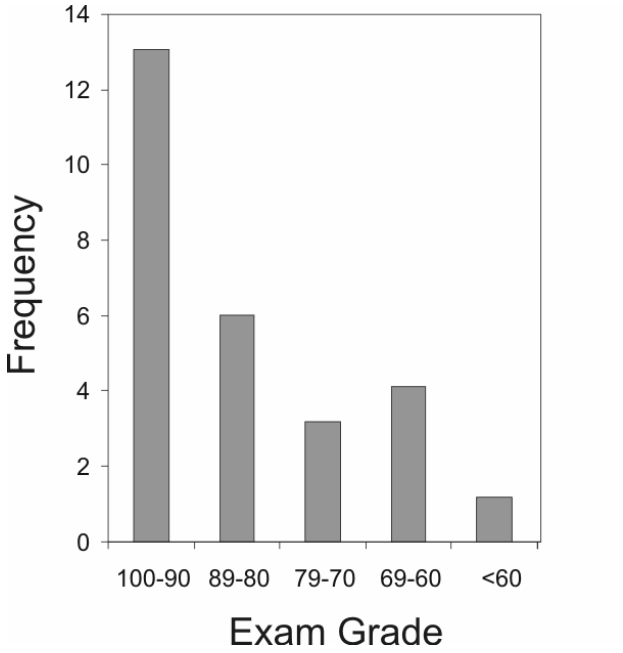
Chemistry 5361/8361 Wednesday, November 5, 2003

Midterm Exam 2
Answer Key

Exam 2 Mean: 83
Exam 2 Median: 86
Exam 2 St. Dev.: 14

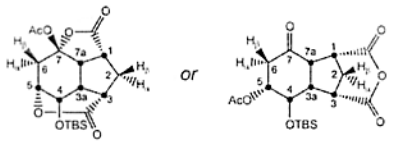


EXAM 2 - 2003

1. a) IN THE HMQC, THERE ARE ONLY TWO PAIRS OF CROSSPEAKS THAT CORRELATE WITH ONE CARBON FREQUENCY (THAT ARE VERTICALLY ALIGNED). ONE @ ~34 ppm, ONE @ ~39 ppm. THESE CARBONS (AND THE CORRESPONDING PROTONS) MUST BE C_2 & C_6.

δ (^{13}C, ppm):	34	39

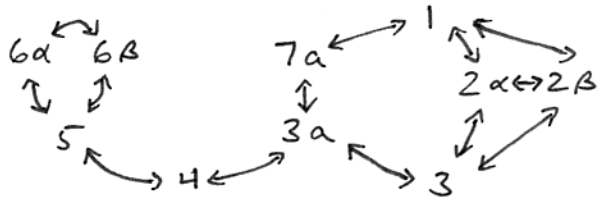
3 POINTS FOR FIRST, 2 POINTS FOR SECOND. (± 2 ppm)



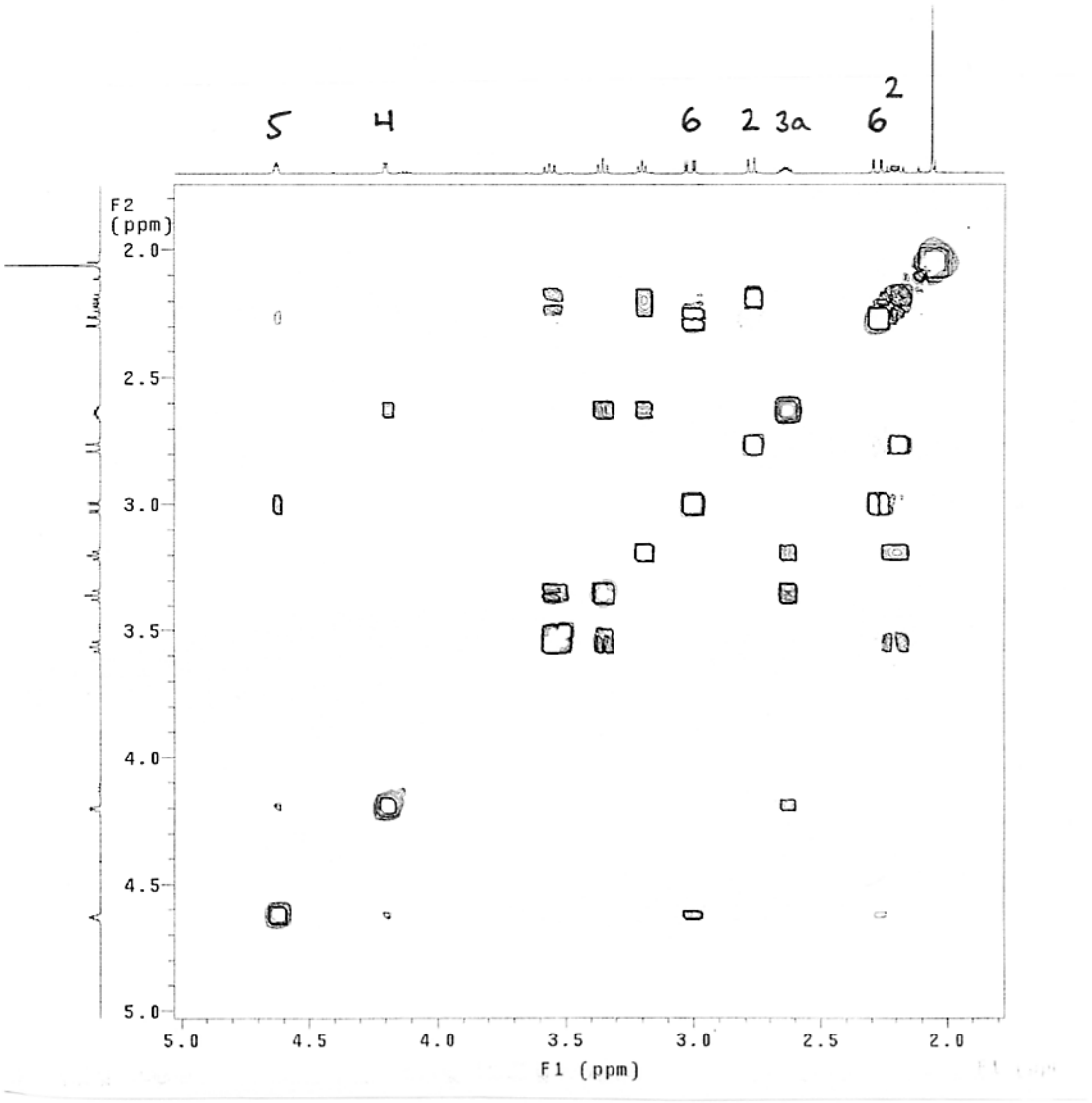
1 2

^{1}H-^{13}C HMQC, 500/125 MHz, $CDCl_3$

b) ASSIGNMENT OF THE SPECTRUM WILL REQUIRE DECODING THE COSY. MAIN QUESTION IS, WHERE TO START? WE KNOW THAT BOTH MOLECULES 1 & 2 HAVE CONNECTIVITY



THIS IS A MESS, AND I DON'T KNOW THAT WE CAN PICK A STARTING POINT BASED ON SPLITTING PATTERNS, BUT WHAT ABOUT CHEMICAL SHIFT? TWO PEAKS ARE PRETTY FAR DOWNFIELD - $\delta \sim 4.6$ & 4.2 ppm - AND THESE ARE LIKELY α TO A HETEROATOM, ONLY H_4 & H_5 FIT THIS BILL. H_4 ONLY HAS TWO COUPLED PARTNERS (ONE OF WHICH IS H_5), AND H_5 HAS THREE (INCLUDING THE PAIR OF H_6 PROTONS WE IDENTIFIED IN (a). THIS ALLOWS US TO ASSIGN ($H_{6\alpha}$, H_{6B}) AND H_{3a} * (SEE NEXT PAGE). SINCE THE ONLY OTHER $-CH_2-$ IS C_2, WE CAN ALSO ASSIGN ($H_{2\alpha}$, H_{2B}) BY ELIMINATION FROM THE HMQC.



TO ROUND EVERYTHING OUT,

- 2α, 2β AND 3a SHARE A SINGLE COUPLED PARTNER: H_3. ($\delta = 3.2$ ppm)
- THEN YOU CAN WALK $H_{3a} \longrightarrow H_{7a}$ ($\delta = 3.35$ ppm), $H_{7a} \longrightarrow H_1$ ($\delta = 3.55$ ppm).

THE BIZARRE PART ABOUT THIS IS THAT ONE OF THE TWO H_2 PROTONS DOESN'T COUPLE TO H_3 OR H_1, WHILE THE OTHER ONE DOES. WEIRD.

SO FINAL QUESTION IS, CAN $H_{2\alpha/\beta}$ OR $H_{6\alpha/\beta}$ BE ASSIGNED UNAMBIGUOUSLY? I BELIEVE $H_{2\alpha/\beta}$ CAN BE – IN BOTH MOLECULES 1 & 2, $H_{2\alpha}$ SITS DIRECTLY OVER e-WITHDRAWING CARBONYLS, WHICH SHOULD DRAG $H_{2\alpha}$ DOWNFIELD OF $H_{2\beta}$. $H_{6\alpha/\beta}$ IS TRICKIER – IF THE PRODUCT IS 1, THEN $H_{6\alpha}$ (equatorial) SHOULD BE DOWNFIELD OF $H_{6\beta}$ (axial) BUT IF THE PRODUCT IS 2 ALL BETS ARE OFF. SO $6\alpha/\beta$ IS UNASSIGNABLE.

Proton	Chemical shift (δ, ppm)	Ambiguities? (Could any of these assignments be switched?)	Chemical shift (δ, ppm)	Proton
H_1	3.56		4.20	H_4
$H_{2\alpha}$	2.77		4.63	H_5
$H_{2\beta}$	2.21		3.01	$H_{6\alpha}$
H_3	3.20		2.28	$H_{6\beta}$
H_{3a}	2.64		3.36	H_{7a}

3 POINTS EACH VALUE.

FOR $H_{2\alpha/2\beta}$: IF AS ABOVE, 6 POINTS (3+3).

IF AS ABOVE OR SWITCHED WITH ARROW, 4 POINTS (2+2).

IF SWITCHED, NO ARROW, 2 POINTS (1+1).

FOR $H_{6\alpha/6\beta}$: ALL ABOVE POSSIBILITIES GET 6 POINTS. (ARROW OR NOT, SWITCHED OR NOT.)

-Each extraneous arrow: -1 point on either side of arrow.

c) MANY POSSIBLE ANSWERS. I PERSONALLY LIKE THE IDEA OF COMPARING COUPLING CONSTANTS. FOR EXAMPLE, H_5 HAS DIFFERENT SPATIAL RELATIONSHIPS WITH ITS NEIGHBORS IN $\underset{\sim}{1}$ AND $\underset{\sim}{2}$. IN $\underset{\sim}{1}$, $\Phi(H_5, H_{6\alpha})$, $\Phi(H_5, H_{6B})$ AND $\Phi(H_5, H_4)$ ARE ALL 60°, SO ONE MIGHT EXPECT ALL COUPLING CONSTANTS TO BE SMALL, BUT IN $\underset{\sim}{2}$ $\Phi(H_5, H_{6B}) = 0^\circ$, WHICH COULD MEAN BIG J, ACTUALLY, ALL J'S AT H_5 ARE SMALL. (CAN SEE A WEIRD $W_{3,5}$ COUPLING IN THIS.) SO THIS POINTS TO $\underset{\sim}{1}$. ON THE OTHER HAND, $\Phi(H_{3a}, H_{7a}) = 0^\circ$ FOR $\underset{\sim}{2}$, AND 60° FOR $\underset{\sim}{1}$; $J_{H_{3a}, H_{7a}} = 8$ Hz, PRETTY SIZEABLE, SO MAYBE THE ANSWER IS $\underset{\sim}{2}$. ANDY JUDD COULDN'T DETERMINE THE ANSWER (AT ALL), AND IT DIDN'T FIT WITH HIS RESEARCH PLAN TO FIGURE IT OUT, SO WE'LL NEVER KNOW.

5 POINTS FOR GIVING ANY PIECE OF DATA.

5 POINTS FOR SAYING HOW THIS DATA IS CONSISTENT W/ ONE STRUCTURE.

OF THIS, 1 POINT JUST FOR ANY ANSWER, 4 POINTS FOR LOGIC.

5 POINTS FOR DISCUSSING HOW DATA IS INCONSISTENT W/ OTHER STRUCTURE.

AGAIN, 1 POINT FOR ANSWER, 4 POINTS FOR LOGIC.

d) AGAIN, MANY POSSIBLE ANSWERS. SOME GOOD ONES:

- 1D NOE EXPERIMENTS. IRRADIATION OF SIGNAL AT $\delta = 2.06$ ppm (-OAc) SHOULD LEAD TO THROUGH-SPACE INTERACTIONS WITH H_{7a}, H_3, $H_{6\beta}$ IF PRODUCT IS $\underset{m}{1}$, OR WITH $H_{6\alpha}$, H_4 IF PRODUCT IS $\underset{m}{2}$.
- NOESY, SAME IDEA, EXCEPT LOOKING FOR CROSSPEAKS (H_{OAc}, H_{7a}), ETC. CAN'T USE NOE & NOESY AS YOUR TWO EXAMPLES.
- HMBC. LOOKING FOR LONG RANGE C-H CORRELATIONS BETWEEN -OAc PROTONS AND C_6 / C_7 / C_{7a} ($\underset{m}{1}$) OR C_5 / C_4 ($\underset{m}{2}$) SHOWING UP AS CROSSPEAKS.
- IR. SIMPLE, YET EFFECTIVE. $\underset{m}{2}$ CONTAINS AN ANHYDRIDE, WHICH SHOULD GIVE DISTINCT RESONANCES AT 1810 cm^{-1} & ~1760 cm^{-1}. THE ESTERS IN $\underset{m}{1}$, ON THE OTHER HAND, SHOULD ONLY ABSORB AT 1750 cm^{-1} AND BELOW.

AN OKAY ANSWER:

- ^{13}C NMR. THE ^{13}C IN THE HMBC LOOKS AWFUL, AND IF WE HAD A BETTER ONE, WE MIGHT DETERMINE WHETHER THE UNKNOWN HAD 3 CARBONYL CARBONS ($\underset{m}{1}$) OR 4 ($\underset{m}{2}$).

FOR EACH ANSWER,

5 POINTS FOR ANY OF THESE OR OTHER JUSTIFIED TECHNIQUES; CANNOT BE REDUNDANT EXAMPLES (i.e., NOE & NOESY).

5 POINTS FOR EXPLICIT ~~EXAMPLE~~ DESCRIPTION OF EXPECTED RESULTS. PARTIAL CREDIT AT DISCRETION.

2. a) THE MOLECULE 5 HAS MOLECULAR FORMULA $C_{18}H_{26}O_3Si$, AND MW = 318.1651 (ISOTOPIC). CLEARLY, THIS IS NOT THE MASS THAT WAS OBTAINED BY MASS SPEC. INSTEAD, MOST LIKELY CHEMICAL FORMULA (ERROR < 5 ppm) FOR "PARENT" PEAK IS $C_{18}H_{30}O_3NSi^+$, OR

$(C_{18}H_{26}O_3Si)\cdot NH_4^+$. THIS MASS MAKES A LOT OF SENSE; INSTRUMENT IS A CI MODE, USING NH_3 AS REAGENT GAS. SO PARENT MASS IS CONSISTENT W/ 5 AS A STRUCTURE.

5 POINTS FOR IS CONSISTENT

5 POINTS FOR RECOGNIZING PARENT MASS INCLUDES NH_4^+

5 POINTS FOR ATTRIBUTING THIS TO CI-MS W/ NH_3 REAGENT

b) A NUMBER OF POSSIBLE ANSWERS:

3418 cm^{-1}: ALCOHOL GROUP.

3074 cm^{-1} (i.e. signal > 3000 cm^{-1}): UNSATURATED C-H FROM PHENYL & ALKENE GROUPS.

2271 cm^{-1}: ALKYNE C≡C STRETCH.

LESS DEFINITIVE, BUT STILL FINE:

2957 cm^{-1}: ALKANE C-H. PRACTICALLY EVERY MOLECULE HAS IT.

1613 cm^{-1}: ALKENE OR ARYL STRETCH.

2000 - 1700 cm^{-1}: ARYL "COMB"  .

ANY OF THESE ARE FINE.

.5 POINTS FOR EACH PAIR OF FREQUENCY & JUSTIFICATION. PAIRING MUST BE CORRECT - CAN'T GIVE CORRECT RESONANCE BUT WRONG REASON.