIAMO SOLO DUE PUNTI

$$V_{\text{HCl}} = 15 \text{ mL}$$

$$\begin{aligned} \text{moli NH}_3 \text{ di PARTENZA} &= V_1 \cdot [\text{NH}_3] \\ &= 25 \cdot 10^{-3} \cdot 0.1 \\ &= 2.5 \cdot 10^{-3} \text{ moli} \end{aligned}$$

$$\text{moli HCl AGGIUNTE} = V_{\text{HCl}} \cdot [\text{HCl}]$$

$$= 15 \cdot 10^{-3} \cdot 0.1$$

$$= 1.5 \cdot 10^{-3} \text{ mol/l}$$



$$n_{\text{NH}_3} = 2.5 \cdot 10^{-3} - 1.5 \cdot 10^{-3}$$

$$= 1.0 \cdot 10^{-3} \text{ mol/l}$$

$$n_{\text{NH}_4^+} = n_{\text{HCl}} = 1.5 \cdot 10^{-3} \text{ mol/l}$$

$$\text{pH} = \text{pK}_a + \log \frac{n_{\text{NH}_3} / V_E}{n_{\text{NH}_4^+} / V_F}$$

$$= \text{pK}_a + \log \frac{n_{\text{NH}_3}}{n_{\text{NH}_4^+}}$$

$$= 9.25 + \log \frac{1 \cdot 10^{-3}}{1.5 \cdot 10^{-3}} =$$

$$= 9.25 - 0.17 = \underline{9.08}$$

$$V_{\text{HCl}} = 30 \text{ mL} \quad V_{\text{HCl}} > V_1 \text{ visto che}$$

$$\text{ho } [\text{HCl}] = [\text{NH}_3] \text{ ovvio che}$$

$$n_{\text{HCl}} > n_{\text{NH}_3} \text{ sono dopo il punto}$$

EQ.

$$n_{\text{NH}_3} = [\text{NH}_3] \cdot V_1 = 0.10 \cdot 25 \cdot 10^{-3} \\ = 2.5 \cdot 10^{-3} \text{ mol}$$

$$n_{\text{HCl}} = [\text{HCl}] \cdot V_{\text{HCl}} = 0.10 \cdot 30 \cdot 10^{-3} \\ = 3.0 \cdot 10^{-3} \text{ mol}$$



CONVERTITA TUTTA NH_3 E RIMANE HCl
IN ECCESSO

$$n_{\text{HCl RIMASTE}} = n_{\text{HCl}} - n_{\text{NH}_3} \\ = 3.0 \cdot 10^{-3} - 2.5 \cdot 10^{-3} \\ = 0.5 \cdot 10^{-3} \text{ mol}$$

$$V_F = V_1 + V_{\text{HCl}} = 25 + 30 = 55 \text{ mL}$$

$$[\text{HCl}] = \frac{n_{\text{HCl}}}{V_F} = \frac{5 \cdot 10^{-4}}{55 \cdot 10^{-3}} = 0.0091 \text{ M}$$

$$[\text{H}_3\text{O}^+] = [\text{HCl}] = 0.0091 \text{ M}$$

$$\text{pH} = \underline{\underline{2.04}}$$