A. M. D. G.

BULLETIN

of the

American Association of Jesuit Scientists

Eastern States Division

(Founded 1922)

(for private circulation)

INCLUDES

PROCEEDINGS

OF THE

TWENTY-FIFTH ANNUAL MEETING

AUGUST 25, 26, AND 27, 1950

GEORGETOWN UNIVERSITY

Published at

WESTON COLLEGE

Weston, Massachusetts

Vol. XXVIII NOVEMBER, 1950 No. 1

Contents

Bulletin of the American Association of Jesuit Scientists

EASTERN STATES DIVISION

VOL. XXVIII NOVEMBER, 1950 NO. 1

NOTICE TO AUTHORS

Manuscripts are to be submitted to associate editors of the appropriate section and *may* be submitted directly to the editor in chief. Clear manuscript, preferably typed, with wide margin to the left, with double spacing between lines, is desirable. Please try to follow the typographical style of the most recent issue of the BULLETIN. Line drawings should be submitted on Bristol board, or similar material, and done in India ink. Figure number should be written on this in pencil. Titles for drawings, with figure numbers, should be typed on a separate sheet. Please try to minimize footnotes. Appended references and bibliographies, clearly so marked, should be done in the style of the A.A.A.S. publication, *Science*.

Program

Twenty-fifth Annual Meeting

of the

AMERICAN ASSOCIATION OF JESUIT SCIENTISTS
EASTERN STATES DIVISION

Georgetown University

AUGUST 25, 26 AND 27, 1950

FIRST GENERAL MEETING

Friday, August 25, 1950 at 8:15 P.M. in Copley Lounge

Address of Welcome — Rev. Edmund A. Walsh, S.J.
Vice-President of Georgetown University

Appointment of Committees

Report of the Secretary

PRESIDENTIAL ADDRESS: The Milky Way — Rev. Francis J. Heyden, S.J.

MEETINGS OF THE SECTIONS

BIOLOGY SECTION

The Problems of Present Premedical Students (A Discussion) — Rev. Michael P. Walsh, S.J.

The Individuality of the Blood — Mr. William K. Masterson, S.J.

Sense Knowledge and the Microcosmic Order — Rev. Joseph P. Kelly, S.J.

a) Ancient Man: Methods and Materials (Movie, in color)

b) Ancient Man: Present Knowledge and Theory (Discussion) — Rev. J. Franklin Ewing, S.J.

CHEMISTRY SECTION

SYMPOSIUM

Theories of Acids and Bases

General Review of the Theories of Acids and Bases — Rev. Joseph J. Sullivan, S.J.

The Electronic Theory of Acids and Bases	Rev. James J. Pallace S.J.
What Should Be Taught in First Chemistry?	Rev. Gerald F. Hutchinson, S.J.
Some Demonstrations in Acid-Base Theory	Rev. Bernard A. Fiekers, S.J.
A New Course for Non-Science Majors	Rev. Eugene A. Gisel, S.J.
Thermodynamics of Solutions	Rev. Edward J. Kilmartin, S.J.
The "Craig Method" of Analysis	Rev. George J. Hilsdorf, S.J.

MATHEMATICS AND PHYSICS SECTION

Presidential Address: The Georgetown Spectrograph	Francis J. Heyden, S.J.
Guest Lecturer: The Diffraction Grating	Dr. Carl C. Kiess *Dept. of Spectroscopy, National Bureau of Standards*
Father Grimaldi and the Principle of Diffraction	Martin F. McCarthy, S.J.
The Lamb Shift in Hydrogen Spectrum	Robert Brennan, S.J.
Microwave Spectroscopy	Joseph Mulligan, S.J.
The Boston College Institute of Spectrography	James J. Devlin, S.J.
Solutions of the Wave Equations	Stanley Bezuszka, S.J.
Nuclear Energy Levels	Frederick Canavan, S.J.
Nuclear Shell Theory	William Guindon, S.J.
Difficulties and Methods of Teaching Nuclear Physics	John A. Tobin, S.J.
Techniques for Obtaining High Vacuum Pressures of the Order of 10^{-8} mm Hg and Lower	James J. Ruddick, S.J.
"You Can Find Uranium"	John P. Delaney, S.J.
The Period and Light Curve of *RT Aurigae*	Vincent Marasigan, S.J.

SECOND GENERAL MEETING

(Business and Final Meeting)

Sunday, August, 27, 1950 at 10:00 A.M. in Copley Lounge

Business Meeting of the ASSOCIATION
Report of the Secretaries of the Sections
Report of the Nominating Committee
Election of Officers
New Business
Report of the Resolutions Committee

RADIO FORUM ON ATOMIC ENERGY

Sunday, August 27, 1950 at 1:00 P.M. in the College Studio

Speakers:

Rev. John P. Delaney, S.J.
Rev. John A. Tobin, S.J.
Rev. Brian A. McGrath, S.J.
Rev. Francis J. Heyden, S.J.

SECRETARY'S REPORT

FIRST GENERAL MEETING

The Twenty-fifth Annual Meeting of the American Association of Jesuit Scientists, Eastern States Division, was called to order by the President of the ASSOCIATION, Rev. Francis J. Heyden, S.J., at 8:15 p.m., Friday, August 25, 1950, in Copley Lounge on the campus of Georgetown University.

Fr. Heyden introduced Rev. Edmund A. Walsh, S.J., Vice-President of Georgetown University and Regent of the School of Foreign Service. Fr. Walsh welcomed the members to Georgetown on behalf of the President of Georgetown University, Rev. J. Hunter Guthrie, S.J., and expressed his personal wishes that the sessions of the Convention would be both pleasant and profitable.

Fr. Heyden next announced the appointment of Mr. Martin F. McCarthy, S.J., as the Acting Secretary of the ASSOCIATION in the absence of the regular Secretary, Rev. Vincent Beatty, S.J. Mr. McCarthy then read the minutes of the Twenty-fourth Meeting of the ASSOCIATION which was held at Fordham University on August 30, 31 and September 1, 1949. These minutes were prepared by Rev. H. A. Boyle, S.J., Secretary of the ASSOCIATION 1948-1949, and were accepted as read.

It was announced that for the final day of the Meeting, August 28, 1950, three tours had been scheduled:

(1) Tour of the National Bureau of Standards for August 28, at 10:00 a.m.

(2) Tour of the Georgetown Medical Center for August 28, at 10:00 a.m.

(3) Tour and Reception at the Institute of Languages and Linguistics for August 28, at 4:00 p.m.

Fr. Heyden then announced the appointment of the following committees:

Committee on Nominations: Rev. Joseph F. Didusch, S.J., Rev. J. Franklin Ewing, S.J., Rev. Thomas J. Smith, S.J.

Committee on Resolutions: Rev. John A. Tobin, S.J., Rev. Eugene A. Gisel, S.J., Rev. John P. Delaney, S.J.

The Presidential Address was then delivered by Fr. Heyden on the topic: *"The Milky Way."*

After the address of the President, there being no further business before the house, the meeting was adjourned at 9:10 p.m. Haustus followed in Copley Lounge.

SECOND GENERAL MEETING

The second and final general meeting of the ASSOCIATION was called to order by the President, Fr. Heyden, at 11:00 a.m., Sunday, August 27, 1950. As before, the general meeting was held in Copley Lounge.

After making clear the final details concerning the tours to the National Bureau of Standards, the Georgetown Medical Center, and to the Georgetown Institute of Languages and Linguistics, Fr. Heyden requested those members who planned to stay at Georgetown after the close of the Convention to give their names to the Acting Secretary in order that the necessary arrangements might be made for their convenience.

Next, Fr. Heyden announced that the Executive Committee had selected Rev. John J. McCarthy, S.J., as the new Editor of the JESUIT SCIENCE BULLETIN and that Fr. McCarthy had accepted the appointment. This announcement was greeted with a hearty round of applause as the members assembled wished success to the new Editor.

Following this announcement, Fr. Heyden called upon Rev. John A. Tobin, S.J., to read the Report of the Resolutions Committee. Fr. Tobin then read the Report which was accepted by the members, after the insertion of a slight correction as proposed by Rev. Bernard A. Fiekers, S.J. The corrected version, which was accepted unanimously by the members, read as follows:

"BE IT RESOLVED:

"1. That the American Association of Jesuit Scientists, Eastern States Division, express its gratitude to Rev. J. Hunter Guthrie, S.J., President of Georgetown University, to Rev. Edmund A. Walsh, S.J., Vice-President, who welcomed us to Georgetown and graciously received the delegates at the new Institute of Languages and Linguistics, and to Rev. William A. Ryan, S.J., Georgetown's Father Minister, for their cordial reception and generous hospitality during our convention.

"2. That the ASSOCIATION express its gratitude to Rev Francis J. Heyden, S.J., President of the Association and to Mr. Martin F. McCarthy, S.J., Acting Secretary of the ASSOCIATION, whose generosity contributed much to the smooth functioning of the convention and to Brother Francis J. Weiss, S.J., for his wonderful help and co-operation in the dining room and at the garden party.

"3. That the ASSOCIATION express its commendation to Rev. Bernard A. Fiekers, S.J., Chairman, and to Mr. Frederick L. Canavan, S.J., Mr. Robert O. Brennan, S.J., and Mr. Joseph F. Mulligan, S.J., members of the Index Committee for their work in publishing the

Index of the JESUIT SCIENCE BULLETIN, and to Fr. Fiekers also for his personal concern with the publication of the issues of the Bulletin during the past year.

"4. That the ASSOCIATION extend its heartfelt congratulations to our members, Rev. Henry M. Brock, S.J. and Rev. Daniel J. Lynch, S.J., on their Golden Anniversary, this year, as Jesuits.

"5. That the Secretary of the ASSOCIATION be instructed to extend these expressions of our appreciation to the authorities of Georgetown University and to the 'Jubilarians'.

(signed) REV. JOHN A. TOBIN, S.J.
REV. EUGENE A. GISEL, S.J.
REV. JOHN P. DELANEY, S.J."

After the report of the Resolutions Committee was read, Fr. Heyden announced that the Executive Committee has accepted the gracious invitation of Rev. William L. Keleher, S.J., President of Boston College, to hold the 1951 Meeting of the ASSOCIATION at Boston College. This announcement met with the unanimous approval of the members as evidenced by their applause. The definite dates for the 1951 Meeting could not be set at this time. The Acting Secretary of the ASSOCIATION was instructed by the ASSOCIATION to write a letter of acceptance of this invitation to the President of Boston College.

Next, Rev. Joseph P. Kelly, S.J., told the members of the progress made by the Committee on the Constitutions. Fr. Kelly declared

(1) That more time would be required by the Committee for the final revision.

(2) That the completed draft of the tentative form of the revised Constitutions would be published about January 1951.

(3) That the members would have the opportunity of discussing the new revision and of voting upon it at the 1951 Meeting.

The Report of the Nominating Committee was then presented. For the Presidency of the ASSOCIATION for the coming year two candidates were nominated: Rev. Michael P. Walsh, S.J., and Rev. Gerald F. Hutchinson, S.J. In the election which followed, Fr. Walsh was elected. No elections for the post of Secretary were held because, according to the plan previously adopted, Fr. Beatty, who was elected in 1949, will hold office for three years, his term expiring in 1952.

As regards the Officers of the various Sections of the ASSOCIATION, no changes were scheduled inasmuch as it had been previously decided that the Chairman and Secretary of the Mathematics Section and the Chairman and Secretary of the Physics Section would hold their positions until the 1951 Meeting, and that the Chairman and Secretary of the Biology Section and the Chairman and Secretary of the Chemistry Section would retain their posts until the 1952 Meeting.

However, in special elections (necessitated by the Course of Studies for Jesuit Scholastics, v.g. the change from Regency to Theology) Mr. Paul Beining, S.J., was named by the Biology Section to succeed Mr. James McKeough, S.J., and Mr. Wallace Campbell, S.J., was selected by the Mathematics Section to serve in place of Mr. William Cogan, S.J.

Father Walsh took the Chair as President, thanked the members for their confidence in him, and expressed the hope that he might serve the members of the ASSOCIATION with something of the same spirit which characterized the service given by the Retiring President, Fr. Heyden.

Fr. Fiekers suggested that the Reading of the Membership List be omitted at this General Meeting of the ASSOCIATION because of the lateness of the hour. He asked that the new members write their names and addresses on a slip of paper in order that the Membership List be brought up to date. He also requested that any member who knew of the change of address of any member of the ASSOCIATION, who was not in attendance at the Georgetown Meeting, forward this information to him at Holy Cross College.

There being no further business before the house, the meeting was adjourned by Fr. Walsh at 11:55 a.m.

Respectfully submitted,

MARTIN F. MCCARTHY, S.J.
Acting Secretary

Presidential Address

"THE MILKY WAY"

FRANCIS J. HEYDEN, S.J.

Like all of the experimental sciences Astronomy has lost the solid complacency it might have had in the past and it faces its new problems with a critical eye fixed upon the observational material that has been bequeathed to it by observers of the last fifty or one hundred years. Periodically, there is a time for examination of methods and results with an appraisal that is sometimes almost brutal. Let us consider for example the hours of labor that went into some tremendous projects in the past. In the nineteenth century one of the great tasks set before observers was the determination of the position of stars by very careful visual observation. In the course of a century some stars were observed thousands of times in perhaps fifty or more big observatories. Taking the accumulated data from all these observatories for all of the thousands of stars which were observed, the net result is a small tome of a little over three thousand stars whose positions can be said to be on a uniform and accurate system. For the rest the positions are primarily useful for purposes of identifying the stars, but not for any further uses in which better accuracy than a tenth of a second of arc is required.

Some of us might be tempted at times to assume a diffident or even a cynical attitude toward methods of modern research because of the apparent wasted hours of labor that have gone into the past. The example which I used is only one. A modern astronomer would say now visual observations of star positions or star brightnesses are a total waste of time since photographic and photoelectric methods have superseded them in accuracy. This is not only true of astronomy but of most of the experimental sciences.

The net result of such an attitude of discouragement is stagnation. On the other hand a slavish devotion to slow routine without a critical study of the results can lead to a much worse stagnation. The happy medium involves some expense and much study because it means a change in equipment and method.

In the field of Milky Way research there have been many investigations that have so far been chiefly of an exploratory nature. Anyone must realize that a determined effort to study just the space density of some thirty thousand million stars is a tremendous project and because of the distances involved the sample material for a statistical study is found within a comparatively small radius of the sun.

The general structure of our Milky Way System, or the Galaxy, as we shall call it, was first presented by Shapley (1) in a series of investigations on the distances of globular star clusters. These huge dynamical aggregations of the many thousands of stars surround the galaxy like a system of satellites or moons. By plotting the space distribution of only one hundred and three globular clusters, the sum total that could be observed with existing telescopes up to 1930, Shapley showed us for the first time that the sun was far from the center of the galaxy, almost in fact, two thirds of the distance from the center to the outermost edge and that the cluster system delineates a discoidal shaped mass of stars which suggests rotation as a dynamical unit.

The rotation of the galaxy was established for certain by the Dutch astronomer Jan Oort in 1927 (2) when he showed that even a simple circular rotation of the stars around a common center should and actually did manifest itself in the observed proper motions and radial velocities of the stars in the neighborhood of the sun. It had been known for some time that certain stars which showed a high radial velocity of some 60 km/sec. (3) were absent from one quadrant of the Milky Way and once the fact of rotation was established, the logical explanation for this dearth of high velocity stars was clear. To move at such a high velocity in the direction of that particular quadrant a star would have to exceed the velocity of escape of the system. And even much more complicated phenomenon, called star-streaming, which had been observed for many years, found a satisfactory explanation in this same theory of galactic rotation. While the simple theory of galactic rotation was being verified, Babcock (4) at Mt. Wilson made spectroscopic measurements of another galaxy, the great Andromeda nebula as it has been called since the days of William Herschel, and found that this great wheel-shaped mass of stars was rotating and that the rotation was not that of a solid mass, but of a complicated dynamical unit in which each star was moving in an orbit about the common center of mass.

The more one studies the evidence of rotation in the galaxy the more fascinated one becomes with the marvelous mixture of dynamical problems involved. For example, stars of certain temperatures and sizes have similar orbital motions in the galaxy and not only that, they also form distribution systems of different degrees of flattening. Hence, too, we can predict certain space velocities for variable stars; and stars with periods of variation in their light of about a day have more elliptical orbits around the galactic center than those with periods of several days. We must confess that we know of no dynamical explanation of this connection between the internal properties of a star and its motion in the galaxy, but the fact seems to stand that such a connection exists. Possibly this typical relationship stems from the conditions under which the stars originated.

As a rather preliminary phantasm of the galaxy, we can imagine a highly flattened dense system of stars in rapid rotation. The sun, for example, is in this system and it is moving around the center at the rate of about 250 kilometers per second. On the outside of this mass of stars there is another system still flattened and consisting of globular clusters. Surrounding all this and rather spherical in shape is a multitude of sparsely scattered variable stars of very short periods. Shapley (5) has referred to these as the aura or halo of the galaxy.

This is only the general picture with broad structural details which one finds from a limited study of objects of a definite class. When we approach the galaxy from another angle and try to study its structure in more detail, our hours of labor become legion and our progress extremely slow. For now we are not working with objects that show us the general outline of the whole galaxy, but we are taking sample volumes and studying them for star densities, motions or whatever we wish to know.

The procedure for determining the star density of a volume of any part of the galaxy would be simply a process of measuring the distances of the stars in any one direction. From such information we would have the number of stars per unit volume. Add to this the apparent magnitudes and we would enhance our star density information further by knowing the number of stars of different absolute brightness per unit volume.

Unfortunately it is not possible to measure star distances or parallaxes so easily. Stellar parallax is a very difficult problem, since it involves measurement of angles as small as 0.01″ of arc and smaller. If we consider just the sources of instrumental errors involved in measuring an angle so small we can readily see the reason why so few trigonometric parallaxes are known.

Other criteria of distance have been developed, but these too become very critical for distances over a few hundred light years at which it often happens that the probable error is as large as the observed value.

A great deal of effort has gone into a careful survey of the stars within a few hundred light years of the sun. The Dutch Astronomers Kapteyn, Van Rhijn and Luyten have spent years on this work and the net result is a fairly complete picture of the star density in the neighborhood of the sun. Compared to the whole volume of the galaxy, this is only a tiny capsule of space, but it is the best that can be done to any degree of accuracy with all of the observational data now available.

We have found from this survey of the stars in our neighborhood a curve which represents the number of stars per unit volume for different absolute magnitudes. It cannot be represented by a mathematical formula for it lacks the regularity and completeness of any distribution function. It is, however, useful for a numerical solution.

It is reasonable to assume that the stars in the galaxy are well mixed. Even if there are occasional parts in its tremendous mass where condensations of stars of one certain type may predominate, by and large, the relative percentage of each type of star should be nearly the same throughout the whole galaxy. This is a necessary assumption, although we have no data at hand for an observational proof. Our only justification is based upon the evidence of a state of dynamic equilibrium as seen in the distribution of globular clusters and in the general appearance of other galaxies in space which must be something like ours. With the increase in our observational data, of course, we shall be able to test the validity of our assumption in the future. It may well be impossible to assume that the relative numbers of different stars in the neighborhood of the sun are not a representative sample for the average constitution of our galaxy.

On the basis of this assumption some progress has been made. But further complications have beset us. Interstellar space is far from transparent. Intermingling with the stars are huge clouds of real dust of varying degrees of density through which we view the stars. To the astronomer who wishes to study distant stars, every night is now a cloudy one; and the process of measuring the obscuration caused by these clouds has become an almost insuperable task.

The dust particles which are the most effective absorbers of starlight are about the size of a wavelength of light. Like the dust particles in our own atmosphere they exert a selective influence on light, knocking out the blue light more than the red. In many instances it has been possible to determine a law for this selectivity of absorption by interstellar dust and it is found that the effect is inversely proportional to the wavelength. Hence by measuring the amount of reddening in the light of a star whose color characteristics are known from another source, we can determine the amount of selective absorption on the basis of the one over the wavelength law.

As a rule this method of measuring absorption is easy and generally in use. It has very serious limitations, for it is applicable only to stars whose normal colors are known. We have fairly accurate knowledge of the normal colors of many types of stars but not for all types. In recent years we have learned that even though two stars may have the same spectral type, they may not have the same color. There is a difference in color between super-giant, giant and dwarf stars of the same spectral type.

This means an entirely new approach to the problem of identifying stars according to their spectra and a considerable amount of fundamental work in observing normal colors for stars in regions reasonably free from absorption.

The best stars for absorption studies are the very bright hot stars in the early spectral classes. Foremost among these are the helium or B type stars which are ordinarily very blue in color and naturally show the effect of dust reddening very definitely. But again, these stars are not too numerous in every part of the sky and from some rather careful photoelectric surveys we now know that the B stars known at present yield data on the interstellar absorption out to about three thousand light years from the sun. This is hardly adequate for a density survey which must go out ten times that distance to give us information on the structure of the galaxy.

Two new approaches to this problem are being tried. One consists in observing the reddening of Cepheid variable stars. These stars are larger and therefore brighter than B stars. What is more, they follow a well known law which connects their spectral type with their period of light variation. Since the period of light variation can be observed whenever the star is visible, the spectrum which cannot always be observed because of the faintness of the star can be found from the period-spectrum relationship.

Quite a few research projects have been centered on these variable stars in the past few years. Mr. Martin McCarthy, S.J., is making a study of a group of Cepheids in the southern Milky Way from plates which were taken with the Georgetown telescopes in Brazil in 1947. Reddening due to interstellar dust is evident in many of the Cepheids because they are stars which are peculiar to the plane of the galaxy and are, therefore, in the midst of the galactic dust clouds. In some regions, Cepheid variables have given us information on the absorption out to a distance of about thirty thousand light years.

This information covers very limited areas since it is confined only to the line of sight between the Cepheid variable and the observers. For a useful study of the absorption in a region of the sky, some object that is more abundant than variable stars is still highly desirable. In recent months observers at the Naval Observatory have suspected that interstellar dust produces circular polarization in transmitted starlight to a degree proportional to the optical density of the dust cloud. Some preliminary studies seem to confirm this. If this is so we shall again be on our way to finding the interstellar absorption to distances at the limit of our telescopes in any region of the sky. The main observational problem here will be the finding of a birefringent filter which will be large enough to cover a suitable area of a photographic plate.

The dust clouds which have dimmed the horizons of Milky Way research workers are most interesting phenomena. There is no doubt about the tremendous volumes of space which they occupy and there is still much speculation as to their exact physical constitution. There are many varieties of free atoms and molecules mingled with the dust particles, but the dust particles themselves are a puzzle. They act somewhat like ice crystals. It will take some time before we can hazard more than a rough guess as to what they are. The clouds are also suspected of being the parents of the stars. When two of these huge milling clouds meet in space, it is possible for the particles at the two colliding edges to form a dense nucleus which will have its own center of gravity and under gravitational pressure the initial stages of heat generation for a star will begin. A huge flabby red super giant star would form, and gradually, as the energy generating processes increase the nuclear activity such as the carbon cycle would start and the star would grow hotter. Theoretically this seems possible and it may be an explanation of the great variety of temperature classes among the stars. We would be very happy if it could be verified by observation in the course of a century or two.

At any rate about one half of the mass of our galaxy is made up of dust and meteoric material. The effect of this dust on our researches into the distribution of stars has limited the extent into space to which we can penetrate with a statistical study of the space distribution of the stars themselves. Our statistical approach is based essentially on the inverse square law and when dust dims the apparent magnitude of a star, the inverse square law fails to account for the apparent magnitude and false distances are attributed to the stars. The process of correcting a distribution analysis for interstellar absorption is still too uncertain at great distances to permit an exact measurement of the star densities beyond three thousand light years.

This brings us to a rather disconcerting position. Not knowing the exact amount of absorption beyond this limit we are forced to wait until better ways of lifting the dust curtain are found. Our current investigations, the most recent one being a space survey in the region of the constellation Cygnus by Father Roger Leclaire, S.J., shows a definite tendency for star densities to fall off sharply in all directions beyond three thousand light years. If this is not entirely due to interstellar absorption we find that our sun is in a rather dense part of the galaxy compared to its immediate surroundings. There are competent astronomers who feel very sure that the opposite is the case. But the final solution of this question must await a better knowledge of the absorption.

Once we have conquered the absorption problem, we can proceed further with tests of the general luminosity function, as we call the relation between the relative number of stars of different absolute brightnesses in the vicinity of the sun. It will be interesting to find how well this sample of the stars in our neighborhood compares with other parts of our galactic system.

It will be more interesting to learn if we can penetrate far enough into the maze of star clouds in our galaxy to reconstruct a picture of the entire system, at least in the quadrant in which we find our sun. We would like to know if our galaxy possesses spiral arms and possibly how tightly they are wound around the galactic center. We see all varieties of galaxies in space and some day we hope to say, this or that neighbor is our twin.

To carry on into these deeper vistas of the galaxy the astronomer turns once more to his available material. For studies of star colors he must have good magnitude standards in all parts of the sky for both blue and red light. We do not have them. To determine normal colors for stars he needs to know the exact spectral type and the luminosity class for each type. This method of spectral classification is still in a preparatory stage. It will take years of hard work before the older spectrum catalogues can be revised to give the luminosity classes; and the research workers who will be able to classify star spectra in this way with speed and consistency are not yet available.

The task of accumulating data goes on apace. At the same time much of the work of the past has to be revised. Magnitude systems which are not uniform have to be done over again. Spectral classifications which were at one time very useful are now growing obsolete and more complicated methods are required to classify fainter stars in the future. There is no doubt in anyone's mind about the future. The observational work of the astronomer is piling up, but the needs are clear to him and where the need is known he will find a way.

References

1. "Star Clusters", Harvard Observatory Monograph No. 2, 1930.
2. Bulletin of Astro. Institute of the Netherlands No. 120, 1927.
3. Bulletin of Astro. Institute of the Netherlands No. 159, 1928.
4. Lick Observatory Bulletin Vol. XIX, 41, 1939.
5. Harvard Reprint No. 173, 1939.

Biology

SENSE PERCEPTION AND THE MICROSCOPIC ORDER

(*Abstract*)

JOSEPH P. KELLY, S.J.

All human knowledge begins from the senses, which are the media of communication between man, as a thinking subject, and the world, as the object known. All men have confidence in the trustworthiness of the sense faculties, as is evident from the history of the human race, from daily experience and from the systematic analysis of our cognition. Hence all branches of knowledge, the ordinary as well as the specialized, are founded on sense perception and must remain in conformity with it.

It needs but slight reflection to recognize the limitations of our sense faculties. Hence our sense-aids, e.g., microscopes, microphones, telescopes, etc. These reveal many realities which are undiscoverable by the unaided, human faculties, and which are sometimes at variance with realities derived through normal perceptions.

In the formulation of a theory, be it scientific or philosophical, we must of necessity begin with sense perception. The theory may be extended from the macrocosmic to the microcosmic order. In this case, the truth of the theory will sometimes demand a corrective or a corroborative factor, since the reality may appear one way in the macroscopic and another in the microscopic order. The factor may be sought for in well founded principles of science or philosophy; in experience or experimental processes or in the logical consistency of established systems. The hasty application of theories, based on the "appearances of things," to minimum particles has given rise to many errors in both philosophy and science.

A DISCUSSION OF PREMEDICAL PROBLEMS

REV. M. P. WALSH, S.J.

(*Abstract*)

Many of the difficulties that present premedical students are facing were discussed in detail. Statistics from various sources on recent admissions to medical schools were reported.

There is at present a good deal of discussion in medical school circles on the curriculum of premedical students. Some Deans are

strongly in favor of a Liberal Arts program with less emphasis on science. But the requirements of some schools and especially basic science teachers in medical schools will continue to urge a heavy science training for premeds.

Various aspects of the Medical College Admission Test were discussed. General hints were given by various members that might prepare our students. It was felt by all present that the number of our premedical students taking these examinations must be reduced if our colleges expect to make a better showing.

THE INDIVIDUALITY OF THE BLOOD

William K. Masterson, S.J.

Up until ten years ago work in blood typing was confined to the ABO system. The MNS system was known (1927) and was used to some extent in medico-legal cases. Then in 1939 and 1940 came the discoveries connected with the now famous Rh factor, and from about 1943 onward every typed person was classified both in the ABO and the Rh systems. During the last five years so intensive has been the research carried on in blood grouping that today, at the half century, there are no less than seven genetically unrelated and immunologically distinct blood group systems in human beings.

Since that memorable day in the year 1900 when Dr. Karl Landsteiner first found that the sera of some human beings agglutinated the cells of others, thereby demonstrating that there were differences in the bloods of members of the same species, modern hematology and serology have advanced from relatively unexplored branches of medicine to the tremendously important fields they are today.

In the programs being drawn up for civilian defense against atomic attack, the blood status of the citizenry is an important consideration. Some have urged that the general population wear dog tags bearing their blood status. Chicago has already begun to tattoo its citizens with their blood types—underneath the armpits because arms might be blown off—in case radiation sickness called for quick transfusions.

Ten years ago, Landsteiner suggested the possibility of establishing the individuality of the blood just as is done with fingerprints. It now looks as though the findings in gene-determined specificity of blood antigens might well lead to such a procedure. The number of different antigens (rare or common) found to date in blood have increased the number of possible genotypes to well over one hundred million, theoretically at least.

As the blood systems stand today there are seven—seven definite systems. They are:

ABO	system	(These systems comprise at least
Rh (CDE)	"	20 separate and specific blood
MNS	"	group antigens. Ten of these
P	"	20 have been found to be re-
Le (Lewis)	"	sponsible for cases involving
Ke (Kell)	"	erythroblastosis.)
Lu (Lutheran)	"	

The ABO system is the oldest and the most familiar of all the blood groups. Antigens A_1, A_2, B and O are inherited as mendelian alleles. That O is a true antigen was discovered only recently (1948—British).

In the Rh system, the British CDE symbols are gradually superseding Wiener's original Rh designations in the more recent papers dealing with the genetics of this system. This is because the Race & Fisher designations enable one to see immediately both the gene picture and the blood antigens since they use only one letter to represent both gene and antigen. Wiener, however, uses one abbreviation for the gene and still another for the antigen.

In the CDE system, it will be remembered, there are three sets of allelic genes; C, C^w (uncommon), and c; D and d; E and e. There is one set for each of three closely associated loci in one pair of chromosomes. It is important to consider the inheritance of these genes as though they were all mendelian dominants.

The CDE system becomes complicated only when it becomes necessary to get a gene picture of a person regarding D (Rh_o). Then the possible combinations at the C locus must be multiplied by those at the D locus and those at the D locus by those at the E locus. This involved process is necessary because there is no anti-d typing serum available at the present time.

From the immunological standpoint, this D antigen is the only really effective antigen and it is the most variable. Its variability is a focal point of Rh research today, the problem revolving around what is called the "D^u factor". This new factor is important for this reason. D-positive red blood cells from most persons are clumped by all anti-D typing reagents. But, about one per cent of D-positive cells are clumped by some anti-D sera and not by others. This one per cent comprises an apparently unlimited variety of peculiar D antigens. The symbol D^u has been given to this group of irregular D antigens. These variants are very difficult to find by routine typing methods. Already, Dr. Louis Diamond, in Boston, has reported a case of fatal hemolytic reaction resulting from the administration of such blood, thought to be D-negative, to a D-negative person who had previously been immunized by D. These D^u variants are inherited genetically just as are the other antigens.

This D^u factor is a good indication of the increasing complexity of the blood picture in man. Rather than go into the genetics and antigenecity of the remaining systems, I should like, instead, to point out in the concluding section of this paper the significant roles these blood systems are playing and will play in blood work, especially in medicolegal paternity tests and in the theory of racial anthropology.

If evidence of paternity is taken from a study of the ABO blood groups of the individuals concerned, obviously, in many instances, no decision can be reached. With the discovery of the existence and kind of inheritance of the M-N types, much use has been made of these. If a child possesses an M or N antigen not present in the putative father, the suspect cannot be the father. "However," says Curt Stern in his book, *Human Genetics*, "genetics is not able to furnish an exclusion of paternity whenever the putative father is MN, since a man of this constitution could be the father of any of the three types of children, M, MN, or N" (p. 1196).

In medicolegal work of this nature only exclusions of paternity can be made; no positive assignment of paternity can be made. According to statistics, today only one in six paternity exclusions have been obtained among several thousand cases from the U.S. and six European countries. But with five other blood systems brought to bear on such cases, it should be possible to reach a high degree of certainty in suspect cases of disputed paternity.

There is today a growing school of anthropologists who hold the thesis that serology (or rather genetics) is destined to oust craniometry and anthropometry as the main tool of racial anthropology. They believe that "race" should be defined in terms of gene differences, or differences in gene frequencies, and that the task facing anthropologists in this field is to accumulate data on the relative frequencies of various genes which are known to vary from population to population.

The most useful genes for this work are the blood group genes. At present racial anthropologists are working with the three systems, ABO, Rh (CDE), and MNS. Certainly with four other systems to apply in their method of racial classification, the position of this school of anthropologists ought to be strengthened considerably.

Other gene determined antigens, not related to these seven blood systems, have been identified, but they have not yet been studied completely enough for definite characterization. In time, undoubtedly, more blood systems will be defined and further decisive proofs for the organic uniqueness of every human being will come from the blood groups.

References

Boyd, W. C., Blood groups in human classification. *Science*, 112: 187-196, 1950.

Diamond, L. K., and Allen, F. H., Rh and other blood groups. *New Eng. J. Med.*, 241: 867-873, 1949.

Stern, C., *Principles of Human Genetics*. W. H. Freeman and Company, San Francisco, 1949.

Chemistry

WHAT SHOULD BE TAUGHT CONCERNING ACIDS AND BASES IN A FIRST YEAR COLLEGE CHEMISTRY COURSE?

Part of a symposium held at the meeting of the American Association of Jesuit Scientists held at Georgetown University, August 25-27, 1950.

(Abstract)

GERALD F. HUTCHINSON, S.J.

The elements which should be considered in this discussion are, the knowledge of chemistry which students bring to first year college chemistry, the time allowed for the course and the utility of the theories of acids and bases in future courses. It might well be considered a part of the wider question discussed at the present time as to what the first year course should emphasize, theory or inorganic information. In the opinion of the speaker first year students should be thoroughly grounded in the classical Arrhenius theory, understanding the hydrogen ion explanation of acids. They should then understand that modern findings make necessary a distinction between the process of formation of a salt and an acid with the two types of valence involved. Then the difference in process in solution will naturally lead to an introduction of the hydronium ion, its place and importance in modern chemistry. Subsequent explanations of theories should be on the simple hydrogen ion. Further development of modern theories can wait till later courses when these theories will actually be used.

UNDERGRADUATE RESEARCH PROGRAM

GEORGE J. HILSDORF, S.J.

At the national convention of the A.C.S. in Chicago, Dr. C. F. Brown, Bethany College, W. Va., presented the results of a survey of the philosophy toward undergraduate research in some eighty colleges and universities. Since the chemistry department at St. Peter's College engaged in a rather extensive program of undergraduate research last year we sent our impressions made in the middle of the year to Dr. Brown in answer to his questionnaire. In this article we wish to outline the work accomplished by the students and formulate a little more sharply our conclusions about its educational value.

There is a requirement at this college that each Senior write a thesis in his major subject. Last year the chemistry department called for volunteers to do experimental work for their thesis under the direction of the professors. The response was good and a number of teams were formed. Four of these teams succeeded in doing such satisfactory work that a representative of each team was able to deliver a paper at the Fourth Annual Eastern Colleges Science Conference. The titles and abstracts of the papers are given below.

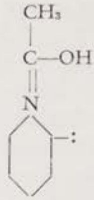
1. *Synthesis of a New Heptylalcohol.* Of the thirty-nine possible heptyl alcohols, thirty-seven had already been reported in chemical literature. A team of three students prepared one of the two remaining isomers, namely 2,2,3-trimethyl-l-butanol. The method used was a Grignard reaction of formaldehyde with 2-chloro-2,3-dimethylbutane. Since this halide is not available it was prepared by chlorinating the alcohol obtained from the reaction of methyl isopropyl ketone and methyl magnesium iodide. The chlorination was done in two different ways; first by the usual method of stirring the alcohol with warm concentrated hydrochloric acid for eight hours; secondly by passing dry HCl gas into the alcohol at 20° C. The course of the latter reaction was followed very conveniently by using a graduate as the reaction flask and stopping the reaction when the calculated amount of water had been precipitated. The yield was almost quantitative after about two hours. Considering the convenience, excellent yields, and mildness of the reaction conditions, it is somewhat surprising that gas chlorination is not more widely used in preparing large tertiary chlorides, most of which, unless extremely pure, are rather unstable.

The research was concluded by measuring the usual physical properties of the new alcohol. A slightly depressing epilogue must be added. A few weeks after the thesis was bound, the 1949 subject index of Chemical Abstracts was printed, and it was found that the same alcohol had been prepared by another group during the year by a different method.

2. *A Conductimetric Study of the Hydrolysis of an Amide.* A team of two students found that in a conductivity cell kept in a bath at the temperature of boiling acetone, the rate of hydrolysis of acetamide in the presence of an equivalent of hydrochloric acid was rapid enough to be followed conductimetrically. The decrease in conductance, due to the formation of ammonium chloride from the acid was found to follow the curve for a reaction of the second order. The reaction constant for the second order reaction was found to be approximately 0.422 as calculated from the formula $K = 1/at^{1/2}$.

3. *The Ratio of Ortho and Para Isomers in the Formation of Chloroacetanilide.* A team of two students worked on this problem. The early literature records the formation of parachloroacetanilide only, and this seems to be the only isomer produced in strongly acid solution. Under certain conditions, however, appreciable amounts of the ortho isomer are produced. The chlorination is carried out in the presence of excess hypochlorite, and acid is added in amount

sufficient to reduce the alkalinity but not sufficient to liberate any chlorine. At the same time there is a tarry residue due to further oxidation of the products. The ortho compound has a higher sublimation pressure than the para, and can be separated by sublimation under reduced pressure. The para compound can also be obtained pure by sublimation, but at a higher temperature. To account for the reaction in alkaline solution it is suggested that we have as a possible resonance structure the tautomer



showing an imido-acid structure in the side chain, with the ortho position favored. If the alkalinity is too great the halogen remains bound to the base as hypochlorite.

4. *The Structure of the Bromine-parabromoacetanilide complex.* Acetanilide in glacial acetic acid was found by a team of two students to react with bromine (excess) to give an orange-red crystalline precipitate. These crystals showed a bromine content corresponding to a compound of the formula p-bromoacetanilide-Br_2. After 14 days the bromine content was only 33.6%; after 21 days 28.2%; after 35 days, 21.2%. The compound decomposed in water and in organic solvents, with liberation of bromine and the formation of pure p-bromoacetanilide.

The ease of handling of the crystals and the readiness with which bromine is liberated suggest the use of this compound as a brominating agent.

This list does not exhaust the number of experimental theses directed by the department. There were others which for one reason or another were either not completed or too late for inclusion at the conference.

After this experience we came to the conclusion that, for a department without a graduate school, a program of undergraduate research is desirable because it benefits the student and the institution. Those who participated were noticeably stimulated and some were led to graduate school as a result. Their enthusiasm reached the lower classmen and many of these sought permission last year to take part in the program for the present year. Participation is considered a privilege and the result has been to encourage better work on the part of all. The source of this enthusiastic response by the student body was undoubtedly the professors. Interested themselves, their spirit was carried to the whole body of students through the conversations of those who picked it up through more intimate contact.

The benefits are not as unquestioned when we look at the department or institution. It is certainly true that increasing the bond between students and faculty increases the bond between alumni and the college. The students represent the college and any way of benefiting them benefits the college. It can also be said that the program enlivened the Affiliate meetings and stimulated the faculty to do some research themselves. This is an important point since it helps to complete the triangle of functions of a college, viz., to preserve, to diffuse, and to advance a body of knowledge. In a college without a graduate school we expect the last function to be filled by the faculty, but in the sciences this is difficult, since the scientist needs so many hands. In our opinion these benefits outweigh some rather serious difficulties.

After our program was well under way we formulated a set of requirements on the part of the student and the subject matter. Experience taught us that many of our difficulties would vanish if these conditions were rigidly applied. The student participant should, (1) have interest enough to sacrifice time from social activities rather than from academic work, (2) have manipulative skill and a sense of responsibility, (3) be capable of using the library intelligently. The subject matter should, (1) be a problem within the limits of the student's comprehension, (pure manual work for a professor cannot be called undergraduate research), (2) it should involve laboratory procedures with which the student is already familiar or simple modifications of these procedures. If this last condition is not applied the professor must lose much time in duplication of instruction.

The objectionable features which still remain even if all the conditions above are met we might call inherent to undergraduate research. They are: (1) a slight added expense to the department. (2) The necessity to have someone in the department who haunts the place, or some plan whereby some member of the staff will always be present so that undergraduates will not be working alone in the laboratories. (3) The limitations imposed upon the subject matter may interfere with research of a much more fundamental and advanced nature which a professor is doing or would do. (4) The student may be "jumping the educational gun,"—too much in too short a time; achievement before experience. This we feel is the most important objection to research by undergraduates. Whoever tries to direct such a program will find that much inadequate, isolated, instruction must be given to fill in the gaps in experience which the student would ordinarily acquire in graduate school. We have no pat answer to this objection.

Only after satisfying ourselves that these above objections were outweighed by the advantages we saw our students and the department derive from the undergraduate research program, did we decide to continue it for the coming year. Circumstances will affect the decision but we feel that our experience can be of help to anyone contemplating a similar program.

Physics

THE GEORGETOWN SPECTROGRAPH

FRANCIS J. HEYDEN, S.J.

In 1941 Dr. Kiess, who will talk to you this morning on the subject of diffraction gratings, made plans with Father McNally to house a large spectrograph at Georgetown Observatory for the measurement of precision wave length standards in the solar spectrum. This work had been undertaken about fifteen years previously by the Allegheny Observatory of the University of Pittsburgh, but it could not be completed there because the Allegheny spectrograph was not transparent to ultra-violet light. The project was approved for Georgetown by Father Arthur O'Leary and by Father Zacheus J. Maher.

The spectrograph was first set up in the old seismic vault at the Observatory which had rather crude but efficient facilities for constant temperature. Four gas jets could be kept burning between the double brick walls of the building. This building, however, was too narrow to permit a full coverage of the spectrum with the Wadsworth type mounting that was desired. Some preliminary adjustments were made, but the war intervened before operations could get into full swing and the work stopped.

Two years ago Dr. Kiess proposed that we resume our work with the spectrograph and try first to find a larger space for it. The ideal location was a spacious room in the basement of the Observatory about twenty-two and one-half by thirteen and one-half in dimensions. There were three drawbacks to its use, in the form of three large granite piers totalling about eight hundred cubic feet which were installed some sixty years ago for the photochronograph of Father Fargis' time.

A contractor cheerfully assured us that he could remove the piers with an air hammer in two days. We gave him the job and then proceeded to draw up plans for the piers for the grating and the plate carriage. It was not long before a thin haze of powdered mortar and stone was penetrating every part of the building while a veritable boiler factory seemed to go into full production in the cellar. Drills which would ordinarily punch holes in concrete and any other kind of stone were bouncing back from the surfaces of the piers and eventually snapping off. The work was extremely slow and consternation ran high when it was discovered that the central pier which was about a hundred years old had a solid granite cap some eight by five by one feet. It took two days to whittle this down to the right dimensions for removal from the building. In about two weeks we were ready to start building forms for the new piers.

We spent a month preparing the room with a sheet rock ceiling, large piers and a new solid concrete floor. Everything was then painted with a thick rubber base paint to keep down moisture and dust from the old white-washed walls. When completed, we had one of the blackest rooms in Washington. When starting something like this, one never realizes at first how much labor would be involved. It took the entire summer before we had the light trap, collimator piers, motor generator, arc and other essential pieces of equipment mounted for tests.

The equipment for the spectrograph has been finally assembled. We have two original concave gratings—one a Rowland grating of 20,000 lines per inch belonging to the Bureau of Standards, and a second grating by Gale of 30,000 lines per inch. The large pier for the plate holder is 15½ feet in length and it lies in the focal plane for both gratings. The Wadsworth type mounting we are using conveniently fits the entire room and we can cover the entire spectrum over all regions in which our work will be practical.

The large collimator, which supplies a six inch beam of parallel light from the slit, is really a reflecting type telescope operating in reverse with the slit mounted at the Newtonian focus. This is an essential part of a spectrograph using the Wadsworth type mounting in which the grating is illuminated by a beam of parallel light. The reflector type collimator was first used by Drs. Meggers and Burns at the Bureau of Standards. The collimator, grating and mounting have been provided by the Bureau of Standards. The dispersion with the Rowland grating is approximately three anstroms per millimeter.

We next turned to the Naval Research Laboratory for the loan of a motor generator set which would provide the necessary voltage for the arc sources we might wish to use. This equipment has been mounted in place and we have been operating it off of a small gasoline generator until the Electric Co. completes a new installation to supply enough power for the three-horsepower motor. This should be finished in another week.

In the meantime the Army Map Service has loaned us a brand new coelostat which has not been put in place as yet. We must construct a temporary wooden platform for it and experiment with its adjustment before setting up a concrete pier and a permanent housing.

While we are not working on the sun at present, two student projects are under way. Both of these are confined to work with the iron-arc, one for the purpose of discovering ghost lines originating from the grating and the other to search for and identify very faint iron lines which have not yet been thoroughly verified. This latter work will be a basic preparation for the future study of the solar spectrum.

ANGULAR DISTRIBUTION STUDIES AND NUCLEAR ENERGY LEVELS

(Abstract)

Frederick L. Canavan, S.J.

In the same way that a knowledge of atomic and molecular energy levels have led to an understanding of the structure of atoms and molecules, it is hoped that a study of nuclear energy levels will lead to some knowledge of the structure of the nucleus. However, in most cases where it is possible to determine the existence of nuclear energy levels it is not possible to assign the quantum numbers associated with the levels. Studies of the variation of the yield of nuclear reactions with the angle of observation—angular distribution studies, as they are called—can in some cases specify the spin and parity of the energy levels of the compound nucleus involved in these reactions. The experimental arrangements for the observation of the angular distribution of the alpha particles from the $Li^7(p,\alpha)\alpha$ reaction are discussed and the interpretation of the resultant data outlined.

DIFFICULTIES AND METHODS OF TEACHING NUCLEAR PHYSICS

(Abstract)

Rev. John A. Tobin, S.J.

The lack of skill in the use of classical physics as, for example, the use of units in electrical measurements, was the first difficulty noticed in teaching this subject. Then a very poor understanding of the theories used to explain the experimental facts, as the Quantum Theory or Relativity Theory, was given as the second difficulty. The third difficulty came from the use of words or symbols, as understood in macrophysics, to explain facts about the nucleus. Many examples of the use of letters or symbols, as related to the experiments in nuclear physics, were shown to be meaningless if not referred back to the experiments.

The purpose of the course determined the methods. The purpose was to excite interest in all these branches so that in the future the student would continue in graduate work. Also to encourage the student to use the courses that he has completed in the past. Then to make the student familiar with the new ideas and symbols and give them some evaluation of the experiments that demanded these new ideas. To avoid the difficulties mentioned above, a quick review was given on the dual nature of waves and particles and the fundamentals of the Quantum Theory. The facts of the photo-electric

effect and the use of the Relativity Theory were reviewed and the effects of electric and magnetic fields on moving charges were recalled by problems. As Beta rays have the same measurements as X-rays, the need of a study of theories of the atom and atomic spectra and energy levels is clearly seen. Then follows a rapid review of natural radioactivity.

In the second part of the course the instruments used to measure artificial radioactivity are discussed, and the reliability of both detectors and amplifiers explained. Then the projectiles, or particles that are accelerated, are studied by their characteristics from their effects on the target. Finally, the gun or accelerator is studied. The final chapters treat of the Atomic Reactor and the phenomena of fusion and fission and the production of isotopes and their peacetime uses.

PERIOD OF *RT AURIGAE*

(*Abstract*)

REV. VICENTE MARASIGAN, S.J.

In 1905, Astbury observed that a particular star in the constellation Auriga was a variable star, now named RT Aurigae, and classified as a Cepheid variable. Since its discovery, its period of variation has been subjected to several independent measurements by different observatories all over the world. There is a fair consensus of approximation of that period, ranging from 3.728 to 3.729 days.

The Georgetown Observatory has a wealth of observational material in its photographic files. This was started in 1933 by Rev. Paul A. McNally, S.J., and at present is being continued under the direction of Rev. Francis J. Heyden, S.J. Of this collection, forty-three plates were found to contain valuable data on RT Aurigae, nine of them being photographs of the star at maximum brightness. These plates cover a period of thirteen years, 1933 to 1946. From a measurement of the time-magnitude curve derived from these plates, the period of variation of RT Aurigae was calculated to be 3.72856 days, with the initial epoch at J.D. 2427117.541. These elements seem to give a better fit to the Georgetown data from 1933 to 1946 than any published so far.

At present, only the abscissa scale (time) of the light-curve is specified. The ordinate scale (magnitude) was temporarily measured in arbitrary units of "steps". A project for calibrating this scale is now under way. The scale was based on visual comparisons with five neighboring stars, whose magnitudes will be measured by comparisons with the north polar sequence.

NUCLEAR SHELL STRUCTURE

(Abstract)

WILLIAM G. GUINDON, S.J.

Nuclei are more than ordinarily stable if the number of their protons (Z) or neutrons (N) is equal to 20, 50, 82, or 126. Some evidence for this is found by a detailed study of the structure of the chart of the stable isotopes, paying particular attention to the numbers of isotopes and isotones, their relative abundance, etc. Also, for the case of neutrons, such nuclei have low neutron capture cross-sections, and give other proofs that their last neutron is especially tightly bound. These facts suggest a shell structure in the nucleus itself, analogous to that of the atomic electrons, although the closure of shells is not so pronounced and takes place for a different series of particle numbers.

While other proposals have been made by Feenberg and by Nordheim, the simplest, and probably the most successful, suggestion is that of Maria Goeppert-Mayer. Using an extreme approximation, that of the nucleons moving independently in the field of the nucleus as a whole, this theory modifies the simple square-well potential by the addition of a very strong spin-orbit coupling interaction. The latter coupling, which gives inverted doublets whose separation increases with the total angular momentum of the level, produces the proper numbers for closed shells. In addition, under the assumption that even numbers of identical particles in any orbit couple to give zero resultant momentum, and hence no magnetic moment, while an odd number in an orbit of momentum j couple to give a resultant j, the spins and magnetic moments of nearly all the observed cases follow naturally from this model. The existence and location among the nuclear species of isomeric transitions is also predicted by this theory, as is the general behavior of the quadrupole moments, although quantitative agreement with measured quadrupole moments has not yet been achieved.

FATHER GRIMALDI AND THE PRINCIPLE OF DIFFRACTION

(Abstract)

MARTIN F. MCCARTHY, S.J.

This paper outlined briefly the life and works of Francesco Maria Grimaldi of the Society of Jesus (1618-1661), who first enuntiated the principle of Diffraction. After portraying his early life in Bologna and his entrance into the Society of Jesus, the details of Father Grimaldi's various positions as Professor of Classical Languages, Professor of Mathematics, and Assistant to Father John Baptist

Riccioli, the Jesuit Astronomer, are sketched briefly. His chief contribution to astronomical literature: the mapping and nomenclature of the lunar formations is next described. There follows a summary of Father Grimaldi's discovery of the phenomenon of diffraction and an outline of the experiments performed by him in demonstrating this new and far-reaching principle of physical optics.

MICROWAVE SPECTROSCOPY

(*Abstract*)

JOSEPH F. MULLIGAN, S.J.

The microwave region of the electromagnetic spectrum lies between the far infra-red and the ultra-short wave radio regions, with wavelengths ranging from approximately 2 mm. to 20 cm. In this region the optical spectrographic techniques of the higher frequency infra-red and visible regions are not practical, and as a result radar techniques have been adapted to spectrographic purposes. In place of the usual infra-red source a velocity-modulated electronic oscillator, or klystron, is used. A section of waveguide replaces the collimating mirrors, and a crystal detector the thermocouple. These elements can be used in a so-called "microwave Wheatstone bridge", which is a null device for measuring the absorption of a gas at different frequencies. This bridge can be easily adapted to give a visual presentation of the absorption-versus-frequency pattern on the screen of an oscilloscope.

The fine and hyperfine structure of atomic spectra have been investigated in the microwave region. In the field of molecular spectra, most of the work has been concerned with the pure rotation spectra of medium-size molecules, and with fine structure effects due to nuclear quadrupole moments. Stark and Zeeman effects have also been investigated.

The precision of measurement in the microwave region is exceptionally high, since frequencies can be measured to better than one part in 10^6. Resolving powers 100,000 times the best obtainable in the infra-red have been obtained. This enables theoretical predictions to be tested in a manner hitherto impossible.

TECHNIQUES FOR OBTAINING VACUUM PRESSURES OF THE ORDER OF 10^{-8} mm-Hg AND LOWER

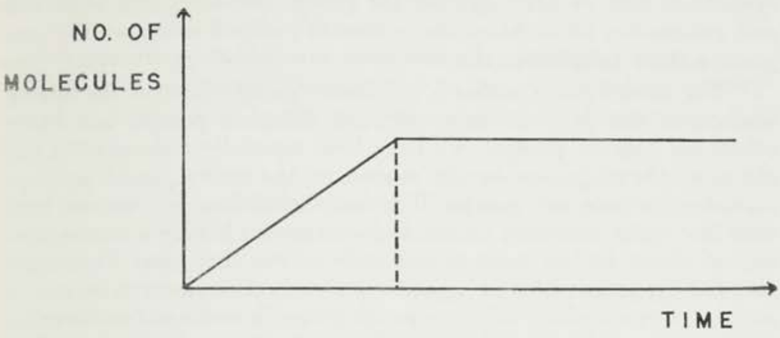
James J. Ruddick, S.J.
St. Louis University

The astronomers have shown us that the "removal" of the dust clouds from the Milky Way involves both extreme refinement in all observational measurements and also the use of the latest developments and techniques of the field of astronomy. Similarly, the high vacuum worker, in his attempt to remove the clouds of molecules from his system must both apply with great care the ordinary apparatus and experimental procedures and also use, and perhaps develop, new techniques for the work in hand. In the following I hope to give some ideas on how vacuum research is carried on in one laboratory. The exact methods we have used at St. Louis may not be applicable to the work the reader may be doing, but the general procedure will be the same. In general, the methods followed are those of the chief workers in this field, including W. B. Nottingham and M. A. Pomerantz.

I. Pressure Measurement

First of all, a brief mention of the terminology is in order. The unit of pressure most commonly used is one millimeter of mercury, sometimes called the Tor, after Torricelli. As for the meaning of high vacuum, although Jnanananda (1) gives two arbitrary definitions of high vacuum, in practical use the highest pressure allowed for a "high vacuum system" is usually taken to be 10^{-4} mm-Hg. Since it is now so comparatively easy to attain a pressure of 10^{-6} mm-Hg, the terms very high and extremely high are in use for pressures no greater than about 10^{-8} mm-Hg.

Next, how is the vacuum pressure measured? The McLeod absolute reading gauge is, of course, quite satisfactory for many applications. However, another method which is, after initial installation and calibration, very convenient is the use of an ionization gauge tube. The ionization produced in this tube is directly proportional to the pressure over a wide range. In the commercial circuits available, the meter for the ionization current is calibrated from about 10^{-3} to 10^{-5} mm-Hg. By the use of a more sensitive meter this range can be extended to considerably lower pressures. Distillation Products, Inc., has just put on the market a circuit which will read pressures down to 10^{-9}. Another method of measuring vacuums is suitable for pressures of the order of 10^{-9} or lower. It is based primarily on the Langmuir theory of the adsorption of gases on the surface of metals (2). Nottingham (3) seems to have been the first to use this method of the deposition time of a monolayer of oxygen on the surface of tungsten. Langmuir found that a clean surface of tungsten in a vacuum gradually became covered with a single layer of oxygen molecules. If the surface is allowed to adsorb gas and is then flashed at high temperature after gradually increasing periods of time, the plot of the number of ejected gas molecules *vs.* time will be as follows:



Since the ejected molecules momentarily raise the pressure, a continuously reading vacuum gauge will register a brief rise in pressure, proportional to the number of molecules ejected. Since the number of molecules incident on a unit surface in unit time is a direct function of the pressure, the time necessary for the saturation effect of the above plot is a measure of the pressure in the system. According to the data given by Dushman (4), the pressure in mm-Hg is given by

$$P = (2.04 \times 10^{-6}) / (\text{time in sec.})$$

Thus, for instance, a monolayer deposition time of thirty minutes gives a pressure value of 1.1×10^{-9} mm-Hg. Since accurate readings are difficult if the deposition time is less than about ten minutes, it is ordinarily not possible to check this method against the ionization gauge, which does not read sufficiently low. However, in at least one case of pressures in the overlapping region we have had reasonably close agreement between the values obtained by the two methods.

II. Preparation of the Vacuum System

a. Pumps

A high vacuum system will require at least two vacuum pumps, a mechanical forepump and a diffusion pump using mercury or oil. The forepump is merely for the purpose of providing a somewhat low pressure for the operation of the diffusion pump. Cenco pumps seem to be satisfactory, although we have been using Welch Duo-Seal pumps for our very high vacuum work. The model 1405, with a guaranteed vacuum of 5×10^{-5} and a free air capacity of 33.4 liters/min, is excellent for backing a moderately high speed VMF metal diffusion pump or a glass three-jet fractionating oil pump. Although the manufacturers of the various diffusion pumps usually say that the forepressure, given a certain minimum allowable, does not affect the speed of the pumps, still we have found that the lower the forepressure, the better the operation of the entire system. With our system of about 4 liters beyond the pump, the forepump alone can pull practically 10^{-3}. After the system is pumped down to 10^{-5} and given a short outgassing, the forepump can hold it at around 10^{-4}.

The second pump needed is a diffusion pump. Some of the leading workers in the field use only mercury diffusion pumps, and many others use only oil pumps. We have been especially influenced in our choice of the oil pumps by the absence of the several liquid air traps necessary for mercury pumps. The butyl phthalate oils we use have very low vapor pressures, Octoil-S, for example, having a vapor pressure of about 10^{-8} at room temperature. Thus they need little trapping for the preservation of a good vacuum in the system to be evacuated. A very excellent diffusion pump is the three-stage fractionating oil pump manufactured by Distillation Products, Inc. According to the manufacturer's literature it requires a forepressure of 10^{-1} mm-Hg, has a speed of 25 liters/sec. at 10^{-4}, and attains an ultimate vacuum of 5×10^{-8} at 25° C. when operated with Octoil-S. We operate with a single cold trap in the pumping line and thus reduce the pressure by about an order of magnitude.

b. Outgassing

After a careful cleaning, we assemble our all-glass system piece by piece and check for leaks. After the system is together and the forepump pulls down to about 10^{-3}, the diffusion pump is started. A trap of dry ice in acetone or of liquid air is used whenever the diffusion pump is in operation, except at times when the glass is being outgassed. If the system is satisfactory, the pressure will go down to 10^{-5} in a short time; we have even had it go down to 10^{-6}. When this has occurred, it is time for the outgassing process. The glass and metal of the vacuum system must be carefully outgassed if a good ultimate vacuum is to be obtained. We formerly used a large marinite-insulated oven but are now using a method first mentioned in print by Stewart (5), although Langton, of Harvard and the Baird Associates, had previously developed a similar procedure. A battery of about 14 375-watt heat lamps is placed about our apparatus from the end of the diffusion pump out. The heads of the lamps are put about a centimeter or so from the glass. Then the system and the surrounding lamp *bulbs* are carefully wrapped with thin aluminum foil. (Dime-store Weynolds Wrap is convenient.) The foil traps practically all of the heat radiation, and the temperature within the enclosure rises rapidly when the lamps are turned on. With all lamps burning, the temperature readily goes to 430° C. When more complete tests are made we hope to take the temperature up to 475° or higher for most workers prefer to outgas at about 500° C. (6). Up to the present, however, we have found an outgassing temperature of 455° C. satisfactory. A very good reference on this matter is the summary of experiment and theory found in Section 6 of Chapter 8 in Dushman's *Vacuum Technique* (7). There the conclusions of the work of Langmuir (8) and of Sherwood (9) are given as follows: The "*exhaust should be carried out in two or more stages of gradually decreasing temperatures,*" and further, the evolution of water vapor (from Pyrex) at temperatures above 500° C. continues indefinitely, apparently due to chemical decomposition of the glass.

The heating of the glass is done at 450° or higher for two or more periods of 8 to 10 hours each. Then there is another period of heating at a somewhat lower temperature. The great effect of this outgassing is seen in the fact that it is not unusual for the pressure to go down to 4 or 5×10^{-7} after only an hour of outgassing at temperatures even less than 450°.

Nevertheless, heating the glass is not sufficient. All metal parts of the apparatus must also be carefully outgassed. This is the most difficult part of the entire outgassing procedure. Some parts of the tube can well be treated by means of an induction heater. We put such parts in a small auxiliary vacuum system and then outgas them. If they are not exposed to the air for any sizeable length of time afterwards, this is a much more satisfactory procedure since the evolved gases are not deposited on the walls of the main vacuum system. Other parts are outgassed by electron bombardment from special filaments inserted in the system. They are heated to white heat for one or more periods of 8 hours each. This outgassing cleans the metals fairly well, although any metal will always evolve some gas with the passage of time. It may be noted that it is well to do the above operations of cleaning the glass and the metal in alternate stages so that the gas evolved in the heating of the one is not permanently left on the other.

The system should allow for some efficient getters. One method is to use getters in the form of a wire and thus capable of being exploded by the passing of a current through them. Another is to use getter pellets which may be exploded by induction heating. We have used a 5-in. bulb off to one side of the system, with a pair of two Kemet Laboratories KIC getters attached to separate current leads. Getters of any type must be carefully outgassed to the highest possible temperature without their exploding. It has been found that on the explosion of the getters, sizeable amounts of gas are liberated unless the elements are thoroughly outgassed beforehand.

c. Sealing-off the System

The last steps of the preparation of the vacuum deal with the sealing off of the tube. The constriction which is to be closed for the sealing of the system must be well heated for some time before the actual seal-off. Unless this is done, the melting of the constriction produces a large quantity of gas. With the metal parts, if possible, at white heat, the getters are flashed. The pumping is continued for about 30 min. more to remove any gas evolved in the explosion; the heating of the metals parts is discontinued; and then the constriction is melted to close off the tube.

After the glass has cooled to room temperature, the pressure should read at least as low as 10^{-8} mm-Hg. Moore and Allison, by the use of a procedure similar to the above, with a specially designed zirconium getter surface were able to reach what they considered a vacuum of 10^{-14} or better after the activation of the getter (10). By means of the monolayer deposition method we have measured vacuums in the region of 10^{-9}.

III. Conclusion

The above remarks merely touch the surface of an extensive field. Those especially interested in the problems of vacuum work are referred to Dushman's complete work (7), to Yarwood (11), and to Dunoyer (12).

The author wishes to state that any original work that may have been referred to above was done in collaboration with Dr. A. H. Weber of St. Louis University.

References

1. Jnanananda, S. *High Vacua*, New York: D. Van Nostrand, 1947, pp. 1-2.
2. See Langmuir, I. *Chem. Rev.*, 1933, **13**, 167 or the summary given in Jnanananda, pp. 276-278.
3. Wayne B. Nottingham describes the method in an unpublished paper of an Electronics Conference held in Chicago.
4. Dushman, S. *Scientific Foundations of Vacuum Technique*, New York: John Wiley & Sons, 1949, p. 730.
5. Stewart, A. B. *R.S.I.*, 1950, **21**, 258.
6. Dushman, pp. 732-738.
7. Dushman, pp. 511-512.
8. Langmuir, I. *J. Am. Chem. Soc.*, 1916, **38**, 2221.
9. Sherwood, R. G. *Phys. Rev.* 1918, **12**, 448.
10. Moore, G. E., and Allison, H. W. *Phys. Rev.*, 1950, 77, 246.
11. Yarwood, J. *High Vacuum Technique*, New York: John Wiley & Sons, 1949, Sec. Ed.
12. Dunoyer, L. *Vacuum Practice*, translated by J. H. Smith. New York: D. Van Nostrand, 1926.