# Gases transport

To support metabolism of each cell there must be delivered oxygen. And carbon dioxide must be transported out of the body. Both called blood gases transport are critical for life. It starts by lungs ventilation to reach optimal alveolar partial pressures of oxygen and carbon dioxide. These pressures play roles in gases dissolving in blood, but here is the total amount of transported gases dependent also on blood flow, binding properties of hemoglobin, temperature and hydrogen ion activity. In tissue microcirculation is blood delivered so close to cells that no other active delivery is needed and only diffusion take place here.



The submodels of gases transport are: ventilation, where is calculated the air flow, water vapor dilution, temperatures and pressures effect; oxygen transport; carbon dioxide transport; and acid-base as hydrogen ion activity calculations.

## Ventilation

Natural ventilation depends on many factors and are driven by neural reflexes. Their sensors are central chemoreceptors, which answer to change of intracellular pH; peripheral chemoreceptors located in arterial sinus and aorta detecting changes of arterial blood pH and pO2 and receptors of skeletal muscle metaboreflex. Whole afferent path of respiratory reflexes are in the model summarized into one normalized value called TotalDrive, from which is in efferent part calculated the respiratory rate (typical 11 per minute) and normalized respiratory center motoric nerve activity.

From the lungs properties are then calculated current tidal volume (450 ml at body conditions - temperature of 37°C and 100% humidity) and current dead space volume (150ml at body conditions). Because the temperature and humidity in lungs differs from surrounding air environment, the alveolar ventilation is recalculated to the inspired air conditions in submodel called alveolarVentilation.



## Oxygen

Content of air oxygen in earth atmosphere is typically 21% with atmospheric pressure 101325 Pa, which give its partial pressure in air around 21 kPa. But the amount of oxygen molecules are still dependent on temperature driven by gas equation Eq1, where P is partial pressure, R is gas constant and T is temperature in Kelvins. For example in 0 degC (273.15 K) dry air is molar concentration of oxygen 9.2 mmol/l, while in 40 degC dry air is oxygen molar concentration only 8.1 mmol/l at the same oxygen partial pressure of 21 kPa.

In respiratory paths are air heated to body temperature and diluted by water. Volume of inspired air is changed, which is reflected in variable AlveolarVentilation recalculated to inspired air conditions. Once the air is transported to the alveolus, the exchange take place. Oxygen dissolve in blood plasma and chemically bound the hemoglobin molecules inside red cells. Dissolving of oxygen in water is driven by Henry’s law, where also take place the body temperature.



## Carbon dioxide

Production 200ml/min (STP) [1] = 8.8 mmol/min.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Arterial plasma | Arterial RBC | Venous plasma | Venous RBC |
| Dissolved CO2 | 1.2 mmol/l | 1.2 mmol/l | 1.4 mmol/l | 1.4 mmol/l |
| HCO3 | 24.4 mmol/l | 13.1 mmol/l | 26.3 mmol/l | 13.2 mmol/l |
| Carbamino | Neligible | 2.4 mmol/l | Neligible | 3.8 mmol/l |
| Total | 25.6 mmol/l | 16.7 mmol/l | 27.6 mmol/l | 18.4 mmol/l |

pCO2=40mmHg,pH=7.4,HCO3=24.5 mmol/l, aCO2= 0.231 (mmol/l)/kPa, pK=6.1 at 37degC

## Acid-base

The blood acid-base balance calculation is based on electroneutrality. In plasma is calculated summary charge concentration for strong ions, which do not significantly change their charge at pH from 5 to 9. This is called strong ion difference SID. From non-bicarbonate acid-base buffers (weak ions) is also calculated the summary charge concentration at normal pH=7.4 and full oxygen saturation, called NormalSID. Their difference (SID-NormalSID) is called base excess of oxygenated blood (BEox) and it is the same as negative titratable hydrogen ions of oxygenated blood (cTHox) used by Siggaard with Van-Slyke equation. The meaning of BEox value is the amount of strong acid needed to add into one liter of fully oxygenated blood to reach pH=7.4, what is typically called titration to pH=7.4.



NormalSID is calculated from plasma and erythrocytes weak ions…



Intracellular pH is calculated only from intracellular potassium(151 mmol/L), bicarbonate(17-23 mmol/L), buffers(22-28 mmol/L) and lactate(1 mmol/L). Other cations (12 mmol/L) and anions (117 mmol/L) are assumed as constant. From electroneutrality can be calculated the current amount of bicarbonate as non-bicarbonate ions difference. And because the carbon dioxide partial pressure is also known, the acidity can be expressed from Hendersom-Hasselbalch EqX.

pH=7.2, pCO2 = 45mmHg – 60 mmHg:

HCO3=0.23\*(45\*101.325/760)\*10^(7.2-6.1)=0.386\*pCO2=17

HCO3=0.23\*(60\*101.325/760)\*10^(7.2-6.1)=23

[1] Arthurs G, Sudhakar M. Carbon dioxide transport. Continuing Education in Anaesthesia, Critical Care & Pain 2005;5:207-10.