

## **Working with numbers and blood cells**

### **General Tips/Notes from this problem set.**

- ⇒ I urge you all to go back and try these problems WITHOUT a calculator (use easy numbers such as 5000 WBC/ $\mu\text{l}$  or 10,000 WBC/ $\mu\text{l}$  and 5 million RBC/ $\mu\text{l}$ ). This is the best way to PRACTICE. If you get stuck, you will uncover some little math convention that you may have forgotten or are uncomfortable with, and THIS is the time to unearth it and get it right, not in the middle of your junior or senior year in your organic chemistry class!
- ⇒ If you did not already use scientific notation, TRY IT! – you will be much less prone to silly errors if you use scientific notation rather than relying on counting 10 or 11 zeros!  
For ex. try checking the following equations
- a)  $5000 \times 4000000 = 20000000000$
  - b)  $5000 \times 4000000 = 20000000000$
  - c)  $5 \times 10^3 \times 4 \times 10^6 = 20 \times 10^9 (= 2 \times 10^{10})$
  - d)  $5 \times 10^3 \times 4 \times 10^6 = 20 \times 10^8 (= 2 \times 10^9)$
- There are two correct and two incorrect, which ones are easier to verify?...especially if your handwriting is not as clear as a computer!
- ⇒ UNITS, UNITS, UNITS!! A number without a unit will never get you full credit because it is meaningless without specifying what you are talking about; the unit is part of the answer!
- ⇒ Note that in the answers I provide, I have used 5000 WBC/ $\mu\text{l}$  and 5million RBC/ $\mu\text{l}$ ; slightly different (but still correct!) answers can be derived if you start with different values, such as 10,000 WBC/ $\mu\text{l}$ )

### **ANSWERS:**

- 1) In your blood, what is the rough ratio of white blood cells (WBC) to red blood cells (RBC)? (ie. for every WBC, how many RBC?).  
*This is a RATIO question, and the ratio of WBC to RBC will be the same, regardless of the volume, thus the answer is 1:1000; ie. for every WBC, there will be 1000 RBC.*
- 2) Express the number of WBCs as a percentage of total blood cells, and do the same for RBCs.  
*You can start with the ratio that you calculated in #1, or you can start with the number of cells in a microliter or in a liter...either way, you should end up with 0.1% WBC and 99.9%RBC.*
- 3) Consider a tube of 5 cc (= 5 ml!) of blood.
  - a. How many WBC are there in this tube?  $2.5 \times 10^7$  WBC/5ml (= "25 million")
  - b. How many RBC are there in this tube?  $2.5 \times 10^{10}$  RBC/5ml (= "25 billion")
- 4) The average adult body contains about 5 L of blood. What is your total number of WBC and RBC?
  - a.  $2.5 \times 10^{10}$  WBC/adult and  $2.5 \times 10^{13}$  RBC/adult (= "25 trillion" !!!)
- 5) Let's try to build a useful analogy to help us visualize this number better. Let's expand our RBC's to the size of something we can see: a poppy seed. We can estimate the volume of a poppy seed: it is similar to a mini-cube in which each side measures 1 mm. If so, then the volume of a poppy seed can be estimated to be  $1 \text{ mm}^3$ , which is  $1 \mu\text{l}$ .
  - a. What volume (in L) of poppy seeds would represent the number of RBC in your body?  
*The math is not complicated here, but the challenge that stumped some of you was understanding what the question was asking...never underestimate how important this step is – understanding a question will often require MORE time and MORE thinking than the subsequent math, so give this step time and effort!*  
 $2.5 \times 10^{13}$  poppyseeds/adult  $\times 1 \mu\text{l}$  /poppyseeds =  $2.5 \times 10^{13} \mu\text{l}$ /adult

leaving the answer like this does not sound right (notice I asked "in L") because it is like reporting the distance from Amherst to Boston in inches...it can be accurate and true, but we don't like to think in trillions of inches, we'd rather convert to miles, so...

$$2.5 \times 10^{13} \mu\text{l}/\text{adult} \times 1\text{L}/10^6 \mu\text{l} \dots$$

notice how  $\mu\text{l}$  cancels out, and we are left with  $2.5 \times 10^7 \text{L}/\text{adult}$  (= "25 million L" !!)

b. How does this compare to an Olympic size swimming pool (= 2.5 million L)?  
10 pools worth of poppyseeds!!!!

- 6) Thank goodness RBC's are so small. They have the shape of a pinched sphere of which the diameter is 8 micrometers (8  $\mu\text{m}$ ). The volume of a RBC is roughly 100 fL.
- a. Use this volume to calculate the actual volume that *all* of your RBCs would take up if they were packed together instead of floating around in your plasma.  
*Again, math not complicated, just a question of understanding the question:*  
 $2.5 \times 10^{13} \text{RBC}/\text{adult} \times 100\text{fL}/\text{RBC} \times 1\text{L}/10^{15}\text{fL} = 2.5\text{L}$
- b. Since you were told that you have about 5 L of blood, what does this tell you about how packed your RBCs are? How does this relate to your "hematocrit"?  
*Half your blood volume is taken up by RBC; this is consistent with a hematocrit of 50%.*
- 7) If you donate blood, the standard donation volume is about a pint of blood, which is roughly  $\frac{1}{2}$  Liter.
- a. Right after blood donation, what percentage of your blood volume have you lost?  
 $0.5\text{L}/5\text{L} = 1/10 = 10\%$
- b. What percentage of your RBCs have you lost? *Same thing: 10% because RBC are not selectively removed; whole blood is removed (but if you want to check this mathematically, you can...just figure out the #RBC in 0.5L and find what % that is out of  $2.5 \times 10^{13}$  RBC.*
- c. How many RBCs is this?  $2.5 \times 10^{12}$  RBC ("2.5 trillion RBC donated!!!")
- d. Within about one day your body absorbs extra fluid to quickly replenish your plasma; this means your blood volume is restored to 5 L by the next day. In contrast, your body is not as fast to restore the missing blood cells, because they need to be made; this will take a while. Your body is constantly making RBCs to replenish all older RBCs that succumb to wear and tear and fall apart. The rate of RBC production is about 2 million per second (!). This rate simply keeps up with a similar rate of destruction (2 million RBCs destroyed per second). So in order to restore your normal RBC count after a blood donation, your bone marrow will need to increase its RBC production above the usual 2 million /sec. Consider that in response to blood loss your bone marrow *doubles* the rate of RBC production (it can even increase more than this!), so that you have an *extra* 2 million RBCs generated each second. This seems like a lot; with all these extra RBCs, how quickly would you restore your normal blood count after a blood donation?
- e. Number of RBC lost:  $2.5 \times 10^{12}$  RBC; rate of making EXTRA RBC =  $2 \times 10^6$  RBC/sec. (*note that the normal rate of 2million RBC/sec is busy replenishing the 2million RBCs that burst every second from normal wear and tear, so we only count the number of RBCs being generated ABOVE the normal rate. Another way to say this is that if after blood donation you do not INCREASE your RBC production rate, you will NOT replenish your RBC count, even though you are madly producing 2 million new RBC/sec!*)  
 $2.5 \times 10^{12} \text{RBC} \times 1\text{sec}/2 \times 10^6 \text{RBC} = 1.2 \times 10^6 \text{seconds}$ ; *some of you left your answer like this....would you tell someone you'll meet them for dinner in 7200 seconds? NO! Why? It is correct after all!...the answer here is actually about 2 weeks...you have just figured out why it is not a good idea to donate blood once a week, but once a month is ok!*
- f. If your hematocrit was 50% right before blood donation, what is it right after blood donation?  
*The same!*

- g. Would your hematocrit be the same, or lower, or higher the next day? Explain your answer. *It would be higher because it is a measure of RBC volume out of total blood volume, and the rapid (24hr) replenishment of plasma would have increased blood volume.*
- 8) Suppose you were given a sample of blood to look at under a microscope and you noticed that the ratio of WBC to RBC is 10:1. Having done problem # 1 on this worksheet, you immediately recognize this blood sample as very abnormal.
- a. Suggest two alternative explanations for the 10:1 ratio (almost *anything* is possible!) *Either WBCs have increased dramatically (variety of reasons such as response to infection or leukemia) or RBCs have decreased dramatically (variety of reasons such as decreased RBC production or increased rate of RBC bursting as is seen in sickle cell anemia)*
- b. Explain how a quick hematocrit measurement would help you assess what might be going on.  
*Hematocrit would allow you to assess the status of RBCs; this would allow you to distinguish between the two general classes of reasons suggested above but would not allow you to specifically identify the cause.*
- 9) A hematocrit is a very quick and easy measurement. It can immediately signal some abnormal conditions. Explain whether or not you would expect the hematocrit to look abnormal for an individual suffering from each of the following conditions, and if you think the hematocrit would be abnormal, indicate whether you think it would be high or low. Unhealthy hematocrit measurements can go as low as 30% or as high as 70%, depending on the condition.
- a. Anemia (from not enough red blood cells made, or too many RBCs rupturing, or chronic hemorrhaging). *Hematocrit would be lower than normal because the number of circulating RBCs is reduced, but blood volume is unchanged.*
- b. High altitude adjustment (increased RBC production). *Hematocrit would be higher than normal because the body would compensate for the low oxygen available by increasing its RBC production; indeed people living at high altitudes have a higher hematocrit.*
- c. Dehydration (from profuse diarrhea or heavy sweating). *This is an interesting one, the hematocrit would be abnormally high even though there is no change in RBCs, it is the blood volume that has decreased due to loss of water (plasma decreases).*
- d. Bacterial Infection. *Hematocrit should be unchanged as RBCs and overall blood volume do not change. The increase in WBCs can be measured with a microscope, but not on a hematocrit reading.*