1. Describe a hydrogen bond. Using dashed lines to represent H bonds, illustrate clearly, the H bonding possibilities between (a) two acetic acid (CH₃COOH) molecules and (b) two methylamine (CH₃NH₂) molecules.

A hydrogen bond exists between a hydrogen atom that is in a polar bond and a nearby electronegative ion or atom, which is usually N, O, or F.

![Diagram of hydrogen bonds](image)

2. Name and describe three other types of noncovalent interactions that are important to living systems.

**London dispersion forces:** These occur in all nonpolar molecules. As the electrons in molecules move around, they will occasionally cluster in one place on an atom setting up a temporary, instantaneous dipole within the molecule. This electron cluster causes a repulsion of electrons in neighboring atoms such that another instantaneous dipole is formed. The interactions between this molecules with temporary dipoles are referred to as London dispersion forces.

**Permanent dipole-dipole interactions:** In polar, non-charged molecules, partial charges exist at the ends of the molecules. The partial positive charge at one end will interact with the partial negative end of another molecule in a dipole-dipole interaction.

**Ionic interactions:** These occur between charged molecules. They are the electrostatic forces between ions of opposite charge.

3. Which type of intermolecular attractive force operates between:
   (a) all molecules – London dispersion forces
   (b) polar molecules – dipole-dipole forces & LDFs
   (c) a hydrogen atom in a polar bond and a nearby O atom – hydrogen bonding & LDFs

4. From the following list of biologically relevant functional groups, choose those that can be hydrogen bond acceptors, draw these functional groups, and circle the hydrogen bond acceptor atom: carboxyl, phosphoryl, hydroxide, phenyl, amino, methyl.
5. Calculate the net charge on the following molecules at (a) pH 2, (b) pH 5, (c) pH 10.
(i) succinic acid
\[
\text{CH}_2\text{CH}_2\text{C} = \text{C} = \text{OH}
\]
\[
\text{pK}_a = 6 \quad \text{below a pKa, the acidic form (protonated) predominates; above the pKa, the basic form (deprotonated) predominates.}
\]
(a) 0
(b) -1
(c) -2

(ii) fructose-6-phosphate
\[
\text{O} \quad \text{H} \quad \text{O} \quad \text{CH} \quad \text{P} \quad \text{O} \quad \text{CH}_2
\]
\[
\text{pK}_a = 1 \quad \text{pK}_a = 6
\]
(a) at pH 2, -1
(b) at pH 5, -1
(c) at pH 10, -2

6. Determine the pH of solutions with the following hydrogen ion or hydroxide ion concentrations. Note whether each is acidic or basic.
(a) \([\text{H}^+] = 10^{-11}\)
(b) \([\text{OH}^-] = 10^{-1}\)
(c) \([\text{H}^+] = 3.5 \times 10^{-7}\)
(a) pH 11, basic
(b) pH 13, basic
(c) pH 6.46, acidic

7. What are the expressions for the dissociation constant for the following equations?
(a) A + B ⇌ C + D
(b) H$_3$O + HA ⇌ H$_3$O$^+$ + A
(a) $K_D = ([C][D]) / ([A][B])$
(b) $K_D = ([H_3O^+][A]) / ([H_2O][HA])$

8. Glutamic acid has three ionizable groups with pK$_a$'s of 2.10, 4.07, and 9.47. The pK$_a$'s of the two ionizable groups in glutamine are 2.17 and 9.13. How would the titration curves for these two amino acids differ?
To begin with, glutamic acid will have three plateau-like areas in its titration curve, while glutamine will have only two in its. These plateaus represent the pK$_a$'s. Since the highest and lowest pK$_a$'s of glutamic acid are similar to those of glutamine, these two plateaus
will be similar to the curve for glutamine. In addition, the titration curve for glutamic acid will have a plateau centered around 4.07.

9. Name one buffer that functions in the human body. What is the standard body pH that it works to maintain? 
bicarbonate; pH 7.4

10. Although most nonpolar organic molecules are insoluble in water, their solubility should be improved by changing the pH of the water. Given a pKₐ for B-naphthol (an alcohol) of around 10, would addition of NaOH or HCl increase its solubility in water? 
Addition of NaOH would increase the pH of the water and should make the B-naphthol more soluble. Above it's pKₐ, the B-naphthol should ionize and be more soluble in the water, theoretically.

11. Many researchers use Tris buffer for all of their experimental solutions ranging from pH 6 to pH 8. The pKa of Tris is 8.08. 
   a) Draw a titration curve for the buffer Tris. Be sure to label your axes and include the protonation state of Tris at each point along your curve. 
      x-axis is H+ or OH- equivalents; y-axis is pH 
      very low slope around pKₐ (8.08) steeper slope on each side. pKₐ at 0.5 H⁺ equivalents. 
      at low pH would be protonated; at high pH unprotonated. At pKₐ, same amount in each form.
   
   b) Are researchers making an appropriate choice when they use Tris for buffers ranging in pH from 6-8? Explain. 
      no because it will only buffer down to about pH 7 and then will not be so good.
   
   c) A patient with emphysema will not be able to exhale CO₂ from her body in sufficient amounts. You can predict how this disease will affect her blood pH. Write the reaction scheme relevant to this situation, state how her blood pH is affected, and explain your answer. 
      \[ \text{CO}_2 + \text{H}_2\text{O} \Leftrightarrow \text{H}_2\text{CO}_3 \Leftrightarrow \text{H}^+ + \text{HCO}_3^- \] 
      too much CO₂ will cause too many protons because the excess CO₂ will shift the above reaction scheme to the right; this means the pH will down below the physiologically correct pH of 7.4.
   
   d) Would the administration of Tris buffer to this patient be useful? Explain. 
      2 possible answers: 
      no because below its pKa, Tris is becoming protonated. Assuming the patient has severe acidosis, her pH will be much less than 7.4 and therefore Tris will not be too effective because out of buffering range. 
      yes, if you assume that the pH will not change to dramatically from pH 7.4. Knowing that the pH can't change more than 0.4 pH units without a likelihood of death, you could say that the lowest possible pH is 7.0. This is at the edge of the buffering range for Tris, but it would probably still help somewhat!