Problems #2 answers

Organic Chemistry 101

Problems #2 Answers Due Fri. Sept. 12

1. For each of the following structures
   i) Draw a 3-dimensional formula
   ii) If the molecule has a dipole moment show it with the proper arrow.
      If it is nonpolar say zero dipole.
   iii) For each atom marked with * indicate the local shape and its hybridization.

   ![Chemical Structures]

2. a) Draw a proper Lewis structure for the phosphate ion \([PO_4]^{3-}\).
   b) Using the curved arrow method show how one can form all the other possible reasonable resonance forms for this ion. There should be 5 structures total that would be acceptable.
   c) What is the shape of the ion? Tetrahedral

   ![Phosphate Ion Resonance Forms]

3. a) An acid has a \(K_a\) value of \(4.44 \times 10^{-5}\). What is its \(pK_a\) value? 4.353
   b) A second acid has a \(pK_a\) value of 4.445. What is its \(K_a\) value? 3.59 \times 10^{-5}
   c) Which of the two, a or b, is the stronger acid? a is the stronger acid
   d) What is the \(pK_a\) value for the conjugate base of the acid in part a? 9.647

4. Indicate the direction of the following reactions using an arrow to denote the direction of the equilibrium. Also write the appropriate \(pK_a\) values beneath each acid. These can be found in the table in the book (Table 2.3), Appendix A7, and other sources.

   a) \(\text{NH}_3 + \text{H}_2\text{C} = \text{CH}_2 \rightleftharpoons \text{NH}_4^+ + \text{H}_2\text{C} = \text{CH}_2 - \text{O}^\cdot\)
      \(9.26\)
   b) \(\text{NH}_3 + \text{H}_2\text{C} = \text{C} \rightleftharpoons \text{NH}_4^+ + \text{H}_2\text{C} = \text{C} - \text{O}^\cdot\)
      \(9.26\)
   c) \(\text{HC} = \text{CH} + \text{Li}^+ \rightleftharpoons \text{HC} = \text{C} + \text{Li}^+ + \text{NH}_3\)
      \(25\)
      \(4.76\)
5. Write the net ionic equations for the reactions in 4, writing them in the forward direction. Also use curved arrows to show how the electrons from the base remove the proton from the acid.

- **a)** \( \text{CH}_3 - \text{CH}_2 - \overset{\cdot}{\text{O}}^- + \overset{\cdot}{\text{H}} - \text{N} - \text{H} \rightarrow \text{CH}_3 - \text{CH}_2 - \overset{\cdot}{\text{O}}^- + \overset{\cdot}{\text{H}} - \text{N} - \text{H} \)

- **b)** \( \overset{\cdot}{\text{H}} - \text{C} - \overset{\cdot}{\text{C}}^- + \cdot\text{NH}_3 \rightarrow \overset{\cdot}{\text{H}} - \text{C} - \overset{\cdot}{\text{C}}^- + \cdot\text{NH}_4 \)

- **c)** \( \overset{\cdot}{\text{H}} - \text{C} = \overset{\cdot}{\text{C}}^- + \cdot\text{NH}_2 \rightarrow \overset{\cdot}{\text{H}} - \text{C} = \overset{\cdot}{\text{C}}^- + \cdot\text{NH}_3 \)

6. The weaker the acid the stronger the conjugate base. The stronger the acid, the weaker the conjugate base. Using \( pK_a \) values available to you and general principles, pick the stronger base in each of the following pairs.

- **a)** \( \text{Cl}_2\text{CHO}_2^- \text{ vs } \text{Cl}_3\text{CO}_2^- \)
  
  Chlorine is electron withdrawing which will stabilize the base more in the second structure.

- **b)** \( \overset{\cdot}{\text{CH}} = \text{CH}_2 \text{ vs } \cdot\text{C} = \text{CH} \)

  The acetylide ion has the electron pair in an sp hybrid orbital which is more stable - higher % s-character than the sp\(^2\) hybrid orbital in the vinyl anion.

- **c)** \( \text{CH}_3\text{O}^- \text{ vs } \text{CH}_3\text{NH}^- \)

  Within a period, the base strength increases to the left (acid strength decreases).

- **d)** \( \text{CH}_2\text{O}^- \text{ vs } \text{CH}_3\text{S}^- \)

  Within a group, the base strength increases moving up (smaller atom is more basic)

7. Complete the following Lewis acid/base reactions by drawing a proper 3-dimensional structure of the complex plus label the Lewis acid and Lewis base in each case. Use a curved arrow to indicate the donation of an electron pair.

- **a)**

- **b)**