Topics covered: review, Chemical Evolution, Water, Non-covalent bonds, Acid/base, pH

1. i) Convert using scientific notation to liters: 4 nanoliters, **4 x 10^{-9} L,** 20 microliters, **2x10^{-5} L**, 35 milliliters, **3.5 x 10-2 L**, 10 deciliters, **1 L**, 7 kiloliters **7 x 10^{3} L**

ii) Convert using scientific notation to grams: 6 mg, **6 x 10^{-3} g**, 21 µg, **2.1 x 10^{-5} g**, 503 ng, **5.03 x 10^{-7} g**, 10 kg, **1 x 10^{4} g**

2. Which of the following properties of water explains its ability to dissolve acetic acid? (there may be more than one correct answer)

a. The high surface tension of water, which is due to the formation of hydrogen bonds between adjacent water molecules.
b. The ability to serve as a buffer, absorbing protons given off by acetic acid.
c. The ability to orient water molecules so that their polarities neutralize the ions formed when the acid dissociates.
d. The ability to form hydrogen bonds with the carbonyl and the hydroxyl groups of acetic acid.

3. The pH of a solution is equal to:

a. the hydrogen ion concentration H+
b. log [H^+]
c. -log[H^+]
d. ln[H^+]
e. -ln[H^+]

4. Physiological pH is 7.4. What is the hydrogen ion concentration of a solution at physiological pH?

a. -7.4 M
b. 0.6 M
c. 0.6 X 10^{-8} M
d. 1 X 10^{-8} M
e. 4 X 10^{-8} M

5. What is the pH of a 10^{-3} M solution of HCl? **pH = 3**

6. What is the pH of a 10^{-10} M solution of HCl? Why? **pH = 7. Pure water has 10^{-7} M H^+. The H+ from 10^{-10} M HCl will not appreciably increase the concentration of H^+ therefore the pH = 7.**

7. If the concentration of H^+ in a solution is 10^{-3} M, what will the concentration of OH^- be in the same solution at 25° C? **[OH^-] = 10^{-11} M from (Kw= [H^+][OH^-])**

8. How many mL of a 0.4 M HCl solution are required to bring the pH of 10 mL of a 0.4 M NaOH solution to pH 7.0 (neutral pH)?

Note: HCl and NaOH both completely dissociate in water (i.e., no pK_a calculation is necessary).

10 mL Have 4 mmol total of OH^- therefore you need to add 4 mmol of H^+. mol = c*v.

9. How many mL of a 0.2 M NaOH solution are required to bring the pH of 20 mL of a 0.4 M HCl solution to pH 7.0?

40 mL. Have 8 mmol of H^+. Need 8 mmol of OH^- to bring it to neutral. 8 mmol/0.2 mmol/mL = 40 mL

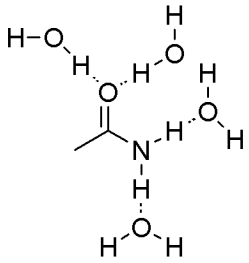
10. Acids are defined as compounds with pK_a values below 7.0. Ture or False, explain.

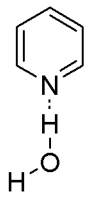
False. Acids are defined as substances that can donate a proton. For example ammonium is an acid since it has a proton to donate and its pKa is approximately 10.

11. The correct operational relationship between pK_a and pH is that:

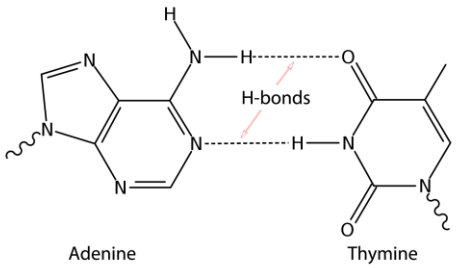
a. both are log functions.
b. both are always <7 for acids, and >7 for bases.
c. These two concepts are not operationally related in any way since biological fluids contains mixtures of too many acids and bases.
d. When pH = pKa , the compound in question will have a charge of +0.5.

12. Draw the hydrogen bonding pattern that water forms with acetamide (CH_3CONH_2) and with pyridine (C_5H_5N).





13. The nuclear bases adenine and thiamine can hydrogen bond to each other. Draw these two bases out and show the hydrogen bonding network. Where the H-bond donor and acceptors?



14. Explain why carbon tetrachloride has a lower dielectric constant then chloroform. Which has a greater dielectric constant acetone or formaldehyde and why would you predict this?

Chloroform ($CHCl_3$) is polar since the dipoles from the three C-Cl bonds do not cancel each other out. Carbon tetrachloride is non-polar since the 4 dipoles from the C-Cl bonds cancel each other out. The greater polarity of chloroform leads to a higher dielectric constant. There is a typo in the second part of the question – it should be "formamide" not "formaldehyde". Formamide is predicted to have a higher dielectric constant due to its polarized bonds and ability to hydrogen bond.

15. Explain why the mobility of H^+ in ice only 10 fold lower than in water but the ion mobility of Na+ in solid NaCl is zero?

In NaCl the Na^+ and Cl^- are rigidly held in a crystalline lattice and are immobile. The same is true of water molecules in ice. However since the OH bonds are orientated pointing to other water molecules (H-bonding to other waters), a proton can easily jump from one water molecule to another. This makes the ion mobility of H^+ in ice much higher than the ion mobility of Na^+ in solid NaCl.

16. The typical volume of an Escherichia coli cell is 1.0 μm^3. At pH 7 how many hydrogen ions are inside the cell? A bacteria cell typically contains 1000s of macromolecules, many with multiple acidic and basic sites. What does your calculation of the number hydrogen ions in a cell tell you about the common notion that ionizable groups are surrounded with many H^+ and OH^- ions?

1 $um^3 = 10^{-15}$ L. At pH 7 [H+] = 10^{-7} mol/L. H+ per cell = 10^{-22} mol. Avogadro's number is 6.02×10^{23} atoms/mol. Therefore there are 6.02×10^1 H^+ per cell! That's 60 H^+ per cell at pH 7. With 1000s of biomolecules all with ionizable groups there are not a lot of extra H^+ available to protonate groups and not many OH^- around to deprotonate groups (only 60 as well!).

17. What is the "RNA world" hypothesis?

This hypothesis proposes that self-replicating RNA molecules were precursors to life on Earth. RNA, like DNA, can store genetic information and, like enzymes, it can catalyze chemical reactions. It may have, therefore, played a key step in the evolution of life.

18. Based on chemical evolution, is it likely that the molecules required for the formation of life could be present on another planet? Why or Why not?

This is an opinion question. There is no right or wrong answer. Your reasoning must support your opinion.

19. Human space exploration has brought bacteria from earth into orbit and likely has deposited many bacteria onto the moon's surface, from the lunar landing missions, and Mars's surface from the Mars rover projects. As a biochemist, do you think it is likely that these organisms will be able to grow in these new environments? Why or why not?

This is an opinion question. There is no right or wrong answer. Your reasoning must support your opinion.