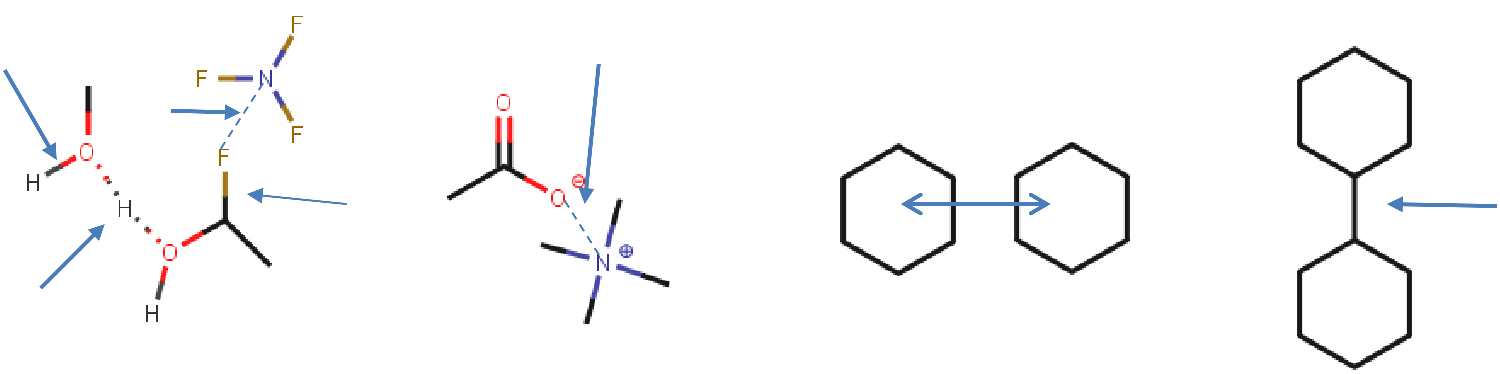
The Solvent of Life

1. Intermolecular forces play an exceptionally important role in biochemistry. This first exercise aims to remind you of the central IMFs and how to identify them. The last part of this section will encourage you to think very critically about the thermodynamics of IMF and use your predictions to understand why non-polar molecules aggregate in polar solvents.
    a. Define a chemical bond.

    b. In your own words, what is an IMF?

    c. Based on your answers to the questions above, what is the difference between an IMF and a bond?

    d. Label each of the following interactions as a bond or IMF. For the IMF, identify what kind of IMF (LDF, H-bond, ion-ion, ion-dipole, dipole-dipole).



    e. H-bonds play a ubiquitous role in biological macromolecules. In your own words, what is needed for two atoms to form an H-bond?

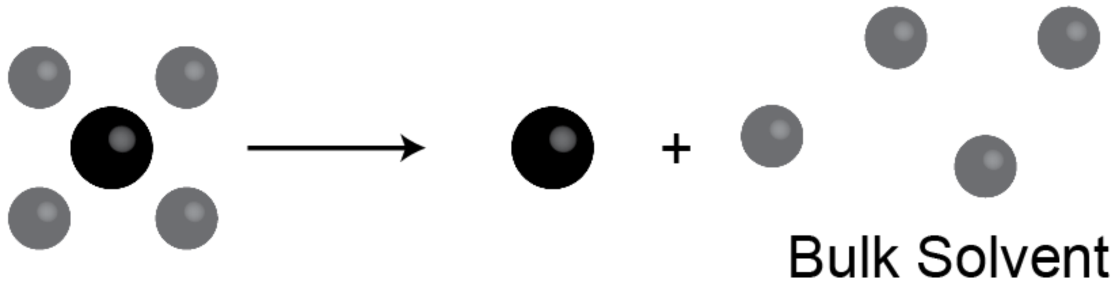
In your reading, you learned about the hydrophobic effect; the phenomenon that causes nonpolar substances to aggregate in water. This exercise aims to help you think about the role of enthalpy and entropy in the aggregation of hydrophobic molecules (this will be very important when we learn about protein folding).

Consider the dimerization of methane in water: $2\ CH_4 \rightarrow (CH4)_2$ This process can be thought of as two separate steps:

- The dehydration of each methane (several water molecules start by weakly interacting with methane and are released to the bulk solvent.

- The newly dehydrated methane molecules interact to form a dimer.

Step 1



Step 2

i. What type of IMF exist between methane and methane?
ii. What type of IMF exist between water and water?
iii. What type of IMF exist between water and methane? You may want to refer to Figure 2-8 in your textbook.
iv. Rank the strength of the IMF in the three previous questions.

v. The overall process (aggregation of methane in water) is spontaneous. What is the sign on ΔG?

$\Delta G = 0$ $\qquad\qquad$ $\Delta G < 0$ $\qquad\qquad$ $\Delta G > 0$

vi. Consider the enthalpy and entropy of each step. Complete the table.

	Step 1 (dehydration and reorganization of water)	**Step 2** (Methane dimerization)	**Overall Process**
ΔH			
ΔS			
ΔG			

vii. Refer to Table 2-2 in your book. Do your predictions for the thermodynamic values match up with the experimental values? If not, reevaluate ΔH and ΔS for each step and figure out why your predictions don't match up to experiment.

viii. Based on Table 2-2 and your predictions from above, what do you think is the biggest contributor to the favorable ΔG for the overall process? Circle your answer on the table and explain your choice.

ix. Collectively, these steps form the conceptual basis of the ***hydrophobic effect***. This name has often been criticized by biochemists.
   1. Why do you think that many consider the term misleading?

   2. Can you think of a better term to describe the aggregation of hydrophobic molecules in water?

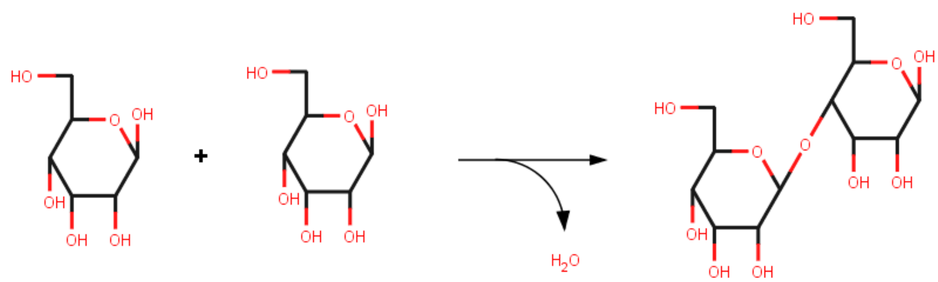
2. Most of the macromolecules that exist in your cells were formed through polymerization reactions.
   a. In your own words:
      i. What is a polymer?

      ii. What is a polymerization reaction?

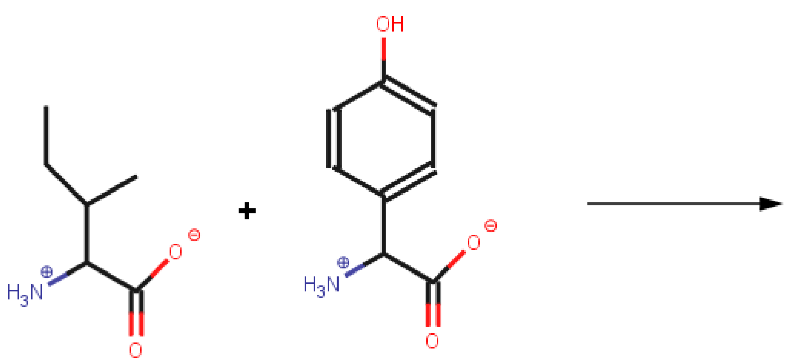
      iii. Which reaction is most likely to be an example of a polymerization?

Condensation Hydrolysis Combustion Double Replacement

      iv. What type of reaction is shown below?

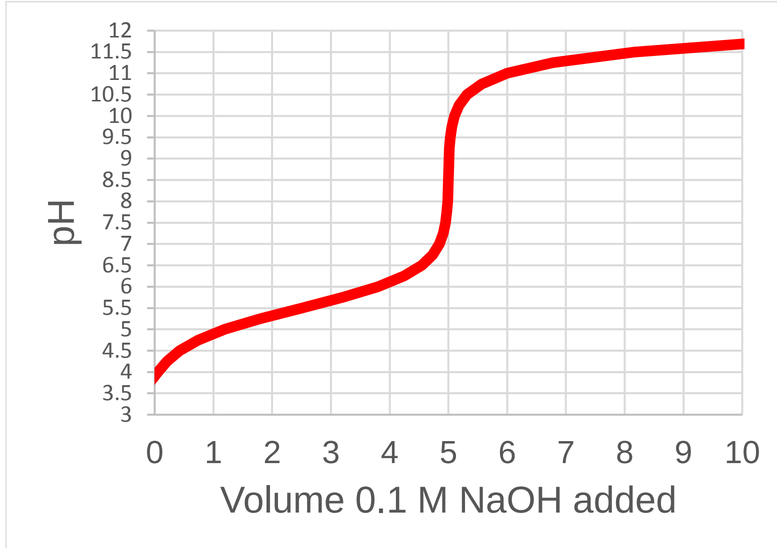


      v. Predict the product(s) of this polymerization reaction.



      vi. In the reaction shown above, do you expect the reactants or product to be more soluble in water? Explain your answer.

3. The titration of 0.1 M NaOH into 100 mL of a weak acid (HX) is shown below. Answer the following questions based on this information.



a. What is the pKa of the acid? How did you determine this?

b. How many moles of base are needed to reach the equivalence point?

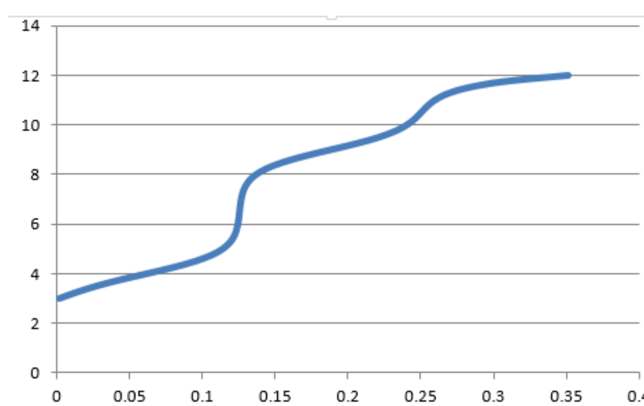
c. If the original volume of the acid solution was 100 mL, what was the original concentration of the acid?

d. Determine the concentration of the conjugate base ([X-]) when:

i. pH = 5.5

ii. pH = 6.0

4. Consider the titration curve shown to the right.



a. Which acid is most likely the titrand?

HX H_2X H_3X H_4X

b. What is/are the pka values for this acid?

c. Draw the two molecular species that are present at pH 4.7 (e.g. X^-)