Chemistry 2713 Name: _____

Biochemistry Student Number: _____

Winter 2018

Midterm Exam #3

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																	18
1 H 1.008	2											13	14	15	16	17	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	3	4	5	6	7	8	9	10	11	12	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		/60
Structure Drawing		/20
Bonus		/6
Total		/75

Question 1
Which of the following is *not* a function of proteins?

a. catalysis
b. energy storage
c. regulation
d. structure
e. transport

Question 2
Which of the following is *not* an example of a conjugated protein?

a. glycoproteins
b. lipoproteins
c. metalloproteins
d. peptoproteins
e. phosphoproteins

Question 3
Which of the following *does not* describe a globular protein?

a. generally function in structure and support roles
b. hemoglobin is an example
c. often function as enzymes or transport proteins
d. peptide chains folded into spherical shapes
e. water soluble

Question 4
The amino acid sequence of a polypeptide is referred to as its _____structure.

a. primary
b. secondary
c. tertiary
d. quaternary
e. peptide

Question 5
When an amino acid sequence changes due to the substitution of a chemically different amino acid without change in the protein's function, the position is called:

a. conservative
b. consistent
c. invariant
d. steady-state
e. variable

Question 6
α-helices are associated with what level of protein structure?

a. primary
b. secondary
c. tertiary
d. quaternary
e. peptide

Question 7
Which of the following amino acids would foster an α-helix?

a. alanine
b. aspartate
c. glutamate
d. glycine
e. proline

Question 8
Which of the following amino acids would be found in a β-hairpin turn?

a. alanine
b. lysine
c. phenylalanine
d. proline
e. tyrosine

Question 9
Which of the following interactions do *not* stabilize tertiary structure?

a. hydrophobic interactions
b. electrostatic interactions
c. hydrogen bonds
d. covalent bonds
e. none of the above

Question 10
Which pair of amino acids can form salt bridges between their side chains at physiological pH?

a. serine and glutamine
b. tryptophan and phenylalanine
c. lysine and histidine
d. aspartate and arginine
e. cysteine and glutamate

Question 11
Which pair of amino acids can form hydrogen bonds between their side chains at physiological pH?

a. serine and valine
b. alanine and threonine
c. lysine and histidine
d. aspartate and glutamate
e. glycine and leucine

Question 12
Invariant amino acids in a protein are presumed:

a. to be unimportant in the structure and function of the protein
b. to be essential to the structure and function of the protein
c. always to occur at the beginning of the amino acid sequence of a protein
d. always to occur at the end of the amino acid sequence of a protein
e. to be part of the prosthetic group

Question 13
Reducing agents denature proteins by disrupting which of the following?

a. hydrogen bonds
b. disulfide bridges
c. hydrophobic interactions
d. salt bridges
e. water bridges

Question 14
Organic solvents denature proteins by disrupting which if the following?

a. hydrogen bonds
b. disulfide bridges
c. hydrophobic interactions
d. salt bridges
e. water bridges

Question 15
What type of process is the denaturation of egg albumin by heating?

a. equilibrium
b. exothermic
c. irreversible
d. osmotic
e. reversible

Question 16
Collagen is classified as which of the following types of protein?

a. enzyme
b. structural
c. movement
d. defence
e. regulatory

Question 17
Aldol condensation reactions occur between which of the following functional groups?

a. alcohol + alcohol
b. alcohol + aldehyde
c. alcohol + alkene
d. aldehyde + aldehyde
e. aldehyde + alkene

Question 18
Which type of chromatography can separate proteins based on enzyme-substrate binding?

a. affinity chromatography
b. ion-exchange chromatography
c. size-exclusion chromatography
d. thin-layer chromatography
e. all types of chromatography

Question 19
In gel-filtration chromatography:

a. large proteins elute first
b. negatively charged proteins elute first
c. non-polar proteins elute first
d. positively charged proteins elute first
e. small proteins elute first

Question 20
Catalysts are effective because they:

a. decrease the activation energy of a reaction
b. decrease the rate of the reverse reaction
c. increase the energy released during a reaction
d. increase the entropy (disorder) of the products
e. increase the temperature of the reaction mixture

Question 21
The minimum amount of energy required to bring about a chemical reaction is called:

a. free energy of activation
b. enthalpy of reaction
c. free energy
d. standard free energy
e. transition state

Question 22
The induced fit model of enzyme activity proposes that each

a. enzymes acts only when fit with a co-factor that induces enzymatic activity
b. enzyme binds a specific substrate because the active site and substrate have rigid complementary structures
c. enzyme binds a specific substrate because the active site and substrate have flexible structures that conform to each other
d. enzyme can react with only a single substrate
e. enzyme has a higher activity than a related inorganic catalyst

Question 23
Enzyme studies are best carried out:

a. in dilute aqueous solution
b. in highly concentrated solutions of the enzyme
c. in highly concentrated solutions of the substrate
d. in the presence of an inert crowding agent
e. in the presence of a membrane

Question 24
In contrast to inorganic catalysts, enzymes have an intricately shaped surface called the _____.

a. substrate
b. cofactor
c. active site
d. apoenzyme
e. holoenzyme

Question 25
Alcohol dehydrogenase without NAD^+ is called a _____:

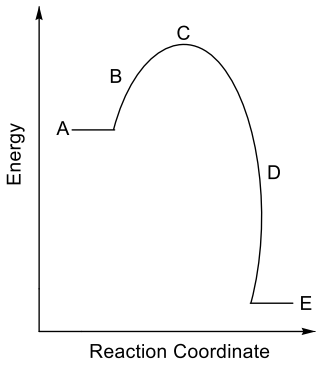
a. apoenzyme
b. holoenzyme
c. substrate
d. cofactor
e. coenzyme

Question 26
The steady state assumption states that if:

k_1 = the rate constant for ES formation
k_2 = the rate constant for ES dissociation
k_3 = the rate constant for product formation

a. k_2 is negligible compared to k_3
b. the rate of formation of ES is equal to the rate of its degradation over the course of the reaction
c. the rate of formation of ES exceeds the rate of degradation over the course of the reaction
d. k_3 is negligible compared to k_2
e. product concentration at the beginning of the reaction is low

Question 27
Consider the following diagram. What constitutes the activation energy for the forward reaction?



a. C – A
b. C – E
c. E – A
d. A – C
e. A – E

Question 28
In irreversible inhibition, increasing the concentration of substrate:

a. decreases the reaction rate
b. double the reaction rate
c. has no effect on the reaction rate
d. overcomes the inhibition, increasing the reaction rate up to $½V_{max}$
e. overcomes the inhibition, increasing the reaction rate up to V_{max}

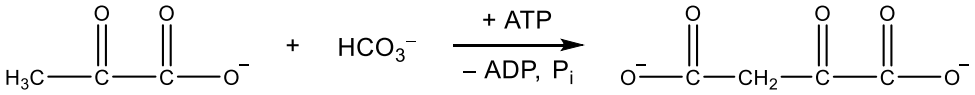
Question 29
In the Lineweaver-Burk double reciprocal plot the vertical intercept is equal to?

a. 1/[S]
b. 1/V
c. K_m/V_{max}
d. $1/V_{max}$
e. $-1/K_m$

Question 30
Which of the following amino acids is capable of acting as a general acid or general base at physiological pH ?

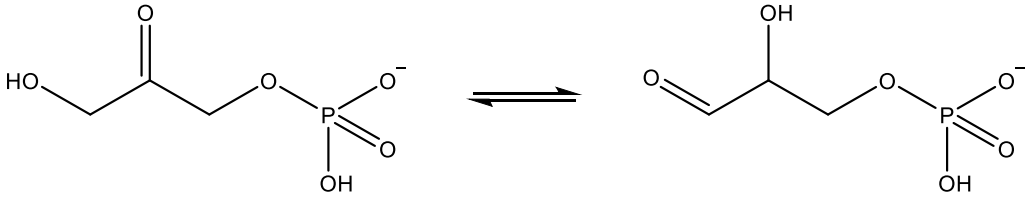
a. glycine
b. histidine
c. proline
d. tyrosine
e. tryptophan

Question 31
What type of enzyme catalyzes the following reaction?



a. hydrolase
b. lyase
c. ligase
d. oxidoreductase
e. transferase

Question 32
What type of enzyme catalyzes the following reaction?

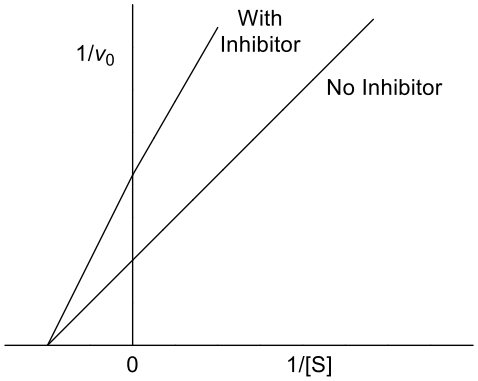


a. isomerase
b. lyase
c. ligase
d. oxidoreductase
e. transferase

Question 33
Alcohol dehydrogenase is an example of which of the following classes of enzymes?

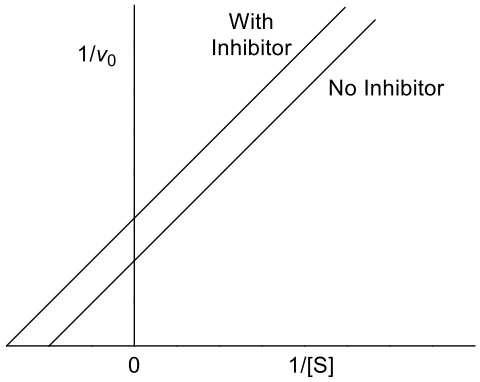
a. hydrolase
b. isomerase
c. lyase
d. oxidoreductases
e. transferase

Question 34
Consider the Lineweaver-Burk plot below. Identify the type of inhibitory action shown.



a. competitive inhibition
b. pure noncompetitive inhibition
c. mixed noncompetitive inhibition
d. uncompetitive inhibition
e. irreversible inhibition

Question 35
Consider the Lineweaver-Burk plot below. Identify the type of inhibitory action shown.



a. competitive inhibition
b. pure noncompetitive inhibition
c. mixed noncompetitive inhibition
d. uncompetitive inhibition
e. irreversible inhibition

Question 36
The kinetics for hydrolysis reactions in biological systems are assumed to follow:

a. zero-order reactions
b. first-order reactions
c. second-order reactions
d. pseudo-first-order reactions
e. pseudo-second-order reactions

Question 37
Which of the following amino acids cannot actively participate in a catalytic site?

a. serine
b. threonine
c. tyrosine
d. glycine
e. glutamine

Question 38
Which of the following is not an important metal in biological systems

a. Na^+
b. K^+
c. Mg^{2+}
d. Cu^{2+}
e. Al^{3+}

Question 39
Consider the following reaction data for the reaction of pyruvate with ADP and phosphate (P_i).

Exp	Concentration (M)			Rate ($M \cdot s^{-1}$)
	Pyruvate	ADP	P_i	
1	0.1	0.1	0.1	8.0×10^{-4}
2	0.2	0.1	0.1	1.6×10^{-3}
3	0.2	0.2	0.1	3.2×10^{-3}
4	0.1	0.1	0.2	3.2×10^{-3}

The reaction is _____ overall.

a. zero-order
b. first-order
c. second-order
d. third-order
e. fourth-order

$$order\ in\ Pyruvate: \frac{Rate(Exp2)}{Rate(Exp1)} = \frac{1.6 \times 10^{-3}}{8.0 \times 10^{-4}} = 2 = \frac{k[0.2]^x[0.1]^y[0.1]^z}{k[0.1]^x[0.1]^y[0.1]^z} = \left(\frac{0.2}{0.1}\right)^x = 2^x$$

$$x = \frac{\log 2}{\log 2} = 1$$

$$order\ in\ ADP: \frac{Rate(Exp3)}{Rate(Exp2)} = \frac{3.2 \times 10^{-3}}{1.6 \times 10^{-3}} = 2 = \frac{k[0.2]^x[0.2]^y[0.1]^z}{k[0.2]^x[0.1]^y[0.1]^z} = \left(\frac{0.2}{0.1}\right)^y = 2^y$$

$$y = \frac{\log 2}{\log 2} = 1$$

$$order\ in\ P_i: \frac{Rate(Exp4)}{Rate(Exp1)} = \frac{3.2 \times 10^{-3}}{8.0 \times 10^{-4}} = 4 = \frac{k[0.1]^x[0.1]^y[0.2]^z}{k[0.1]^x[0.1]^y[0.1]^z} = \left(\frac{0.2}{0.1}\right)^z = 2^z$$

$$z = \frac{\log 4}{\log 2} = 2$$

$$overall\ reaction\ order = 1 + 1 + 2 = 4$$

Question 40

Medical isotopes are a Canadian innovation. Technetium-99, the most commonly used medical radioisotope in the world, decomposes in a first-order process with a half-life of 6.01 h. How long before 95% of the radioactive technetium has decayed in a patient?

a. 0.445 h
b. 0.498 h
c. 5.71 h
d. 22.8 h
e. 26.0 h

$$t_{1/2} = \frac{\ln 2}{k}$$

$$k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{6.01h} = 0.1153h^{-1}$$

$$[S]_t = 0.05 \times [S]_0$$

$$\ln \frac{[S]_t}{[S]_0} = -kt$$

$$\ln \frac{0.05[S]_0}{[S]_0} = \ln 0.05 = -(0.1153h^{-1})t$$

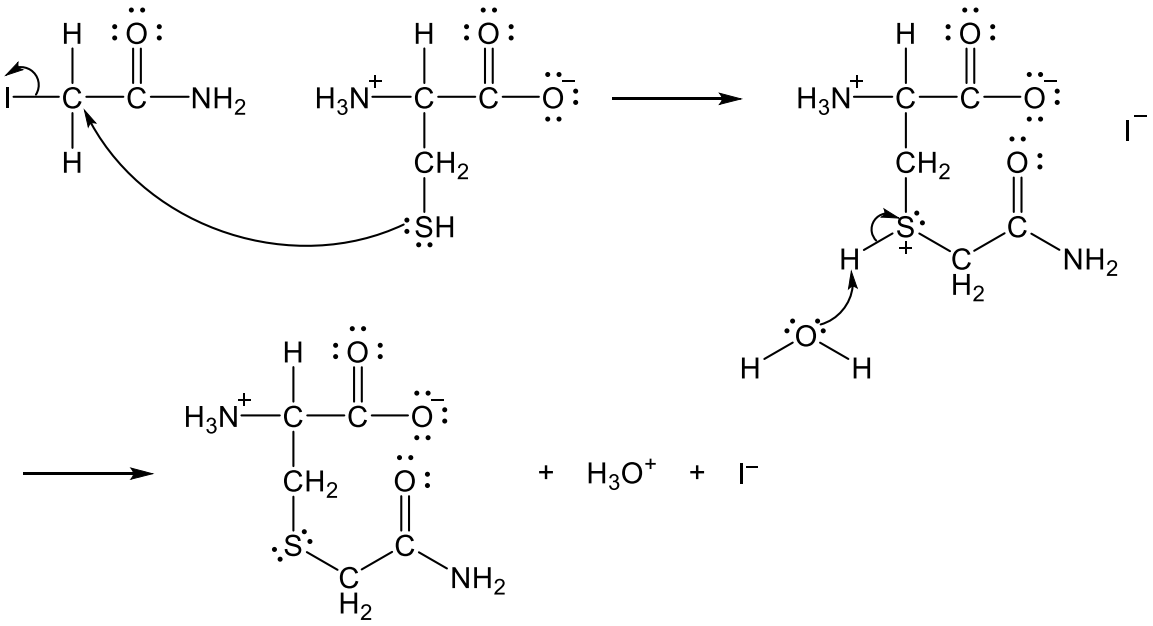
$$t = \frac{\ln 0.05}{-0.1153h^{-1}} = 26.0h$$

Question 41 (15 points)

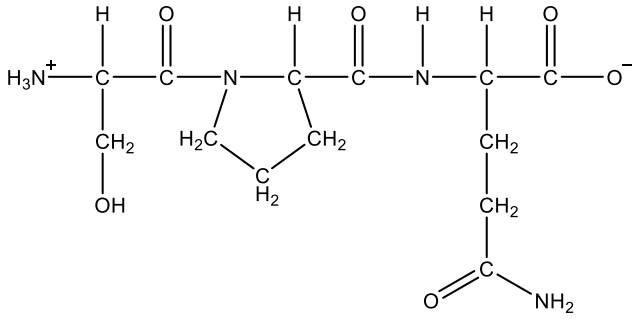
Draw the primary structure of the amino acid (indicated by its abbreviation) at physiological pH.

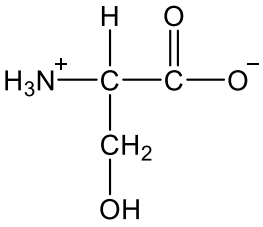
His	M	Ser

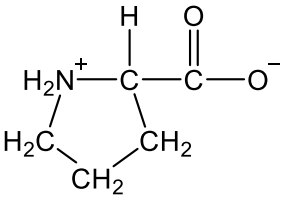
Question 42 (10 points)
Iodoacetamide (shown below) is an irreversible inhibitor of several enzymes that have a cysteine residue in their active sites. Draw an appropriate mechanism for the reaction of iodoacetamide with cysteine at physiological pH.

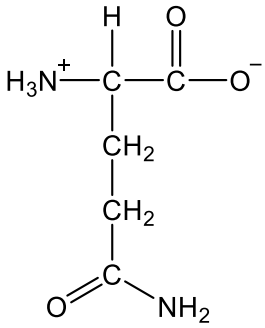


Question 43 (5 points)
Draw the product(s) at physiological pH of a protease enzyme acting on the following peptide:









Bonus Question (6 points)

The velocity of an enzyme-catalyzed reaction that follows Michaelis-Menten kinetics was measured at several substrate concentrations (shown below). Calculate K_m and V_{max}.

[S] (μM)	v_0 (mM·s^{-1})		1/[S]	$1/v_0$
0.25	0.179		4	5.587
0.50	0.263	→	2	3.802
1.00	0.345		1	2.899
2.00	0.408		0.5	2.451
4.00	0.449		0.25	2.225

$$slope = \frac{K_m}{V_{max}} = \frac{\Delta y}{\Delta x} = \frac{3.802 - 5.587}{2 - 4} = \frac{-1.785}{-2} = 0.8925$$

$$y = mx + b$$

$$5.587 = (0.8925)(4) + b$$

$$b = 5.587 - 3.57 = 2.017 = \frac{1}{V_{max}}$$

$$V_{max} = \frac{1}{2.017} = 0.496 mM \cdot s^{-1}$$

$$slope = 0.8925 = \frac{K_m}{V_{max}} = \frac{K_m}{0.496}$$

$$K_m = (0.8925)(0.496) = 0.443 \mu M$$

OR from the $x - intercept$

$$0 = (0.8925)x + 2.017$$

$$-0.8925x = 2.017$$

$$x = \frac{2.017}{-0.8925} = -2.26 = \frac{-1}{K_m}$$

$$K_m = \frac{-1}{-2.26} = 0.442\mu M$$

Potentially Useful Information

Equations

$\frac{k_F}{k_R} = \frac{[\mathrm{B}]^m}{[\mathrm{A}]^n} = K_{eq}$ for $k_F[\mathrm{A}]^n = k_R[\mathrm{B}]^m$

$v_0 = \frac{-\Delta[\mathrm{S}]}{\Delta t} = \frac{\Delta[\mathrm{P}]}{\Delta t}$

$v = \frac{\mathrm{V}_{max}[\mathrm{S}]}{[\mathrm{S}] + K_m}$

$k_{cat} = \frac{\mathrm{V}_{max}}{[E_t]}$

Rate Law Equations

Order	Rate Law	Integrated Rate Law	Half-Life
First	$Rate = k[\mathrm{S}]$	$\ln[\mathrm{S}] - \ln[\mathrm{S}]_0 = -kt$	$t_{1/2} = \frac{\ln 2}{k} \approx \frac{0.693}{k}$
Second (S_1+S_1 or $[S_1]=[S_2]$)	$Rate = k[\mathrm{S}_1]^2$	$\frac{1}{[\mathrm{S}_1]_t} - \frac{1}{[\mathrm{S}_1]_0} = kt$	$t_{1/2} = \frac{1}{k[\mathrm{S}_1]_0}$
Second ($[S_1]\neq[S_2]$)	$Rate = k[\mathrm{S}_1][\mathrm{S}_2]$	$\ln\frac{[\mathrm{S}_2][\mathrm{S}_1]_0}{[\mathrm{S}_1][\mathrm{S}_2]_0} = k([\mathrm{S}_2]_0 - [\mathrm{S}_1]_0)t$	

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}