West Virginia University Bulletin

Issued Monthly

Series No. 27, No. 1

PROCEEDINGS of the West Virginia Academy of Science

Vol. 1
No. 1

August
1926

Published by THE UNIVERSITY
MORGANTOWN, WEST VIRGINIA

Entered as second class matter, May 27, 1909, at the postoffice at
Morgantown, W. Va., under the Act of July 16, 1904

PROCEEDINGS
of the West Virginia Academy of Science

Vol. 1
No. 1

August
1926

First and Second Annual Sessions
held at

Morgantown, November 28, 1924
Huntington, November 6-7, 1925

WEST VIRGINIA UNIVERSITY

MORGANTOWN

Established February 7, 1867

THE STATE BOARD OF CONTROL

	TERM EXPIRES
JAMES S. LAKIN, PRESIDENT, *Charleston*	June 30, 1927
C. A. JACKSON, *Charleston*	June 30, 1929
F. W. McCULLOUGH, TREASURER, *Charleston*	June 30, 1931

The State Board of Control has the direction of the financial and business affairs of the state educational institutions.

THE STATE BOARD OF EDUCATION

	TERM EXPIRES
GEORGE M. FORD, STATE SUPERINTENDENT OF SCHOOLS, PRESIDENT, *Charleston*	March 4, 1929
W. G. CONLEY, *Charleston*	June 30, 1932
MRS. LENA LOWE YOST, *Charleston*	June 30, 1927
BERNARD McCLAUGHERTY, *Bluefield*	June 30, 1928
*EARL W. OGLEBAY, *Wheeling*	June 30, 1929
W. C. COOK, *Welch*	June 30, 1930
J. B. McLAUGHLIN, *Strange Creek*	June 30, 1931

The State Board of Education has charge of all matters of a purely scholastic nature concerning the state educational institutions.

NOTICE

West Virginia University publishes a catalog of over 400 pages as well as smaller bulletins descriptive of each of the various colleges and schools. Requests for copies of these publications and inquiries for information about the University and its work should be addressed to

THE PRESIDENT'S OFFICE,
West Virginia University,
Morgantown, W. Va.

*Deceased.

CONTENTS

OFFICERS OF THE WEST VIRGINIA ACADEMY OF SCIENCE

OFFICERS FOR 1924-1925

President	Geo. R. Bancroft
Vice-President	B. R. Weimer
Secretary	John Eiesland
Treasurer	A. S. White

OFFICERS FOR 1925-1926

President	John Eiesland
Vice-President	B. R. Weimer
Secretary	John E. Winter
Treasurer	Lilian Hackney

Editorial Committee: Earl Davies, John Eiesland, C. N. Reynolds, J. L. Tilton, J. E. Winter.

PROCEEDINGS OF THE FIRST ANNUAL MEETING OF THE WEST VIRGINIA ACADEMY OF SCIENCE

Held at Morgantown, November 28, 1924.

The meeting was called to order by Dr. Bancroft, President of the West Virginia University Scientific Society. Dr. Bancroft stated briefly that the purpose of the meeting was to bring about closer affiliation among the scientists of the state and to organize as a group to secure national recognition. This was to be accomplished by organizing a West Virginia Academy of Science.

President F. B. Trotter of West Virginia University welcomed the group and called attention to the fact that a larger and wider spread interest was being manifested throughout the state in scientific research as the concrete evidence of some recent gifts seemed to show. He strongly urged the assemblage to pass a resolution to be presented to the coming State Legislature calling attention to the need of a Natural Science Building for the Department of Botany, Geology, and Zoology which, due to their rapid growth, are much hampered for lack of room.

Dr. John Eiesland outlined the object of the meeting more fully stating that (1) it was to be an organization of all state scientists and those interested in science; (2) a medium for the publication of scientific papers which otherwise might be lost; (3) such meetings tended to broaden one's scientific vision and (4) by this means national recognition might be obtained for the scientists of West Virginia.

Following Dr. Eiesland's address the President appointed the following committees:

For drafting Constitution and By-Laws—
Dr. R. P. Davis, West Virginia University.
Dr. R. J. Garber, West Virginia University.
Prof. H. F. Rogers, Fairmont State Teachers' College.

Dean A. C. Workman, Bethany College.
Prof. A. S. White, Marshall College.

Nomination committee—

Prof. T. L. Harris, West Virginia University.
Prof. E. P. Dietrich, West Virginia University.
Prof. A. Leitch, Bethany College.

A motion was then made by Prof. A. M. Reese and duly seconded by Dean C. R. Jones, which amendment was accepted, that a committee on resolutions be appointed by the President to report at the general business meeting in the afternoon. Motion carried and the following were appointed:

Prof. A. M. Reese, West Virginia University.
Prof. J. L. Tilton, West Virginia University.
Hon. A. B. Brooks, Buckhannon.

A motion was made by Prof. Molby and duly seconded that a resolution be passed the sense of which is that this body is opposed to the construction of an eight foot wall on the stadium, the resolution to be later presented to the authorities of the University. Motion was lost but ordered to be referred to the Committee on Resolutions.

Following the very excellent lecture, "Lighting the Lamp of Conservation in West Virginia," by Hon. A. B. Brooks, the general meeting adjourned to meet at 1:45 p. m.

The second general meeting of the proposed West Virginia Academy of Science was called to order by Dr. M. J. Dorsey, Vice-President of the West Virginia Scientific Society.

A very interesting Popular Demonstration Lecture on Physics was given by Dr. A. C. Colwell and staff following which the following business was transacted:

The report of the Committee on Constitution and By-Laws was presented by Prof. White of Marshall College as follows:

CONSTITUTION OF THE WEST VIRGINIA ACADEMY OF SCIENCE

ARTICLE I—**Name.** This organization shall be known as The West Virginia Academy of Science.

ARTICLE II.—**Object.** The object of the Academy of Science shall be the encouragement of scientific work in the State of West Virginia.

ARTICLE III.—**Membership.** Membership of this Academy shall consist of active members and corresponding members. Active members shall be residents of the State of West Virginia who are interested in scientific work. They shall be of two classes to-wit: National members, who are members of the American Association for the Advancement of Science as well as of the West Virginia Academy of Science, and Local Members, who are members of the West Virginia Academy of Science but not of the Association.

Corresponding members shall be persons who are actively engaged in scientific work not resident in the State of West Virginia. They shall have the same privileges and duties as Active Members.

For election to any class of membership the candidate must have been nominated in writing by two members, one of whom must know the applicant personally; receive a majority of vote of the executive committee and a three-fourths vote of the members of the Academy present at any session.

ARTICLE IV.—**Fees.** Each active member shall pay to the Secretary of the Academy an initiation fee of one dollar ($1.00) at the time of election. Local members shall pay an annual fee to the Secretary of the Academy of one dollar ($1.00) due at each annual meeting. National members pay five dollars ($5.00) annually to the Secretary of the American Association for the Advancement of Science, one dollar of which is returned to the State Academy.

Corresponding members are exempt from dues.

ARTICLE V.—**Officers.** The officers of the Academy shall be a president, a vice-president, a secretary, and a treasurer. These officers shall be elected at the annual meeting from the active members in good standing on the recommendation of a nominating committee of three appointed by the President.

The Executive Committee consisting of the four above officers and the President of the previous year shall have the authority to fix the time and place of meetings and to transact such other business as may need attention between the meetings of the Academy.

The Secretary and Treasurer only shall be eligible to re-election for consecutive terms.

ARTICLE VI.—**Standing Committees.** The standing committees shall be as follows:

A Committee on Membership appointed annually by the President, consisting of three members.

A Committee on Publications consisting of the President, Secretary, and a third member chosen annually by the Academy.

ARTICLE VII.—**Meetings.** The regular meetings of the Academy shall be held at such time and place as the Executive Committee may select. The Executive Committee may call a special session, and a special session shall be called at the written request of twenty per cent of members.

ARTICLE VIII—**Publications.** The Academy shall publish its transactions and papers which the Committee on Publications deem suitable. All papers presented to the Academy for publication shall be of a scientific nature. All members shall receive the publications of the Academy gratis.

ARTICLE IX.—**Sections.** Members, not less than ten in number, may by special permission of the Academy unite to form a section for the investigation of any branch of science. Each section shall bear the name of the science which it represents, thus: The Section of Geology of the West Virginia Academy of Science.

Each section is empowered to perfect its own organization as limited by the Constitution and By-Laws of the Academy:

ARTICLE X.—**Amendments.** This Constitution may be amended at any regular annual meeting by a three-fourths vote of all active members present, provided a notice of said amendment has been sent to each member thirty days in advance of the meeting.

BY-LAWS

I.—The following shall be the order of business:

1. Call to order.
2. Reports of Officers.
3. Reports of Executive Commitee.
4. Report of Standing Committees.
5. Election of Members.
6. Report of Special Committees.
7. Appointment of Special Committees.
8. Unfinished Business.
9. New Business.
10. Election of Officers.
11. Program.
12. Adjournment.

II.—No meeting of this Academy shall be held without thirty days' notice having been given by the Secretary to all members.

III.—Twelve members shall constitute a quorum of the Academy for the transaction of business. Three of the Executive Committee shall constitute a quorum of the Executive Committee.

IV.—No bill against the Academy shall be paid without an order signed by the President and Secretary.

V.—Members who shall allow their dues to be unpaid for two years, having been annually notified of their arrearage by Treasurer, shall have their names stricken from the roll.

VI.—The President shall annually appoint an auditing committee of three who shall examine and report in writing upon the account of the Treasurer.

VII.—These by-laws may be amended or suspended by a two-thirds vote of the members present at any meeting.

Motion was made by Dr. John Eiesland and duly seconded that the Constitution be adopted as read. After due discussion the motion carried.

Motion made by Dr. Dodd and duly seconded that the By-Laws be adopted as read was carried.

The nominating committee made the following nominations for the coming year:

President, G. R. Bancroft.
Vice-President, B. R. Weimer.
Secretary, John Eiesland.
Treasurer, A. S. White.

The report was approved and the officers duly elected as nominated.

The report of the Committee on Resolutions was made by A. M. Reese and was as follows:

1. Resolution. Resolved that it is the sense of this body that the policy of the conservation of the resources of the state, to which the organization is unalterably committed, shall include also the conservation of the natural scenery of the state.

2. Whereas, the Departments of Geology, Botany, and Zoology at the State University and the State Geological Survey have been for years seriously handicapped in conducting their work by lack of room, so that further expansion of these departments is now impossible,

Be it Resolved, That the West Virginia Academy of Science in session at Morgantown urges that the Board of Control favor the immediate erection of a suitable fireproof building to meet the needs of these Departments and the

Geological Survey, which building shall provide space for the display of the wonderful natural resources of the State.

On motion duly made and seconded the above resolutions were adopted.

It was then duly moved and seconded that the Secretary of the Academy of Science be requested to call the attention of the West Virginia University Officials to this resolution and to its application to the pending question concerning the erection of a permanent wall obstructing the view from Sunnyside bridge. After some discussion, the motion was carried.

It was moved by Prof. Hodge and duly seconded that the thanks of the Academy be extended to Director Frame and the Extension Division of West Virginia University for their generous help and cooperation in preparing programs, notices and advertising. Motion carried unanimously.

On motion, the meeting adjourned.

Charter members enrolled for the 1924 meeting:

Bailey, Sebie D.	Botany and Biology	Fairmont, W. Va.
Bancroft, G. R.	Chemistry	Morgantown, W. Va.
Bayles, C. H.	Engineering	Morgantown, W. Va.
Bergy, O. A.	Pharmacy	Morgantown, W. Va.
Boomsliter, G. P.	Engineering	Morgantown, W. Va.
Bourne, W. S.	Zoology	Morgantown, W. Va.
Brooks, A. B.	Game and Fish. Comm.	Buckhannon, W. Va.
Brown, S. B.	Geology	Morgantown, W. Va.
Bromley, H. W.	Minister	Cynthiana, Ky.
Carpenter, L. V.	Engineering	Morgantown, W. Va.
Colwell, R. C.	Physics	Morgantown, W. Va.
Chidester, F. E.	Zoology	Morgantown, W. Va.
Clark, F. E.	Chemistry	Morgantown, W. Va.
Cunningham, H. E.	Philosophy	Morgantown, W. Va.
Davis, H. A.	Mathematics	Morgantown, W. Va.
Davies, C. C.	Chemistry	Morgantown, W. Va.
Dadisman, J. S.	Agronomy	Morgantown, W. Va.
Deatrich, E. P.	Soil Technology	Morgantown, W. Va.
Dodds, G. S.	Embryology	Morgantown, W. Va.
Dorsey, M. J.	Horticulture	Morgantown, W. Va.
Eiesland, John	Mathematics	Morgantown, W. Va.
Fields, M. J.	Economics	Morgantown, W. Va.
Gayley, C. F.	Metallurgist	East Pittsburgh, Pa.
Garber, R. J.	Agronomy	Morgantown, W. Va.

George, E. F.	Physics	Morgantown, W. Va.
Giddings, N. J.	Botany	Morgantown, W. Va.
Hall, A. A.	Engineering	Morgantown, W. Va.
Hammond, E. L.	Pharmacy	Morgantown, W. Va.
Hill, Harry	Physics	Morgantown, W. Va.
Hill, Hubert	Chemistry	Morgantown, W. Va.
Jones, C. R.	Engineering	Morgantown, W. Va.
Knowlton, H. E.	Botany	Morgantown, W. Va.
Lawall, C. E.	Mining	Morgantown, W. Va.
Leitch, Andrew	Psychology	Bethany, W. Va.
Lyman, G. R.	Agriculture	Morgantown, W. Va.
McDowell, C. W.	Engineering	Morgantown, W. Va.
McMillen, Herbert	Chemistry	Morgantown, W. Va.
Molby, F. A.	Physics	Morgantown, W. Va.
Peairs, L. M.	Entomology	Morgantown, W. Va.
Price, P. H.	Geology	Morgantown, W. Va.
Reger, D. B.	Geology	Morgantown, W. Va.
Reese, A. M.	Zoology	Morgantown, W. Va.
Reynolds, C. N.	Mathematics	Morgantown, W. Va.
Rumsey, W. E.	Entomology	Morgantown, W. Va.
Rhine, J. B.	Botany	Morgantown, W. Va.
Rodgers, H. F.	Chemistry	Fairmont, W. Va.
Scheffel, E. R.	Geology	Morgantown, W. Va.
Schultz, J. A.		
Simpson, J. D.	Medicine	Morgantown, W. Va.
Strausbaugh, P. D.	Botany	Morgantown, W. Va.
Spangler, R. C.	Botany	Morgantown, W. Va.
Stark, A. H.		Charleston, W. Va.
Swan, W. O.	Chemistry	Morgantown, W. Va.
Tilton, J. L.	Geology	Morgantown, W. Va.
Turner, B. M.	Mathematics	Morgantown, W. Va.
Upton, A. Van Gordon	Chemistry	Clarksburg, W. Va.
Wagner, C. E.	Physics	Morgantown, W. Va.
Wade, B. L.	Agronomy	Morgantown, W. Va.
Weimer, B. R.	Biology	Bethany, W. Va.
White, A. S.	Political Science	Huntington, W. Va.
White, B. S.	Engineering	Morgantown, W. Va.
White, A. B.		Morgantown, W. Va.
White, I. C.	Geology	Morgantown, W. Va.
Winter, J. E.	Psychology	Morgantown, W. Va.
Workman, A. C.	Chemistry	Bethany, W. Va.

PROGRAM OF THE FIRST ANNUAL MEETING OF THE WEST VIRGINIA ACADEMY OF SCIENCE

GENERAL PROGRAM

Organization Meeting of The West Virginia Academy of Science, West Virginia University, November 29, 1924.

9:30 A. M.—Meet in the Physics Lecture Room, 20 Martin Hall, Dr. Bancroft, President W. V. U. Scientific Society, presiding.

Words of Welcome, Dr. F. B. Trotter, President, University.

Statement of the Objects of the Meeting, Dr. John Eiesland.

Appointment of Committees and Announcements.

10:00—Lecture: Lighting the Lamp of Conservation in West Virginia, Hon. A. B. Brooks, Chief Game and Fish Protector of West Virginia, Buckhannon.

10:45—Meeting of Sections for the Discussion of Papers:

Sections.	Room.		Leader.
Biology, Botany, Zoology	46	Woodburn Hall	Dr. A. M. Reese.
Physiology, Hygiene, Medicine		Woodburn Hall	Dr. G. S. Dodds.
Chemistry, Pharmacy	11	Science Hall	Dr. E. C. H. Davies.
Engineering	221	Mechanical Hall	Dean C. R. Jones.
Geology, Mining	111	Mechanical Hall	Dr. John L. Tilton.
Mathematics, Physics and Philosophy	15	Martin Hall	Dr. John Eiesland.
Social Science	127	Mechanical Hall	Dr. J. E. Winter.

12:00 M. to 1:30 P. M.—Lunch at W. V. U. Cafeteria. Tables may be arranged for sections to sit together. It is urged that local scientists join with the visitors for lunch and dinner.

1:45—Meet in the Physics Lecture Room, 20 Martin Hall. Dr. M. J. Dorsey, Vice-President, W. V. U. Scientific Society, presiding.

Popular Demonstration Lecture on Physics, Dr. R. C. Colwell and staff.

Business meeting, report of committees, election of officers.

3:00—Sectional meetings continued. (Same rooms as in the forenoon).

4:00—Inspection Trips:
Visit a Mine in Scott's Run, 111 Mechanical Hall, Prof. C. E. Lawall. University Building and Equipment, Physics Lecture Room, Dr. G. A. Bergy in charge.

6:00—Dinner at W. V. U. Cafeteria.

8:00—Lecture: Dr. Francis H. Herrick, Western Reserve University. Subject: Bird and Animal Instinct and Intelligence (illustrated). Physics Lecture Room.

SECTIONAL PROGRAM

Biology, Botany, Zoology. 46 Woodburn Hall. (3d. floor). Dr. A. M. Reese, leader.

Microscopic Crustacea Collected in the Canal Zone. Dr. G. S. Dodds.

Breeding of Corn for Resistance to Smut (Ustilage zeac). Dr. R. J. Garber.

Pit of Pit Vipers. Dr. A. M. Reese.

Habits of Brook Lampreys. Mr. W. S. Bourne.

Some Aspects of the Axial Gradient Theory of Structural Relationship in Organisms. Prof. B. R. Weimer, Bethany College.

Discharge and Dissemination of Fungus Spores.

Some Aspects of the Role of Temperature in Development. Dr. L. M. Peairs.

Smoke Injury to Vegetation. Prof. J. B. Rhine.

The Development of the Tetral Wall and Coats of the Pollen Grain. Dr. P. D. Strausbaugh.

The West Virginia University Course in Public Health. Dr. F. E. Chidester. Migration in Animals, Dr. F. E. Chidester.

Leaf Mold of Tomato. Dr. R. C. Spangler.

The Female Gametophyte of the Trillium Sessile. Dr. R. C. Spangler.

Fresh Water Mussels (Naiades). Prof. W. L. Utterback, Marshall College.

Chemistry and Pharmacy. 11 Science Hall. Dr. Earl C. H. Davies, leader.

Syntheses with Chloro-Ethers. Dr. Friend E. Clark.

Variation in Mineral Content in Morgantown City Water. Prof. W. W. Hodge.

Subject to be Announced. Prof. H. F. Rodgers, Fairmont State Normal School.

Molecular Orientation on Solids and in Gels. Dr. Earl C. H. Davies.

Engineering. 221 Mechanical Hall. Dean C. R. Jones, leader.

Bridge Building in West Virginia. Dr. R. P. Davis.

The Use of the Strain Gage in Engineering Investigations. Prof. G. P. Boomsliter.

Afternoon Meeting 3:00 P. M. Joint Meeting with Geology and Mining.

Tests on Suitability of Rocks of West Virginia for Road Building Purposes. Mr. R. B. Dayton, Materials Engineer, State Road Commission.

Geology, Mining. 111 Mechanical Hall. Dr. John L. Tilton, leader.

The Terraces Along the Monongahela. Prof. S. B. Brown.

The Conglomerate Rocks of West Virginia. Mr. D. B. Reger, Assistant Geologist, State Geological Survey.

The Principles of Soil Classification. Dr. E. P. Deatrick.

Some of the Problems in Oil and Gas Geology. Dr. E. R. Scheffel.

Tests on Suitability of Rocks of West Virginia for Road Building Purposes. Mr. R. B. Dayton, Meterials Engineer, State Road Commission.

Mining Machinery. Mr. M. L. O'Neale, Fairmont.

Excursion to a Mine in Scott's Run. Prof. C. E. Lawall.

Mathematics, Physics, and Philosophy. Dr. John Eiesland, leader.

Graphical Methods and Lines of Force. Dr. R. C. Colwell.

Some Studies of Absorption of Light by Mixed Solutions. Dr. E. F. George.

The Map Coloring Problem. Dr. C. N. Reynolds.

A Configuration of Pencils of Cubics. Prof. B. M. Turner.

On the Class of a Centro-Symmetric Space in Theory of Relativity. Dr. John Eiesland.

Logic in Mathematical Science. Dr. H. E. Cunningham.

Some Low Temperature Measurements of Refractive Indices. Dr. F. A. Molby.

Social Sciences. 127 Mechanical Hall. Dr. J. E. Winter, leader.

Teaching of History and Social Science. Prof. J. F. Boughter, Salem College.

A Study of Blondes and Brunettes. Dr. J. E. Winter.

The West Virginia Academy of Science following the completion of the business and program as before outlined adjourned to meet at the time and place as may be selected by the Executive Committee.

B. R. WEIMER,
Acting Secretary.

SECTIONAL PROGRAM FOR THE GEOLOGY AND MINING SECTION

The meeting was called to order by the leader, Dr. John L. Tilton, at 10:45 A. M. in room 111, Mechanical Hall. P. H. Price was appointed temporary secretary. Mr. D. B. Reger and Mr. S. B. Brown, Jr., were appointed as a committee on nomination of officers.

Those present at the morning session were:

Dr. John L. Tilton, leader.
Prof. S. B. Brown.
Prof. E. R. Scheffel.
Prof. E. P. Deatrick.
Prof. C. E. Lawall.
Mr. D. B. Reger.
Mr. S. B. Brown, Jr.
Mr. P. H. Price.

The following papers were presented at the morning session:

1. Terraces Along the Monongahela River. Prof. S. B. Brown.
2. The Conglomerates of West Virginia. Mr. D. B. Reger.
3. Principles of Soil Classification. Dr. E. P. Deatrick.

Discussion was taken up after each paper was presented.

The meeting was adjourned at 12:15 for lunch at the W. V. U. Cafeteria where reservations had been made for the section to eat together.

The afternoon session was called at 3:30 by the leader, Dr. Tilton. A report of committees was called for. The Committee on Nominations recommended for President, Dr. John L. Tilton, and Prof. C. E. Lawall for Secretary. The nominations were accepted by the members and declared duly elected.

The following were present at the afternoon session:

Dr. J. L. Tilton, leader.
Dr. I. C. White.
Prof. S. B. Brown.
Prof. E. R. Scheffel.
Prof. W. W. Hodge.
Prof. C. E. Lawall.
Mr. R. B. Dayton.
Mr. M. L. O'Neale.
Mr. P. H. Price.
Mr. D. B. Reger.
Prof. G. P. Boomsliter.
Prof. R. P. Davis.
Mr. R. C. Tucker.
Mr. S. B. Brown, Jr.

The following papers were presented during the afternoon meeting:

4. Some of the Problems of Oil and Gas Geology. Prof. E. R. Scheffel.

5. Tests on Suitability of Rocks for Road Building Purposes. Mr. R. B. Dayton.

6. Mining Machinery. M. L. O'Neale.

A general discussion of all papers was held. Dr. I. C. White spoke of coal mining in France.

At 4:00 P. M. Prof. C. E. Lawall conducted an excursion to a mine on Scott's Run.

Meeting Adjourned.

JOHN L. TILTON,
Chairman.

P. H. PRICE,
Acting Secretary.

PROGRAM OF THE SECOND ANNUAL MEETING OF THE WEST VIRGINIA ACADEMY OF SCIENCE

Held in Marshall College, Huntington, W. Va., November 6th and 7th, 1925.

Friday, 9:00 A. M.

Registration and Organization.

9:30 A. M.—Address of Welcome by President M. J. Shawkey.

Address by Superintendent Clarence C. Wright, Chamber of Commerce.

Address by Dr. James R. Bloss, Cabell County Medical Society.

Address by Mr. Howard A. Levering, Huntington Chapter A. A. E.

10:30—President's Address. Dr. George R. Bancroft.

Organization of sectional meetings.

12:30—Lunch.

Friday, 2:30 P. M.

Annual Business Meeting.

Sectional Meetings continued.

Biology Section. Chairman, Prof. B. R. Weimer, Department of Biology, Bethany College.

The Temporary Closure of the Oesophagus in Vertebrates. Professor H. Reese, Ph. D., Department of Biology, West Virginia University.

Fungi in the Economic Affairs of Men. Professor N. J. Giddings, Ph. D., Department of Plant Pathology, West Virginia University.

The Effect of High Pressure in the Germination of Seeds. Dr. Henry G. Knight, Director Experiment Station, West Virginia University.

Biology as Related to Altruism. Prof. W. S. Utterback, M. A., Department of Biology, Marshall College.

Can the Fats Move From Cell to Cell in the Plants? Dr.

J. B. Rhine, Department of Botany, West Virginia University.

Thoughts on Evolution With the Bible as a Background. Prof. C. A. Jacobson, Ph. D., Department of Chemistry, West Virginia University.

Chemistry Section. Chairman, Dr. E. C. H. Davies, Department of Chemistry, West Virginia University.

Pandemic Chemistry. Dr. Edward E. Phelps, Department of Chemistry, Marshall College.

The Educational Value of Chemistry. Prof. H. F. Rodgers, Fairmont Normal School.

The Hostile Chlorine Becomes a Friend to Man. Mr. D. W. Stubblefield, General Manager, Belle Alkali Co.

The Strength of Metals as Shown by Their Crystalline Structure. Dr. Mudge, International Nickel Plant.

The Use of Chemistry in Medical Diagnosis. James S. Klumpp, M. D., University of Michigan.

The Preparation of Esters Derived From Substituted Propyl Alcohols, and the Effect of Their Constitution Upon the Rate of Hydrolysis. Dr. George R. Bancroft, Ph. D., Department of Physiological Chemistry, School of Medicine, West Virginia University.

The Coagulation of Gum Colloids by Electrolytes. Dr. E. C. H. Davies, Department of Chemistry, West Virginia University.

All Chemical Papers to be given on Friday. Saturday to be devoted to the visiting of Chemical Plants in Huntington. Transportation by courtesy of Huntington Chamber of Commerce.

Geology Section. Chairman, Prof. J. L. Tilton, Department of Geology, West Virginia University.

(a) The Evolution Controversy.
(b) A Phase of Coal Conservation. Prof. E. R. Scheffel, Department of Geology, West Virginia University.
(a) The Permian of West Virginia as a Field of Research.
(b) A Notable Disconformity. Prof. John L. Tilton, Department of Geology, West Virginia University.

Excursions:—The members of the section will be offered the choice of two field excursions (either or both). One is along the Teay Valley, conducted by John L. Hussell; the other, details to be arranged later, will be a more extended trip to a coal area, probably conducted by Mr. Ivan Hollandsworth.

It is hoped that the members may find it convenient to lunch together on at least one occasion.

Mathematics, Philosophy, and Physics Section. Chairman, Dr. John A. Eiesland, Department of Mathematics, West Virginia University.

Operational Methods in Mechanics and Electricity. Prof. R. C. Colwell, Ph. D., Department of Physics, West Virginia University.

(a) Some Popular Misconceptions of the Einstein Theory.

(b) Singularities of the Flat Sphere Transformation. Prof. J. A. Eiesland, Ph. D., Department of Mathematics, West Virginia University.

Social Science Section. Chairman, Dr. Winter.

The Psychology of Freshmen Rules. Prof. J. E. Winter, Department of Psychology, West Virginia University.

Evaluation in Science and Education. Prof. Watson Selvage, Fellow of Owen College, Manchester University, Department of Psychology and Philosophy, Marshall College.

Changes in Curriculum Building. E. Turner Stump, Marshall College.

The Basic Assumption in Self-Government and the Teaching of Citizenship, Dr. Arthur S. White, Marshall College.

SECTIONAL PROGRAM FOR THE GEOLOGY, MINING, AND BIOLOGY SECTIONS

Minutes of the Meeting of the Section at Huntington, 1925.

Geology Mining section met with the Biology and Zoology section at 4 P. M., November 6, 1925, in room 211 at Marshall College, Huntington, West Virginia.

The meeting was called to order by Dr. John L. Tilton, Chairman of the section and the minutes of the last meeting were read by Mr. C. E. Lawall, Secretary.

After the reading of the minutes the Biology and Zoology section presented their papers. After this the Geology and the Mining section presented their papers. The papers presented were as follows:

Biology and Zoology:

Paper No. 1—Biology as Related to Altruism by Prof. W. S. Utterback, Marshall College.

Paper No. 2—Can the Fats Move From Cell to Cell in the Plants. Read by title. J. B. Rhine.

Geology and Mining:

Paper No. 3—A Phase of Coal Conservation. Earl R. Scheffel.

Paper No. 4—The Evolution Controversy. Earl R. Scheffel.

Paper No. 5—The Permian of West Virginia as a Field for Research. Dr. J. L. Tilton.

Paper No. 6—Local Conditions at a Mississippian Disconformity. Dr. J. L. Tilton.

After reading the papers the Chairman requested the Committee on Nominations, consisting of Mr. H. F. Becker, Marshall College, Mr. Homer M. Derr, of New River State School, to bring in nominations for new officers for the following year. The committee presented the name of Mr. C. E. Lawall as Chairman of the section for the following year, but failed to bring in nominations for Secretary. It was suggested that the Secretary be elected at the next meeting of the section.

After the adjournment of the meeting for the day, the members went to the Mary E. Ann Tea Room for supper.

Saturday, November 7, 1925

The members gathered at room 201, Science Hall, Marshall College, and went, by automobile, to the plant of the International Nickel Company. This trip proved to be a most interesting one. Later some of the members went up the Teays Valley as far as Barboursville on a very interesting geological trip.

JOHN L. TILTON,
Chairman.
CHAS. E. LAWALL,
Secretary.

The following resolution of appreciation offered by Dr. John L. Tilton of Morgantown was adopted unanimously:

Resolved, That we express our appreciation of the cordial reception and hospitality that we have received at our second annual meeting held at Marshall College, Huntington, West Virginia, on Friday and Saturday, November the sixth and seventh, 1925. The local arrangements for the success of the meeting were all that could be desired, as they afforded adequate rooms for the meetings at the college, arrangements for luncheon together, and arrangements for excursions to the nickel plant and to points of geologic interest in the region through the cooperation and generosity of the Chamber of Commerce, the members of which arranged for the autos.

We appreciate, too, the words of greeting extended to the Academy by the President of Marshall College, M. P. Shawkey, by the Superintendent of Schools, Clarence L. Wright, representing the Chamber of Commerce, by Dr. James B. Bloss, representing the State Medical Association, and by Howard A. Levering and H. J. Spellman, representing the Huntington Chapter of the American Association of Engineers.

Such friendly greetings and cordial treatment speak well for the spirit of Huntington. As an Academy we wish to acknowledge our indebtedness to this kindness and to this interest in science and education.

DATE-SEED GERMINATION

BY NELLIE P. AMMONS

The date (Phoenix dactylifera) belongs to the family Palmaceae, one of the monocots. It is a native of tropical countries, but it is now being grown successfully in the southwestern part of the United States.

The seed of monocots usually contains a strongly developed endosperm with a comparatively small embryo, and this feature is clearly shown in the seed of the date (Fig. 10). The seed develops from an anatropous ovule, and during the process of development a torsion of the ovule takes place so that at maturity the embryo is at right angles to its original position, now lying embedded transversely in the large endosperm (Fig. 10), on the side of the seed opposite the raphe (Fig. 2). The endosperm is composed of cells with very hard thick walls, the constituents of which serve as reserve food material.

Germination proceeds very slowly. Seeds were soaked in water from six to eight weeks before there was any outward manifestation of germination. The first change noted was the lifting of the endosperm plug that covers the micropyle (Fig. 1), this being followed by the projection of the cylindrical or sheath-like region of the cotyledon (Fig. 3). This part of the cotyledon becomes such elongated (Figs. 4, 5) and just above the tip it is considerably swollen (Fig. 6) by reason of the enlargement of the young embryo which lies within. The lower end of the axis of the embryo develops into the primary root (Fig. 7) which grows downward, producing secondary roots (Fig. 8) and forming contact with the soil. The upper end of the axis develops the plumule (Figs. 7, 8) which consists of two leaf-like structures, one giving rise to a sheath-like leaf (Figs. 8, 9) and the other to a linear leaf plaited or folded together like a fan (Figs. 7, 9). These elongate and escape from the cotyledonary sheath (Fig. 8), the former sheathing the folded leaf which shoots upward establishing the first photosynthetic machinery of the plant (Fig. 9). The first leaves above the cotyledon are small simple leaves, blade-like in form (Fig. 9), and less perfectly developed than the later ones which are pinnately compound leaves. The axis remains very short during germination without forming any visible internodes. The upper part or apex of the cotyledon remains embedded in the endosperm as an organ of absorption (Fig. 11). As the seedling enlarges, this part of the cotyledon encroaches upon the endosperm, until eventually it is all consumed by the growing seedling (Figs. 11, 12, 7, 13). By this time the photosynthetic area is great enough that further reserve material is not necessary.

A rather remarkable phenomenon of adaptation is exhibited by the action of this cotyledon. The natural habitat of the date is in an arid region, water being found commonly only at considerable depths.

This cotyledon by the elongation of its axis carries the delicate growing points of roots and stem downward to the region of water supply, thus protecting them from the hot and dry soil near the surface.

All habit sketches are natural size.

EXPLANATION OF PLATE

Abbreviations: m, micropyle; hi, hilum; r, raphe; c, chalaza; t, testa; cs, cotyledonary sheath; co, absorptive region of cotyledon; p, plumule; p_1, first leaf succeeding cotyledon; p_2, first foliage leaf; r_1, primary root; r_2, secondary root; rc, rootcap; e, endosperm; em, embryo; sw, swollen area due to enlargement of embryo.

Fig. 1.—Dormant seed showing dorsal surface.

Fig. 2.—Dormant seed showing ventral surface.

Fig. 3.—Seed germinating after soaking for six weeks.

Figs. 4 and 5.—Later stages of germination.

Fig. 6.—Stage showing swollen area in cotyledon.

Fig. 7.—A longitudinal section of a seedling slightly older than that of Fig. 6 (After Sachs).

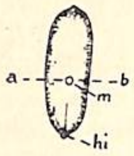
Fig. 8.—Seedling with plumule emerging through ruptured cotyledonary sheath.

Fig. 9.—Young plant with first foliage leaf expanded. About four months old.

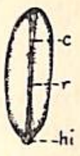
Fig. 10.—Cross section of a dormant seed at a—b, Fig. 1.

Fig. 11.—Cross section of a germinating seed as c—d, Fig. 3.

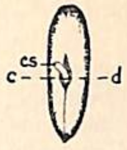
Figs. 12 and 13.—Cross sections showing later stages of development of the absorptive region of the cotyledon, as found in seedlings of Figs. 6 and 9, respectively.



1

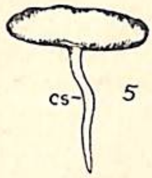


2

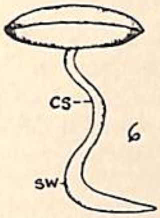


3

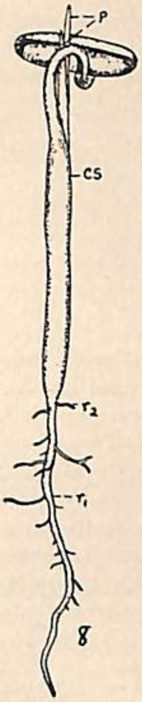
4



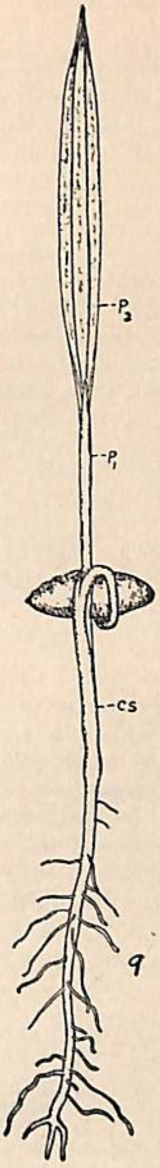
5



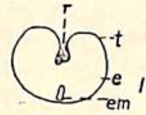
6



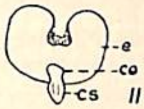
8



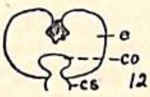
9



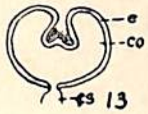
10



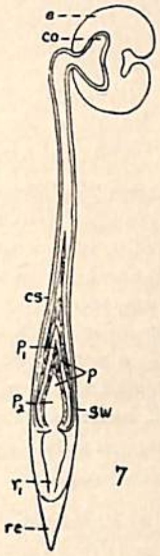
11



12



13



7

H.P.B., del.

THE PLASTICITY OF SPECIES IN GENUS FUSARIUM

BY LEON H. LEONIAN

The species concept has been the source of many controversies since the dawn of taxonomic period in biology. Many people have gone no farther than mere academic discussions; others have based their judgments on field observations and on studies of herbarium or museum specimens; only comparatively few have attempted to seek a better answer to the riddle by means of controlled physiological experiments.

The species concept seems to offer no difficulty to the old-school taxonomist; he has placed all his organisms in well defined and highly rigid pigeon-holes; whenever he encounters an organism which fails to fit into any of the pigeon-holes at his disposal, he immediately constructs others; then there is much glee and beating of drums in celebration of the birth of another new species.

The experimental physiologist, however, offers no cast-iron cells for the housing of his species; in fact he can not regard the species as definite and immutable units, each placed in an isolated sphere. Any one species is a highly plastic and overlapping component of a continuous stream called life. Mere classification, therefore, can have no great biological significance because human conception of species is a highly artificial and clumsy attempt to imprison the living protoplasm with its infinite potentialities within the bleak walls of a name.

It can not be denied, however, that taxonomy is a necessary evil; but unless it is greatly liberalized it may prove to be replete with danger. When life is expressed in terms of mathematical formulae, it loses much of its majesty. To put a rigid fence around a living organism means to reduce it to the level of a dead matter. The successful investigator approaches even the simplest living being with awe and reverence because he realizes that even a microbe is a very much unknown and mysterious entity. Yet most taxonomists speak glibly of thousands of species and display them on formal parade, each species waving a flag, the trade mark of some investigator who perpetuated his name by building a prison for some unfortunate protoplasm.

There are a great number of cases on record where one can see a sort of protoplasmic revolt against the unsympathetic viewpoint of taxonomists. Well bred and well behaved species have suddenly gone on a rampage and have produced unexpected and embarrassing forms which skilfully elude all attempts of the lariat and the branding iron. Such cases are known as reversible mutations: a given species suddenly throws off forms which are remarkably different from their maternal strain. After breeding true for several generations these filial forms may suddenly and completely reverse to their maternal type again. It appears that at one time these organisms represent one species and at another time a different species; a most baffling situation for the puzzled taxonomist.

The writer has isolated and studies nearly two hundred fixed and reversible mutations which occurred in the genus Fusarium. This fungus has a world-wide distribution and is causing a larger number of destructive plant diseases than any other group of fungi. Usually an organism produces only one mutation; but three to eight mutations from one fungus culture are not uncommon. One species has thrown off nineteen well defined forms and has not ceased mutating yet. The remarkable thing about this organism is the fact that for over one year it showed no sign of mutating, and then suddenly it began to split up.

The taxonomists classify the species of Fusarium on the following characteristics: color, aerial hyphae, rate of growth, presence or absence of sporodochia and pionnotes (types of reproductive bodies), sclerotia, type of spores (three kinds of spores are known, microconidia, macroconidia and chlamydospores), sizes and shapes of these spores, and pathogenic relationships. However these characteristics are not only too limited in number but they are, in most cases, highly unstable as well and the mutations play havoc with them, as can be seen, for example, by the action of the eight mutations of **Fusarium stilboides:** four of these produce sporodochia, one gives rise to pionnotes, and the remaining three have neither sporodochia nor pionnotes. Five of these eight forms yield no microconidia or chlamydospores, one produces no spores at all, and another borders on sterility because of the extreme rareness of its reproductive bodies. Only one of these is colored a bright purple, the remaining are colorless, and while one form produces sclerotia, the other seven do not. Six of these mutations can not tolerate more than four-tenths of a per cent of tartaric acid, one can not grow in presence of more than two-tenths of a per cent of acid, and one grows well in as high as three per cent of this acid. Seven of these organisms can form no spores in presence of two-tenths of a per cent of tartaric acid, but one produces a great quantity of spores in the presence of one and one half per cent of the acid. Three of these organisms can attack the egg albumin, seven attack and digest milk casein, only one does not reduce nitrates to nitrites, only one forms aldehyde in culture; seven produce catalase but only two give rise to a very limited amount of free oxidase; three can not precipitate colloidial gold, two bring about partial precipitation and three precipitate it completely; seven are able to reduce methylene green and one is unable to do so. Four of these can not cause a rot of lemon, one causes a local rot and three attack the lemon fairly readily.

The foregoing is just a partial list showing the differences between the mutations of the same species. The remaining of the two hundred mutations show just as striking differences among themselves. It is fairly obvious that the taxonomist is unable to meet the situation because the specific steps with which he is trying to approach a satisfactory solution are necessarily limited in number and one or two hundred closely related organisms can not be separated from each other by ten or twenty more or less dubious and overlapping differences. It is up to the experimental physiologist to develop at least one hundred clear-cut reactions and to combine these with what stable morphological features this genus possesses and thus have a working scheme whereby more closely related forms can be recognized with more ease and certainty. But it should be realized that no two organisms are absolutely alike and that two members of the same species found in different parts of the world can not be expected to show similar reactions in all cases without a number of exceptions. When the worker realizes that a few exceptions in morphological characteristics and physiological reactions can safely be considered as normal even though constant variations of the members of the same species rather than cross-roads leading to new species, then the chaotic condition prevailing in the taxonomy of many groups will be greatly simplified.

THE AXIAL GRADIENT THEORY OF STRUCTURAL RELATIONS

BY B. R. WEIMER

In the brief span of twenty minutes it is obviously absurd to attempt to do more than merely introduce a theory in support of which several volumes have been written and on which a multitude of research has been done. However, in view of the fact that two volumes have appeared recently in which the Axial Gradient Theory is suggested as a basis for the study of animal behavior and since two recent textbooks on zoology make liberal application of the same, it seemed that it might be worthwhile at least to introduce the subject of Axial Gradients for your consideration. The compiler of this short outline claims no particular fitness for the presentation of this topic other than a live interest in the subject and having had an opportunity to repeat some of the experiments under the supervision of the chief exponent of the theory, Dr. Child of the University of Chicago.

According to the Gradient concept there are in all organisms, both plant and animal, quantitative graduations in the intensities of metabolic rate along certain axes. Usually there is present a chief or major axis with various subordinate axes. In most axiate individuals the chief or polar axis first appears and differentiation and specialization, both qualitatively and spatially, occur in reference to this. In each axis or gradient there is a region of very high metabolic rate or dynamic activity. This is designated usually as the anterior or apical end. This is the head region of most embryos and here is found the first appearance of the nervous system. In plants this region is the growing tip of the stem or the root. The region of lowest intensity is the basal or posterior end where sessile organisms are attached or regions under control of the anterior end. Transmissions of excitation travel with diminishing intensity from the anterior or apical end to the posterior or basal, somewhat as waves appear on a pond, the intensity of the transmission depending upon the intensity of the stimulus and the distance travelled as well as the nature of the protoplasm. Repeated transmissions have a tendency to increase conductivity. By this means the relations of dominance and subordinance in the various parts of the organism are kept relatively constant.

Gradients may be measured and demonstrated by differences in rate of oxygen consumption and carbon dioxide elimination. In regions of greatest metabolic activity this exchange will be greatest and will decrease toward the basal end of the gradient. Various means have been used to demonstrate this differential exchange. Use has been made of KCN, $KMnO_4$, alcohol, formaldehyde, chloretone, neutral red, sea water, and various other poisons and solutions. Direct measurements of oxygen consumption and carbon dioxide production have been made. Several readings have been made of the changes in electrical potential.

Potassium cyanide first attacks regions where the greatest oxidation is taking place with the result that the tissue disintegrates. Thus regions of high metabolism may be demonstrated. This works out very satisfactorily with eggs and embryos and certain animals, particularly the flat worms, Coelenterates, and Protozoa.

The reduction of potassium permanganate shows the gradient very well since the different levals of the gradient reduce the substance in varying amounts thus leaving it black or brownish due to the deposition of $MnO\frac{1}{2}$ or other oxides in the protoplasm. The reduction of methylene blue after the protoplasm has been stained with it has also been used for gradient demonstration in both plants and animals. (See chart).

The direct measurement of oxygen consumption and carbon dioxide elimination has been made by placing equal weights of pieces from different levels of the organism in small vials and later measuring the amount of oxygen consumed and carbon dioxide given off. By these and various other methods it has been proven rather conclusively that such gradients do exist.

Various explanations are offered for the origin of gradients or, in other words, the axes of an organism. Are they inherited? Apparently not. The position of a gradient and thus the axis of in protoplasm is determined by the environment of that particular bit of protoplasm. In the plant Fucus, for example, the polarity of the egg is determined by light. In other organisms, particularly in the case of plants, gravity may have some effect.

Differential exposure whereby one part of an egg may have a greater oxygen and carbon dioxide exchange than the remaining surface may determine what may be the apical or what may be the basal end of a gradient and so in this way is determined the polarity of the developing organism. Thus the place of attachment in some eggs, as in Chaetopterus, Phialidium, Sternapsis, being the region of least exchange, becomes the basal end and the free end becomes the anterior or apical. That exposure does have some effect on the determination of the gradient can be readily demonstrated by the work on Corymorpha where the principal gradient has been changed from its former position to one at right angles to it or even completely reversed. (See chart).

Thus the conclusion is offered that polarity of an individual is determined by environment through the various potentialities are found in the chromatin.

It would appear from many experiments on various animals and plants that the regions of high metabolic activity exercise a dominance over regions of less activity in the same or in different axes. This being true any change in metabolic rate in the dominant region will affect the dimensions and distance relations of parts along an axis. Changes in the nature of the gradient have been made by various means. Immersion of aquatic animals in dilute poisons or narcotics have a tendency to lower the rate. In plants crushing, compressing, or cutting, changes the gradient relations. Sometimes the original gradient is entirely obliterated and a new one established as in the case of Corymorpha, Planaria, Marchantia, etc. (Consult chart).

Removal of the head region of planaria results in fission and the formation of a new animal from posterior zooids. The same result; namely, fission, can be brought about by use of an inhibiting agent whose tendency is to lower the rate at the apical end of the gradient, thus decreasing the dominance of that region which in turn gives a greater relative rise to some posterior zooid which pulls off and becomes an independent living organism.

In plants removal of the growing point of a stem frees the buds in posterior regions from dominance and results in their growth, as may be seen in experiments with leguminous seedlings of beans and peas. Here removal of the growing tip results in one or more branches arising from axils of the leaves. (See chart). Inclosure of the growing tip in plaster-paris or an atmosphere of hydrogen brings about the same result without apparent interference with the transportative system of the plant. Practically the same results can be accomplished in willow and other stems. Plants may be isolated by cutting the fibro-vascular bundles leading to the leaves as can be seen in the budding of the leaf of Bryophyllum and the leaf formation in Cyclamen.

A gradient apparently exists in the roots of plants though this is in the opposite direction from that in the stem and in turn seems to exert an inhibiting influence on the development of roots in other parts of the plant. Remove or incase the root tip thus changing the metabolism of that part and adventitious roots appear further up the stem or the present lateral roots may change their direction of growth. (See chart). Child admits that here the inhibiting influence of the root system on the formation of roots in other parts of the plant may be a transportative rather than a transmissive correlation, and that other parts give rise to roots when this transportation falls below a certain minimum or when they are isolated from it in any way.

Perhaps the most interesting results in animals have been secured by what Child calls differential inhabition which means that parts of the body which normally have the highest rate of metabolism and are the first to differentiate are most readily inhabited by growth-depressing agents while parts with the lower or lowest metabolic rates are least affected. This means that subordinate axes may develop at the expense of the primary and thus the form of an organism may be radically changed. The primary gradient may be reestablished but never, so to speak, with its old power of dominance. The old part of an organism may regenerate but not in quite the same form as may be seen in the regeneration of heads and eye formation in planaria. If, however, the recovery from the effects of the inhibiting agent is rapid, the regions of highest metabolic rate recover more rapidly and may in turn develop more rapidly than the more posterior portions. (See chart).

The application of the Axial Gradient Theory is applied in an interesting way by Newman in his Vertebrate Zoology to explain the many varied and bizarre forms of fishes. He says, "In general the eel-like type may be interpreted as a result of a suppression of the head parts" (by inhibition of apical end of gradient) "and consequent relative increase in the development of the body and tail." The antithesis of the eel-like type is one with head parts abnormally large and body and tail suppressed which may be due to the more rapid recovery in the apical end of the axis and a higher rise in metabolic rate." Short, high, laterally compressed types, such as the common sunfish, for example, and low laterally expanded types, exemplified by the skates and flounders, are due to exaggerations of the dorso-ventral axis or the bilateral axis. All of these types as well as more extreme forms have been obtained by experimental methods in the laboratory. Newman suggests that the slowing down of metabolic rate due to racial senescence may supply the necessary inhibitory influence on the gradient. Whether or not Newman is too premature in the application of the theory will not be discussed here but it, at least, offers an interesting explanation of form regulation and development from a physiological point of view.

CHLORO ETHERS

BY FRIEND E. CLARK

Since the report of the work on chloro ethers before the annual meeting of the West Virginia Academy of Science, in 1924, some results of the investigations have been published. The Editor of the Journal of the American Chemical Society has given his permission to reprint the article from Vol. **47**, 2419-2423 (1925), as here given.

[Reprint from the Journal of the American Chemical Society, **47**, 2419 (1925.)]
[Contribution from the Chemical Laboratory of West Virginia University.]

CHLORO ETHERS. II. PREPARATION OF SOME NEW CHLORO ETHERS AND ALKOXYMETHYL ESTERS

By J. W. Farren and H. R. Fife,[1] with F. E. Clark and C. E. Garland

Received June 20, 1925. Published September 5, 1925.

In a previous article[2] from this Laboratory Clark, Cox, and Mack have described a series of esters prepared by the action of chlorodimethyl ether on the salts of formic, acetic, propionic and butyric acids. A continuation of this work has led to a study of other chloro ethers of this same series of acids, in addition to the preparation of some new chloromethyl ethers which include those of secondary as well as primary alcohols. Gaspari[3] studied the action of chloromethylethyl ether on fused sodium acetate and recorded the properties of the compounds formed. Wedekind[4] has also studied the action of chloromethylethyl ether on potassium acetate and lead formate but no physical properties of these products were reported. This work was furthered by W. H. Moran in this laboratory and a study made of the ethers from the salts of formic, acetic, propionic and butyric acids, but the incompleteness of data and lack of analyses have necessitated its duplication. A search of the literature indicated that only one secondary alcohol has been used in the preparation of a chloro ether. Stappers[5] prepared chloromethyl-*iso*propyl ether and reported some of its constants.

In this investigation a modification of the methods of Wedekind and Henry was used in preparing the chloro ethers. In general it con-

---

[1] This article is an abstract from theses submitted by J. W. Farren and H. R. Fife for degrees of Master of Science at West Virginia University. A preliminary paper was presented before the Organic Divsion at the 69th Meeting of the American Chemical Society, April 6-10, 1925 (by F. E. Clark).

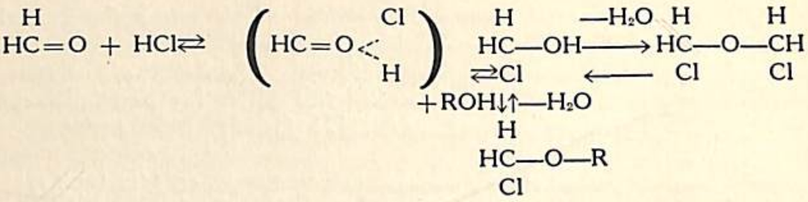
[2] Clark, Cox and Mack, This Journal, **30**, 712 (1917).

[3] Gaspari, Gazz. chim. ital., [II] **27**, 297 (1897).

[4] Wedekind, Ber., **36**, 1383 (1903).

[5] Stappers, Bull, Acad. Roy. Belgique, 1161-70 (1904); Chem. Centr., **76**, 921 (1905).

sists in treating molecular equivalent quantities of an alcohol and aldehyde, in the form of trioxymethylene, with dry hydrogen chloride. We propose to represent the reaction mechanism as follows:



$$\overset{H}{HC}{=}O + HCl \rightleftarrows \left(HC{=}O\overset{Cl}{\underset{H}{<}} \right) \begin{array}{c} \overset{H}{HC}{-}OH \xrightarrow{-H_2O} \overset{H}{\underset{Cl}{HC}}{-}O{-}\overset{H}{\underset{Cl}{CH}} \\ \rightleftarrows Cl \quad \longleftarrow \\ +ROH\downarrow\uparrow{-}H_2O \\ \overset{H}{\underset{Cl}{HC}}{-}O{-}R \end{array}$$

It is known that aldehydes tend to add hydrogen chloride, and in the case of formaldehyde one of the products is chloromethyl alcohol, which may possibly be formed through the intermediate development of an oxonium compound. The chloromethyl alcohol unites with the alcohol used in the reaction with the elimination of a molecule of water to form the mono-chloromethyl-alkyl ether. There is also some of the symmetrical dichlorodimethyl ether, which, since it resembles α-chloro ethers tends to revert to chloromethyl alcohol. This general tendency is well known in the case of α-chloro ethers which tend to hydrolyze readily with the formation of the corresponding chloro alcohol, this in turn breaking up to give the aldehyde and hydrogen chloride. For example, α-chlorodiethyl ether yields ethyl alcohol, acetaldehyde and hydrogen chloride. The ease of hydrolysis of chloromethyl-alkyl ethers may, then, be considered as due to the fact that a substitution of chlorine for hydrogen renders the methyl radical more negative, thereby allowing the bond between it and the ether oxygen to be more readily broken.

EXPERIMENTAL PART

Preparation of Chloro Ethers.—In the modification of the methods of Wedekind and Henry equivalent quantities of alcohol and trioxymethylene were treated with dry hydrogen chloride in a reaction flask surrounded with an ice-bath in order to remove the heat liberated and at the same time to increase the solubility of the hydrogen chloride. After a state of saturation had been reached the product was separated from the aqueous hydrochloric layer and dried over fused calcium chloride. After the product was thoroughly dried, a stream of dry hydrogen was passed through it in order to remove any free hydrogen chloride and also any which might be retained as an oxonium compound of the ether. The material was then further distilled in a current of dry hydrogen which practically eliminated decomposition at this point. Previous fractionation without the use of hydrogen always resulted in a large amount of decomposition together with deposition of trioxymethylene in the condenser. After being distilled twice in a current of hydrogen the product was fractionated, and an average yield of 90% of constant-boiling ether was obtained. With the alcohols used in these syntheses, the same amount of care being taken to insure against moisture, there is no marked tendency toward decomposition of one product as compared with another.

New chloromethyl ethers have been prepared from the following alcohols: *sec.*-butyl, cyclohexanol, ethylene chlorohydrin and *iso*propyl alcohols. However, the last has previously been prepared by Stappers, but some additional data are given on this and the ether from ethyl alcohol as well. Reactions were carried out using ethylene glycol and glycerol respectively, in an attempt to form the corresponding chloromethyl ethers. In each case the reaction took place very readily, all of the solid trioxymethylene disappearing from the mixture, but as yet we have been unable to separate and purify the products formed.

TABLE I

CHLORO ETHERS. GENERAL FORMULA: $R—O—CH_2—Cl$

	R	B. p. °C	d_4^0	d_4^{20}	n	Molecular refraction Calcd.	Molecular refraction Obs.
1.	$C_2H_5—$	81-82	1.0463	1.0263	1.0282 (12°)	22.49	22.55
2.	$(CH_3)_2CH—$	97-98	1.0000	0.9790	1.4592 (16°)	27.05	26.85
3.	$\begin{matrix} CH_3 \\ C_2H_5 \end{matrix} > CH—$	121-123	0.9947	0.9751	1.4205 (16°)	31.62	32.08
4.	$(R) C_6H_{11}—$	183-185	1.0712	1.0432	1.4713 (9°)	38.56	39.02
5.	$Cl—CH_2CH_2—$	145-147	1.3157	1.2817	1.4952 (11°)	27.39	27.23

	Formula	Mol. wt. Calcd.	Mol. wt. Obs.	Analysis for Cl, % Calcd.	Analysis for Cl, % Found	Yield, %
1.	C_3M_7OCl	94.5	95.7	37.53	37.42	85
2.	C_4H_9OCl	108.5	107.8	32.67	32.02	85
3.	$C_5H_{11}OCl$	122.5	122.2	28.90	29.56	70
4.	$C_7H_{13}OCl$	148.5	149.2	23.86	23.01	50
5.	$C_3H_5OCl_2$	128.9	130.1	54.98	54.32	65

ESTERS BY REACTION OF CHLORO ETHERS WITH SALTS OF ALIPHATIC ACIDS

The reaction of chloro ethers with salts of organic acids has been described in a previous article published from this laboratory. In the present investigation the technique has been modified so as to warrant a detailed description here, changes having been introduced so that yields of 80-90% may be obtained. All sodium salts of the acids were carefully fused, with the exception of the formate, which was dried in a desiccator over sulfuric acid. The salts were placed in a reaction flask which was fitted with a mercury-sealed mechanical stirrer, reflex condenser, dropping funnel, inlet and exit tubes. The flask was then immersed in an ice-bath and the contents were stirred rapidly while the ether was slowly introduced. It was found advantageous to continue the stirring to completion of the reaction by refluxing on a water-bath as had previously been done. On completion of the reaction the ester was distilled from the reaction flask in a current of dry hydrogen to a second flask, and redistilled to a third in a stream of hydrogen before final fractionation. Before beginning the preparation, the three flasks with condensers in series between were carefully dried by passing dry heated air for several hours through the entire system. This was done in order to carry out the preparation and purification of the material without having it come at any time into contact with the moisture of the air.

The series of esters prepared includes the formates, acetates, propionates and butyrates from the following ethers: chloromethylethyl, chloromethyl*iso*propyl, chloromethyl-*sec.*-butyl. A formic ester, which boiled at 184-188°, was prepared from β-chloro-ethyl-chloromethyl ether. This was not purified sufficiently to allow us to report its properties. An analysis of this product shows that only one chloride has re-

TABLE II

ESTERS PREPARED FROM CHLORO ETHERS. GENERAL FORMULA: $RCOOCH_2OR'$

	R.	R′	°C B. p.	d_4^0	d_4^{20}	*n*	Molecular refraction	
							Calcd.	Obs.
1.	H-	ethyl	114-116	1.0537	1.0343	1.3900 (12°)	23.77	23.55
2.	Methyl	ethyl	128-129	1.0081	0.9932	1.3903 (12°)	28.30	27.87
3.	Ethyl	ethyl	145-146	0.9931	.9711	1.4000 (12°)	32.91	32.75
4.	Propyl	ethyl	160-162	.9816	.9656	1.4050 (16°)	37.52	38.33
5.	H-	*iso*propyl	124-126	1.0270	1.0000	1.3910 (25°)	28.30	27.70
6.	Methyl	*iso*propyl	133-135	0.9761	0.9502	1.3890 (16°)	32.91	32.50
7.	Ethyl	*iso*propyl	147-149	.9626	.9444	1.3980 (18°)	37.52	37.30
8.	Propyl	*iso*propyl	164-166	.9617	.9432	1.4001 (16°)	42.05	41.92
9.	H-	*sec.*-butyl	147-148	.9683	.9477	1.4020 (17°)	32.91	33.51
10.	Methyl	*sec.*-butyl	156-158	.9574	.9319	1.4035 (19°)	37.52	37.38
11.	Ethyl	*sec.*-butyl	164-166	.9519	.9291	1.4075 (18°)	42.05	42.38
12.	Propyl	*sec.*-butyl	177-178	.9492	.9283	1.4085 (20°)	46.62	46.00

	Empirical formula	Mol. wt.		Analyses				Yield %
				Carbon, %		Hydrogen, %		
		Calcd.	Obs.	Calcd.	Found	Calcd.	Found	
1.	$C_4H_8O_3$	104.0	105.2	46.15	46.25	7.70	7.98	70
2.	$C_5H_{10}O_3$	118.0	117.8	50.80	50.99	8.53	8.27	85
3.	$C_6H_{12}O_3$	132.0	133.4	54.54	54.35	9.15	9.32	85
4.	$C_7H_{14}O_3$	146.1	145.7	57.51	57.30	9.60	9.61	90
5.	$C_5H_{10}O_3$	118.0	120.1	50.80	50.71	8.53	8.56	60
6.	$C_6H_{12}O_3$	132.0	133.0	54.54	54.36	9.15	9.05	66
7.	$C_7H_{14}O_3$	146.1	145.2	57.51	57.40	9.60	9.66	75
8.	$C_8H_{16}O_3$	160.1	158.4	60.00	59.90	10.00	9.78	85
9.	$C_6H_{12}O_3$	132.0	132.4	54.54	54.05	9.15	9.09	65
10.	$C_7H_{14}O_3$	146.1	146.7	57.51	57.61	9.60	9.54	75
11.	$C_8H_{16}O_3$	160.1	158.0	60.00	59.60	10.00	9.91	80
12.	$C_9H_{18}O_3$	174.1	173.0	62.05	61.80	10.34	9.96	65

acted with the sodium salt of the acid. A further study is being made of this reaction.

Carbon and hydrogen were determined by the usual method of combustion, samples being sealed in small weighed bulbs and the tips broken before introduction into the furnace. Chlorine was determined by the Parr bomb method. In this case samples were sealed in small vials as in the combustion method. The difficulty of filling these vials without causing traces of hydrolysis probably accounts for the fact that the chlorine values tend to run consistently low. For molecular-weight determinations the freezing-point method was employed, benzene being used as a solvent.

SUMMARY

1. Some new chloromethyl ethers have been prepared from primary and secondary alcohols and their physical properties and reactions with sodium salts of aliphatic acids studied.

2. Three series of four esters each, which include the formates, acetates, propionates and butyrates, have been prepared from the chloromethyl ethers of ethyl, *iso*propyl and *sec.*-butyl alcohols.

THE COAGULATION OF GUM COLLOIDS BY ELECTROLYTES

BY E. C. H. DAVIES AND P. W. EDEBURN

According to C. R. Toothaker[1] "Gums, resins and related substances are so varied in their character and qualities that it requires much care to classify, define and describe them accurately. The word gum loosely used and in popular language is applied in a very general way to any substance which has certain qualities which are easier to recognize than to describe. In this broad sense the word gum is often applied to rubber, resins, camphor and to oils which have become thick or sticky.

"Strictly speaking, true gum is a vegetable substance which dissolves in cold water forming a mucilage or else swells up and makes a thick, sticky mass.

"Gum copal is not a true gum in this sense but is really a resin. Gum camphor is chemically a volatile or essential oil and is called a gum only because it has a feel and tenacity which are understood when we say that it is gummy. Rubber is called gum because it has this same peculiar feeling when handled."

According to K. Dieterich[2] gum benzoes obtained from Siam contains 40% benzoic acid (C_6H_5COOH); 55% siresinotannol ($C_{12}H_{14}O_3$); and 5% benzoresorcinol ($C_{16}H_{26}O_2$).

Gum copal obtained from Africa, America and East Indies contains 80% trachylolic acid ($C_{54}H_{85}O_3OH\ (COOH)_2$); 10% etherial oil.

Gum dammar obtained from India contains 23% dammarolic acid ($C_{54}H_{77}O_3(COOH)_2$); 40% Alpha-dammar resene ($C_{11}H_{17}O$); 23% Beta-dammar resene ($C_{31}H_{52}O$).

Gum gamboge obtained from Siam and Ceylon contains 70% gamboge acid ($C_{30}H_{35}O_6$); 17% gum.

Gum guaiac obtained from tropical America contains guaiacum resin ($C_{20}H_{23}O_3OH$); guaiaconic acid ($C_{20}H_{22}O_3(OH)_2$); guaiac acid ($C_{21}H_{19}O_4\ (OH)_3$)

Gum mastic obtained from Chios contains Alpha-masticonic acid 20% ($C_{32}H_{48}O_4$); Beta-masticonic acid 18% $C_{32}H_{48}O_4$); Alpha-masticoresene 30% ($C_{35}H_{56}O_4$); Beta-masticoresene 20% ($C_{35}H_{56}O_4$).

The literature gives little information concerning work on the preparation and study of colloidal solutions made from the many types of gums and resins.

Considerable work has heretofore been done on such gums as mastic and gamboge,[3] but there seems to have been no comparison of gum colloids.

Our problem has been to compare colloids made from gums: arabic, benzoes, camphor, congo, copal, dammar, gamboge, guaiac, mastic, rosin, sandarac and tragacanth. The solvents were methyl, ethyl, propyl, butyl and amyl alcohols, acetone, ethyl acetate and ethyl ether. These permitted a comparison of a series of five aliphatic alcohols, a ketone, an ester, and an ether. These solvents were purified by redistillation. One gram of the pulverized gum obtained from the centers of large characteristic pieces was shaken in a test tube with 25 cubic centimeters of the solvent. This mixture was then thoroughly shaken at least once each day for two weeks.

Due to variations in the solubilities of different gums, it was necessary to adopt a standard for comparison and then adjust the colloids to the same concentration. Since gum mastic was almost completely dissolved in all solvents, it was chosen as a standard. In the dispersion of a gum, its solution was allowed to slowly drip from a burette whose tip extended below the surface of redistilled water, mechanically stirred, until a sample of the filtered colloid had the opacity given by two cubic centimeters of the methyl alcohol solution of gum mastic dispersed in 500 cubic centimeters of water. After dispersion the concentration of the colloids was further adjusted by a Burker Colorimeter.

It was found impossible, by this method, to disperse any of the gums dissolved in butyl alcohol, amyl alcohol, ethyl acetate or ethyl ether. This may be related to the fact that these solvents are not very miscible with water. Instead of dispersing from these solvents, the gums coagulated. Gums arabic, tragacanth, sandarac and camphor did not disperse in water. Gum arabic, which is a true gum, is insoluble in the above solvents, but soluble in water. Gum tragacanth, also a true gum, is similar to gum arabic in that it does not dissolve in the organic solvents used, but on the other hand it does swell in water. Gum sandarac, although soluble in the organic solvents, does not disperse in water. Gum camphor dissolves in the organic solvents but does not disperse in water. Further attempts will be made to modify the procedure to make colloids from these gums.

To obtain results for Table II, four cubic centimeters, of the respective gum dammar colloids, were poured into a test tube containing one cubic centimeter of 1 N electrotyte such as lithium nitrate. The mixture was then poured ten times from one test tube to another and allowed to stand. Observations were made at frequent intervals both day and night. The time in hours is given for initial and complete coagulation.

SUMMARY

The method of other observers for obtaining the precipitating

TABLE 1

Observed results obtained by allowing the different gums to stand in contact with the solvent for six months.

GUMS	Methyl Alcohol	Ethyl Alcohol	Propyl Alcohol	Butyl Alcohol	Amyl Alcohol	Acetone	Ethyl Acetate	Ethyl Ether	Water
ARABIC									
solubility	0	0	0	0	0	0	0	0	95%
swelling	25%	15%	0	0	0	0	0	0	0
dispersion	no	no	no	no	no	no	no	no	no
BENZOES									
solubility	85%	85%	85%	85%	85%	85%	85%	95%	0
swelling	0	0	0	0	0	0	0	0	0
dispersion	yes	yes	yes	no	no	yes	no	no	no
CAMPHOR									
solubility	100%	100%	100%	100%	100%	100%	100%	100%	50%
swelling	0	0	0	0	0	0	0	0	0
dispersion	no	no	no	no	no	no	no	no	no
CONGO									
solubility	25%	0	0	90%	95%	0	0	0	0
swelling	0	25%	500%	0	0	0	100%	0	0
dispersion	yes	yes	yes	no	no	yes	no	no	no
COPAL									
solubility	90%	98%	98%	90%	90%	85%	85%	25%	0
swelling	0	0	0	0	0	0	0	0	0
dispersion	yes	yes	yes	no	no	yes	no	no	no
DAMMAR									
solubility	0	0	0	0	0	0	10%	75%	0
swelling	0	125%	150%	225%	200%	25%	0	0	0
dispersion	yes	yes	yes	no	no	yes	no	no	no

TABLE I (Continued)

GUMS	Methyl Alcohol	Ethyl Alcohol	Propyl Alcohol	Butyl Alcohol	Amyl Alcohol	Acetone	Ethyl Acetate	Ethyl Ether	Water
GAMBOGE									
solubility	60%	30%	0	0	0	0	0	0	0
swelling	0	0	0	0	0	0	0	0	0
dispersion	yes	yes	yes	no	no	yes	no	no	yes
GUAIAC									
solubility	50%	50%	50%	75%	75%	60%	75%	50%	0
swelling	0	0	0	0	0	0	0	0	0
dispersion	yes	yes	yes	no	no	yes	no	no	no
MASTIC									
solubility	85%	90%	95%	95%	90%	90%	80%	90%	0
swelling	0	0	0	0	0	0	0	0	10%
dispersion	yes	yes	yes	no	no	yes	no	no	no
ROSIN									
solubility	95%	100%	100%	100%	100%	98%	99%	100%	0
swelling	0	0	0	0	0	0	0	0	0
dispersion	yes	yes	yes	no	no	yes	no	no	no
SANDARAC									
solubility	5%	90%	98%	98%	98%	95%	90%	80%	0
swelling	0	0	0	0	0	0	0	0	0
dispersion	no	no	no	no	no	no	no	no	no
TRAGACANTH									
solubility	0	0	0	0	0	0	0	0	0
swelling	0	0	0	0	0	0	0	0	800%
dispersion	no	no	no	no	no	no	no	no	0

TABLE II

Electrolytes	Methyl Alcohol		Ethyl Alcohol		Propyl Alcohol		Acetone	
	Initial	Complete	Initial	Complete	Initial	Complete	Initial	Complete
$LiNO_3$	3	7	2.5	7	2.5	6	3	7
Li_2SO_4	No	....	50+	....	No	....	50+	....
KCl	40	50+	5.5	14	No	....	9.5	7
KNO_3	50+	....	50+	....	25	....	25	....
K_2SO_4	12	....	12	....	22	....	12	....
$NaCl$	5.25	14	50+	....	50+	....	3	....
Na_2SO_4	5.5	7	5.5	7	50+	....	5.5	9
$CuCl_2$	2.25	5	2.25	5	4	14	2.25	5
$AgNO_3$	1.5	3.5	1.25	3.5	1.25	3.5	1.5	3.5
$MgCl_2$	1.25	4.5	1.25	3.5	4	6	1.75	5
$CaCl_2$	1.5	4	1	4	3.5	6	3.25	4
$Zn(NO_3)_2$	2.5	4	3	4	2.5	6	2	4
$SrCl_2$	2.5	5	2	5	3.75	....	1.25	5
$CdCl_2$	2.5	5	1.25	4	2.5	5	1.5	3.5
$BaCl_2$	1.25	3.5	1.25	3	2	4	1.25	3

power of electrolytes is essentially that used in the experiment recorded in Table II. Even a casual perusal of this table shows many irregularities. We have shown these to be related to the rate of settling. It is seen therefore that some modified precedure is essential.

Preliminary experiments indicate that we shall probably be able to introduce some such method. At present the experiments have not reached such a state of finality as to warrant the tabulation or discussion of these later developments.

BIBLIOGRAPHY

(1) "The Soluble Gums". The Commercial Museum, Philadelphia, Pa.

(2) "Analysis of Resins, Balsams and Gum-resins" (2nd revised edition, 1920). Scott, Greenwood and Son, London.

(3) "The Role of the H—ion Concentration in the Precipitation of Colloids." Tartar and Gailey, Journal of American Chemical Society, vol. 44, (1922), pp. 2212-18.
"Some Quantitative Experiments on the Coagulation of Colloids." Murphy and Matthiews, Journal of American Chemical Society, vol. 45, (1923), pp. 16-22.

THE EDUCATIONAL VALUES OF GENERAL CHEMISTRY

BY HAROLD F. ROGERS

(Professor of Chemistry, Fairmont State Normal School)

According to the teacher's views of relative values, or, as too often happens, according to his individual interests and special preparation, intentionally or otherwise, certain features of the general chemistry course will receive greater emphasis. The proportionate amount of time which a given teacher will devote say to the stoichiometric problems, or to purely descriptive features, or to historical chemistry, or to physico-chemical theory, or to spectacular demonstrations, or to quantitative experiments, or to qualitative analysis, or to any other aspect of chemistry will be a factor in determining the value of the course. A course that is too scattered with nothing done well enough to make a lasting impression is of little value; on the other hand a too intensive treatment of a few features may give the pupils a poorly organized view of the subject of chemistry as a whole.

Far be it from the writer to suggest that teachers should come to an agreement about the content of a course in general chemistry or about the manner or order of presentation, what to emphasize, etc. Such standardization is clearly undesirable. The teacher will teach best those features which he himself knows best, likes best and regards as most worth while. Our plea is that teachers, regardless of their personal preferences, need to try to determine what items of chemistry are **for their pupils** most useful and needful in contributing to their intellectual, spiritual and social development. Some teachers have no other basis for choice of subject matter than to rigidly follow a text-book. Whatever the text-book offers must be taught regardless of its interest or worth. Such a teacher will make a big forward step when he realizes that all text-books have to be adapted to the pupils' capacities, interests and educational needs.

There are many aims and values in chemistry teaching so obvious to almost any one that I need hardly allude to them. The wealth of purely informational matter in general chemistry and the abundance of collateral reading matter valuable as information is well known. No mention need be made of the large number of "practical" suggestions which students incidentally pick up in a course in general chemistry. Some of these we admit are tricks worth knowing. I refer to such matters as stain removal, electrolytic silver cleaning, use of zinc chloride in soldering or borax in welding, and softening hard water. Of course no knowledge is practical in the sense that these bits of information are supposed to be, unless such knowledge is actually put to use by the pupils. But I am convinced that many of these suggestions are used and so do "carry over into life," while, unfortunately some of the bigger ideas which we try so hard to get students to grasp, fail to make any really useful impression.

The educational value of teaching the technical language of chemistry is a matter of disagreement, but there is no doubt that many terms, usually regarded as too technical for common use, deserve to be better known and would prove to be very useful to non-chemical people if more widely known. Just where to set a limit to the teaching of technical language is a nice point. Though we cannot teach much useful chemistry without a certain minimum of this special chemical language, most teachers use some terms that might very well be left out, or simplified, as for example dibasic acids may with less confusion be called dihydric acids, and acid anhydrides may be called acid-forming oxides. Another obvious aim of chemistry teaching is to give our students an insight into the methods of various kinds of chemical work and thus have them to acquire to some extent the chemist's viewpoint, for with every new point there is added breath, and no thinker or leader or would-be scholar these days can afford to be without the chemist's "slant." Much is already being done through popular books, articles, lectures and radio talks to set forth what chemistry has done and is doing for civilization. The high school and college essay contests are helping to achieve this aim in chemistry teaching, namely to lead the students to a genuine appreciation of science, as to its intimate relation with practically every necessary and useful commodity of modern life. Most chemistry teachers have in mind more or less constantly another aim: that of correcting a host of popular fallacies, incorrect and unfounded impressions that persist almost generally among people uninformed in the latest chemical knowledge. It would be an interesting pastime to relate and discuss a lot of these popular misconceptions, but I shall refrain. Teachers need not go out of their way to try to discover and correct these wrong ideas, but should correct them if possible as they arise.

Among the most marvelous intellectual achievements of mankind are the elaborations of thought by which thinkers in chemical theory,—philosophers, shall we call them?—have arrived at the modern conceptions of molecules and atoms. To induce pupils to follow the logical processes in the development of the theories and laws pertaining to atomic and molecular weights, ionization, radioactivity, atomic numbers, radioactive transformations and atomic structure will confer upon them great intellectual benefits. To show them how the utilization of experimental findings has led the investigators into what would seem to be the realm of the unknowable, will, if they can grasp and appreciate this kind of thinking, afford great satisfaction to our pupils and pay well for the efforts expended. Moreover to be ignorant of these theories and laws of chemistry is to be a back number in matters of present day thought, for these conceptions are fundamental not only to chemical science but to all science.

General chemistry text-books for college students are sufficiently comprehensive in content to serve the purpose of a foundation course for the various classes of students whether they are later to take up the professions of medicine, dentistry, pharmacy, engineering, agriculture, etc., or are to study chemistry merely as a part of a liberal education. It is not practicable nor necessary to have separate classes in general chemistry differentiated for the several classes of students. All need practically the same fundamental introductory matter. The students having definite professional aims already in mind can and will appropriate out of the large amount of material in the general course much that has direct bearing on their chosen professions, but—even with these students the general fundamental principles of chemistry will be most valuable, since the applications of chemistry required in their professions will be made at the proper time when definite needs for such applications arise. The fundamental principles to which we refer are chiefly the working tools of chemistry such as the meaning and use of formulas, equations, chemical calculations, chemical nomenclature.

A course in general chemistry will have other values which are incidental and depend partly upon the personality of the teacher. Incidentally one may teach such ideas as neatness and order in laboratory work; or, if you please, laboratory technique; one may teach orderly, accurate and systematic note-taking, precision of expression as in the use of scientific terms with exactly the right shade of meaning. Chemistry in its relation to industry may occasion the teaching of ideals of business methods, chemical control of operations and the economic value of research. These educational by-products of general chemistry may or may not be intentional aims of the instructor, but it seems to the writer that these are important educational aims to strive for even though they are incidental to the teaching of the fundamental principles of chemistry. Particularly one should aim at imparting a conception of the meaning of the scientific method of discovery and the extension of knowledge through unbiased investigation. Brief references to the historical development of chemistry will bring out many lessons of value. The teacher who realizes most of the intimate relationship of chemistry to life and who vitalizes his subject by making contacts with the pupils' own life experiences will best succeed. One should justify himself in whatever he requires his pupils to learn by asking whether or not the knowledge to be imparted is directly or indirectly of any use to the pupil in his own life outside of the chemistry laboratory and lecture room.

THE TERRACES ALONG THE MONONGAHELA RIVER

BY S. B. BROWN

(Professor of Geology, West Virginia University)

When the Monongahela River began to flow it was on a plain that had a gentle slope northward. There were no hills on either side. It was simply a coastal plain following a retreating sea. As elevation went on the sea disappeared and the river began to trench itself below the even surface of the plain. But the elevation was not equal everywhere. It was less in the west, more in the valley of the Monongahela, and still more further east. It has gone on until now the tops of the hills along the river are 1400 feet above the sea. The Pittsburgh coal around Morgantown now lies at a level of about 1200 feet above sea level. At Moundsville it lies at a level of about 500 feet. That is, as elevation went on the strata became tilted until now the layers have a dip of about ten feet to the mile toward the Ohio River. As we pass to the southward the elevation has been much greater.

At the head of the river up in Randolph County at Mingo Flats the river now takes its rise on the Greenbrier Limestone at an elevation of 3000 feet above sea level.

The coal measures above the Greenbrier have been eroded away in the lapse of the ages. Probably 1500 to 2000 feet have been lost from the strata on the upper reaches of the river. As it is, at present the river has a profile somewhat as follows:

Beginning at Mingo Flats at about 3000 feet above sea level the river flows northward with a rapid fall until at Elkins 40 miles away it is flowing at a level of 2000 feet. It has fallen 25 feet to the mile.

It makes a transverse valley through the mountain as it turns toward Belington, for it is a master river and cuts through the mountain rather than be guided by it. In its flow of 60 miles to Grafton the river has fallen another 1000 feet, so that it has had a fall of 16 feet to the mile. In its flow toward Fairmont it also cuts through the southern end of Chestnut Ridge and its labors at the Valley Falls show that it has reached the backbone of that mountain. In its course of 22 miles to Fairmont it has a fall of 150 feet or 7½ feet per mile.

From Fairmont to Morgantown, a distance of 25 miles, the river falls 64 feet or 2½ feet per mile. This is only one-tenth of its rate above Elkins.

From Morgantown to Pittsburgh, a distance of 100 miles, it falls 86 feet. This makes so gentle a slope that it only has a fall of 10 inches to the mile. It is approaching its base level. Here it enters the Ohio River at the level of 700 feet.

Now all the way from head to mouth the river has been flowing along the strike of the rocks while the dip of these rocks has been to the westward. This tilt of the rocks to the westward has had a certain effect upon the course of the river. It has caused the current to be swifter and deeper near the western bank.

As landslides have come into the river on the west side the swift water has gradually removed them and deposited them as alluvial material in the slower water farther down along the east side. The effect of this work has been to subtract from the west side and add the material to the east side.

So as we follow along the river we see that the hills are steeper on the west side while on the east side the hills stand far back from the river and a wide flood plain or bottom land lies between the river and the hills. These facts have had a great influence upon the development of the valley. As the flood plain on the west is wanting or very narrow most of the good town sites are found on the east side.

When the engineers located the locks along the Monongahela they found the current and deep water on the west side. So they located most of the locks on the west side. When the first railroad was built up the river the engineers found the wide flood plain and most of the towns on the east side while the expense of building the road was much less on that side. So the road was built on the east side first. The second railroad that came up the river was obliged to build on the west side where it was necessary to make deeper cuts into the hills, where landslides are more frequent and where expense of maintenance was greater.

The elevation that caused the river to trench itself from four to six hundred feet to its present level has brought about many halts and meanderings in the course of the river. The upper terrace, which of course is the oldest one, now lies at a level of 1020 to 1040 feet above sea level. This terrace is not well connected but an old bend may be seen on the Flats toward Star City. This was a quiet bend in which a great deposit of potters clay accumlated. This will be of economic value in the future. Other deposits of similar clay are known at this level.

The second terrace is more continuous and the best farms along the river are situated on this terrace. This may be called the residence terrace or the town site terrace. At Morgantown this terrace is divided into two benches. The first bench is that on which the Post Office and Court House are situated. The second bench is that on which the University is situated.

The first terrace which is the most continuous, is the one along the river and of course is the most recent. This may be called the railroad terrace or the factory terrace. It is to be noticed that the laborers houses are also situated largely upon this terrace. Thus a certain social stratification may be seen in following these river terraces.

These observations that have been made along the Monongahela are not unique for this river, but they may be seen along any river where conditions are essentially similar. I think it is worth while to interpret pure science in terms of its economic uses and to show what relation our observations may have to human activities.

PRINCIPLES OF SOIL CLASSIFICATION

BY E. P. DEATRICK
(Department of Soils, West Virginia University)

The definite effort to classify soils started with the organization of the Bureau of Soils of the United States Department of Agriculture in 1895. The work was new, and in the words of a Bureau representative it "was to proceed in a thorough, systematic way to map, name, and classify the different soils of the country; to show their extent and their relation to one another, to existing agriculture and to the possibilities of agricultural changes and extension. It was proposed also to investigate, in properly equipped laboratories, the physical and chemical properties of soils."

The soil surveyor needs a base map to start work. The Bureau of Soils was fortunate to be able to rely on older government bureaus such as those of Geological Survey, Coast and Geodetic Survey and the Land Grant Office for many of the base maps needed. Thus a great amount of duplication of labor was saved. The base map, like the one I have here published by the United States Geological Survey covers a square of 30 by 30 minutes of longitude and latitude. The "quadrangle" as it is termed is in case a topographical map showing three groups of features. There is the 1, **water,** including such bodies as seas, lakes, ponds, rivers, streams, canals, and swamps; 2, **relief,** including mountains, hills, valleys, and cliffs; and, 3, **culture,** including towns, cities, roads, railroads, boundaries, coke ovens, oil wells, and mines. The scale is 1:62,500 or very nearly one inch to the mile. Smaller scales are used for the less important and less thickly settled areas.

I have here a number of samples of soil collected from various points throughout our state. The most noticeable characteristic is that of color. Had we collected these samples from the field we might have noticed another characteristic, especially if the collection had been made this spring. Were we sufficiently conversant with the tribulations of Job, we would no doubt have been in a position to appreciate his long suffering when he was "clothed with worms and clods of dust." Had the translator been an agronomist he likely would have written "clods of mud or soil." However that is, certain soils, when wet, are more plastic and cohesive than others. These properties are dependent on the size of the soil grains, and are more pronounced in soils of the finest texture. Determination of the size of the soil particle is accomplished by the separating of the oven dry soil into portions the sizes of the grains in each ranging within certain arbitrary limits. The determination is termed the mechanical analysis. The Bureau of Soils recognizes seven groups of separates.

Fine gravel	2 mm.	— 1 mm.
Coarse sand	1 mm.	— 5 mm.
Medium sand	5 mm.	— .25 mm.
Fine sand	.25 mm.	— .1 mm.
Very fine sand	1 mm.	— .05 mm.
Silt	.05 mm.	— .005 mm.
Clay		Below .005 mm.

The silt and clay are separated from the sands and from each other by agitation and sedimentation in water. After being dried, the sands are separated by shaking in a battery of sieves. The results of the analysis are reported as seven numbers, as for example 1, 3, 2, 8, 8, 62, 16. For the sakes of clearness, let us consider that this analysis is that of soils A, B, C, and D. Within certain limits of variation that are negligible this is approximately accurate at any rate. Let us imagine ourselves in the Bureau of Soils at Washington and that the field men have sent these samples from various sections of the country. Now while these are all West Virginia soils we will simply let them represent exactly identical soils from the other States of which I wish to speak.

Soil A, has been sent, we will therefore assume, from the banks of the Ohio River in Lawrence County, Ohio. Referring to the chart and key published by the Bureau[1] one may determine from the mechanical analysis given that the class is "silt loam." (Use of the key and chart demonstrated.) Since this is the first of the river bottom soils to be sampled it is given the series name of Huntington, appropriately, as you see, after the nearby West Virginia city. The term "silt loam" is a cover name. Nature sorts soil materials very efficiently, but seldom do we discover that the material falls entirely within the limits of the group of our classification.

The cover name indicates that this soil, in its massed characteristic resembles those of a silt. Particularly does the dry soil resemble silt in that it has a talc-like feel when rubbed between thumb and fingers. Inasmuch as the soil contains appreciable quantities of both clay and sand it has been termed a "silt mixture" or "silt loam." Combining the class and series name as Huntington silt loam, we have the complete or type name.

Now soil B has a similar analysis, and therefore belongs to the class of silt loam. Coming from the river bank in Montgomery County, Tennessee it was first named Clarksville silt loam. This, too, was appropriate for Clarksville is the county seat of Montgomery County. Soil C is a sample of a soil near Hagerstown, Maryland. Having the same analysis as A and B it belongs to the same class-that of silt loams-and to a series termed Hagerstown. Now as the work progressed it was found necessary to make certain changes. In some cases similar soils were

---

[1] Whitney, M. The Use Soils East of the Great Plains Region: U. S. Department of Agriculture Bulletin 78, p. 12 and 13, 1911.
[1] Ibidem.

to have been assigned to different series and in other dissimilar ones were found classed in the same series. In 1910, Bulletin 78[1] was published. It contains a description of all the series named to date. Now soils A and B are found to be more similar than at first thought.

The soil material of both is river wash of the Appalachian and limestone areas forming first bottom land. The name of the Tennessee soil was therefore changed from Clarksville to Huntington silt loam and "Clarksville" was kept for the name of another soil. Since Soil C is the residue from the weathering of pure limestone and not a transported soil, it is distinctly different from A and B. The name Hagerstown silt loam, therefore was not changed.

Further distinction in the classification became necessary as the study advanced. Soil D is similar to the Huntington soils A and B in that it is the wash from the Appalachian and limestone material. It was, however, sampled from a soil laid down as a second river bottom. Distinguished thus from the first bottom soils the Huntington series-this soil was assigned to the Holston series, inasmuch as it was sample on the second bottom land along the Holston River in south western Virginia.

Reference to the key to river soils [1] shows that A and B, and D are classified as follows:

Appalachian and Limestone Material

	(A B) Huntington	D Holston
Drainage	Poorly established	Well established
Color		
Soil	Brown	Light brown
Subsoil	Yellow	Yellow
Material	Sandstone and limestone	Alluvial over shale and sandstone (partly residual)
Position	First bottom	Second bottom

Soil E is the residue from pure limestone and is compared with Soil C as follows:

Pure limestone material
Brown Soils

C Hagerstown	E Brooke
Light brown to reddish brown subsoil	Yellow subsoil
Rock outcrops common	Residual crest of hills and ridges

---

[1] Seaton, Charles H. Uses of the Soil Survey Yearbook of the Dapartment of Agriculture, 1920, p 413.

These differences are recognized in classifying soil E as belonging to the Brooke series instead of the Hagerstown to which C has been assigned. Having an analysis of 4, 13, 12, 25, 13, 21, 12, it is a Brooke sandy loam. Soils are then, classified according to their position, material, and the agency of formulation. A soil map of the United States is divided into irregular areas each colored differently. Instead of representing different political units as on our more familiar geographical maps, the colors represent areas within which the soils have been formed by the same general agencies. It is therefore a map showing the great geology divisions called provinces. There are seven of these.

Glacial Lake and River Terraces
Glacial and Loissial
Limestone Valleys and Uplands
Applachian Mountains and Plateaus
Piedmont Plateau
River Flood Plains
Atlantic and Gulf Coastal Plains

These are all in the eastern part of the country. The areas in the less thickly populated West are termed regions. The regions will be divided into provinces as necessity demands. The regions are:

Western Mountain Region
Pacific Coast
Arid Southwest
Rocky Mountain Valleys and Plains
Northwestern Intermountain Region
Great Basin
Residual Soils of the Western Prairies

From the name of the soil one can therefore learn its geological formation, the composition of the soil material and the massed textural characteristics. As these determine to a large extent the general agricultural character of the soil the soil name also is an index to the productivity.

MINING MACHINERY

BY M. L. O'NEALE, FAIRMONT, W. VA.

I have been assigned the subject of Mining Machinery, which is far too broad for a brief talk. I am therefore taking the liberty of confining my remarks to bituminous coal preparation equipment. I must still further limit my remarks to the mechanical preparation of coal, for the production of coke, gases, coal tars, and coal tar productions leads us into the field of chemistry.

The mechanical preparation of coal has two objects. First, the separation of coal into various sizes and, secondly, freeing the coal of refuse to lower the ash content of the shipped product.

The demand for prepared coal has grown very rapidly within the past eight years. Higher cost of mining and of freight have so increased the consumer's coal bill that it is only natural that he pay more heed to the quality of coal he is being furnished. Over production and keener competition among producers makes for the same end because the progressive operator teaches the consumer the value of quality coal in order to profit by broader markets and higher prices.

The preparation of coal starts at the working face underground. The use of cutting machines, the selection of the proper kind of explosive, the correct placing of shot holes, the charging of the holes with the proper amount of explosive, these, and other precautions insure the breaking down of the coal with least degradation, and in such manner that bands of slate and other impurities that may occur in the seam or be brought down from the roof may be most readily separated from the coal by the miner and thrown into the waste or "gob" underground. I recall one instance in particular where a seam of coal with several inches of fire clay parting is so carefully handled underground that no further cleaning of the coal at the tipple is found necessary. However, this is the exception. The increasing percentage of unskilled and careless miners and the growing use of coal loading machines underground, combined with other developments in the art of mining, add to the necessity of better preparation at the tipple.

Let us consider first the sizing of coal. In the early days gravity screens were used for this purpose. These consist generally of a number of narrow strips of iron or steel set edgeways in slotted bars or rests, and spread to give clear openings between bars to make the proper size of coal, the large coal passing over and the small sizes dropping through. The whole assembly is called a gravity or bar screen. By superimposing screens of different mesh or by placing them in tandem more than two sizes of coal may be made if desired. The coal passes over the screen by gravity and the inclination is adjusted according to the physical properties of the particular coal being handled, the usual angle being between 26 and 30 degrees. This type of screen answered the purpose very well when the consumer was less particular than he is today. It has the following objections: The inclination of the screen depends upon the friction of coal on steel. This friction varies widely. One car of coal may consist largely of fine coal or slack and it may be damp or sticky. The coefficient of friction is high and the screen must be set at an angle sufficient for it to go slow without sticking and clogging the screen. The next car may be largely lump and this class of coal will then rush too rapidly across the screen. Furthermore, the larger sizes of coal that pass over the entire length of the screen start from a state of near rest and accelerate the entire distance leaving the screen at high velocity. The velocity is suddenly checked in the loading chutes or railroad cars, and the lumps, which the equipment was designed to separate from the smaller sizes, are there degraded, thereby largely defeating the purpose for which the screen was installed.

To overcome these objections it was necessary to mechanically control the flow of coal over the screen, giving it a uniform velocity regardless of its physical properties and the distance traveled. This was accomplished by the introduction of the shaker screen.

The shaker screen, broadly speaking, is of two kinds: the inclined shaker and the horizontal shaker.

The inclined shaker secures this control, but at the same time partly utilizes gravity, hereby reducing the power required to drive it. It also premits the use of a simple drive in balance. It consists usually of two sections carrying the screen plates, the sections being either in tandem or superimposed. These sections are suspended to swing freely, Connecting rods attached to each section are given their forward and back strokes from a crankshaft or eccentrics on a countershaft. One screen moves forward as the other moves back. The time velocity curve for each section is one of simple harmonic motion and the two balance. The stroke of the connecting rod is generally five or six inches and the complete strokes per minute 75 to 125. Horsepower required for a 250 to 300 ton per hour screen will ordinarily run 10 or less.

Instead of bars as a screening medium perforated plate is used. The plate may be flat, that is, uncrimped with round, square, oblong or tapered slots. Instead of the flat plate, however, it is more usual to use a stepped plate. This is a crimped plate, forming steps in the direction of coal travel. Perforations are long slots almost the length of the steps and tapered, the greater width being at the lower end. Standards vary widely, the most usual being 12" steps with about a 1¾" drop in which case the taper may be around ¼" per ft. The stepped or lip screen plate, as it is commonly called, has the advantage of teetering the lumps of coal as they pass along, thereby ridding them of particles of small coal which may be riding atop them and which otherwise might carry over into the larger sizes of coal. The tapered slots also reduce clogging of coal in the screen openings, which clogging of course cuts down effective screening surface and causes more degradation on the screen from the impact of coal against the blocked pieces.

The horizontal shaker screen makes no use of gravity but depends upon inertia to move the coal forward. The screen plate is given a comparatively slow forward motion, carrying the coal along with it. The return stroke is very rapidly accelerated, so that in effect the screen plate is jerked from beneath the coal upon it. Practically all the movement of the coal relative to the screen surface is therefore accomplished during the return stroke. Specially designed drive heads are used to effect this motion. Generally the screen is in one continous section unbalanced so that the driving mechanism must be heavy and well anchored to absorb the slack. The screen surface is necessarily flat.

The relative merits of the flat and inclined shaker screens offer a fertile field for argument. It is only fair that I refrain from such a discussion here, as I happen to be identified with a manufacturer of one of these types.

With both types of screen it is a rule, almost without exception, to feed the coal at a fairly uniform rate into the screens. The usual feeder is either of the apron conveyor or reciprocating plate type. The efficiency of the screens is greatly increased by such uniform delivery of the coal upon them.

Other types of screens have been used but are not sufficiently popular to warrant extended discussion. For example there is the revolving screen used so much for ores, gravels, stone, anthracite coal, etc., but not in favor for bituminous coal because of the increased breakage of the product. Also the so-called knocker screen, one end of which is given a vertical lift and drop by means of cams such as used in stamp mills.

With the improvement in screening media it was only natural to seek better means of handling the prepared sizes of coal from the screens into the railroad car. Lowering the coal by gravity chutes causes enough breakage to largely counteract the good of the better screening. The use of larger railroad equipment and resultant higher tipple clearances made this need even more imperative. Hence the loading boom.

The loading boom receives the coal from the screens practically without drop and lowers it mechanically into the railroad car. Railroad cars vary widely in height from top of rail to top of car. To take care of this condition and also to deposit the coal close to the bottom of the car that is just started loading, the boom is pivoted and equipped with a hoist so that it may readily be raised or lowered as required. The hoist may be run in connection with the boom drive, but it is more usual to use a small self contained electric hoist, either of the suspension or wall type to accomplish this. Generally most of the weight of the boom is counterweighted to release the hoist.

Two types of booms are in general use. One is the shaking chute type similar in principle to the inclined shaker screen. However, such a boom must necessarily be very long to reduce the variation in the angle of inclination at different loading heights. It is also an unbalanced unit and throws cross stresses into the tipple structure. Again it does not lend itself to use as a picking table, and for these as well as minor reasons, it is not so popular as the conveyor type boom.

The conveyor boom is an endless conveyor usually of the steel apron type, carried in a steel frame, the upper end being carried on a pivot shaft for raising and lowering. It travels at a uniform speed, commonly within the limits of 60 to 100 feet per minute. If the bed of coal is thick enough upon it, it may be lowered to an angle as great as 30 degrees without the coal rolling or sliding, particularly if the aprons are of the reverse beaded type giving a stepped effect. Belt conveyors have been used for booms but are not common as they should not be lowered to an angle greater than 18 or 19 degrees, and must therefore be longer and require more tipple structure.

We will now look briefly into the cleaning of coal, that is the removal of the slate and impurities that are loaded with it. Throughout most of the bituminous coal fields of this country hand cleaning is the chief method used and machinery is utilized only to facilitate this manual labor. It is not generally considered practicable to hand pick coal under 1" to 1½" in size and many mines are fortunate in that the impurities occur chiefly in the sizes above this. Picking may be most thoroughly and economically done where the coal is spread out in a thin layer on the picking medium and where the coal sizes do not cover too great a range. Hence cleaning equipment goes hand in hand with screening equipment.

Where horizontal screens are used picking is generally done on the screen itself, though this is open to the criticism that the jerky motion of the screen and coal interferes with the efficiency of the pickers. Such practice also limits the width and capacity of the screen unit as the picker should not have to reach more than about 30 inches to the center of the screen.

Revolving picking tables, consisting of an annular metal table revolving slowly about a vertical shaft are in use, but require considerable unobstructed floor space. The most generally used and perhaps the most satisfactory picking medium, or picking table, is the horizontal conveyor, either of the steel apron or belt type. Where shaker screens are in use the picking table is commonly a horizontal section of the loading boom, the same conveyor thus serving as a picking table and loading boom. The apron conveyor is more popular than the belt, partly because of this fact, partly due to its ruggedness which permits the picker to break up a lump of coal on the table to remove a stratum of slate, and partly due to less obvious advantage. The speed of such conveyors is generally 60 to 80 feet per minute, though satisfactory picking may be done at a speed of 100 feet per minute.

The modern tipple may have certain auxiliary equipment such as refuse conveyors, house coal conveyors, remixing conveyors, coal storage equipment, or perhaps a crusher for adding to the small sizes as the market requires.

The cleaning of the sizes too small for hand picking leads us into another field, which I will dwell upon but briefly. Most of the methods depend upon the difference in specific gravity of coal and impurities. The most commonly used is the wet cleaning plant or washer. The small coal is generally still further sized and then treated in jigs, or in some cases over tables with large amount of water, the underlying principle being the difference in falling velocities or in buoyancy of materials of approximately equal sizes but of different specific gravity in water. The wet method has inherent disadvantages such as adequate water supply, disposal of sludge without damage to land and streams, removal of water from coal before shipment, prevention of freezing in cold weather, etc.

These troubles have led to the development of the dry cleaning process, whereby separation is effected on tables using compressed air as the buoyant medium instead of water. Although there are now several plants in existence using this method in a commercial way. I feel that the process is still somewhat experimental, and the large investment required for such a plant will doubtless confine its users to the very large operators for some time to come. However, it has very interesting possibilities.

It has been rather difficult to cover such a broad field in so brief a paper and I have been able to touch the high spots only. To those who are not so familiar with the coal mines I hope this has given some slight idea of the problems faced and the methods used.

CONGLOMERATE ROCKS OF WEST VIRGINIA

BY DAVID B. REGER

Assistant Geologist, West Virginia Geological Survey.

(Prepared for first meeting of West Virginia Academy of Science, Morgantown, West Virginia, November 28, 1924.)

INTRODUCTION

A conglomerate may be defined as a stratified bed of rock in which are included particles of matter distinctly different in size and character from the constituents of the principal mass, or matrix, of the bed. These particles are usually, though not always, water-worn pebbles and in some cases are the same kind of material as the finer grains of the matrix but in other cases are foreign substances. Quartz pebbles, because of their resistance to wear, are the most common and they occur most frequently in sandstone. Fragments of limestone, shale, iron ore or other substances are sometimes found.

In West Virginia the outcropping stratified rocks range from Cambrian deposits, lying upon the igneous rocks, up to the Permian, and include all the known intermediate geologic periods, unconformities being confined to series, groups or smaller subdivisions. The Cambrian rocks outcrop along the eastern border near Harpers Ferry but they soon pass under drainage in the general, though intermittent, westward dip so that successively younger rocks form the surface until a broad belt of Permian beds is finally preserved in the Appalachian Geo-Syncline which extends from the southwestern corner of Pennsylvania southward to the Kentucky line at the southen border of Wayne County. With the exception of limestones and coals, which are formed in places from organic remains, it is generally conceded that most of these clastic beds were formed by erosion of high mountain ranges which successively occupied the present Atlantic Coastal Plain and Piedmont Provinces east of the Appalachian System. It is thus apparent that the more abundant conglomerates might be anticipated along the south-eastern border of the State and that exceptions to this rule indicate a stage of excessive erosion or the presence of an ancient drainage channel with a strong current.

TABLE OF CONGLOMERATE STRATA

Omitting the homogeneous beds for the sake of brevity, the following table indicates the various conglomeratic horizons of the State as taken from reports of the West Virginia Geological Survey, the United States Geological Survey, and from private observations of the writer, there being reliable data on perhaps four-fifths of the territory:

Lower Connellsville Sandstone (15′-30′). Rounded or slightly angular quartz pebbles in Barbour and Braxton Counties.

Morgantown Sandstone (15′-35′). Rounded or slightly angular quartz pebbles in Braxton County.

Grafton Sandstone (15′-25′). Rounded or slightly angular quartz pebbles in Taylor, Preston, Barbour, Braxton and Lincoln Counties.

Saltsburg Sandstone (15′-30′). Rounded or slightly angular quartz pebbles in Taylor, Preston, Braxton and Kanawha Counties. Full of iron ore nuggets (possibly local concretions) at Central City, Cabell County.

Buffalo Sandstone (20′-60′). Rounded or slightly angular quartz pebbles in Monongalia, Taylor, Barbour, Preston, Braxton, Roane, Kanawha and Wayne Counties. Contains iron ore nodules (possibly local concretions) in Lincoln County.

Mahoning Sandstones, Upper and Lower (50′-75′). (not always differentiated). Rounded or slightly angular quartz pebbles in Taylor, Barbour, Upshur, Braxton, Nicholas, Lincoln and Wayne Counties.

Allegheny Series (100′-350′)

Upper Freeport Sandstone (20′-50′). Rounded or slightly angular quartz pebbles at scattered points in Marion and Upshur Conties. Much larger and more numerous rounded quartz pebbles (1″diameter) in Webster, Braxton, Clay and Nicholas Counties.

Lower Freeport Sandstone (20′-30′) (referring to ledge just over Upper Kittanning Coal). Rounded or slightly angular quartz pebbles in Mineral, Barbour, Randolph, Nicholas and Clay Counties.

Upper East Lynn Sandstone (15′-30′) (referring to ledge just over Middle Kittanning Coal). Rounded or slightly angular Quartz pebbles generally in Clay County.

East Lynn Sandstone (25′-50′) (referring to ledge just over Lower Kittanning (No. 5 Block) Coal). Rounded angular quartz pebbles in Upshur and Webster Counties. or partly angular quartz pebbles in Preston, Barbour, Upshur, Braxton, Clay and Kanawha Counties. Much more abundant pebbles in Logan, Mingo, Lincoln and Wayne Counties

Kittanning Sandstone (10′-30′) (referring to ledge just over Clarion Coal). Rounded or slightly angular quartz pebbles in Barbour, Upshur and Wayne Counties.

Pottsville Series-Kanawha Group (200′-2100′)

Homewood Sandstone (50′-100′). Angular quartz pebbles only partly rounded in Mineral, Grant, Tucker, Preston, Monongalia, Marion, Barbour, Upshur, Randolph, Clay and Wayne Counties.

Upper Connoquenessing (Upper Coalburg?) Sandstone (50'-150'). Angular quartz pebbles only partly rounded in Mineral, Grant, Tucker, Monongalia, Marion, Taylor, Barbour, Upshur and Randolph Counties. Most abundant and largest in valley of Middlefork River, Randolph County.

Lower War Eagle Sandstone (0'-30'). Partly rounded quartz pebbles in southern Webster County.

Lower Connoquenessing (Lower Gilbert?) Sandstone (50'-80'). Partly rounded quartz pebbles in Randolph, Nicholas and McDowell Counties.

Dotson (Bearwallow) Sandstone (0'-125'). Partly rounded quartz pebbles in Fayette, Raleigh, Wyoming and McDowell Counties.

Lower Dotson Sandstone (0'-100'). Partly rounded quartz pebbles in Webster, Fayette, Raleigh, Wyoming and McDowell Counties.

Pottsville Series-New River Group (50'-1030')

Upper Nuttall Sandstone (10'-100'). Partly rounded quartz pebbles in McDowell County.

Lower Nuttall Sandstone (10'-100'). Partly rounded quartz pebbles in Tucker, Webster, Nicholas and Fayette Counties.

Harvey Sandstone (0'-125'). Partly rounded quartz pebbles in Fayette, Raleigh and McDowell Counties.

Guyandot Sandstone (10'-75'). Partly rounded quartz pebbles in Tucker, Fayette, Raleigh and McDowell Counties.

Lower Guyandot Sandstone (0'-50'). Partly rounded quartz pebbles in Tucker and McDowell Counties.

Sharon (Upper Raleigh) Sandstone (25'-75'). Mostly rounded but some slightly ovoid quartz pebbles, with maximum diameter of about 2 inches, in Tucker, Preston, Barbour, Randolph, Webster, Pocahontas, Greenbrier, Nicholas, Fayette, Raleigh and McDowell Counties. Most presistant and abundant pebbles of the entire Pottsville Series.

MISSISSIPPIAN PERIOD

Mauch Chuck Series-Bluestone Group (25'-800')

Glady Fork Sandstone (0'-50'). Pebbles of shale or breccia at base in Summers and Mercer Counties.

Mauch Chunk Series-Princeton Conglomerate (20'-50')

Princeton Sandstone (20'-50'). Anqular quartz pebbles only partly rounded in Tucker, Randolph, Pocahontas, Webster, Greenbrier, Nicholas, Fayette, Summers, Raleigh and Mercer Counties. Limestone and shale pebbles in its base in Summers, Raleigh and Mercer Counties.

Mauch Chunk Series-Hinton Group (100′-1350′)

Stony Gap (Hinton) Sandstone (20′-35′). No pebbles in the sandstone proper but just beneath it is a mass of puddingstone or breccia having siliceous matrix and great amount of drab shale inclusions, principally along New River in Summers County. Forms Sandstone Falls.

Pocono Series (25′-2000′)

Logan (Burgoon, Pinkerton (?) Sandstone; Big Injun Oil Sand) Sandstone (25′-250′). Ovoid or flattened quartz pebbles in the majority of its outcrops from Morgan County westward across the State and also recorded in numerous well records where the ledge is beneath drainage; maximum diameter about two inches.

Purslane Sandstone (10′-250′). Ovoid or flattened quartz pebbles in Morgan County and probably southwestward across State but horizon is not definitely traced.

Berea (Griswold Gap Inkles?) Sandstone (10′-100′). Quartz and jasper pebbles, ovoid or flattened, in Morgan County. Ovoid or flattened quartz pebbles at many outcrops southwestward across State and also in deep wells.

DEVONIAN PERIOD

Chemung Series (1500′-3500′)

Hendricks Sandstone (5′-25′). Small flattened and elongated quartz pebbles in Hampshire, Hardy, Grant, Mineral and Tucker Counties, often arranged in distinctly straified layers.

Lackawaxen Conglomerate (5′-50′). Flattened and elongated quartz pebbles in Morgan, Mineral, Grant, Tucker, Preston, Greenbrier and Monroe Counties, often arranged in distinctly stratified layers. Maximum diameter about two inches. Formation not yet studied in intermediate counties.

Allegrippus Conglomerate (5′-25′). Small flattened and elongated quartz pebbles in Mineral, Grant, Tucker and Preston Counties, often arranged in distinctly stratified layers. Formation not yet described in several other counties.

Portage Series (500′-2000′)

Parkhead Sandstone (0′-350′). Quartz pebbles in Morgan County.

Oriskany Series (25′-200′)

Ridgeley Sandstone (25′-175′). Small elongated yellowish quartz pebbles, about the size and shape of a grain of wheat, in Morgan, Hampshire, Hardy, Mineral, Grant and Pendleton Counties.

SILURIAN PERIOD

White Medina Sandstone (50′-300′). A few rounded or slightly angular quartz pebbles in Grant, Mineral, Monroe and Mercer Counties. Not yet described at intermediate outcrops.

ORDOVICIAN PERIOD

Beekmantown Limestone (1500′-2500′)

Stonehenge Member (400′600′). Edgewise pebbles of limestone or shale arranged in vertical or slanting positions in Berkeley County.

CAMBRIAN PERIOD

Conococheague Limestone (1500′-1800′). Tabular sandstone blocks 1½′ across in upper portion, and light-colored limestone pebbles, either rounded, angular, elongated or prismatic in shape, arranged in edgewise fashion, in Jefferson and Morgan Counties.

Weverton Sandstone (500′-600′). Small quartz pebbles in Jefferson County.

Loudoun Formation (10′-800′). Described as entirely concealed at its only outcrop in Jefferson County, but as containing blue and white angular quartz fragments and pieces of epidote and jasper in Loudoun County, Virginia.

INTERPRETATION OF DATA

Starting at the bottom it is apparent that the angular fragments of quartz and jasper of Loudoun time were deposited comparatively near the original source. The variety of the material is also an indication of quick erosion and redeposition which did not permit continued sorting. In Weverton time, on the contrary, the pebbles are small and indicate a more distant origin. The edgewise limestone conglomerate of Conococheague time indicates an upward warping of slightly older limestones the particles of which were carried a short distance out to sea and stranded in the calcareous ooze.

In the Ordovician Period, in which the deposits were principally limestone and shale, conglomerates are not found, with the exception of the edgewise fragments of the Beekmantown, and the seaward currents were sluggish or else disentegration at the source was complete.

In the Silurian Period the earlier beds were principally sandstone and shale but the material was well sorted, there being only a comparatively few pebbles in White Medina time. The matrix of this enormous ledge, however, is almost a pure quartzite and its great thickness and extent reveal a probable stage of unusual chemical activity which produced vast quantities of liquid silica.

In the Devonian Period the peculiar wheat grain pebbles in the Ridgeley Sandstone, with their close resemblance to the typical crystallization of quartz, can scarcely be explained except by considering them as formed from liquid silica at no great distance from their present position. In the Portage and Chemung the pebbles are invariably oblong and much flattened, indicating a long stage of sliding backward and forward which should have occurred only along the strand of an extensive body of water. The pebbles of the Lackawaxen Conglomerate become progressively larger and more numerous toward the southern part of the State.

In the Mississippian Period the pebbles of the Pocono Series are of mixed types, some being ovoid or flattened while others retain much of their primitive angularity. Their great abundance and comparatively short passage from the source to the present position postulate a time of excessive igneous activity in the neighboring mountains. It is quite probable also, that an excessive amount of carbonic acid gas was released at the same time, causing the rapid development of the coal flora which suddenly sprang into existence for the first time. In the Mauch Chunk Series conglomerates are almost wholly lacking except in Princeton time. Here there are limestone pebbles possibly derived from local warping of the massive Greenbrier deposits of the same Period, although no proof has yet been secured to substantiate such an assumption. The Princeton also contains a much greater abundance of angular or partly rounded quartz pebbles indicating range of ancient granite or quartz at a comparatively short distance southeastward. The pebbles of this sandstone are known to persist for several hundred miles up and down the Appalachian foot-hills but their width along the opposite axis is scarely more than 50 miles so that their accumulation must have been caused by a comparatively brief stage of uniform flooding along the entire mountain front, but this flooding ceased as abruptly as it began.

In the Pennsylvanian Period there are vast amounts of pebbles in Pottsville time, with attendant recurrence of abundant coal flora. The two phenomena indicate a sudden recurrence of the igneous activity noticed in Pocono time. Of these Pottsville conglomerates by far the most persistent is the Sharon, which is found not only in Pennsylvania and Maryland but extends entirely across West Virginia and doubtless corresponds to one of the great pebbly beds of Virginia and Tennessee. The Upper Connoquenessing, however, which is quite conglomeratic in

Pennsylvania and northeastern West Virginia suddenly loses its pebbles in southern Upshur County of the latter State and they do not again appear although the matrix of the rock undoubtedly is persistent southwestward into Kentucky. A peculiarity of this bed is its excessively pebbly nature in the valley of Middlefork River, Randolph County, recording the presence of an ancient swift water course. The Home-Wood Sandstone, also, loses most of its pebbles in southern Upshur, although they recur intermittently as far south as Kentucky.

In the Allegheny Series there are sporadic occurrences of quartz pebbles at many points in the State but in portions of Logan, Mingo, Lincoln and Wayne Counties the East Lynn Sandstone becomes excessively conglomeratic and in Webster, Braxton, Clay and Nicholas Counties the same statement is true of the Upper Freeport. These two occurrences indicate delta accumulations near the mouths of ancient rivers. In the Conemaugh Series there are quartz pebbles in several of the sandstones but they are seldom abundant and do not indicate pronounced deltas or strong currents. Pehaps they may be almost wholly attributed to occasional storms which produced temporary undertows or currents. In the Monongahela Series pebbles are scarce with the exception of a noticeable delta which must have existed in Sewickley time in Lewis, Gilmer, Braxton and Roane Counties.

In the Permian Period pebbles are seldom found in the Dunkard Series except in the Waynesburg Sandstone in which they are fairly abundant in several counties. These were probably carried outward into the Appalachian waters by the impulse which attended the submergence of the Waynesburg Coal swamp and the probable compensation elevation of land farther southeast.

SOME PROBLEMS OF THE OIL AND GAS INDUSTRY

BY EARL R. SCHEFFEL
(Associate Professor of Geology, West Virginia University)

The first word of the title used is significant. When the field is looked over in detail one is forced to the conclusion that problems exist in all phases of the oil and gas industry, though this industry is doubtless not exceptional in this respect.

The scientific search for oil and gas is of comparatively recent origin. The structural theory which is the mainstay of present day search was proposed, it is true, as early as 1859 by Dr. T. Sterry Hunt, a Canadian geologist, and still later by other men, most of them arriving at the same conclusion independently. It was not until about 1884, however, that this theory was put to a practical test when Dr. I. C. White, the present State Geologist of West Virginia, encouraged by the suggestion of an oil operator, Mr. William A. Farseman, of Allegheny, Pennsylvania, used the principle in locating oil pools for a Pittsburgh syndicate by whom he was then employed. While these pools were not immediately tested, the drilling results later gave ample vindication of the theory.

The last Great War did much toward focussing attention on the scientific search for oil and gas. Oil was needed promptly and ample reserves were desired. Many oil and gas companies which formerly had paid little attention to the geologist sought him as the one most likely to get results quickly. The geologist, by application of the structural theory, then made good, so that today practically all companies of standing rely upon him for this search.

What is the structural theory? Briefly it may be defined as a belief based upon experience, that in a region favorable for the burial of organic remains and their subsequent partial conversion into oil and gas, that these substances tend to be forced into the more porous strata, and in the presence of water, move to the higher portions of these porous strata; gas, oil and water then being arranged according to their specific gravities. The boundaries of such higher portions beyond which the oil and gas cannot pass if accumulation is to occur, may be determined by overlying fine rock charged with water, through which the oil and gas cannot move, and a change in the dip of the stratum in which it is collected which will prevent upward movement in the same rock. Other impediments may limit the upward movement, as breaks through the porous rock which have become sealed, and sealing within the porous rock. The structure most favored by geologists is the anticline and related forms. The anticline may be described as a huge wave or upfold in the rock.

The principal work of the geologist is to map the position of the rock independently of the surface topography to find out whether such structures exist below the loose surface rock, and to locate upon them the most favorable points for drilling. In a new territory he is very apt to fail, but is justified by the fact that his proportion of failures is very much less than when the locations are made by a layman.

Why does the geologist so often fail? Favorable reservoirs are found in porous or fissured rock. The structure may be favorable but if a reservoir rock is lacking there can be no accumulation. Determination before drilling as to the presence or absence of such rock is not always a simple matter. While the geologist can often make up columnar rock sections from rock outcrops so that he can infer the sequence where these dip into the ground, he cannot always be sure that the rock which appears favorable elsewhere will continue with similar characters at the points where he recommends a well. Usually only the drill can tell. If he plans to drill on the top of an anticline, later results may prove that he has drilled on the flank of the favorable sand, as its crest may have shifted to one side of the upper crest of rock on which the map has been based. Again, in the process of folding, especially if the folding has been very sharp, breaks may have been opened in the tighter strata through which all the oil and gas has leaked upward to the surface. Another source of error lies in the fact that strata considered porous are often only patchily so. The drill unluckily may happen to hit the productive sand at a point where the interstices between the rock grains may be tightly filled with some cement. Only a few feet away may lie the coveted oil or gas: Torpedoing may prove this, or the effects of the torpedoing may not go far enough, and the well is given up in discouragement.

As before indicated, sharp folding tends to so break up strata as to permit the escape of oil and gas. Just what degree of folding is necessary to bring about this result is probably not determinable as for many reasons it would vary in different localities as well as with depth. A theory proposed in 1915 by Mr. David White promises to answer this question in another way. Mr. White found that when the fixed carbon ratio of coal (on the pure fuel basis) exceeded a certain percent drilling results were negative. With a lowering of this percent gas was often found, and with further lowering the lighter to heavier oils were tapped. This does not seem to be a chance relationship. A disturbance great enough to change coal to a high fixed carbon ratio is conceived as great enough to change the character of the oil to lighter grades or even entirely to gas, with an increasing chance approaching a certainty of so fracturing the rock that all the oil and gas escapes. The data at hand seems to indicate that when the fixed carbon ratio exceeds 65 percent in West Virginia, there is no use in drilling for oil, and when it exceeds 70 percent no hope may be entertained for commercial quantities of gas. The problems in connection with the use of this principle are first, that the data is not yet sufficient to indicate its absolute reliability. Second, that the percentages indicating the limits vary in different areas, so that they must be determined independently for the various areas. Third, some oil and gas fields are found in areas where coal is lacking. In such areas bituminous shales are usually present, but so far as yet known they cannot be used in the same way as coal in conjecturing probabilities. A fourth problem in connection with the use of the principle is the fact that it can only be practically applied where drilling is to the usual depths. Whether the 65 percent rule for oil would hold in West Virginia at depths say of nine thousand feet is highly problematical. No drill has yet reached such a depth. Folding may and probably nearly always does become less intense with depth, while the rock is more easily bent and less easily broken at such depths. Hence a badly fractured zone may exist near the surface, this gradually shading into unfractured rock below. Dr. I. C. White has expressed the belief that great thicknesses of shale will tend to shingle in such a way as to impede or prevent the escape of oil and gas. If conditions with depth so change as to favor the retention of oil and gas in highly folded regions, West Virginia may well develop fields to the east of the Chestnut Ridge line in what has been considered hopeless territory.

An experiment along this line is now being undertaken. There is at present a well drilling near Terra Alta, West Virginia, on which no depth limit has been placed except as the discovery of commercial quantities of oil or gas may stop its progress, or drilling troubles with the entailed expense makes it unfeasible to go further. At present this well is about 4,500 feet deep. It seems probable that drilling troubles will prevent any adequate testing of great depths.

Leaving out of consideration excessive folding, it would seem certain that possibilities of deep oil and gas exist in many of the areas where it is now found at present drilling depths. There is no inherent reason why it should not be present. While it is true that rock tends to become more compact with greater depth, it must be remembered that many of our oil and gas sands were at one time buried at depths exceeding our present drilling limits. Nature, by kindly moving thousands of feet, in some cases, of overlying rock has brought these sands within reach of the drill. Why may there not be at the present time favorable but deeply buried sands where nature has not performed this function. True it is that structures may be flatter, and hence more unfavorable for concentration at greater depths, but the greater chance of retention would be a strong offsetting factor.

The question of whether deep oil and gas may be found can be settled only by deeper drilling, and deeper drilling brings in problems of its own. The deeper the well, the greater the cost per foot, and for very deep wells this cost may become so great as to be prohibitive. Where conditions are very unfavorable wells sometimes now cost as high as one hundred and fifty to two hundred thousand dollars and more. The cost of drilling a well even under exceptionally favorable conditions to twice the present maximum depth, would doubtless be a startling figure. The chances for a profitable return are so uncertain that no such venture is looked for soon.

It may be added that the deepest well in the world is but 7,579 feet. This is a dry hole located about eight miles southeast of Fairmont, West Virginia, and known as the Lake well. Drilling troubles stopped progress before the calculated depth to the oil sand was reached. The deepest producing well in the world struck gas on November 28, 1924, at a depth of about 7,340 feet. This is located near Ligonier, Pennsylvania.

Structures have been located in the past by the geologist taking elevations upon a given rock where exposed, or using well data in a similar way. Science Service on page XII of Science, November 28th, 1924, calls attention to the use of the Eotvos Torsion Balance in locating underlying mass and hence makes possible the mapping of any continuous structure. This balance indicates variations in specific gravity of the underlying rock in its relation to the topographic surface. Many corrections must be made and other difficulties exist, so that the method cannot be said to have had adequate test. It is apparently, however, being given serious consideration and a fair trial by several oil companies at the present time.

Another method used in the hunt for oil and gas has been developed within the last few years. One of the difficulties in oil and gas work is the certain determination of a stratum wherever it may be found. In the past large fossils, when present, have been a most valuable method of indentification. More recently it has been found that some shales contain microscopic fossils, which it is believed are localized in their occurrence. If this conclusion proves reliable, and it is claimed that some oil companies in the Gulf states are now successfully using the principle, the indentification of strata whether exposed at the surface or examined in the drill cuttings, will be much more reliable.

Our present methods of extracting oil from the ground are highly inefficient. It is estimated that in many cases fields are abandoned before one-fourth of the oil has been obtained. It is not probable that a method one hundred percent efficient will ever be discovered. Efforts to increase recovery have been made by flooding the sands with water to drive the oil ahead to the wells, and similarly to force it out by compressed air or gas. Sometimes a vacuum method of recovery is used. These methods are applied with varying degrees of success, but when wells are profitable it is often best to leave well enough alone, and resort to special methods only when the other alternative is abandonment.

A unique method of increasing recovery was developed though not originated by Germany under stress of war conditions. Her fields were not yielding enough oil, so tunnels were driven into the sand with the expectation of mining and treating the rock. Seepage into the tunnels from the adjacent rock proved so effective that the idea of extraction by special methods was abandoned, at least for the time being, and the natural seepage was collected. This proved in amount to be almost the total remaining percentage of the oil. As the rock near tunnels becomes drained the supply is maintained by advancing the old and construction of cross tunnels. While not unknown in this country, this method has not here reached an important stage of development and may never do so on account of the prevailingly great depths of the sands. The method will unquestionably bring new problems with any further attempt at development in this country.

With the advent of the internal combustion engine, particularly its application to the automobile, the demand for gasoline became excessive. At one time gasoline was less desirable than kerosene, but with the increased demand induced by the new type of engine, its value mounted and a shortage was felt. Two ways existed of supplying this shortage. Finding new fields, as well as the better development and management of fields both new and old, and by increasing the percentage of gasoline obtained from petroleum. Several ways have been found to increase this percentage. One method is by mixing with the gasoline heavier distillates approaching the kerosene character, and counteracting the deadening effect of such a mix by putting in some unusually light gasoline (casing head gasoline) which formerly was allowed to waste or was sold as gas. Thus the amount is increased at both ends of the former distilling limits for gasoline. The second method of increasing the quantity of gasoline is by a process known as cracking. Several such processes are known. Their effect is to break up some of the heavier constituents of petroleum into the lighter of which gasoline is composed. New or improved cracking processes that will increase the amount of gasoline at a reasonable cost are desired by the oil companies, and herein is a problem to tax the ingenuity of the chemist and physicist.

Many minor problems might be discussed, but time and space necessitate omitting many of these and barely touching upon others. A cheaper method of extracting helium (when it is present) from natural gas is desirable. For the good of themselves as well as for the good of the community at large it is desirable that oil and gas companies operating in adjacent areas should work in harmony. Tremendous wastes have occurred in the past and some even at the present due to a frantic endeavor of rival companies to get all the oil or gas first, before any adequate facilities for taking care of it after extraction from the ground, were provided. Gas is frequently still allowed to go to waste, not only resulting in a irreparable loss of this commodity, but increasing the difficulty of getting the oil from the ground. Some of these problems are such as can be most effectively solved by legislation.

The amount of oil and gas in the ground is limited. It was estimated by the United States Geological Survey in collaboration with the American Association of Petroleum Geologists a few years ago, that the reserves of petroleum in this country lying within the present drilling depths and obtainable by present methods, would approximate ten billion barrels. At our present rate of use, provided we could continue to take the oil from the ground at the same rate, such as a reserve would last the country until about 1940. As a matter of fact the oil cannot be obtained from the ground this fast, so petroleum may be extracted indefinitely from the ground in this country, but at a rapidly lessening rate, a lessening rate that will probably start within a few years time, and which has already started in some of the older fields, notably the Appalachian. What will we do when this decline sets in in earnest? There are several ways out. The simplest is the importation from other countries where development is on the up-grade. But we are safest in not having to depend on other countries, for aside from political reasons, these in turn will decline in production in time. The possible mining of some of our fields has been suggested, but this cannot be highly effective on account of the great depth of most sands. Another alternative is the utilization of our bituminous shales which are estimated to contain potential oils equivalent to petroleum many, many times in excess of the reserves of the latter. The destructive distillation of coal wastes or increased distillation of coal itself many eliminate by substitutions the need for so much petroleum.

In this paper there has been hardly more than an attempt to call attention to some of the problems of the oil and gas industry. Its purpose is to stimulate thought along these lines and it is hoped it will be effective in this.

A PHASE OF COAL CONSERVATION

BY EARL R. SCHEFFEL,
Department of Geology, West Virginia University.

Estimates of coal recovery are usually if not always based upon the percentage of coal secured from the bed desired. The loss is the coal left as ceiling or floor or supporting pillars or walls, or losses from cave-ins of coal which it is not deemed practical to recover.

From the standpoint of the coal operator this method of estimating is quite proper. It fails to take into consideration, however, coals because of high ash, thin character, interbedding with shales or other reasons. Such coals by subsequent caving in mined areas may be above or below the bed mined which are accounted valueless either permanently lost or later recovered at considerably enhanced expense.

The Pittsburgh coal may be cited as an example of what is meant. This coal as measured by the mine operator has a thickness of about eight feet with considerable varation each way according to locality. This eight feet or so is comparatively pure coal with little (or no) interbedding of bone or shale. The operator endeavors to mine as much of this thickness as he safely can with profitable economy. He ignores the fact that usually overlying the coal is a multiple bedding of thin coals and shales; the aggregate of the coals some times approaching four feet. In order to obtain this coal sometimes an equal or greater amount of shale would have to be mined. As such mining has generally not been considered feasible in the past, very few analyses of these thin beds of coal have been made and little can be said about their composition.

What has been said with regard to the Pittsburgh coal is also in a large measure true of other coals in West Virginia. The Upper Freeport particularly may be mentioned. An estimate of the losses in West Virginia for these two coals alone, should present practices continue until these beds are exhausted, would amount into many billions of tons.

The phase of conservation considered by this article is the possibility of recovering such thin or dirty coals and to urge upon mining operators the importance of including them in estimates of recovery. As long as they are ignored the extent of the wastage is not appreciated. Cold figures might well be the motive force to compel action.

It is urged that geologists when making sections, will not only include the thin coals as is usually done, but will describe them as accurately and completely as possible. The lack of such descriptions and the absence of analyses largely destroys the value of such sections for working out future possibilities. Unfortunately analyses and detailed descriptions are usually made only on those coals which are looked upon as having economic possibilities according to present standards.

Geologists have long recognized the existence of this waste, and have occasionally speculated how it might be avoided. The literature on the subject is, however, very scattered and generally unindexed. Practically all the comments concerning this wastage were found by the writer in a page to page perusal of books on coal. One of the most virile comments is to be found in Volume II (1903) "Coal" of the West Virginia Geological Survey, I. C. White, State Geologist. On page 167 is a discussion of the wastes in thin coals overlying the Pittsburgh, and a prediction that these will be later mined. It may be stated that mining of similar character has already been successfully undertaken following the removal of the main bed and subsequent to caving. Would it not be far better to try and work out a method for removing all at the same time?

Perhaps the nearest anticipation to this article in any extended report is the pamphlet of the Pennsylvania Geologic Survey on the "Oil Resources in Coal and Carbonaceous Shales of Pennsylvania" (1923) by Chas. R. Fettke. The emphasis in this pamplet, however, is in a somewhat different direction.

How to remedy the situation is of course a problem. As one practical geologist has stated, the mine operator has trouble now in profitably mining the better and thicker coals without attempting conservation of this sort. Nevertheless, if anything is to be done a start has to be made sometime, and the sooner such a start is made the smaller the loss will be.

It is suggested that special methods of utilization may have to be resorted to in most cases. It is hardly to be expected that such coals, which can usually be mined and cleaned only at greatly increased cost per ton, will compete on the market with coal mined under present conditions.

As the less expensively mined or purer coal may stand more readily the cost of transportation, the solution of the problem may be in finding a practical method of utilizing the beds now in roof or floor, immediately at the mine. A more elaborate paper by the writer discusses such possibilities in some detail. It is sufficient here to merely note them.

The Bureau of Mines has made many experiments converting coal into Producer Gas. The results of these experiments seem to indicate that more energy may be obtained from a ton of high ash coal utlized in this way than from a ton of low ash coal used in the ordinary way. As the gas fields of West Virginia will doubtless be on the decline within a shorter period of years, it may be found satisfactory after this decline starts in or the demand for gas becomes greater, to mingle the natural and artificial gas for a time, and ultimately to use the natural gas pipes solely for the transportation of producer or other gas derived from the coal.

Reports from Germany indicate that a large percentage of a petroleum like product can be secured from coal by the introduction of hydrogen under certain conditions. Coals of the character here considered may be suitable for this purpose. If the production of a petroleum substitute in this way is found practical, the solution of another threatened problem, a petroleum shortage, may be found. Much has been written about oil shales in this connection. Yet oil shales are generally much higher in ash, as a whole more inaccessible, and offer smaller potential oil resources than will the thin and low grade coals, if the German method is practical and has not been misrepresented. As with gas, pipe lines already laid for petroleum could be used for transporting its substitute. These pipe lines are already favorably located for such change of function.

Some mines now use low grade coals for their own heating and power. Such uses might profitably be greatly extended to include adjacent settlements or enterprises.

Conversion of coal energy into electric power which may be transmitted with reasonable economy at present up to about two hundred and fifty miles, is a use that may be considered, for the low grade coals as it has been considered especially for the high grade coals in the past.

By-product coking with utilization of the high ash coke for gas is worthy of consideration.

CONCLUSION.

The proper conservation of our coal is of first importance to West Virginians. This state has closely contested for second place with Illinois in coal production for a number of years past. Coal is easily the most important of West Virginia's mineral products, constituting almost seventy percent of the total mineral production for 1923, estimated at $413,075,026 (U. S. G. S.). Indirectly much of the non-mineral industry of the state is dependent on coal production. As yet less than 1.2 percent of the estimated coal resources of the state has been mined, but it should be remembered that the estimates of reserves include huge tonnages far less favorably situated for mining than the coals considered in this article. Recognition of the present wastage and a successful method of preventing it will mean to the state the saving of a great tonnage that ranks only second in ease of recovery to the coal now mined.

Utilizations such as those suggested may seem visionary. The same argument has been advanced against almost every suggested radical departure from current practice. Sometimes such departures prove failures. Very often they are amply justified by results. It is only by making the venture that we can find out whether success or failure awaits, and without such venturing all progress must cease. It is hoped that coal companies or corporations of farsighted vision will open up this pioneer field of attempting to utilize a class of coals now practically ignored.

LOCAL CONDITIONS AT A MISSISSIPPIAN DISCONFORMITY

BY JOHN L. TILTON

Professor of Geology, West Virginia University.

The disconformity referred to lies just above the Pocono as seen near Greer about seven miles southeast of Morgantown on the Morgantown and Kingwood branch of the Baltimore and Ohio railroad. At Greer is located a quarry of Greenbrier limestone identified by D. B. Reger as Gasper limestone, the upper part of the Union. Standing by the railroad at the bend southeast from the quarry one looks across the valley of Deckers Creek to the long line of limestone in the quarry face. From the floor of the quarry a road winds down the slope passing first the Rosiclaire shale and then the siliceous and somewhat concretionary Fredonia limestone lying about fifteen feet above the level of the railroad by the mill. Further on to the west and a little to the left may be seen a railroad bridge over Deckers Creek the buttresses and pier of which rest upon the Pocono sandstone, identified by Reger as the Burgoon sandstone (Big Injun Oil Sand? Keener?). The evident disconformity lies between these two beds, the Fredonia above and the Burgoon below. It is noteworthy because of the character of the evidence seen in the field in this locality, and because of the absence of extensive beds that are present in the southern part of the state and farther west in the Mississippi valley.

Along Deckers Creek west from the railroad bridge the strata dip toward the northwest, so that at Sturgisson, about a mile and a half further down the valley, the Gasper limestone is at the level of the track, a difference in level of about a hundred feet. In this distance the surface of the Burgoon sandstone is first at about a uniform level for a quarter of a mile along the stream. Then the surface of the sandstone gradually rises till in another quarter of a mile it reaches a height of twenty feet above the track, or three-times that height above the creek. At this point opposite Sturgisson school a road goes southwest up the hillside, crossing first a heavy bed of the Burgoon sandstone, and immediately above it a cross-bedded sandstone with bedding planes dipping toward the west. Above this sandstone lies the Fredonia limestone, cross bedded and siliceous, just like that seen at the mill. At the first bend in the road the contact of the limestone with the sandstone is visible, and so clear that it can be detected within a twentieth of an inch. Above is the limestone, as already mentioned, and below for about an inch a yellowish, clayey, fine-grained standstone which even with this proximity to the limestone effervesces but slightly. Beneath this lies a light brownish thin bedded, very poorly cemented and almost shaly sandstone,

which in turn lies upon the above mentioned cross-bedded better cemented sandstone with bedding planes dipping toward the west.

Looking up at the bottom of the limestone one discovers lines like mud-cracks in outline, but the parts project downward into the underlying sandstone. The cracks are irregular though somewhat hexagonal. The interpretation is that on gradual subsidence the last sandy deposits before the limestone was laid down, was exposed as a sand flat between tides long enough for the surface to dry somewhat and crack and possibly fill with calcareous wind blown material. On return of the water there was no further exposure at low tide, but the conditions of deposition formed an accumulation with more of lime and less of sand. There was, however, current action during the deposition of the limestone, as shown by the cross-bedding in the limestone; and somewhat of fine sand was transported into the region and mingled with the deposition calcium carbonate, for the limestone is siliceous. A portion of the first of this calcareous material laid down on the old flat sifted into the cracks in the partially dried surface and hardened there. Now as we excavate beneath the limestone we look up at the former floor of the bay.

The position was such that I despaired of getting a photograph of the old mud-cracks till on the other side of the creek I came upon a large slab of what appeared to be this same Fredonia limestone that had been excavated in work upon the new Kingwood pike and turned upside down by the roadside. Here also the projecting lines are visible where the limestone filled down into the cracks in the sandstone.

These facts raise a question as to where the plane or planes of the disconformity actually lie. Here is clearly a change in a subsiding area, in which the old landscape had at its surface the coarse Burgoon sandstone of the Pocono, which on gradual flooding (subsidence) was later covered by limestone (Fredonia—Gasper); but where does the cross-bedded sandstone belongs? Is it a part of the Burgoon that happened to be at the surface at this point, or is it the first sandy material washed into the depressions as subsidence took place, and thus really belonging with the overlying deposits—the Tennesseian division of the Mississippian, and not the Waverlian division? If it is the first sandy material washed into the depressions as subsidence took place it would occupy the relation of a basal conglomerate, though it is not a conglomerate. Evidently the crucial test is to be sought in the character of the fossils, but as yet the sandstone is not to be found to be fossiliferous. The only evidences at present available are the coarseness of the siliceous grains in the strata, and in the relation of the beds. The lowest bed (Burgoon) has well rounded quartz grains ranging, among those that were examined, from .35 mm. to .9 mm. with an average of .565 mm. As a whole the sandstone is a slightly yellowish almost white, sandstone beneath the brownish weathered surface. The cross-bedded sandstone above lacks the largest grains and, though the grains average about the same (.50 mm.) the general character of the stone is that of a finer grained sandstone than that below it; it contains many nicely rounded quartz grains.

The grains in the sandstone close to the base of the limestone and in the limestone itself near Sturgisson school are uniformly fine, much finer than in either the cross-bedded sandstone or the coarser sandstone (Burgoon) below. This sharp contrast allies the topmost portions of the sandstone with the limestone (Fredonia). Nor is this contrast nullified by the presence of a few quartz grains as large as .70 mm. near the mill, for the average there is .32 mm.

Thus in size of grains the cross-bedded sandstone is as a whole more closely related to the underlying Burgoon than it is to the Fredonia. It could have been laid down in connection with contemporaneous erosion when the Burgoon was laid down, or it could have been the first somewhat coarse deposit laid down as the subsidence of the region began. Fossils only can supply the evidence needed to ascertain whether in time of deposition the basal cross-bedded part of the sandstone, and the greater part of its mass, was laid down with the Pocono sandstone, or as a basal portion of nearly the same age as the Fredonia limestone.

The topmost portions of the sandstone are distinctly related to the conditions of subsidence, and are thus to that extent beds associated with the limestone. There is, however, the break marked by the mudcracks, a break the duration of which we at present have no means of ascertaining. Here, too, in the sandstone a foot or so beneath the limestone, fossils are needed to give the evidence as to whether this sandstone was laid down before Pocono conditions had passed, or whether the break is of short duration, the subsidence following immediately, and thus this portion only having the relation of a basal sandstone to the Fredonia. The break may be of short duration, or it may be of long duration in the region of a low-lying sea margin; but its surface was soft when it cracked.

An additional reason why this disconformity is noteworthy is because of the absence of extensive beds that are present in the southern part of the state and farther west in the Mississippi valley. Mr. Reger reports that in the southern part of the state fifteen hundred feet of strata fit into the gap between the Burgoon and the Fredonia, fully half of which is Maccrady shale and sandstone, between which and the Fredonia are numerous and thick beds of limestone. According to the local conditions above described the thin beds of sandstone near the base of the Fredonia limestone near Sturgisson school, if not the cross-bedded portion beneath, may prove to be representative of the Maccrady. However this may be, the conditions here presented attending this great break (or two) above the Pocono, are such as to mark local conditions as noteworthy.

LONGITUDINAL VIBRATIONS OF AN ELASTIC PENDULUM

BY JOHN EIESLAND

I.

Neglecting the weight of the cable we have the following general equations for the motion of an elastic pendulum (Föpple, Technische Mechanik, Vol. 6, p. 140):

$$\begin{aligned} -g\sin\varphi &= 2\,\frac{dl_2}{dt}\cdot\frac{d\varphi}{dt} + l\,\frac{d^2\varphi}{dt^2}, \\ g\cos\varphi &= \frac{d^2l_2}{dt^2} - l\left(\frac{d\varphi}{dt}\right)^2 + \frac{c}{M}\,l_2, \end{aligned} \qquad (1)$$

$$\text{Let } l = l_1 + l_2 = l_1 + \frac{T}{\lambda}l_1 \text{, where}$$

l_1 = length of the natural cable,
l_2 = length of the stretch,
T = tension , λ = modulus of elasticity.

For longitudinal vibrations we have $\varphi = 0$, so that (1) becomes,

$$g = \frac{d^2l_2}{dt^2} + \frac{c}{M}l_2 \ , \qquad (2)$$

We put $z = l = l_1 + l_2 = l_1 + \frac{T}{\lambda}l_1$, so that we have, counting z positive downward.

$$l_2 = \frac{T}{\lambda}l_1 \ , \ T = \frac{l_2}{l_1}\lambda = cl_2 \ , \ c = \frac{\lambda}{l_1} \ ,$$

$$\frac{Ml_1}{\lambda}\,\frac{d^2T}{dt^2} = Mg - T \ , \qquad (3)$$

$$\frac{d^2z}{dt^2} = \frac{l_1}{\lambda}\,\frac{d^2T}{d^2t} \qquad (4)$$

$$M\frac{d^2z}{dt^2} = Mg - T \ , \qquad (5)$$

which last equation may also be obtained from elementary considerations, instead of starting with the Lagrangian equations (1).

Integrating (3) we find

$$T = Mg + A\cos\alpha t\,, \qquad (6)$$

where $\alpha^2 = \frac{\lambda}{l_1 M}$, or $\alpha = \sqrt{\frac{\lambda}{l_1 M}}$.

From (4) we get by integrating,

$$z = l_1 + \frac{Mgl_1}{\lambda} + \frac{l_1 A}{\lambda}\cos\alpha t\,,$$

$$z - l_1 = l_2 = \frac{Mgl_1}{\lambda} + \frac{l_1 A}{\lambda}\cos\sqrt{\frac{\lambda}{Ml_1}}\,t\,. \qquad (7)$$

A is an arbitrary constant and can differ from zero only if system is not in equilibrium at $t = O$. Since $\varphi = O$ in (1), it means that we must initially stretch the cable in a longitudinal direction and then let it go. If this pull is initially T_1, then from (6), $T_1 = A$.

We also find for the period of vibrations and velocity of lower end of cable

$$\text{Period} = P = \frac{2\pi}{\sqrt{\frac{\lambda}{Ml_1}}} = 2\pi\sqrt{\frac{l_1 M}{\lambda}} \qquad (8)$$

$$v = \frac{dz}{dt} = -\frac{\alpha l_1 A}{\lambda}\sin\alpha t = -A\sqrt{\frac{l_1}{\lambda M}}\sin\sqrt{\frac{\lambda}{l_1 M}}\,t. \qquad (9)$$

If $A = 0$, equation (7) tells us that the cable has been lengthened by an amount $\frac{Mgl_1}{\lambda}$.

Suppose now that the system is carried upward with an acceleration <u>a</u>. We may approximate this initial condition by supposing the cable with weight Mg at lower end to be wound about a drum at the top in such a way that $\frac{dz}{dt} = -\,at$. We may neglect the shortening of the pendulum for the first few seconds at least. An other method, more exact, would be to imagine the pendulum suspended in an elevator which is ascending with a velocity $= - at$. We have then for the tension

$$T = M(g+a) + A\cos\sqrt{\frac{\lambda}{l_1M}}\,t\,. \qquad (10)$$

that is, the effect on the tension is only to add a weight αM to Mg. Equation (5) now becomes ,

$$M\frac{d^2z}{dt^2} = Mg - (Mg+Ma) - A\cos\sqrt{\frac{\lambda}{l_1M}}\,t$$

$$z = l_1 + \frac{M(g+a)l_1}{\lambda} + \frac{l_1A}{\lambda}\cos\sqrt{\frac{\lambda}{l_1M}}\,t - \frac{at^2}{2}\,. \qquad (12)$$

The effect of pulling the system upward with an acceleration <u>a</u> has therefore no effect on the constant A. If system is in equilibrium at $t = 0$, A is zero and cable is lengthened by an amount $\frac{Mal_1}{\lambda}$ due to the added tension.

If we imagine the pendulum suspended in an elevator which starts upward with an acceleration <u>a</u>, that is with a velocity $= - at$, no vibrations will occur, the length will alter and become equal to $l_1 + \frac{M(g+a)l_1}{\lambda}$. If, however, the elevator stops, or the motion becomes uniform at a given moment vibrations will take place. In the same way, friction, or a sudden jolt, will start vibrations in the system.

II.

THE GENERAL PROBLEM

Suppose we have a string which we shall to begin with, suppose to be inelastic, and let Xmds, Ymds, Zmds be given forces acting on an element of string ds, whose mass of unit length is m.

Let u, v, w be components of velocity of elements parallel to axes. By D'Alembert's principle the element ds of the string is acted upon by the forces

$$mds\left(Z - \frac{du}{dt} \right), \quad mds\left(Y - \frac{dv}{dt} \right), \quad mds\left(X - \frac{dm}{dt} \right)$$

and also by the tensions at both ends.

Let $T \frac{dx}{ds}$, $T \frac{dy}{ds}$, $T \frac{dz}{ds}$ be the components of tension T at point (x,y,z). The components of the tension at the other end of the element are

$$T \frac{dx}{ds} + \frac{d}{ds} \left(T \frac{dx}{ds} \right), \quad T \frac{dy}{ds} + \frac{d}{ds} \left(T \frac{dy}{ds} \right)$$

$$T \frac{dz}{ds} + \frac{d}{ds} \left(T \frac{dz}{ds} \right)$$

The equations of motions are therefore (Routh's Rigid Mechanics, Vol. II, Ch. XIII):

$$\begin{aligned} m \frac{\partial u}{\partial t} &= \frac{\partial}{\partial s} \left(T \frac{\partial x}{\partial s} \right) + mX, \\ m \frac{\partial v}{\partial t} &= \frac{\partial}{\partial s} \left(T \frac{\partial y}{\partial s} \right) + mY, \\ m \frac{\partial w}{\partial t} &= \frac{\partial}{\partial s} \left(T \frac{\partial z}{\partial s} \right) + mZ, \end{aligned} \tag{1}$$

s and t being independent variables; s is constant for the same element of the string and its path is determined by varying t. But the curve which the string forms at any time t is obtained by varying s, holding t constant. s is measured from a point in the curve up to the element under consideration.

By geometry we have

$$\left(\frac{\partial x}{\partial s}\right)^2 + \left(\frac{\partial y}{\partial s}\right)^2 + \left(\frac{\partial z}{\partial s}\right)^2 = 1 \tag{2}$$

and differentiating with respect to t,

$$\frac{\partial x}{\partial s}\frac{\partial u}{\partial s} + \frac{\partial y}{\partial s}\frac{\partial v}{\partial s} + \frac{\partial z}{\partial s}\frac{\partial w}{\partial s} = 0. \tag{3}$$

The equations (1) and (3) are sufficient to determine x, y, z and T as functions of s and t.

The Elastic String. We shall now suppose that the string is elastic. Let σ be the un-stretched length of the arc s, and $m d\sigma$ the mass of an element $d\sigma$ and ds the element of the stretched arc. We have then,

$$\frac{\partial s}{\partial \sigma} = 1 + \frac{T}{\lambda}, \tag{4}$$

λ being the modulus of elasticity, and also

$$T. \frac{\dfrac{\partial x}{\partial \sigma}}{\dfrac{\partial s}{\partial \sigma}} = T \frac{\partial x}{\partial s}, \; T \frac{\dfrac{\partial y}{\partial \sigma}}{\dfrac{\partial s}{\partial \sigma}} = T \frac{\partial y}{\partial s}, \; T \frac{\dfrac{\partial z}{\partial \sigma}}{\dfrac{\partial s}{\partial \sigma}} = T \frac{\partial z}{\partial s}. \tag{5}$$

$$\left(\frac{\partial x}{\partial \sigma}\right)^2 + \left(\frac{\partial y}{\partial \sigma}\right)^2 + \left(\frac{\partial z}{\partial \sigma}\right)^2 = \left(\frac{\partial s}{\partial \sigma}\right)^2, \tag{6}$$

σ and t being independent variables The equations (1) now become

$$\begin{aligned} m \frac{\partial u}{\partial t} &= \frac{\partial}{\partial \sigma}\left(T \frac{\partial x}{\partial s}\right) + mX, \\ m \frac{\partial v}{\partial t} &= \frac{\partial}{\partial \sigma}\left(T \frac{\partial y}{\partial s}\right) + mY, \\ m \frac{\partial w}{\partial t} &= \frac{\partial}{\partial \sigma}\left(T \frac{\partial z}{\partial s}\right) + mZ, \end{aligned} \tag{7}$$

Differentiating (6) with respect to t we have,

$$\frac{\partial x}{\partial \sigma}\frac{\partial u}{\partial \sigma} + \frac{\partial y}{\partial \sigma}\frac{\partial v}{\partial \sigma} + \frac{\partial z}{\partial \sigma}\frac{\partial w}{\partial \sigma} = \frac{\partial s}{\partial \sigma}\frac{\partial}{\partial t}\left(\frac{\partial s}{\partial \sigma}\right),$$

which by (5) becomes

$$\frac{\partial x}{\partial \sigma}\frac{\partial u}{\partial \sigma} + \frac{\partial y}{\partial \sigma}\frac{\partial v}{\partial \sigma} + \frac{dz}{\partial \sigma}\frac{dw}{\partial \sigma} = \left(1 + \frac{T}{\lambda}\right)\frac{1}{\lambda}\frac{\partial T}{\partial t} \tag{8}$$

Equations (7), (4) and (8) will determine u, v, w, a and T as functions of σ and t.

Longitudinal Vibrations. Suppose that longitudinal vibrations only occur. U and v are zero, $\frac{\partial x}{\partial s}$, $\frac{\partial y}{\partial s}$, x and y are zero, $\frac{\partial z}{\partial s} = 1$ and we get,

$$m\frac{\partial w}{\partial t} = \frac{\partial T}{\partial \sigma} + mZ, \tag{9}$$

$$\frac{\partial z}{\partial \sigma}\frac{\partial w}{\partial \sigma} = \left(1 + \frac{T}{\lambda}\right)\frac{1}{\lambda}\frac{\partial T}{\partial t}, \tag{10}$$

$$\frac{\partial s}{\partial \sigma} = 1 + \frac{T}{\lambda}, \tag{4}$$

But $\frac{\partial z}{\partial \sigma} = \frac{\partial z}{\partial s}\frac{\partial s}{\partial \sigma} = 1 + \frac{T}{\lambda}$ and hence (10) becomes

$$\frac{\partial w}{\partial \sigma} = \frac{1}{\lambda}\frac{\partial T}{\partial t}, \tag{11}$$

Equations (4), (9) and (11) will determine the motion.

Let a weight Mg be attached to the lower end of a rope. (We may conceive of Mg as a basket of coal at the bottom of a shaft suspended by a steel cable. The basket is lifted from the bottom.

We have now,

$$\begin{cases} \text{(a)} & m\dfrac{\partial w}{\partial t} = \dfrac{\partial T}{\partial \sigma} + mg\,, \\ \text{(b)} & \dfrac{\partial w}{\partial \sigma} = \dfrac{1}{\lambda}\dfrac{\partial T}{\partial t}\,, \\ \text{(c)} & \dfrac{\partial s}{\partial \sigma} = 1 + \dfrac{T}{\lambda}\,. \end{cases} \qquad (12)$$

Since conditions for integration must be satisfied, we must have

$$\frac{\partial^2 w}{\partial \sigma \partial t} = \frac{\partial^2 w}{\partial t\, \partial \sigma}\,,$$

hence,

$$\frac{1}{\lambda}\frac{\partial^2 T}{\partial t^2} = \frac{1}{m}\frac{\partial^2 T}{\partial \sigma^2}\,, \qquad (13)$$

which partial differential equation must be integrated. We put

$$T = A\cos\alpha t\cos\beta\sigma + B\alpha + C$$

$$\frac{\partial^2 T}{\partial t^2} = -\,A\alpha^2\cos\alpha t\cos\beta\sigma,$$

$$\frac{\partial^2 T}{\partial \sigma^2} = -\,A\beta^2\cos\alpha t\cos\beta\sigma$$

Substituting in (13) we find

$$\frac{1}{\lambda}\alpha^2 = \frac{1}{m}\beta^2\,,\ \text{or,}\ \frac{\alpha}{\beta} = \sqrt{\frac{\lambda}{m}}\,. \qquad (14)$$

The initial tention T_0 is obtained by putting $\frac{\partial w}{\partial t} = 0$ in (12) (a), that is

$$\frac{\partial T}{\partial \sigma} + mg = 0.$$

Hence,

$$T_0 = Mg + mg\ (l - \sigma). \qquad (15)$$

Thus at bottom $T_0 = Mg$, and at top $T_0 = Mg + mgl$. We have then for T at any time

$$T = A\cos\alpha t\cos\beta s + mg\ (l - \sigma) + Mg. \qquad (16)$$

From (12) (a) and (b) we get

$$\left.\begin{aligned}\frac{\partial w}{\partial t} &= -\frac{\beta A}{m}\cos\alpha t\sin\beta\sigma\ ,\\ \frac{\partial w}{\partial \sigma} &= -\frac{\alpha}{\lambda}A\sin\alpha t\cos\beta\sigma\ ,\end{aligned}\right\} \qquad (17)$$

Integrating we find,

$$= \frac{\partial z}{\partial t} = \frac{\beta A}{\alpha m} - \sin\alpha t\sin\beta\sigma$$

and from (12) (c)

$$\frac{\partial z}{\partial \sigma} = \frac{\partial s}{\partial \sigma} = 1 + \frac{A\cos\alpha t\cos\beta\sigma + Mg + mg(l - \alpha),}{\lambda}$$

which integrated gives,

$$z = \frac{\beta A}{\alpha^2 m}\cos\alpha t\sin\beta\sigma + \sigma + \frac{g\sigma(M + ml)}{\lambda} - \frac{mgl\sigma^2}{2\lambda}, \qquad (18)$$

where $\frac{\alpha^2}{\lambda} = \frac{\beta^2}{m}$. In order to determine α and β we observe that when $m = 0$ and $\sigma = l$ we must have the result obtained for an elastic pendulum with mass of rope neglected. But we found in this case (p. 2)

$$\alpha = \sqrt{\frac{\lambda}{lM}}$$

and from (14), m being zero, we have $\beta = 0$. But

$$\frac{\alpha^2}{\beta^2} = \frac{\lambda}{m}, \ \alpha^2 = p\lambda, \ \beta^2 = pm ;$$

hence,

$$p = \frac{1}{lM}.$$

We thus obtain the following values of α and β :

$$\alpha = \sqrt{\frac{\lambda}{lM}}, \qquad \beta = \sqrt{\frac{m}{lM}}.$$

Substituting these values in 18) we have

$$\begin{aligned}
&\text{(a)} \quad T = A\cos\sqrt{\frac{\lambda}{lM}}\,t\cos\sqrt{\frac{m}{lM}}\,\sigma + mg\,(l - \sigma) + Mg\,, \\
&\text{(b)} \quad w = \frac{\partial z}{\partial t} = -\frac{A}{\lambda M}\sin\sqrt{\frac{\lambda}{lM}}\cdot\sin\sqrt{\frac{m}{lM}}\,\sigma \\
&\text{(c)} \quad z = \frac{lM}{m}\frac{A}{\lambda}\cos\sqrt{\frac{m}{lM}}\cdot t\sin\sqrt{\frac{m}{lM}}\cdot\sigma \\
&\qquad\qquad + \sigma + \frac{g\sigma}{\lambda}(M + ml) - \frac{mgl\sigma^2}{2\lambda}.
\end{aligned} \tag{19}$$

In order to show that this value of z will agree with the one obtained in the case when m is negligible and $\sigma = l$ we proceed to find the limit of $\frac{lM}{m}\sin\sqrt{\frac{\lambda}{lM}}\sigma$ when $\sigma = l$ and $m = 0$. We write this product in the form

$$\frac{\sin\sqrt{\frac{m}{lM}\cdot l}}{m} = \frac{\sqrt{\frac{m}{lM}\cdot l} - {}^{1/3}_{\,3}\left(\frac{m}{lM}\right)^{3/2} l^3 + \ldots}{\sqrt{\frac{{}_1m}{lM}}}$$

The limit of this expression as it approaches zero is l. Hence

$$z = \frac{1}{\lambda} A\cos\sqrt{\frac{\lambda}{lM}} \cdot t + l + \frac{Mgl}{\lambda},$$

which agrees with (7) p. 82.

If the system is carried up with acceleration a, the tension T will be

$$T = A\cos\sqrt{\frac{\lambda}{lM}}\, t.\ \cos\sqrt{\frac{m}{lM}}\,\sigma + mg\,(l - \sigma) + M(g + a)$$

$$w = \frac{\partial z}{\partial t} = - \frac{A}{\sqrt{\lambda m}} \sin\sqrt{\frac{\lambda}{lM}}\, t \,.\, \sin\sqrt{\frac{m}{lM}}\,\sigma - at\,, \qquad (20)$$

$$z = \sqrt{\frac{l.M}{m}}\,\frac{A}{\lambda} \cos\sqrt{\frac{\lambda}{lM}}\, t\sin\sqrt{\frac{m}{l.M}}\,\sigma + \sigma$$

$$+ \frac{g\sigma}{\lambda}\,(M + ml) - \frac{mgl\sigma^2}{2\lambda} - \frac{at^2}{2}\,.$$

The point $\sigma = 0$ is carried upwards with a velocity —at, and the point $\sigma = l$ with a velocity.

$$w = - \frac{A}{\sqrt{\lambda M}} \sin\sqrt{\frac{\lambda}{l.M}}\, t \sin\sqrt{\frac{ml}{M}} - at.$$

SOME NEW METHODS OF APPROACHING THE FOUR COLOR PROBLEM

BY CLARENCE N. REYNOLDS, JR.

The problem of proving it possible to color in only four colors the map of any set of countries or regions on the surface of a sphere or other simply connected closed surface was first proposed in 1878. Since then many men have worked upon the problem, but no one has at yet published a correct solution of it. In 1923 Dr. H. R. Brahana of the University of Illinois published an account of the methods which had been used in studying the problem up to that time.[1] Since then some progress has been made. The purpose of this paper is to outline the methods of investigation, as distinguished from methods of demonstration, which the author has used in deriving certain theorems concerning the four color problem which are to be published elsewhere;[2] and to supplement Brahana's paper with an account of the progress which has been made by others since 1923. For definitions of the terms used in the course of this paper, and for the bibliography of the subject, prior to 1923, the author refers to Brahana's paper.

If there exists a map of regions on a simply connected closed surface which cannot be colored in four colors then it is known that five colors are sufficient for that purpose. If such maps exist then among them there are one or more maps for which the number of regions is a minimum. Such maps are known as irreducible maps and concerning them a considerable number of theorems has been proven. It has been proven, for example, that in such maps not more than three regions can meet at a point, that no region can be bounded by fewer than five regions, and that of such "pentagons" there are at least twelve. It has also been proven that no boundary of either a pentagon or a hexagon may be surrounded by that pentagon or hexagon and three other pentagons. These restraints restrict the possible ways in which the pentagons of our map may be arranged. On the other hand such restraints do not define uniquely the arrangement of our pentagons. This suggests an investigation of the possible connected configurations of pentagons which may exist in an irreducible map. In such an investigation we might consider an isolated pentagon as the first possibility. The second possibility might be a pair of pentagons in contact with one another but insolated from all other pentagons. The third possibilty

---

[1] "The Mapcoloring Problem," American Mathematical Monthly, XXX (1923) p. 234.

[2] "The Problem of Coloring Maps in Four Colors, I," Annals of Mathematics, XXVIII, pp 1-15. Part II of this paper is to appear in the same journal in September, 1927.

"The Problem of Coloring Maps in Four Colors," Comptes Rendus de l'Association Française pour l'Aancement des Sciences, 1926, pp 88-91.

might be a triad of pentagons meeting at a point. Then by repeated adjunctions of pentagons we find that our various configurations may be classified according to certain numerical topological characteristics:

(1) Each configuration will contain a certain number, a_5, of pentagons.

(2) Each configuration will contain a certain number, t, of points at which three pentagons meet.

(3) Each configuration will be so shaped that there exist a certain number of contacts, y_n, between n of its pentagons and an adjacent non-pentagon. For each configuration $\Sigma_3 y_n$ will be a particularly significant numerical characteristic.

If $\Sigma_6 y_n > 0$ for any configuration then certain reductions due to Philip Franklin (cf. Brahana, l. c.) imply that there must be regions of our map with at least eight sides. If we restrict ourselves to maps with no region of more than seven sides, and to maps for which $\Sigma^5_3 y_n \leqq 4$, we find it possible, although somewhat tedious, to compile a census of those connected configurations of pentagons which satisfy our restraints. Of such connected configurations there are 194 homeomorphically distinct types. These may be classified according to the values of $\Sigma_3 y_n$, t, and a_5 which are associated with them. Such a classification is given in the following table which gives the number of homeomorphically distinct connected configurations of pentagons in each class. For classes not mentioned in the table the number of configurations is zero.

$a_5 =$	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$\Sigma_3 y_n = 0$, $t = 0$ . . .	1	1	0	0	0	0	0	0	0	0	0	0	0	0
$\Sigma_3 y_n = 0$, $t = 1$ . . .	0	0	1	0	0	0	0	0	0	0	0	0	0	0
$\Sigma_3 y_n = 1$, $t = 0$ . . .	0	0	1	1	1	0	0	0	0	0	0	0	0	0
$\Sigma_3 y_n = 2$, $t = 0$ . . .	0	0	0	1	1	2	1	1	0	0	0	0	0	0
$\Sigma_3 y_n = 2$, $t = 1$ . . .	0	0	0	1	1	1	0	0	0	0	0	0	0	0
$\Sigma_3 y_n = 2$, $t = 2$ . . .	0	0	0	0	0	1	0	0	0	0	0	0	0	0
$\Sigma_3 y_n = 3$, $t = 0$ . . .	0	0	0	0	1	2	4	4	4	2	1	0	0	0
$\Sigma_3 y_n = 3$, $t = 1$ . . .	0	0	0	0	1	4	6	6	3	0	0	0	0	0
$\Sigma_3 y_n = 3$, $t = 2$ . . .	0	0	0	0	0	0	2	2	2	0	0	0	0	0
$\Sigma_3 y_n = 4$, $t = 0$ . . .	0	0	0	0	0	1	2	6	8	11	8	6	2	1
$\Sigma_3 y_n = 4$, $t = 1$ . . .	0	0	0	0	0	0	3	10	19	19	12	3	0	0
$\Sigma_3 y_n = 4$, $t = 2$ . . .	0	0	0	0	0	0	0	3	5	7	4	3	0	0
$\Sigma_3 y_n = 4$, $t = 3$ . . .	0	0	0	0	0	0	0	0	0	1	0	0	0	0

From this census we find, for example, such an inequality as

$$2 - t - a_5 + 3\Sigma_3 y_n \geqq 0$$

which is true for all of the configurations of our list with the exception of the single configuration consisting of three pentagons meeting at a point. Acting upon this and other suggestions from the same source the author has been able to prove rigorously a set of generalizations of this and other inequalities which suffice to prove that

Any irreducible map contains at least twenty-eight regions.

Since the publication of Brahana's paper the Belgian mathematician Alfred Errera has considered[3] rings of polygons of three types:

(a) Rings formed by an even number of hexagons, arbitrarily arranged in the ring, and an even number of pentagons, arranged in consecutive sequences each containing an even number of pentagons. Here the number of pentagons or the number of hexagons, but not both simultaneously, may be zero.

(b) Rings formed by an even number of consecutive pentagons and any other two adjacent polygons.

(c) Rings formed by an even number of consecutive pentagons and any other polygon.

Errera has proven rings of these types absent from any irreducible map, provided that the erasure of certain boundaries, well defined with respect to the rings and the insertion of certain other equally well defined boundaries leaves no portion of the total network of boundaries attached to the remaining boundaries by a single boundary. Such a restriction as this must unfortunately be verified experimentally with each map to which the reduction is applied.

Errera does show, however, that certain more specifically defined rings are in fact reduced by his reduction, viz:

(1) A ring of six hexagons surrounding three pentagons which meet at a point. This has been proven by Philip Franklin, using a different method.

(2) A ring of six hexagons surrounding two adjacent pentagons.

(3) A ring of eight hexagons surrounding two hexagons and a pentagon which meet at a point.

(4) A ring of eight hexagons surrounding the figure formed by a hexagon bounded on opposite sides by pentagons.

(5) A pseudo ring of eight hexagons formed from two rings of five hexagons each surrounding isolated pentagons, the two rings of five hexagons having two hexagons in common, is proven reducible whenever a map containing such a ring has no region of more than six sides.

By means of these reductions Errera proves his most important theorem:

No irreducible map may be composed entirely of pentagons and hexagons.

Errera publishes a map of fifty-two regions, irreducible under his reductions, as an indication of the progress which he has made, without, however, making a specific claim that all maps irreducible in his sense

---

[3] "Une contribution au problème des quatre couleurs." Bull. de la Soc. Math. de France, t. LIII (1925) p. 42-55.

must have at least fifty-two regions..[4]) In this connection we present with this paper a map of only thirty-six regions which is irreducible with respect to Errera's reductions (see figure 1).

In proving the reducibility of all maps of fewer than twenty-eight regions the author has developed two distinct proofs. The earlier proof is based upon the reductions of Kempe, Birkhoff, and Franklin. With this paper we present (figure 2) a map of only twenty-eight regions which is irreducible with respect to these reductions. Therefore it is impossible to prove the number of regions in such a map greater than twenty-eight. The later proof involves, in addition to the earlier reductions one of Errera's reductions, viz. Rings of the type (2) defined above.

The addition of this reduction to the hypothesis of our theorem enables us to avoid the extensive case-making which seems to be unnecessary without it. In figure (3) we have a map of 30 regions which is irreducible with respect to this reduction and all earlier reductions.

Turning now to a more detailed discussion of the accompanying maps mentioned above, we note that in figures one and three the arrow heads marked "A" represent one point on our map. Similarly, the pairs of arrow heads marked "B" and "C" represent single points of our maps. With this convention understood we see that these maps remain invariant under a cyclic group of three rotations about points O and O′ as poles (cf. Klein's lectures on the Icosahedron, Part I, Chapter 1, Section 4). In each of these maps we have two groups of three hexagons each, one group meeting at O, the other at O′. The remaining regions are pentagons (drawn square) and heptagons. We therefore have twenty-one pentagons, six hexagons, and nine heptagons in figure one; eighteen pentagons, six hexagons, and six heptagons in figure three.

In figure two we have a map which is invariant under the group of tetrahedral rotations (Klein, l. c., Part I, Chapter 1, Section 6). Here we have twelve pentagons and eighteen hexagons; three hexagons being associated with each vertex of our tetrahedron, a pair of adjacent pentagons being associated with each edge, and a hexagon lying in the middle of each face of our tetrahedron.

All three maps may be easily colored in four colors, so that they are useful only in so far as they indicate the progress which has been made on the map coloring problem, and suggest configurations the reduction of which would raise the minimum number of regions known to be in an irreducible map.

---

[4] "Sur le problèm des quatre couleurs," Assoc. Franç. p. avanc. des Sciences, Lieége, 1924, p. 96.

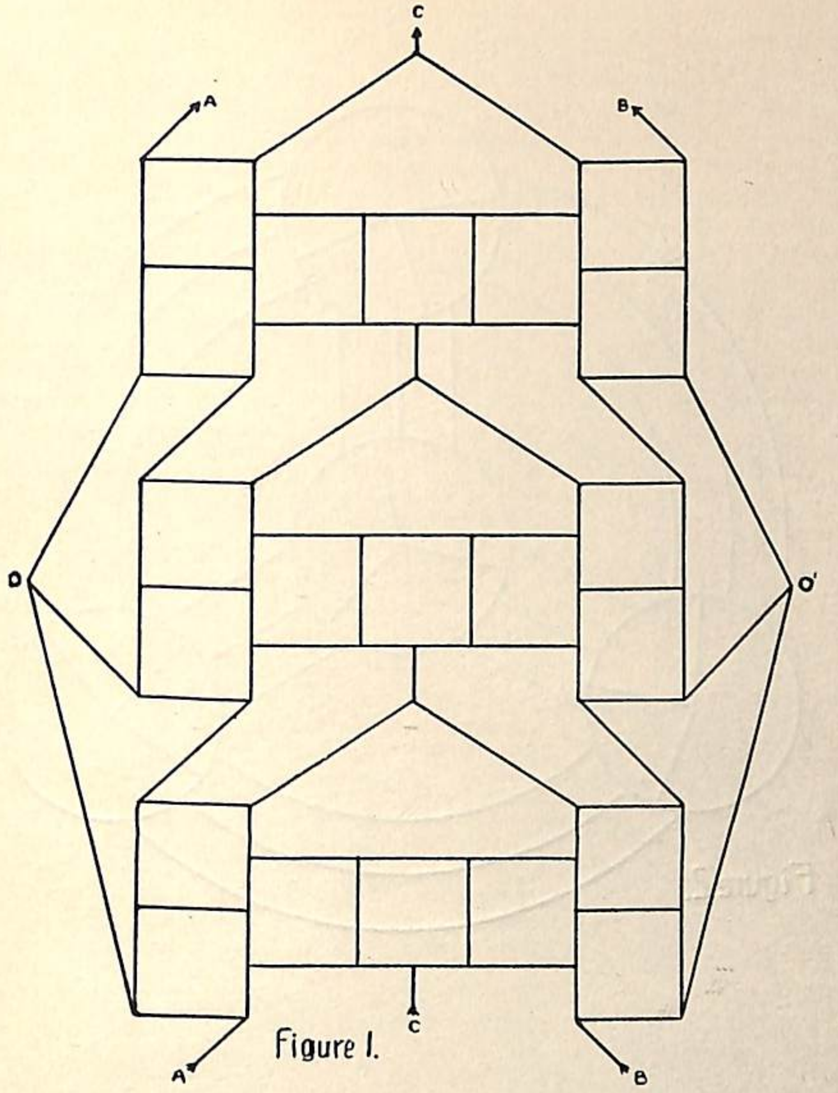


Figure I.

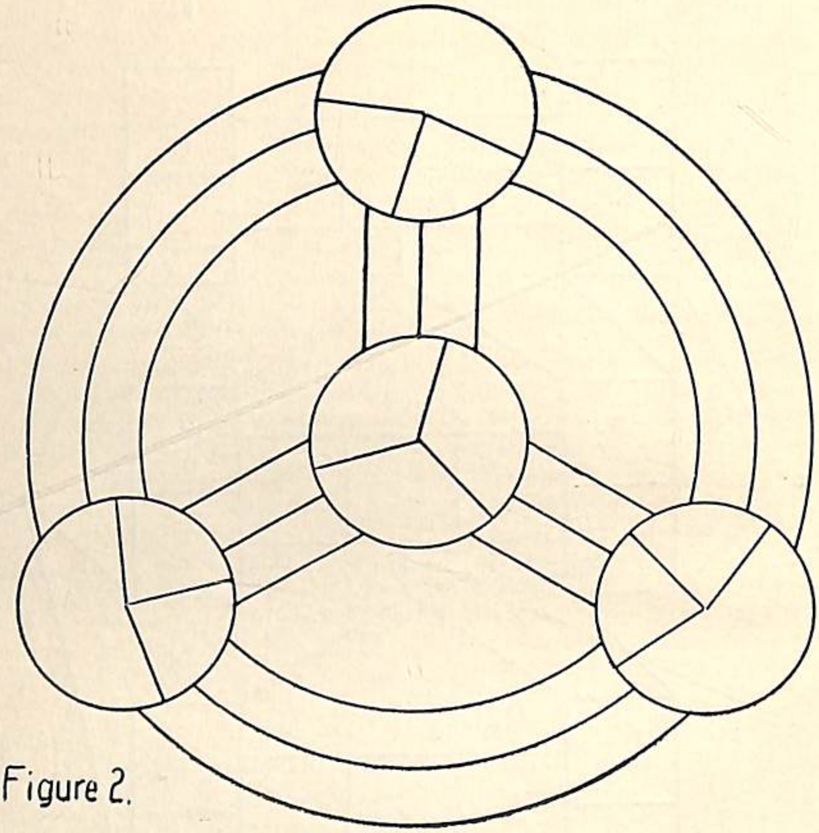


Figure 2.

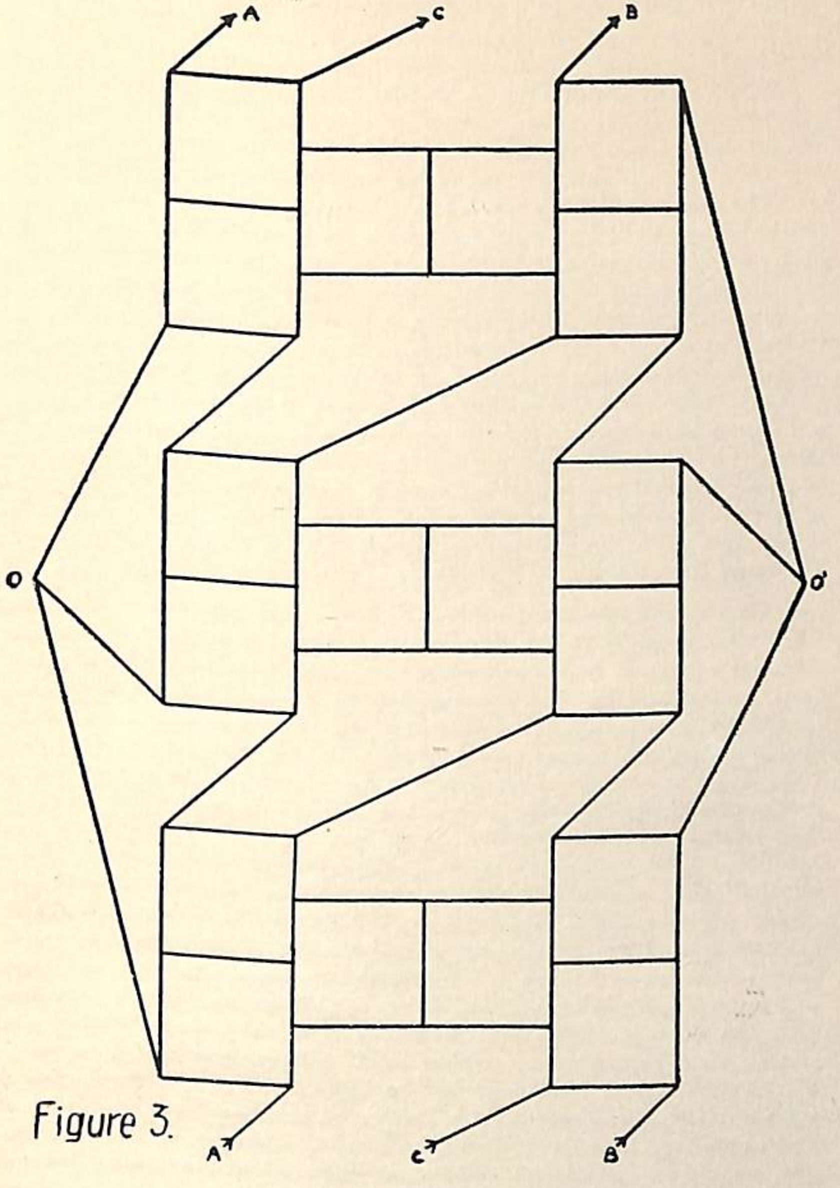


Figure 3.

SOME PROBLEMS ON THE FUNDAMENTAL CONCEPTS OF SCIENCE

BY H. E. CUNNINGHAM

I

The devotees of a science, when it has reached a stage in its growth at which it is able to be disentangled from the parent which gave it birth, seek a set of categories or fundamental concepts in terms of which it is possible to interpret the facts, pseudo-facts, and quasi-facts which seem to make up the corpus of the science in question. Generally a practical scientist, as an inventor, or mechanic, or engineer, or technician, accepts without question such categories as in **rerum natura,** and looks upon his more theoretical and critical colleague as some one to be tolerated but not to be listened to seriously. It is only when these fundamental concepts become shaken by a reinterpretation of the facts of experience in terms of novel sets of categories or in the terms of old ones so redefined and reconstructed as to have little in common with the old save the name, that the technician and manipulator of things and theories will be shaken from his dogmatic slumbers.

But genuine advance is made in science when facts are encountered which fail to yield to the preconceived forms into which they were formerly squeezed, and when some one, taking seriously these exceptions, re-fashions the fundamental categories so that the discordant facts find therein a rational place. In other words, it is through a careful interpretation of abnormal occurrences that new heavens of science are created and new earths of practice determined. In such a reconstruction it is generally the case that as much of the old is salvaged as possible. A complete scientific revolution is as unusual as a complete political revolution. An example in scientific thought will illustrate this. Newtonian physics centered about the concepts of mass, space, and time, giving origin to our C. G. S. system. The C. G. S. system is a system built up around a particular set of concepts as to the nature of space, time, and mass—all three being assumed to have objective existence, and to be the fundamental scaffolding for all natural events. In contrast is the atomic hypothesis which assumes the non-indivisibility of matter, an hypothesis that reaches back to Leucippus and Democritus of the Greeks, and later used by the Epicureans as a metaphysics of morality, and more recently by Dalton as the head stone of physics and chemistry. For Newton and the physicists matter, space, and time are continuous. For Dalton matter, at least, is discontinuous. Newton developed a technique for dealing with continuous variables—a technique which has been lauded as "the keenest tool the mind of man has ever invented." The anomalous situation then in this: that while nature's elements are assumed to be discrete, we yet use a technique devised for handling continuous phenomena. A finite calculus in the form of numbers has not completely replaced the techinque for continuous phenomena through infinitesimals. So a tendency persists, unfortunate for theory and symmetry and logic, but adequate enough in practice where errors are always gross, of placing the new wine of scientific speculation in the old bottles of traditional concepts.

II

For the purpose of formulating an interpretation of one of the fundamental concepts of science and suggesting interpretations of others, it is desirable that the leading details of the fact-material which induce those who believe that the fundamental stuff of nature is mathematical, be pointed out. There are those from the Pythagoreans and down who have believed that God geometrizes eternally. Back of all are form and order. Amidst the vicissitudes of change there runs the thread of order which molds apparent discrete facts and events into a unity. The multiverse of sense experience is cast into a universe through the instrumentality of organizing relations which are at heart mathematical. The designs of the Architect of the universe are carved on the trestle board of limitless space, and all events from the sweep of the comets to the behavior of the tiniest grain of sand on the shore behave in accordance with them. Nature knows the differential calculus. Such as has been and is now the belief of many.

In our discussion of these questions, time, ability, and the knowledge of the writer, impose limitations. Indeed, in recent times, the greatest theoretical problem that has confronted the mathematician is to determine precisely what fundamental concepts he is willing to adopt: What is the marrow of mathematics? Is it **form, invarience, functionality**? Is it **relations** or **terms** or both? Does he deal with **quantity** or **quality** or **modality** or **relations** or with all these? Is all mathematics statable in terms of arithmetic, in terms of numbers—rational and irrational, real and imaginary? And are numbers fundamentally **cardinal** or **ordinal** or is there a "neutral stuff" which generates both? Such problems engage the mathematical philosopher.

At the other extreme (mathematics being the most fundamental of the so-called sciences, excepting perhaps **logic**) are the social sciences which are certainly not lacking in fundamental categories, and which are indeed in sore need of them, but for which as yet a recognized group has not been formulated. I doubt if the average historian would have an answer ready at hand such as the chemist would have, for example, to the question, "What is your science about?"—granted that it is a science. The sociologist and the economist would probably be in a similar position. Such a state of facts accounts for the cyclonic effects of much teaching and much learning in such fields as these.

Wind and words constitute the material and rhetoric and technology. But it is comforting to note that wind and words and rhetoric have been essential means in the development of every science, however firmly grounded it may now seem to us. There was a time when the axioms of Euclid were as unformed as the **instincts** of contemporary psychology or as the hoped-for fundamentals in a social philosophy of internationalism upon which and in terms of which an organization may be effected for the stabilization and re-direction of human energies.

These considerations lead us to select a middle course, chosing neither the extreme of mathematics and logic nor that of the so-called social sciences, the former, in the almost classic language, "a ghostly ballet of bloodless categories"; and the latter, so dripping with concreteness as to be weakened for purposes of rigorous thinking. Such a middle course would lead us to the foundations or fundamental categories of the physical sciences. For the development of a science such as physics or chemistry or astronomy it is essential that there be first, a set of terms which, if not accurately defined, are at least pointed out, i. e., defined concretely; second, a relation or two—that in the physical sciences which has figured most prominently being the relation of causation, which is interpreted mathematically in terms of equality, and, by one possessed of metaphysical intoxication, as indentity, and third, some propositions—the chief of which in the physical sciences would embrace the general though ambiguous "law of the uniformity of nature" and more specifically, of the conservation of mass and energy. The above are the logical demands of any scientific system, and the best way to seek the heart of any science is to go directly to these three conditions, asking this question: What are the fundamental terms, relations, propositions?

Let us ask this question of the physical sciences. The answer that may be given is that they are matter, space, and time, conceived in classical physics as terms, i. e., things. The relation is that of causation, visualized not as a force, or urge which **produces** events, but in terms of impact and counter reaction of bodies stripped of all Aristotelian qualities and possessed only of the mathematical traits of form, position, size, motion and rest. That is, "the substance of the physical body is exhausted in the totality of properties which arithmetic and geometry can discover in it, (Cassirer, E., Substance and Function, p. 156) but the atoms or corpuscles are still **things**, conceived as bodies and not as twists or knots of space. The propositions would be those relative to conservation, of the universality of the causal relation, and of gravitation. Common names bear witness to man's interest in matter. **Things** embody one of the deepseated categories of experience. Adjectives which qualify them form another, and relation words represented by verbs, conjunctions and prepositions form a third. Language has been built up about things and their characteristics and relations—which is to say that thought is modelled on the pattern of things, attributes and relations. For common sense a thing is something which has a degree of permanence—some matter back of it and constituting it. It represents the fairly stable aspect of experience. A thing is something that must be reckoned with, it is something that matters. We cannot avoid things, there is a solidness and persistence about them which is compelling. So when we say "What is the matter?" we are really asking a question that is expressive of the fundamental common-sense notion of a thing.

Speculative philosophy and science arose in the west through a definite and conscious attempt to find the thing that lay at the bottom of all things—that is, to find the fundamental stuff out of which all things are made. It is this quest which differentiates primitive thought from philosophy and science; "it is the concept of substance which historically marks the line of distinction between investigation and myth." Greek genius exhausted itself in almost uncontrolled imaginings in its answers to this problem, and, lacking a technique for its solution, bequeathed it to the modern world—a symbol of the underlying vitality of the problems presented in Greek experience. Earth, air, fire, water—one, then the other, and finally all four became the "elements" in terms of which things in their qualitative richness and infinite variety could finally be interpreted. Along another, and what seems now a more fruitful, line the "stuff" of things was conceived as numbers, or as space configurations. The elements, however are not elements as the modern chemist uses the term. For him something is an element which resists further chemical analysis. For one wing of Greek thought the four elements were expressions of states of matter, analogous to our conceptions of solids, liquids, and gases.

It is almost impossible to overestimate the importance of the four elements for ancient and medieval science. The four hypostatized sense qualities, hot and cold, wet and dry, conceived as forces, issue in various combinations in the four elements. The theory of the humors in medicine, of the temperaments in psychology, and the whole idea of balance, measure, and harmony as these were expressed in the physical, ethical, and political realms of experience are all witnesses of the vitality of the ancient idea of the elements. The elevation of sense qualities into essences which have existence separate and distinct from particular things is the procedure which gives point to the practices of the early alchemists and the later chemists. But the logic implicit in Greek metaphysical speculations imposed such limitations on scientific thought as to render it sterile. The world seemed to be made up of things and their attributes, and science consisted in the discovery of the attributes of things presented in perception. Classification, therefore, became par excellence the method of science. This limitation is made clearer by an example of modern procedure in such a science as biology. For a long time—indeed since the days of Aristotle—no real advance was made in the biological sciences, due to the perseverance of the Aristotelian tradition that science consists in finding the proximate genus and the essential difference of the species in question. One has but to recall the Linnaean scheme of classification of plants, or the tendency in zoology up until the advent of the evolutionary hypothesis to refresh the memory on the tenacity of the ancient tradition of the thing—attribute. In other words, science fails to progress through the application of an adjective to a thing. Bodies may be heavy or light; liquid, solid, or gaseous; they may possess the attributes of tenacity, malleability, viscocity, impenetrability, and such; but that is not science as we now conceive it. Science progresses when we no longer attribute adjectives to things but when we state the conditions under which an event may be repeated, or the conditions that make for or against the appearance of a specified phenomenon. Such a statement is possible only when events are described with reference to each other and not as they are classified with reference to affectation of men's sense organs. To state that white light may be broken into the colors of the rainbow is to state a fact, but to state that a certain spectrum is a sign of a specific type of atomic structure is to make use of sense preception as a sign of something not directly open to sense perception.

But as remarked earlier, matter, since the Greeks, has generally been conceived as the substratum of all solid things of perception. Man, it seems, needs **things** in order to give content and body to his thought. Hence, instead of earlier explaining heat as a mechanical phenomenon, the early modern scientist looked for an imponderable substance which he called **caloric** to account for the fact of perception that some things are hotter than others. Early modern physics and chemistry were burdened with the impedimenta of "imponderables" and "phlogistons"—all of them substances, that is matter, to afford the imagination a method of visualizing the prenomena of nature. Not long since electricity and magnetism were conceived as imponderables—facts reemphasizing the almost innate prejudice of thinking only in terms of things, that is, of substance or matter; and only recently a "vital force" was essential in explaining the phenomena of organic chemistry.

While this paper is given over mainly to a discussion of the concept of substance as it occurs in the physical sciences, it might not be amiss to indicate briefly how the tendency to substantialize experience has expressed itself in other regions. Glaring examples are seen in psychology where functions are readily reduced to substances. A fact of observation of such a nature as to involve choice is explained by positing a thing called the Will; one with the characteristics of a re-direction of action as a result of a present stimulus operating as a control over future behavior is explained by the operation of a thing called the **Reason**; an event or process which possesses the characteristic of the past and the present and the future is explained by positing a substance called the **Soul.** When such hypostatizations are made, man is confronted with numerous questions such as "the freedom of the Will," "the limits of Reason," and "the immortality of the Soul." In religious experience the same tendency is seen, namely, to substantialize a mode of action.

Hence a proper interpretation of substance would tend to free other disciplines which are struggling to become scientific of their ancient disabilities.

III

There is an ancient tradition that the fundamental stuff or substance which enters into the constitution of all things, celestial and terrestial, is number. Not number in the sense of definite integers and fractions as we understand number, but as forms or outlines. There are, for example, square numbers, triangular numbers, and the like. The business of research, or this assumption, is to discover the number of the thing in question, thereby giving a means by which the thing in question could be controlled and its occurrences predicted. The quite common expression today, "I have your number," is a vague reminder of a theory once almost dominant and now winning command in certain fields of scientific endeavor. The answer which the Pythogoreans gave to the question, "What is the fundamental stuff out of which all things are made?" was answered not in terms of water, earth, fire, and air, but rather in terms of certain fundamental number patterns. The same attitude is reflected in Plato's **Timaeus** where he visualizes the elements in terms of the regular geometrical solids—a view that in many respects finds a recrudescence in such theories as those of van't Hoff in the field of chemistry in space, or in what may be called the geometry of chemistry.

Even technical and correspondingly uninteresting as are the details of the modern development of the relationship between the facts of experience and number a fair knowledge of this development is a **sine qua non** of any adequate appreciation of present day speculation in the exact sciences. For that reason and for the added one, namely, that the relationship between perception and number is so often misinterpreted, resulting in a false metaphysics through a process of hypostatization, I wish to develop this theme.

IV

Omitting further reference to ancient speculation in which the imagination was not submitted to the rigor of facts determined through experimentation, we come at once to the modern conception as to the relation between number and substance, and finally to the idea that number is substance. In 1789 Higgins formulated the idea that the molecules of a given compound contain the same number of atoms, but he made the mistake of assuming that all atoms have the same weight. Proust's law of constant proportions coupled with the law of multiple proportions, to-wit: When the same two elements combine together to form more than one compound, the different weights of one of the elements which united with a constant weight of the other, bear a simple ratio to one another, formed the fact material which enabled Dalton (1808) to formulate the atomic hypothesis. This hypothesis is stated in such a way as to render chemistry a department of arithmetic—the idea, first, of indivisible atoms remaining identical during chemical re- one element, but that atoms of different elements differ from each other; and third, that chemical compounds are produced by juxtaposition of atoms, and that they unite in definite numbers in the constitution of molecules. Such an hypothesis makes it possible to formulate an exhaustive deductive chemistry, in which the only business of experimentation would be to find what combinations nature will permit of the infinite variety made possible as a result of submitting the ideas of chemistry to the technique of arithmetic. The application of Dalton's hypothesis to the problems requires a knowledge of atomic weights. He formulated a table of weights (in 1808) taking hydrogen as one or the unit. The difficulties of Dalton's method of obtaining atomic weights were mitigated by Avogadro by a further arithmetization of the facts, through the assumption of molecules each containing a plurality of identical atoms.

The fact-material determined as a result of experimentation on the hypothesis of Dalton, Avogadro, and Proust (among others), the hypothesis of the latter, to the effect that atomic weights are integral multiples of the weight of hydrogen, was reinterpreted in the periodic classification. This classification is based on the observation that there is a relation between the properties of simple bodies and their atomic weights; the principle is stated more accurately in the proposition that the properties of elements vary periodically in accordance with variations in atomic weights. This rhythmical variation includes such phenomena as melting point, electro-chemical character, and atomic volume. The assumption upon which the periodic table is based is that elements are made up of a small number of primordial substances, and that their atoms are complex systems between which there are likenesses of composition and structure. The atomic number is obtained by placing the elements in a series beginning with hydrogen and ending with uranium —making 92 elements counting the four gaps. The atomic number functions more easily in the arithmetization of chemistry than does the atomic weight, and, in part, for this reason is more important.

X-ray spectra also shows a regular progression throughout the series of elements, showing the correctness of the order adopted. When by the atomic number an element would be placed in a given place, which it would not occupy if placed by the atomic weight, as is the case with argon which is placed before potassium, X-ray spectra indicate, by their progressive nature, the wisdom of classification by atomic numbers.

Both the periodic relations among the elements and properties displayed progressively by means of X-ray spectra render it probable that a common stuff numerically related lies back of all physical things. A search for such common stuff has issued in the electronic theory of matter. Everyone knows the general outlines of this theory, and it is not necessary to state it here. Some details which bear on the theme of the arithmetization of physics and chemistry will be mentioned—details which are likely to lead one to the view of the Pythagoreans.

An added remark may make this discussion more significant. Physics and chemistry are basic sciences—that is, they are involved in all the sciences on the hierarchy above them—biochemistry, biology, physiology, psychology. If it is possible to say that such basic sciences are purely mathematical, what would our inference concerning the others naturally be? It might not be too far a flight of the imagination to say that in the future of psychology of religion, for example, the fact of conversion can be explained scientifically in terms of the shift of rings of electrons, or of a clearing up of elements in a compound nucleus analogous to Aston's theory of isotopy. But that is only a prediction as Lavosier or Prout or Boyle might have made concerning the present electron theory.

Our present concern is to state the facts which can best be interpreted on the hypothesis that physical events are primarily (i. e., scientifically) a chapter in the book of numbers. A great mass of fact-material has been displayed by means of the spectroscope, and the material has been explained by Niels Bohr. The spectroscope, as all know, displays two sorts of light, namely bands and lines, the former due to molecules, and the latter to atoms. Much of our knowledge of atomic structure results from interpretation of line spectra. Why does a given element have a spectrum consisting of sharp lines? The hydrogen spectrum will serve the purpose of this paper. It and the spectrum of positively electrified helium have been studied exhaustively and everything explained.

The problem is to determine the connection between the lines in the spectrum of hydrogen. Ritz, in 1908, found that all lines were connected with a certain number of inferred wave numbers (equals the number of waves in a centimeter) called terms. So that every line has a wave number which is the difference between 2 terms; and this difference between any 2 terms gives a line. Rydberg's constant is a fundamental wave number, being 109,700 waves per centimeter. This is the fundamental term in the hydrogen spectrum. Others (terms) are found by dividing it by 4(2x2), 9(3x3), 16(4x4), etc. This gives all the terms, and lines are found by subtracting one term from another.

Various series of terms are discovered by use of this rule. One series is found by subtracting from Rydberg's constant, first 1-4, 1-9, 1-16, etc., of itself, giving as wave numbers of the lines 3-4, 8-9, 15-16 of Rydberg's constant. These wave numbers correspond to lines in the ultra-violet and are called the Lyman series. Another series—found by subtracting from a quarter of Rydberg's constant 1-9, 1-16, 1-25, giving wave numbers of this series as 5-36, 3-16, 21-100, called the Balmer series, was discovered 1885. Various other series can be obtained, some visible, some not, as Paschen's series. All the lines of the hydrogen spectrum are obtained from Rydberg's constant, by dividing it by any 2 square numbers and subtracting the smaller resultory number from the larger. Thus far, Rydberg's work is purely observational or factual. The fact material of Ritz's "Principle of Composition" and of Rydberg's constant and the empirical work done about them found a place in a theory of the hydrogen atom vastly different from that to the effect that when light is going on all the time that what causes it is going on all the time. Line spectra led Bohr to a more fruitful hypothesis, namely, that terms correspond to stable states of the atoms and that light is emitted when the atom passes from one stable state to another. "Lines of the spectrum are due to various possible transitions between stable states." When the hydrogen atom gives light, its electron suddenly moves from a distant orbit to a near orbit. When the reverse occurs, the atom absorbs light rather than giving it.

If in the hydrogen atom, the single electron moves about the nucleus in a circle, on Newton's dynamics the orbit would be determined by the velocity and the direction of its motion in a given moment. But on the present theory only a few of the possible orbits are possible.[1] The only possible ones are 1, (or 2), 4, 9, 16, 25, etc., i. e., the series of square numbers, the same as found in the formula for the hydrogen spectrum. When the electron jumps from a larger to a smaller orbit it emits light which will be one of the lines of the hydrogen spectrum. E. g., if it jumps from circle of radius 4 to the smallest, light is emitted with a wave number ¾ of Rydberg's constant. From 9 to smallest 8-9 of Rydberg's constant. Such a passage involves the notion of the discontinuity of space which is hard to grip by us brought up on continuity in various fields especially in biology and in the physics of relativity. Russel, paraphrasing Poincare, says that we should give up thinking of time as continuous and think of a minute as a finite number of jerks with nothing between them. There may be no intervening space between 2, 4, 9, 16, 25, etc.

The same principles that apply to the hydrogen atom apply to all other elements as far as we know. It is sure the same conclusions hold in the positively electrified helium atom. The difference between them is that the charge on the nucleus is twice as great as that on the electron

---

[1] Russel, B., The A B C of Atoms.

and the mass of the nucleus is four times that of the hydrogen nucleus. "The changes which this produces in the spectrum are exactly as theory would predict."

Bohr's theory is a special case of the theory of quanta. There is no time here to go into the quantum theory of Planck. Very generally, as every one knows, the theory, projected primarily to account for heat radiation, is that if a body is undergoing periodic motion or vibration of any frequency v, there is a constant **h** such that the energy of the body is **hv** or a multiple thereof. If energy is greater than **hv** it is twice, or three times as great, etc. Originally it was thought that there were energy atoms analogous to the atom of a molecule. Such a conception while incorrect may help to visualize the constant **h**. The only point for our purpose is that Planck's theory is a further evidence of the arithmetic nature of the facts of nature; and an invitation to modify our technique for dealing with events in microcosmic nature, and an invitation to develop a theory of space and of time that may make a place for the conception of matter that is congenial to the quantum idea.

We must remember that for microcosmic nature, space and time are conceived as continuous phonomena and in the nature of classical physics, as objective "containers" of natural events. Events are spoken of as being **in** space and **in** time. The theory of relativity has taught us to conceive of space-time as something "elastic," so to speak, and probably as a matrix out of which things develop, following the idea of emergent evolution in the recent contribution of C. Lloyd Morgan and Alexander:—but space and time are continuous, like the continuity of the germ plasm in Weismann or of the **elan vital** in the philosophy of Bergson. Of discontinuity in space and time, we have yet to learn. The idea of discontinuity is not new in some fields of present science, as in biology where the DeVriesian notion of mutation finds a haven, and in the physiological psychology of the Weber-Fechner school where the relation between a stimulus and the sensation is expressed in terms of discontinuity to-wit: that the stimulus increases arithmetically with a corresponding geometric increase in the sensation—ideas which in some ways indicate the arithmetization of biology and physiological psychology.

It was said above that the electron of the hydrogen atom travels in a circle or at least practically so. This is only partially true, but the refinements of the hydrogen spectrum are too detailed. It is enough to point out that the Zeeman effect, the Stark effect, and the phenomenon of the "fine structure" demands other courses. These effects are explicable on the assumption of the elliptic orbit of the hydrogen electron. But in this case and in the case of rings of electrons the same principles seem to hold, so that experimentation need not modify the principle, but with the advent of more powerful intellectual tools for analysis, especially in mathematics, may possibly verify it in more complex structure as it has in the simpler cases of the hydrogen atom and that of the positively electrified atom of helium.

Quantitative and arithmetic relations are found to exist in X-ray spectra as in the optical spectrum of hydrogen. The same may be said of the behavior of radio-active elements, in both the **Alpha** particles consisting of the nucleus of helium, or in the **Beta rays**, consisting of electrons.

To enter the field of the relationship between atomic structure and problem of chemistry would take us too far afield. Of course everything here is not explained—for example, the exact relationships between the peripheral rings of electrons to which chemical phenomena are due and the problems of valency. But the problem has received a new interpretation in the electronic theory of matter, to the effect that chemical affinity is of an electrical nature, being of negative or positive kinds, the former corresponding to electrons which the atom has taken on to itself, the latter to electrons which have been taken from the atom. "The valence, instead of being denoted by a number, is stated as a positive or negative number." (Falk, Enzymes, p. 14). But barely to generalize, though in full recognition of the fact that organic chemists have failed to welcome wholeheartedly the electronic theory of matter rather for technical reasons than for reasons of theory, on the ground that "abandoning the usual structural formulae and replacing them by electronic symbols the subject is being complicated instead of simplified," (Stewart, A. W., **Recent Advances in Organic Chemistry, 1920**), we may say that the number theory of matter finds decisive expression in the various forms of chemical experimentation.

In the chemistry of highly organized material the principles are identical, though the problems be more complex. The chemistry of the carbon compounds, once appearing recalcitrant and explained on the assumption of a vital force by Berzelius and his contemporaries and successors, gradually yielded to the same principles as were found fundamental in general chemistry. Indeed in the chemistry of the carbon compounds we find represented the two great antagonists, as it were, of mathematics, namely arithmetic and geometry, the one the very expression of discreteness, the other of continuity—the union of which (or rather the lack of union) brought about the first defeat to the Pythagorean philosophy. Arithmetic finds expression in atomic structure; geometry, in the arrangement of the other atoms about the carbon atom. For example, the "attachment points of the hydrogen atoms of methane emerge from the central carbon nucleus in the direction of the axes of a regular tetrahedron, the valencies forming angles of 109°28′ with one another." (Armstrong, **Chemistry in the Twentieth Century**, p. 94).

V

What, then, is this thing called **matter**? Is it, as it might seem from the discussion so far, just animated numbers playing a game of tag in a medium called space and time, according to the simple rules of multiples, roots, and powers? Is it **electricity**, as the electronic hypothesis might lead one hastily to believe? And if so, what is electricity —something behaving in keeping with the multiplication table, or is rather a name for the way things behave, or more preferable still, just the behavior? First, it might be pointed out what matter is not. Certainly it is not a substratum underlying and producing or causing events. Matter is not the name of anything, like the Chemistry Building of West Virginia University. That one can point to, and one cannot point to matter. Then is matter not numbers? The belief that this is so arises from confusing a technique with the content upon which that technique is directed. There is no more fertile source of fallacy than in this connection—that of hypostatizing the instruments by which we perform our intellectual operations. This is likewise a pernicious fallacy, leading as it does to the erection into the fabric of nature of our implements of manipulation, and the consequent problems that come, which are indeed pseudo-problems. I believe the whole metaphysical structure produced by the great geniuses of Greece, notably Plato and Aristotle, results in this manner. And anyone who has the least inkling of the perseverance of their ideas on down through the middle ages, as these ideas became embodied in the institutions of that time, compelling obedience even under the penalty of death, will realize the supreme importance to present thought, especially social and religious, of a recognition of the fallacy and the obligation imposed upon all thoughtful men of building anew such foundations as will meet our problems on the level of man's own energies and resources.

Matter is not number or numbers. Man's most successful tool for dealing with his experiences is number. He handles nature when he can count, tell how much, and how little; he controls events when he visualizes the causal relation as the impact and counter-impact of bodies, and establishes quantitative units for the determination of such impacts. It is little wonder then that the means becomes an end. Successful means are transformed into the warp and woof of the universe. How often this happens in respect to institutions, always established for a purpose, for the achieving of some desired goal—then, forgetting the goal, the institution becomes an end in itself, often standing as a chief barrier to the on-coming of new ideas, or the growth of a more adequate social order! When instruments are erected into ends man falls in palsied obedience to the gods of his creation, be they in religious regions where **church** becomes the end, or in politics where the **state** takes a similar position, or in business experience where **money** becomes the end, or in science where **matter** assumes the role of god.

Hence in philosophy, men are called materialists when they have erected out of a means of controlling and predicting events a substratum in the form of matter which **causes** events and which gives them body and content. A scientist, intoxicated with his own weapons, the weapons, namely, of mass, space, time, motion, number, and casuality (to name a few), make **things** of them, and interprets events as details within their objective framework. Newton, for example, made things out of space and time. It took genius to define them, not as things, but as relations; and genius again to conceive them not as containers of events, but as abstractions from events—to see, that is, that there is a possibility that time and space are in nature, instead of nature being in time and space. How many have sinned likewise in making a substance out of cause, in conceiving cause as something that **produces** events and **forces** things to occur, rather than in taking it to be the name given to the fact **that** the events do happen in a specified and specificable way. Cause thus becomes another **caloric,** or **phlogiston,** or **imponderable.** Barely to mention one of the pseudo-problems that arises from the fallacy of substantializing cause, let me point to the old question: What or who **caused** the world? The cause is here personified and the pseudo-problem of accounting for the **cause** of the **cause, ad infinitum,** engages man's mind. Let us, again, think of cause as a name given to the fact that events occur in a specified or specificable way, and the problem of an unknown cause or un-moved mover becomes meaningless. Here, as often, the statement of the wise Bishop Berkeley comes to mind, namely, that men kick up a dust and then complain they cannot see. Many of the great problems of science and philosophy have turned out to be straw men set up by the imagination—they are found not to be problems, but to be fictions resulting often from the very fallacy that gives origin to a thing called substance, to another called imponderable fluids, and to the belief that everything is composed of numbers.

Matter is best conceived as an adjective, that is, it is a characteristic of events. To make my meaning as clear as possible at the sacrifice of accuracy of statement, let me say that the "substance" of nature is events, and matter is a term used adjectively to describe a particular kind of event. Again, matter is an instrument for the interpretation of events, and not a substance underlying them.

Space, time, and mass, the constants of classical physics, are not then, things existing in their own name and right, but are means, adjectival in nature, of man's devising for the control of events through purposive observation, fruitful hypothecation, and quantitatively determined experimentation.

Such a conception of the nature of the fundamental concepts of the physical sciences will, when tanslated into the social and human sciences, clear the ground of the metaphysical lumber of tradition, and make ready for the erection of statelier mansions of ethics, politics, and religion.

FADING CURVES AND RADIO RECEPTION

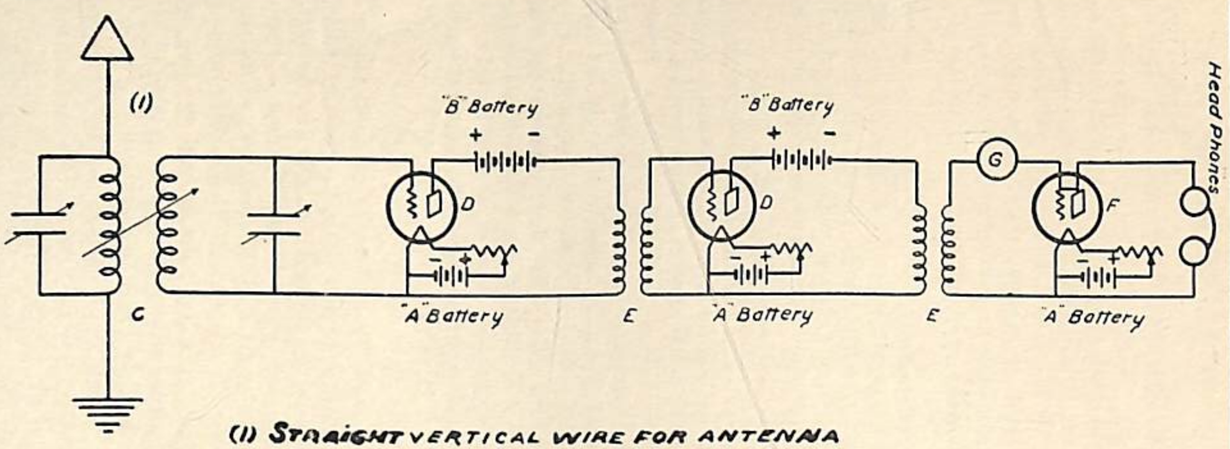
R. C. COLWELL, E. F. GEORGE, AND O. R. FORD

Although radio waves are similar to light waves, they seem to travel over the surface of the earth following the curvature rather than in straight lines as is required by Maxwell's theory. For this reason it was thought that accurate measurements of the intensity of signal strength from a definite station (such as KDKA of Pittsburgh) might give some information regarding the propagation of wireless waves.

The receiving apparatus consisted of a single wire vertical antenna about forty feet in length which was connected to a vario-coupler made especially for these measurements. The signal was amplified twice at radio frequency and then passed into a detector. (Fig. 1). The detector consisted of a triode used as a diode. A galvanometer in series with the diode gave readings proportional to the received energy.

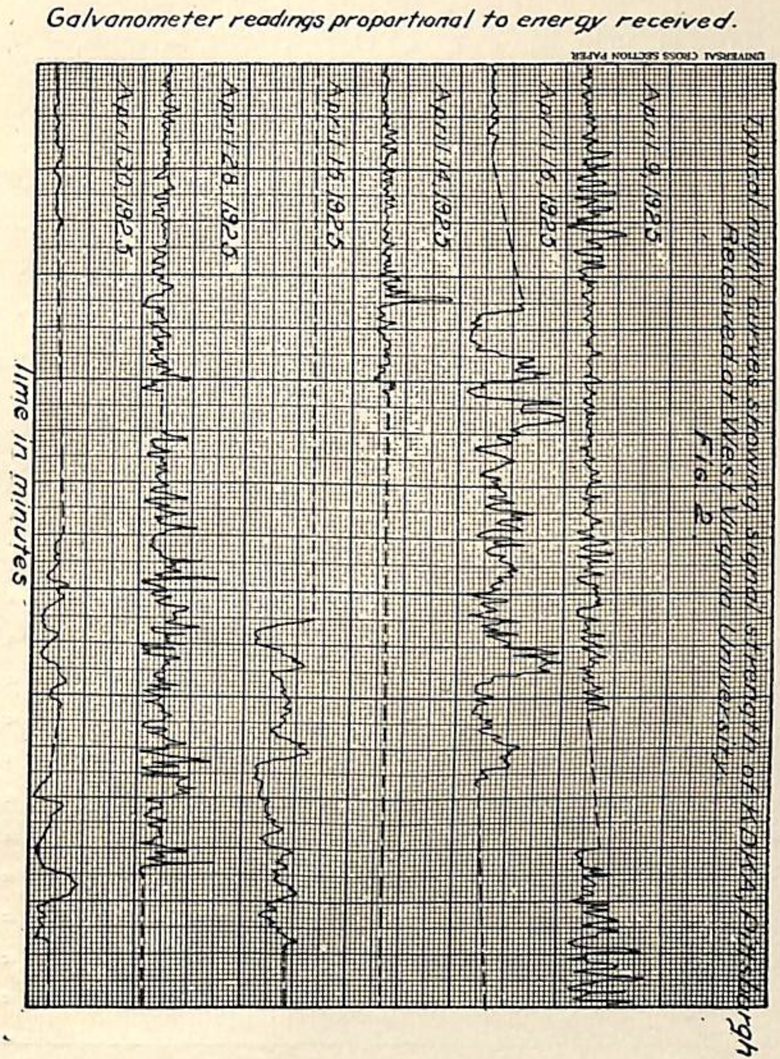
It is apparent from the curves (Figs. 2 and 3) that the propagation by night is radically different from that by day. The typical day curves show an extremely small variation from minute to minute—the energy remaining approximately the same during the day-light hours. At night the energy received fluctuates violently—the maximum energy is several times the daylight average while the minimum at night is far below that average. In fact the signal by night may fade out entirely. In the case of KDKA which is about sixty miles from Morgantown, the signal never fades out for more than a second or so at a time. The night average of signal intensity is about two and one-half times the day average for this particular station. While the day signal changes little from day to day, the night signal is extremely variable and there is no apparent relation between signals from one night to another.

These fading curves are best explained by an hypothesis which has been developed during the past two years. It states that by day the radiation along the surface of the earth continues to cling to the surface while the radiation into space passes away from the earth altogether. At night, a reflecting layer forms at a height of one hundred miles and this reflects the space wave back to the earth. The surface wave and the space wave then interfere at points along the ground and this interference causes a fluctuation of signal strength. On the whole, however, more energy is received by night than by day.

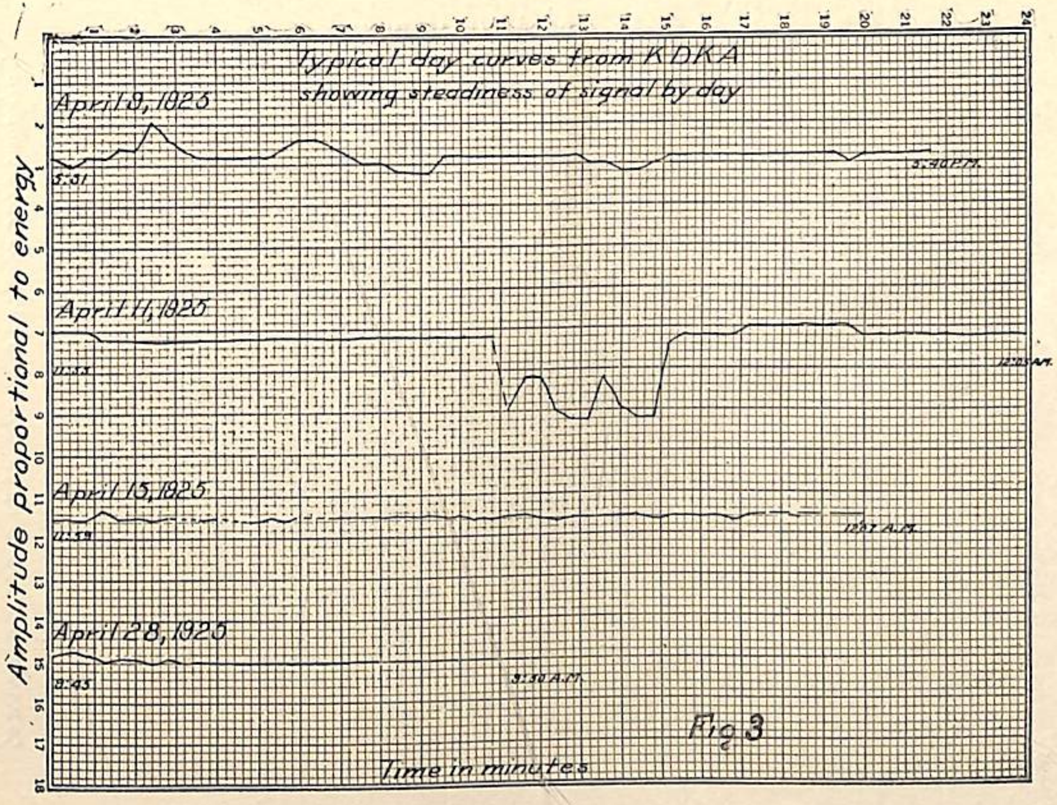


(1) STRAIGHT VERTICAL WIRE FOR ANTENNA
C A VARIOCOUPLER FOR ACCURATE TUNING
D RADIO FREQUENCY AMPLIFYING TUBES
E RADIO FREQUENCY TRANSFORMERS
F A TRIODE USED AS A DIODE RECTIFIER
G THE GALVANOMETER ON WHICH THE READINGS WERE TAKEN
THE HEAD PHONES WERE USED FOR MONITORING PURPOSES

FIGURE (1)



Typical night curves showing signal strength of KDKA, Pittsburgh. Received at West Virginia University. Fig. 2.



Typical day curves from KDKA showing steadiness of signal by day

Fig 3

OPERATIONAL METHODS IN MECHANICS AND ELECTRICITY

BY R. C. COLWELL

In the solution of many physical problems, differential equations of the form

$$\frac{d^2s}{dt^2} + K\frac{ds}{dt} + h^2 s = E \cos \omega t \qquad (1)$$

are developed. The usual method of solving (1) is to substitute $S = \varepsilon^{\lambda t}$ for the natural motion of the system and $S = \alpha \cos (pt - \alpha)$ for the forced oscillation—the two parts thus obtained giving the complete solution. However it has been shown by Carson (Physical Review Sept. 1917 p.217) that in the case of normal vibrations, a general solution of (1) may be obtained in the form

$$x_k = E_1 \left\{ \frac{M_{1k}(p)}{D(p)} \varepsilon^{pt} - \sum_{m=1}^{m=n} \frac{M_1 K (P_m)}{(P - Pm)\ D(Pm)} \varepsilon^{P_m t} \right\} \qquad (2)$$

in which for a single equation $M_{1k}(p) = 1$ and $D(p) = (p^2 + Kp + h^2)$ writing $\frac{d}{dt} = p$ for the operator.

The process for finding S (or x) is then simply an algebraic one and the final result is given in terms of the constants of the system. For example, writing (1) in operational form we get

$$(p^2 + Kp + h^2)s = E\ \varepsilon^{j\omega t}. \qquad (3)$$

$$S = \frac{E\ \varepsilon^{j\omega t}}{p^2 + Kp + h^2} \qquad (4)$$

The operator p for oscillatory motion is such that $p = j\omega$ then

$$S = \frac{E\ [\cos \omega t + j \sin \omega t]}{(h^2 - \omega^2) + Kj\omega} \qquad (5)$$

The real part of (5) gives the forced oscillation of the system; namely

$$S = \frac{E}{\sqrt{(h^2 - \omega^2) + K^2\omega^2}} \cos (\omega t - \alpha) \tag{6}$$

where

$$\tan \alpha = \frac{K\omega}{h^2 - \omega^2} \tag{7}$$

This part of the process is well known; but the second term of equation (2) gives the oscillations which are present before the final steady state denoted by (6). In this problem the second term may be written

$$E \, \Sigma \frac{\varepsilon^{P_m t}}{(P_m - j\omega) \, (\frac{dZ}{dp})_m} \tag{8}$$

Then

$$Z(p) = p^2 + Kp + h^2 \tag{9}$$

$$p_1 = \frac{-K + \sqrt{K^2 - 4h^2}}{2} \quad p_2 = \frac{-K - \sqrt{K^2 - 4h^2}}{2} \tag{10}$$

$$\left.\begin{aligned} (\tfrac{dZ}{dp})_2 &= -j\sqrt{4h^2 - K^2} \\ (\tfrac{dZ}{dp})_1 &= 2p + K = +j\sqrt{4h^2 - K} \end{aligned}\right\} \tag{11}$$

$(\frac{dZ}{dp})_1$ and $(\frac{dZ}{dp})_2$ being given the imaginary form for oscillating systems.

$$-\frac{E\,\varepsilon^{\frac{K}{2}t}\,4h^2}{\sqrt{4h^2 - K^2}} \left[(h^2 - \omega^2)\sqrt{4h^2 - K^2} \cos \frac{\sqrt{4h_2 - K^2}}{2} t \right.$$
$$\left. + (h^2 + \omega^2) \operatorname{sen} \frac{\sqrt{4h^2 - K^2}}{2} t \right] \tag{12}$$

or

$$\frac{-2h\,E\,\varepsilon^{-\frac{K}{2}t}}{\sqrt{4h^2-K^2}}\left[\text{Cos}\left(\frac{\frac{\sqrt{4h^2-K^2}}{2}\,t-\beta)}{\sqrt{(h^2-\omega^2)^2+K^2\omega^2}}\right)\right] \tag{13}$$

(6) and (13) together give the complete solution in the form

$$S\ z\ \frac{E}{\sqrt{(h^2-\omega^2)+K^2\omega^2}}\left\{\cos(\omega t-\alpha)-\frac{2h\,\varepsilon^{-\frac{K}{2}t}}{\sqrt{4h^2-K^2}}\cos\left(\frac{\sqrt{4h^2-K^2}}{2}t-B\right)\right\} \tag{14}$$

If h and ω are nearly equal and K small (14) becomes

$$S=\frac{E}{\sqrt{(h^2-\omega^2)^2+K^2\omega^2}}\left\{\cos(\omega t-\alpha)-\varepsilon^{-\frac{K}{2}t}\cos\left(h^2-\frac{K^2}{4}\,t\ \beta\right)\right\} \tag{15}$$

II.

For electrical problems, the appropriate solution is

$$I=E\left[\frac{\varepsilon^{pt}}{Z(p)}+\Sigma\,\frac{\varepsilon^{P_m t}}{(P_m-p)\,Z^1(p_m)}\right] \tag{16}$$

Example: If the system consists of an inductance L in series with a resistance R, and the driving force is E sin (pt + θ) the differential equation is

$$L\,\frac{dt}{di}+Ri=E\sin(\omega t+\theta) \tag{17}$$

the driving force is then $\frac{1}{i}$ times $E\,\varepsilon^{j(\omega t+\theta)}$

In operational form

$$(Lp + R)\ i = E\,\varepsilon^{j(\omega t+\theta)} \tag{18}$$

The current in the final steady state is therefore

$$l_1 = \frac{E}{R^2+\omega^2L^2}\left[R\ \mathrm{Sin}\ (\omega t+\theta) - \omega\ L_1 \cos\ (\omega t+\theta)\right] \tag{19}$$

The transient oscillations are given by the second term of (16) in the form

$$E\,\varepsilon^{j\theta}\ \Sigma m\ \frac{\varepsilon^{P_1t}}{(p_1-p)Z^1(p_1)} \tag{20}$$

$$Z(p) = Lp + R\ ,\ \frac{dZ}{dp} = Z^1(p_1) = L\ ,\ P_1\ z - \frac{R}{L} \tag{21}$$

These values in (20) give

$$l_2 = \frac{-\,\varepsilon^{-\frac{R}{L}t}\,E\ [\cos\theta + j\sin\ \theta]}{R + j\ \omega}$$

the real part of which is

$$-\,\varepsilon^{-\frac{R}{L}t}\,E\ [R\ \sin\ \theta - \omega\ L\ \cos\ \theta] \tag{22}$$

Equations (19) and (22) together give the complete current

$$I = \frac{E}{R^2+L^2\omega^2}\left[R\ \mathrm{sen}\ (\omega t+\theta) - \omega\ L\ \cos\ (\omega t+\theta) + \varepsilon^{-\frac{R}{4}t}\,(\omega\,L\cos\theta - R\ \mathrm{sen}\ \theta)\right] \tag{23}$$

III.

For a simple pendulum with forced oscillations

$$\frac{d^2x}{dt^2} + n^2x = F \varepsilon^{j\omega t} \tag{24}$$

$$Z(p) = p^2 + n^2 : \frac{dZ}{dp} = 2p \quad P_{1,2} = \pm jn \tag{25}$$

$$\therefore x = \frac{F \varepsilon^{j\omega t}}{p^2+n^2} + \Sigma \frac{\varepsilon^{P_m t}}{(P_m - j\omega) \left(\frac{dZ}{dp}\right)_m} \tag{26}$$

$$= \frac{F \varepsilon^{j\omega t}}{n^2 - \omega^2} - \frac{F \varepsilon^{jnt}}{2n\ (n - \omega} - \frac{F \varepsilon^{-jnt}}{2n\ (n + \omega)} \tag{27}$$

the real part of this gives

$$x = \frac{F}{n^2 - \omega^2} [\cos \omega\, t - \cos n\, t] \tag{28}$$

More generally if the driving is f (t) (which can be expanded in a Fouriers Series) equation (24) takes the form

$$\frac{d^2x}{dt^2} + n^2x = f\ (t) \tag{29}$$

and the solution is

$$x = \frac{d}{dt} \int_0^t f\ (\lambda)\ A\ (t = \lambda)\ d\lambda \tag{30}$$

where

$$A\ (t) = \frac{1}{n^2} (1 - \cos n\, t) \tag{31}$$

Therefore

$$x = \frac{d}{dt} \int_0^t f\ (\lambda) \frac{1}{n^2} [1 - \cos n\ (t - \lambda)]\ d\lambda \tag{32}$$

(2) Carson Transient Oscillations AIEE. Feb., 1927.

$$x = \frac{1}{n} \operatorname{sen} n\,t \int_{o}^{t} \cos (n\lambda)\, f(\lambda)\, d\lambda - \frac{1}{n} \cos n\,t \int_{o}^{t} \sin (n\lambda)\, f(\lambda)\, d\lambda \quad (33)$$

Equation (1) may also be put in the more general form

$$\frac{d^2 s}{dt^2} + K \frac{ds}{dt} + h^2 s = f\,(t) \quad (34)$$

$$A(t) = \frac{1}{h^2} \left[1 - \frac{\varepsilon^{-\frac{K}{2} t}}{\sqrt{4h^2 - K^2}} \cos \left(\frac{\sqrt{4h^2 - K^2}}{2}\, t - B \right) \right] \quad (35)$$

$$x = \frac{d}{dt} \int_{o}^{t} f(\lambda)\, \frac{1}{h^2} \left[1 - \frac{\varepsilon^{-\frac{K}{2}(t-\lambda)}\, 2h}{\sqrt{4h^2 - K^2}} \cos \frac{\sqrt{4h^2 - K^2}}{2}\, (t - \lambda - B) \right] d\lambda \quad (36)$$

$$x = \int_{o}^{t} \frac{f(\lambda)}{h^2} \left[\frac{K\,h\,\varepsilon^{-\frac{K}{2}(t-\lambda)}}{\sqrt{4h^2 - K^2}} \cos \frac{\sqrt{4h^2 - K^2}}{2}\, (t - \lambda - B) + h\,\varepsilon^{-\frac{K}{2}(t-\lambda)} \operatorname{sen} \frac{\sqrt{4h^2 K^2}}{2}\, (t - \lambda - B) \right] d\lambda \quad (37)$$

SOME STUDIES IN ABSORPTION OF LIGHT BY MIXED SOLUTIONS

BY E. F. GEORGE

If we could solve completely the problem of the structure of the atom, we should doubtless come to understand clearly many processes which now behold "as through a glass darkly." One of these processes is the mechanism of the absorption of light by solutions. Many theories have been advanced to account for absorption and none have proved satisfactory. It is an interesting and puzzling fact that if to a colored solution a colorless salt is added, the color of the solution may be decidedly changed. The absorption bands may be increased, decreased, broadened, or shifted. As particular instances the following may be mentioned: an aqueous solution was prepared containing $CuCl_2$ and NH_4Cl, the concentration of the former being .274 and the latter 3.1 mols per liter. The mixture shows very great absorption in the violet, although a solution of $CuCl_2$ alone of the same concentration is quite transparent in that region of the spectrum. There in a decrease in absorption in the green and yellow and an increase in the red, as compared with that of the $CuCl_2$ alone. If the $CuCl_2$ is mixed with NaCl or with KCl there are very great changes in absorption. When $FeCl_3$ is mixed with NH_4Cl or with $ZnCl_2$ there is a tremendous increase in absorption in the violet and a decrease in the green. The absorption spectrum of a mixture of $NiCl_2$ and LiCl shows an enormous increase throughout the visible spectrum over that of the $NiCl_2$ alone. The absorption of a mixture of $CuCl_2$, $FeCl_3$, and NaCl, as compared with the sum of absorptions of these three salts, shows an astonishing increase at each end of the visible spectrum and none whatever in the middle of the spectrum at about wave-length 5500 A. U.

These changes in absorption have been explained by Jones in terms of his "Solvate Theory." According to this theory the molecules or ions of the salt form loose compounds with the molecules of the solvent. The colored molecules or ions are thus weighted down and their natural frequency of vibration changed. If another salt now goes into solution it also tends to form combinations with the solvent. The result is that a part of the molecular aggregates already formed will be broken up. The colored ions and molecules will thus be relieved of their extra loads and will vibrate with new frequencies.

The author wishes to extend and amplify a somewhat different explanation already set forth in two former publications.[1] The absorption of light can probably be explained only in terms of the interorbial

---

[1] E. F. George, Doctor's thesis, Ohio State University, 1920, and Bulletin of the West Virginia University Scientific Association, Vol. II, No. 1, April, 1923.

transitions of the valence electrons of the atom. The atom may exist in any one of a number of different "stationary states" of different energy levels. In any one of these states, characterized by the revolution of electrons in definite orbits about the nucleus, energy is neither absorbed nor emitted. The change of the atom from one stationary state to another, which is characterized by the transition of a valence electron from one orbit to another, is accompanied by absorbtion or emission of energy. If the electron shifts to a virtual orbit further out, the atom passes to a state of higher energy level, and the energy is absorbed. Such a process takes place in accordance with the quantum relation $W_2 - W_1 = h\upsilon$ where W_1 represents the energy of the atom in the first state, W_2 its energy in the second state, υ is the frequency of the exciting light, and h is Planck's constant. If this energy is gained at the expense of the radiant energy in the light source in question, then we have the absorbtion of light.

In the case of a neutral atom energy may be absorbed in the following way: It takes a certain amount of energy to transfer a valence electron from its normal orbit to the first virtual orbit further out. It requires a greater amount to move it to the second virtual orbit, and so on. If the electron has already been removed to any one of the virtual orbits, it may absorb sufficient energy to be lifted to another orbit still further out. This corresponds to what is known in gas as the partial spectrum, except that the crowded condition of the atoms and frequency of collision, resulting in forced vibrations, give us broad absorbtion bands rather than sharp lines.

A positive ion requires more energy for the removal of a valence electron to an outer orbit because the electron is bound more firmly to the atom. The effective positive charge is greater and therefore the force of attraction between the electron and the atom is greater. The quantity $W_2 - W_1$ is thus seen to be greater, and consequently $h\upsilon$ is greater. A different part of the spectrum is therefore absorbed. Thus we get what approximates in a gas to the partial enhanced or partial spark spectrum.

If the absorbing atom is a constituent part of a molecule, where one or more of its valence electrons may be shared with other atoms, the state of affairs is much more complicated. Here the energy relations will be different from either of the above cases. Part of the absorbed energy may be utilized in the production of ionization. We may expect something analyogous to the band spectrum of gaseous molecules.

It is evident, then, that the dissociated ions in an electrolytic solution will absorb quite differently from the undissociated molecules. Absorption is thus a function of dissociation, and dissociation is known to be a function of the concentration. This makes absorption a function of the concentration and affords a simple explanation of the repeated failure of Beer's law, which states that absorption is proportional to the number of absorbing units in the path of the beam of light.

Suppose we have, then, an aqueous solution of some colored salt, such as $CuCl_2$. A certain part of the $CuCl_2$ molecules will dissociate into copper ions and chlorine ions, the extent of dissociation depending upon the concentration and the temperature. Let us now add some colorless salt, such as NaCl. Even though the density of the copper remains unchanged, the density of the chlorine ions is increased. This will result in a number of copper ions being driven back into the molecular state. That is, the addition of the colorless salt has resulted in a decrease in the density of the colored ions and an increase in the colored molecules, and therefore a change in the absorption of light.

(ABSTRACTS)

GRAPHICAL METHODS AND LINES OF FORCE

BY R. C. COLWELL

The lines of force of a field due to two electric charges may be plotted by joining the opposite angles of the quadrelaterals formed by the separate lines of force of the two charges. The field thus plotted may be joined to the field of a third charge and so on. In this way it is possible to draw the complicated fields due to charged rods. An application is made to the fields of force about antenna's of different shapes.

A NEW METHOD FOR THE DETECTION AND ESTIMATION OF PLATIUM

By Earl C. H. Davies (Chairman of Chemistry Section), and Victorian Sivertz.

When reduced by light in an appropriate silicic acid gel, as little as 0.0000085 gram of platinum per cubic centimeter may be accurately determined by matching the black color of the unknown with gel tubes of known platinum content. This type of reduction by light might be extended to include analysis of gold and perhaps other substances.

To try out the delicacy of the test and to provide a set of standard, thirteen tubes were made up by adding to 130 cc. of 3 normal acetic acid, 130 cc. of density 1.16 water glass and using 20 cc. of this mixture for each tube. While still liquid there was added to the first tube 0.8 cc. of 1% platinic chloride and to each succeeding tube decreasing amounts of the same solution. These were allowed to stand over night in the dark and on the following day were exposed to the sunlight. Reduction to the black occurred in all tubes within ten minutes. By comparison with a blank, a darkening could be easily detected in the lowest concentration, corresponding to 0.0000085 gram of platinum per cubic centimeter. Such as a set of standards permits matching, as in other colorimetric methods, with the unknown platinum. This at once tells the weight of platinum in each cubic centimeter of the unknown. We have not yet worked out the application of this method to analysis with respect to interfering elements and its possibility of extension to include other metals, especially gold.

PANDEMIC CHEMISTRY

By Edward P. Phelps (Associate Professor of Chemistry at Marshall College).

In the fall of 1924 the writer went to Cornell University in order to assist Prof. Wilder D. Bancroft in the preparation of lectures for a new course in chemistry, to be called Pandemic Chemistry.

Pandemic Chemistry, as the name indicates, is a course in chemistry for all the people. It is designed primarily for college students who are non-chemical majors. It is particularly adapted to students who have never had any chemistry, but who desire a bird's eye view of the whole field of chemistry. There is no reason, however, why a student who is a chemical major cannot take a course with profit, since he should obtain a perspective of the entire subject of chemistry which cannot be obtained by any single course now given.

In this course in Pandemic Chemistry, we are attempting to present the most important features of all branches of chemistry in a popular manner, pointing out the uses of this science in everyday life. We are trying to bring into the course as many striking things as possible. Our aim is to make the course an interesting one.

The lecures have not been entirely completed. The first and hardest part of the course has, however, been fairly satisfactorily worked out. The writer is now engaged in completing the rest of the course.

Marshall College is the first institution to install this course in Pandemic Chemistry. Eventually, the course will probably be given at Cornell University. Other colleges and universities will probably install such a course in time.

The writer will now consider some of the material to be included in this course. For the first few lectures we shall take up topics such as:—the world about us; mineral, vegetable, and animal kingdoms, composition of air; gas laws; common gases and densities; water-evaporation; boiling point; and freezing point; geysers; liquefaction of gases; critical temperature and pressure; solubility and crystallization; distillation and fractional distillation; liquid air and its fractional distillation; use of Dewar flask and thermos bottle. Other topics will follow in about this order:—properties and uses of metals; properties and uses of alloys; properties and uses of non—metals; compounds and elements; atoms and molecules; vapor density, gram-molecular weight and volume; Avogadro's number; acids, bases, and salts with examples; qualitative analysis; organic chemistry; spectrumanalycis, periodic law, radio-activity, isotopes, atomic structure; chemistry of rocks and minerals;

electrochemistry and electric furnace products; occurrence and extraction of the metals; manufacture of heavy chemicals including catalytic processes; coal, coke, gas, oil, tar, asphalt; destructive distillation of wood; oils, fats, and soaps; softening of water; glass, porcelain, cement; cellulose nitrate, collodion, celluloid, firms, artifical silks; gelatine and glue; photography; leather; rubber; textiles, wood, and paper; dyes and explosives; war gases; matches and fireworks; paints and varnishes; chemistry and agriculture; foods; chemistry and medicine.

Certain of these topics may be omitted if time does not permit consideration of them. Certain other topics may be added. The course will undoubtedly undergo many changes as time goes on. The writer desires to improve the course in Pandemic Chemistry in every possible way. Suggestions, then, will be welcomed.

THE PERMIAN OF WEST VIRGINIA AS A FIELD OF RESEARCH

BY JOHN L. TILTON
(Professor of Geology, West Virginia University)

The Permian area of West Virginia stretches along the highlands east of Ohio River for one hundred and thirty miles, with a maximum width of fifty miles and an area of two hundred and thirty-four square miles. Its extent is broken only by Volcano anticline, where erosion has cut through the Permian and exposed the underlying Monongahela and much of the Conemaugh series of rocks. The various outcrops, and the deep well records obtained in the search for oil and gas, have revealed the general structure throughout the region, as given in the county reports of the West Virginia Geological Survey, and as illustrated by diagrams here presented. A study of the area in the summer of 1922 brought to light several horizons at which evidences of plants and animals have been preserved, together with evidences of the condition of the region as the strata were laid down, and evidences of diastems. The fossil horizons are marked on the accompanying charts, and the nature of the finds there indicated. Much remains to be ascertained concerning the life of the times, and concerning the variations and relations in sedimentation in this large area of continental deposition, with its great beds of limestone formed in freshwater lakes. It is an area that in some places as indicated yields an abundance of minute forms of life, and here and there occasionally a more rare and valuable type, that will help in the correlation of the Permian of West Virginia with Permian elsewhere, as in Texas. Here, too, is a structural-dynamic problem, in differentiating the two sets of folds in the region and in referring each to its time of origin. The relation of one set is well known. The relation of the other has not as yet been worked out. Here, too, in addition to Leverett's work on the Pleistocene silts, is a physiographic history, well known in a general way, but not yet worked out in detail. Thus the region invites study along several lines of research.