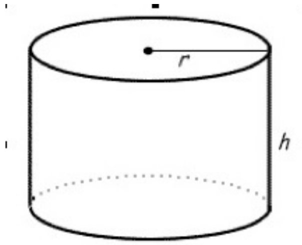
Answers to PS I.

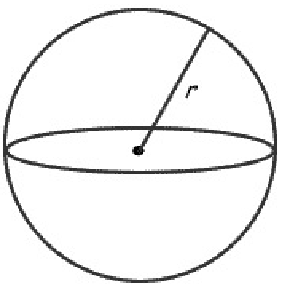
i. Red blood cells as a first approximation can assumed to be a cylinder.



r = 3.5 μm and h = 2 μm

surface area (S) = $2\pi r^2 + 2\pi rh = 120.95\ \mu m^2$
volume (V) = $\pi\, r^2h = 77\ \mu m^3$

ii. *S. aureus* cells are assumed to be spherical.



surface area (S) = $4\pi r^2 = 1.13\ \mu m^2$
volume (V) = $4/3\pi\, r^3 = 0.11\ \mu m^3$

iii. S/V for RBCs = 1.6, while the S/V in *S. aureus* = 10. The large S/V ratio in bacteria permits efficient diffusion of small molecules like O_2 across the membrane. The small volume and rate constant for diffusion allows rapid dissemination of the small molecule throughout the intracellular environment. On the other hand, the S/V ratio is much smaller in eukaryotic cells (most eukaryotic cells are larger than RBCs) and the volume is much larger requiring protein molecules to transport small molecules. You will see that myoglobin transports O_2 within cells.

iv. You are given that cells have 350 mg/mL of macromolecules and you can assume it is all protein. In RBC you are given that 95% of the protein is Hb and therefore Hb is 332mg/mL. We calculated above that the V for a RBC = 77 μm^3 = 7.7×10^{-12} mL. Therefore,

(332mg/mL)(7.7×10^{-12} mL) = 2.5×10^{-8} mg of Hb. The MW of Hb is 6.7×10^4 g/mole.

Therefore 2.5×10^{-11} g/[6.7 x 10g/mole] = 3.7×10^{-16} moles

There are 6.02×10^{23} molecules/mole x 3.7×10^{-16} moles = 2.2×10^8 molecules

The answer from the website found in Google that states that there are 300 million molecules in a RBC is consistent with our calculation. The concentration of Hb in

M or moles/L = 3.7×10^{-16} moles/7.7×10^{-14} L = 4.8 mM

v. Assume Hb is a sphere with a radius of 27.5 Å. 1 μm = 10^4 Å The volume of Hb

is $4/3\pi r^3 = 8.7 \times 10^{-8}\ \mu m^3$

A crude calculation suggests that the volume of a RBC is $77\ \mu m^3/8.7 \times 10^{-8}\ \mu m^3 = 8.8 \times 10^8$

Therefore our 200 million molecules can fit into the RBC.

Problem 2

a. $CO_2 + H_2O \underset{}{\overset{K_1 = 1.7 \times 10^{-3}}{\rightleftharpoons}} H_2CO_3 \overset{K_2 = 2.5 \times 10^{-4}}{\rightleftharpoons} HCO_3^- + H^+$

$K_1 = [H_2CO_3]/[CO_2][H_2O] = 1.7 \times 10^{-3}$ $K_2 = [H^+][HCO_3^-]/[H_2CO_3] = 2.5 \times 10^{-4}$

$K_3 = [HCO_3^-][H^+]/[CO_2][H_2O] = 4.2 \times 10^{-7}$ $pK_3 = -\text{Log}\ K_3 = 6.4$

b. Given that $HCO_3^- + H^+ \rightarrow H_2CO_3 \rightarrow CO_2 + H_2O$, at pH 1, the $[H^+]$ drives the reaction to the right and CO_2, a gas, is trapped in the head space of the vessel. You collect 5.6 mL of CO_2

1 mole/22.6 L = X/0.0056 L then X = 2.5×10^{-4} moles

c. You will use the Eq

$$pH = pK_3 + \log [HCO_3^-]/[CO_2]$$

You know the pH of your blood is 7.35 and you have calculated pK_3 the in part a. You know the total amount of "C" (HCO_3^-, H_2CO_3 and CO_2) in all of its forms based on trapping all of the material as CO_2.

$7.35 = 6.4 + \log [HCO_3^-]/[CO_2]$ This gives a $[HCO_3^-]/[CO_2] = 9/1$

therefore $[HCO_3^-]$ is (9/10)(0.025 M) = 0.02 M, while CO_2 is (1/10)(0.025 M) = 0.0025

d. Cells have a high buffer capacity that is in the range of 7 to 7.4. Many molecules, large and small, contribute to this buffer capacity. On example is phosphate, that you examined in the background problems on concepts that are important to know for 5.07. Also the side chains of amino acids such as the imidazole of His play an important role.

Note: In an upcoming recitation and Lecture you will learn about Hb, the key player in removal of CO_2 the end product of metabolism in your tissues. You will rethink about the equilibria introduced in this problem set.