

PART ONE:

For each condition, answer the following questions:

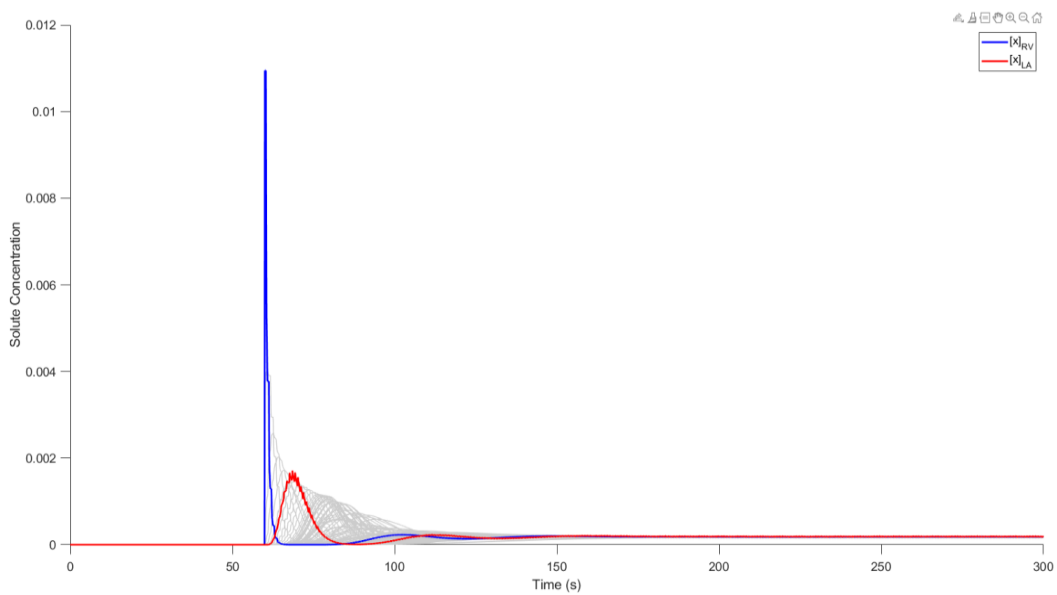
1. How much compute time was required for each simulation? Make sure you run both simulations on the same machine to get a fair comparison.

Beating Heart: 18.9 s

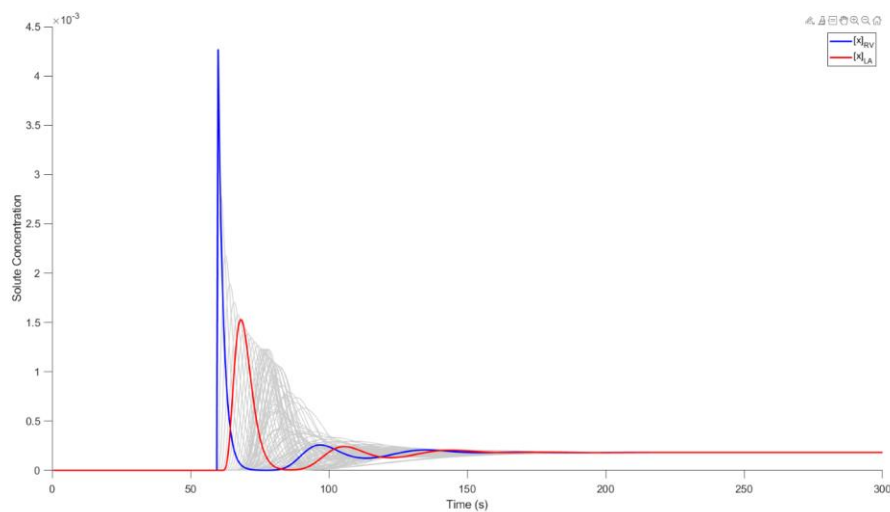
Constant Flow: 1 s

2. Provide the figure of solute concentration over time for each condition.

Beating Heart:



Constant Flow:



3. What is the final solute concentration? Is this value consistent with the calculation of 1 unit of solute distributed uniformly throughout the total blood volume?

Beating Heart: 0.0001879,

Constant Flow: 0.00018134,

4. In each case, how long after t_{inj} does it take for the signal to peak in the left atrium? Note this value represents the mean transit time for the lungs.

Beating Heart: 8.52 s

Constant Flow: 8.5 s

5. In each case, how long after t_{inj} does it take to observe the first recirculation peak in the right ventricle? Note this value represents only the tissue compartments with the fastest mean transit times.

Beating Heart: 41.62 s

Constant Flow: 37 s

6. Based on the animations of solute concentration, which systemic compartment(s) exhibit the fastest mean transit times? Which appear to be the slowest?

Beating Heart: Fast: heart brain kidneys, thyroid, adrenal

Slow: bone, fat, other

Constant Flow: Fast: all but bone and other went incredibly quickly

Slow: bone and other

PART TWO:

Description of system:

Throughout the vasculature, the amount of CO₂ is regulated within the bloodstream by keeping track of PPCO₂ and pH levels. The chemoreceptors activate pH sensors within the bloodstream, which in turn sense and regulate the levels of PPCO₂. The chemoreceptors then communicate with the CNS via electrochemical signals to produce a firing rate that controls the minute ventilation of the bloodstream. The Lungs will deplete CO₂ within the bloodstream relative to the provided minute ventilation. This cycle creates a negative feedback loop that regulates the minute ventilation as a function of PPCO₂ and calculates pH using the Henderson Hasselbach equation and Alveolar Gas equation (Feher). While all organs and systems play a part in the production of CO₂, we have chosen to separate them into the following categories: lungs, brain, heart, liver/gi, kidneys, muscle, skin, bone, fat, thyroid, sex gland, adrenal, and other. The amount of CO₂ produced by each tissue is roughly produced by a function of the amount of blood supplied to that tissue. The summation of the generated CO₂ by these tissues is based on the amount of CO₂ a person produces per time constant (0.02s). Lungs play the opposing role, depleting the blood stream of CO₂ and therefore, for the purpose of this model, creating no CO₂ and will instead deplete the CO₂ depending on the pH and minute ventilation. During homeostasis, the blood has a PPCO₂ level between 25 and 45 mmHg/L, the body has a pH of 7.4, and a minute ventilation between 3 and 50 L/min (Messina). Simulating a vomiting scene will cause a loss of acid in the liver/gi tissue (stomach) and create an increase of CO₂ in the tissue due to metabolic alkalosis (C.C. medical). The chemoreceptors will sense the imbalance of pH and adjust the minute ventilation to try and return the body back to homeostasis.

References

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PART THREE:

Question 3:

For the sensor/comparator/controller block;

Input: PPCO₂ is given

Calculated: PH using the Henderson Hasselback equation

Minute Volume (MV) given by a parametric function provided in the MATLAB program files.

Output: Minute Volume

For Actuator block;

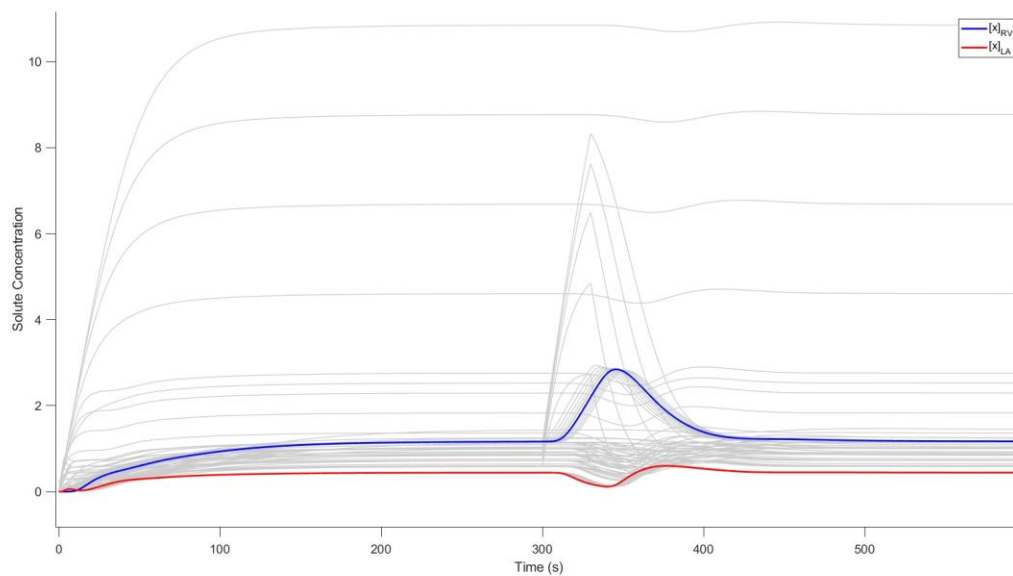
Input: Minute Volume

Calculated: Depletion (D) = $\text{PPCO}_2 * 0.005\text{MV}$

Amount of solute X given in function solute transport provided in MATLAB program files.

Output: Amount of solute X

Question 4:



The sharp gray line at time 300 is the actual signal, the blue $[x]_{RV}$ is the measured signal, red $[x]_{LV}$ is the command signal taking place.

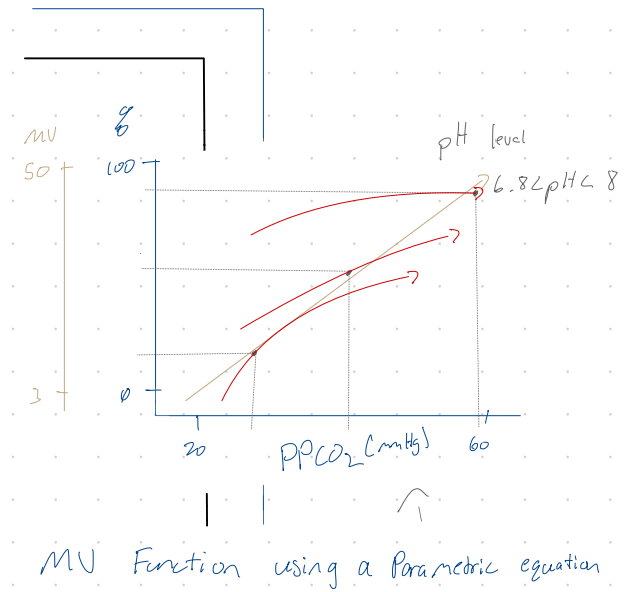
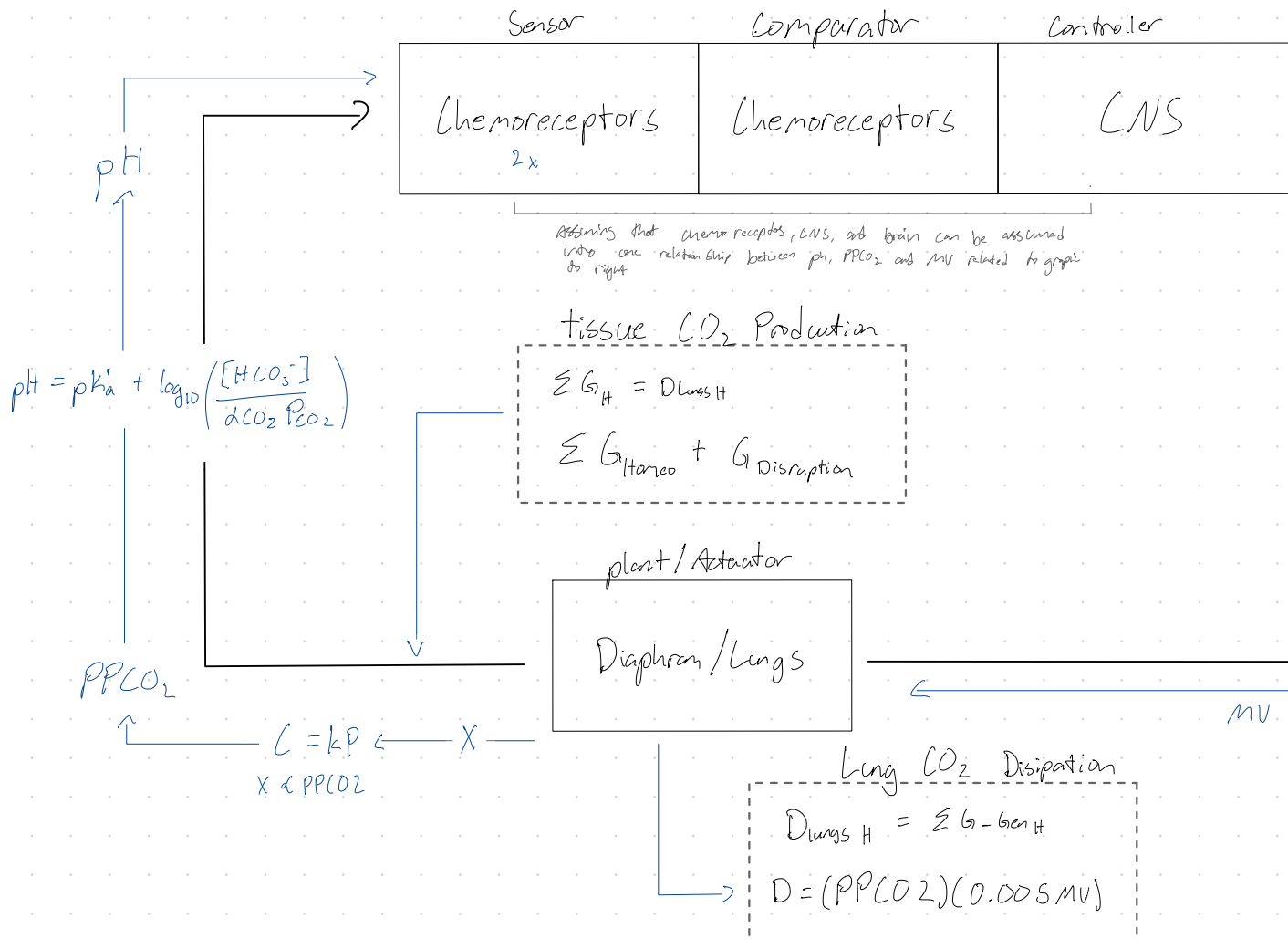
Question 5:

Time Delay: Actual to Measured = 10 seconds

Actual to Command = 10 seconds

The two-time delays were from the 300 second (about 5 minutes) mark where the disturbance happened.

Homeostatic time constant is roughly 100 seconds (about 1 and a half minutes), which is where [x] RV and LA return to their pre disturbance values.



Assumed from Figure 6.6.6
that brain pH and PPCO₂ relationship to percent max spinal activity, that is directly related with maximal and minimal MV