Deacon's Challenge

No 131 - Answer

A patient is admitted to ITU with a blood hydrogen ion concentration of 105 nmol/L, Pco_2 of 5.9 kPa and an actual bicarbonate of 10.2 mmol/L. After taking steps to improve ventilation and circulation a second set of blood gases were: Pco_2 5.1 kPa and bicarbonate 20 mmol/L. Calculate the new hydrogen ion concentration in nmol/L.

FRCPath, Spring 2011

There are several ways of solving this problem:

Method 1
Insert the new values for Pco_2 and bicarbonate into the Henderson-Haselbalch, solve for pH then convert this to hydrogen ion concentration. This approach requires knowledge of pKa (6.1) and the Bunsen coefficient of CO_2 (0.225).

$$\text{pH} = \text{pKa} + \log_{10} \frac{[HCO_3^-]}{\alpha Pco_2}$$

$$\text{pH} = 6.1 + \log_{10} \frac{20}{0.225 \times 5.1}$$

$$= 6.1 + \log_{10} 17.4$$

$$= 6.1 + 1.24$$

$$= 7.34$$

$\text{pH} = -\log_{10} [H^+]$ which rearranges to $[H^+] = \text{antilog}_{10} (-\text{pH})$

Therefore $[H^+] = \text{antilog}_{10} (-7.34) = 4.6 \times 10^{-8}$ mol/L (to 2 sig figs)

Converting to nmol/L, $[H^+] = 4.6 \times 10^{-8} \times 10^{9}$ = **46 nmol/L**

Method 2
Using the constant of 180 which is the ratio of hydrogen ion concentration (in **nmol/L**), multiplied by the bicarbonate concentration (in **mmol/L**) and divided by the Pco_2 (in **kPa**):

$$180 = \frac{[H^+]\,[HCO_3^-]}{Pco_2}$$

Which can be rearranged and evaluated:

$$[H^+] = \frac{180\ Pco_2}{[HCO_3^-]} = \frac{180 \times 5.1}{20} = \textbf{46 nmol/L} \text{ (to 2 sig figs)}$$

This is the simplest method but requires knowledge of the 180 factor. It is quite possible, simpler (and many would argue preferable) to perform acid-base calculations and interpret acid-base data without resorting to a logarithmic function for hydrogen ion concentration (i.e. pH).

Method 3
It is possible to use the relationship between the hydrogen ion concentration, and bicarbonate concentration without utilizing any numerical constants:

$$K = \frac{[H^+] \times [HCO_3^-]}{Pco_2}$$

where *K* is a constant with components from the equilibrium constants for carbonic acid formation and dissociation, water concentration and the Bunsen solubility coefficient for CO_2.

Therefore the parameters both before and after treatment are related:

$$\frac{\text{Initial } [H^+] \times \text{Initial } [HCO_3^-]}{\text{Initial } Pco_2} = \frac{\text{Final } [H^+] \times \text{Final } [HCO_3^-]}{\text{Final } Pco_2}$$

It does not matter if the units for the individual components differ as long as they are the same on both sides of the equation.

Rearrangement gives the following expression for the final hydrogen ion concentration:

$$\text{Final } [H^+] = \frac{\text{Initial } [H^+] \times \text{Initial } [HCO_3^-] \times \text{Final } Pco_2}{\text{Initial } Pco_2 \times \text{Final } [HCO_3^-]}$$

Substitute: Initial $[H^+]$ = 105 nmol/L

Initial Pco_2 = 5.9 kPa   Final Pco_2 = 5.1 kPa

Initial $[HCO_3^-]$ = 10.2 mmol/L   Final $[HCO_3^-]$ = 20 mmol/L

$$\text{Final } [H^+] = \frac{105 \times 10.2 \times 5.1}{5.9 \times 20} = \textbf{46 nmol/L} \text{ (to 2 sig figs)}$$

Since the examiners gave the pre-treatment data this is probably the procedure they expected candidates to follow.

Question 132

Recent NICE guidelines for the use of newer agents in the treatment of Type 2 Diabetes have recommended that glucagon-like peptide 1 (GLP-1) agonist drugs such as exenatide should only be continued if their introduction results in a reduction in HbA1c of at least 8 mmol/molHb. If the biological within-subject variance is 0.1, what analytical precision must the assay achieve in order to be able to detect a true fall of 8 mmol/mol with greater than 95% certainty?

Values of the normal deviate (*z*-score) and *P* are:

P(%)	10	5	2	1	0.2	0.1
z	1.65	1.96	2.33	2.58	3.09	3.29

FRCPath, Spring 2011