Deacon's Challenge

No 113 - Answer

How many grams of anhydrous sodium dihydrogen phosphate and disodium hydrogen phosphate are required to prepare 1 Litre of buffer of physiological pH (7.4) and osmolality (290 mmol/L)? (pKa_2 of phosphate = 6.82. Atomic weights: Na = 23, P = 31)

The dissociation to consider is:

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

and the corresponding Henderson-Hasselbalch equation is:

$$pH = pKa + \log_{10} \frac{[HPO_4^{2-}]}{[H_2PO_4^-]}$$

where the concentrations are in mmol/L.

Substitute pH = 7.4 and pKa = 6.82 then solve for $[HPO_4^{2-}]/[H_2PO_4^-]$:

$$7.4 = 6.82 + \log_{10} \frac{[HPO_4^{2-}]}{[H_2PO_4^-]}$$

$$\log_{10} \frac{[HPO_4^{2-}]}{[H_2PO_4^-]} = 7.4 - 6.82 = 0.58$$

$$\frac{[HPO_4^{2-}]}{[H_2PO_4^-]} = \text{antilog}_{10}\, 0.58 = 3.80$$

The osmolality is given, not the total phosphate concentration, and is the sum of all ionic species:

$$\text{Osmolality} = [Na^+] + [HPO_4^{2-}] + [H_2PO_4^-]$$

which can also be written:

$$\text{Total osmolality} = \text{Osmolality } NaH_2PO_4 + \text{Osmolality } Na_2HPO_4$$

Since each HPO_4^{2-} ion is associated with two Na^+ ions:

$$\text{Osmolality of } Na_2HPO_4 = 3\,[HPO_4^{2-}]$$

Similarly each $H_2PO_4^-$ ion is associated with one Na^+ ion:

$$\text{Osmolality of } NaH_2PO_4 = 2\,[H_2PO_4^-]$$

Therefore total osmolality $= 3[HPO_4^{2-}] + 2[H_2PO_4^-] = 290$ mmol/L

Rearranging:

$$[H_2PO_4^-] = \frac{290 - 3[HPO_4^{2-}]}{2}$$

$$[H_2PO_4^-] = 145 - 1.5[HPO_4^{2-}]$$

Substitute this expression for $[H_2PO_4^-]$ into $\frac{[HPO_4^{2-}]}{[H_2PO_4^-]} = 3.80$ then solve for $[HPO_4^{2-}]$:

$$\frac{[HPO_4^{2-}]}{145 - 1.5[HPO_4^{2-}]} = 3.80$$

$$[HPO_4^{2-}] = 3.80\,\{145 - 1.5[HPO_4^{2-}]\}$$

$$[HPO_4^{2-}] = 551 - 5.7[HPO_4^{2-}]$$

$$[HPO_4^{2-}] + 5.7[HPO4^{2-}] = 551$$

$$6.7\,[HPO_4^{2-}] = 551$$

$$[HPO_4^{2-}] = \frac{551}{6.7} = 82.2 \text{ mmol/L}$$

Next substitute this value for $[HPO_4^{2-}]$ into:

$$[H_2PO_4^-] = 145 - 1.5[HPO_4^{2-}]$$

then solve for $[H_2PO_4^-]$:

$$[H_2PO_4^-] = 145 - (1.5 \times 82.2)$$

$$= 145 - 123.3$$

$$= 21.7 \text{ mmol/L}$$

To prepare 1 L solution:

$$\text{Wt (g)} = \frac{\text{Concentration (mmol/L)} \times \text{MW}}{1000}$$

For Na_2HPO_4:

$$\text{MW} = (2 \times 23) + 1 + 31 + (4 \times 16) = 142$$

$$\text{Wt} = \frac{82.2 \times 142}{1000} = \mathbf{11.7\ g}$$

For NaH_2PO_4:

$$\text{MW} = 23 + (2 \times 1) + 31 + (4 \times 16) = 120$$

$$\text{Wt} = \frac{21.7 \times 120}{1000} = \mathbf{2.60\ g}$$

Question 114

100 serum samples from healthy individuals were analysed in order to determine a reference range for a new analyte. The data were found to be significantly skewed so a logarithmic transformation was used to derive a 95% confidence interval of 20-100 nmol/L. What is the probability of obtaining a value of 116 nmol/L or greater from a normal subject? Values of the normal deviate (*z*-score) and *P* are:

P(%)	10	5	2	1	0.2	0.1
z	1.65	1.96	2.32	2.58	3.09	3.29