ACID-BASE

1. Define the pH.

The pH is $-\log_{10} [H^+]$.

2. What is the pH of the blood?

7.36–7.44.

3. Where does the H^+ in the body come from?

Most of the H^+ in the body comes from CO_2 generated by metabolism. This enters solution, forming carbonic acid through a reaction mediated by the enzyme carbonic anhydrase.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

Acid is also generated by

- Metabolism of the sulphur-containing amino acids cysteine and methionine
- Anaerobic metabolism, generating lactic acid
- Generation of the ketone bodies: acetone, acetoacetate and β-hydroxybutyrate

4. What are the main buffer systems in the intravascular, interstitial and intracellular compartments?

In the *plasma* the main systems are:

- The bicarbonate system
- The phosphate system ($HPO_4^{2-} + H^+ \rightleftharpoons H_2PO_4^-$)
- Plasma proteins
- Globin component of haemoglobin

Interstitial: the bicarbonate system

Intracellular: cytoplasmic proteins.

5. What does the Henderson–Hasselbalch equation describe, and how is it derived?

This equation, which may be applied to any buffer system, defines the relationship between dissociated and

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undissociated acids and bases. It is used mainly to describe the equilibrium of the bicarbonate system.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

The dissociation constant,

$$K = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$$

Therefore

$$[H^+] = K\frac{[H_2CO_3]}{[HCO_3^-]}$$

Taking the $\log_{10}$

$$\log_{10}[H^+] = \log_{10} K + \log_{10}\frac{[H_2CO_3]}{[HCO_3^-]}$$

Taking the negative log, which expresses the pH, and where $-\log_{10}K$ is the pK

$$pH = pK - \log_{10}\frac{[H_2CO_3]}{[HCO_3^-]}$$

Invert the term to remove the minus sign:

$$pH = pK + \log_{10}\frac{[HCO_3^-]}{[H_2CO_3]}$$

The $[H_2CO_3]$ may be expressed as $pCO_2 \times 0.23$, where 0.23 is the solubility coefficient of CO_2 (when the pCO_2 is in kPa).

The pK is equal to 6.1.

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Thus,

$$pH = 6.1 + \log_{10} \frac{[HCO_3^-]}{pCO_2 \times 0.23}.$$

6. Which organ systems are involved in regulating acid-base balance?

The main organ systems are:

- *Respiratory system:* this controls the pCO_2 through alterations in the alveolar ventilation. Carbon dioxide indirectly stimulates central chemoceptors (found in the ventro-lateral surface of the medulla oblongata) through H^+ released when it crosses the blood-brain barrier (BBB) and dissolves in the cerebrospinal fluid (CSF)
- *Kidney:* this controls the $[HCO_3^-]$, and is important for long-term control and compensation of acid-base disturbances
- *Blood:* through buffering by plasma proteins and haemoglobin
- *Bone:* H^+ may exchange with cations from bone mineral. There is also carbonate in bone that can be used to support plasma HCO_3^- levels
- *Liver:* this may generate HCO_3^- and NH_4^+ (ammonia) by glutamine metabolism. In the kidney tubules, ammonia excretion generates more bicarbonate

7. How does the kidney absorb bicarbonate?

There are three main methods by which the kidneys increase the plasma bicarbonate:

- Replacement of filtered bicarbonate with bicarbonate that is generated in the tubular cells
- Replacement of filtered phosphate with bicarbonate that is generated in the tubular cells
- By generation of 'new' bicarbonate from glutamine molecules that are absorbed by the tubular cell

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8. Define the base deficit.

The base deficit is the amount of acid or alkali required to restore 1 l of blood to a normal pH at a pCO_2 of 5.3 kPa and at 37°C. It is an indicator of the metabolic component to an acid-base disturbance. The normal range is −2 to +2 mmol/l.

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