

literature, resulting in equation (10). The numerical values in equation (10) are similar to those found in

$$r_{\text{CO}_2} = \frac{k_c P_{\text{CO}_2} C_c}{1 + K_1 P_{\text{CO}_2} + K_2 P_{\text{CO}}} \quad (10)$$

$$k_c = 7.83 \times 10^4 \exp[-184000/RT] \quad (\text{kPa}\cdot\text{sec})^{-1}$$

$$k_1 = 0.0495 \text{ (kPa)}^{-1}$$

$$k_2 = 5.0 \text{ (kPa)}^{-1}$$

the coal literature except that the inhibiting effect of CO is ten times greater.

STEAM GASIFICATION

STEAM GASIFICATION ALSO PROVED difficult to isolate since the CO formed by reaction (3) was found to react very rapidly via the water gas shift reaction (WGSR), reaction (4). The CO₂ formed in that reaction then competes with H₂O for the available carbon. In fact the net effect of steam gasification is to produce H₂ and CO₂ and, after CO₂ scrubbing, the H₂ could be used to offset hydrotreating requirements for the raw shale oil. We were able to circumvent these interactions by taking initial rate data [7] and the rate expression is given in equation (11).

$$r_{\text{H}_2\text{O}} = \frac{k_s P_{\text{H}_2\text{O}}}{1 + K_3 P_{\text{H}_2\text{O}} + K_4 P_{\text{H}_2}} \quad (11)$$

$$k_s = 6.62 \exp[-100700/RT] \text{ (kPa}\cdot\text{sec)}^{-1}$$

$$K_3 = 0.20 \exp[-17000/RT] \text{ (kPa)}^{-1}$$

$$K_4 = 0.15 \text{ (kPa)}^{-1}$$

CATALYTIC EFFECTS

OVER THE YEARS THERE HAS been a continuing interest in alkali promoted catalysis of coal gasification and, more recently, of biomass pyrolysis. In both of these applications an alkali salt must be added to the fuel, either by impregnation or by admixing. However, with oil shale we already have many of these elements in place. It is not surprising then that CaO was found to catalyze char combustion and, later, to catalyze steam gasification [7]. Recall that iron is also present in the shale, either in the form of ankerite (Table 1) or pyrite. In either case, oxidation and its associated high temperatures result in producing one or more of the oxidation states of iron (FeO, Fe₂O₃, Fe₃O₄). We have studied the WGSR over shale ash [7] and not only is it catalyzed by iron, but the iron oxidation state changes as the surrounding gas composition changes. Again, as in the case of CaO, we have a variable catalyst concentration and the dependence

of activity as a function of catalyst concentration has yet to be quantified.

CONCLUSIONS

As is the case with most complex mixtures, the study of oil shale and its reactions is a challenging subject. Whereas we have managed some success with the obvious, the subtle and varying catalytic effects of the inorganic matrix is still in the early stages of investigation. It is likely that we will discover more interesting catalytic properties of shale ash as we continue our studies. □

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ChE book reviews

COAL AND MODERN COAL PROCESSING: AN INTRODUCTION

By G. J. Pitt and G. R. Millward
Academic Press, New York, 1979

Reviewed by T. D. Wheelock
Iowa State University

A number of books dealing with the properties of coal and methods of utilizing this complex and interesting material have recently appeared. Not least among them is this volume of lectures presented during the 1976-77 session of the University College of Wales to commemorate a British coal scientist Dr. Walter Idris Jones. These lectures were presented by various technical experts from the National Coal Board in England and edited by G. J. Pitt, one of the lectures, and G. R. Millward who was with the University at the time.

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COAL PROCESSING

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The lectures or chapters cover a wide range of topics starting with the origin and formation of coal and continuing through the physical and chemical structure and properties of coal, and methods for processing and utilizing various kinds of coal. Although established technology is reviewed, there is an important emphasis on newer techniques such as fluidized bed combustion, supercritical gas extraction, and the production of carbon fibers. New processes under development for manufacturing gaseous and liquid fuels from coal are also discussed. There is an additional chapter not covered by the original lectures which deals with the application of high resolution electron microscopy to study the microstructure of graphitized and partially graphitized carbons derived from coal.

The volume is highly readable and provides a basic but rather brief (210 pages) introduction to the science and technology of coal utilization. It does not probe any topic in great depth nor provide many details and the list of references at the end of each chapter is short. On the other hand, it does provide a good overview of a number of topical areas and should appeal to a great many readers who desire a brief introduction to the subject. Furthermore, even though the book tends to emphasize technology which is of particular interest to the British, it includes enough material about new developments in the United States and other countries to insure world-wide interest. The volume could well serve as a text for an introductory course on coal science and technology for college students with some background in chemistry and chemical engineering. □

THE CHEMICAL REACTOR OMNIBOOK

By Octave Levenspiel; published by the author and distributed by Oregon State University Book Stores, Corvallis, OR 97330

Reviewed by Rutherford Aris
University of Minnesota

As one who has often been puzzled by the ways of publishers it is refreshing to find them at once so right and so wrong. So wrong those conventional publishers who declined a book of Octave Levenspiel's; so right, the author and the Oregon

State University Book Stores who published the book in the form which it takes. In it the problems are beautifully typed and are linked by chapters in Levenspiel's own hand. This is a round cursive of admirable clarity and consistency and in itself conveys the vitality and interest of the spoken word. When linked with his figures and sketches in the organic way which he achieves, we have the effect of being in the classroom with a teacher of known and valued vitality and his pages have all the immediacy and effectiveness of the author's presence.

One of the first things the teacher of chemical engineering will spot is that here is a positive gold mine of problems. There are no less than 1394, though it must be admitted that many are one-line modifications of their neighbors. The book is divided into seven main divisions (numbered to leave a small remainder when 10 n is subtracted, $n = 0, 2, 3, 4, 5, 6, 8$) with an interlude between the first two and a coda on "Dimensions units, conversions and the orders of magnitude of this and that." Single phase reactors are the burden of the first division which is divided into seven sections and has more than a third of the problems. The interlude (sec. 11) is on the background of multiphase reactors and leads to a division on (secs. 21-25) reactors with solid catalysts that ranges from the particle to the fluidized bed. Then there is a discussion (secs. 31-34) of catalytic reactors with changing phases, of gas/liquid and liquid/liquid reactions (secs. 41, 42) and the reactions of solids (secs. 51-55). Levenspiel next groups together some discussions of the flow of materials through reactors (secs. 61-64, 66, 68) and concludes with a section on biochemical reactors using enzymes and microbes (secs. 81-85). It is interesting to speculate whether a future doctorate (a D.Ed. perhaps) will be awarded for discussion of what forms of life might once have played in these "Lacunae of Levenspiel" (secs. 65, 67, and the 70's).

The style of the text sections is, by design, sketchy. More often than not, it jumps from the statement of a problem and its background to a conclusion and adds certain comments afterwards. This makes it an interesting book to think of using in a course since, although one would be to some extent committed to its notation (and who among us is not fiercely jealous of their own) it would provide a most useful framework with the least restriction. Indeed Levenspiel suggests that its use might be as a supplementary text in a course and