World peace meets resonance? As the dynamics of Soviet dogma evolved, the enmity surrounding the so-called resonance controversy simmered down, and by the late 1960s Pauling had gone from being a disparaged name in Soviet chemistry to a respected scientist and much-admired advocate of nuclear test bans and international peace.* For these efforts he was awarded the Lenin Prize in 1970.


Note: Your exam should consist of 5 pages including the cover page and grade tabulation sheet. Skim the entire exam and solve the easiest problems first. Exams not returned at the end of the period will not be graded.
1. Acid HA has a $pK_a = 12$; acid HB has a $pK_a = 22$. (a) Circle the stronger acid. (b) Will an acid-base reaction with an equilibrium lying to the right take place if Na$^+$A$^-$ is added to HB? Explain your answer with a sentence. Note: HA and HB are hypothetical acids. part a: 2 pts, part b: 6 pts

2. Write valid Lewis structures, including any important resonance structures, for each of the following. If applicable, circle the "best" resonance structure, using the "rules of resonance" as your guide. 4 pts ea
   
   a. nitrite ion, NO$_2^-$ (arranged ONO)
   
   b. carbon monoxide, CO

3. Tranexamic acid, shown below, is used to prevent excessive blood loss during surgery. part a: 2 pts, part b: 6 pts
   
   a. What is the molecular formula for Tranexamic acid?
   
   b. Label two unique non-alkane functional groups that are present in the Tranexamic structure, being sure to circle the atoms comprising the functional group.

4. Describe an example exhibiting an ion-dipole intermolecular force and comment briefly on the importance of dipole moment and dielectric constant in this type of situation. Use equations to make your case for each. 8 pts

5. Circle the column of IR data (Data A or Data B) that most closely matches your expectations for the two functional groups shown. The data corresponds to C=X (where X = N or C) stretching frequencies. 4 pts

   \[
   \begin{array}{ccc}
   \text{R} & \text{N} & \text{C} & \text{C} & \text{N} & \text{R} \\
   \text{R}_2\text{C} & \text{C} & \text{C} & \text{R}_2 \\
   \end{array}
   \]

   Data A: 2145-2120, medium*
   Data B: 2145-2120, strong
   2000-1900, strong
   2000-1900, medium

   *data interpretation key: 2145-2120 cm$^{-1}$, peak of medium intensity.
6. Sodium perborate (NaBO₃) has enjoyed recent success as a laundry bleaching agent. In this question, we'll examine a possible structure for this chemical.

a. Write the best Lewis structure for an anion of the form OBOO. 4 pts
b. Would you expect this anion to be BENT or LINEAR? 4 pts
c. Assign hybridization to each atom in your Lewis structure. 4 pts

d. Draw an orbital picture for the OBOO anion (orbitals superimposed on the molecular skeleton, like we did in class for methane, ethane, ethylene, and acetylene). 8 pts

Answer a and c here.

7. The amide ion, NH₂⁻, whose conjugate acid ammonia has a pKₐ = 35, is a much stronger base than hydroxide. Yet a 0.001 M solution of either base in water has pH = 11. Explain why the solution of the stronger base doesn't have a higher pH. Use lightly annotated chemical reactions to make your point. 4 pts

8. What is the relationship between the members of the following pairs? That is, are they constitutional isomers, identical, or something else (specify)? 12 pts
9. Researchers at Haverford College have developed an IR method for detecting motions within proteins as they travel through different environments within a cell. The method uses a thiocyanate (SCN) group (shown in the structure at right). Explain what the researchers might see in the CN IR spectrum as the protein moves from a nonpolar aprotic environment (where $\nu_{CN} = 2160$ cm$^{-1}$) into a polar protic (aqueous) environment. Circle your answer and rationalize your prediction with structures. 6 pts

10. The pKa value for hydronium ion and protonated acetone are shown below. What is the origin of this difference? What does this say about the basicity of lone pairs on these oxygen atoms? Which molecules/pK$_a$ values would you pull from your tool box to show that the difference in pK$_a$ values for A and B is really not that surprising. Use annotated structures in your answer. This is not an essay question. 6 pts

![Structures](image)

A. $\text{H}_3\text{O}^+$, pK$_a$ = -1.7
B. $\text{CH}_3\text{COH}_2^+$, pK$_a$ = -7.2

11. Add lone pairs and draw reasonable resonance structures for the following ion. Circle the structure which is the strongest contributor to the ion's electronic structure. 6 pts

![Resonance structure](image)

12. (a) Compute the pH of a 1.0 M aqueous solution of NH$_4$Cl. The $K_a$ for the ammonium ion is $1 \times 10^{-9}$. (b) If you put ammonium ions into a buffer held at pH = 8, what will be the ratio of charged (ammonium) to uncharged (ammonia) molecules? 10 pts (a = 7 pts, b = 3 pts)

a. 

b. 

Chemistry 110a  
FIRST EXAM  
September 19, 2014

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