Preparation of Buffer Solutions by Different laboratory ways

- Objective:

-To learn how to prepare a buffer by different laboratory ways.

- Dissociation of triprotic acid:

- Triprotic acid is acid that contain three hydrogen ions .
- It dissociates in solution in three steps, with three Ka values .
- phosphoric acid is an example of triprotic acid.

- It dissociates in solution as following:

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^- \qquad pK_1 = 2.12$$

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{-2} \qquad pK_2 = 7.21$$

$$HPO_4^{-2} \rightleftharpoons H^+ + PO_4^{-3} \qquad pK_3 = 12.30$$

The buffer can be prepared in any one of several ways:

For example if you was asked to prepare sodium phosphate buffer [e.g. NaH_2PO_4 / Na_2HPO_4]: you can by……..

1. By mixing NaH_2PO_4 (conjugate acid) and Na_2HPO_4 (conjugate base) in the proper proportions.
2. By starting with NaH_3PO_4 and converting it to NaH_2PO_4 plus Na_2HPO_4 by adding the proper amount of NaOH.
3. By starting with NaH_2PO_4 and converting a portion of it to Na_2HPO_4 by adding NaOH.
4. By starting with Na_2HPO_4 and converting a portion of it to NaH_2PO_4 by adding a strong acid such as HCL.
5. By starting with Na_3PO_4 and converting it to Na_2HPO_4 plus NaH_2PO_4 by adding HCL.
6. By mixing Na_3PO_4 and NaH_2PO_4 in the proper proportions.

- Example:

Prepare 0.1 liters of 0.045 M sodium phosphate buffer, pH=7.5, [pKa1= 2.12, pKa2 = 7.21 and pKa3 = 12.30]:

a) From concentrated (15M) H3PO4 and solution of 1.5 M NaOH .

b) From solid NaH2PO4 and solid NaOH

- 1st -- Write the equations of phosphoric acid dissociation and the pKa of corresponding ones:

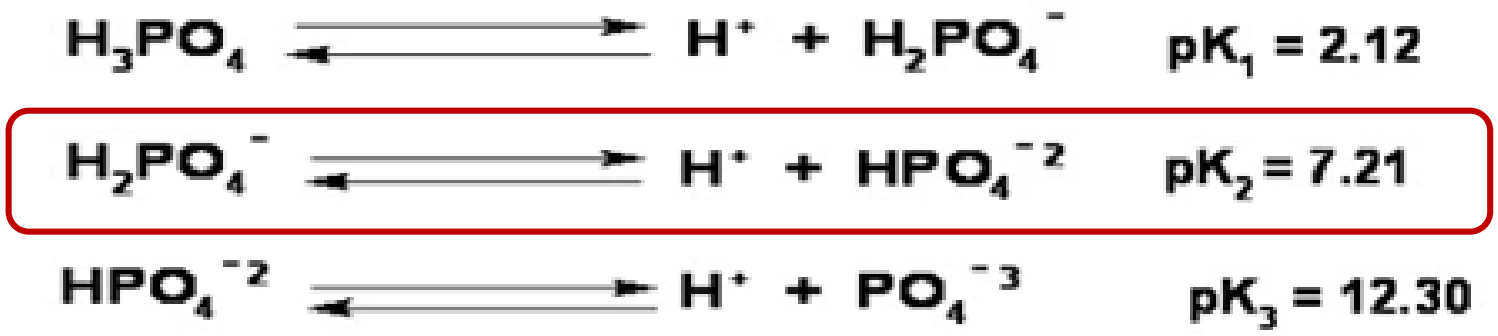
- Because phosphoric acid [H3PO4] is triprotic acid it has 3 dissociation phases so:

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^- \qquad pK_1 = 2.12$$

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{-2} \qquad pK_2 = 7.21$$

$$HPO_4^{-2} \rightleftharpoons H^+ + PO_4^{-3} \qquad pK_3 = 12.30$$

2nd , choose the pka value which is near the pH value of the required buffer, to be able to know the ionic species involved in your buffer:



- The pH of the required buffer [pH =7.5] is near the value of pka_2 , consequently , the two major ionic species present are $H_2Po_4^-$ (conjugate acid) and HPO_4^{-2} (conjugate base), with the **HPO_4^{-2} predominating** { since the pH of the buffer is slightly basic }

- Calculations cont':

3rd -- Calculate No. of moles for the two ionic species in the buffer:

pH =pKa2 + log [HPO42-] / [H2PO4-] ⟶ **Note that: [A-] = HPO42- , [HA] = H2PO4**

- **Since the buffer concentration is 0.045M, so assume [A-] = y , [HA]= 0.045 – y :**

7.5 = 7.2 + log (y / 0.045-y)

7.5-7.2 = log (y / 0.045-y)

0.3= log(y / 0.045-y) → **antilog for both sides:**

2=(y / 0.045-y)

y= 0.09 - 2 y → 3 y = 0.09

y= 0.9/3 = 0.03 M →conc. of [HPO_4^{-2}] = [A^-] = **0.03 M**

Note that :
[A^-] = HPO_4^{-2}
[HA] = $H_2PO_4^-$

So, conc. of [$H_2PO_4^-$] =[HA] = 0.045 – y = 0.045- 0.03 = **0.015 M**

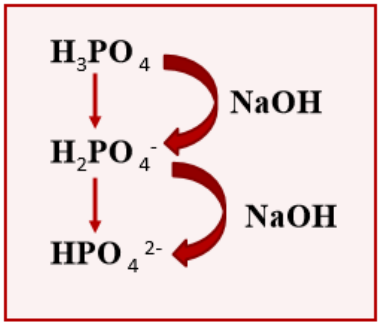
- Now found the number of mole for the two ionic species in the buffer:

- No. of moles of HPO_4^{-2} (A^-) = M x V = 0.03 x 0.1 = 0.003 moles

- No. of moles of $H_2PO_4^-$ (HA)= M x V = 0.015 x 0.1= 0.0015 moles.

- Now, to prepare the required buffer:

a) From concentrated (15M) NaH_3PO_4 and solution of 1.5 M NaOH .



- Calculations:

- Start with 0.0045 mole of H_3PO_4 and add 0.0045 moles of NaOH to convert H_3PO_4 completely to $H_2PO_4^-$ (HA) , then add 0.003 moles of NaOH to convert $H_2PO_4^-$ to give HPO_4^{-2} (A^-):

- **No. of moles needed of NaOH=** 0.0045+0.003= 0.0075 moles

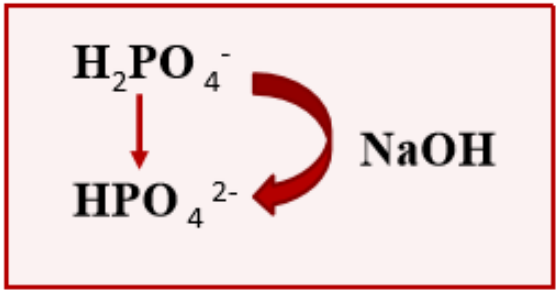
Volume of NaOH needed= no.of moles / M = 0.0075/ 1.5 = 0.005 L =5 ml

Volume of H_3PO_4 needed = no.of moles / M = 0.0045/ 15 =0.0003 L = 0.3 ml

→ Add **5ml** of NaOH to the **0.3 ml** of concentrate H_3PO_4, mix ; then add **sufficient water** to bring the final volume to **0.1 liters (100 ml),** and **check the pH**

Now, to prepare the required buffer:

b) From solid NaH_2PO_4 and solid NaOH.



- Calculations:

- Start with 0.0045 mole of NaH_2PO_4 (HA) and add 0.003 moles of NaOH to convert NaH_2PO_4 to give Na_2HPO_4 (A^-):

- Wt in grams of NaH_2PO_4 needed = no. of moles x mwt =0.0045 x 141.98 = **0.638 g**

- Wt in grams of NaOH needed = no. of moles x mwt = 0.003 x 40 =**0.12 g**

- Dissolve the **NaH_2PO_4** and **NaOH** in some water, mix ; then add sufficient water to bring the final volume to 0.1 liters (100 ml), and **check the pH**

Practical part

- Prepare 0.1 liters of 0.045 M sodium phosphate buffer, pH=7.5, [pKa1= 2.12, pKa2 = 7.21 and pKa3 = 12.30]:

a) From concentrated (15M) H_3PO_4 and solution of 1.5 M NaOH:

- Add **5ml** of **NaOH** to the **0.3 ml** of concentrate **H_3PO_4**, mix ; then add **sufficient water to bring the final volume to 0.1 liters (100 ml),** and **check the pH.**

b) From solid NaH_2PO_4 and solid NaOH:

- Dissolve the **0.638g** of **NaH_2PO_4** and **0.12g** of **NaOH** in some water, mix ; then add **sufficient water to bring the final volume to 0.1 liters (100 ml), and check the pH.**