Deacon's Challenge No. 90 Answer

A plasma sample has a total CO_2 content (TCO2) of 28 mmol/L. If the pH is 7.4, estimate the pCO_2 (in kPa). (The pKa for this buffer system is 6.1, the millimolar solubility coefficient of CO_2 (in kPa) is 0.225).

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Plasma total CO_2 includes bicarbonate ions, dissolved CO_2, carbonic acid and various carbamino compounds. Contribution from the latter two is negligible so for practical purposes the components of total CO_2 can be written:

$$[CO_2]\text{Total} = [HCO_3^-] + [CO_2]_{\text{dissolved}}$$

The dissolved carbon dioxide component can be obtained by multiplying the partial pressure for CO_2 (i.e. PCO_2) by its solubility coefficient (α):

$$[CO_2]_{\text{dissolved}} = \alpha PCO_2$$

Therefore $$[CO_2]_{\text{Total}} = [HCO_3^-] + \alpha PCO_2$$

Which can be rearranged to give an expression for bicarbonate concentration:

$$[HCO_3^-] = [CO_2]_{\text{Total}} - \alpha PCO_2$$

The Henderson Hasselbalch equation for the CO_2/bicarbonate pair can be written:

$$pH = pKa + \log_{10} \frac{[HCO_3^-]}{\alpha PCO_2}$$

Substituting $[HCO_3^-] = [CO_2]_{\text{Total}} - \alpha PCO_2$ gives a form of the Henderson Hasselbalch equation containing only pH and PCO_2 as variables:

$$pH = pKa + \log_{10} \frac{[CO2]_{\text{Total}} - \alpha PCO_2}{\alpha PCO_2}$$

Substitute
pH = 7.4, $[CO_2]_{\text{Total}}$ = 28 mmol/L and α = 0.225 and solve for PCO_2:

$$7.4 = 6.1 + \log_{10} \frac{(28 - 0.225\ PCO_2)}{0.225\ PCO_2}$$

$$\frac{\log_{10}(28 - 0.225\ PCO_2)}{0.225\ PCO_2} = 7.4 - 6.1 = 1.3$$

$$\frac{(28 - 0.225\ PCO_2)}{0.225\ PCO_2} = \text{antilog}_{10}\ 1.3 = 20.0 \text{ (3 sig figs)}$$

$$28 - 0.225\ PCO_2 = 20.0 \times 0.225\ PCO_2 = 4.50\ PCO_2$$

$$4.50\ PCO_2 + 0.225\ PCO_2 = 28$$

$$4.725\ PCO_2 = 28$$

$$PCO_2 = \frac{28}{4.725} = \mathbf{5.9\ kPa} \text{ (2 sig figs)}$$

This question was designed to test the candidates awareness that total $[CO_2]$ is not exactly the same as $[HCO_3^-]$. If they are assumed to be the same then the value for PCO_2 comes out at 6.2 kPa.

Question 91

A patient attending a renal clinic for the first time has a serum creatinine concentration of 110 µmol/L and GFR (measured by Cr-EDTA clearance) of 60 mL/min/1.73m^2. It is proposed to monitor his progress by measurement of plasma creatinine at each clinic visit. Given that the analytical CV of the plasma creatinine method at this level is 2.8% and the average intra-individual CV of plasma creatinine is 7.7%, estimate the smallest significant fall in GFR ($p<0.05$) which can be detected by plasma creatinine measurement alone.

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