Preparation of Buffer Solutions by Different Laboratory Ways

Dissociation of triprotic acid:

- **Triprotic acid** is acid that contain three hydrogens 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:

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

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

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

Note: $Ka_1 > Ka_2 > Ka_3$ Always true for polyprotic acids

Preparation of buffer by several ways:

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

1. By mixing NaH_2PO_4 (conjugate acid) and Na_2HPO_4 (conjugate base) in the proper proportions.
2. By starting with H_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.

H_3PO_4

$H_2PO_4^-$

HCl

'donate H^+'

HPO_4^{2-}

NaOH

'accept H^+'

PO_4^{3-}

Example: **Prepare 0.1 liter 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 .

b) From solid NaH_2PO_4 and solid NaOH.

Regardless of which method is used, the first step involves determine the buffer ionic species, calculating number of moles and amounts of the two ionic species in the buffer.

Calculations:

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

Because phosphoric acid [H_3PO_4] is **triprotic acid** it has 3 dissociation phases so:

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

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

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

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:

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

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

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

➔ The pH of the required buffer [pH =7.5] is near the value of pKa2 , 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 [HPO_4^{2-}] / [$H_2PO_4^-$] ➔ Note that: [A^-] = HPO_4^{2-} , [HA] = $H_2PO_4^-$

- 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 = **0.03M** ➔ conc. of [HPO_4^{2-}] = [A-] = y

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

- **Now find 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.

➔ Note that Total no. of moles of phosphate buffer = M x V= 0.045 x 0.1 = 0.0045 moles.

Now, to prepare the required buffer:

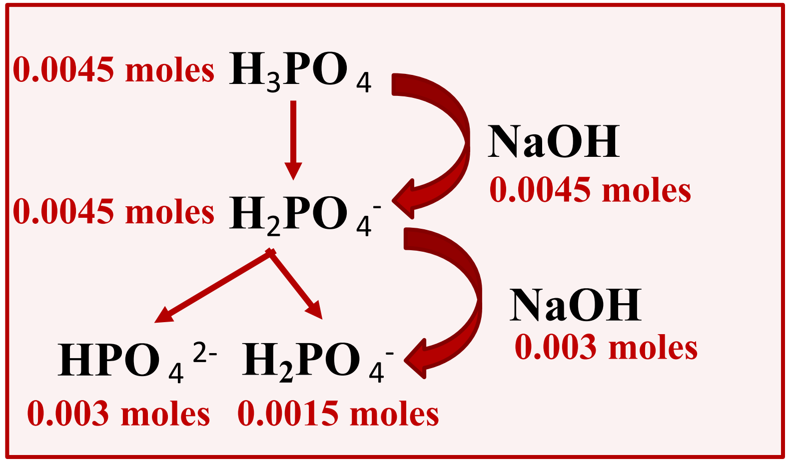
Remember that the two ionic species involved in the buffer are:

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$$

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

Calculations:

Start with 0.0045 mole of H_3PO_4 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

So:

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.

Remember that the two ionic species involved in the buffer are:

$$H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$$

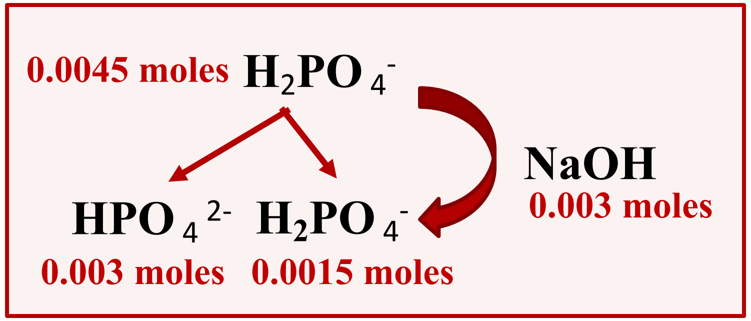
Calculations:

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^-):

➔ Weight in grams of $\mathbf{NaH_2PO_4}$ needed = no.of moles x MW =0.0045 x 119.98 = 0.54 g

➔ Weight in grams of **NaOH** needed = no. of moles x MW = 0.003 x 40 =0.12 g

So: Dissolve the 0.548g of $\mathbf{NaH_2PO_4}$ 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.



Practical Part

Objective:

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

Method:

- **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 **0.584g** 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.

Homework

- **Prepare 0.1 liters of 0.045 M sodium phosphate buffer, pH=7.5,**

[pka1= 2.12, pka2 = 7.21 and pka3 = 12.30]:

You are provided with solid Na_3PO_4 and 2 M HCL.