The physical nature and manufacture of activated carbon

by G.J. McDOUGALL*

SYNOPSIS

After defining activated carbon, the author describes its structure and outlines the physical characteristics distinguishing one type of activated carbon from another. The adsorptive properties of these carbons, the raw materials used, and the manufacturing processes—chemical activation, and physical or thermal activation—are outlined. The high-temperature thermal route (which is the most important for the products employed in gold recovery) using coconut shells or coal as the raw material is then discussed in some detail.

SAMEVATTING

Na 'n omskrywing van geaktiveerde koolstof bespreek die skrywer die struktuur daarvan en gee in hooftrekke die fisiese eienskappe wat een soort geaktiveerde koolstof van 'n ander onderskei. Die adsorpsie-eienskappe van hierdie koolstowwe, die grondstowwe wat gebruik word, en die verwaardigingsprosesse—chemiese aktivering en fisiese of termiese aktivering—word in hooftrekke behandel. Die termiese hoëtemperatuurroete (die belangrikste roete wat betref die produkte wat in goudherwinning gebruik word) wat van klapperdoppe of steenkool as die grondstof gebruik maak, word daarna redelik in besonderhede bespreek.

Introduction

Carbonized wood, which can be regarded as a crude form of activated carbon by present-day standards, has been in use for many thousands of years. In about 1500 B.C., the Egyptians, who were aware of the adsorbent properties of wood charcoal, used it for medicinal purposes and as a purifying agent, as did the ancient Hindus, who filtered their drinking water through charcoal¹.

The decolorization and gas-adsorption properties of various carbon products were first investigated in the late nineteenth century, their development having gained impetus from the need for gas adsorbents to protect people against the poisonous gases used in World War I, and also from new applications that arose in the sugar industry and that are related to decolorization.

The ability of activated carbon to adsorb gold from chloride solutions was first reported² in 1847. This information attracted considerable interest and, in 1880, Davis³ patented a process in which wood charcoal was used to recover gold from chloride leach liquors. This process was subsequently to become popular, particularly in Australia.

Shortly after the discovery by MacArthur and the Forrest brothers in 1890 that cyanide was a good solvent for gold⁴, Johnson⁵ (1894) patented the use of wood charcoal for the recovery of gold from cyanide solutions. Since then, major developments have occurred in the technology relating to the manufacture of activated carbons, which are currently employed commercially in a wide range of industries.

Important applications relate to the use of activated carbons to render water potable by the removal of taste, colour, odour, and undesirable organic impurities, in the treatment of domestic and industrial waste water, in the removal of colour from various types of sugar syrups, in a variety of gas-phase applications, and in the purification of many chemical and pharmaceutical products and foodstuffs. Activated carbon also recently found increased application in the field of hydrometallurgy, particularly in the recovery of gold, silver and, to a lesser extent, molybdenum⁶⁻⁸.

Despite the commercial importance of activated carbon, little is known outside the industry itself about the raw materials that are suitable for conversion into activated carbon, the methods of manufacture, and the properties that make a product superior for a particular use and apparently unsuitable for another.

In South Africa, the gold-mining industry is the largest single consumer of activated carbon, and it was felt that a paper dealing with general aspects relating to the manufacture of activated carbons, as well as with the properties of the resultant products, would be of interest to personnel in the industry.

What is Activated Carbon?

Activated carbon is a generic term for a family of highly porous carbonaceous materials, none of which can be characterized by a structural formula or by chemical analysis¹. The volume of the pores in activated cárbons is generally defined as being greater than 0,2 ml/g, and the internal surface area is generally larger than $400 \text{ m}^2/\text{g}$ as measured by the nitrogen BET method. The width of the pores varies from 3 Å to several thousand angstroms, and the pores are generally classified for convenience in terms of their diameters:

Macropores	500 to 20	≠ 000 Å
Transitional pores (mesopores)	100 to	500 Å
Micropores	8 to	100 Å.

In cross-section, the pores appear to be cylindrical or rectangular in shape, but can also occur in a variety of

^{*} NCP, P.O. Box 284, Bedfordview, 2008 Transvaal.

[©] The South African Institute of Mining and Metallurgy, 1991. Paper received 25th October, 1989. SA ISSN 0038-223X/3.00 + 0.00.