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The Effect of Magnetic Fields on Heterogeneous Catalytic Reactions

The possibility that a magnetic field may have an effect on chemical reactions has been investigated sporadically for nearly two centuries; indeed as early as 1847 Wartmann (*1*) published a study on this topic and showed that a magnetic field had no effect on gas evolution during the electrolysis of water or on the deposition of copper from a solution of its salts. A century later Selwood (*2*) reviewed many pertinent reactions and the qualitative effect of magnetic fields on reaction rates and on solubility parameters. Selwood continued his interest in magneto-catalysis with particular reference to *ortho–para* hydrogen conversion in the presence of rare-earth oxides in a magnetic field. A review of this work has been presented (*3*). Other studies relating to magnetism and rate of crystallization, or concerned with magnetism and biological behavior, have also received attention.

The magnetic properties of the catalyst itself in relation to reactivity have received careful study, particularly in respect to hydrocarbon manipulation. However, the effect of an external magnetic field on a heterogeneous catalytic reaction in which the catalyst is ferromagnetic and one of the gaseous reactants has magnetic properties has not been reported; at least a literature search assisted by both the Lockheed and Dialog data bases revealed no published information. The present note now describes such an experiment.

The simple system of the oxidation of carbon monoxide over a ferromagnetic iron oxide catalyst was chosen for the study because of the ease of monitoring the reaction. Any change in the product gas composition was measured by an infrared gas analyzer capable of detecting CO_2 concentration changes of 0.02%. Within experimental error, no change in the composition of the product gases could be detected when the reaction zone was subjected to magnetic fields up to 18 kG, at temperatures between 20 and 250°C. The procedure followed is considered to justify a short report in order to illustrate the rigor of the test.

The reactant gas was a certified calibrated mixture of 9% CO, 4.5% O_2, and 86.5% N_2 delivered from a cylinder which was provided with a two-stage pressure reducer followed by a needle valve to control the flow. Two 3-liter rubber balloons were placed in the gas line to the catalyst chamber to act as ballast tanks and to ensure even flow. Sintered glass flow distributors were placed immediately "upstream" from the catalyst bed.

The reactor was a 30 cm length of Vycor silica tubing (diam. 14 mm) centrally packed with roughly powdered catalyst to a length of 65 mm. Heating was obtained by means of two 11-cm-long Nichrome strips placed lengthwise along the top and bottom of the packed section of the reactor. The electromagnet (Alpha type M7500) was capable of providing a field of up to ca. 20 kG using a 22-mm gap. Shaped pole pieces distributed a linear field across the catalyst section of the tubular reactor which fitted snugly within the pole gap. A thermocouple was placed within the catalyst bed.

The product gas left the reactor via a cooling coil and an exit flow meter. Pressure in the catalyst chamber was maintained constant at 0.74 kPa (gauge) at a gas flow rate of 400 ml/min.

The gas analyzer was a Horiba Mexa

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double-beam infrared gas analyzer (Model 300A) modified by the manufacturer to estimate CO and CO_2 in two ranges (CO, 0–10% and 0–2%; and CO_2, 0–15% and 0–5%), with an accuracy of 2% full-scale (after calibration) and a lower scale sensitivity of better than 0.03% for either gas. The instrument contained diaphragm-type exhaust pumps and ancillary equipment.

Each experiment consisted in the passage of the mixed gas through the catalyst bed for about 30 min at a determined temperature until the composition of the gas reached a steady state. The magnet was then energized and the gas composition was monitored.

To obtain a qualitative appreciation of the magnetic properties of the catalyst, a separate experiment was conducted in which a test tube was vertically placed so that only the upper portion was between the magnet pole pieces. Approximately 4 ml of catalyst pellets was placed in the tube in such a position that, on energizing the field, the pellets were lifted vertically en masse about 7 cm. The bottom 6 cm of the tube was heated by a small hand-wound furnace and the temperature of the catalyst measured by a thermocouple placed within the catalyst charge. The catalyst was heated slowly and the magnet energized, at 20°C intervals, between ambient temperature and 290°C. Throughout the whole temperature range the catalyst behaved in a strongly ferromagnetic fashion. Several proprietary catalysts were examined and the behavior reported herein is that of a well-established commercial high-temperature carbon monoxide conversion catalyst.

Under the conditions described above, within a temperature range from 20 to 250°C and with conversions up to 92% CO_2, the magnetic field had no detectable effect on the composition of the product gas.

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