# Chapter 2

# POROUS ADSORBENTS

## 2.1 Industrial Adsorbents

In general, industrial adsorbents can be divided into two groups; i.e. organic and inorganic based adsorbents. The former is usually known as activated carbons of which the characteristics depend on types of carbonaceous materials, such as coconut shell, and processes of activation including condition of the processes. The latter consists of several types accordingly to composition of metal oxides and structures. Common inorganic based adsorbents are reviewed below.

### 2.1.1 Silica Gel

Pure silica, $SiO_2$, is naturally a chemically inactive, nonpolar material like quartz. However, when hydroxyl functional groups (silanol group) are formed, the surface becomes very polar and hydrophilic, as illustrated in Figure 2.1. Therefore, silica gel must contain certain fraction of water in the crystals, i.e. at least 4-6 % by weight. According to pore sizes and specific surface area, silica gel, which is

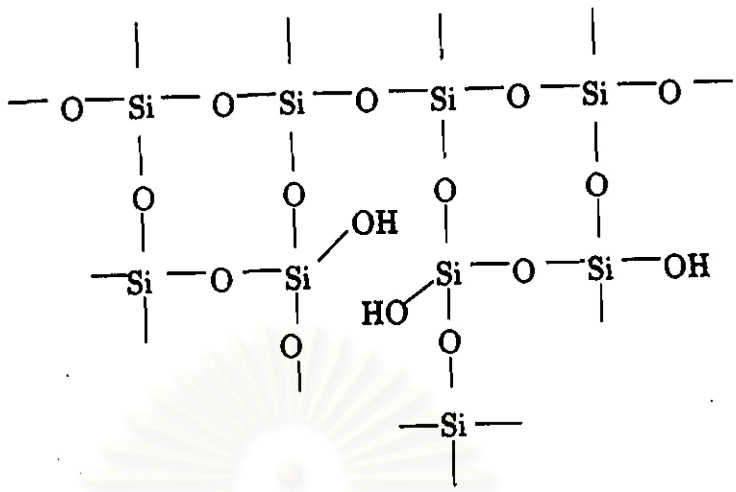



Figure 2.1: Surface hydroxyl group on silica surface

one of well-known desiccant has been divided in to 2 types : type A and type B, as summarized in Table 2.1. Type A provides higher degree of moisture adsorption than type B at low up to moderate relative humidity; on the contrary, at high relative humidity.

Table 2.1: Characteristics and Dehumidification Conditions for Common Desiccants

| | Silica Gel A | Silica Gel B | Alumina | Zeolite A |
|---|---|---|---|---|
| Pore size | 30Å | 70Å | 30-120Å | 140.21 |
| Specific surface area | 650 $m^2/g$ | 450 $m^2/g$ | 150-500 $m^2/g$ | 25.29 $m^2/g$ |
| Dehumidification condition | up to moderate humidity | high humidity | high Temperature | Extremely low humidity |

### 2.1.2 Activated Alumina

Aluminum oxides consist of several forms of crystals. Porous alumina used as an adsorbent is mainly $\gamma$-alumina. It is usually produced by dehydration of alumina hydrates, or alumina trihydrate, $Al_2O_3.3H_2O$, at controlled temperature conditions to reduce moisture content down to about 6% by weight. Both characteristics and appropriate application are given in Table 2.1. In addition, it can also be employed for removal of polar gases from hydrocarbon streams.

### 2.1.3 Zeolites

Zeolites are aluminosilicate minerals with crystalline structures. Each silicon atom, as well as aluminum atom, is bonded with 4 oxygen atoms to form tetrahedron as a primary unit. These primary units one bonded one another by sharing oxygen atom to form several types of secondary units, as illustrated in Figure 2.2. Eight of S6R units and six of S4R units are combined together to form a complex unit, called sodalite unit, which is illustrated in Figure 2.3. Each sodalite unit is bond with other sodalite units via D4R unit to form continuous crystalline structure for zeolite A, of which Si/Al ratio is equal to unity [6]. Since, aluminum (Al) atom in the tetrahedron produces a negative electrostatic charge, it is balanced with an appropriate cation, such as sodium ion. Therefore, formula for a unit cell of zeolite A, consisting of a sodalite unit and a D4R unit, are given in Table 2.2.

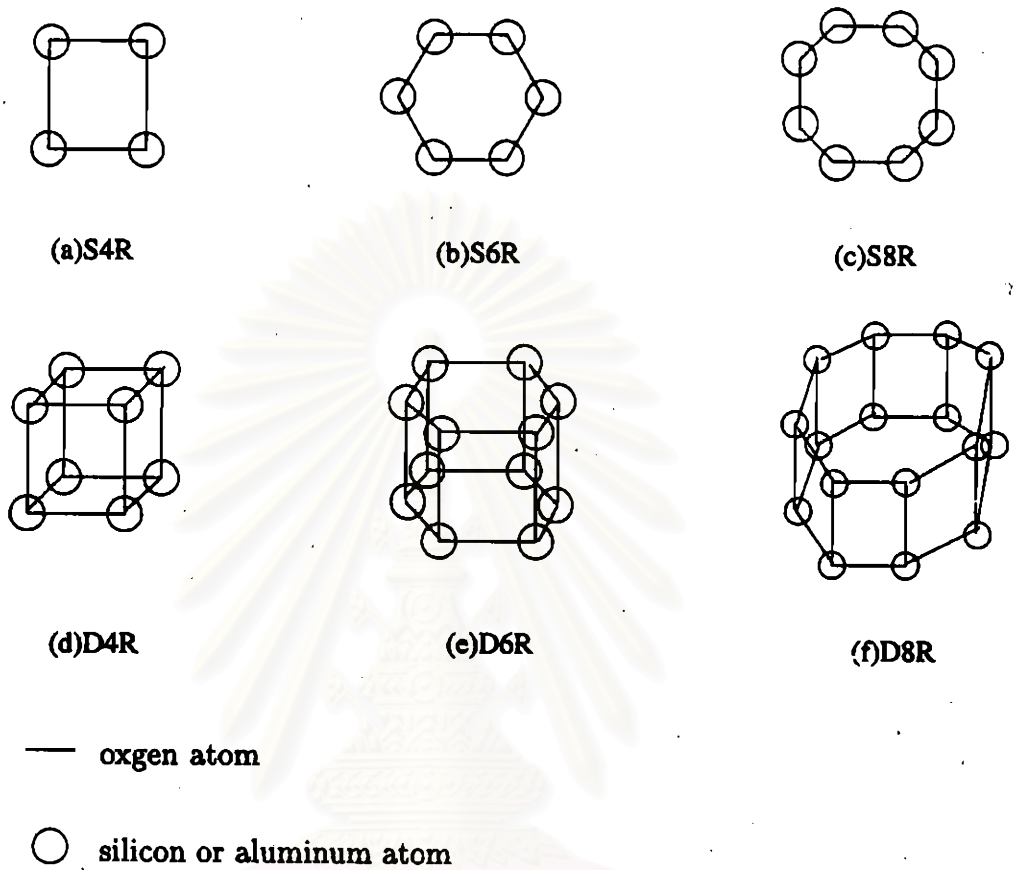
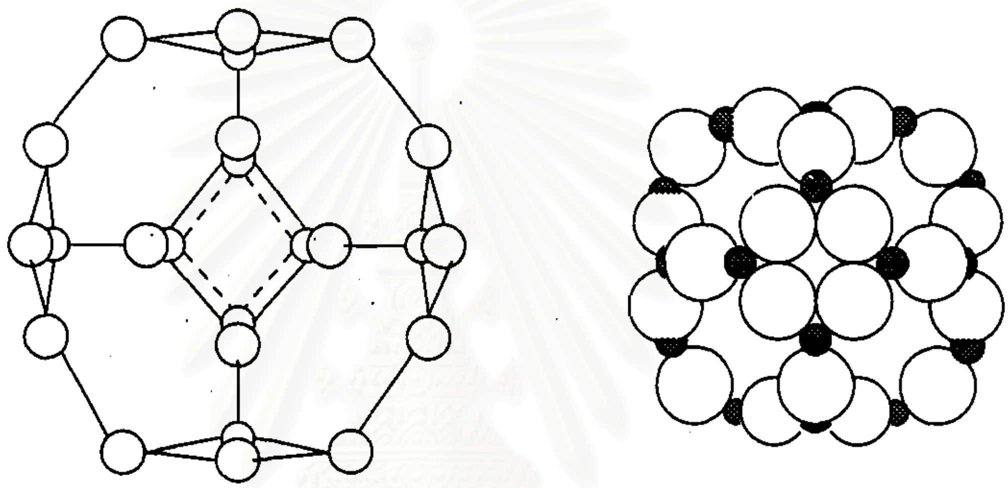



Figure 2.2: Types of secondary units in zeolite structure ( a line represents an oxygen atom, and a circle represents a silicon or aluminum atom)



Table 2.2: Formula for a unit cell of zeolite A

| Cation | Formula | Pore Diameter |
|---|---|---|
| Na | $Na_{12}[(AlO_2)_{12}(SiO_2)_{12}]$ | 3.8 |
| K | $K_{12}[(AlO_2)_{12}(SiO_2)_{12}]$ | 2.9 |
| Ca | $Ca_5Na_2[(AlO_2)_{12}(SiO_2)_{12}]$ | 4.4 |



a) Sodalite unit ($\beta$-cage)

b) Sodalite unit (with oxygen atoms)

○ Si/Al — oxygen

○ oxygen ● Si/Al

Figure 2.3: Structure unit of sodalite

## 2.2 Natural Adsorbents

### 2.2.1 Perlites

Perlites defined as a glassy volcanic rocks have been recognized since the Third Century; B.C. It was product of explosive volcanic eruption [7]. After eruption, perlite has occured as flows associated with thick accumulations of pyroclastic debris and other flow rocks, as dikes, sills, domes, and as selvages of intrusive bodies of volcanic rocks. In its naturally occurring form by immediately cooled lava and flow out of the crater. Under the proper conditions of preparation crushing and sizing, then applied to the commercial product that was higher vesicular, light weight material formed by the shock calcination, that is the distinguishing feature which set perlite apart from other volcanic rocks. When perlite was heated to a suitable point in its softening in its softening range, it expands from four to twenty times of its original volume and creates countless of tiny bubbles which account for the light weight and other exceptional physical properties of expanded perlite.

This expansion also creates one of perlite a most distinguishing characteristics: its white color.

The uses of expanded perlite are many and varied based primarily upon its physical and chemical properties. Some perlites are considered hard and has high compaction resistance and are known as hard perlite [8].

Hard perlites are particularly suited for plaster and concrete aggregate and low-temperature insulation. Because of its low thermal conductivity, high adsorption of sound, low bulk density, and fire resistance: perlite aggregate plasters hold many advantages over conventional plaster. Perlite aggregate plaster lends itself to machine applications, dries quickly, and has relatively high elasticity which reduces cracking after drying. The lower weight of perlite concrete results in substantial reducing in the cost of structural steel and foundations of large buildings.

Expanded perlite which are not suited for these applications will mill readily to produce good filter aids. As most perlites have a high silica content, usually greater than 70% and are adsorptive. They are chemically inert in many environments and hence were excellent filter aids and fillers in various processes and materials. As filter aids, expanded perlite has become increasingly more important and especially will adapted to the filtration of industrial water supplies, to the extraction of fruit juices, in sugar refining, and in the processing of pharmaceuticals.

Significant uses are made of perlite, because of its adsorptive properties in agriculture as a diluent and carrier of insecticides and herbicides and most recently, for dry bulk-blended and wet-granulated fertilizers. Because of its low specific gravity, perlite is used as a soil conditioner.

In Thailand, Perlite has been recognized since ten years ago and locates at Lamnarai volcanic rock Groups on latitude 15°00' to 15°30' north and longitude 100°45' east at amphor Chaibadan, Lopburi Province.

## 2.2.2 Pumice

Pumice is defined as essentially an aluminosilicate of igneous origin with a light-colored [9]. Pumice has occured simultaneously with perlite. The formation of pumice being with the natural build up of pressure within a blocked volcanic vent, then explosive out of the crater with high pressure into the atmosphere and fall on the ground. Upon eruption, the pressure is suddenly released resulting in the rapid expansion and the escape of the volatiles. Once contacting with the atmosphere, the molten globules cool quickly, freezing the constituent atoms into an amorphous mineral glass containing numerous bubble. Since, pumice is composed of a metastable glass which is subject to progressive devitrification (usually into fine-grained clay mineral), deposits are effectively restricted to the area of relatively recent volcanism.

The detail about definition of clay, classification of clay, structuring including formation of montmorillonits are in Appendix A.

Physical Properties of perlite and pumice

1. Light weight low density
2. Low thermal conductivity
3. High resistance to fire
4. Low sound transmission
5. Non-chemical reaction