This unit of instruction provides a laboratory oriented study of the chemical reaction involved in the life processes. Students enrolling in this course should have successfully completed the units on Scientific Mathematics, Introduction to Chemistry, Reactions of Atoms and Molecules, and Chemistry of Carbon and Its Compounds. The booklet lists texts recommended as student references and states the performance objectives for the unit. It provides an outline of the course content and suggests special laboratory procedures, laboratory experiments, and appropriate readings from a variety of books and periodicals. Also listed are relevant films available from the Dade County Audiovisual Center and other sources. A master sheet is provided relating each suggested activity to the specific performance objectives. (JR)
AUTHORIZED COURSE OF INSTRUCTION FOR THE QUINMESTER PROGRAM

BIOCHEMISTRY

5317.66

SCIENCE

(Experimental)
BIOCHEMISTRY
5317.66
SCIENCE
(Experimental)

Written by Ray S. Rasmussen
for the
DIVISION OF INSTRUCTION
Dade County Public Schools
Miami, Florida
1972
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BIOCHEMISTRY

COURSE DESCRIPTION

In depth study of the chemical reactions involved in the life processes.

ENROLLMENT GUIDELINES

Students should have successfully completed Scientific Mathematics, Introduction to Chemistry, Reactions of Atoms and Molecules, and Chemistry of Carbon and Its Compounds, or show readiness by passing a test. The course is laboratory oriented and students should be adept at assembling and setting up equipment.

RECOMMENDED STUDENT REFERENCES


PERFORMANCE OBJECTIVES

The student should be able to:

1. Demonstrate an understanding of the material presented in Organic Chemistry Course Number 5317.65.

2. Diagram the dehydration syntheses of sugars, fatty acids, glycerol, and amino acids.

3. Demonstrate how large molecular units of carbohydrates, fats and proteins are built up by dehydration synthesis.

4. Illustrate how the peptide and polypeptide bonds in protein synthesis are the result of dehydration.

5. Show how hydrogen bonding and peptide linkage are used in the construction of all proteins.

6. Explain why the essential amino acids are called "essential".

7. Diagram the hydrolysis of carbohydrates, fats and proteins to simpler and smaller molecules.

8. Demonstrate the specificity of enzymes.

9. Demonstrate that enzymes work most efficiently at certain optimum temperatures.

10. Define substrate: (1) That the substance upon which the enzymatically controlled reaction occurs is called the substrate. (2) That the substrate for the enzyme sucrase is sucrose; for lactase, it is lactose; for trypsin, proteins.

11. Explain why glucose is an energy rich compound.

12. Demonstrate, by use of a diagram, the steps by which the glucose molecule is broken down, bit by bit, with small amounts of energy being released at each step, rather than all at once.

13. Explain the role of nucleic acids in the synthesis of proteins.
COURSE OUTLINE

I. Review of Basic Chemistry
   A. Acids, bases and neutralization
      1. pH
      2. Buffer systems
   B. Organic compounds
      1. Functional groups
      2. Hydrogen bonding
      3. Dipolar charges and delta notation

II. Fundamental Organic Substances in Living Material
   A. Carbohydrates
      1. Types
         a. Sugars, monosaccharides
            (1) Pentoses – ribose, deoxyribose, xylose, arabinose
            (2) Hexoses – glucose, fructose, galactose
         b. Sugars, disaccharides
            (1) Lactose
            (2) Maltose
         c. Sugars, polysaccharides
            (1) n-number of monosaccharide units, called starches
            (2) Starch, glycogen, dextrins, cellulose, mucilage
      2. Chemical characteristics of carbohydrates
         a. Formation of disaccharides and polysaccharides – dehydration synthesis
         b. Carbohydrates as fuels
         c. Hydrolysis
   B. Lipids
      1. Ratio of hydrogen to oxygen as compared to the carbohydrates
2. Parts of a true fat molecule
   a. An alcohol, usually glycerol or glycerine (a tri-alcohol)
   b. A group of compounds known as fatty acids
   c. Ester linkage between glycerol and fatty acids

3. Dehydration synthesis of fatty acids to lipids - relate to carbohydrates and proteins

4. Hydrolysis - relate to carbohydrates and proteins
   a. Lipase - breaking the ester linkage between glycerol and fatty acid molecules
   b. Bile - emulsification

5. Saturated and unsaturated fatty acids and lipids

C. Proteins

1. Amino acids and the primary structure of proteins
   a. Peptide linkage
   b. Dehydration synthesis - relate to fats and carbohydrates

2. Other factors determining the shape of protein molecules
   a. Hydrogen bonding
   b. The alpha helix
   c. Denaturing - permanently breaking the hydrogen bonds
   d. Beta configuration

3. The buffering action of proteins and amino acids

D. Enzymes

1. Characteristics

2. Specificity

3. Theories of enzyme activity
   a. Enzyme - substrate
   b. Lock and key

4. Enzymes and energy

5. Conditions necessary for enzyme activity
COURSE OUTLINE (Continued)

E. Nucleic Acids
   1. Types of nucleic acids
   2. Chemical composition
   3. DNA structure
   4. RNA structure
   5. Nucleic acids and protein synthesis

III. Blood Chemistry (optional) - See Laboratory Experiments

SPECIAL LABORATORY PROCEDURES


1. Potentiometric Acid-Base Titrations (p. 173)
2. Appendix 7: Instructions for Construction of a Simple Poggendorf Potentiometer (p. 311)
3. Iodimetry: Some of the Chief Reasons for the Wide Use of Iodine in Volumetric Analysis Are Summarized (p. 130)
4. Methods of Separating the Components of Heterogeneous and Homogeneous Mixtures (p. 207)
5. Appendix 5: Spectrometer and Photoelectric Colorimeter (p. 301)

LABORATORY EXPERIMENTS


1. Determination of the Normality of a Solution of Sodium Hydroxide From a Known Weight of Potassium Hydrogen Phthalate (p. 105)
2. Oxidation-Reduction Titration: Analysis of an Oxalate (p. 109)
3. Iodimetry: Volumetric Determination of Cu(II) ion by Reaction with Iodide Ion (p. 115)
4. Iodimetry: Determination of Antimony (p. 123)
5. Ion Exchange: Determination of the Concentration of an Anion (Using an Anionic Resin) (p. 129)
LABORATORY EXPERIMENTS (Continued)

6. Colorimetry: Determination of Manganese (See Appendix 5, p. 301)
   To be done only:
   a. If a simple optical colorimeter is available
   b. If a photoelectric spectrometer is available
   An excellent explanation of the Lambert-Beer Law is given. (p. 135)

7. Titration of a Tripotric Acid - H₃PO₄ (p. 141)
8. Oxidation - Reduction Titration Using H₂O₂ and Fe(II) Solutions (p. 145)
9. Oxidation - Reduction Titration Using Chlorax (p. 149)
10. Preparation and Structure of Coordination Complexes (p. 163)
11. Preparation of Polymers - Phenol and Formaldehyde (p. 179)
12. Determination of the Rate Law for a Reaction: Catalysis (p. 201)
13. Effect of Concentration, Surface Area, and Catalyst on the Rate of Reaction - HCl and Mg ribbon (p. 207)
15. pH: Indicators and Hydrolysis (p. 235)
16. Qualitative Analysis: Semimicro Methods. Centrifuge necessary (p. 251)


(Many of these experiments are similar to those listed in the Brescia, et al. Laboratory Manual. But there is a great difference between them. These are much more sophisticated and, in some cases, require considerable mathematics background and ability to construct laboratory apparatus.)

17. The Determination of the Composition of Sodium Bicarbonate by Gas Evolution Analysis. Use of the Ideal Gas Law (p. 57)
19. The Standardization of a Sodium Thiosulfate Solution (p. 129)
20. Acid-Base Indicators. A Study of the Dissociation of a Weak Acid (p. 157)
21. The Preparation of Standard NaOH and HCl Solutions (p. 167)
   A quinhydrone electrode, platinum reference electrode, and potentiometer are needed. See Appendix 7, p. 311. (p. 173)
23. The Determination of the Total Base Strength of Soda Ash (p. 183)
24. Extraction and Separation of Components of Mixtures (p. 207)
25. Separation of Cations from Aqueous Solution by Column Chromatography (No special equipment needed) (p. 231)
26. The Separation of Cations by Paper Chromatography (p. 235)
27. The Separation of Cations from Aqueous Solution by Ion Exchange Chromatography (p. 241)
LABORATORY EXPERIMENTS (Continued)


28. Diffusion Through a Membrane (p. 45)
29. Enzymes in Living Tissues - Catalase (p. 53)
30. Enzyme Action on a Protein (p. 55)
31. Factors Influencing Enzyme Activity (p. 59)
32. Digestion of Foods by Microorganisms (p. 91)
33. Human Kidney Function (Maintaining the homeostatic condition of the blood) (p. 187)
34. Sickle Cells and Selection - Use for differences in hemoglobin structure (p. 255)
35. Malaria Life Cycle (p. 3)
   Prepared slides or blood samples from Jackson Memorial.
   Relate malaria to sickle cell anemia. Immunological studies.
   Same additional reference as Experiment 34.


36. Hemoglobin Turns Bright Red in the Presence of Oxygen (p. 61)
   Use dialysis technique
   Dried blood (fertilizer) in a chloroplast suspension
37. Extracting Enzymes from Microscopic Cells. Fermentation with Yeast Extract. "Zymase" is tested on a group of sugar substrates; sucrose, glucose, maltose, lactose, etc. (p. 103)
38. Discovering the Function of Catalase (p. 111)
39. Paper Chromatography


40. Preparation of the Reagents and Solutions Needed, e.g. Benedict's, Lugol's Biuret, Buffer Solutions, Normal Saline, Stains and Indicators. (p. 658)
41. Evolution of Photosynthesizing Systems (p. 159)
42. Cell Contents, Macromolecules
   Separation of molecules by dialysis
   Pentose sugars in plants
   Xylose compared with glucose (p. 134)
LABORATORY EXPERIMENTS (Continued)

43. Tests for Proteins
   Millon's Test for sulfhydryl groups - Tyrosine, Tryptophan, Cysteine
   Nitroprusside Test for sulfhydryl group
   Tryptophan reaction (p. 135)

44. Test for Proteins
   Biuret Test for 2 carbamyl (-CONH₂) groups. Biuret is specific
   for the presence of peptide linkage
   Ninhydrin Test for the concentration of amino acid (p. 137)

45. Simple Method for Paper Electrophoresis
   pH, acidity and alkalinity relative to the isoelectric point
   of proteins (p. 141)

46. Enzymes
   Relate to role of hydrogen acceptors. Removal of hydrogen in
   oxidation and its transfer to a hydrogen acceptor. Catalase,
   Dehydrogenase, Cytochrome Oxidase, Phosphorylase (Demonstration),
   Cholinesterase, Acetylcholine, Amylase, Invertase, Luciferin,
   Luciferase. (p. 143)

47. Nucleic Acids
   Preparation of extract from yeast cells (DNA and RNA). The
   hydrolyzed extract contains nucleotides, even hydrolyzed
   nucleotides. Adenine, cytosine, uracil and guanine are obtained
   from hydrolyzed RNA. Paper chromatography is used for the
   separation and identification. (p. 145)

48. Proteolytic Enzymes: Bromelin, Papain (p. 147)

49. Biochemistry of Digestion
   Review oxidation of glucose
   Respiration quotients of glucose, fatty acids, others
   The metabolism of sugars, fats and nitrogenous compounds are
   all linked in the Krebs Cycle (p. 262)

50. Digestion of Starch by Saliva
   Effect of temperature and dilution on enzyme activity (p. 210)

51. Specific Tests for Proteins
   Zanthoproteic Test - albumin
   Biuret Test - Proteoses and Peptones
   Millon's Reaction - Solid Proteins (p. 213)

52. Digestion of Proteins by Pepsin -
   Effect of temperature on pepsin digestion
   Action of rennin on milk
   Digestion by trypsin in the small intestine. Demonstrate
   optimum pH for trypsin.
   Pancreatin and casein of milk; amylase activity of pancreatic juice
   Invertase - sucrose hydrolyzed to glucose and fructose (p. 213)

53. Fats: Emulsification
   Hydrolysis by lipase (control of pH for neutrality) Small
   intestine and pancreatic lipase.
   Litmus milk test using pancreatin. Show that pancreatin
   contains digestive enzymes which split fats into fatty acids
   and proteins into amino acids. (p. 215)
LABORATORY EXPERIMENTS (Continued)

54. Summary of Nutrient Tests: starch, carbohydrates, sugars, proteins, fats and oils, water, minerals. (p. 218)
55. Preparation of Blood Plasma (p. 253)
56. Preparation of Oxalated Blood (p. 251)
57. Preparation of Citrated Blood (p. 660)

If whole blood can be obtained, any Standard Laboratory Procedures Book used by hospitals gives the tests and the reagents needed for human blood chemistry: sugar, urea, non-protein nitrogen, uric acid, albumin-globulin ratio, creatinine, cholesterol, chlorides, calcium, phosphorus, etc.

FILMS

Dade County 16 mm Films

1. Acids, Bases and Salts
   AV# 1-10947, 21', C

2. Acid-Base Indicators
   AV# 1-10788, 19', C

3. Alcohol and the Human Body
   AV# 1-12393, 14', B/W

4. The Atom and Biological Science
   AV# 1-03550, 12' B/W

5. Biochemical Genetics
   AV# 1-30572, 28', C, B/W

6. Chemical Bonding
   AV# 1-10814, 20', C

7. Cell Biology - Growth and Replacement
   AV# 1-30510, 30', C

8. Cell Biology - Transfer of Materials
   AV# 1-30526, 30', C

9. Cell's Chemical Organization
   AV# 1-30505, 30', C, B/W
FILMS (Continued)

10. Digestion, Chemical  
    AV# 1-11235, 18', B/W

11. Endocrine Glands  
    AV# 1-03441, 11', B/W

12. Equilibrium  
    AV# 1-10829, 22', C

13. Foods and Nutrition  
    AV# 1-03128, 11', B/W

14. Human Body, Nutrition and Metabolism  
    AV# 1-11244, 14', C

15. Hormones  
    AV# 1-30479, 28', C, B/W

16. Human Body, Circulatory System  
    AV# 1-11226, 14', C

17. Patterns of Energy Transfer  
    AV# 1-30527, 30', C, B/W

18. Water and Life  
    AV# 1-11054, 15', C

19. Ionic Equilibrium  
    AV# 1-10930, 16', C

20. Molecular Spectroscopy (No. 4142)  
    AV# 1-10869, 22', C

21. Properties of Solutions  
    AV# 1-30345, 28', B/W

CHEM Study Films (Not in Dade County AV)

22. Biochemistry and Molecular Structure  
    22', C

23. Shapes and Polarities of Molecules  
    18', C
Other Films

24. The Chemical Synthesis of Proteins
Available from: Films for the Humanities and Sciences
505 - 8th Avenue
New York, New York 10018

$300 purchase price. $27.50 rental per showing.

RECOMMENDED READINGS


An understandable and very comprehensive text, an excellent reference for nomenclature and all types of organic reactions.

Chapter 17, p. 493 Fats: Occurrence and composition; hydrolysis, saponification; fats as sources of pure acids; reduction to alcohols; unsaturated

Chapter 19, p. 518 Amines: Nomenclature; preparation and physical properties; secondary and tertiary amines; amides

Chapter 20, p. 540 Amines: Reactions

Chapter 22, p. 585 Phenols (ArOH)

Chapter 23, p. 611 Aldehydes and Ketones
RECOMMENDED READINGS (Continued)

Chapter 24, p. 650  Glycols
Chapter 25, p. 676  Dicarboxylic Acids (Oxalic, Succinic, Glutaric, Phthalic)
Chapter 26, p. 700  Keto Acids (Pyruvic)
Chapter 27, p. 714  Hydroxy Acids (Lactic, Malic, Tartaric)
Chapter 29, p. 745  Carbohydrates I (Very comprehensive)
Chapter 30, p. 781  Carbohydrates II (Di and Polysaccharides)
Chapter 32, p. 834  Heterocyclic Compounds (Pyridine, Pyrimidine, Purine)
Chapter 33, p. 858  Amino Acids and Proteins: Peptide chain; polypeptide chain; nucleoproteins and nucleic acids, conjugated proteins (prosthetic group) - hemoglobin; amino acids as dipolar ions


A good text although not as detailed or as comprehensive as Morrison and Boyd except in the area of biological processes.

Chapter 23, p. 375  Biological Processes: Hydrolysis of proteins; enzymes involved in protein hydrolysis; hydration and dehydration and enzymes involved; Krebs Cycle; oxidation and reduction; nicotinamide adenine dinucleotide; lactic dehydrogenase; fermentation; aldolase; biosynthesis of terpenes (steroids); biosynthesis of the biological isoprene unit; polymerization of isopentenyl pyrophosphate; bile acids and steroid hormones


Bronsted-Lowry and Lewis Acid-Base Theories
Important background material, not difficult to read
RECOMMENDED READINGS  (Continued)

   p. 46 Glycolysis, Alcoholic Fermentation, Aerobic Respiration in Cells
   p. 47 Synthesis of ATP
   p. 49 Synthesis of ATP
   p. 51 Krebs Cycle
   p. 66 Respiratory Chain: Enzymes are Conjugated Proteins (Prosthetic Group); Krebs Cycle Substrates
   p. 78 Events involved in the ordering of the amino acid sequence of protein by nuclear DNA
   p. 93 Components of the nucleotide subunit of DNA

    Easy reading; up to date; non-technical; good glossary.

    Written for laymen. Based upon up to date biochemical research.

    Chapter 2 The Amino Acids - Optical activity; neutral, acidic, basic analogs
    Chapter 3 The Chemical Structure of Proteins - Amino acid linkage; Sequential arrangement; Primary structures and variations.
    Chapter 4 The Size, Shape and Electric Charge of Protein Molecules
    Chapter 5 Spatial Organization of Proteins
    Chapter 6 Structure and Function of Certain Important Proteins
                Collagen, Antibodies, Fibrinogen, Plasma Proteins, Serum Albumin, Hemoglobin, Myoglobin
RECOMMENDED READINGS (Continued)

Chapter 7 Catalytic Proteins: The Enzymes
Chapter 8 The Nucleotides
Chapter 9 Deoxyribonucleic Acids
Chapter 10 Ribonucleic Acids and the Biosynthesis of Proteins
Chapter 11 Nucleic Acids of Viruses as Carriers of Biological Information
Chapter 12 The Carbohydrates and their Biosynthesis
Chapter 13 Energy Transformations by Biological Systems
Appendix C Synthesis of Polypeptides
Appendix D Biological Oxidation and Reduction


Up to date. Technical but not difficult. Excellent on:
Chapter 7 Structure and Function of Carbohydrates
Chapter 11 Macromolecular Biosynthesis


A volume dedicated to Linus Pauling by his students, colleagues and friends. Very technical and specialized.

p. 29 "Binding Site of Phosphate Ion to Ribonuclease Molecules" G. Knuth, J. Bello, D. Harker

p. 38 "Structure of an Enzyme" - W. N. Lipscomb

p. 88 "Thought on the Conformation of Proteins in Solution" J. T. Edsall
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