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Inverse Systems – Nanoporous Solids

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11.1 Introduction

Many natural materials are characterised by an inorganic framework, generally negatively charged, containing cavities, cages, or tunnels in which inorganic (charge-balancing) cations and/or water molecules are occluded. Among these materials, the zeolites form one large family of crystalline porous materials (from the Greek zein meaning ‘to boil’ and lithos meaning ‘stone’). Pore sizes in these aluminosilicates are generally of nanometric order. Because of their specific properties, the synthesis of zeolites, and more generally, zeolitic materials (zeolites and related solids) has considerably increased over the last few years. Indeed, applications are many and varied. They are relevant not only to the chemical industry (or more precisely, the petrochemical industry), but also to our everyday lives (phosphate-free washing powders, double-glazing insulation, and many others). By virtue of their porous structure and the mobility of the cations and water molecules occluded within their porous structures, these materials can be used as highly selective cation exchangers and adsorbents.

A major step forward in the synthesis of porous materials was obtained by introducing self-assembling organic entities (surfactant micelles) into reaction gels. This was the step from crystalline microporous materials to ordered mesoporous materials.

After discussing the nomenclature of porous materials in Sect. 11.2, the main families of porous solids are described in Sects. 11.3–11.5, paying particular attention to solids with ordered pore systems such as zeolites and ordered mesoporous solids.

11.2 Nomenclature: The Main Families of Porous Materials

Depending on the pore size, there are three main categories of porous solid. These are illustrated in Fig. 11.1 together with a number of examples. The
mesoporous solids, with pore sizes between 2 and 50 nm according to the IUPAC classification [1], form the intermediate category (whence the name ‘mesoporous’) between the microporous solids (pore diameter < 2 nm) and the macroporous solids (pore diameter > 50 nm). All these solids, in which pore sizes vary between the nanometer and a few tens of nanometers, can be grouped together in the family of nanoporous solids.

In the present chapter, we shall be concerned primarily with the crystalline nanoporous solids with their 3D inorganic framework, and more particularly with the zeolites and ordered nanoporous solids of the M41S family [2]. Indeed, these two families of porous solids are the only ones to have very narrow pore size distributions. We shall then describe other solids with less ordered nanopore systems that are commonly used in industry.