

Coal Liquefaction

The tightening of worldwide oil reserves is causing the price of oil to escalate — and makes coal, which is much more abundantly available, an interesting starting material for liquid fuels and chemical raw materials. Researchers at the Max Planck Institute for Coal Research in Mülheim on the Ruhr have developed a new process that makes it possible to liquefy high-grade bituminous coal (semianthracite coal) for the first time. This type of coal has previously been used exclusively in combustion and gasification processes.

“Methods of coal liquefaction have been available since the beginning of the last century, but the cost has caused us to search for more effective new processes,” explains Matthias W. Haenel. Coal is a complicated, difficult to analyze mixture of organic components. In what is called the Bergius process for direct coal liquefaction, the coal is treated with hydrogen under pressure (>30 MPa) at 450 °C in the presence of a solvent and an iron oxide catalyst. The activity of this catalyst is low, however, because the solid iron oxide cannot enter the macromolecular network structure of the insoluble coal. Semianthracite coal, which only contains a small amount of volatile components, cannot be converted by this process at all. Haenel and his team hoped that a soluble catalyst would serve them better.

They thought the family of borane catalysts, boron–hydrogen compounds known to transfer hydrogen atoms to organic molecules, seemed especially promising. Their studies of a German Magerkohle (low-volatile bituminous coal) showed that a mixture of sodium borohydride and iodine, which formed an iodine–borane catalyst in the reaction mixture, is particularly effective. Surprisingly, under the drastic reaction conditions used (25 MPa hydrogen pressure, 350 °C), iodine alone is catalytically active, though boron triiodide is best.

The solubility of the coal in pyridine is drastically increased by this treatment. One reason for this is that carbon–carbon bonds between aromatic and nonaromatic (aliphatic) parts of the molecules are broken and the free “bonding arms” are saturated with hydrogen (hydrated); the network structure of the coal is disrupted. In addition, the double bonds of the aromatic ring systems are partially hydrated so that the aliphatic content rises at the cost of the aromatic. The new process is the first “true” coal hydration in the sense of hydrogen being added to unsaturated structures. Once prepared in this way, high-rank coals could now be liquefied in a subsequent conventional hydrocracking process for the first time.

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