Chemistry 3A - Fall 1998
Midterm Exam 1

Professor Jean Fréchet

September 23, 1998

Your full signature __________________________

Print your full name_________________________

(Last name, First name, Middle)

Your SID_____________________________

Please check the section number and name of your GSI/TA.

111 Turculet, Laura
121 Klei, Steven
131 Krumper, Jennifer
141 Downey, Karen
211 Eng, Christina
221 Shiau, Timothy
311 Kita, Ryoko
321 Davis, Anna
331 Yeh, Robert
341 Mork, Benjamin

361 Fischer, Fabian
371 Bennett, Miriam
381 Fujdala, Kyle
411 Hodges, Alan
421 Ahrendt, Kateri
431 Borths, Christopher
511 Saxon, Eliana
521 Wiener, John
531 de Graffenried, Christopher
541 Dosa, Peter

If you are making up an I-grade, indicate the semester you took 3A_______ and the Professor__________

This exam has 10 pages; make sure that you have them all. We will only grade answers that are in the designated spaces. Please do your scratch work on the backs of the exam pages. Write only one answer to each problem; multiple answers will receive no credit, even if one of them is correct.

Note: This examination runs for a total of 80 minutes. No questions will be answered by proctors after the exam begins. Please write legibly; ambiguous or messy answers will receive no credit.

A partial periodic table and data needed for calculations can be found on page 10 of the exam.

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1. (9 points)
1. Name or draw, as appropriate, the following molecules according to IUPAC rules. Do not forget stereochemistry (cis, trans) where appropriate.

a. 

b. 

c. cis-1,2-dibromocyclopentane

d. 7,7-dimethylbicyclo[2.2.1]heptane
2. (9 points)

2a. Calculate the formal charge on each of the atoms indicated by an arrow in the structure below. Write the answer in the appropriate box (do not forget the sign!)

$$\begin{array}{c}
\text{CH}_3 \\
\vdots \\
\text{O} \\
\text{N} \quad \text{CH}_3 \\
\text{CH}_3 \\
\end{array}$$

2b. What is the hybridization of each carbon atom indicated by an arrow in the structure below. Write the answer in the appropriate box.

$$\begin{array}{c}
\text{H}_2\text{C} \equiv \text{CH} \equiv \text{CN} \\
\end{array}$$

2c. The dipole moment of methanol CH$_3$OH is 1.70D. What does the letter "D" stand for (spell out the name of the unit of dipole moment)

Answer:

2d. Consider the following molecules: HCl, CH$_3$OH, NH$_3$, CH$_4$, HC≡CH and H$_2$C═CH$_2$

i) Which molecule is the strongest acid? Answer:

ii) Which has a pK$_a$ closest to that of water Answer:

iii) Which is the most acidic hydrocarbon Answer:
3. (9 points)

3a. Using the model given for $^4\text{Be}$ below, show the ground state electronic configuration for phosphorus $^{15}\text{P}$

3b. Just as Carbon bonds to hydrogen to form methane, phosphorus bonds to hydrogen to form phosphine. Show the Lewis-dot structure of phosphine.

3c. What is the shape of the molecule of phosphine? Explain your answer.

Shape:

Explanation:
4. (11 points)

4a. Show one Lewis-dot representation for the molecule of SO₃ in which S is surrounded by three O atoms and all atoms have an octet. Your answer must clearly show the location of formal charge, if any.

4b. Draw two additional resonance forms for the structure shown below. Your answers should include arrows to show the movement of electrons.

\[ \text{Diagram of resonance structure} \]

4c. The H–N–H bond angle in ammonia is: (circle one answer only)

- 60°
- 90°
- 109.5°
- 120°
- between 109 and 115°
- between 105 and 110°
- between 60 and 90°

4d. What is the C–C–C bond angle in the molecule of 1,2-propadiene? Explain briefly using VSEPR

\[ \text{H}_2\text{C}≡\text{C}≡\text{CH}_2 \]

Answer: bond angle =

Expansion:

4e. What is the hybridization of the central carbon atom in \( \text{H}_2\text{C}≡\text{C}≡\text{CH}_2 \)

Answer: hybridization of central C atom:
5. (9 points)

5a. Draw clear representations of the two possible chair conformations for cis-4-t-butyl-1-methylcyclohexane and circle the most stable conformation.

5b. Calculate the difference in free energy between these two conformations. Show your detailed calculations and explain clearly the origin of the differences.

Answer:

Explanation and details of calculation:
6. (10 points)

6a. Draw a sawhorse projection of the least stable conformation of pentane (draw along the C₂ to C₃ bond of the molecule).

6b. Draw a Newman projection of the most stable conformation of butane (draw along the C₂ to C₃ bond of the molecule).

6c. Draw an energy diagram showing potential energy versus dihedral angle (0 to 180°) for propane CH₃CH₂CH₃. Label all axes and use the data on page 10 to scale your drawing indicating the largest energy difference between conformers.
7. (8 Points) (a) Consider the equilibrium between the two chair conformations of cyanocyclohexane

Chair with CN equatorial $\rightleftharpoons$ Chair with CN axial

For the process (chair with CN equatorial $\rightarrow$ chair with CN axial) $\Delta G^0 = +0.2$ kcal mol$^{-1}$

Calculate the percentage of axial cyanocyclohexane at 25°C. Show equations and a detailed calculation.

Answer: $%$ axial =

(b). Which of the three acids below is strongest? Circle your answer and explain briefly

\[
\begin{align*}
\text{H}_3\text{C}-\text{C}^{\text{O}} \quad \text{F}_3\text{C}-\text{C}^{\text{O}} \quad \text{Br}_3\text{C}-\text{C}^{\text{O}} \\
\text{OH} & \quad \text{OH} & \quad \text{OH}
\end{align*}
\]
8. (10 Points)

8a. Write a balanced equation for the combustion of cyclohexane in oxygen

8b. What is the relationship between $K_a$ and $K_{eq}$?

Answer:

8c. Write an equation showing $K_{eq}$ for the following reaction and then calculate the value of $K_{eq}$. Show your calculations. (See data on page 10)

\[ \text{HC} = \text{CH} + \text{NH}_2^- \rightleftharpoons K_{eq} \rightarrow \text{HC} = \text{C}^- + \text{NH}_3 \]

Equation for $K_{eq} =$

Calculation of $K_{eq}$

Value of $K_{eq}:$
Note: There are no questions to be answered on this page, it only contains data that may be of use in solving the questions contained in this exam. Not all of the data given is needed.

Value of gas constant: \( R = 2.0 \text{ cal deg}^{-1} \text{ mol}^{-1} \)

Value of e (base for natural logarithms) \( e = 2.718 \)

Value of absolute zero (kelvin) = \(-273^0C\)

**Values of strain energies:**

- Each CH\(_3\) - H eclipsing interaction: 1.5 kcal mol\(^{-1}\)
- Each H - H eclipsing interaction: 1.0 kcal mol\(^{-1}\)

- Each CH\(_3\) - CH\(_3\) eclipsing interaction: 2.5 kcal mol\(^{-1}\)
- Each CH\(_3\) - CH\(_3\) butane-gauche interaction: 0.9 kcal mol\(^{-1}\)

- Each t-Butyl - CH\(_3\) gauche interaction: 2.0 kcal mol\(^{-1}\)

- Each CH\(_3\) - H 1,3-diaxial interaction: 0.9 kcal mol\(^{-1}\)
- Each Cl - H 1,3-diaxial interaction: 0.25 kcal mol\(^{-1}\)
- Each CH\(_3\) - CH\(_3\) 1,3-diaxial interaction: 1.6 kcal mol\(^{-1}\)
- Each H - CN 1,3-diaxial interaction: 0.1 kcal mol\(^{-1}\)
- Each H - C(CH\(_3\))\(_3\) 1,3-diaxial interaction: 2.5 kcal mol\(^{-1}\)

**Partial periodic table of the elements**

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<th>GROUP</th>
<th>IA</th>
<th>II A</th>
<th>III B</th>
<th>IV B</th>
<th>V B</th>
<th>VI B</th>
<th>VII B</th>
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