Midterm 1 Practice Exam *Solutions*

Topics Covered:
- Chapter 1, 2, and 3 of Smith textbook
- Content specific to Professor Dong’s curriculum

Answers are bolded and in red. A brief explanation/description is provided. Please come to office hours or our review session for a full explanation. Good luck on that midterm!

1) Which of the following compounds are paired to their proper functional group name?

   I. $\text{CH}_3\text{OCH}_3$ Ester
   II. $\text{CH}_3\text{SH}$ Thiol
   III. $\text{CH}_3(\text{CO})\text{CH}_3$ Carbonyl
   IV. $\text{CH}_3\text{NH}_2$ Amide

   A) I, II
   B) II, III
   C) I, II, III
   D) III, IV

**Brief Explanation:**

I is an ether. IV is an amine. Thio comes from Ancient Greek and means “sulfur”.
2) Which of the following is the correct condensed formula for the compound below?

\[
\begin{align*}
\text{CH}_3(\text{CO})\text{CHCH(CO)}\text{CH}_3 & \quad \text{CH}_3(\text{CO})\text{CH}_2C_{\text{H}}(\text{CO})\text{CH}_3 \\
\text{I} & \quad \text{II} \\
\text{CH}_3(\text{CO})\text{CHCH}_2(\text{CO})\text{CH}_3 & \quad \text{CH}_3(\text{CO})\text{CH}_2C_{\text{H}}C\text{HOCH}_3 \\
\text{III} & \quad \text{IV}
\end{align*}
\]

A) I  
B) II  
C) III  
D) IV  
E) None of the above

**Brief Explanation:**

Pay attention to the number of hydrogen atoms connected to each carbon atom in the chain.
3) Name the orbitals used to form the sigma C-N bond in hydrogen cyanide.

\[
\begin{array}{c}
\text{H} \equiv \text{C} \equiv \text{N} \\
\text{hydrogen cyanide}
\end{array}
\]

A) Csp and Nsp²
B) Csp and Nsp
C) Csp³ and Nsp²
D) Csp and Csp

**Brief Explanation:**

Your sigma bond is made from the hybridized orbitals of C and N. What is the hybridization of C and N?
4) Morphine is a potent painkiller. Name all the functional groups in morphine.

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A) Alcohol, ester, aromatic ring, amine
B) Alcohol, ether, aromatic ring, amide
C) Alcohol, ether, aromatic ring, amine
D) Alcohol, ester, aromatic ring, amide
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**Brief Explanation:**

Esters contain two oxygen atoms and a carbon atom: \( R-(CO)O-R' \).

Amides contain an oxygen atom, a carbon atom, and a nitrogen atom: \( R-(CO)NR_2 \).
5) Which structure(s) below contain a secondary alcohol?

A) I
B) II
C) II, III
D) IV

**Brief Explanation:**

I is a primary alcohol. III is a phenol, not a secondary alcohol. IV is a tertiary alcohol.
6) Which molecule has the highest boiling point?

A) I  
B) II  
C) III  
D) IV

**Brief Explanation:**

I has hydrogen bonding. IV also has hydrogen bonding but I has more ideal IMF interactions due to lacking the methyl group; in addition, I has two H-bond donors versus only one for IV. II only has dipole-dipole interactions. III is only Van der Waal interactions.

**Fun fact:** UCI has an organic chemistry professor named Christopher Vanderwal.
7) HATU is a common coupling agent used in solid phase peptide synthesis. Label the hybridization of the indicated atoms.

A) I = sp2, II = sp2, III = sp2, IV = sp2  
B) I = sp3, II = sp2, III = sp3, IV = sp3  
C) I = sp3, II = sp3, III = sp2, IV = sp3  
D) I = sp3, II = sp2, III = sp2, IV = sp2

**Brief Explanation:**

I has 4 groups, so it is sp3. II has 3 groups, so it is sp2. III has 3 groups, so it is sp2. IV is tricky; consider drawing a resonance structure. It has 3 groups attached, so it is sp2. One set of lone pairs on the oxygen is linked to the neighboring pi system.
8) Which of the following compounds would be most soluble in a 1 M HCl aqueous solution?

A) IV  
B) III  
C) II  
D) I  

**Brief Explanation:**

1 M HCl in water is an acid solution. The “1 M HCl” part is not necessary to answer this question. We are looking for a molecule with the most number of sites for hydrogen bonding; water has 4 sites for hydrogen bonding.
9) Rank the following molecules from **least to most acidic**.

A) II < I < III < IV  
B) I < II < III < IV  
C) II < III < I < IV  
D) IV < III < II < I

**Brief Explanation:**

The strength of acids can be determined by the stability of the conjugate base. There are four general principles in order of importance: **Atom, Resonance, Inductive Effect, Orbital (ARIO)**.
10) DMAP is an expensive nucleophilic catalyst for various carbonyl reactions. Rank the nucleophilicity of the labeled electron groups from least to most nucleophilic.

A) II < III < I
B) I < II < III
C) III < II < I
D) III < I < II

**Brief Explanation:**

III is a sigma C-H bond; these electrons are much less nucleophilic when compared to lone pairs. II donates into a pi system, making it slightly less nucleophilic than I. I is orthogonal to the pi system.
11) Choose the correct hybrid structure for the following molecule.

A) I
B) II
C) III
D) IV

Brief Explanation:

The resonance structure drawn shows you the starting and ending parts of the pi system. The hybrid structure will only reside within the bounds of the resonance structure.
12) Which of the molecules below can form dipole-dipole interactions with itself?

![Molecules Diagram]

A) II, III  
B) II, IV  
C) II, III, IV  
D) I, III, IV  
E) All the molecules can form dipole-dipole interactions with itself

**Brief Explanation:**

II and IV both have polar groups that do not cancel each other out. Therefore, they have dipole-dipole interactions. III has dipoles that cancel each other out. I has no polar functional groups.
13) DIC is a coupling agent used for peptide synthesis. Label the hybridization of the indicated atoms.

A) I = sp$^2$, II = sp$^3$, III = sp$^2$
B) I = sp, II = sp$^3$, III = sp$^3$
C) I = sp, II = sp, III = sp$^3$
D) I = sp, II = sp$^3$, III = sp$^2$

**Brief Explanation:**

I has two groups, so it is sp. II is methyl group. Methyl groups have 4 groups, so it is sp$^3$. III has three groups, so it is sp$^2$. 
14) Which molecule is more acidic and why?

A) Methanol because of hybridization
B) Methanol because of electronegativity
C) Methyl mercaptan because of hybridization
D) Methyl mercaptan because of electronegativity
E) Methyl mercaptan because of polarizability

**Brief Explanation:**

**Polarizability is more important than electronegativity when determining conjugate base stability.**
15) The following is an arrow-pushing mechanism for the acid-base reaction of LDA and acetone. Select the best mechanism.

A) I  
B) II  
C) III  
D) IV

**Brief Explanation:**

Arrows ALWAYS start on electrons and end on atoms/bonds. Therefore, arrows ALWAYS start on lone pairs or bonds. In addition, it is important to pay attention to the octet rule.
16) Identify the most electrophilic site in the following molecules.

A) I = oxygen, II = carbon, III = phosphorous
B) I = oxygen, II = chlorine, III = phosphorous
C) I = carbon, II = carbon, III = hydrogen
D) I = carbon, II = carbon, III = phosphorous

Brief Explanation:

For I, oxygen cannot have any more electrons added to it due to the octet rule. Thus, it is the carbon atoms that are the most electrophilic. The C of II has a couple electronegative groups attached, making it very electrophilic. For III, phosphorus also has a double bonded oxygen attached that makes it electrophilic.
17) The left compound is diisopropylamine. The right compound is $N$-methylcyanoamide. Which one is more acidic and why?

A) Diisopropylamine because of orbital shape
B) Diisopropylamine because of resonance
C) $N$-methylcyanoamide because of orbital shape
D) $N$-methylcyanoamide because of resonance

Brief Explanation:

The orbital shapes are the same for both, sp2. Therefore, it is the resonance stability afforded by the neighboring system of $N$-methylcyanoamide that is most important.
18) Select the correct resonance structure(s) for the following molecule.

A) I
B) I, II
C) II, III
D) I, II, IV

**Brief Explanation:**

Consider drawing out the resonance structures by hand; pay close attention to the octet rule. In addition, the total charge of the system must be the same for all resonance structures.
The following is an acid-base reaction. What is the role of the bolded and blue chlorine?

A) Lewis base
B) Lewis acid
C) Nucleophile
D) Arrhenius base
E) A and C

**Brief Explanation:**

Lewis bases are the most general class of bases. They are simply lone pairs that can pour their electron density into any electron deficient atom; in this case, the Lewis acid. Lewis bases also frequently behave as nucleophiles; the difference in definition is dependent on whether or not we are explicitly referring to an acid-base reaction. Arrhenius bases must be a hydroxide anion (HO-).
20) \( p \)-toluene sulfonic acid is a strong acid. What are the main effects for describing why it is a strong acid?

A) Electronegative atom  
B) Large s character  
C) Resonance  
D) Inductive effect  
E) A, C, D

**Brief Explanation:**

The oxygen with the proton is sp\(^3\) hybridized. That is very low in s character. All the other reasons are present.
21) Taxol is a chemotherapy medication and natural product, with 11 published total syntheses.
   a. Label all functional groups on Taxol.

   ![Functional groups labeled on Taxol](image)

   b. Label hybridization, bond angle, and molecular geometry of selected atoms.

   ![Atoms with hybridization labels](image)

   a. sp², trigonal planar
   b. sp³, bent
   c. sp³, tetrahedral
22) Draw the best lewis structure for the following molecules. Show all atoms and lone pairs. Show non-zero formal charges. Bonds are drawn to show connectivity.

1. Start by calculating the total valence electrons for each atom
2. Make connections between atoms, keeping duet rule in mind for hydrogens, and octet rule, for carbon/nitrogen/oxygen. Carbons are typically central, and hydrogens are terminal.
3. Add lone pairs/double bonds to satisfy the octet/duet rule for every atom.
4. Calculate formal charge for atoms:

   Formal charge = #valence electrons - #non-bonding electrons - #bonds (balls-sticks)

   Ensure to minimize formal charge as much as possible
23) Draw resonance structures for the following molecules, then draw the resonance hybrid.

- Look for lone pairs or pi bonds to push electrons to
- Carbonyls are likely to resonate
- Electrons can be pushed through aromatic rings
24) Draw three constitutional isomers for hexane ($C_6H_{14}$). There are multiple correct responses.

There are many possible answers

25) Label the acid-base pairs for the reaction below. Label the pKa of the acid and conjugate acid. Calculate $K_{eq}$, and indicate which side of the reaction is favored at equilibrium.

\[
\begin{align*}
\text{base} & \quad \text{acid} & \quad \text{conjugate acid} & \quad \text{conjugate base} \\
\Theta_O & \quad \text{H-O-H} & \quad \Theta_O & \quad H-O-H \\
pK_a = 15.7 & \quad \text{pK}_a = 16.5 & \quad \text{pK}_a = 10^{\Delta \text{pK}_a} & \quad \text{products are favored}
\end{align*}
\]