complete magnetic alignment of the iron because of demagnetizing effects in the powder particles of varying shapes.

More experimental data on the complicated solid/gas reaction processes are clearly needed before these interesting magnetic effects can be explained. It seems that the energy changes in the magnetic field of the reaction components are too small to give observable changes in the equilibria.

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¹ Skorski, R., *Nature phys. Sci.*, **240**, 15 (1972).

² *Hb. chem. Phys.*, E-61 (Chem. Rubber Co., 1964/5).

Accelerated Reaction Rates in a Magnetic Field

SKORSKI¹ reports that the rate of reduction of haematite powder to metallic iron by hydrogen is significantly increased by the application of a magnetic field. Because this effect was not observed using other reducing gases, he proposed that the acceleration is due to the magnetic properties of hydrogen.

An accelerated reaction rate for this process in a magnetic field may be predicted on a thermodynamic basis similar to that outlined by Peters *et al.*². This approach predicts that a magnetic field will exert a large effect on reactions in which the parent and product species differ widely in their magnetic properties.

The reacting haematite is antiferromagnetic and the product is strongly ferromagnetic. In a magnetic field, the ferromagnetic phase will be favoured; this will give rise to two possible effects: a lower transformation start temperature, and an accelerated reaction rate at a given temperature.

Both these effects were observed by Skorski¹.

This simplified picture outlined is complicated because the reduction of haematite to iron occurs via an intermediate reaction:

But this reaction will also be favoured by an applied magnetic field. The rate-controlling factor in haematite reduction is very difficult to define, the overall reaction kinetics being very dependent on the morphology of the reacting particles and other experimental variables. Because both the participating reactions are favoured by a magnetic field, it is safe to assume that a noticeable increase in reduction rate will occur when a field is applied.

In the thermodynamic approach, the accelerating factor is proportional to the field strength (at constant temperature). Thus the acceleration effect will always increase with increasing field strength, although the relationship will not necessarily be linear. The model proposed by Skorski does not satisfactorily explain the increased acceleration by field strengths above the magnetic saturation of iron (where the attraction for hydrogen molecules would remain virtually constant), nor does it readily explain the observed shift in the reaction start temperature.

The obvious drawback to the thermodynamic approach is its failure to account for the extremely interesting observation that the reduction kinetics in CO and CH₄ atmospheres were virtually unaffected by a magnetic field. It is possible that the rate-controlling factor in these experiments was the ability of the reducing gases (much larger molecules than H₂) to reach the reaction interface. In this case the magnetic field would show little or no effect.

It would be most interesting to perform similar experiments

in such a manner that the magnetic field may be applied at various times during the reduction process, and the corresponding change in reaction rate recorded. This could be achieved using a modified thermal autobalance incorporating an electromagnet around the specimen holder. Quantitative analysis of results would be simplified by consideration of a simpler reduction process (single stage) and a more well defined reaction volume. If the standard (zero field) kinetics for the chosen reaction are well established and quantitatively defined, the results of such experiments may well prove useful in the evaluation of thermodynamic data for the reaction considered. This is made possible because the application of magnetic field may be regarded as the injection of a well-defined (and readily calculated²⁻⁴) increment of energy into the reacting system, whilst remaining under isothermal conditions. Thermodynamic changes due to changes in temperature, pressure or composition are much less easy to evaluate.

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¹ Skorski, R., *Nature phys. Sci.*, **240**, 15 (1972).

² Peters, C. T., Bolton, P., and Miodownik, A. P., *Acta Met.*, **20**, 881 (1972).

³ Satyanarayan, K. R., Elias, W., and Miodownik, A. P., *Acta Met.*, **16**, 877 (1968).

⁴ Satyanarayan, K. R., and Miodownik, A. P., *The Mechanism of Phase Transformations in Crystalline Solids*, 162 (Institute of Metals, 1969).

Reference Abbreviations

FROM September 1 it is *Nature's* intention that all abbreviations of references should conform to the style of the *World List of Scientific Periodicals*, fourth ed. (Butterworth, 1963-65). The changeover will be gradual and authors submitting manuscripts from now on are asked to ensure that the references are written appropriately.

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