the epithet "efficient"—the parasite or the host? Had not the title of the paper better be "The Efficient Host"? In this case this is undoubtedly true. These same parasites which behaved in such an exemplary manner in the bush Negro's body, behaved very badly in my own. It is the bush Negro's body which, first by refusing to be killed, and afterwards by a judicious and not too far carried reduction of the number of parasites, finally obtains that nicely adjusted equilibrium which does not even require the intervention of the spleen. Nevertheless, I maintain the parasite's claim to the title of "efficient" since it allows itself to be domesticated in this way.

So we come to this conclusion. If we see a parasite behaving as it should behave—not harming its host and, as a consequence, not harming itself—in short, if we see it behaving as an efficient parasite, we know that this is the outcome of an interaction between host and parasite of a struggle in which both have had to sacrifice something. The host has had to get rid of his over-sensitiveness, he has had to become tolerant of the parasite's presence in his body. And the parasite has had to suffer a considerable reduction in its procreative powers. It is an adaptation of the host to a greatly subdued parasite. The Negro body, better than the body of most human beings, seems extraordinarily well fitted to pass unscathed through the various stages of this adaptation.

And now, finally, you will allow me to say something on the subject which I have had in mind these last five months: the settlement of political refugees in the tropics, more especially in the Guianas. It has little to do with the efficient parasite but a great deal with the propensity of the African race to act as a highly efficient host of the malaria parasites.

Up till now the importance of this peculiarity of the African race has been underrated because many of the greatest authorities have refused to regard it as a racial quality by which the African races fundamentally differ from other races. Every race can acquire some measure of immunity to malaria. The African race, together with a few obscure hill-tribes in India, are the only ones to be born with it.

I need hardly emphasize that this racial quality affords the Africans a considerable advantage over the other races in the case of the interracial struggle for existence developing in an environment in which malaria plays an important part. I am not going to enlarge on this subject which would completely carry me away from the beaten track I am following. To those who wish to reflect on this remark of mine, I would recommend the perusal of Grenfell Price's book on "White Settlement in the Tropics," recently issued by the American Geographical Society. Notably, his remarks on the fate of the white race in some parts of the tropical world are worth reading in this connection.

But this I would say. Any attempt at settlement of whites in areas where malaria is rife and where, by the conditions under which the settlement is organized they will have to compete with the African race on a footing approaching equality, is bound to be a cruel failure unless malaria has been reduced to insignificance before the settlement is started or unless an enforced segregation is rigorously applied to keep the two races so much apart that there can be no longer any competition between the two.

I realize that my address has been somewhat out of tune with the highly cultured scientific sphere of this congress, where the serene atmosphere of the laboratory and the lecture room prevails. I came here directly from the wilds. The field has been my laboratory for months and I have consorted more with bush Negroes and Indians than with cultured people. Moreover, I can not get rid at a moment's notice of the ideas and interests which have occupied my mind since I left Holland and which, although of little importance in the present circumstances, are bound to clamor for notice at some future date. Accept my address as a contribution to the vexed question of the host-parasite relationship. That I did not quite succeed at the end in keeping away from the subject I have very much at heart must be regarded as an amiable mental aberration comparable with that from which one of Charles Dickens's famous characters of fiction suffered when he never succeeded in keeping King Charles' head out of the Memorial he was writing. If I had had Mr. Dick's unlimited time at my disposal I would have torn up this memorial to write another one. Since I had not the time, I had to offer it to you as it is.

THE KINETICS OF CONTACT CATALYSTS AND THE INDUSTRIAL BACKGROUND[1]

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It is a tragedy of the efforts of the student of chemical reactions at surfaces, in these closing decades of the two centuries of service to culture and civilization that the University of Pennsylvania is now celebrating, that the finest flowers of the effort should have synchronized with and been made subservient to the inter-

[1] Read at the Bicentennial Conference of the University of Pennsylvania, September 17, 1940.

national tragedy of 1914–1918 and that which now burdens the human race. It was not mere accident that, in the decade preceding the first Great War, out of the fundamental researches of Sabatier on the capacity of nickel and other metals to induce the combination of hydrogen with unsaturated substances, there emerged the answer to the famous query of Napoleon to his French scientists one hundred years earlier as to the possibility, in a blockaded country, of converting liquid fats into the solid fats necessary for the production of margarine and of soaps. It was a proud boast of an English technician in 1919 that they had succeeded in converting fifth-grade whale oil into edible fats in the last years of the first World War. It can not be chance alone that the industrialization of Haber's researches on the fixation of atmospheric nitrogen and the production of the ammonia necessary for fertilizers and explosives should have been achieved on the eve of that same war which found Germany cut off, by British sea-power, from the only hitherto available source of fixed nitrogen, the nitrate deposits of Chile. These processes demanded in their turn cheaper sources of hydrogen. This was achieved by new processes of formation at catalytic surfaces and put to use for the filling of those now archaic "sausage balloons" that served as observation posts on the battle lines of Flanders. To-day it is the "barrage balloons" that use hydrogen to protect areas against the invasions of invading bombers.

Two decades of "progress" demanded the solution of new problems for the coming new war. The mechanization of transport has profoundly modified the technique of modern warfare. The present distribution of sea-power compelled a blockaded country to ensure for herself either accessibility to the necessary raw materials of transport such as oil and rubber or alternatively so to shape her technological development as to insure the production of such materials synthetically from raw materials available within the blockaded area. Within Germany during the last years there have been developed, by means of reactions at surfaces, methods of converting coal into high quality aviation gasoline and synthetic rubber materials which have gone far towards making that country independent of supplies from abroad. Similarly, her need for fats, mitigated in part by her conquests of the present year, demanded the replacement of the fats used in soap manufacture by synthetic detergents and the development of methods for the conversion of available raw materials into synthetic fatty acids. Marked progress has been achieved in these directions.

Even in the case of countries open to the available resources of nature it has been found that nature does not always produce the most highly desirable forms of the materials to be consumed. Petroleum supplies an excellent example of such a situation. In the early days of the automobile, adequate fuels could be obtained by simple distillation of crude oil. Improvements were demanded by increasing fuel requirements which led to the development of cracking processes for increasing the gasoline fraction from a given barrel of crude. The demand for increased power in the automobile, stimulated further by progress in aviation, led to the realization that certain types of gasoline molecules, notably iso-octane, possess fuel characteristics that far exceed those of other molecules within the range of volatility demanded by the engines in question. New problems were thus presented to the chemist, the conversion of low-grade natural products into the more valuable high-grade fuels. In the solution of these problems the catalytic chemist has made notable contributions. Catalytic methods have been developed for cracking complex petroleum molecules into simpler high-grade automobile and aviation fuels, for polymerizing or putting together the simpler hydrocarbon molecules to form molecules of high anti-knock value in the gasoline range, for adding simpler saturated molecules to unsaturated molecules to form valuable fuels, the so-called processes of catalytic alkylation; catalytic isomerization, the changing of molecules of a given configuration to other configurations more powerful in fuel characteristics, catalytic dehydrogenation, which, coupled with catalytic processes of ring formation, lead to the formation of aromatic fuels containing benzene, toluene and xylene. As a by-product of these latter new processes of dehydro-aromatization the petroleum industry is becoming an active competitor of the by-product coke oven industry upon which, hitherto, we have been dependent entirely for the raw materials of the dyestuff industry, explosives and many pharmaceutical preparations.

Paralleling in intensity these developments with the more complex units of petroleum raw materials a series of efforts have evaluated the lighter constituents of petroleum, natural gas and the cracked gases of refinery operations. Catalytic processes have been developed for the direct oxidation of ethylene at metal surfaces, notably silver surfaces, to yield ethylene oxide, itself a reagent of great value in a series of synthetic processes and the intermediate in the production of ethylene glycol, a product now required on a tonnage basis for anti-freeze solutions. Propylene, the next higher unsaturated olefinic hydrocarbon, is by reason of a newly developed process, the raw material for synthetic production of glycerine available at any moment when the by-product glycerine of soap manufacture becomes inadequate to meet the demands. Butene, a four-carbon atom olefine, yields by further catalytic removal of hydrogen the butadiene which is the starting material for the synthetic rubbers of the Buna-types developed in Germany. There, due to lack of petroleum, coal is the raw material and the production of butadiene occurs via the formation of calcium carbide and acetylene. That butadiene, under the influence of metallic sodium, would polymerize to a rubber-like material has been known since the end of the last century. It was such materials which were employed as rubber substitutes by the Germans in the latter phases of the last war. The progress achieved in the recent researches arises from the discovery that "cross-polymerization," the introduction of other molecules into the growing unit, rubber, like the plastics, cellulose, starch, etc., being "macro-molecular," that is, composed of large numbers of constituent units combined with each other into a structural pattern conferring on the mass its particular characteristics. The newer synthetic rubbers build into the growing butadiene polymer such other materials as styrene and acrylic nitrile with the result that products having abrasion characteristics and resistance to oxidation, and therefore to deterioration, are from 5 to 30 per cent. better than the best natural rubbers that have been produced. Superior characteristics over the natural products also obtain in the case of such special products as neo-prene and thiokol, which, in addition to their carbon and hydrogen constituents, contain also chlorine and sulphur respectively, thus deviating markedly in constitution from the natural product, possessing properties which for certain purposes render them more valuable than the natural product.

In the field of plastics also the chemistry of reactions at surfaces is making notable contributions. These materials have almost endless uses and possibilities alike for peacetime and war uses. They can be used as substitutes for metals and for glass. Optical instruments, aeroplane parts, possibly even impregnating material for ply-wood aeroplane wings are among their immediate uses in the era of defense now upon us. Solvents for plastics, ethers, alcohols and esters are allied materials that the catalytic chemist is contributing. From these researches also stem the newer synthetic fibers of which nylon as a material superior in many characteristics to silk is now in large-scale production. The raw materials from which they are made, coal, limestone, petroleum, water and air require the chemistry of reactions at surfaces for the transformations that ultimately yield the desired products.

America can face the intense competition that rages in this field with equanimity. Thanks to her universities and the large bodies of trained personnel which they have turned out American chemical industry finds itself to-day in a vastly more favorable position, when national emergency once more confronts her, than 25 years ago. During this quarter of a century the industry has grown from the tiniest of infants to a giant, has seized the initiative from all competitors and potentially can outstrip them all. Side by side with the intensive industrial developments here outlined there has grown up also in industrial research, governmental and university laboratories a broad program of theoretical study in this field. Upon the pioneering investigations of Langmuir has been built a body of theoretical fundamental knowledge, the major contributions to which have come from American laboratories, and with the aid of which a more rapid and certain approach to the solution of problems of industry can be achieved. Langmuir recognized that the seat of chemical change at surfaces was a layer of absorbed gas one molecule thick associated with the surface by chemical forces. The heterogeneity of catalytic surfaces was then recognized and its importance in the interpretation of the great sensitivity of surfaces to poisons became understood. This concept led also to an understanding of the phenomenon of promoter action whereby, with suitable added material, the efficiency of a given quantity of catalyst material could be enormously enhanced. The quantitative extent of the surface could be increased and its quality multiplied. Later researches revealed that two types of association of a gas with a surface, the one physical, the other chemical, could obtain and that the operating temperatures determined which type of interaction occurred. With different surfaces, different temperature ranges could be employed. The range of catalytic materials and the temperature ranges in which they operate were correspondingly expanded. With the advent of isotope separations, signalized by Urey's discovery of heavy hydrogen, followed by heavy oxygen, carbon, nitrogen and sulfur, new tools became available for the study of the associations with surfaces involved in catalytic changes. To-day the analysis is going yet deeper. With the modern tools of x-ray and electron diffraction the catalytic chemist is examining the activities of individual faces of crystals and is demonstrating that the geometrical configurations characteristic of particular faces are more favorable to the activation of reactants than are other faces. As a consequence methods can be developed to produce the desired crystal faces in preponderant amount. Twenty-five years ago the science of catalysis was almost purely empirical, dependent entirely on trial and error. As the University of Pennsylvania enters upon its third century of intellectual effort, the chemistry of reactions at surfaces has become a highly refined scientific study, rich in possibilities for applied science and in joyous endeavor for the fundamental scientist.