Chemistry 2713 Name: ________________________

Biochemistry Student Number: _______________

Winter 2018

Midterm Exam #1

Answer all questions on the test. Each multiple choice question has a value of two points and must be answered in pencil on the bubble sheet provided. The value for each short answer question is given with the questions.

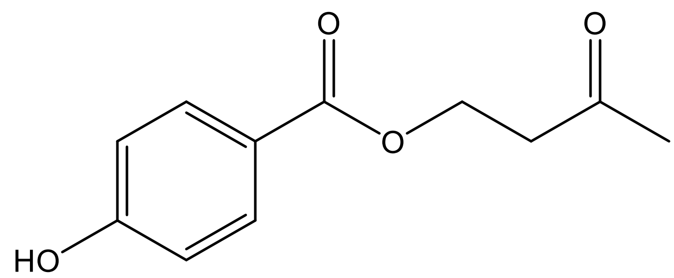
The final page of the exam has equations and other relevant information. Feel free to remove this page, but the rest of the midterm and the bubble sheet must be submitted to receive marks for all questions.

Programmable calculators are not allowed.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.84	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.0	89 Ac 227.0	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 (284)	114 Fl (289)	115 Mc (288)	116 Lv (293)	117 Ts (294)	118 Og (294)

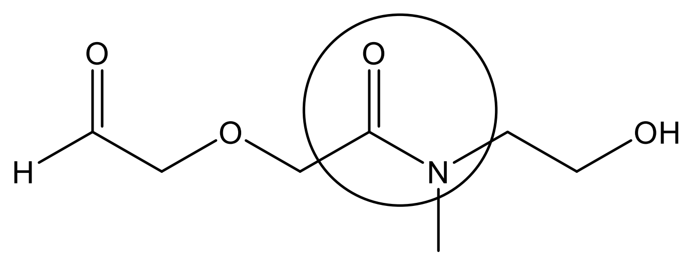
Multiple Choice		/70
Drawing		/25
Bonus		/5
Total		/95

Question 1
The molecule shown below *does not* contain a/an _________ functional group.



a. alcohol
b. carbonyl
c. ester
d. ether
e. ketone

Question 2
The functional group circled in the molecule is a/an:

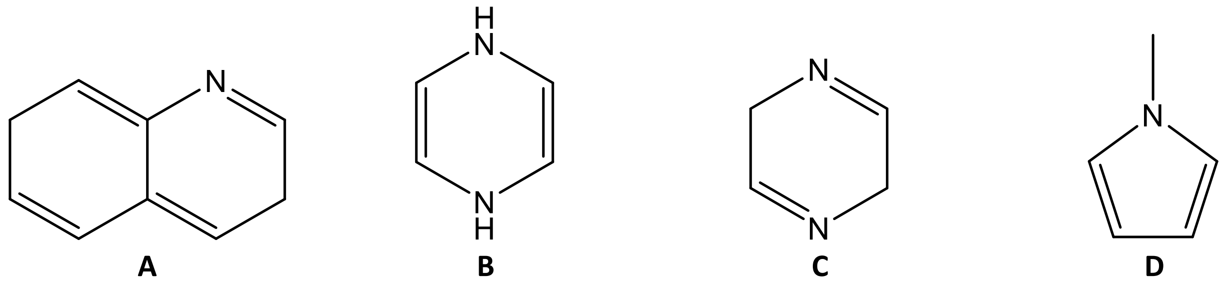


a. alcohol
b. aldehyde
c. amide
d. amine
e. ether

Question 3
Aromatic molecules follow what pattern of the number of electrons in their π-electron cloud?

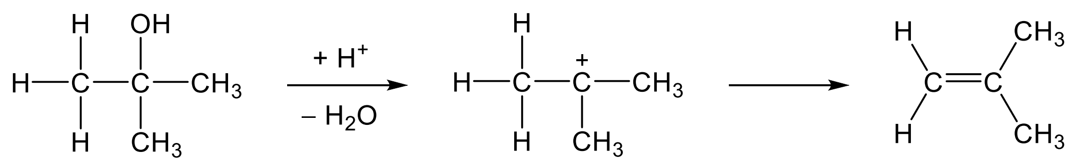
a. 2n
b. 2n+2
c. 2n+4
d. 4n
e. 4n+2

Question 4
Which of the following molecules is aromatic?



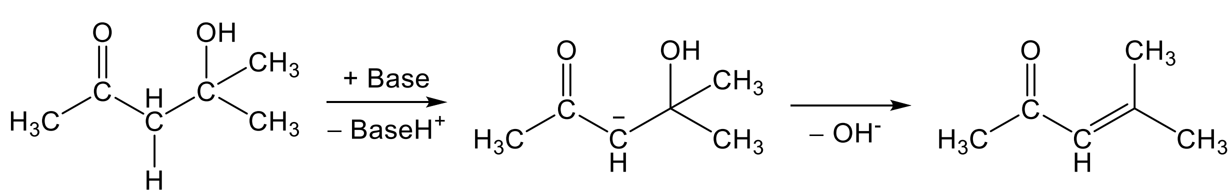
a. A
b. B
c. C
d. D
e. none of the molecules are aromatic

Question 5
What type of mechanism is shown by the following reaction scheme:



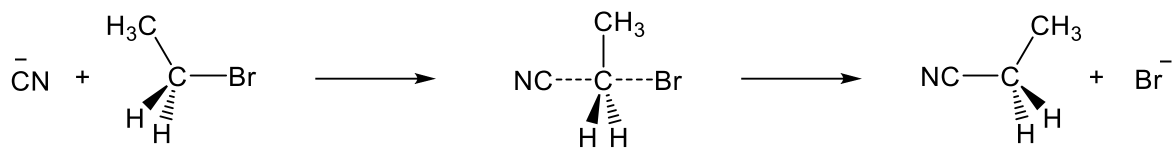
a. S_N1
b. S_N2
c. E1
d. E1cb
e. E2

Question 6
What type of mechanism is shown by the following reaction scheme:



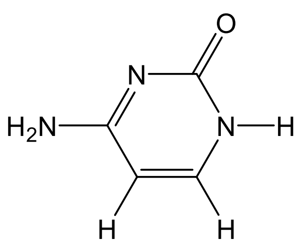
a. S_N1
b. S_N2
c. E1
d. E1cb
e. E2

Question 7
What type of mechanism is shown by the following reaction scheme:



a. S_N1
b. S_N2
c. E1
d. E1cb
e. E2

Question 8
Cytosine, shown below, is an example of what class of organic base?



a. purines
b. purimides
c. pyridines
d. pyrimidines
e. pyrroles

Question 9
Polypeptides are an example of what type of molecule?

a. carbohydrates
b. clathrates
c. DNA
d. macromolecules
e. metabolites

Question 10
Peptide bonds are formed through condensation reactions between

a. amides and amines
b. amides and carboxylic acids
c. amines and carboxylic acids
d. amines and esters
e. carboxylic acids and esters

Question 11
Organisms that obtain energy by degrading food molecules obtained by consuming other organisms are called:

a. anabolic
b. autotrophs
c. catabolic
d. heterotrophs
e. foodtrophs

Question 12
The metabolic pathway that involves the degradation of large, complex molecules into smaller, simpler products is called:

a. anabolic
b. autotropic
c. catabolic
d. heterobolic
e. syntholic

Question 13
Molecules that have both an affinity towards water (water-loving) and are repelled by water are called:

a. aquatropic
b. hydrophobic
c. hydrophilic
d. amphipathic
e. ambiphilic

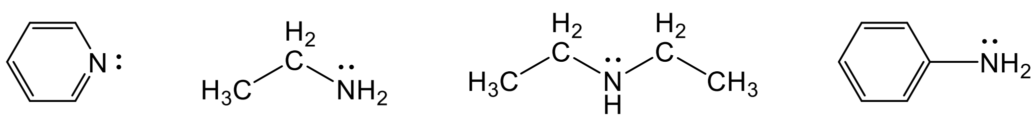
Question 14
When small amounts of fatty acids salts are added to water, __________ form(s).

a. macromolecules
b. clathrates
c. micelles
d. osmosis
e. zeolytes

Question 15
When cells are in a solution with higher solute concentration than in the cells, this is known as a(n) _____ solution.

a. equitonic
b. hypertonic
c. hypotonic
d. isotonic
e. subtonic

Question 16
Rank the following bases by decreasing base strength:



Pyridine Ethylamine Diethylamine Aniline

a. Aniline > Diethylamine > Ethylamine > Pyridine
b. Diethylamine > Ethylamine > Aniline > Pyridine
c. Diethylamine > Ethylamine > Pyridine > Aniline
d. Ethylamine > Diethylamine > Aniline > Pyridine
e. Ethylamine > Diethylamine > Pyridine > Aniline

Question 17
Rank the following types of non-covalent bonding by the strength of the interaction:

Dipole-Dipole Dipole-Induced Dipole Hydrogen Bonds Induced Dipole-Induced Dipole

a. Dipole-Dipole > Dipole-Induced Dipole > Induced Dipole-Induced Dipole > Hydrogen Bonds
b. Induced Dipole-Induced Dipole > Dipole-Induced Dipole > Dipole-Dipole > Hydrogen Bonds
c. Hydrogen Bonds > Dipole-Dipole > Dipole-Induced Dipole > Induced Dipole-Induced Dipole
d. Hydrogen Bonds > Induced Dipole-Induced Dipole > Dipole-Induced Dipole > Dipole-Dipole
e. Dipole-Dipole > Dipole-Induced Dipole > Hydrogen Bonds > Induced Dipole-Induced Dipole

Question 18
When blood pH falls below 7.35, a condition called _____ occurs.

a. acidosis
b. acidphilic
c. alkaphilic
d. alkalosis
e. acidalkosis

Question 19
Which of the following is one of the important buffers in our bodies?

a. acetate buffer
b. bicarbonate buffer
c. carbonate buffer
d. carbohydrate buffer
e. none of the above are important physiological buffers

Question 20
Ammonium chloride, NH_4Cl, is an example of a:

a. strong acid
b. strong base
c. weak acid
d. weak base
e. buffer

Question 21
Which weak acid/conjugate base pair would be the best choice for a buffer with a pH of 4.0?

a. acetic acid / acetate
b. benzoic acid / benzoate
c. formic acid / formate
d. lactic acid / lactate
e. propanoic acid / propanoate

Question 22
A semipermeable membrane separates two aqueous solutions X and Y at 20 °C.
Determine the net flow of water (if any). Assume 100% dissociation for salts.

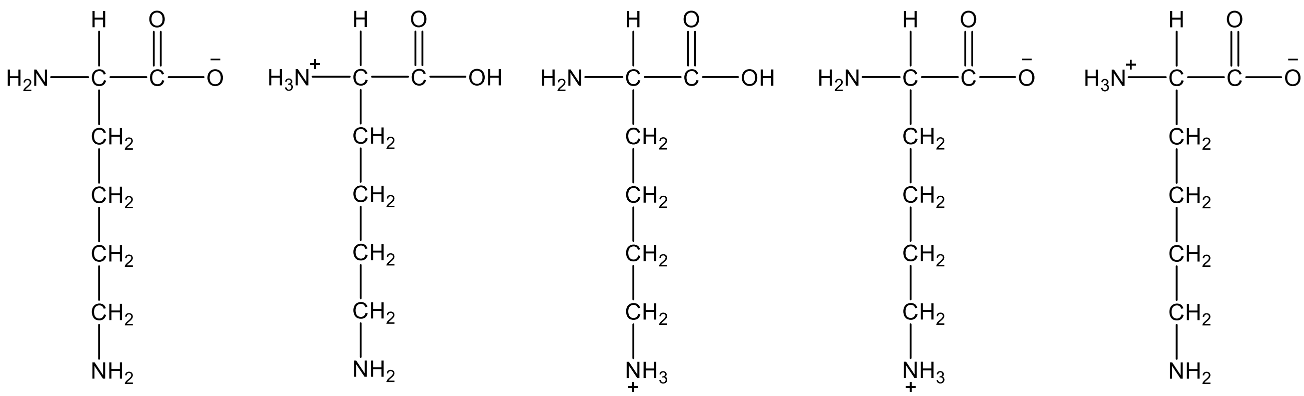
Solution X: 0.3 M $Al(NO_3)_3$ Solution Y: 0.4 M $Mg(NO_3)_2$

a. towards X
b. towards Y
c. towards both X and Y
d. no net flow
e. need more data

Question 23

Based on the pK_a values given below, what will be the major form of lysine at pH 9?

Amino Acid	pK_1 (–COOH)	pK_2 ($-NH_3^+$)	pK_3 (–R)
Lysine	2.18	8.95	10.79

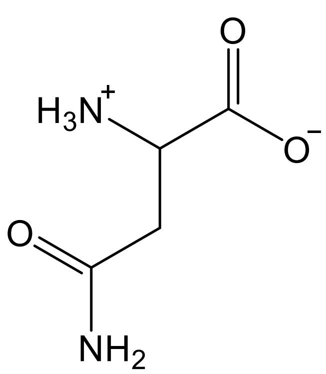


A B C D E

a. A
b. B
c. C
d. D
e. E

Question 24

Asparagine is a polar amino acid, shown below at pH 7. What is the maximum theoretical number of water molecules that one asparagine molecule at pH 7 can hydrogen bond with (assuming they all fit)?



a. 5
b. 7
c. 10
d. 13
e. 15

Question 25
If a weak acid is titrated with a strong base, the pH at the equivalence point will be:

a. 1
b. <7
c. 7
d. >7
e. more information is needed

Question 26
Given that blood exerts an osmotic pressure of 7.64 atm, adding blood to which if the following dilute NaCl solutions would result in an isotonic solution at 37 °C? (assume complete ionization)

a. 0.05 M
b. 0.15 M
c. 0.30 M
d. 0.60 M
e. 1.85 M

$$\pi = iMRT$$
$$M = \frac{\pi}{iRT} = \frac{7.64\ atm}{(2)(0.08206\ L \cdot bar \cdot K^{-1} \cdot mol^{-1})(37 + 273K)} = 0.150\ mol \cdot L^{-1}$$

Question 27
Bovine serum albumin (BSA) is a biochemically useful protein. A 0.296 gram sample of bovine serum albumin is dissolved in water to make 150 mL of solution, and the osmotic pressure of the solution at 25 °C is found to be 0.736 mbar. Calculate the molecular mass of bovine serum albumin.

a. 70 g mol^{-1}
b. 5600 g mol^{-1}
c. 12,000 g mol^{-1}
d. 66,000 g mol^{-1}
e. 410,000 g mol^{-1}

$$\pi = iMRT$$
$$M = \frac{\pi}{iRT} = \frac{0.736 \times 10^{-3} bar}{(1)(0.08314\ L \cdot bar \cdot K^{-1} \cdot mol^{-1})(25 + 273K)} = 2.97 \times 10^{-5}\ mol \cdot L^{-1}$$

$$C = n/V$$
$$n = C \times V = (2.97 \times 10^{-5} mol \cdot L^{-1})(0.150L) = 4.46 \times 10^{-6}\ mol$$

$$MM = \frac{m}{n} = \frac{0.296g}{4.46 \times 10^{-6} mol} = 66{,}427 g \cdot mol^{-1}$$

Question 28

On average, the pH of ketchup is 3.9. What is the average hydrogen ion concentration [H^+] in ketchup?

a. 3.90×10^{-7} M
b. 3.90×10^{-5} M
c. 1.26×10^{-4} M
d. 1.00×10^{-3} M
e. 7.90×10^{-3} M

$$pH = -\log[H^+]$$
$$[H^+] = 10^{-pH} = 1.26 \times 10^{-4} M$$

Question 29

What is the pH of a buffer containing 1.30 M phenol and 1.20 M sodium phenolate?

a. 4.11
b. 8.89
c. 9.86
d. 9.89
e. 9.92

$$pH = pKa + \log\frac{[base]}{[acid]} = 9.89 + \log\frac{1.2}{1.3} = 9.89 - 0.03 = 9.86$$

Question 30
What is the pH of a 0.500 M formic acid, HCOOH, solution?

a. 0.30
b. 1.72
c. 2.03
d. 3.45
e. 3.75

weak acid → use ICE table

	HA	⇆	H^+	+	A^-
i	0.500		0		0
c	–x		+x		+x
e	0.500 – x		x		x

$$K_a = 1.78 \times 10^{-4} = \frac{x^2}{0.500 - x} \approx \frac{x^2}{0.500}$$

$$check\ assumption: \frac{[HA]_{init}}{K_a} = \frac{0.500}{1.78 \times 10^{-4}} = 2809 > 400 \therefore valid\ assumption$$

$$x^2 = (1.78 \times 10^{-4})(0.500) = 8.90 \times 10^{-5}$$

$$x = 9.43 \times 10^{-3} M = [H^+]$$

$$pH = -\log[H^+] = -\log 9.43 \times 10^{-3} = 2.03$$

Question 31
What is the pH of a 1.0 M sodium hydrogen tartrate, $Na[HO_2CCH(OH)CH(OH)CO_2]$, solution?

a. 2.20
b. 2.89
c. 3.64
d. 4.40
e. 7.29

monodeprotonated diprotic acid → pH is the average of pK_a values

$$pH = \frac{pK_{a1} + pK_{a2}}{2} = \frac{2.89 + 4.40}{2} = 3.64$$

Question 32

If a 0.25 M buffer solution of acetic acid and sodium acetate has a pH of 4.45, what is the concentration of acetate?

a. 0.062 M
b. 0.082 M
c. 0.12 M
d. 0.17 M
e. 0.23 M

$$pH = 4.45 = pKa + \log\frac{[base]}{[acid]} = 4.76 + \log\frac{[base]}{[acid]}$$
$$-0.31 = \log\frac{[base]}{[acid]}$$
$$\frac{[base]}{[acid]} = 10^{-0.31} = 0.4898$$

$$let\ x = [base]\ and\ [acid] = 0.25 - x$$

$$\frac{x}{0.25 - x} = 0.4898$$
$$x = 0.4898(0.25 - x) = 0.1224 - 0.4898x$$
$$1.4898x = 0.1224$$
$$x = 0.082M = [base]$$
$$[acid] = 0.25 - x = 0.25 - 0.082 = 0.168M$$

Question 33

Calculate the pH during the titration of 25.00 mL of 0.1000 M NH_3 with 0.1000 M HCl solution after 25.00 mL of titrant has been added. The pK_b for ammonia is 4.75.

a. 2.87
b. 3.02
c. 3.67
d. 5.13
e. 5.28

$$mol\ weak\ base = (0.1000M)(0.02500L) = 0.0025mol$$
$$mol\ strong\ acid = (0.1000M)(0.02500L) = 0.0025mol$$

	B	+	H^+	→	HB^+
i	0.0025		0.0025		0
c	–0.0025		–0.0025		+0.0025
f	0		0		0.0025

only weak acid remains → use ICE table

$$[HB^+] = \frac{mol}{total\ volume} = \frac{0.0025mol}{0.050L} = 0.0500M$$

	HA	⇆	H⁺	+	A⁻
i	0.050		0		0
c	–x		+x		+x
e	0.050 – x		x		x

$$pK_a = pK_w - pK_b = 14 - 4.75 = 9.25$$
$$K_a = 10^{-pK_a} = 10^{-9.25} = 5.62 \times 10^{-10} = \frac{x^2}{0.0500 - x} \approx \frac{x^2}{0.0500}$$
$$check\ assumption: \frac{[HA]_{init}}{K_a} = \frac{0.0500}{5.62 \times 10^{-10}} = 8.90 \times 10^7 > 400 \therefore valid\ assumption$$
$$x^2 = (5.62 \times 10^{-10})(0.0500) = 2.81 \times 10^{-11}$$
$$x = 5.30 \times 10^{-6}M = [H^+]$$

$$pH = -\log[H^+] = -\log 5.30 \times 10^{-6} = 5.28$$

Question 34
Calculate the pH during the titration of 50.00 mL of 0.1000 M formic acid with 0.1000 M KOH solution after 60.00 mL of titrant has been added.

a. 11.00
b. 11.10
c. 11.96
d. 12.22
e. 12.30

$$mol\ weak\ base = (0.1000M)(0.05000L) = 0.0050mol$$
$$mol\ strong\ acid = (0.1000M)(0.06000L) = 0.0060mol$$

	HA	+	OH⁻	→	A⁻
i	0.0050		0.0060		0
c	–0.0050		–0.0050		+0.0050
f	0		0.0010		0.0050

excess strong base → strong base determines pH

$$[OH^-] = \frac{mol}{total\ volume} = \frac{0.0010mol}{0.110L} = 0.00909M$$

$$pOH = -\log[OH^-] = -\log 0.00909 = 2.04$$
$$pH = 14 - pOH = 14 - 2.04 = 11.96$$

Question 35

A solution of an unknown monoprotic acid has an equilibrium concentration of 7.69 × 10^{-7} M of undissociated acid (i.e., HA) a pH of 5.50. What is the identity of the acid?

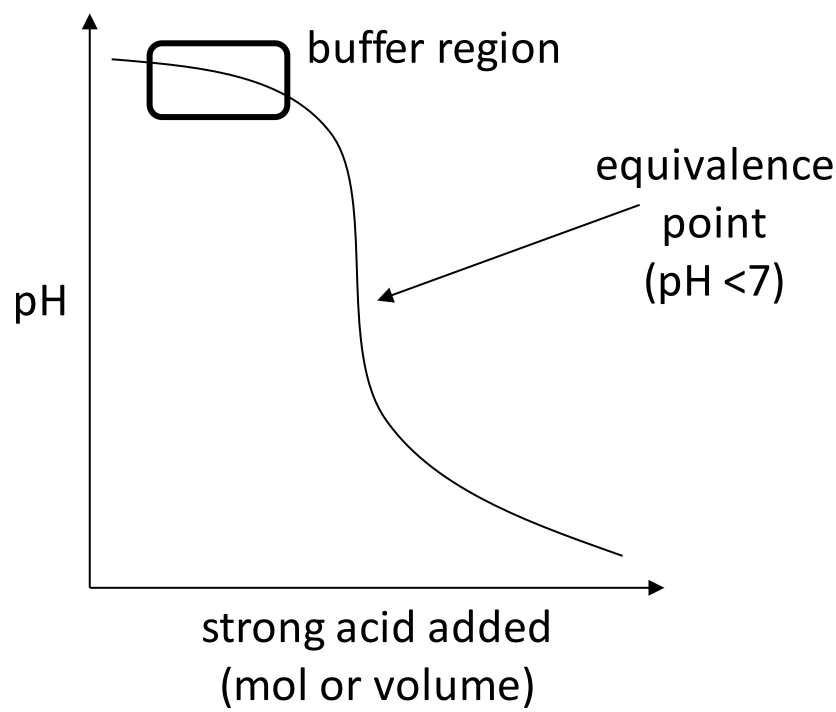
a. acetic acid
b. butanoic acid
c. formic acid
d. lactic acid
e. propanoic acid

$$[H^+] = 10^{-pH} = 10^{-5.50} = 3.16 \times 10^{-6} = [A^-]$$

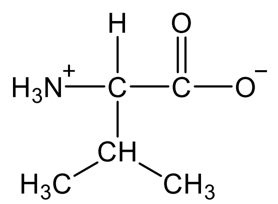
$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{(3.16 \times 10^{-6})(3.16 \times 10^{-6})}{7.69 \times 10^{-7}} = 1.30 \times 10^{-5} = K_a(propanoic\ acid)$$

Question 36 (5 points)

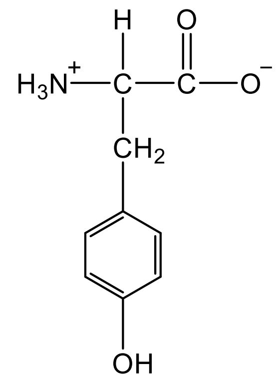
Sketch a rough titration curve of a weak base with strong acid. Label the axes, identify the equivalence point and the optimal buffer region.



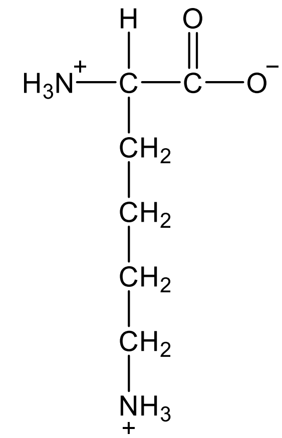
Question 37 (15 points)
Draw the primary (dominant) structure of the indicated amino acids at pH 7



Valine

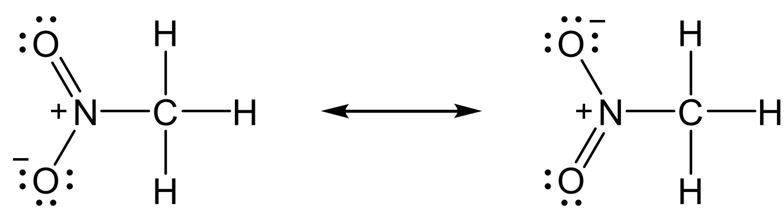


Tyrosine

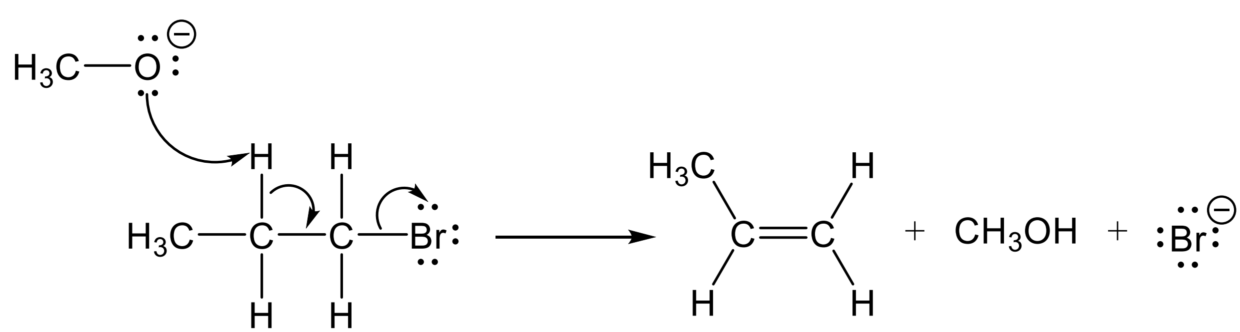


Lysine

Question 38 (5 points)
Draw the Lewis structure of nitromethane, CH_3NO_2, including all resonance structures.



Bonus Question (5 points)
Draw the E2 mechanism for the reaction of 1-bromopropane with methoxide.



Potentially Useful Information

Equations

$pH = -\log [H^+]$

$K_w = [H^+][OH^-]$

$\pi = iMRT$

$pOH = -\log [OH^-]$

$K_w = K_a \times K_b$

$pK_w = pH + pOH$

$pK_a = -\log K_a$

$pK_w = pKa + pK_b$

$pK_b = -\log K_b$

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_b = \frac{[HB^+][OH^-]}{[B]}$$

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

Constants

Gas Constant, R	0.08206 L·atm·K^{-1}·mol^{-1} 0.08314 L·bar·K^{-1}·mol^{-1} 8.314 J mol^{-1} K^{-1}
Ion Product of Water at 25 °C, K_w	1.0×10^{-14}

Dissociation Constants and pK_a Values for Selected Monoprotic Weak Acids

Weak Acid	K_a	pK_a
Acetic Acid, CH_3COOH	1.76×10^{-5}	4.76
Benzoic Acid, C_6H_5COOH	6.31×10^{-5}	4.20
Butanoic Acid, $CH_3CH_2CH_2CH_2COOH$	1.54×10^{-5}	4.81
Formic Acid, HCOOH	1.78×10^{-4}	3.75
Lactic Acid, $CH_3CH(OH)COOH$	1.38×10^{-4}	3.86
Phenol, C_6H_5OH	1.28×10^{-10}	9.89
Propanoic Acid, CH_3CH_2COOH	1.30×10^{-5}	4.89

Dissociation Constants and pK_a Values for Selected Diprotic Weak Acids

Acid	K_{a1}	K_{a2}	pK_{a1}	pK_{a2}
Ascorbic Acid, $C_6H_8O_6$	1.0×10^{-5}	5.0×10^{-12}	5.00	11.30
Carbonic Acid, H_2CO_3	4.5×10^{-7}	5.61×10^{-11}	6.35	10.33
Malonic Acid, $HOOCCH_2COOH$	1.4×10^{-3}	2.0×10^{-6}	2.85	5.70
Succinic Acid, $HOOC(CH_2)_2COOH$	6.2×10^{-5}	2.3×10^{-6}	4.21	5.64
Tartaric Acid, HOOCCH(OH)CH(OH)COOH	1.3×10^{-3}	4.0×10^{-5}	2.89	4.40