UCSC, Binder

Name_______________________________________

Student ID # _____________________ Section Day/Time ____________

CHEM 109 - Organic Chemistry with Biological Applications
EXAM 1B (*250 points*)

<u>DO NOT BEGIN THE EXAM OR TURN THE PAGE UNTIL INSTRUCTED TO DO SO.</u>
In the meantime, please read the instructions below.

Page 1 (45)	
Page 2 (60)	
Page 3 (45)	
Page 4 (40)	
Page 5/6 (30)	
Page 7 (30)	
Total	

In each of the following problems, use your knowledge of organic chemistry conventions to answer the questions in the proper manner. **Be sure to read each question carefully.** You have <u>1.5 hours</u> to complete this exam. Point distributions are given throughout the exam so you can use your time wisely. **<u>There are options to skip parts of problems (Page 4) or whole pages (Page 5 or 6).</u>** *Be sure to clearly indicate which problems to skip or the first parts/pages will be graded, even if it is blank!*

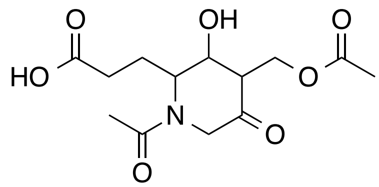
Keep your eyes on your own paper. “Cheat sheets” and electronic devices of any kind are not allowed, including cell phones and calculators. Any student found using any of said devices, or found examining another student’s exam, will be promptly removed from the exam room and at minimum will receive a zero on this exam. Such an incident may also be considered a form of academic dishonesty and reported to the UCSC Judiciary Affairs Committee.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																	2 **He** 4.0026
3 **Li** 6.94	4 **Be** 9.0122											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.085	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.38	31 **Ga** 69.723	32 **Ge** 72.630	33 **As** 74.922	34 **Se** 78.97	35 **Br** 79.904	36 **Kr** 83.798
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.95	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57-71 *	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89-103 #	104 **Rf** (265)	105 **Db** (268)	106 **Sg** (271)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (276)	110 **Ds** (281)	111 **Rg** (280)	112 **Cn** (285)	113 **Nh** (286)	114 **Fl** (289)	115 **Mc** (289)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (294)

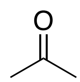
* Lanthanide series	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
# Actinide series	89 **Ac** (227)	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

1. Fundamentals

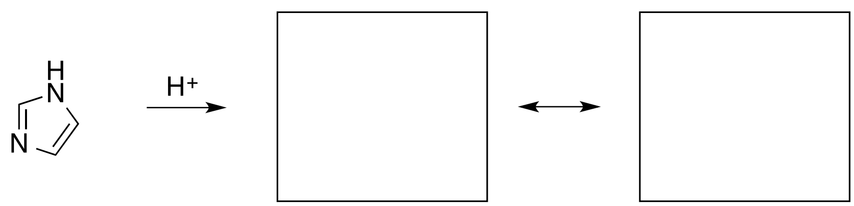
(a) (*15 points*) **Functional Groups – <u>Circle and name each functional group</u>** in the fictitious molecule below (not including alkane portions).



(b) (*10 points*) **Provide the approximate pKa** of each of the following compounds on the lines provided.

HCl		H_2S	NH_3	NH_4^+
_______	_______	_______	_______	_______

(c) (*10 points*) **Consider the basicity of the imidazole ring,** the heterocycle in histidine. **<u>Circle the more basic nitrogen</u>** and draw its **<u>conjugate acid</u>**. Draw one equivalent **<u>resonance structure</u>**, including curved arrow notation to explain movement of electrons through resonance.



(d) (*10 points*) **Draw a simple example of each of the following functional groups (no R groups).**

<u>Acyl Phosphate</u>
(AKA phosphoric-carboxylic mixed anhydride)

<u>Thioester</u>

2. Amino Acids & Peptides

(a) Draw the dominant ionic species of the amino acids at the appropriate pH ranges based on the given pKa's. Indicate all charged atoms. Circle any formal charges.

(i) (*20 points*) *Titration of Histidine* - pKa_1 1.8; pKa_2 9.2; pKa_R 6.1

pH < _____ | _____ < pH < ______ | _____ < pH < ______ | pH > _____

Charge: [ ] [ ] [ ] [ ]

(ii) (*10 points*) *Titration of Valine* – pKa_1 2.3; pKa_2 9.7

pH < _______ | _____ < pH < ______ | pH > _____

Charge: [ ] [ ] [ ]

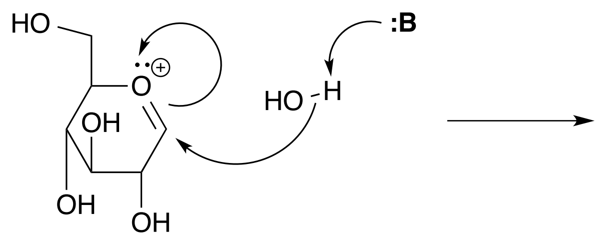
(b) (*20 points*) **Amino Acids – fill in the table**. The full name or abbreviation is given for an amino acid. Fill in the blank cells with the corresponding **missing name or abbreviation**. Given the pKa's, determine the **charge of the dominant ionic species at pH 3 and pH 10**.

Full Name	Single-Letter Abbreviation	Three-Letter Abbreviation	pKa_1	pKa_2	pKa_R	Charge	
						pH 3	pH 11
L-Aspartic Acid			2.1	9.8	3.9		
	C		2.1	10.3	8.0		
		Asn	2.0	8.8	-		
L-Histidine			1.8	9.2	6.1		
	K		2.2	9.0	10.5		

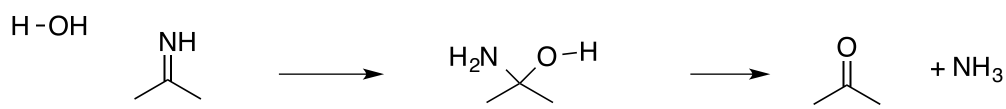
(c) (*10 points*) **Draw a tripeptide** containing serine, histidine, and cysteine at physiological pH.

3. Mechanism Warm-up
No abbreviating structures on this page please.

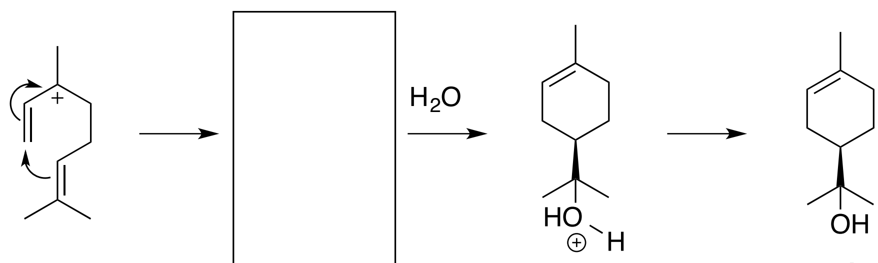
(a) (*10 points*) **Follow the arrows and draw all of the products.**



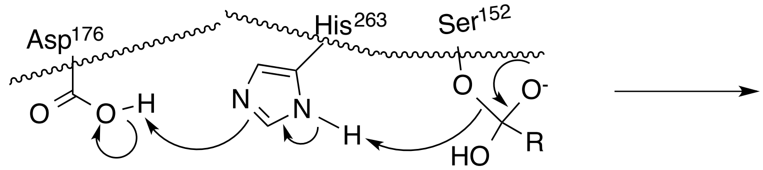
(b) (*10 points*) **Add arrows to complete the mechanism.** *Do not add more intermediates.* You will need to add an acid (**H$^+$**) and base (**:B**) to complete each step as written.



(c) (*10 points*) **Add the missing elements in the hydration reaction below** – either add the missing arrows or follow the arrows and draw the missing intermediate. Add any acids (H$^+$) and bases (:B) needed to complete each step as written.



(d) (*15 points*) **Follow the arrows** in this active site. Draw the released product and the resultant amino acid residues.



4. Fill in the Box

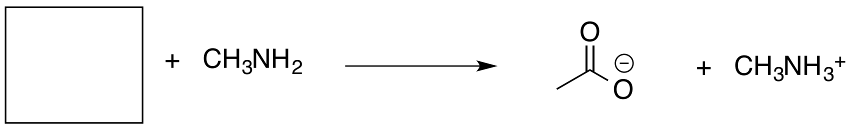
Choose any four, skip one. Draw a large "X" over the part to skip, otherwise **(a)-(d)** will be graded.

Each reaction below is missing a component (reactant or product). There is ample information/clues given to reasonably complete the reaction scheme. Be sure to balance reaction if needed. No arrows necessary! Draw full structures – no defining R groups on this page.

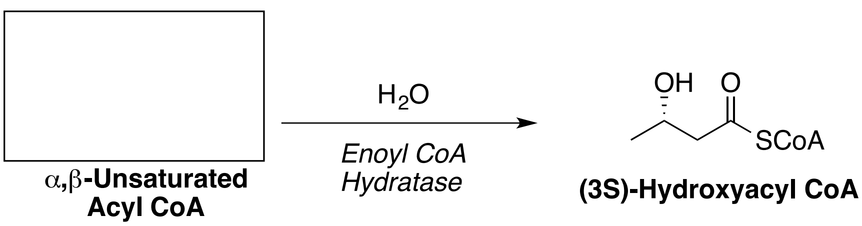
(a)

H_3PO_4 + KOH ⟶ [ ] + [ ]

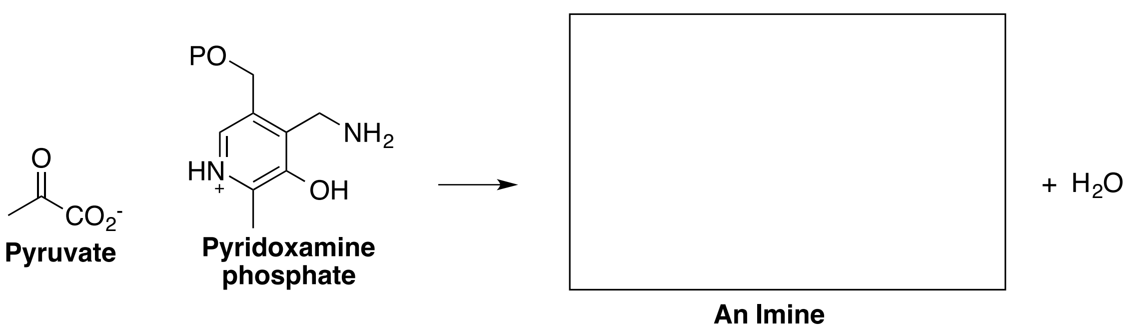
(b)



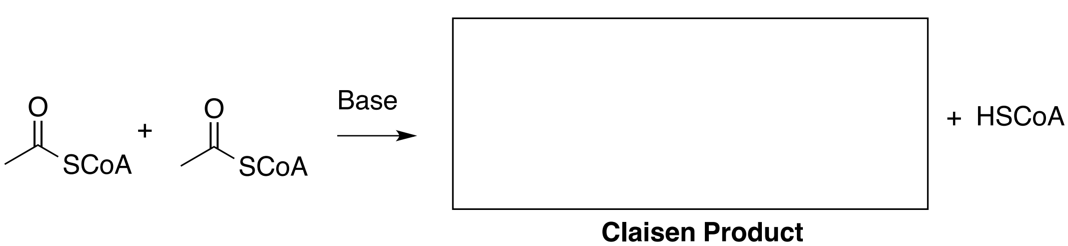
(c)



(d)

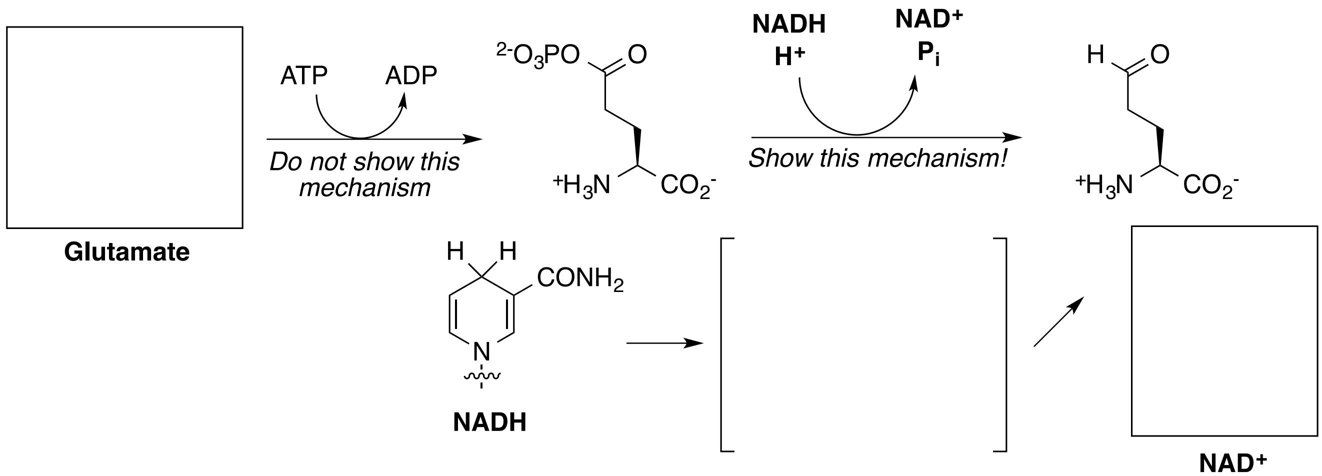


(e)

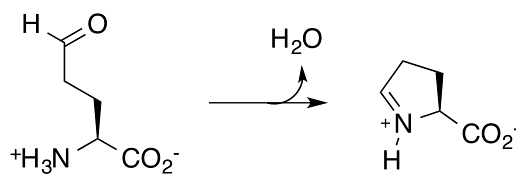


5. Reaction Mechanisms - _Complete either page 5 or 6_. Draw a large "X" over the page to skip or page 5 will be graded. **Show the mechanism for each step in the synthesis of proline from glutamate**. Bring in acids (**H^+**) and bases (**:B**) where necessary. Abbreviate structures as necessary, but be sure to draw out the bonds needed to draw the complete mechanism. No lazy mechanisms!

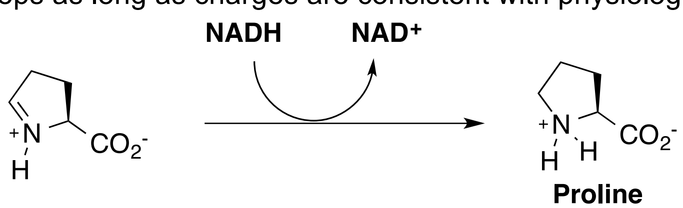
(i) (*10 points*) Draw the structure of **glutamate**. Then complete the **reaction mechanism** for the second step, including **one reaction intermediate** and the resultant structure of **NAD^+**.



(ii) (*15 points*) Draw the **mechanism** for the cyclization reaction leading to proline. This can be done in <u>as few as two steps</u>. It is ok to propose a mechanism with more steps as long as charges are consistent with physiological pH 7.4.

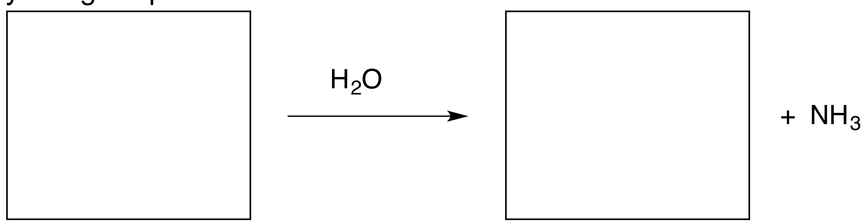


(iii) (*5 points*) Draw the abbreviated structure of **NADH** (copy from part **(i)**) to **complete the mechanism** in the synthesis of **proline**. This can be done in one step. It is ok to propose a mechanism with more steps as long as charges are consistent with physiological pH 7.4.



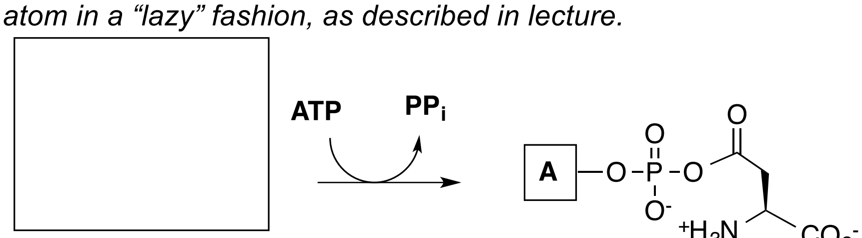
6. Reaction Mechanisms - *Complete either page 5 or 6*. Draw a large "X" over the page to skip or page 5 will be graded. **Show the mechanism for each step in the synthesis of asparagine from glutamine and aspartate**. Note that this is a slightly different pathway than that presented in lecture. Bring in acids (**H^+**) and bases (**:B**) and abbreviate structures as necessary, but be sure to draw out the bonds needed to draw the complete mechanism.

(i) (*10 points*) It's a good thing you memorized amino acid structures! Begin by drawing the full structures of **glutamine** and **glutamate**, then draw the **mechanism for hydrolysis**. This can be done in as few as two steps. It is ok to propose a mechanism with more steps as long as charges are consistent with physiological pH 7.4.



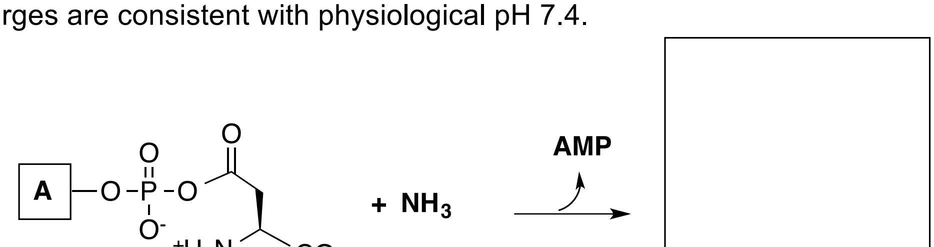
Glutamine **Glutamate**

(ii) (*10 points*) Begin by drawing the structure of **aspartate** and the **three phosphate groups in ATP**, then draw the **mechanism for ATP activation**. *Hint: you may draw this nucleophilic acyl substitution reaction on the P atom in a "lazy" fashion, as described in lecture.*



Aspartate

(iii) (*10 points*) Begin by drawing the structure of **asparagine**, then draw the mechanism for its synthesis. This can be done in as few as two steps. It is ok to propose a mechanism with more steps as long as charges are consistent with physiological pH 7.4.



Asparagine

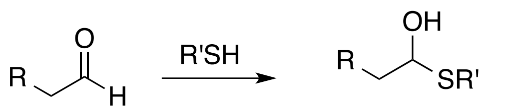
7. (*30 points*) **Active Site Design**

Propose mechanisms for both steps in the conversion of an aldehyde into a thioester by **designing the enzyme active sites.** Use the appropriate **amino acid residues as acids and bases**, where appropriate. **Redraw each reactant** in the space below and **add at least one stabilizing factor per reactant** to hold it in place in the active site. The appropriately **abbreviated structure of NADH** is on page 5. Use this as an aid in drawing the **structure of NAD$^+$** needed in the second step. It is recommended, though not required, that you make a list of all bonds broken and formed before anything else.

READ THE INSTRUCTIONS ABOVE CAREFULLY BEFORE YOU BEGIN!

The biological conversion of an aldehyde to a thioester occurs in two steps:

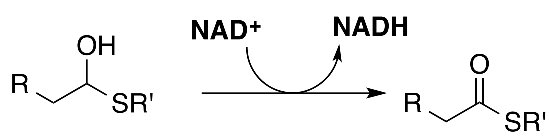
(1) Nucleophilic addition of thiol – one step (no intermediate)*



Thiohemiacetal

Bonds broken *Bonds formed*

(2) Oxidation of thiohemiacetal – one step (no intermediate)*



Thiohemiacetal

Bonds broken *Bonds formed*

** Note: It is most efficient to perform each reaction in one step without an intermediate. However, it is acceptable to propose mechanisms with two steps as long as charges are consistent with physiological pH 7.4.*