

Robert J. Good, innovator in colloid and surface chemistry

INTRODUCTION

Professor Robert J. Good, to whom this Festschrift is dedicated, is one of those phenomena one encounters very rarely: a genuine scientist's scientist. For the last 40 years Good has unremittingly studied the interfacial aspects of wetting, adhesion, contact angles, and solubility. In 1957 and 1960 he published, with L. A. Girifalco, the now world-famous papers, introducing the 'geometric mean' hypothesis and the Φ parameter [7, 8, 13], which provided the first modern breakthrough in the quest to understand the puzzling nature of interfacial interactions between organic compounds and water. Widespread recognition soon came and prestigious awards followed. However, all this did not lead him to rest on his laurels, nor did it instill in him a rigid conviction of the infallibility of his theory. The theory is, indeed, perfectly sound, and predictive with respect to one major class of interactions. But it gradually became apparent that whilst it covered all the observed phenomena impeccably, it did not 'describe' them in a manner which could significantly enhance our understanding of the fundamental physical and/or chemical nature of the interactions in highly polar substances. Thus, with his deep-rooted curiosity and his thorough understanding of the problem and of its complete physical-chemical background, Good not only remained receptive to all suggestions for improvement and to new theories from other workers, but he also continued to encourage and to lead discussions on the subject within his own circle, and kept a research program going in the field of apolar and polar interactions among condensed-phase materials. When novel breakthroughs arose from these activities within his own circle, he was, and still is, delighted with these developments and never hesitated to abandon less-promising pathways in favor of more productive approaches and of theories which appeared more cogent from a physical-chemical viewpoint.

Thus, the sheer number, the high quality, the unusual diversity, and, frequently, the marked originality of the papers contributed to the Symposium in Honor of Professor Robert J. Good by his colleagues and former and present collaborators should not surprise anyone who knows him and his work.

BIOGRAPHICAL SKETCH

Professor Good was the second son of four sons of a family living in Nebraska. Professor Good's mother was from Exmouth, Devonshire, England; his father met her in England while on a Rhodes scholarship to the University of Oxford, where he took his law degree. His father subsequently practiced law in Lincoln, NB, and later in Omaha; in 1931 he was elected Attorney-General of the State of Nebraska and served in that position for 2 years.

Robert Good attended elementary school and high school in Lincoln, NB, and

then went to Amherst College, Amherst, MA, where he obtained his B.A. in chemistry in 1942. He went on to the University of California at Berkeley, where he obtained an M.S. in chemistry in 1943. In 1950 he obtained a Ph.D. in chemistry at the University of Michigan.

At Amherst, he started in a pre-medical major, but switched to chemistry after 1 year. This was after taking freshman chemistry from a fine surface chemist and physical chemist, Ralph A. Beebe. He did a senior project under another important surface chemist, David C. Graham, on the electric double layer at the dropping mercury electrode. At Berkeley, he started to work on a thermodynamic problem under Kenneth S. Pitzer. He then turned to nuclear chemistry to prepare for work on the Manhattan Project, but was advised, 'Forget it': Draft boards hadn't been told about that project, and were calling up everybody who went on it.

During 1943–1944 Good worked as a chemist at Dow Chemical Co., Pittsburg, CA, and from 1944 to 1946 at American Cyanamid & Chemical Co., Azusa, CA. During 1953–1957 he was Associate Professor in the Department of Applied Science, University of Cincinnati, Cincinnati, OH. During 1957–1964 he was Senior Scientist at the Convair Space Science Laboratory, General Dynamics Co., San Diego, CA. Since 1964 Good has been Professor, Department of Chemical Engineering, State University of New York at Buffalo.

At Dow Chemical Co., Pittsburg, CA, he worked as a chemist on the development of chlorination reactions. At American Cyanamid, Azusa, CA, he worked in a poison gas plant that made cyanogen chloride, doing control analysis. After V-J day, while waiting for admission to graduate school, he worked on additives for oil well drilling mud. He read up on the colloidal chemistry of clays, on rheology, and on DLVO theory. (The Verwey and Overbeek book *Theory of the Stability of Lyophobic Colloids* became available in 1948.) At Michigan, he learned considerable colloid chemistry from F. E. Bartell and from his students such as Robert S. Hansen, Ying Fu, and others. He chose Lawrence O. Brockway for research advisor, to work on a surface chemistry problem: the flotation of sulfide ores, with alkyl xanthates to make them hydrophobic. Electron diffraction by solid surfaces was the principal research tool. His first independent paper was based on work done while at Michigan but not included in his thesis [2].

After he received his Ph.D., he worked in the Research Laboratory of the Monsanto Chemical Co., Anniston, AL. There, he worked on liquid dielectrics for capacitors and transformers: the chlorinated biphenyls. (See ref. 9 on this subject.) Monsanto wanted to publish some papers on 'pure' chemistry and so asked him to propose something. The result was ref. 3, which includes some solubility theory after the manner of Hildebrand and Guggenheim. In 1953 he went to Cincinnati as an assistant professor, to take charge of several existing, sponsored projects for the Navy, the Air Force, the Army, and private industry. Results: refs 4–13 and 16, 19, and 20. Reference 4 (which was mainly the Ph.D. thesis of Louis A. Girifalco), though a report to the Air Force, may be ranked as a publication because it contains the material that became the Good–Girifalco theory, [7, 8, 13], and it is sometimes cited in the literature. Eight other papers, between 1960 and 1986, were direct outgrowths of those first three. The acid–base theory, which started in collaboration with Chaudhury and van Oss in 1986, has so far led to over 25 papers.

Other studies at Cincinnati included the 'direct' problem of adhesion, e.g. mechanical tests on coatings and adhesives, and also the adhesion of ice to aircraft wings (see the title of ref. 4). He also studied surface diffusion in an adsorbed film, the swelling of rubber by solvents, and the diffusion of oxygen through synthetic polymers, as well as the dielectric losses in polar, insulating liquids, and the theory of surface entropy. At the University of Cincinnati, he taught surface chemistry and statistical thermodynamics. At the Convair Space Science Lab, General Dynamics at San Diego, he continued the development of the Good-Girifalco theory and did some measurements related to it, e.g. interfacial tensions and contact angles (see refs 14, 15, 17, and 18). He also worked, from time to time, on projects related to the *Atlas* rocket production and to various aircraft made by Convair.

At Buffalo, he was taught surface chemistry, materials science, corrosion engineering, thermodynamics, and statistical thermodynamics. His research has been on surface and colloid chemistry, and he also wrote some papers on the direct problem of adhesion (15 papers; see, in particular, refs 33, 39, 44, and 126), on corrosion, on materials science (e.g. cement [73, 74]), and on thermodynamics. He holds a patent [51] on the use of polymers for the stationary phase in open-tube gas chromatography; the work was done for Phillips Petroleum Co. Recently, he has worked on the surface chemistry of coal, with a view to alleviating the acid rain problem. Four papers are in print [121, 129-131], and there is a patent applied for [128] based on this work; several more papers are in preparation. One paper on corrosion [83] explains the passivity of iron, aluminum, nickel, chromium, etc. (which is of great importance in corrosion resistance and in electrochemistry) as being caused by the semiconductor behavior of oxides such as Fe_2O_3 . Another paper on corrosion is ref. 22, about grain-boundary attack on metals.

His theoretical thermodynamics and statistical thermodynamics papers, other than the Good-Girifalco-van Oss-Chaudhury papers are refs 2, 6, 21, 25, 28-30, 38, 52, 53, 60, 69, 71, 79, 80, 97, and 106. Many of these arose from teaching, alternately, courses in surface chemistry and in thermodynamics.

In 1984, Dr. M. K. Chaudhury obtained his Ph.D. with Professor Good, with a thesis on 'Short-range and long-range forces in colloidal and macroscopic systems'. Here Chaudhury applied the Lifshitz approach to interfacial interactions and to surface properties of condensed-phase materials. Chaudhury and Good [109, 127] showed that in macroscopic systems, dispersion, induction, and orientation interaction forces can all be grouped together, and are described by similar equations and decay at the same rate, as a function of distance. The theory of these electromagnetic interactions had been developed first by van der Waals and later, London, and after the war (for macroscopic phenomena) by Lifshitz. So, it was proposed to allude to these collective electrodynamic interactions as Lifshitz-van der Waals or LW forces. These results suddenly made it easy to emerge from the quandary which had stymied everyone up to this point, namely how to distinguish 'polar' interactions such as Keesom (dipole-dipole) forces from other 'polar' interactions of the class of, for example, hydrogen bonds. This opened the way to a rational treatment of the interplay between Lifshitz-van der Waals and Lewis acid-base (AB), or electron acceptor/electron donor, interactions in interfacial phenomena [95, 99, 100, 102-105,

107–112, 114, 116–125, 128, 130]. Many of these papers are of biological interest, as are, in addition, refs 24, 40–42, and 49.

Professor Good also worked on microemulsions, bringing to bear (in collaboration with Drs. Ho and van Oss) the techniques of light scattering and ultracentrifugation. He discovered an anomalous sedimentation effect, in which the particles drifted downward at a rate that was about an order of magnitude larger than that expected from the particle size. With Dr. M. V. Ostrovsky, he studied the dynamics of particle fissioning and recombination in multiphase systems [87–89, 96]. He contributed to the study of porosity, particularly the role played by adsorbed films on the internal pore surface, ahead of the advancing liquid front [34, 45, 57, 58]. This led to a generalization of the Lucas–Washburn equation for the rate of penetration of a liquid into a bed of powder or a porous solid. He also investigated the effect of internal roughness of pores and how it affects the determination of pore size [77, 86].

Professor Good also long had an interest in the philosophy of science, and in 1980 [75] he published a model of the methodology used by most (if not all) physical scientists. It involves two feedback loops: one is a cycle of theorizing (without additional experimentation) and the other a cycle of experimentation to test the results from the theorizing loop. The scientist switches back and forth between the two kinds of loop. The closure of the process comes when the experimental results, and the predictions, are in agreement, and when both are compatible with all the rest of scientific knowledge.

On a personal level, Bob Good is the most agreeable companion imaginable. He is exceedingly entertaining, polite but incisive in his opinions, most convivial, and unfailingly helpful to friends and colleagues. His charming Scottish wife, Maud, even though not personally conversant with our abstruse discipline, has become as much a landmark in the world of colloid and surface chemistry as Bob himself. Bob Good is further known for his excellent taste in unblended malt Scotch whisky, and for his predilection for English poetry, in the venerable mode of the limerick.

CAREL J. VAN OSS
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AWARDS

The two major awards earned by Professor Good were:

Kendall (1976): The American Chemical Society Award in Colloid or Surface Chemistry, sponsored by the Kendall Co.:

‘For his pioneering investigations of atomic and molecular interactions across interfaces, and the application of the resulting, new concepts to scientific, technological, and biological problems.’

The Jacob R. Schoellkopf Award (1979): The Western New York Section of the American Chemical Society:

‘For his pioneering research in surface thermodynamics, the theoretical chemistry of adhesion phenomena, the factors controlling the penetration of liquids into porous solids, and physical aspects influencing the aggregation of living cells.’

SELECTED SCIENTIFIC AND PROFESSIONAL SOCIETIES AND ACTIVITIES

American Chemical Society.

The Chemical Society, Faraday Division.

National Association of Corrosion Engineers.

Chairman, San Diego Section, American Chemical Society, 1961–1962.

Chairman, Gordon Conference on Chemistry at Interfaces, 1975.

National Councilor, American Chemical Society, 1974–1982, representing Western New York Section.

National Alternate Councilor, American Chemical Society, 1968–1971, representing Colloid and Surface Chemistry Division.

The Adhesion Society.

Member, National Colloid Symposium Committee, American Chemical Society, 1966, and Chairman for 41st Symposium, 1966.

Chairman, Educational Committee, Western New York Section, National Association of Corrosion Engineers, 1975–1979.

Chairman, Buffalo Section, Sigma Xi, 1975–1976.

Colloid and Surface Science Symposium: General Chairman for 51st Annual Meeting, 1977.

PUBLICATIONS

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16. R. J. Good, Theory for the estimation of surface and interfacial energies, IV. Surface energies of some fluorocarbon surfaces from contact angle measurements. In: *Contact Angle, Wettability and Adhesion*, Advances in Chemistry Series, No. 43, pp. 74–87. American Chemical Society, Washington, DC (1964).

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- The molecular nature of interfacial tension, Gordon Research Conference on the Science of Adhesion (1963).

Surface energies and the embrittlement of metals by liquid metals, Gordon Research Conference on Chemistry at Interfaces (1964).
 Intermolecular forces, interfacial energy and adhesion, Gordon Conference on the Science of Adhesion (1964).
 Heat of peeling, and the theory of adhesive failure, Gordon Research Conference on the Science of Adhesion (1969).
 Invited Lecturer, 7th Annual Conference on Adhesion, London (1969): A new thermal effect in the peeling separation of an adhesive system.
 Invited Lecturer, International Conference on the Physics of Adhesion, Karlsruhe, Germany (1969): A new thermal effect in the peeling separation of an adhesive system.
 Interface forces and the general theory of adhesion, University of Utah, Conference on Adhesion (1970).
 Theory of wetting and spreading in adhesion, 9th Annual Conference on Adhesion, London (1971).
 Theory of the adhesion of living cells and the spontaneous sorting-out of cells from aggregates, Gordon Research Conference on Chemistry at Interfaces (1971).
 Kendall Award Lecture, American Chemical Society Centennial Meeting, New York, 6 April (1976): Surface free energy of solids: thermodynamics, molecular forces and structure.
 The adhesion of coatings and films to solids, Gordon Research Conference on Coatings and Films (1978).
 Surface chemistry and the difference between search and research, Lecture on receiving the Schoellkopf Award of the Western New York Section of the American Chemical Society (1979).
 Theory of the oxidation rate laws of metals that form non-stoichiometric oxides, 5th International Symposium on Passivity, Bombannes, France (1983).
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