Electrolyte Balance

An electrolyte is any substance that dissociates into ions in aqueous solution.:

Ions can be positively charged (cations) or negatively charged (anions).

The major electrolytes in the human body are:

Sodium (Na^+),	Chloride (Cl^-)	Potassium (K^+),	Phosphate (HPO_4^{--})
Calcium (Ca^{++})	Sulfate (SO_4^{--})	Magnesium (Mg^{++})	Bicarbonate (HCO_3^-)

Interstitial fluid and blood plasma are similar in their electrolyte make up. Na^+ and Cl^- being the major electrolytes. In the intracellular fluid, K^+ and HPO_4^- are the major electrolytes.

Sodium Balance:

This plays a crucial role in the excitability of muscles and neurons. It is also of crucial importance in regulating fluid balance in the body. Sodium levels are extremely closely regulated by kidney function. Sodium is easily filtered in the glomerular portion of the kidneys and most of it is reabsorbed in the kidney tubules. The rate of excretion is directly affected by the rate of filtration of sodium in the glomerulus. (GFR).

Major factors that control the GFR include the blood pressure at the glomerulus and the stimulation of renal arteriole by the sympathetic nervous system. The hormone aldosterone controls the rate of reabsorption of sodium in the distal convoluted tubules and the collecting ducts of the kidneys. The amount of sodium reabsorbed in the proximal convoluted tubule remains almost constantly at around 67%.

Release of aldosterone occurs as a result of a complex process known as the renin-angiotensin-aldosterone pathway.

If the arterial BP falls, renin is released. This readily converts angiotensinogen into its active form angiotensin I. This then travels to the capillary beds where it becomes angiotensin II which is one of the most powerful vasoconstrictors in the body. It is also a stimulator for aldosterone release from the adrenal glands. Because water has a close chemical affinity for sodium, it will follow that more water is reabsorbed in the kidney as well and this will put up the BP to a normal level.

An increase in the arterial BP will result in the release of atrial natriuretic factor (ANF) from the left and right atria of the heart. This hormone actually inhibits renin and aldosterone release. By so doing the loss of sodium by the kidneys is enhanced by the decrease of aldosterone stimulated reabsorption. As we have already seen that water will follow sodium, it follows that water is lost from the body allowing the BP to drop to a normal level.

Potassium Balance

Potassium is the major cation of intracellular fluid. Concentration within the cells is 28x that of the extra cellular fluids. As with sodium it is extremely important in the correct functioning of excitable cells such as muscles, neurons, sensory receptors etc. It is also importantly involved in the regulation of fluid levels within the cell and in maintaining the correct pH balance within the body.

Potassium output is usually equal to potassium input. Sodium reabsorption by aldosterone is usually in exchange for either hydrogen ions or potassium ions. Therefore, if sodium ions are reabsorbed more potassium is lost and vice versa. Thus, high levels of potassium in the interstitial fluid stimulate aldosterone response. Diseases such as Cushing's disease (over production of ACTH) and hyperaldosteronism (overproduction of aldosterone) can lead to a condition known as hypokalaemia (symptoms caused by low potassium levels) which manifests in muscle weakness, flaccid paralysis, cardiac arrhythmia, and alkalosis.

The pH balance of the body also affects potassium levels. In acidosis potassium excretion is decreased (leads to hyperkalaemia higher than normal levels of potassium) whereas the opposite occurs in alkalosis.

Calcium and Phosphorous Balance

Calcium is found mainly in the extracellular fluids whilst phosphorous is found mostly in the intracellular fluids.

Both are important in the maintenance of healthy bones and teeth.

Calcium is also important in the transmission of nerve impulses across synapses, the clotting of blood and the contraction of muscles. If the levels of calcium fall below normal level both muscles and nerves become more excitable.

Phosphorous is required in the synthesis of nucleic acids and high-energy compounds such as ATP. It is also important in the maintenance of pH balance.

If the levels of calcium in the body fall the parathyroid gland is stimulated to secrete parathyroid hormone (PTH). This causes an increase in both the calcium and the phosphate levels of the interstitial fluids by releasing them from the reservoirs of these minerals lodged in the bones and the teeth. PTH also decreases calcium excretion by the kidneys.

If the levels of calcium in the body become too high the thyroid gland releases a hormone called Calcitonin. This inhibits the release of calcium and potassium from the bones. It also inhibits the absorption of calcium from the gastro-intestinal tract and increases calcium excretion by the kidneys.

Magnesium Balance

Most magnesium is found in the intracellular fluid and in bone. Within cells, magnesium functions in the sodium-potassium pump and as an aid to the action of enzymes. It plays a role in muscle contraction, action potential conduction, and bone and teeth production. Aldosterone controls magnesium concentrations in the extracellular fluid. Low Mg^{++} levels result in an increased aldosterone secretion, and the aldosterone increases Mg^{++} reabsorption by the kidneys.

Chloride Balance

Chloride (Cl^-) is the most plentiful extracellular anion with an extracellular concentration 26 times that of its intracellular concentration. Chloride ions are able to diffuse easily across plasma membranes and their transport is closely linked to sodium movement, which also explains the indirect role of aldosterone in chlorine regulation. When sodium is reabsorbed, chlorine follows passively. It helps to regulate osmotic pressure differences between fluid compartments and is essential in pH balance. The chloride shift within the blood helps to move bicarbonate ions out of the red blood cells and into the plasma for transport. In the gastric mucosa, chlorine and hydrogen combine to form hydrochloric acid.

pH Balance

pH is a measurement of the hydrogen concentration of a solution. Lower pH values indicate a higher hydrogen concentration, or a higher acidity. Higher pH values indicate a lower hydrogen concentration, or higher alkalinity. see

Therefore, hydrogen ion balance is often referred to as pH balance or acid-base balance. Hydrogen ion regulation in the fluid compartments of the body is of critical importance to health. Even a slight change in hydrogen ion concentration can result in a marked alteration in the rate of chemical reactions. Changes in hydrogen ion concentration can also affect the distribution of ions such as sodium, potassium, and calcium. It also can affect the structure and function of proteins.

The normal pH of the arterial blood is 7.4, whereas that of the venous blood is 7.35. The lower pH of the venous blood is due to the higher concentration of carbon dioxide in the venous blood, which dissolves in water to make a weak acid, called carbonic acid. When the pH changes in the arterial blood, two conditions may result: acidosis or alkalosis.

Acidosis is a condition occurring when the hydrogen ion concentration of the arterial blood increases and, therefore, the pH decreases. Alkalosis is the condition occurring when the hydrogen ion concentrations in the arterial blood decreases and the pH increases.

Sources of hydrogen ions in the body include carbonic acid formed as mentioned above, sulfuric acid (a by-product in the breakdown of proteins), phosphoric acid (a by-product of protein and phospholipid metabolism), ketone bodies from fat metabolism, and lactic acid (a product formed in skeletal muscle during exercise).

About half of all the acid formed or introduced into the body is neutralized by the ingestion of alkaline foods. The remaining acid is neutralized by three major systems of the body. Namely chemical buffers, the respiratory system and the kidneys.

Chemical buffers have an instantaneous effect on pH changes. They are very effective in minimizing pH changes but do not entirely eliminate the change. Within cells chemical buffer generally take about 2 to 4 hours to minimize changes in pH. The respiratory system also helps to minimize pH changes; the effects occur within minutes. Renal regulation of pH is able to completely return the pH to normal and requires from hours to several days.