PARTICLE SIZE EFFECT ON THE PRODUCTION OF ACTIVATED CARBONS FROM ANTHRACITES

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Introduction

There is a continuous worldwide growing demand for the production of activated carbons, due to the increasing number of applications of these materials, especially those related to environmental protection [1]. Each application is associated with a specific set of properties of the activated carbon, and precursors that can easily be converted into the required adsorbent materials will excel. This is the case of anthracites, since their fine pore structure makes them excellent raw materials for the production of adsorbent carbons with molecular sieve properties for gas separation in pollution control technologies [2]. However, the use of anthracites as precursors for adsorbent materials is being under-exploited, probably due to the limited number of studies assessing the possible routes for their conversion into activated carbons. Accordingly, this work presents the development of optimum routes for the use of anthracites as precursors for adsorbent carbons. A single step carbonization/activation process was used for the activation, using steam as the activating agent. The effect of particle size on the porosity of the resultant activated carbons has been investigated. The porous structure of the resultant activated carbons was characterized by conducting N_2 isotherms at 77K.

Experimental

The Pennsylvania anthracite selected for this study contains 6.8 % ash (db) and has an atomic H/C ratio of 0.19. The anthracite was ground and sieved to generate 150-250 μm and 1-3 mm particle size fractions. The activation of the samples was carried out in an activation furnace, that consists of a stainless steel tube reactor and a vertical tube furnace, as previously described [3]. Typically 5 g of sample was held isothermally at 850°C for periods of 60 to 90 minutes while flowing steam (~ 1.5 g/min). N_2 adsorption isotherms at 77K were conducted using a Quantachrome adsorption apparatus, Autosorb-1 Model ASIT.

Results and Discussion

Table 1 lists the solid yields, BET surface area (SA) and total pore volume (V_{TOT}) for the activated anthracites. For the particle size fraction 150-250 μm, the solid yield decreases as the activation time increases, going from 59% to 33% after 60 and 90 minutes activation, respectively. The larger particle size fraction presents a much higher solid yield, 79% for the 1-3 mm fraction at 90 minutes activation, compared to that of 33% for the 150-250 μm fraction. Thus, the solid yield is strongly dependent on the particle size of the precursor.

The anthracite fraction 150-250 μm activated for 90 minutes presents the highest SA and V_{TOT} (1037 m^2/g and 0.46 cc/g, respectively), while the fraction 1-3 mm activated for 90 minutes presents the lowest SA and V_{TOT} (284 m^2/g and 0.13 cc/g, respectively). These differences are strongly related to the solid yields, as illustrated in Figure 1. A very good correlation is obtained between the solid yields and the surface area and total pore volume, regardless of the particle size of the precursor.

The adsorption isotherms of the raw anthracite and the activated samples are Type I, corresponding to microporous systems. Figure 2 shows the evolution of the micro- and mesopore volume with solid yield. For all the activated anthracites, the micropore volume is significantly larger than the mesopore volume. However, extensive gasification (solid yields < 60%) seems to promote the formation of mesopores, as illustrated by the rapid change of slope of the mesopore volume evolution (Figure 3). For instance, the mesopore volume accounts for only ~8% of the total pore volume at 59% solid yield (fraction 150-250 μm activated for 60 minutes), while the mesopore volume comprises ~19% of the total pore volume at 33% solid yield (fraction 150-1250 μm activated for 90 minutes). Previous studies have shown that the increasing formation of mesopores with decreasing solid yields are due to the removal of some pore walls and enlargement of some micropores [2].

Conclusions

Anthracites can easily be converted into activated carbons by steam activation. The particle size of the precursor strongly affects the solid yields of the resultant activated samples, with higher yields for bigger particle size fractions. A very good correlation is obtained between the solid yields and the surface area and total pore volume,

regardless of the particle size of the precursor. Solid yields below 60% enhance the formation of mesopores. The molecular sieve properties of the activated carbons generated will be reported. In addition, the structural variations during the activation process, that have been monitored by using NMR and X-ray, will be presented.

References

1. Song CS and Schobert HH. Non-fuel uses of coals and synthesis of chemicals and materials. Fuel 1995; 75(6); 724-736.
2. Gergova K, Eser S and Schobert HH. Preparation and characterization of activated carbons from anthracite. Energy & Fuels 1993; 7; 661-668.
3. Maroto-Valer MM, Taulbee DN and Schobert HH. Assessing condensed aromatic coal materials as precursors for high-value carbon products. Prepr. Am. Chem. Soc. Fuel Division 1998; 44(1); 101-105.

Acknowledgments

Table 1. Solid yield, BET surface area and total pore volume for the activated anthracites.

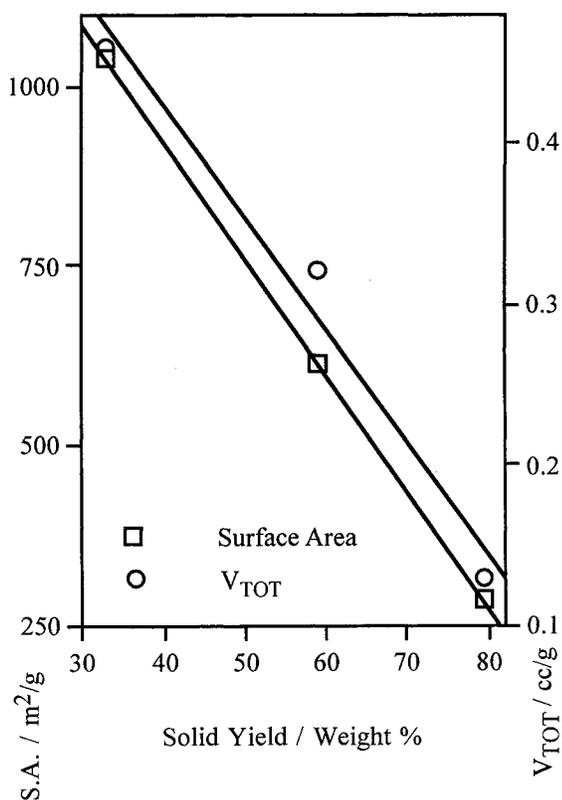| Particle size fraction	Activation time / min	Solid yield / % weight	BET S.A. / m^2/g	V_{total} / cc/g
150-250 µm	60	59	613	0.32
150-250 µm	90	33	1037	0.46
1-3 mm	90	79	284	0.13

Figure 1. Relationship between solid yields, SA and V_{TOT} for all the activated anthracites investigated.
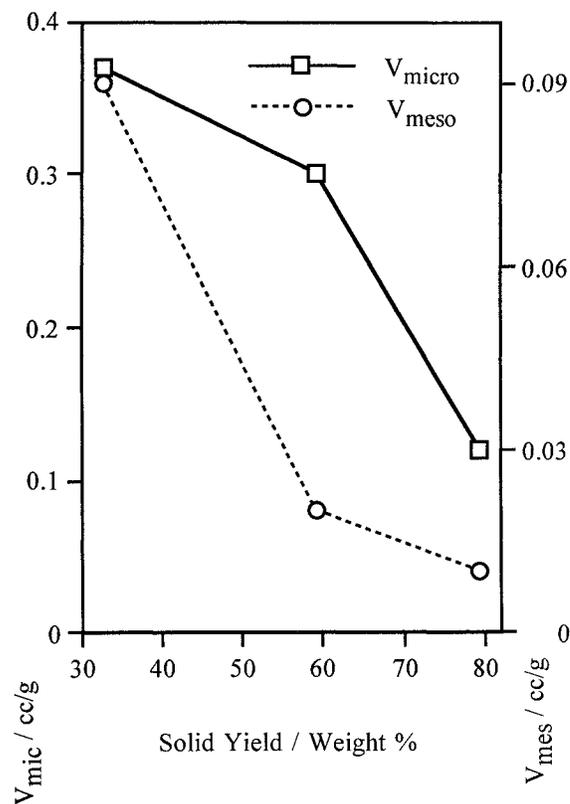
Figure 2. Evolution of the micro- and mesopore volume for the activated samples as a function of the solid yield.