Blood Buffer System

For a quick revision of the blood buffer system, watch this: https://www.youtube.com/watch?v=5_S5wZks9v8. Before attempting the GAMSAT-style questions, I recommend revising acid-base chemistry, including buffers and the Henderson-Hasselbalch equation.

Warm-up Questions:

1) Fill in the blanks:

   In human blood, the pH must be kept between pH ________ and ________ . Therefore, our blood is slightly a________ . pH is controlled using the b________ buffer system.

2) Two equilibrium reactions occur as part of the blood's buffer system. What are they? How can we write them to show they are simultaneous and linked?

3) Delete as appropriate:

   H_2CO_3 is a weak/strong acid. It forms when O_2/CO_2 dissolved in the blood reacts with water. Levels of H_2CO_3 in the blood are principally controlled by respiration/perspiration/inflammation.

   When we breathe out CO_2, the equilibrium moves to the right/left and H_2CO_3 levels decrease/increase. Excess HCO_3^- is excreted in sweat/breath/urine by the kidneys.

   It is important for the blood pH to stay within a certain range because even slight deviations can cause organ damage/disease/death/all listed options.

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GAMSAT-style questions:

The pH of the blood can be estimated using the Henderson-Hasselbalch equation given below:

$$pH = pK_a + \log_{10}\left(\frac{[A^-]}{[HA]}\right)$$

HA represents an acid and A^- represents its conjugate base.

The bicarbonate buffering system operates in the blood to keep it at approximately pH 7.4. The equilibria are as follows

$$H^+(aq) + HCO_3^-(aq) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H_2O(l) + CO_2(g)$$

Question 1

If the ratio of H_2CO_3 to HCO_3^- in the blood is 2 to 20, what is the most accurate approximation of pKa?

A. 7.35

B. 9.4

C. 5.4

D. 6.4

Question 2

The pH is found to be 7.2 and the pKa of H_2CO_3 is 6.1. What is the ratio of H_2CO_3 to HCO_3^-?

A. 6 : 1

B. 1 : 1.6

C. 1.1 : 1

D. 1 : 1.1

Question 3

H_2CO_3 forms when CO_2 gas dissolved in the blood reacts with water. The following equation relates the partial pressure of CO_2 (pCO_2), pH and HCO_3^- concentration

$$pH = 6.1 + \log\left(\frac{[HCO_3^-]}{0.03 \times pCO_2}\right)$$

If pCO2 is 100 mmHg and the concentration of H_2CO_3 is 3 mmol/L, what is the pH of the blood?

A. 6.1

B. 7.1

C. 7.4

D. 6.4

Blood Buffer System

Solutions

Warm-up questions:

1) In human blood, the pH must be kept between pH 7.35 and 7.45. Therefore, our blood is slightly alkaline. pH is controlled using the bicarbonate buffer system.

2) Two equilibrium reactions occur as part of the blood's buffer system. You can write them as follows:

$$H^+ (aq) + HCO_3^- (aq) \rightleftharpoons H_2CO_3 (aq) \rightleftharpoons H_2O (l) + CO_2 (g)$$

3) H_2CO_3 is a weak acid. It forms when CO_2 dissolved in the blood reacts with water. Levels of H_2CO_3 in the blood are principally controlled by respiration.

   When we breathe out CO_2 the equilibrium moves to the right and H_2CO_3 levels decrease. Excess HCO_3- is excreted in urine by the kidneys.

   It is important for the blood pH to stay within a set range because even slight deviations can cause organ damage, disease and even death (all listed options).

GAMSAT-style questions:

1) D (6.4)

   [carbonate]/[carbonic acid] = 20/2 = 10
   $\log_{10}(10) = 1$
   Substitute data in H-H equation and solve…
   7.4 = pKa + 1
   pKa = 7.4 – 1 = 6.4

2) D (1 : 1.1)

Substitute data into H-H equation and solve...
7.2 = 6.1 + [carbonate]/[carbonic acid]
[carbonate]/[carbonic acid] = 7.2 - 6.1 = 1.1
1.1 = 1.1/1

3) A (6.1)

0.03 x 100 = 3
Therefore [carbonate]/(0.03 x pCO_2) = 3/3 = 1
$\log_{10}(1) = 0$
Therefore pH = 6.1 + 0 = 6.1