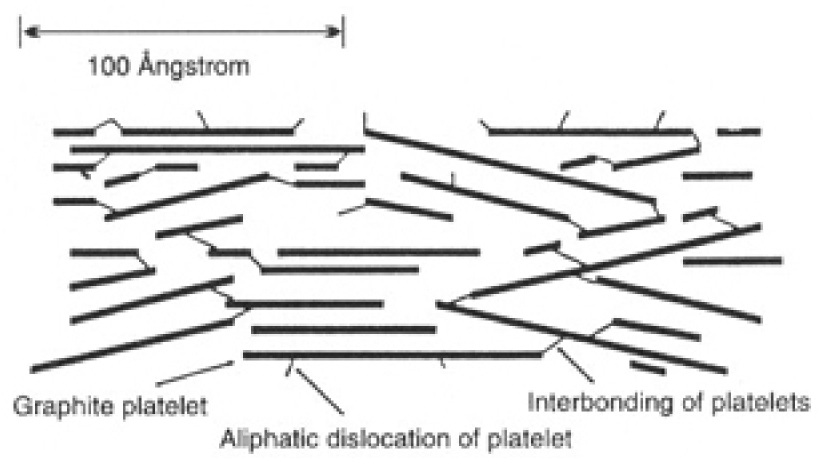
Information Bulletin

ACTIVATED CARBON PRINCIPLES

Activated Carbon



Activated carbon has been used to purify different products since Roman times. Carbon treatment is primarily based on a naturally occurring phenomenon called adsorption, in which molecules of a liquid or gas are trapped by either an external or internal surface of a solid. The phenomenon is somewhat similar to iron filings being held by a magnet. Activated carbon has a very high internal surface area and is thus an ideal material for adsorption. Purification of fluids with activated carbon can be located in any part of the sequence of plant operations. It is used from raw material purification to improving final product quality with the removal of trace components. Industrial effluents are also treated with activated carbon to remove undesirable organic compounds.

Special types of activated carbon are also produced for gas purification. Carbon has several forms in nature. The two best known crystalline structures of carbon are graphite, which is a flat hexagonal structure, and diamond which is a tetrahedral form. The following definition of activated carbon is given by Dr.M.Greenbank of Calgon Carbon Corporation.

“Activated carbon is a crude form of graphite with a random or amorphous structure, which is highly porous over a broad range of pore sizes, from visible cracks and crevices to cracks and crevices of molecular dimensions.”

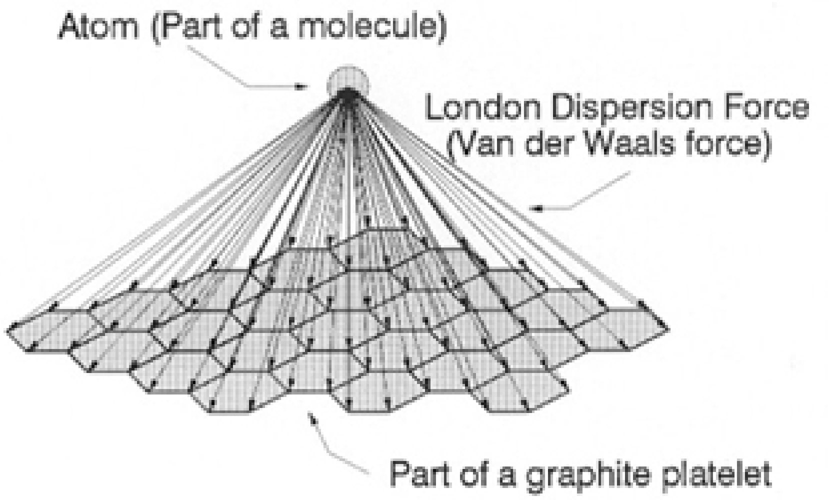
This means that activated carbon consists of a random, but locally semi-organized, number of these graphite platelets. The force that fixes the products to be adsorbed is called the London dispersion force.

This force is in fact a form of Van der Waals force, one of the four elementary forces in nature. The force is very strong, but only over short distances. The force is equal between all carbon atoms and is not dependent on outside parameters such as temperature and pressure. When considering this we can understand that adsorbate molecules will be held most strongly where they are surrounded by the most carbon atoms.

The average distance between the adsorbate molecule and the surrounding graphite platelets will govern the strength of the adsorption force. As can be seen from the picture below, some regions have a high density of graphite plates, and molecules in these areas will be subject to very high adsorption forces. Conversely there are areas with a lower density of platelets and these will exhibit lower adsorption forces. During adsorption those areas having the highest adsorption potential are occupied first and molecules adsorbed in these regions tend to be more strongly held than molecules adsorbed in areas with a lower adsorption potential. Raw material and production processes used in the manufacture of activated carbon are the basis for the different physical properties and pore size distributions found in commercial grades of carbon.

Carbon Manufacture

Activated carbon can be manufactured from a wide variety of raw materials. The predominant qualification is that the raw material should have a high percentage of carbon content. Commonly used raw materials are coal, wood, peat, coconut shells and petroleum coke. The process of converting the raw material into the finished adsorbent may be divided into chemical and thermal processes. Furthermore, the end product may be granular, pelletized or powder.



Most of the volatile organic compounds in the raw material are removed during the carbonizing stage. For some raw material such as coconut shell, the carbonizing stage is carried out where the raw material grows, e.g. in Sri Lanka, Indonesia and the Philippines.

The char or charcoal is then shipped to the manufacturers. For other raw materials, coal for example, the carbonization step is part of the activated carbon production process.

Calgon Carbon's activated carbons used in the treatment of liquid streams, e.g. potable water supplies, are produced by thermal activation of selected grades of bituminous coals.

The activation process consists of selectively oxidizing part of the structure. The activating gases that can be used are air, water vapor and carbon dioxide. Water vapor and carbon dioxide are preferred, since the reactions with oxygen are more violent, attacking the outer surface of the granules rather than developing the inner pore structure. To accelerate the endothermic reactions between the raw material, the water vapor and carbon dioxide, temperatures between 800 and 1000^{o}C are required. The properties of the final product are determined by the choice of raw materials as well as by the activation process, the retention time and activating conditions in the furnace. Steam activated carbons as produced by Calgon Carbon are produced by a multistage process involving the following steps:

- Preparation of the raw material
- Agglomeration, crushing and sieving to obtain granules of selected size
- Backing (oxidation + carbonization)
- Activation
- Screening

The most important stages of the production are the baking and activating steps. During baking, the raw materials are oxidized and carbonized. The process is highly exothermic and the temperature is strictly controlled. The oxidation stage starts at 150^{o}C increasing slowly up to 500^{o}C at the carbonization stage.

The baker product is virtually free of volatiles and already contains some pores that are, however, too small or restricted for it to be useful as an adsorbent.

$$H_2O + C \rightarrow CO + H_2 \quad \Delta H = +117 kJ$$
$$2H_2O + C \rightarrow CO_2 + 2H_2 \quad \Delta H = +75 kJ$$
$$CO_2 + C \rightarrow 2\,CO \quad \Delta H = +159 kJ$$
$$CO + \tfrac{1}{2}O_2 \rightarrow CO_2 \quad \Delta H = -285 kJ$$
$$H_2 + \tfrac{1}{2}O_2 \rightarrow H_2O \quad \Delta H = -238 kJ$$

The creation of the active surface is done during the activation step. The final structure is created in such a way that the adsorbate molecules can move between the platelets, and this is achieved by reacting the baker product with oxidizing gases. Water vapor and carbon dioxide are the preferred oxidizing gases as oxygen reacts with carbon several hundred thousand times faster than carbon dioxide or water vapor. As the reactions taking place are endothermic, heat must be supplied and a temperature of 800 to 1000^{o} is required. The energy balance is improved by burning the reaction products, hydrogen and carbon monoxide, in the furnace. The combustion of the reaction products also regenerates the oxidation gases and water vapor.

Safety Message

Wet activated carbon preferentially removes oxygen from air. In closed or partially closed containers and vessels, oxygen depletion may reach hazardous levels. If workers are to enter a vessel containing carbon, appropriate sampling and work procedures for potentially low oxygen spaces should be followed, including all applicable federal and state requirements. For additional details, see Calgon Carbon Bulletin AB-006-08/94: Safety Considerations with Activated Carbon.