**THE UNIVERSITY OF MANITOBA**

December 17, 2013 | 6:00 pm – 8:00 pm | Page 1 of 13
CHEM / MBIO 2770 | Elements of Biochemistry I | Final Examination
210 – 224 University Centre | Seats 203 – 328
Examiners: Dr. J. O'Neil and Dr. E. Nichols

***Instructions***

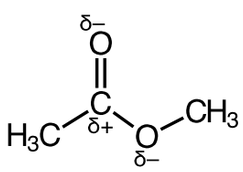
- *Please mark the Answer Sheet using PENCIL ONLY.*
- *Enter your NAME and STUDENT NUMBER on the Answer Sheet.*
- *The exam consists of 60 multiple-choice questions. Enter your answers on the Answer Sheet.*
- *There is only 1 correct answer for each question.*
- *Please read each question CAREFULLY.*
- *Please protect your Answer Sheet from the view of other students.*
- *Scratch Paper is available at the back of the examination.*

**LECTURE SECTION (Questions 1 to 45)**

1. _____ is the most abundant constituent of most cells.
   A) Protein
   B) Nucleic acid
   C) Carbohydrate
   D) Lipid
   E) Water

2. _____ is the most electronegative atom.
   A) Oxygen.
   B) Hydrogen.
   C) Carbon.
   D) Nitrogen.
   E) Phosphorous.

3. The following structure represents a(n) _____




   A) Carboxylic acid.
   B) Ester.
   C) Thioester.
   D) Ketone.
   E) Aldehyde.

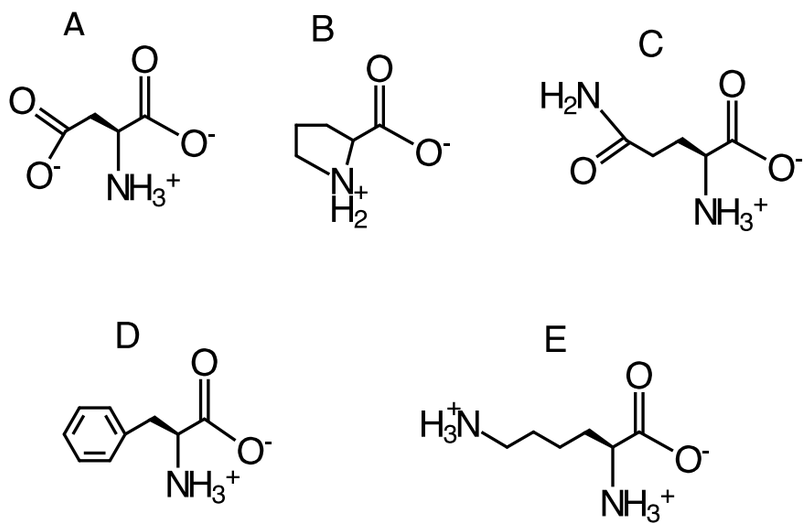
4. Potential energy _____
   A) is the energy of an object owing to its position in a field.
   B) is the heat energy of an object at constant pressure.
   C) is the energy of an object owing to its motion.
   D) is a measure of the disorder of a system.
   E) is the capacity of a system to do work or release heat.

5. Water exists as a H-bonded network with an average of ___ H-bonds per water molecule in solid ice and ____ H-bonds per water in the liquid.
   A) 1, 2
   B) 3, 5
   C) 4, 3.4
   D) 1.2, 3.6
   E) 4, 5

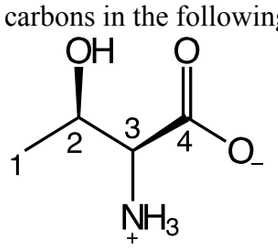
6. What is the concentration of the form of serine in which the amino and carboxyl groups are both protonated in a 50 mL solution of 100 mM serine at pH 1.8? The $pK_a$ of the carboxyl group is 2.2 and the $pK_a$ of the amino group is 9.2.
   A) 1.4 mM
   B) 3.6 mM
   C) 20 mM
   D) 50 mM
   E) 71.5 mM

7. What is the pH after 10 mL of 500 mM NaOH are added to the solution of serine in question 6?
   A) 1.8.
   B) 5.7.
   C) 8.8.
   D) 9.2.
   E) 9.6.

8. Identify the amino acid proline.




9. Identify the chiral carbons in the following amino acid:




   A) 1 only
   B) 1 and 2 only
   C) 2 and 4 only
   D) 3 only
   E) 2 and 3 only

10. In amino acid analysis the reagent Ninhydrin performs which function?
    A) It is an ion exchange resin used to separate the individual amino acids.
    B) Upon reaction with the amino acids it yields a purple pigment used to quantify the amino acids.
    C) It is used to hydrolyze a protein into individual amino acid components.
    D) It reacts with each amino acid producing a distinctly different colour used to measure the amounts of each amino acid
    E) It is used as a standard to calibrate ε in Beer's Law.

11. Since the protein backbone__i__ angle is fixed, the backbone conformation is determined by the __ii__ and ___iii___ bond angles.
    A) i = ϕ; ii = ψ; iii = ω.
    B) i = ω; ii = ϕ; iii = ψ.
    C) i = ψ; ii = ω; iii = ϕ.
    D) i = ϕ; ii = ω; iii = ψ.
    E) i = χ; ii = ϕ; iii = ω.

12. Tertiary structure is defined as:
    A) The way in which separate folded monomeric protein subunits associate to form oligomeric proteins.
    B) The sequence of amino acids.
    C) Hydrogen bonding interactions between adjacent amino acid residues in helical or pleated segments.
    D) A classification of fibrous proteins.
    E) The folding of a single polypeptide chain in three-dimensional space.

13. Identify the **FALSE** statement:
    A) β–strands are conformations in which the polypeptide backbone forms a tightly coiled structure.
    B) β–strands can form sheets in which the side-chains are alternatively above and below the plane of the sheet.
    C) β–strands are structures in which the polypeptide is in an extended conformation.
    D) β–strands can form parallel or antiparallel sheets held together by H-bonding.
    E) β–strands are the main constituent of soft, flexible silk fibroin.

14. In affinity chromatography, _____i_____ bind immobilized _____ii_____ and are eluted by the application of high concentrations of free _____iii_____
    A) i = amino acids ii = proteins iii = base.
    B) i = lipids; ii = silica gel; iii = acid.
    C) i = proteins; ii = amino acids; iii = hormones.
    D) i = carbohydrates; ii = Ninhydrin; iii = acid.
    E) i = proteins; ii = ligand; iii = ligand.

15. Which of the following statements about a plot of $V_0$ *vs*. [S] for an enzyme that follows allosteric kinetics is **FALSE**?
    A) The [S] at which $V_o = ½ V_{max}$ is usually called $[S]_{0.5}$.
    B) The shape of the curve is a hyperbolic.
    C) At very high [S], the velocity curve becomes a horizontal line that intersects the y-axis at $V_{max}$.
    D) The enzyme will be very sensitive to [S] over a narrow range and behaves like an on-off switch.
    E) The binding curve can be interpreted to mean that substrate binding to one enzyme subunit raises the affinity of binding of the remaining subunits.

16. An enzyme following Michaelis-Menten kinetics catalyzes a reaction in which 1% of the substrate molecules are transformed into 50 micromoles of product in the first 10 seconds of the reaction. The initial substrate concentration was 100*$K_M$. The $K_M$ of the enzyme is 10 micromolar. What is the initial velocity of the reaction when the substrate concentration is 10 micromolar?

A) 0.5 micromoles/second
B) 0.75 micromoles/second
C) 2.5 micromoles/second
D) 5.0 micromoles/second
E) 10 micromoles/second

17. Which of the following statements are **correct**?

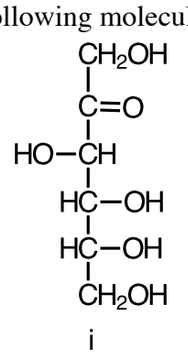
i. At high temperatures enzymes unfold and reaction rates decrease.
ii. For an enzyme following Michaelis-Menten kinetics, $K_m$ is the [S] at which $V_0 = V_{max}$
iii. A reaction may not occur at a detectable rate even though it has a large, negative $\Delta G'^o$.
iv. For many enzymes following Michaelis-Menten kinetics, the smaller the $K_m$ for a substrate, the more tightly it binds to the enzyme.
v. Enzymes catalyze reactions by shifting the equilibrium in favour of the product.

A) i only
B) i & ii only
C) i, iii & iv only
D) iii & iv only
E) iii & v only

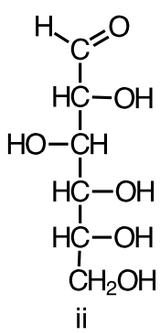
18. Substrate binding energy is used in enzyme-catalyzed reactions to _____

A) raise the free energy of the transition state.
B) increase substrate entropy.
C) solvate substrates.
D) increase electronic and / or steric strain in the substrate.
E) induce the proper conformation of the active site residues.

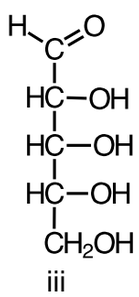
19. Identify the following molecules.



i



ii



iii

A) i = *D*-glucose; ii = *D*-fructose; iii = *L*-ribose
B) i = *D*-fructose; ii = *D*-glucose; iii = *D*-ribose
C) i = *L*-ribose; ii = *D*-fructose; iii = *L*-glucose
D) i = *L*-fructose; ii = *L*-ribose; iii = *L*-glucose
E) i = *D*-glucose; ii = *D*-ribose; iii = *L*-fructose

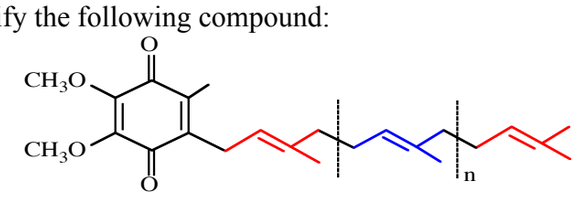
20. Identify the **CORRECT** statement:
    A) α-D-glucose and α-D-mannose are epimers at C2.
    B) α-D-glucose and α-D-mannose are anomers.
    C) α-D-glucose and α-D-mannose are nonsuperimposable mirror image stereoisomers.
    D) α-D-glucose and α-D-mannose are ketoses.
    E) α-D-glucose and α-D-mannose are conformational isomers.

21. Starch is a storage form of _____i_____ found in _____ii_____. The unbranched polymers form a tightly coiled _____iii_____ structure stabilized by H-bonding with ___iv____ residues per turn.
    A) i = galactose; ii = viruses; iii = helix; iv = 4.
    B) i = ribose; ii = bacteria; iii = strand; iv = 3.6.
    C) i = nucleic acids; ii = mammals; iii = sheet; iv = 2.
    D) i = fructose; ii = animals; iii = coil; iv = 3.
    E) i = glucose; ii = plants; iii = helical; iv = 6.

22. Primates and fruit bats have lost the ability to make _____ so it is an essential nutrient for them.
    A) vitamin A.
    B) vitamin B.
    C) vitamin C.
    D) vitamin D.
    E) vitamin E.

23. Most fatty acids have a(n) ____i_____ number of carbon atoms, may contain sites of unsaturation in the ___ii___ configuration, and ___iii____ conjugated double bonds.
    A) i = even; ii = *cis*; iii = no;
    B) i = odd; ii = *trans*; iii = many;
    C) i = random; ii = *d*-; iii = few;
    D) i = small; ii = *isomeric*; iii = some;
    E) i = large; ii = *l*-; iii = complex;

24. Identify the following compound:




n = 4 - 8

    A) cholesterol
    B) stearic acid
    C) ubiquinone
    D) vitamin E
    E) sphingomyelin

25. O, A, and B blood group antigens are _____.
    A) glycerophospholipids
    B) plasmalogens
    C) phospholipases
    D) lysophospholipids
    E) glycosphingolipids

26. The melting points of fatty acids _____i_____ with increasing chain length and _____ii_____ with increasing numbers of double bonds.
    A) i = decrease; ii = decrease;
    B) i = increase; ii = increase;
    C) i = increase; ii = decrease;
    D) i = decrease; ii = increase;
    E) none of the above

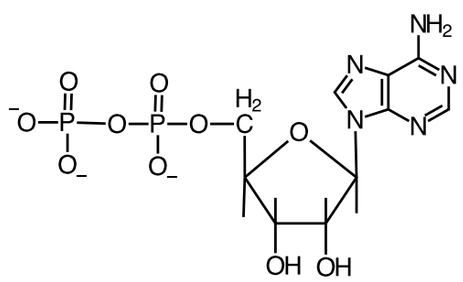
27. Which molecule below is NOT a second messenger:
    A) ATP
    B) inositol-1,4,5,trisphosphate
    C) $Ca^{2+}$
    D) cAMP
    E) NO

28. Natural and artificial bilayers undergo phase transitions. At low temperatures the lipids exist in a ____i_____ phase with _____ii_____ fatty acid chains and at high temperatures the fatty acid chains become _____iii_____ in the ____iv_____ phase.
    A) i = solid; ii = ordered; iii = disordered; iv = gas.
    B) i = gel; ii = disordered; iii = ordered; iv = liquid crystalline.
    C) i = gel; ii = ordered; iii = disordered; iv = liquid crystalline.
    D) i = solid; ii = ordered; iii = liquid; iv = disordered.
    E) i = liquid; ii = ordered; iii = disordered; iv = gas.

29. Water can cross lipid bilayers by _____
    i. gel sieving.
    ii. simple diffusion.
    iii. facilitated diffusion.
    iv. active transport.
    v. electrophoresis.

    A) ii & iii are correct.
    B) ii, iii & iv are correct.
    C) i & v are correct.
    D) i, ii & v are correct.
    E) i & iv are correct.

30. Identify the following molecule:




    A) cAMP
    B) CoA
    C) ADP
    D) TDP
    E) ATP.

31. Which of the following sequences will form a hairpin loop structure?
    A) (5') ATTTAGCAATCATTTA(3').
    B) (5') GCACGGCAATCGGAATT (3').
    C) (5') UGAUAGCAACCTGGGT(3').
    D) (5') GCCCGGCAATCUCCCU (3').
    E) (5') GCACGGCAATCCGTGC (3').

32. The fact that DNA contains thymine and RNA contains uracil is important to cells because:
    A. depurination is a frequent occurrence in all cells.
    B. demethylation of thymine is a frequent occurrence in all cells.
    C. oxidation of adenine is a frequent occurrence in all cells.
    D. deamination of cytosine is a frequent occurrence in all cells.
    E. knowing this helps biochemistry students pass their exams.

33. Translation refers to which of the following processes?
    A) The synthesis of proteins from information encoded in RNA.
    B) The synthesis of RNA from information encoded in DNA.
    C) The duplication of DNA in preparation for cell division.
    D) The synthesis of DNA from information encoded in RNA.
    E) The synthesis of proteins from information encoded in DNA.

34. Dehydrogenation means the same as _____
    A) reduction.
    B) oxidation.
    C) hydrogenation.
    D) saturation.
    E) decomposition.

35. Approximately how many kilojoules of free energy are conserved in the formation of ATP molecules during anaerobic oxidation of glucose by glycolysis?
    A) 19 kJ/mole
    B) 30.5 kJ/mole
    C) 49 kJ/mol
    D) 61 kJ/mol
    E) 122 kJ/mol

36. _____ is a(n) _____ electron carrier that donates and receives electrons in oxidation-reduction reactions.
    A) NADH; insoluble.
    B) Coenzyme Q; covalently-attached.
    C) Ubiquinone; hydrophobic.
    D) Glucose; hydrophilic.
    E) $FADH_2$; soluble.

37. The standard reduction potentials ($E'^{o}$) for the following half reactions are given.

    $\frac{1}{2}\ O_2 + 2H^+ + 2e^- \rightarrow H_2O$ + 0.816 V

    Ubiquinone + $2H^+ + 2e^- \rightarrow$ Ubiquinol +0.030 V

    Calculate the equilibrium constant for the coupled redox reaction given that R = 8.3 J/mol*K, T = 298 K, and $\mathcal{F}$ (Faraday constant) = 96.4 kJ/volt*mol.
    A) $4.4X10^{28}$
    B) $1.2X10^{5}$
    C) – 4.4.
    D) $4.0X10^{26}$
    E) $1.8X10^{61}$

38. Which set of enzymes are responsible for the synthesis of ATP by substrate-level phosphorylation?
    A) lactate dehydrogenase; succinyl CoA-synthetase; ATP synthase.
    B) phosphoglycerate kinase; pyruvate kinase; succinyl CoA-synthetase
    C) hexokinase; glyceraldehyde-3-phosphate dehydrogenase; ATP synthase.
    D) lactate dehydrogenase; succinyl CoA-synthetase; aconitase.
    E) phosphofructokinase; pyruvate dehydrogenase; succinyl CoA-synthetase.

39. The reaction of malate oxidation to oxaloacetate is not thermodynamically favored under standard conditions. It occurs because _____
    A) it involves substrate-level phosphorylation.
    B) oxaloacetate is used in the next reaction which has a large negative ΔG.
    C) it is coupled with a strong reduction.
    D) it is coupled with ATP hydrolysis.
    E) the previous reaction has a large negative ΔG.

40. When succinate is oxidized to fumarate the free energy of oxidation is stored in _____
    A) the reduced form of the electron carrier FAD.
    B) the reduced form of the electron carrier NAD.
    C) ATP.
    D) succinate.
    E) fumarate.

41. What fraction of TCA cycle steps conserve the free energy of oxidation in the form of reduced electron carriers?
    A) 12.5%.
    B) 25%.
    C) 37.5%.
    D) 50%.
    E) 62.5%.

42. The conversion of α-ketoglutarate to succinyl-CoA is catalyzed by _____i_____ and utilizes _____ii_____ as a cofactor to aid in C–C bond cleavage.
    A) i = malate dehydrogenase; ii = lipoic acid
    B) i = pyruvate dehydrogenase complex; ii = coenzyme A
    C) i = citrate synthase; ii = coenzyme A
    D) i = aconitase; ii = NADH
    E) i = α-ketoglutarate dehydrogenase complex; ii = TPP

43. Protons **CANNOT** pass through which of the following proteins in the electron transport chain?
    A) Complex 1.
    B) Complex 2.
    C) Complex 3.
    D) Complex 4.
    E) ATP Synthase.

44. How many oxygen atoms are reduced in the complete oxidation of 1 molecule of Acetyl-CoA?
    A) 1.
    B) 2.
    C) 3.
    D) 4.
    E) 5.

45. The following reaction is catalyzed by _____.

$$4\text{Cyt c-Fe}^{2+} + O_2 + 4H^+ \rightleftharpoons 4\text{Cyt c-Fe}^{3+} + 2H_2O$$

A) Complex I of the ETC
B) Complex II of the ETC
C) Complex III of the ETC
D) Complex IV of the ETC
E) ATP Synthase.

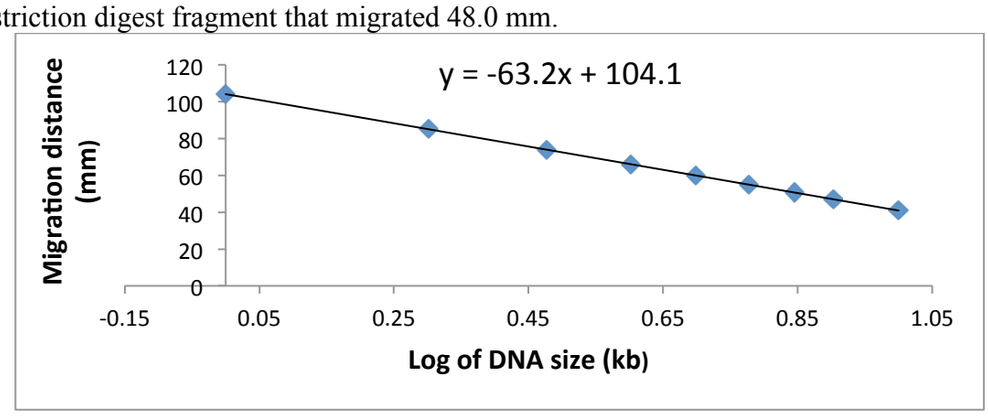
**LABORATORY SECTION (Questions 46 to 60)**

46. Which of the following statements about the Bradford Assay is incorrect?
A) It was developed during the 1970s.
B) The assay is based upon the dye Coomassie Brilliant Blue G-250 (CBB).
C) The dye CBB has three different colored forms.
D) When protein is added to the Bradford Reagent the absorbance value at 466 nm decreases.
E) None of the above.

47. You prepared reaction progress curves for the hydrolysis of substrate BA by trypsin. Which of the following combination of y and x-axis labels would be used for those curves?
A) y-axis: initial rate, x-axis: [BA]
B) y-axis: 1/initial rate, x-axis: time
C) y-axis: absorbance, x-axis: time
D) y-axis: absorbance, x-axis: 1/[BA]
E) y-axis: absorbance, x-axis: [BA]

48. You made four different TRIS buffers of identical concentration and volume. The only difference between them is their pH values that are 7.7, 7.8, 7.9, and 8.0 respectively. If you added 1 mL of 1.0 M HCl to each of them, which one would exhibit the smallest net change in pH? The pKa of TRIS is 8.10.
A) 7.9
B) 8.0
C) 7.7
D) 7.8
E) They are all buffers of equal concentration and volume and therefore their net change in pH will be identical.

49. Based upon the calibration curve for an agarose gel shown below, calculate the size of a restriction digest fragment that migrated 48.0 mm.

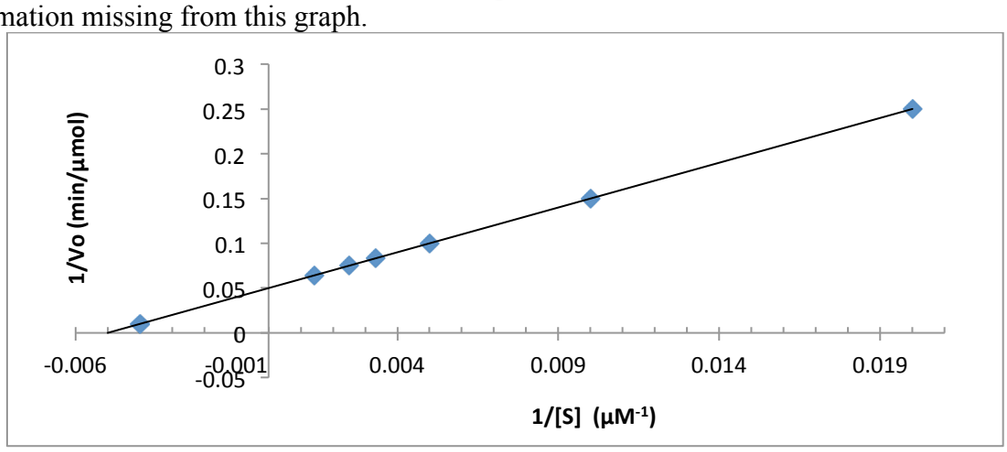



A) 7.72 kb
B) 0.888 kb
C) 772 base pairs
D) 11.7 kb
E) 2.43 kb

50. The iodine value for a 0.22 gram lipid sample was determined to be 88. How much iodine was taken up by the lipid?

A) 0.14 grams
B) 400 milligrams
C) The volume of thiosulfate used to titrate the control is required to answer this question
D) 0.19 grams
E) 2.5 x $10^{-3}$ grams

51. Based upon the Lineweaver-burke graph depicted below, indicate which values for $K_M$ and $V_{max}$ are the **nearest** to the true values for these two parameters. **Note:** there is no required information missing from this graph.

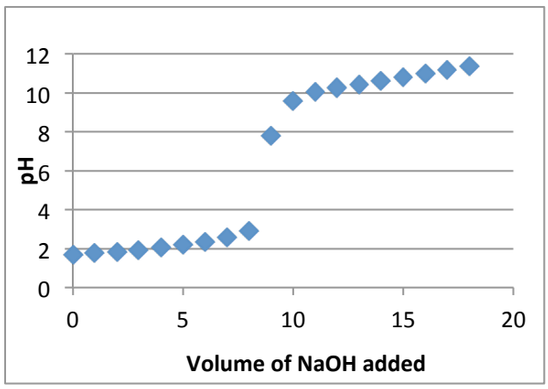



A) 20.0 µM and 20.0 µmol/min
B) 200 mM and 20.0 mmol/min
C) 200 µM and 20 mmol/min
D) 200 mM and 20 µmol/min
E) 200 µM and 20.0 µmol/min

52. An agarose gel can be used to separate DNA molecules on the basis of size because
A) They have different frictional coefficients.
B) They have the same *q/f* ratios.
C) Large DNA molecules have greater net negative charge and therefore migrate more slowly than short DNA molecules.
D) Short DNA molecules have less net negative charge and therefore migrate more quickly than long DNA molecules.
E) None of the above.

53. Single stranded DNA absorbs more light at 260 nm than double stranded DNA because:
A) there are three hydrogen bonds between a GC pair.
B) the nitrogenous bases are fully exposed.
C) the salt concentration was increased.
D) the salt concentration was decreased
E) the nitrogenous bases are shielded by the sugar phosphate backbone.

54. A titration curve for an unknown amino acid is depicted below.

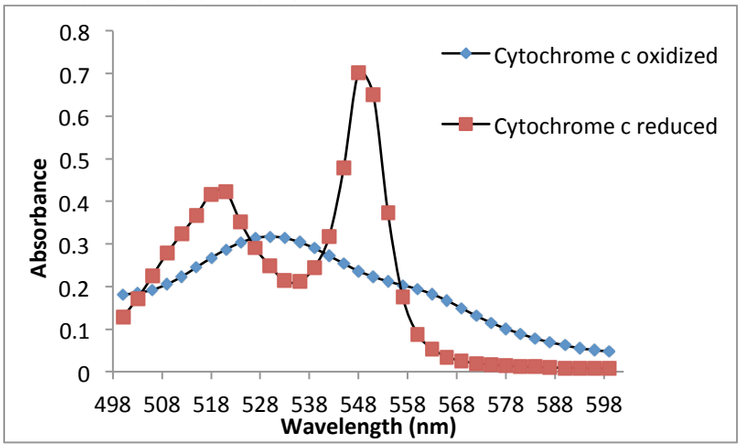



Based upon the following table of pKa values, identify the unknown amino acid.

| **Amino acid** | **pKa Values** | | |
|---|---|---|---|
| | carboxyl | amino | R-group |
| Histidine | 1.9 | 9.2 | 6.0 |
| Proline | 2.1 | 10.6 | - |
| Asparagine | 2.0 | 8.8 | - |
| Alanine | 2.2 | 9.8 | - |
| Glutamic acid | 2.2 | 9.7 | 4.3 |

A) Histidine
B) Proline
C) Asparagine
D) Alanine
E) Glutamic acid

55. The figure below depicts the absorption spectra for the oxidized and reduced forms of the mitochondrial electron transport protein cytochrome c. You want to monitor the conversion of reduced cytochrome c to oxidized cytochrome c. Which of the following wavelengths would be the best one to use?




A) 498 nm
B) 598 nm
C) 521 nm
D) 548 nm
E) 535 nm

56. For the determination of the iodine number of a lipid you used 0.05 M sodium thiosulfate. If the concentration of the sodium thiosulfate had been 0.06 M instead, which of the following statements is **TRUE**?

A) The iodine value would have been higher.
B) The iodine value would have been lower.
C) The volume of sodium thiosulfate used would have been greater.
D) The volume of sodium thiosulfate used would have been less.
E) Both A) and C) are true

57. The absorbance at 260 nm for a sample of double-stranded DNA was 0.500. Additional absorbance measurements at 260 nm were taken as the DNA was slowly heated. At approximately what absorbance value could you conclude it was fully denatured?

A) 0.540
B) 0.600
C) 0.500
D) 0.580
E) 0.700

58. Which of the following is a natural substrate of β-galactosidase?

A) ONPG
B) Galactose
C) Lactose
D) Glucose
E) BA

59. The catalytic rate for hydrolysis of ONPG by β-galactosidase was found to be 0.010 absorbance units/second. If the total volume of enzyme and substrate in the cuvette was 3.00 mL and the absorption coefficient of the reaction product ONP is 3500 $M^{-1}cm^{-1}$, what is the reaction rate in units of M/minute?

A) The concentration and volume of enzyme used is required to answer this question.
B) $5.1 \times 10^{-7}$
C) $2.9 \times 10^{-6}$
D) $1.7 \times 10^{-4}$
E) 0.60

60. You mixed 0.5 mL of a 4-nitroaniline stock solution with 2.0 mL of buffer and measured the absorbance at 405 nm against a buffer blank. If the absorbance of this diluted 4-nitroaniline solution was 0.811, what would the original absorbance of the stock solution have been if you had not diluted it?

A) 4.055
B) 3.540
C) 0.811
D) The molar absorption coefficient of 4-nitroaniline is required to answer this question.
E) 1.622

**Scratch Paper**

**Scratch Paper**