Deacon's Challenge

No 148 - Answer

It is becoming increasingly common practice to replace pH with hydrogen ion concentration when reporting acid-base data. Analysis of cord blood in a neonate gave a hydrogen ion concentration of 66 nmol/L, with a pCO_2 of 7.4 kPa and an actual bicarbonate of 20 mmol/L. After taking steps to improve ventilation and circulation the end-expiration pCO_2 is 5.1 kPa and the actual bicarbonate of 16 nmol/L. Calculate the new hydrogen ion concentration in nmol/L, stating any assumptions made.

FRCPath, Autumn 2012

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).

$$pH = pKa + \log_{10} \frac{[HCO_3^-]}{\alpha pCO_2}$$

$$pH = 6.1 + \log_{10} \frac{16}{0.225 \times 5.1}$$

$$= 6.1 + \log_{10} 13.94$$

$$= 6.1 + 1.14$$

$$= 7.24$$

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

Therefore $[H^+] = \text{antilog}_{10}(-7.24) = 5.8 \times 10^{-8}$ mol/L (to 2 sig figs)

Converting to nmol/L, $[H^+] = 5.8 \times 10^{-8} \times 10^9 =$ **58 nmol/L**

Method 2
Using the constant of 180 which is the 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:

$$[H^+] = \frac{180\ pCO_2}{[HCO3^-]} = \frac{180 \times 5.1}{16} =$$ **57 nmol/L** (to 2 sig figs)

This is the simplest method but requires knowledge of the 180 factor.

Method 3
It is possible to use the relationship between the hydrogen ion concentration, pCO_2 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 $[H^+]$	=	66 nmol/L
Initial pCO_2	=	7.4 kPa
Final pCO_2	=	5.1 kPa
Initial $[HCO_3^-]$	=	20 mmol/L
Final $[HCO_3^-]$	=	16 mmol/L

$$\text{Final } [H^+] = \frac{66 \times 20 \times 5.1}{7.4 \times 16} =$$ **57 nmol/L** (to 2 sig figs)

Question 149

You are provided with the details of the alkaline phosphatase method used in your laboratory. Calculate the serum alkaline phosphatase activity in a sample for which the absorbance change was 0.073 absorbance units over 270 seconds.

Method details:
Serum alkaline phosphatase activity is measured by monitoring the rate of hydrolysis of p-nitrophenyl phosphate to p-nitrophenol. p-nitrophenol has a molar absorption coefficient of 18,700 $L.mol^{-1}.cm^{-1}$. By convention, 1 U alkaline phosphatase is defined as the amount of enzyme that results in the formation of p-nitrophenol at a rate of 16.67 nmol per second under standard conditions. Your laboratory analyzer uses 5 µL serum diluted with 250 µL reagent in a 0.5 cm light path cuvette. Absorbance is monitored over a period of 270 seconds during which a linear increase in absorbance is expected.

FRCPath, Autumn 2012