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:

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

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

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

Preparation of buffer by several ways:

- **For example if you were 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

$H_2PO_4^-$

HPO_4^{2-}

PO_4^{3-}

HCl

'donate H^+'

NaOH

'accept H^+'

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:

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

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

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

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:

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

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

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

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➔ 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:

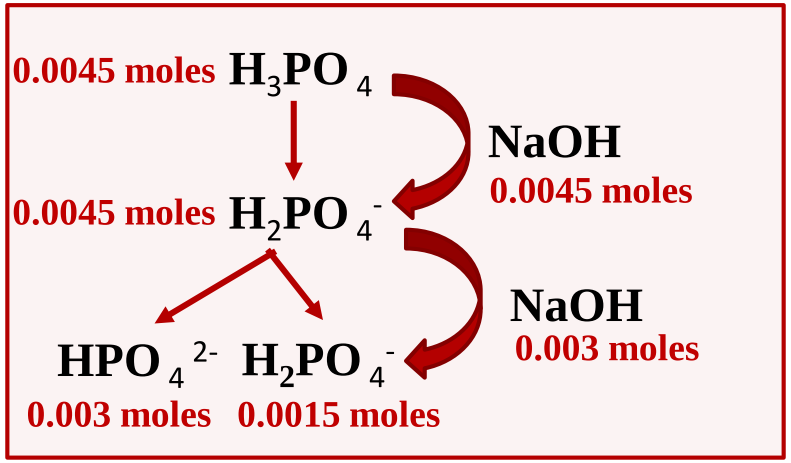
Remember that the two ionic species involved in the buffer are:

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

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:

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

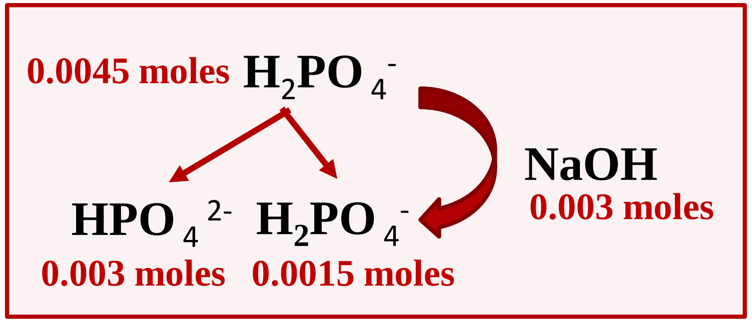
Calculations:

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 **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 **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 **0.638g** 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.