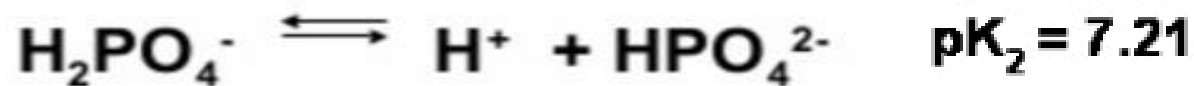


Preparation of Buffer Solutions by Different Laboratory Ways

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:



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.

HCl
'donate H⁺'



NaOH
'accept H⁺'

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]:

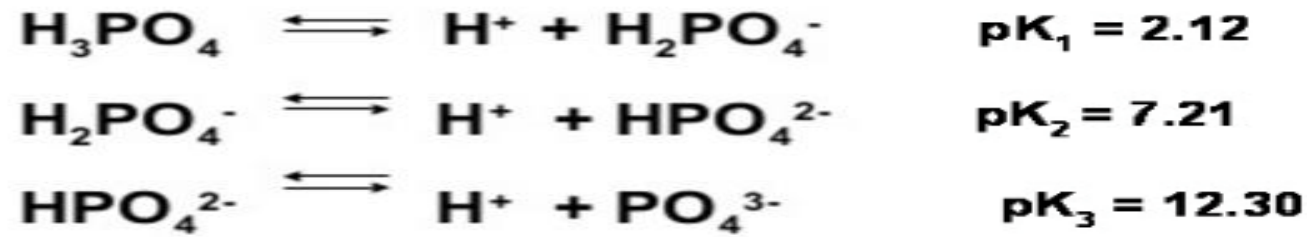
a) From concentrated (15M) H_3PO_4 and solution of 1.5 M NaOH .

b) From solid NaH_2PO_4 and solid NaOH.

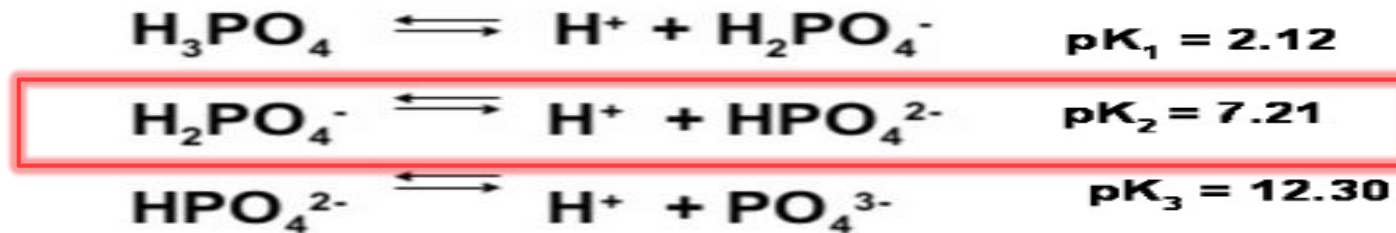
Regardless of which method is used , the first step involves determine the buffer ionic species, calculating number of moles and amounts of the two ionic species in the buffer.

Calculations:

1st → Write the equations of phosphoric acid dissociation and the pKa of corresponding ones:
Because phosphoric acid $[\text{H}_3\text{PO}_4]$ is **triprotic acid** it has 3 dissociation phases so:



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 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:

$$\text{pH} = \text{pKa} + \log \left[\frac{\text{HPO}_4^{2-}}{\text{H}_2\text{PO}_4^-} \right] \quad \rightarrow \text{Note that: } [\text{A}^-] = \text{HPO}_4^{2-}, [\text{HA}] = \text{H}_2\text{PO}_4^-$$

- Since the buffer concentration is **0.045M**, so assume $[\text{A}^-] = y$, $[\text{HA}] = 0.045 - y$:

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

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

$$0.3 = \log (y / 0.045 - y) \rightarrow \text{antilog for both sides}$$

$$\rightarrow 2 = (y / 0.045 - y) \rightarrow y = 0.09 - 2y \rightarrow 3y = 0.09 \rightarrow y = 0.09 / 3 = \underline{\underline{0.03\text{M}}} \rightarrow \text{conc. of } [\text{HPO}_4^{2-}] = [\text{A}^-] = y$$

$$\text{So, conc. of } [\text{H}_2\text{PO}_4^-] = [\text{HA}] = 0.045 - y = 0.045 - 0.03 = \underline{\underline{0.015\text{ M}}}$$

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

$$\text{- No. of moles of } \text{HPO}_4^{2-} (\text{A}^-) = M \times V = 0.03 \times 0.1 = \boxed{0.003 \text{ moles.}}$$

$$\text{- No. of moles of } \text{H}_2\text{PO}_4^- (\text{HA}) = M \times V = 0.015 \times 0.1 = \boxed{0.0015 \text{ moles.}}$$

→ Note that Total no. of moles of phosphate buffer
= $M \times V = 0.045 \times 0.1 = 0.0045$ moles.

Now, to prepare the required buffer:

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

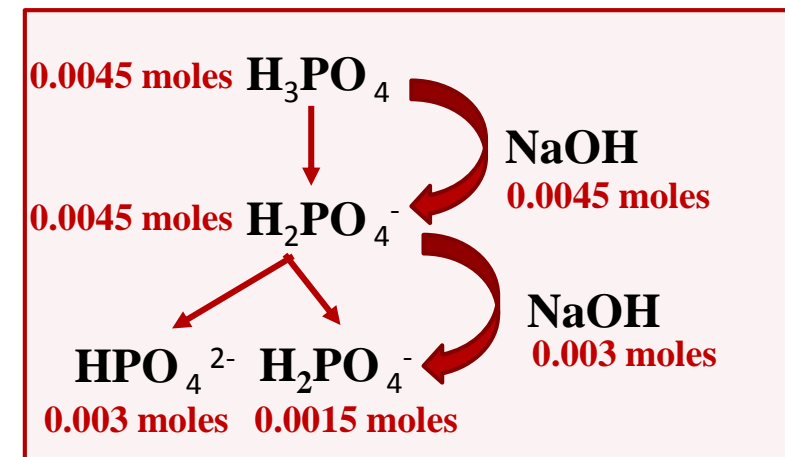
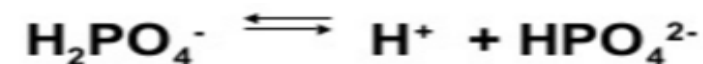
→ Volume of NaOH needed= no.of moles / M = 0.0075/ 1.5 = 0.005 L = 5 ml

→ 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.

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



b) From solid NaH_2PO_4 and solid NaOH .

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



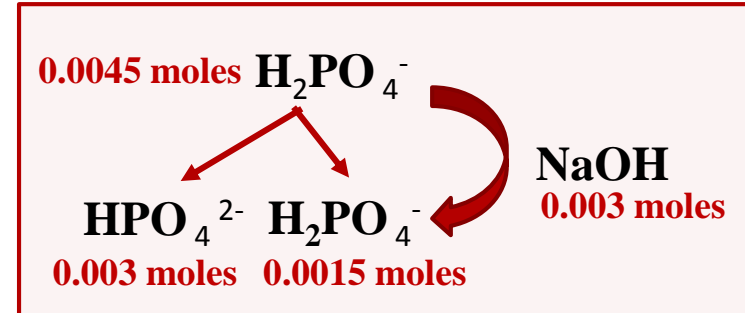
Calculations:

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 = $0.0045 \times 141.98 = \underline{0.638 \text{ g}}$

→ Weight in grams of NaOH needed = no. of moles x MW = $0.003 \times 40 = \underline{0.12 \text{ g}}$

So: 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.



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.

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]:

c) You are provided with solid Na_2HPO_4 and 2M HCl.

d) You are provided with solid Na_3PO_4 and 2 M HCL .