H. T. Hall

Reprinted from Science, May 17, 1963, Vol. 140, No. 3568, pages 781-789

High-Temperature Research

By means of "liquid containers," liquid metals can be studied at much higher temperatures than heretofore.

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The field of high-temperature research is a great frontier of science. But it is by no means a new frontier. Since prehistoric times the attainment of higher and still higher temperatures has characterized successively more advanced civilizations. Thus, the stone age gave way to the bronze age, and the bronze age, to the iron age. In the last 20 years men have learned how to produce temperatures equivalent to those of the sun and stars, if only for an instant, and we have the atomic age and the space age. But space technology requires the production of exceedingly high temperatures for long periods, not just instants, for powering rockets and producing the components of spacecraft. This we must accomplish if we are to continue our scientific advance and lead the way into space.

High-temperature research is a field of very broad scope, involving as it does the sciences of chemistry, physics, metallurgy, and ceramics. An important problem is that of producing high temperatures by chemical reactions, which necessarily must have thermally stable reaction products. This can be achieved in several ways—through combustion of metals in oxygen; through combustion of gaseous mixtures; or through plasma jets. In every case, there is a corollary problem—that of confining or containing chemical substances at temperatures which conventional containers cannot withstand. In this article I discuss the high-temperature research conducted by the Research Institute of Temple University, since it illustrates several important aspects of the subject. The Research Institute has devoted its main efforts to this field for the last 16 years. I will attempt to give a more or less historical outline of our studies and to show how our investigations led to new possibilities—to the attainment of high flame temperatures, the development of a "liquid crucible," and the establishment of some relationships for liquid metals.

The first problem we considered was, How high a temperature can be reached for extended periods through chemical reactions? Combustion of wood, charcoal, and coal has been for ages the standard method of producing heat. In contrast, the combustion of metals in oxygen had hardly been studied at all, and our first efforts were devoted to this subject.

The chemical production of high temperatures requires not only the evolution of great heat in particular chemical reactions but also thermal stability of the reaction products. As the temperature increases, the dissociation of the reaction products into atoms, radicals, or intermediate unstable molecules increases until a balance between the evolution of heat and the energy of dissociation is reached at a particular temperature, usually defined as the flame temperature.

At the temperature of the sun's disk —that is, about 5000° to 5500°K— only about a dozen compounds can exist, as one may easily deduce from spectroscopic analysis (*1*). This group of compounds can be divided into metallic and nonmetallic compounds. The metallic compounds include four oxides (AlO, MgO, ZrO, TiO), two fluorides (MgF and SrF), and two hydrides (MgH and CaH). The five nonmetallic compounds are N_2, CO, C_2, CN, and OH. The heats of combustion of various metals in oxygen are given in Table 1 and compared with the heats of combustion of hydrogen, carbon, methane, and carbon monoxide. As Table 1 shows, hydrogen and hydrocarbons generate, on an equal weight basis, more heat than the metals generate; this is due to their high heats of combustion and their low atomic

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