Chemistry 125   Second Semester   Name _____

May 6, 2011   Final Examination

This exam is budgeted for 150 minutes, but you may have 180 minutes to finish it. Good Luck.

1. (36 minutes).   Give as realistic an example as you can for each of 9 of the following 15 reactions (use front and back of this sheet) OMIT SIX (only your first 9 answers will be graded)   NO MECHANISMS REQUIRED, JUST REGENTS AND PRODUCTS.

a)   a Friedel-Crafts acylation
b) CH_2 insertion by the Arndt-Eistert Reaction
c)   a Claisen condensation
d)   an anti-Markovnikov addition
e)   the iodoform test
f)   a reaction involving an o,p-directing, deactivating substitutent
g)   an epoxidation
h)   proof that Friedel-Crafts propylation does not involve protonated cyclopropane
i)   cross-linking a polymer
j)   an oxidation that stops at an aldehyde
k)   a reaction involving a carbene
l)   a reaction involving N-bromosuccinimide (NBS)
m)   a Mitsunobu Inversion
n)   reduction of an acid derivative that stops at an aldehyde
o)   a Wittig Reaction

2. (5 min) Describe and Explain briefly one (ONE ONLY) of the following two experiments:

    A) Veronica Bierbaum's determination of the energy for gas-phase deprotonation of CH_3OH (381.9±0.5 kcal/mole), given the corresponding value for HF (370.424±.0.003 kcal/mole).

<div align="center">

OR

</div>

    B) Engelking, Ellison, Lineberger's determination of the electron affinity of the $CH_3O\bullet$ radical (1.572±0.004 ev).

3. (7.5 min) Consider these influences on the rate of this elimination reaction:

    A) Increasing [NaOEt] to 0.1 M doubles the rate.

    B) Using s-BuI instead of s-BuBr increases the rate.

    C) Using the fully deuterated bromide slows the rate about 7-fold.
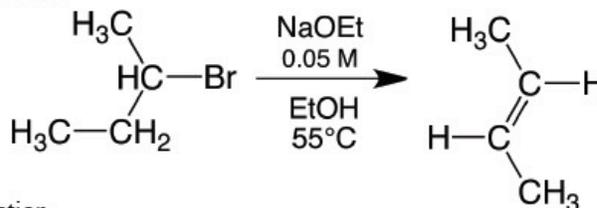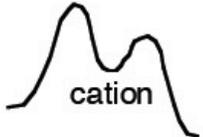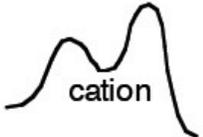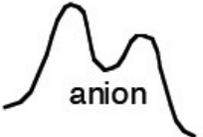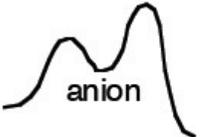
Below are five possible reaction coordinate diagrams for the reaction.
The first two involve initial loss of bromide with formation a carbon cation intermediate.
The second two involve initial abstraction of a proton by ethoxide with formation of a carbon anion intermediate.
Put an **X** in the box for each mechanism that **IS consistent** with the corresponding experimental observation (A-C) above.

Mechanism	cation	cation	anion	anion	
(A) 0.1M NaOEt					
(B) I for Br					
(C) D for H					

4. (3 min) Explain **two structural features** that make Girard's Reagent T [$(CH_3)_3N^+$-CH_2-CO-NH-NH_2] a particularly good tool for isolating certain steroids from biological sources.

5. (7.5 min) After considerable work and thought Fischer had established that one of the sugars below is glucose and the other is gulose. **What did he then do to establish which was which?** [answer using the abbreviated structures]
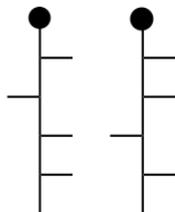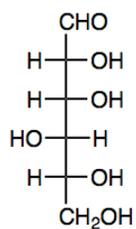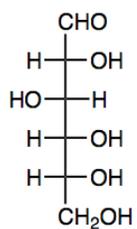
6. The first ring that Woodward constructed in his synthesis of cortisone was the 6-membered Ring "D?", which after a number of other manipulations was destined to become the 5-membered ring D of the portion of the intermediate product shown on the right.
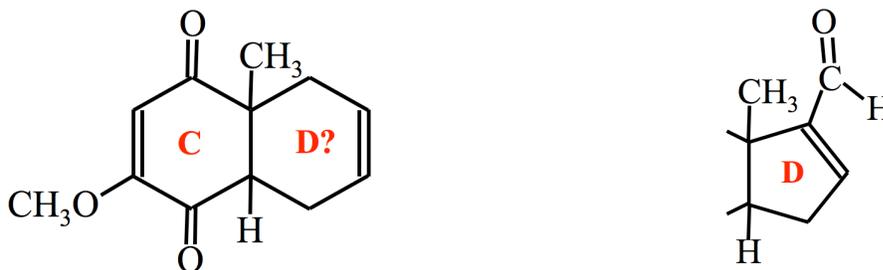
    NOTE that in answering parts A-D you need NOT show detailed mechanisms and curved arrows.
    Just show reagents and, when several steps are involved, the intermediate products.

A) (3 min)   What reaction was used at the start of the synthesis to construct the cyclohexene ring (D?)?

B) (8 min) When C=C bonds elsewhere in other intermediates were hydrogenated it was necessary to modify Ring D? in such a way that its functional group would be protected so as to allow making Ring D later on. What modification/protection/deprotection scheme was used? (Just show the 6-membered ring)

C) (5 min) How was 6-membered ring converted to the 5-membered Ring D shown? Explain how an element of luck was involved. [Hint: if you have trouble remembering what was done, think backward about what would be required to build the functional group of Ring D.]

D) (1 min) The acid from the aldehyde on Ring D was converted into a methyl ester using a reagent that would maximize the yield of this precious material. What reagent was used? [If you can't remember, guess]

THE REST OF THE EXAM CONCERNS THE CHEMISTRY OF ACETONE (MESITE)

Mostly irrelevant background: At the age of 23 in 1859 your chemical four-times-greatgrandfather, Rudolph Fittig, published papers entitled "On Several Products from Dry Distillation of Acetate Salts" and "On Several Metamorphoses of the Ketone from Acetic Acid." In the early days it was common to make new compounds by heating the heck out of existing materials (*e.g* wood alcohol from wood). The name "acetone" (Greek "daughter of vinegar") was coined in 1833 because this simplest ketone was discovered as a product of the pyrolysis of acetate salts. (In fact the word "ketone" was coined in 1848 as a generalization of "acetone".) In the early days acetone was also known as "mesite" (from "meso", between), because its properties were thought to be between those of wood and grain alcohol.

By 1969, when it was easier to identify and measure products, it was reported that heating sodium acetate at 500°C for about 30 seconds gave the following major products, **all presumably coming from intermediate acetone**:
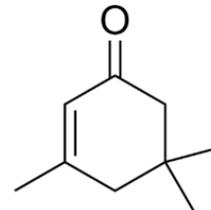
Mesityl oxide ($C_6H_{10}O$; 26%)   **Mesitylene** (C_9H_{12} ; 9%)   **Isophorone** ($C_9H_{14}O$; 18%)

The first two compounds obviously derive their names for the old name of acetone.

The structure of **isophorone** is shown on the right. Not surprisingly it is an isomer of phorone.

7A. (12 min) Isophorone, an important industrial solvent, is said to be the product of a Robinson Annulation process. Supposing this is true, draw the **two** molecules that come together to give isophorone, and **draw a mechanism** with curved arrows to show how they react. Several steps and catalysis are necessary.

7B. (18 min) The next task is to identify the structures of Phorone, Mesityl Oxide, and Mesitylene. The fact that these compounds are all formed in several steps from acetone should be a help, as might be Question 9E.

Page 9 of this exam provides C-13 NMR and Proton NMR spectra for all three compounds, together with IR spectra for two of them.

ON PAGE 9 you should:

(1) DRAW STRUCTURES of the three compounds,

(2) Draw clear arrows to INDICATE WHICH NMR PEAKS come from which protons, and

(3) EXPLAIN THE INTERPRETABLE DIFFERENCE BETWEEN THE IR SPECTRA of phorone and mesityl oxide.

7C. (7 min) One of Fittig's "metamorphoses" of acetone involved treating it with sodium metal to form "pinacol" ($C_6H_{14}O_2$, a symmetrical "dimer"). This reaction that is more commonly done with magnesium nowadays. **Draw the mechanism** with curved arrows for formation of pinacol from acetone **and explain** how examining the formulae of starting material and product shows that a reagent like sodium or magnesium is required.

7D. (8 min) When heated with strong acid pinacol isomerizes to methyl-t-butylketone. **Draw a curved arrow mechanism** for this rearrangement **AND discuss** two factors that could influence which isomeric ketone product would be expected if one began with the pinacol derived from methylethylketone rather than from acetone.

7E. (6 min) It is certainly likely that isophorone is formed by a Robinson Annulation (Question 9A, p. 5), but at 500°C many processes are possible. Another possibility is that the enol of isophorone is formed by a pericyclic reaction of the "vinylogous enol" of phorone. (Hint: we mentioned "vinylogous enolates" when discussing accesss to the difficult position for introducting the ketone of cortisone.)

Draw the vinylogous enol of phorone
with **curved arrows** that show the
pericyclic ring closure to form the
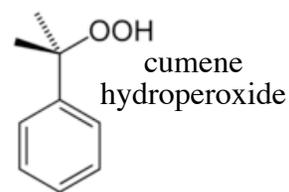enol of isophorone.
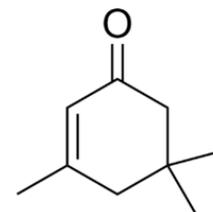
isophorone

7F. (13 min) Explain how the energies of occupied pi MOs would change during the pericyclic reaction of Question 9E, and whether the process should be **conrotatory or disrotatory** (this is an academic question since both rotations would give the same product).

7G. (12 min) Industrially valuable phenol and acetone are produced from cheap benzene and propene by the "cumene" or "Hock" process. The three steps of this process are:

1) Acid catalyzed reaction of propene with benzene to give cumene;

2) Free-radical "autoxidation" of cumene to cumene hydroperoxide;

3) Acid-catalyzed transformation of cumene hydroperoxide to acetone and phenol.

Draw mechanisms for all three of these reactions (with curved arrows).

cumene hydroperoxide

See Question 7B

Phorone
$C_9H_{14}O$

3342 84	2456 84	1633 4
3276 84	2410 84	1623 6
2975 22	2400 84	1616 6
2935 20	2054 84	1445 8
2912 16	1918 84	1381 12
2730 77	1714 55	1356 32
2672 84	1673 8	1221 13

Mesityl
Oxide
$C_6H_{10}O$

3616 81	1620 6
3369 79	1449 21
2978 50	1379 27
2939 50	1358 19
2915 46	1265 72
1690 4	1220 14
1662 43	1166 17

Mesitylene
C_9H_{12}