Midterm 1 Review Packet Key

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Evaluation Form: https://forms.gle/C22CrVVRbbMAzJjZ7

Question 1:

a. \( \text{CH}_3\text{O}^- \)

- [1] \( \text{H} \quad \text{C} \quad \text{O} \quad \text{H} \)
- [2] Count valence \( e^- \):
  - \( 1\text{C} \times 4 \text{e}^- = 4 \)
  - \( 3\text{H} \times 1 \text{e}^- = 3 \)
  - \( 1\text{O} \times 6 \text{e}^- = 6 \)
  - Total \( e^- = 13 \)
- Assign charge.
  - Add 1 for (-) charge = 14

b. \( \text{HC}_2^- \)

- [1] \( \text{H} \quad \text{C} \quad \text{C} \quad \text{H} \)
- [2] Count valence \( e^- \):
  - \( 2\text{C} \times 4 \text{e}^- = 8 \)
  - \( 1\text{H} \times 1 \text{e}^- = 1 \)
  - Total \( e^- = 9 \)
- Assign charge.
  - Add 1 for (-) charge = 10

c. \( \text{(CH}_3\text{NH})^+ \)

- [1] \( \text{H} \quad \text{H} \quad \text{C} \quad \text{N} \quad \text{H} \quad \text{H} \)
- [2] Count valence \( e^- \):
  - \( 1\text{C} \times 4 \text{e}^- = 4 \)
  - \( 6\text{H} \times 1 \text{e}^- = 6 \)
  - \( 1\text{N} \times 5 \text{e}^- = 5 \)
  - Total \( e^- = 15 \)
- Assign charge.
  - Subtract 1 for (+) charge = 14

d. \( \text{(CH}_3\text{NH})^- \)

- [1] \( \text{H} \quad \text{C} \quad \text{N} \quad \text{H} \quad \text{H} \)
- [2] Count valence \( e^- \):
  - \( 1\text{C} \times 4 \text{e}^- = 4 \)
  - \( 4\text{H} \times 1 \text{e}^- = 4 \)
  - \( 1\text{N} \times 5 \text{e}^- = 5 \)
  - Total \( e^- = 13 \)
- Complete octet and assign charge.
  - Add 1 for (-) charge = 14

Question 2:
Question 3:

![Chemical structures and legends](image)

**b. and d.** bond (1) longest, weakest C–C bond

**c.** shortest, strongest C–C bond

**a.** shortest C–C single bond

**e.** strongest C–H bond

**f.** Bond (1) is a C$_{sp^3}$–C$_{sp^3}$ bond, and bond (2) is a C$_{sp^3}$–C$_{sp^2}$ bond. Bond (2) is shorter due to the increased percent s-character in the sp$^2$ hybridized carbon.

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Question 4:

1.57 A “better” resonance structure is one that has more bonds and fewer charges. The better structure is the major contributor and all others are minor contributors.

**a.**

- $\text{CH}_3-\text{C}^\text{=O}-\text{CH}_3$
- $\text{CH}_3-\text{C}^\text{=O}-\text{CH}_3$
- $\text{CH}_3-\text{C}^\text{=O}-\text{CH}_3$

3 C–O bonds no charges contributes the most = 3
2 charges contributes the least = 1

**b.**

- $\text{CH}_3-\text{C}^\text{=N}-\text{NH}_2$
- $\text{CH}_3-\text{C}^\text{=N}-\text{NH}_2$
- $\text{CH}_3-\text{C}^\text{=N}-\text{NH}_2$

3 bonds for this N no charges contributes the most = 3
2 charges contributes the least = 1
Question 5: Draw the products of each proton transfer reaction. Label the acid and base in the starting materials, and the conjugate acid and base in the products.

Label the Bronsted–Lowry acid and Brønsted–Lowry base in the starting materials and transfer a proton from the acid to the base for the products. Recall that a BLA is a proton donor and a BLB is a proton acceptor. Typically, acids have protons and bases have electron density (double/triple bonds or lone pairs). Another hint is that acids can have positive charges whereas bases can have negative charges. Also know that the acid becomes the conjugate base, and the base becomes the conjugate acid.
Question 6: The pKa’s of the two ammonium cations drawn below are 8.33 and 11.1. Which pKa corresponds to which cation? Explain your choice.

Recall that four factors affect the acidity of H – A and, therefore, the pKa:

[1] Element Effects - The most important factor determining the acidity of H – A is the location of A in the periodic table. Across a row of the periodic table, the acidity of H – A increases as the electronegativity of A increases. Positive or negative charge is stabilized when it is spread over a larger volume. Down a column of the periodic table, the acidity of H – A increases as the size of A increases.

[2] Inductive Effects - An inductive effect is the pull of electron density through r bonds caused by electronegativity differences of atoms. More electronegative atoms stabilize regions of high electron density by an electron- withdrawing inductive effect. The acidity of H – A increases with the presence of electron-withdrawing groups in A.

[3] Resonance Effects - The acidity of H – A increases when the conjugate base A:– is resonance stabilized.

[4] Hybridization Effects - The higher the percent s-character of the hybrid orbital, the more stable the conjugate base. The acidity of H – A increases as the percent s-character of the A:– increases.

Compare element effects first and then resonance, hybridization, and electron-withdrawing groups to determine the relative strengths of the acids. Remember the lower the pKa, the higher the acidity.

More electronegative atoms stabilize the conjugate base by an electron-withdrawing inductive effect, making the acid stronger. Thus, an O atom increases the acidity of an acid.
Question 7:

a. Label the Lewis acid and Lewis base in each reaction.
b. Draw the products of this reaction.
c. Use curved arrows to show the movement of electron pairs.

A Lewis acid is an electron pair acceptor and either has a proton or is poor in electrons. A Lewis base is an electron pair donor and typically has higher electron density (double/triple bonds or lone pairs). Electron-rich species react with electron-poor species. A Lewis acid is also called an electrophile. The Lewis base is called a nucleophile.

In a Lewis acid–base reaction, a Lewis base donates an electron pair to a Lewis acid. Most of the reactions in organic chemistry involving movement of electron pairs can be classified as Lewis acid–base reactions.

In the simplest Lewis acid–base reaction one bond is formed and no bonds are broken. In some Lewis acid–base reactions, one bond is formed and one bond is broken. To draw the products of these reactions, keep the following steps in mind.

1. Always identify the Lewis acid and base first.
2. Draw a curved arrow from the electron pair of the base to the electron-deficient atom of the acid.
3. Count electron pairs and break a bond when needed to keep the correct number of valence electrons.
Question 8: Classify each reaction as either a proton transfer reaction, or a reaction of a nucleophile with an electrophile. Use curved arrows to show how the electron pairs move.

A proton transfer reaction is similar to a bronsted lowry reaction in which one compound takes the proton of another. A nucleophile and electrophile do not always involve protons. They typically involve reactions between electron-poor and electron-rich species. In the reaction below, the benzene is the nucleophile because it is electron-rich (has a lot of double bonds) and the Br$^-\$ is electron-poor, as indicated by the plus charge. Therefore, this will be a reaction between a Nucleophile and an Electrophile. For the second reaction, a negatively charged Br is taking a proton from the ring, forming HBr. This is a proton transfer since a proton is being taken from one molecule and added to another atom.

Question 9: Identify the functional groups in each molecule.
Question 10: By using only electron density arguments, determine whether the following reactions will occur:

Electronegative heteroatoms like N, O, or X make a carbon atom an electrophile. A lone pair on a heteroatom makes it basic and nucleophilic. Bonds create nucleophilic sites and are more easily broken than bonds.

For this reaction, both species have electron density. The benzene has three pi bonds and Br⁻ has several lone pairs (which is why it is negatively charged).

In this reaction, the carbonyl carbon is considered electron-poor. This is because it has a resonance structure where the pi bond moves onto the oxygen, giving it an extra lone pair.
pair and a negative charge, while leaving the carbon with a positive charge. Because this resonance pair exists, this carbon has a partial positive charge. Thus, it is an electrophile. The $\text{CH}_3$ has electron density because the negative charge indicates the presence of lone pairs. This makes it electron-rich and, therefore is a nucleophile.

**Question 11:** Predict the water solubility of each of the following organic molecules:

- Recall that like dissolves like. Polar compounds dissolve in polar solvents. Nonpolar or weakly polar compounds dissolve in nonpolar or weakly polar solvents.

- To be soluble in water, a molecule must be ionic, or have a polar functional group capable of H-bonding for every 5 C’s. An organic compound is water soluble only if it contains one polar functional group capable of hydrogen bonding with the solvent for every five C atoms it contains. In other words, a water-soluble organic compound has an O- or N- containing functional group that solubilizes its nonpolar carbon backbone.

- Organic compounds are generally soluble in organic solvents regardless of size or functional group.

**DDT**

- no N or O
- **not water soluble**

**Caffeine**

- many polar bonds with N and O atoms
- **many opportunities for H-bonding**
- **water soluble**

**Question 12:** Explain why benzene has a lower boiling point but much higher melting point than toluene.
Boiling point is determined solely by the strength of the intermolecular forces. Since benzene has a smaller size, it has less surface area and weaker VDW interactions and therefore a lower boiling point than toluene.

The increased melting point for benzene can be explained by symmetry: benzene is much more symmetrical than toluene. More symmetrical molecules can pack more tightly together, increasing their melting point. Symmetry has no effect on boiling point.

**Question 13:** Draw five constitutional isomers having the molecular formula $\text{C}_4\text{H}_8$.

Begin by identifying the formula of this compound. In this case, it is $\text{C}_n\text{H}_{2n}$. This tells us that it can be a cycloalkane or it can have multiple bonds. Thus, all 5 isomers will either have a ring or multiple bonds. Then, start with the simplest structure, which in this case is a square. From there, you can begin moving bonds around to get isomers. These problems require a lot of practice, as things might not seem intuitive right away. With enough practice, this will become second nature!

**Question 14:** Give the IUPAC name for each compound.

Follow these steps to name an alkane:
[1] Name the parent chain by finding the longest C chain.

[2] Number the chain so that the first substituent gets the lower number. Then name and number all substituents, giving like substituents a prefix (di, tri, etc.).

[3] Combine all parts, alphabetizing the substituents, ignoring all prefixes except iso.

**Extra Problems**

**Question 1:** Draw the products formed from the acid–base reaction of KOH with each compound.
Label the Brønsted–Lowry acid and Brønsted–Lowry base in the starting materials and transfer a proton from the acid to the base for the products. Recall that a BLA is a proton donor and a BLB is a proton acceptor. Typically, acids have protons and bases have electron density (double/triple bonds or lone pairs). Another hint is that acids can have positive charges whereas bases can have negative charges. Also know that the acid becomes the conjugate base, and the base becomes the conjugate acid.

**Question 2:** Atenolol is a β (beta) blocker, a drug used to treat high blood pressure. Which of the indicated N – H bonds is more acidic? Explain your reasoning.

Compare the Lewis structures of the conjugate bases when each H is removed. The more stable base makes the proton more acidic.
Question 3: Amino acids such as glycine are the building blocks of large molecules called proteins that give structure to muscle, tendon, hair, and nails.

a. Explain why glycine does not actually exist in the form with all atoms uncharged, but actually exists as a salt called a zwitterion.
   i. The COOH group of glycine gives up a proton to the basic NH2 group to form the zwitterion.

b. What product is formed when glycine zwitterion is treated with concentrated HCl?
c. What product is formed when glycine zwitterion is treated with NaOH?

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<th>ND</th>
<th>OCH$_3$</th>
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<td>VDW / Dipole-Dipole</td>
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**Question 4:** What types of intermolecular forces are exhibited by each compound?

**Summary of forces:**

- All compounds exhibit van der Waals forces (VDW).
- Polar molecules have dipole–dipole forces (DD).
- Hydrogen bonding (H-bonding) can occur only when a H is bonded to an O, N, or F.

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