

"Accepting this view, Gurlt considers steel as a combination of $\text{Fe}_3\text{C} + \text{Fe}$; Tunner, as a combination of $\text{Fe}_4\text{C} + \text{Fe}$; Lohage, as certain combinations of carbon (Fe_{12}C , Fe_{20}C , Fe_{28}C) consisting of tetrahedral molecules which admit of hardening in opposition to compounds forming octahedral molecules which cannot be hardened.

I have quoted this somewhat fully because the opinions expressed are not a little remarkable. It will be seen that the chemist of that day had formulated theories which at any rate to some extent were running in the direction in which modern research seems to be tending with regard to combinations of iron and carbon. It seems to me, too, that we have not followed up this particular direction of research as much as might have been the case.

Prize for Research Work.

This is a rich and profitable field for the younger chemist if he will devote his attention to this particular branch of chemical research. In fact, to show the importance I attach to this subject, I have suggested to the two leading Institutes in England and America, namely, the Iron and Steel Institute and the American Institute of Mining Engineers, that I am willing to offer a prize of £200 for the best paper or research on this subject—in other words, to continue the investigations with regard to the combinations of iron and carbon, and thus follow up the great work originated by Abel, Muller and Ledebur. This competition is not confined to any particular country, but is international and open to all.

The following suggestions are also added for the guidance of those who wish to take part in this competition. While it is not desired to define too closely the exact lines or scope of the research, as it is advisable to make these as broad as possible, the object in mind may be said to be generally as follows:

To elaborate and find out the best methods of determining the forms of carbon in steel or iron, including those in iron alloys. A portion of the work would probably be a continuation of the researches which have in the past been carried out by Jullien, Abel, Muller, Ledebur, T. Sterry Hunt, Akerman, Arnold, E. D. Campbell, Stead, Hogg, Parry and others.

In a generic way, metallurgists now speak of carbides, sub-carbides, double carbides, special carbides and other combinations. It is very desirable that those should be accurately defined and understood.

It is also desirable to know whether there are other or new forms; if so, can these be separated and their characteristics obtained?

It may be interesting to point out that the carbon compounds now definitely known are stated to number over 80,000. It is very probable, therefore, that there is room for much valuable and useful research to be carried out with the object of increasing our knowledge of the various combinations of carbon with iron, as probably some of these are still unknown.

In addition to research work upon particular forms of carbide which have not yet been determined, it is also desirable and necessary to determine the state in which the carbon exists. For example, there exists what is termed a "missing form" of carbon, about which little is known or understood. More light is required about this form, as for many years very little has been added to our knowledge on this subject. It would be desirable, for example, to know whether the carbon not accounted for as carbide is "missed" in consequence of its being in so fine a state of division,

or whether it is present in some special form or condition.

It may be mentioned as a general statement that when steel is in the austenitic condition it is softer than when transformed to the martensitic formation. In the former, the carbon is considered to be in complete solution; yet steel showing martensitic structure is said to contain its carbon in complete solution also. If it could be shown that the martensitic formation results from the commencement of the falling out of solution of the carbon, this would be of great assistance to all those who are desirous to have increased knowledge in this direction. It is therefore desirable to know exactly in what state the carbon exists in the austenitic and martensitic formations.

It is also necessary, if possible, to ascertain the molecular constitution of the carbides. Such a point has been raised by the able American scientist Prof. E. D. Campbell, and much important research work has been carried out by him with regard to certain particular combinations or forms of carbide. In other words, is the ordinary carbide Fe_3C , Fe_4C_2 , or is it some other combination? If so, what is its nature and molecular constitution?

The above seems to be an outline of the general direction which should guide those considering and taking part in this research. It is hoped that the results obtained will throw much light on the cause of the hardness of steel, also the nature and form of carbon combinations with iron and its alloys.

Effect of Carbon Upon Iron.

In the matter of alloys of iron with other elements, the fact should not be lost sight of that carbon still pre-eminently holds a position of supreme importance, for the presence of carbon even in special alloy steels is, with some few exceptions, absolutely necessary. Take as an illustration high-speed tool steel, which has led to such an enormous saving in machine shop practice, with consequent benefit both as regards quicker and greater output, combined with greater precision of execution. Whilst the carbon present need not be relatively high, yet there must be sufficient carbon present, otherwise the cutting properties of the steel in question would not be attained. The explanation is probably as follows: In high-speed tool steel of modern composition there is usually about 16 to 20 per cent. of tungsten, 2 to 4 per cent. of chromium, and about .70 per cent. of carbon. Before treatment of the steel, the carbon exists in the form of carbide carbon and hardening carbon as defined by Ledebur.

Hardening carbon	.18%
Carbide carbon	.56%
Total carbon	.74%

After treatment, and with the nose of the tool in the condition required for mechanical work, we find the carbon content to have been transformed into

Hardening carbon	.60%
Carbide carbon	.14%
Total carbon	.74%

Therefore, when we talk about the wonderful effect of the addition of elements other than carbon to iron, we must not fail to recognize that many, if not all, the new properties acquired by the steel are due entirely to the marvellous change that the treatment has wrought in the form of the carbon present, that is, its transformation from the soft or carbide carbon into