

ARJUNA

JEE AIR 2024

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Physical Chemistry

Ionic Equilibrium




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Lecture No. – 08

**By– Dr. Gopal Chaturvedi Sir
(GC Sir)**

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Topics to be Covered

Topic

Titration

Topic

Indicator Theory

TopicSolubility (S) **ATDB.uno****Topic**Solubility product (K_{sp})

Recap of Previous Lecture



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Topic

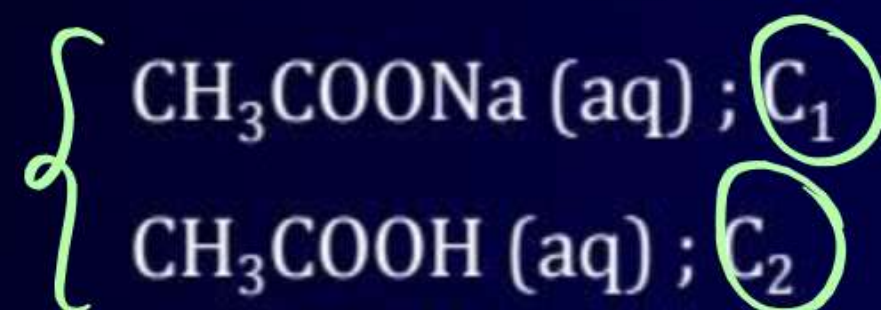
Buffer Action

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#

Dilution of Buffer solution :-

Addition of $H_2O(l)$



Before dilution ;

$$K_a = \frac{(C_1 + x)x}{(C_2 - x)} ; x = [H^+]$$

After dilution ; $C_1 \& C_2$

$$K_a = \frac{(C'_1 + x')x'}{(C'_2 - x')} ; x' = [H^+]_{new}$$

After dilution.



(i). Addition of $H_2O(l)$ in small amount ; no appreciable change in pH

(ii). Addition of $H_2O(l)$ in large amount ; pH of buffer solution $\rightarrow 7$ at $25^\circ C$



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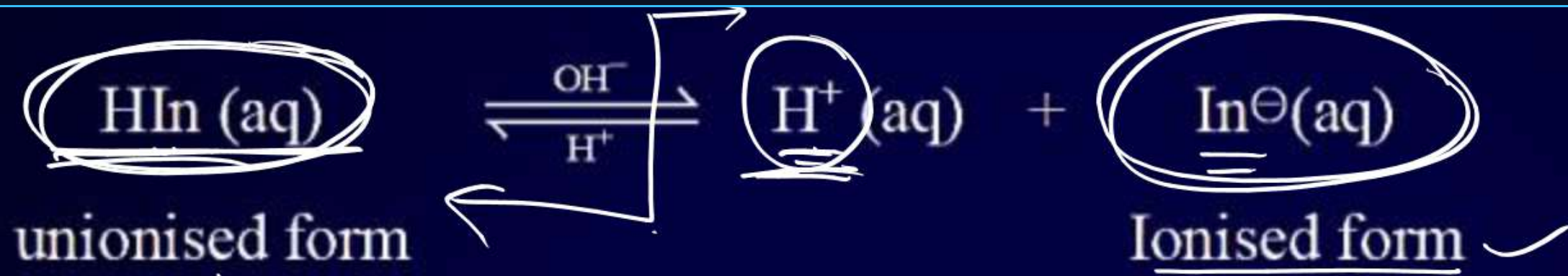
In general indicators are either weak organic acids or weak organic bases having different coloured characteristics in ionised and unionised form.

General acidic indicator ; HIn

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or

✓ Acidic form
(colour I) ✓

or

✓ Ionic form ✓
(Colour II) ✓

$$K_{\text{HIn}} \text{ or } K_{\text{In}} = \frac{[\text{H}^+]_{\text{sol}} [\text{In}^-]}{[\text{HIn}]}$$

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$$[\text{H}^+]_{\text{sol}} = K_{\text{In}} \left\{ \frac{[\text{HIn}]}{[\text{In}^-]} \right\}$$



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$$\boxed{\text{pH} = \text{pK}_{\text{In}} + \log \frac{[\text{In}^-]}{[\text{HIn}]}} \quad \checkmark$$

$$\% \text{ ionised form of indicator} = \frac{[\text{In}^-]}{[\text{HIn}] + [\text{In}^-]} \times 100 = \frac{[\text{In}^-] / [\text{HIn}]}{1 + \frac{[\text{In}^-]}{[\text{HIn}]}} \times 100$$

$$\% \text{ unionised form of indicator} = \frac{[\text{HIn}]}{[\text{HIn}] + [\text{In}^-]} \times 100$$

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Titration



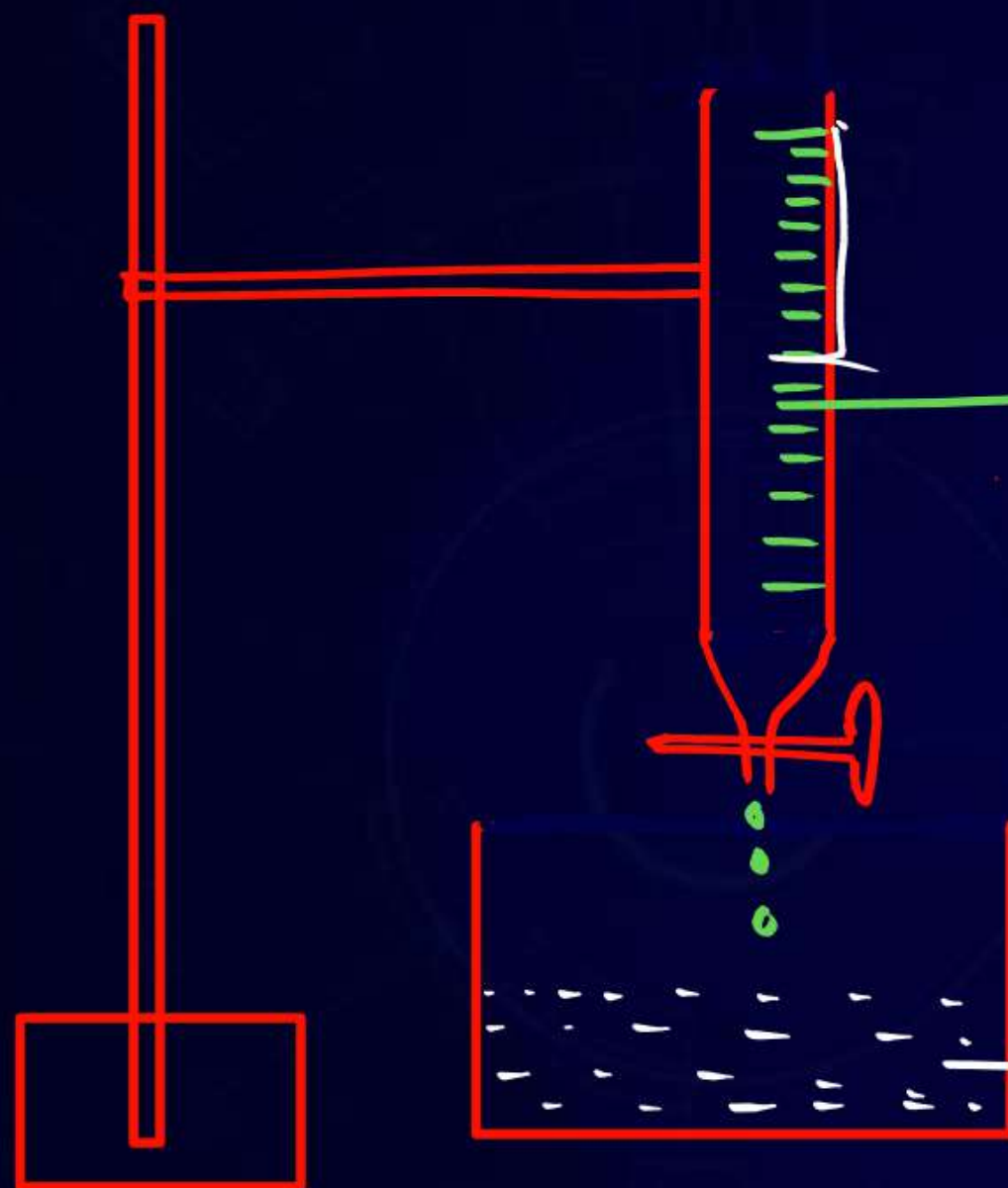
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This is an experimental technique by which we can determine amount of unknown concⁿ solution with the help of reaction between different nature of substance.

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Standard Solution (Titrant)
[known concⁿ Solution]

M_2 e.g. Acid $HCl(aq)$

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Analyte [Unknown Concⁿ Solution]

V_1 ml (Given)

M_1 (Unknown)

e.g. $NaOH(aq)$



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Given.



M_2

V_1 ml

V_2 ml

M_1

(Used)

(Unknown)

When $M_1 V_1 = M_2 V_2$ Equivalent point or neutralisation point.

NaCl(aq) Sol^n .

$$M_1 = \frac{M_2 V_2}{V_1}$$



NaOH base

M_2, V_2



M_1, V_1

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At equivalent point in acid-base neutralisation
No. of equivalent of Acid = No. of equivalent of base

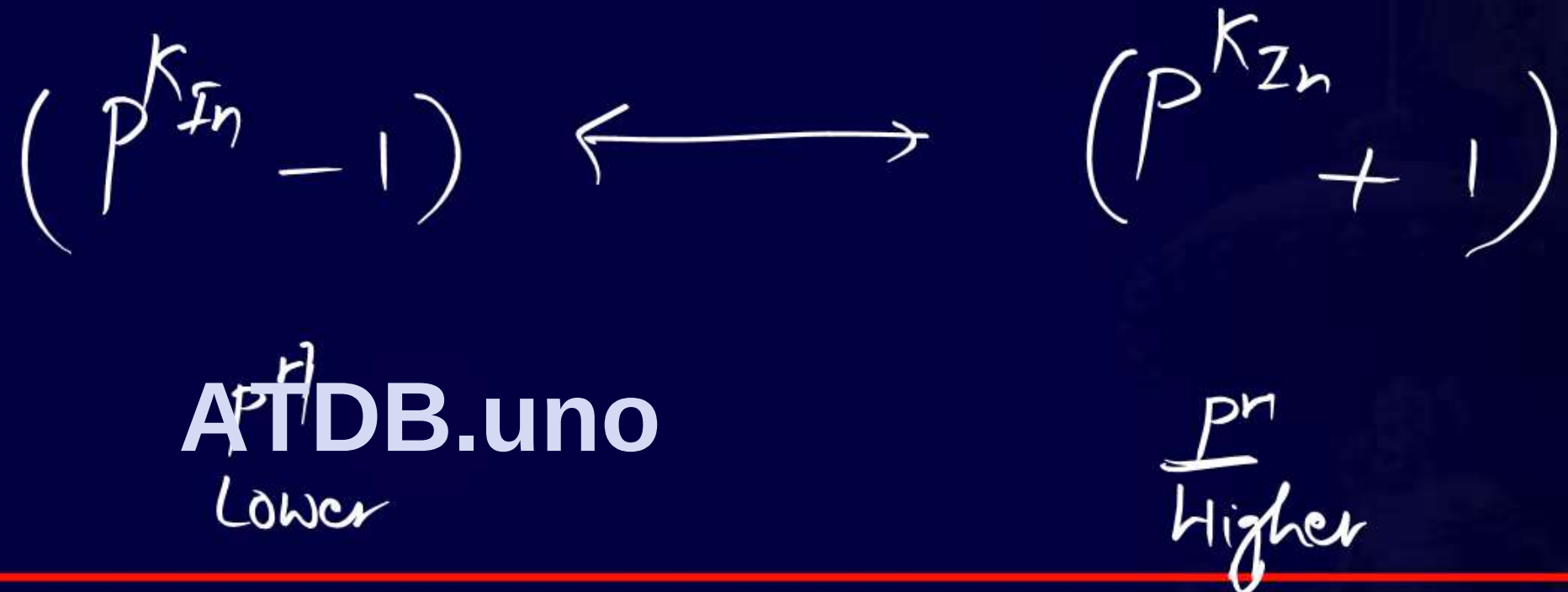
$$1 \times \boxed{M_1 V_1} = \boxed{M_2 V_2} \times 1$$

Indicator change its colour in certain pH range, this pH range is called colour transition range.



$$\frac{[\text{In}^-]}{[\text{HIn}]} \simeq \frac{1}{10} \text{ to } \frac{10}{1}$$

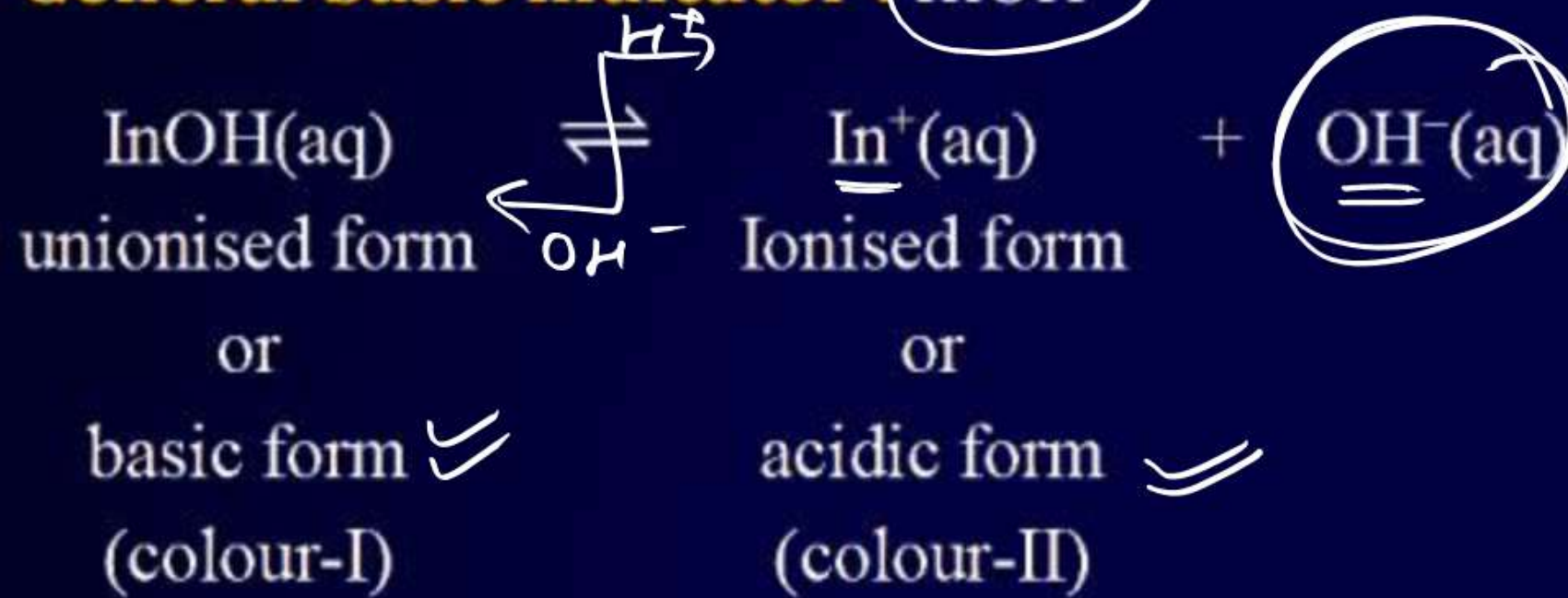
$$\boxed{\text{pH} = \text{pKIn} \pm 1}$$





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General basic indicator : InOH

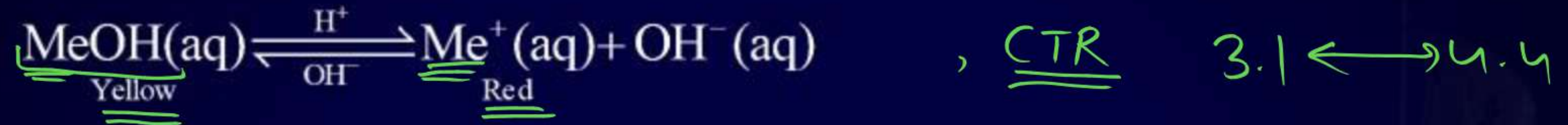


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Methyl Orange : Basic Indicator



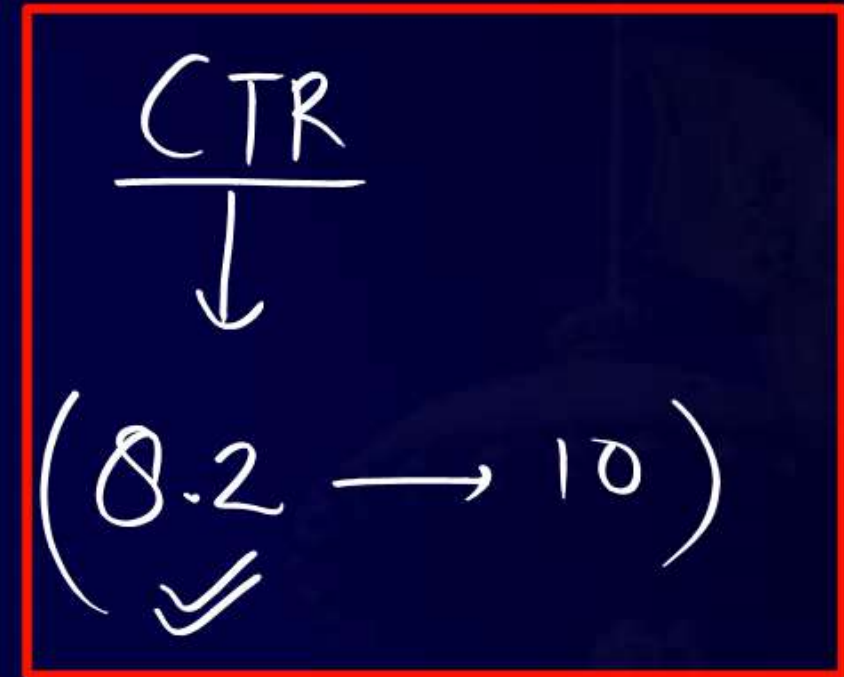
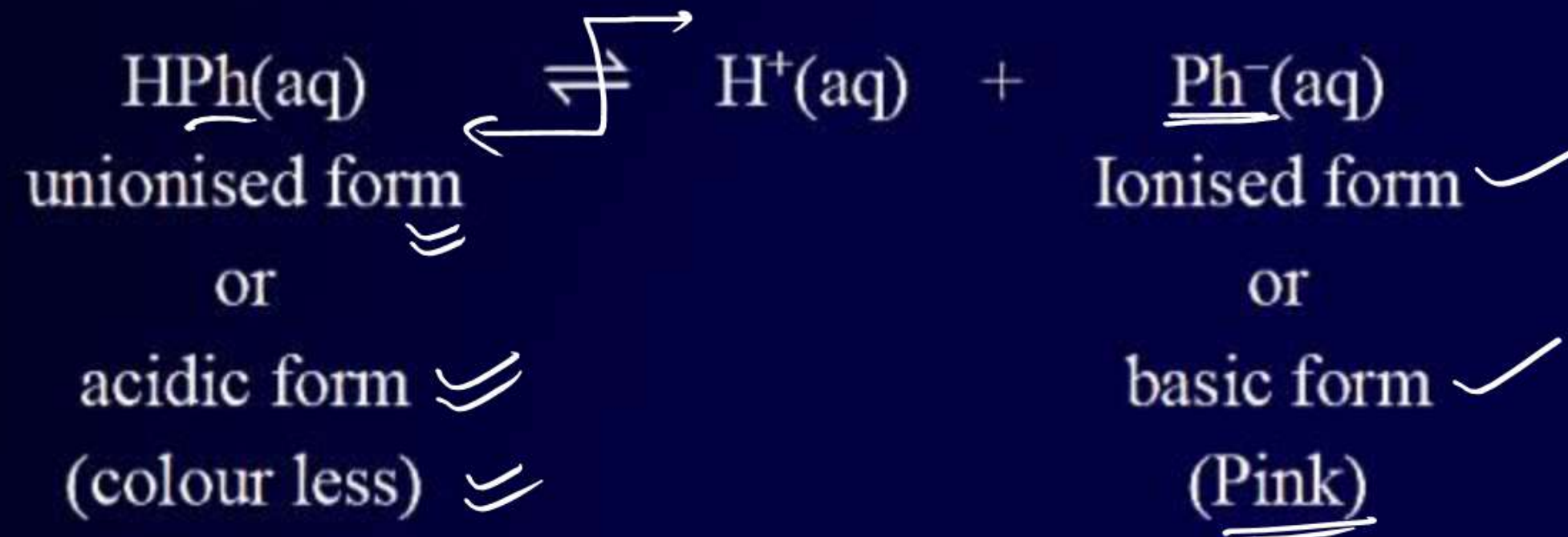
- ⇒ If pH of solution ≥ 4.4 ; then solution has yellow colour.
- ⇒ ✓ If pH of solution ≤ 3.1 ; then solution has (red) colour
- ⇒ In between 3.1 to 4.4 ; indicator change its colour.

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Phenolphthalein :- Acidic indicator



⇒ If pH of solution ≥ 10 ; then solution has pink colour.

⇒ If pH of solution ≤ 8.2 ; then solution is colourless.

⇒ In between 8.2 to 10 ; indicator change its colour.

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Q.

Titration of SA with SB



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Q. If $HCl(aq)$ is titrated against $0.1M NaOH(aq)$ solution.
(50ml)

Used Volume of $NaOH$ (1) 0 ml

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(2) 49 ml

(3) 50 ml

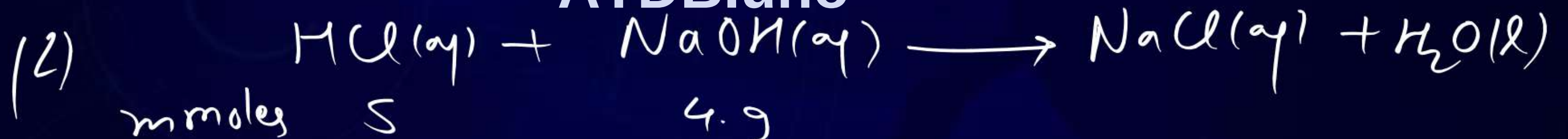
Calculate the P^H of sol^n . (4) 51 ml

(1) Resulting solⁿ.

HCl(aq)
 50ml
 0.1M

$$P^H = -\log 10^{-1} = 1$$

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Resulting Solution HCl(aq) & NaCl(aq)

$$\text{HCl(aq)} = \frac{(5 - 4.9)}{99} = \frac{0.1}{99};$$

$$P^H = -\log\left(\frac{0.1}{99}\right) \approx 3$$



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mmoles (5) (5)



$\longrightarrow \text{p}^{\text{H}} = \frac{1}{2} \text{p}^{\text{Kw}} = 7$
at 25°C

Neutralisation point.



mmole 5 5.1 — —

After reaction mmole — (5.1 - 5) = 0.1 5 5



$[\text{NaOH(aq)}] = \frac{0.1}{101} \approx 10^{-3}$
 $\text{p}^{\text{OH}} \approx 3, \text{p}^{\text{H}} = 11$ at 25°C



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Titration of WA against SB

If $\text{CH}_3\text{COOH(aq)}$ is titrated against 0.1M NaOH(aq) solution.
(50ml)
(0.1M)

Used volume of 0.1M NaOH(aq) are

$$K_a = 1.8 \times 10^{-5}$$

(CH_3COOH)

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(1) 0 ml

(2) 25 ml

(3) 49 ml

(4) 50 ml

(5) 51 ml

Calculate p^{H} of resulting solution



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Sol.
1.

Resulting Solution

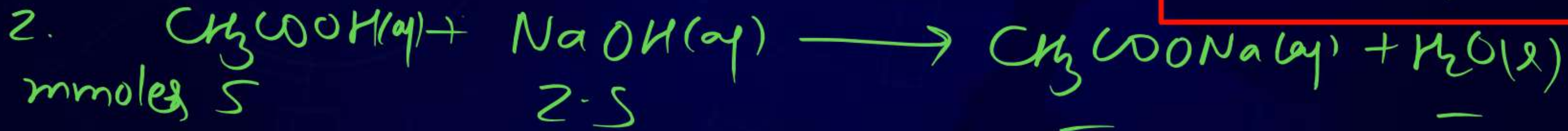
$\text{CH}_3\text{COOH(aq)}$ Solⁿ
50 ml
0.1 M

W. Acid Solⁿ

$$[\text{H}^+] = \sqrt{K_a \times C}$$

$$\begin{aligned} \text{pH} &= \frac{1}{2}(\text{p}K_a - \log C) \\ &= \frac{1}{2}(4.74 + 1) = 2.87 \end{aligned}$$

$$\begin{aligned} \text{p}K_a &= -\log(1.8 \times 10^{-5}) \\ &= 4.74 \end{aligned}$$



After
reacⁿ mmoles 2.5

Acid $\left(\text{CH}_3\text{COOH(aq)}, \text{CH}_3\text{COONa(aq)} \right)$ 2.5

Max. Buffer Capacity
 $\text{pH} = \text{p}K_a$
 $\text{pH} = 4.74$
 $\text{S} = \text{a}$



mmoles 5 4.9

m moles 0.1 — 4.9 4.9

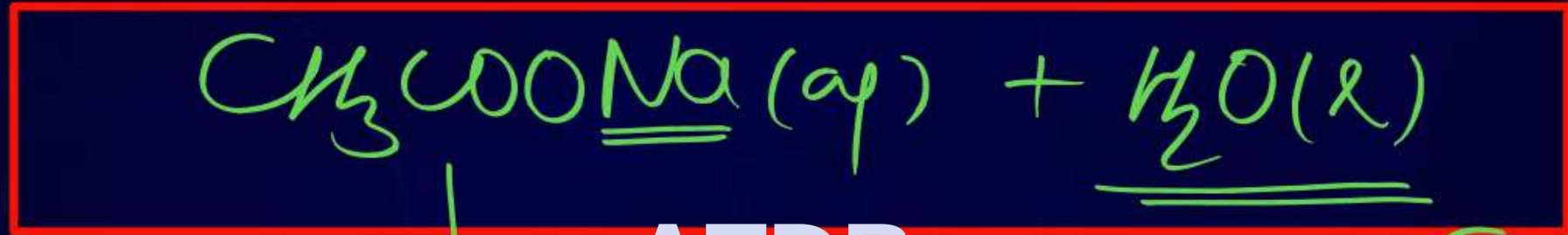
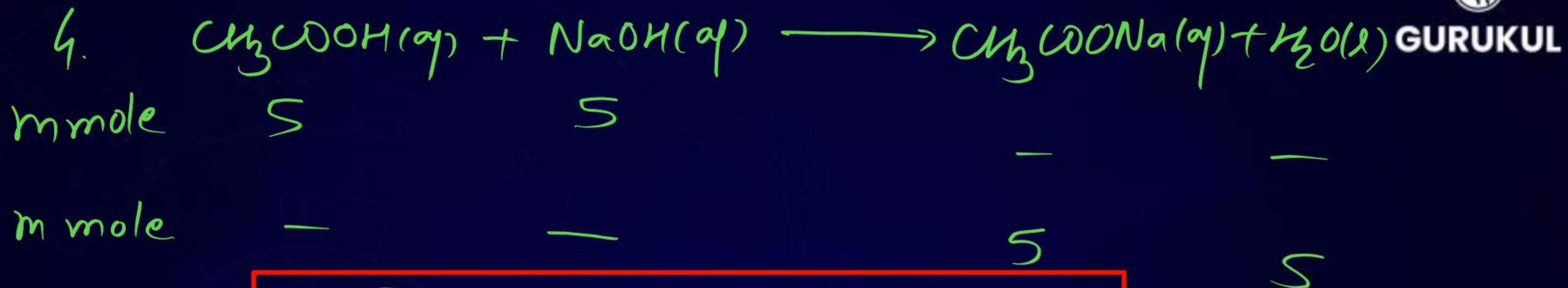
Resulting solution $\text{CH}_3\text{COOH(aq)}, \text{CH}_3\text{COONa(aq)}$

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$$\begin{aligned} \text{pH} &= 4.74 + \log\left(\frac{4.9}{0.1}\right) = 4.74 + 2 \underbrace{\log 7}_{\downarrow 0.8451} \\ &= 6.43 \end{aligned}$$



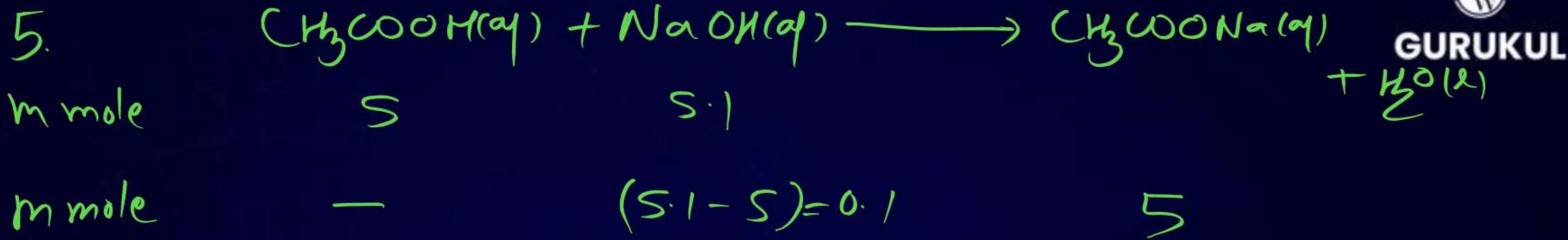
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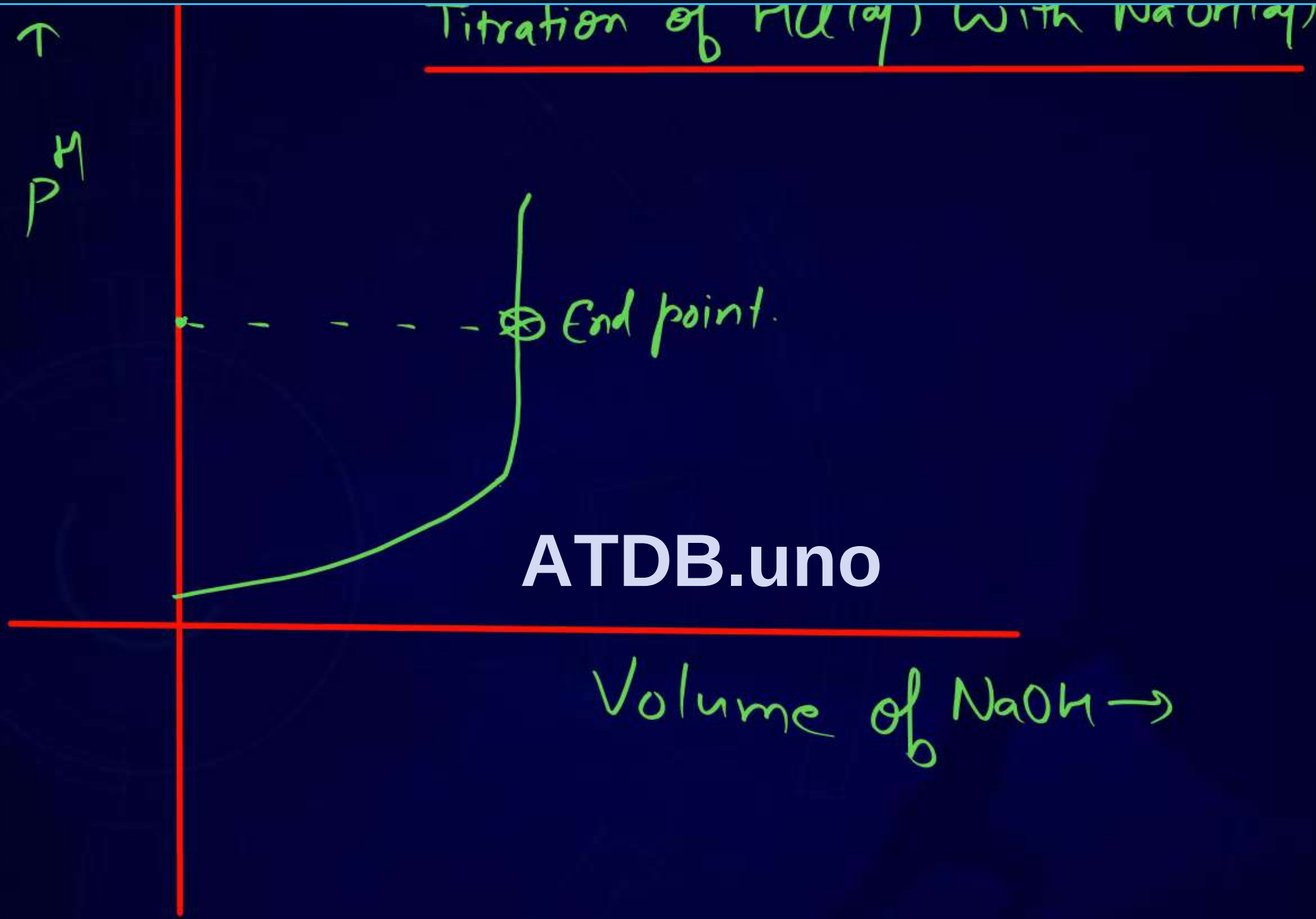


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$$[\text{CH}_3\text{COONa(aq)}] = \frac{5}{100} = 0.05$$

$$p^H = p^{Kw} - p^{OH}, \quad p^H = \frac{1}{2} p^{Kw} + \frac{1}{2} (p^{Ka} + \log c) = 7 + \frac{1}{2} [4.74 + \log(0.05)] \approx 8.71$$





Question



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- #Q. (a) Determine the pH of a 0.2 M solution of pyridine C_5H_5N . $K_b = 1.5 \times 10^{-9}$
- (b) Predict the effect of addition of pyridinium ion $C_5H_5NH^+$ on the position of the equilibrium. Will the pH be raised or lowered?
- (c) Calculate the pH of 1.0 L of 0.10 M pyridine solution to which 0.3 mol of pyridinium chlorides $C_5H_5NH^+ Cl$, has been added, assuming no change in volume.

HW

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Ans. (a) pH = 9.239 (b) lowered (c) pH = 4.699



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Question



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#Q. Calculate the pH of a solution which result from the mixing of 50.0 ml of 0.3 M HCl with 50.0 ml of 0.4 M NH_3 . [$K_b (\text{NH}_3) = 1.8 \times 10^{-5}$]

HW

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Ans. 8.7782



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Question



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#Q. Calculate the pH of a solution made mixing 50.0 ml of 0.2 M NH_4Cl & 75.0 ml of 0.1 M NaOH . [$K_b(\text{NH}_3) = 1.8 \times 10^{-5}$]

HW

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Ans. 9.7324



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Question



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#Q. A buffer solution was prepared by dissolving 0.02 mol propionic acid & 0.015 mol sodium propionate enough water to make 1.00 L of solution (K_a for propionic acid is 1.34×10^{-5})

- (a) What is the pH of the buffer?
- (b) What would be the pH if 1.0×10^{-5} mol HCl were added per 10 ml of the buffer?
- (c) What would be the pH if 1.0×10^{-5} mol NaOH were added per 10 ml of the buffer.

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HW

Ans. (a) 4.7525 (b) 4.697, (c) 4.798



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Question



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#Q. A solution was made up to be 0.01 M in chloroacetic acid, ClCH_2COOH and also 0.002 M in sodium chloroacetate $\text{ClCH}_2\text{COONa}$. What is $[\text{H}^+]$ in the solution? $K_a = 1.5 \times 10^{-3}$.

HW

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Ans. $[H^+] = 2.5 \times 10^{-3}$



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Question



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#Q. For the indicator thymol blue, pH is 2.0 when half the indicator is in unionized form. Find the % of indicator in unionized form in the solution with $[H^+] = 4 \times 10^{-3} \text{ M}$.

HW

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Ans. $[HI_n] = 28.57 \%$



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Question



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#Q. Bromophenol blue is an indicator with a K_a value of 6×10^{-5} . What % of this indicator is in its basic form at a pH of 5?

HW

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Ans. 85.71%



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Question

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#Q. An acid base indicator has a K_a of 3×10^{-5} . The acid form of the indicator is red & the basic form is blue. By how much must the pH change in order to change the indicator form 75% red to 75% blue?

HW

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Ans. $\Delta\text{pH} = 0.954$



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Question



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#Q. Calculate the hydronium ion concentration and pH at the equivalence point in the reaction of 22.0 mL of 0.10 M acetic acid, CH_3COOH , with 22.0 mL of 0.10 M NaOH .

HW

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Ans. 8.71



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Question



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#Q. Calculate the hydronium ion concentration and the pH at the equivalence point in a titration of 50.0 mL of 0.40 M NH_3 with 0.40 M HCl.

HW

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Ans. 4.98



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Thank
You
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