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The Contribution of Carl (Speed) Marvel to Polymer Science

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The Contribution of Carl (Speed) Marvel to Polymer Science

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It is an exceptional honor and privilege for me to contribute to this special symposium "Polymer Synthesis–The 1980's," and I am very much obliged to Eli Pearce for giving me the opportunity to present to you a short report on the life and on the extraordinary accomplishments of our new Honorary Doctor of Sciences. When, about a year ago a group of us thought that our Polymer Research Institute should recognize Professor Marvel's outstanding contribution to polymer science in an unusual manner, it was felt that a special symposium should be organized in his honor and that he should receive an Honorary Degree of Science at this occasion. The conferment of such a degree is, of course, a matter of the faculty, but our Provost, Professor Donaruma, succeeded to overcome all difficulties and we were able to issue the invitation for this symposium which, to our great satisfaction, is being attended by such a large group of friends and admirers of our honoree. A few who would have liked to be here were unable to come but sent letters with the expression of their sincere regrets to be absent and of their congratulations. I am giving these letters to Professor Marvel; they are signed by Ed Jefferson, Dick Heckert, Paul Flory, and Frank Press. But now to the topic of my address.

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1. BIRTH AND EARLY YEARS

Carl Shipp Marvel was born in September 11, 1894, in Waynesville, Illinois, where he also attended public school and high school. In 1915 he received a Master of Science Degree from the Wesleyan University in Middletown, Connecticut; he then moved to the University of Illinois in Urbana where he was awarded a MA in 1916 and a PhD in Organic Chemistry in 1920. He remained in Urbana and rapidly climbed the ladder from Assistant to Associate and full Professor in the Chemistry Department until, in 1953, he was appointed Research Professor of the University, a position which he occupied for eight years, until in 1961 he retired from the staff in Urbana and joined the Chemistry Department of the University of Arizona in Tucson. There he is still supervising important research projects of students and of postdoctoral visitors on a very substantial scale.

2. FROM ORGANIC CHEMISTRY TO POLYMERS

Organic chemistry, in the early decades of this century, was a highly developed and sophisticated branch of science which had succeeded in synthesizing many hundreds of thousands of substances which never before existed on earth and which were of enormous benefit to such vital fields of human activity as agriculture, husbandry, food production, hygiene, medicine, and cosmetics. Their systematic application started to dominate such industries as textiles, leather, rubber, food, coatings, insulation, and adhesives, changing and enriching the existence of everyone and extending the life span of generations. Its synthetic power was based on such molecular processes as the Hoffmann rearrangement and the reactions of Kolbe, Friedel-Crafts, Grignard, and Diels-Alder and on catalytic hydrogenation, dehydrogenation, hydrolysis and disproportionation. Its analytical methods included highly refined processes of distillation, crystallization, fractionation, centrifugation, and adsorption. Its principle was to work only with well-defined and highly purified substances.

In the course of the years its activities led to the structural classification of many important substances of the plant and animal kingdom such as the perfumes and colors of flowers, the vitamins, hormones, and enzymes. Analysis was promptly followed by synthesis which resulted in numerous successful and effective variations of the original materials and opened wide and unexpected fields of substantial improvements in the comfort and safety of life. At the same time much work was carried out to improve our basic understanding of organic chemical structures and reactions. Representative efforts of this kind were the famous studies of Willstätter on conjugated double bonds in cyclic compounds–cyclooctatetracene–and of Richard Kuhn on linear conjugated-diphenylene polymers. In the 1920s the University of Illinois in Urbana was the mecca of organic chemistry in the United

States with such prominent representatives as W. A. Noyes, Roger Adams, and Vincent du Vigneau.

When young Dr Marvel became a member of the Chemistry Department he rapidly joined his colleagues in their various professional activities: giving courses, supervising laboratory work, and taking care of doctoral candidates. In these earlier years at the university he also acquired the nickname "Speed." There are several theories which explain the origin of this name, which soon was exclusively used with complete elimination of all other possible names. One explanation was given by Dr Marvel himself who once explained it with the following words:

"When I entered the University of Illinois in the fall of 1915, the Dean of the Graduate College thought I was not as well prepared as I should be to finish work for a Master's degree in one year. Thus he assigned me extra work which I needed to complete if I were to meet the requirements for that degree, which was supposed to be completed during the year of my scholarship. I found I had a very heavy load of laboratory work and classes which required work at the chemistry building from about 8:00 in the morning to 5:00 in the afternoon, with extra work in the evening to keep up with the laboratory assignments. As a result of this, I did not have much time to study until after dinner. I'd eat, then work, and was always very late getting to bed. I acquired the habit of sleeping as late as possible and then hurrying to get ready for breakfast before the house in which I lived closed the dining room door at 7:30 a.m. It was the only time in the day when I really moved fairly fast, and the rest of the time I was rather slow-motioned, so my fellow students gave me the nickname "Speed" which has stayed with me the rest of my life."

This story is typical for the humble and modest nature of Dr Marvel but in spite of it, another version was given by his colleagues and students, namely: he studied and worked so fast and with such success that he accomplished everything before anybody else; hence he was "Speed." Today, in the clarifying hindsight of many years, the second version appears to be definitely preferable.

As it is usual for the first scientific efforts of a novice, Speed–as he will be called from now on–published a few articles on organic chemical problems with his peers–two with W. A. Noyes, one on "The Possible Asymmetry of Aliphatic Diazo Compounds," two with Roger Adams on "Organic Chemical Reagents," and two with Vincent du Vigneau, one on "Pressure Anesthetics" and the other on a "New Organic Reagent for Nitrates and Perchlorates." But the apprentice was learning fast and soon begun to spread his own wings. During the next decade he published more than 60 papers with an almost equal number of co-workers, some of whom became famous representatives of their profession, including D. D. Coffman, Paul L. Salzberg, and R. L. Shriner. There were essentially three main themes which interested Speed and which he studied systematically with amazing

width and depth; they all had to do with problems of bond strength and bond stability inside or between organic molecules.

One of them was devoted to the strength and stability of the carbon-carbon bond in substituted ethanes. More than 20 articles–between 1925 and 1944–were devoted to this theme, and a large number of new and hitherto unknown ethane derivatives were synthesized with an incredibly large variety of substituents–aliphatic and aromatic. The last ones, XIII to XVI–1942 to 1944–, contributed extremely valuable information to the problem of the "trivalent" carbon atom which had been discovered earlier in this country by M. Gomberg and later systematically studied by W. Schlenk in Germany.

Another valence problem which attracted Speed's attention had to do with elements of the fifth column of the periodic system–nitrogen, phosphorus, and arsenic; an article with F. D. Hager on "The Volume of Nitrogen in Quaternary Ammonium Compounds" opened these investigations in 1926. The above-named elements possess three unpaired valence electrons and one valence electron pair. They are tervalent as in the amines NR_3, phosphines PR_3, and arsines AsR_3 if the three unpaired electrons form three covalent bonds with unpaired electrons of the substituents R. These elements may also be pentavalent if one electron of the valence electron pair is donated to the partner–Cl, Br, and others–so that four unpaired electrons are becoming available for the covalent bonding of four substituents R:

$(NH_4)^+ Cl^-$; $(PH_4)^+ Br^-$; etc.

Evidently it was an interesting question whether the valence fields of these elements could be so modified as to bind covalently five monovalent radicals in order to give compounds of the composition

NR_5, PR_5, etc.

Nitrogen, probably, would be too small an atom to accommodate five groups in covalent bonding and Speed, therefore, made his first attempt in this direction with phosphonons in a paper with D. D. Coffman, published in 1929. When this failed he did not give up but tried one year later again with M. E. P. Friedrich to arrive at a pentavalent AsR_5 compound. They reacted tetraethyl arsonium bromide in benzene with a solution of n-butyllithium. Both reagents require very careful treatment; all processes must be carried out in the complete absence of moisture and oxygen:

$$2(AsEt_4)^+ Br^- + 2BuLi \longrightarrow 2LiBr + AsEt_3 + \text{gaseous products}$$

The result of the experiment was the immediate formation of LiBr, triethylarsine, and the development of a gas–the desired compound

$AsEt_4Bu$ was not formed. It would have been natural to conclude that such a compound does not exist or, at least, cannot be prepared in this way, and most chemists would have discontinued the investigation. Not so, Speed; he proceeded to analyze the gas, which was not an easy task.

Suppose somebody gives you an empty glass bottle and says: "In there is a mixture of C_2 and C_4 hydrocarbons: please find out their proportions." Not a very simple demand!

Delicate and somewhat time-consuming analysis gave a surprising result: ethane and C_4's were there in the expected quantities but ethylene was missing–or almost missing–in the gas mixture.

This again could have been the end of this study but Speed wanted to know exactly why it was not there and passed ethylene gas through a solution of n-BuLi in a high boiling mineral oil at somewhat elevated temperatures. He obtained a white, solid powder: linear polyethylene. At that time–1930–many attempts had been made to polymerize gaseous ethylene without and with catalysts but the results had always been only oily or waxy fractions. Here was the first solid polyethylene in excellent yield by direct addition polymerization under very mild conditions with a metal organic catalyst: Twenty-four years before Karl Ziegler's famous polymerization of ethylene with coordination complexed catalysts. Seven years had to pass before ICI chemists would develop the high pressure and high temperature synthesis of low density polyethylene–Polythene–and 20 years before the scientists and engineers of the Phillips Petroleum Company produced a high density species–Marlex–at intermediate pressures and temperatures. In 1930 polyethylene did not seem to be a very attractive material and the catalyst, n-butyllithium, was still a laboratory curiosity. The DuPont company, where Professor Marvel had just started to become a technical consultant was busy with nylon, Neoprene, Lucite and several vinylpolymers and there was no immediate follow-up on this "curious" observation.

Another phenomenon which attracted Speed's interest and led in the course of the years to almost 20 interesting publications was the hydrogen bonding between organic molecules and its influence on solubility and compatibility. By 1938 five papers had already been published with G. F. Zellhoefer and M. J. Copley on "Hydrogen Bonds Involving the C–H Link," the solubility of various compounds in donor solvents, and the effect of solvent association on solubility. These studies and many others which followed clarified many of the vexing problems of this phenomenon but also led to a remarkably important consequence: Speed suggested to the DuPont scientists that liquids like dimethylformamide or dimethylacetamide might be solvents for polyacrylonitrile. In fact, the technical production of Orlon was then and still is based on DMF as solvent.

The word "polymerization" first appeared in the title of an article together with C. F. Gibbs and E. R. Littman in 1933; all other research up to that date–about 70 publications–had to do with an amazingly wide variety of problems in organic chemistry; improvement of analytical techniques, the synthesis of taurine, the influence of tryptophane on growth, a synthesis of methionine, and the rearrangement of

polyines. Each paper made a valuable contribution to our knowledge. In their entirety, however, they reveal his scientific thinking and working style. It is a grand style: First, a fundamentally interesting and attractive problem is selected; its study leads to an idea which in turn provides for a practical approach. Then impeccable and intense experimentation follows, crowned by a critical evaluation of the obtained results. It was an enviable, high level, and grand style of scientific research which Speed maintained and, wherever and whenever possible, refined and improved during the following years of his career. In doing so he came close to Faraday's famous definition of scientific research. When he was asked by a prominent member of the House of Lords how he was able to produce such prodigious results, Faraday said only three words: "Work, Finish, Publish." This was also Speed's program; in the foreground of everything is observation and quantitative experimentation with endless patience. Speed liked his molecules and they in turn, liked him and did the best to satisfy his intentions.

Sometime late in his career he was asked during a discussion at one of the famous Gordon Research Conferences: "Professor Marvel, don't you think that these molecules ought to have a higher degree of elasticity?" Speed answered: "I don't know what these molecules ought to have, I only know what they have."

The selection of stimulating problems, the grand style of their treatment, and the large number (about 50 in the first 10 years) of publications soon created for Speed an enviable reputation as researcher and teacher in academia and industry. He became widely demanded as lecturer at scientific meetings and seminars and, around 1930, he was asked by Dr E. K. Bolton, then Research Director of the DuPont Company, to visit their Experimental Station in Wilmington as a consultant and exchange with its personnel on the various fields of their activities. Speed accepted and continues these visits and conferences even today–more than 50 years later–with unabated enthusiasm and success.

3. POLYMERS–CLASSICAL STYLE

This ongoing intense intellectual contact was not only of considerable advantage for the chemists at DuPont but it also turned Speed's interests to the wide and important field of organic polymers which he included from now on in his studies in a systematic manner.

In one of Speed's earlier visits in Wilmington, Dr Bolton drew his attention to the reaction of SO_2 with alkylenes and other unsaturated organic compounds which produces linear polymers of high molecular weight.

The two components are readily available and inexpensive, and polymers built on them would have an interesting headstart in comparison with other substances which were then successfully studied at DuPont–

polyamides and polychloroprene. Speed took up this suggestion and in his systematic and indefatigable way produced with a number of co-workers more than 30 publications on this subject matter within 26 years. He published in 1934 with D. S. Frederick and H. D. Cogan an article on "The Reaction between Sulfur Dioxide and Olefins" and concluded–for the time being–his studies on sulfur-containing polymers in 1960 through a paper on "Polyalkylene Disulfides Containing Silicon" with P. V. Bonsignore and Sahadeb Banerjee. However, the enormous field of organic polymers offered so many challenging and attractive problems that, in the course of the years, it became the main domain of teaching and research for Speed. For instance, in 1950 he published 11 papers of which only one dealt with "normal" organic chemistry, and in 1951 out of 19 papers, only two. Naturally, Speed cultivated with preference such problems where specific organic chemical methods would lead to conclusive results. One of them was a thorough study of head-to-tail–head-to-head structure of vinyl polymers such as polymethylvinyl ketone and polyvinyl alcohol in 1938, the polymers of alpha-augelica lactone, methyl-alpha-haloacrylates, vinyl halides, and acrylic chloride in 1930 with a few additional investigations in the following years.

Considerable emphasis was given to studies on copolymerization including the quantitative determination of relative reactivity ratios–no less than 40 publications between 1942 and 1960!

Some systems were investigated with special emphasis and concentration such as styrene derivatives of all kinds–optically active, p-cyano-, six dichloro-, four dimethyl- and some alkyl derivatives; all in six publications with C. G. Overberger in 1945 and 1946.

During World War II, Speed was a prominent member of the Synthetic Rubber Research team and immediately after the war he went to Europe and visited several R&D centers where important work had been done in organic and polymer chemistry in Germany. These activities aroused his interest in emulsion polymerization and redox activation, and there resulted no less than 15 important contributions to this subject between 1947 and 1955.

Besides these larger themes of systematic studies, polyalkylene sulfides, microstructure of vinyl polymers, copolymerization, and emulsion polymers, Speed added many interesting details to our knowledge of polymer chemistry. Soon after Ziegler's famous discovery, Speed used coordination complex catalysts for the polymerization of higher alpha-diolefins and of beta-pinene (1959). Later–1960 to 1968–he contributed more than 10 articles on the preparation and characterization of block and graft copolymers.

Altogether, between the beginning of his interest in polymers (1933) to the end of his activities at the University of Illinois (1961), Speed was by far the most prolific contributor to this branch of chemistry–not only from the numerical point of view–with more than 250 publications, but also through the impact which his work has had on academia and industry. Yet as we shall see, this part of his life can be considered only as a preparation for the next period during which

he introduced an entirely new generation of polymeric materials with properties of extreme importance for developments in modern transportation, communications, and energy conservation.

4. POLYMERS–MARVEL STYLE

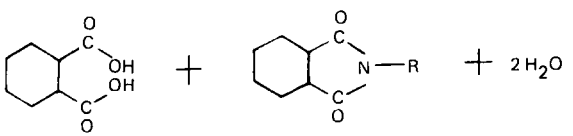
In the mid-1950s, polymer science and engineering was essentially based on the use of long flexible chains which were easily available by addition and condensation polymerization; the polyolefins, vinyls, acrylics, and polydienes by the first, the polyesters, polyamides, phenolics, and alkyds by the second. They were all relatively easy to prepare, many of them were soluble, and all were readily processible from solutions or from the melt by extrusion, injection, compression, spinning, and casting. Two general and eminently useful principles were established to convert these materials into objects of increased softening range, greater stiffness, and improved resistence against the attack of solvents and chemicals. The first was crystallization which can be achieved by orientation and alignment of the individual flexible chains through mechanical action whenever the microstructure of the chains is sufficiently regular to let them fit into a crystal-like lattice. These ordered or crystalline domains act like a reinforcing filler; they harden and strengthen the system and make it more difficult to swell and dissolve. Since the "crystallites" are held together by physical forces–"van der Waals bonds"–they may be reversibly softened and melted and the phenomenon of crystallization dominates the wide and enormously useful domain of the thermoplastic materials. The second principle was cross-linking which consists in the establishment of randomly distributed chemical bonds between the individual chain molecules. In the neighborhood of each of these fix points the segmental motion of the flexible chains is inhibited and the material becomes harder and has higher softening. Also, the three-dimensional network formed by the cross-links permits swelling of the system but not dissolution. Altogether the mechanical and thermal effects of cross-linking and crystallization are similar, but the chemical bonds of the cross-linked network cannot be opened and closed reversibly. Cross-linking is therefore characteristic for the other large kingdom of polymers: thermosetting resins. Both types of polymers have been and still are extremely useful and applicable but, with all conceivable refinements and innovations, no combination of these two principles has produced materials that can sustain exposure to 250 °C for prolonged service periods; the thermoplastics soften and develop creep, the thermosettings undergo chemical decomposition and become brittle. It was then that Speed proclaimed: "In the future we should not start with flexible chains and rigidify our systems by crystallization or cross-linking but we should place rigidity and thermostability in the chain molecules themselves–we should work with rigid chains." When he was promptly asked: "How can we do that?", he answered, "Let us synthe-

size chains which consist substantially of rings." This opened a new dimension for polymer science and engineering which is still in full swing; it has already produced innumerable rigid and thermostable polymers, and the new methods and approaches are such that they will provide many more.

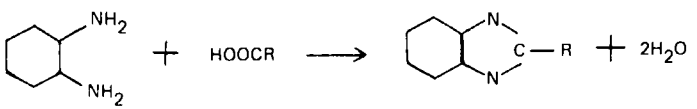
The important consequences of aromatic units in the backbone of chain molecules had already been encountered by Whinfield and Dickson in Terylene and later–more clearly–by Morgan and his many distinguished associates in the aramides and arylates; Speed, however, went an important step beyond this. If the functional groups of an aromatic polyamide, COOH and NH_2, are reacted with each other in the usual molar ratio of 1 to 1, then three single bonds are formed in the chain skeleton:

$$R\text{–}COOH + H_2NR' \longrightarrow R\text{–}CO\text{–}NH\text{–}R' + H_2O$$

and a considerable degree of conformational flexibility is introduced. Speed, therefore, proposed the formation of an additional ring during the polymerization reaction by using molar ratios of 2 to 1 or 1 to 2 between the carboxyl and the amino groups. The first choice leads to polyimides



the other to polybenzimidazoles



Through these choices aromatic dianhydrides and tetramines or tetraisocyanates became important building units for the new and ever-growing brands of thermostable polymers which conquered vast new fields of important applications in the preparation of fibers, films, sheets, rods, tubes, and more complicated objects, all of which were able to take the place of the heavier, more corrosive, and more difficultly tractable metals which had been used before. To the commodity plastics of the past were added the engineering plastics of the future. Speed himself led the parade into the newly proposed territory; in 1958 he published two studies aimed in this direction–papers on the polymerization of phthalocyanines with J. H. Rassweiler and M. M.

Martin–and in 1959 a very important investigation on the polymerization and aromatization of poly-1,3-cyclohexadiene followed. But the real all-encompassing offensive began in 1961 with a paper on "Polybenzimidazoles, New Thermally Stable Polymers" with Herward Vogel which was followed by not less than four more extensive articles on the same topic. Films and fibers were produced from a variety of these materials, and eventually large quantities of fabrics were made into garments of many kinds because PBI was not only exceedingly thermostable but also practically incombustible; they have a limiting oxygen index higher than 35 in comparison with 20 or less for cotton, nylon, and polyester. This means that a fabric or PBI which is burning in a flame immediately extinguishes as soon as the flame is removed. Also, the result of burning is nothing else than char, and there are few obnoxious or toxic gases evolved. Even now there is no better flame-retardant material than PBI. However, the PBI's were only a rather small fraction of the new generation of rigid–"honeycombed"–macromolecules which were developed by Speed and his associates and later by scores of other scientists. If the reaction between functional moieties–COOH and NH_2 or other groups–is carried out in a molar ratio of two to two, then one obtains chains of condensed rings or so-called "ladder" polymers for which polyquinoxalines, polypyrrolones, and polyanthraquinones are characteristic examples. Between 1960 and 1982 Speed published more than 120 articles on the subject of rigid polymer chains which contain rings and represent a third principle, together with crystallization and cross-linking, to modify and manipulate the ultimate properties of synthetic polymer systems with special emphasis on rigidity, thermal stability, and flame retardancy. There exists a Friedel-Crafts and a Diels-Alder reaction, a HaberBosch and a Fischer-Tropsch process, and there also exists Grignard and Ziegler-Natta catalysts. It would only serve to accept existing realities and accomplishments if we could get accustomed to speak of Marvel Polymers.

5. EDUCATOR, ORGANIZER, PUBLIC SERVANT, AND ELDER STATESMAN

Obviously, all these nearly incredible performances could not have been done alone. There has been a large number of students and associates–some 400 in the course of time. All speakers today are scientists who have worked with Speed on one or another occasion. The relations between Speed and his students were–and still are–exceptional in both directions. He not only conveyed to them knowledge, skill, and perception, but also enthusiasm and devotion for their profession together with a good deal of sound realism for the values of their work from the human and practical aspects. Each of our speakers today has found adequate words to express his feeling of gratitude and indebtedness to his teacher and mentor and–if the members of our audience

would be allowed to speak–they all would agree wholeheartedly with these feelings. I, myself, have, unfortunately, never been a member of Speed's community, but the study of each of his papers and the listening to each of his lectures and speeches has been of deep influence on me. Any new contact with him is always a refreshing and memorable encounter.

Since science and engineering became an important factor in human life and evolution, the leaders and protagonists of convents, universities, or other schools have had a decisive influence on the formation of the coming generation. Even in comparison with physicists like Bohr and Sommerfeld or with chemists like Willstätter or Roger Adams, Speed obviously holds a unique record in not only providing unusually gifted and skilled researchers and educators for universities and other higher schools of learning but also efficient and critical staff members and managers for industrial organizations and government laboratories. In order to avoid the difficulty of making any kind of personal selection, I have added to this appreciation of Speed's work a list of all his publications from 1917 to 1983–it reads like a "Who's Who in Polymers" and everybody will enjoy finding the names of many good friends.

Traditionally, prominent performances and the demonstration of outstanding abilities are accompanied by titles and honors and also by the bestowal of additional responsibilities and offices. As you may see from the attached "biography," Speed has received a full measure of both. All the many honors–degrees, medals, awards, prizes and citations, etc.–he accepted with his usual grace and modesty, all the many offices–member, editor, chairman, vice president, president, etc.–he discharged with accuracy, distinction, and imagination; in each case with considerable advantage for the organization which called on his services. They will all long remember their affiliation with him and will have to wait a long time for a similarly congenial and effective counsellor and protector.

Speed, as a few of you may already know, is also a farmer. For many years he has owned a farm in Illinois. It is a rather large and substantial property–several hundred acres–and he grows a variety of crops–soy beans, corn, and other grain–in good yield and of high quality. In fact, some of these crops are even quite profitable. But, Speed, your really important crop is not on the fields in Illinois–it is here, right here in this room! Each one of us has profited enormously from your indefatigable farming in the vast fields of chemistry, and today we are all here to express to you our gratitude, friendship, and admiration, and we are all telling you: Thank you and God bless you!

6. HONORS AND AWARDS

1946 Honorary DSc, Illinois-Wesleyan University
1963 Honorary DSc, University of Illinois in Urbana

1970 Doctor Honoris Causa, University of Louvain, Belgium
1983 DSc Honoris Causa, Polytechnic Institute of New York

1944 Nichols Medal, American Chemical Society
1950 Gibbs Medal, American Chemical Society
1955 Gold Medal of the American Institute of Chemists
1956 Priestley Medal of the American Chemical Society
1964 Witco Award of the Division of Polymer Chemistry
1964 International Award of the Society of Plastics Engineers
1965 Perkin Medal of the American Section of the Society of Chemical Industry
1966 Madison Marshall Award from the American Chemical Society
1967 Chemical Pioneer Award, American Institute of Chemists
1970 John R. Kuebler Award of Alpha Chi Sigma Fraternity
1973 Borden Award, American Chemical Society
1976 Alumni Achievement Award of the University of Illinois
1978 Polymer Award of the Division of Polymer Chemistry
1978 Creative Science Award of the University of Arizona

7. MEMBERSHIPS

National Academy of Sciences (1938)
American Philosophical Society (1946)
American Academy of Arts and Sciences (1960)
Board of Material Studies
Board of Synthetic Antimaterials
National Research Council
National Materials Advisory Board (Chairman)
National Health Council
International Union of Chemical Encyclopedia (Chairman)
Southern Regional Laboratory Advisory Board
Advisory Panel of the National Science Foundation (Chairman)
Robert A. Welch Foundation

8. FAMILY–RECREATION

Dr Marvel married Alberta Hughes in December 1933. They have a daughter, Mary Catharine, born in 1935, and a son John Thomas, born in 1938. The daughter graduated in home economics and merchandising from the University of Illinois and then joined the J. C. Hudson Company in Detroit, where she has become a very successful buyer of children's clothing for her store and its Detroit affiliates. The son graduated from the University of Illinois in chemistry and took his PhD in chemistry at the Massachusetts Institute of Technology. After four years as a research associate and assistant professor at the

University of Arizona in agricultural chemistry, he joined Monsanto's Agricultural Products Company where he now holds the prestigious position of General Manager of their Research Division.

Everybody in this room and, in fact, everybody who ever met Speed, even for a short time, will enthusiastically agree that Speed is a typical "good sport," enjoying family life, parties, and any kind of societal activities.

He was, and probably still is, a dangerous poker player; in fact, one explanation of his name "Speed" refers to the rapidity with which he moved the money of the other players from their pockets to his own.

Speed has always liked outdoor life and nature. When he was young, strong, and active, he was a hunter, following and stalking his prey for endless hours through woods and fields in bad weather and during the night. Later, when the enthusiasms for sporting activities gradually attenuated, Speed acquired exceptional skill and experience in the less exhausting sport of fishing where running, walking, and shooting is replaced by patient waiting and careful observation of the fish. At times when even this activity is too strenuous, there exist still other interesting and attractive hobbies for anybody who wants to continue outdoor life. If you like to look downward you can start snorkeling and observe fish in their various activities. However, if you prefer to look upward, then it is recommended you become a bird watcher. Speed decided to do the latter, and in his systematic careful and tireless manner developed bird watching into a real science. He has a list of about 629 species in North America which he has seen and identified. He has also looked for birds in Mexico, Brazil, England, Scotland, France, Belgium, Switzerland, Germany, Israel, Iran, and Japan, and has a world list of 1043!

9. PUBLICATIONS OF C. S. MARVEL

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2. With W. A. Noyes: "Cyancarboxyethyl 3,3-Dimethylcyclopentanone," Ibid., 39, 1267-1271 (1917).
3. With Roger Adams and O. Kamm: "Organic Chemical Reagents. II. Amylene, Tertiary Amyl Alcohol," Ibid., 40, 1950-1955 (1918).
4. With Oliver Kamm: "Organic Chemical Reagents. III. β-Phenylhydroxylamine and Cupferron," Ibid., 41, 276-282 (1919).
5. With Oliver Kamm: "Organic Chemical Reagents. V. The preparation of Alkyl and Alkylene Bromides," Ibid., 42, 299-309 (1920).
6. With Roger Adams: "Organic Chemical Reagents. VI. Reagents from n-Butyl Alcohol," Ibid., 42, 310-320 (1920).
7. With W. A. Noyes: "A Study of the Possible Asymmetry of the Aliphatic Diazo Compounds," Ibid., 42, 2259-2278 (1920).

8. With V. L. Gould: "The Preparation of Dialkyl Mercury Compounds from the Grignard Reagent," Ibid., 44, 153-157 (1922).
9. With A. L. Tannenbaum: "The Preparation of 1,4-Dihalogen Derivatives of Butane," Ibid., 44, 2645-2650 (1922).
10. With H. O. Calvery: "The Preparation of Dialkyl Mercury Compounds from the Grignard Reagent. II. The Relative Stability of the Carbon-Mercury Linkage in Dialkyl Mercury Compounds," Ibid., 45, 820-823 (1923).
11. With F. E. Smith: "Identification of Amines," Ibid., 45, 2696-2698 (1923).
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