The adsorption characteristics of helium on different activated carbons at 4.5-77K

Niannian Dai[1,2], Peng Jia[2*], Liguo Wang[1,2], Qianxi Qu[1,2], Huan Chen[1,2], Rong Bao[1,2], Dong Xu[2*] and Laifeng Li[1,2]

[1] Key Laboratory of Cryogenic Science and Technology, Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing 100190, China

[2] University of Chinese Academy of Sciences, Beijing, 100049, China

Wed-Po-2.4
Poster ID: 187

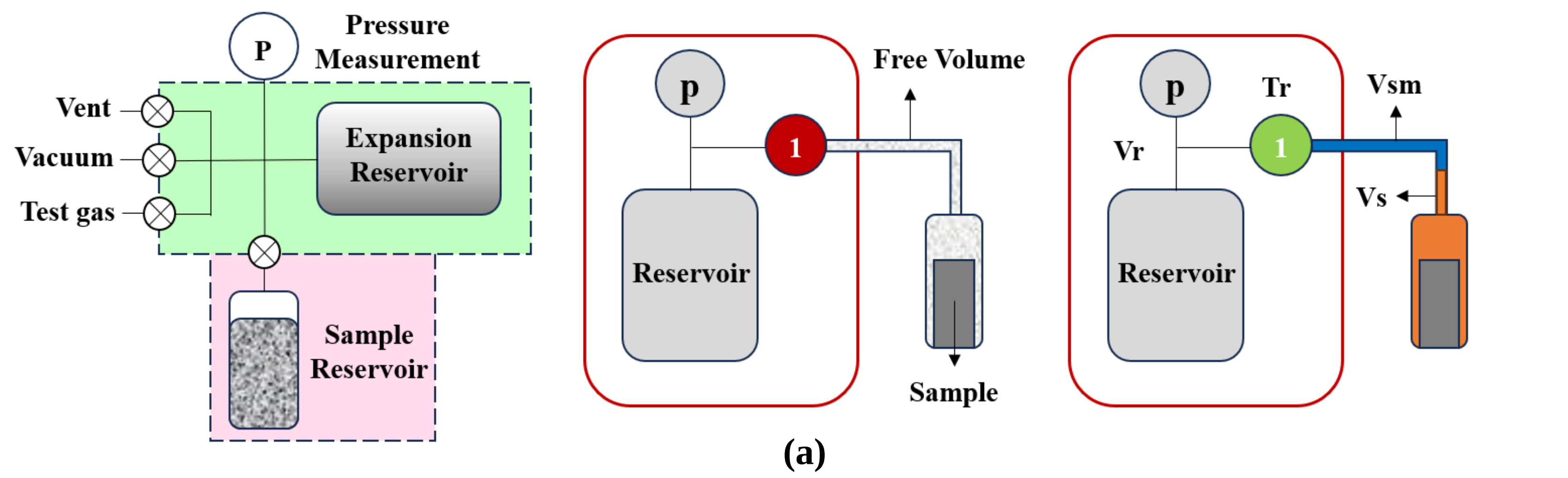
ICEC/ICMC
29th International Cryogenic Engineering Conference
International Cryogenic Materials Conference 2024
July 22-26, 2024, Geneva, Switzerland

1. Introduction

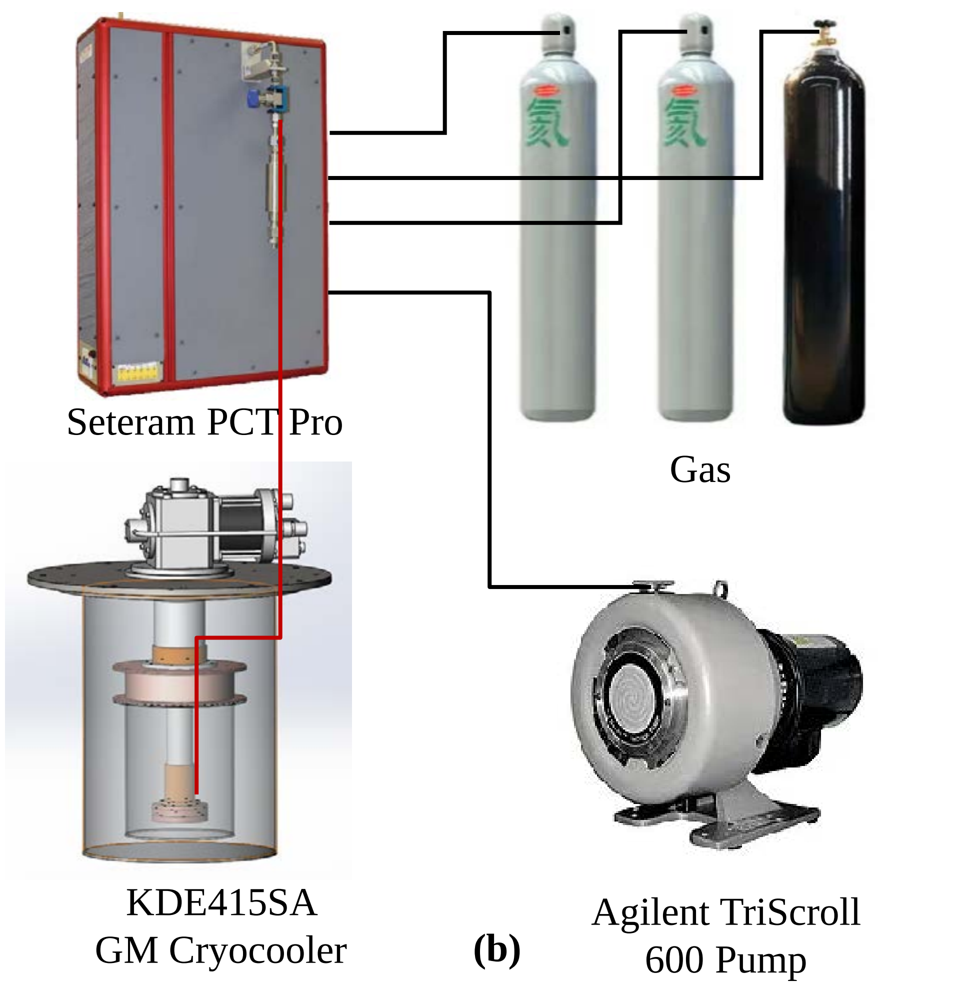
- Among three main cryogenic methods to purify ^{3}He, cryogenic adsorption can purify ^{3}He to 99.99%, which relies on the difference in adsorption energy of helium isotopes in the adsorbents.
- A crucial step in the development of helium isotope gas separation technology using adsorbents is the evaluation of the adsorption properties of different materials.
- A self-constructed cryostat has been employed to establish the helium adsorption characteristics of several commercially available activated carbon in the temperature-pressure range (4.5-77 K, 0 -1.0 MPa).

2. Experiment and methods

➢ Experimental setup



(a)



(b)

- The adsorption measurement device utilized a "Sieverts apparatus" approach to determine the gas quantities adsorbed by the specific adsorbent.
- Based on a commercial gas sorption analyzer Setaram PCT evo, a cryo-sorption setup was fabricated and a self-designed chamber was modified to connect to the second stage of the GM Cryocooler.

- Brunauer-Emmett-Teller (BET) method:

$$\frac{P}{V(P_0-P)}=\frac{1}{V_m\times c}+\frac{c-1}{V_m\times c}\frac{p}{P_0}$$

$$V_m=\frac{1}{a+b}$$

$$S=4.35V_m$$

- Langmuir model:

$$n=n_1\frac{b_1P}{1+b_1P}$$

- Isosteric heat of adsorption:

$$Q_{st}=-R\left(\frac{dlnP}{d\left(\frac{1}{T}\right)}\right)_n$$

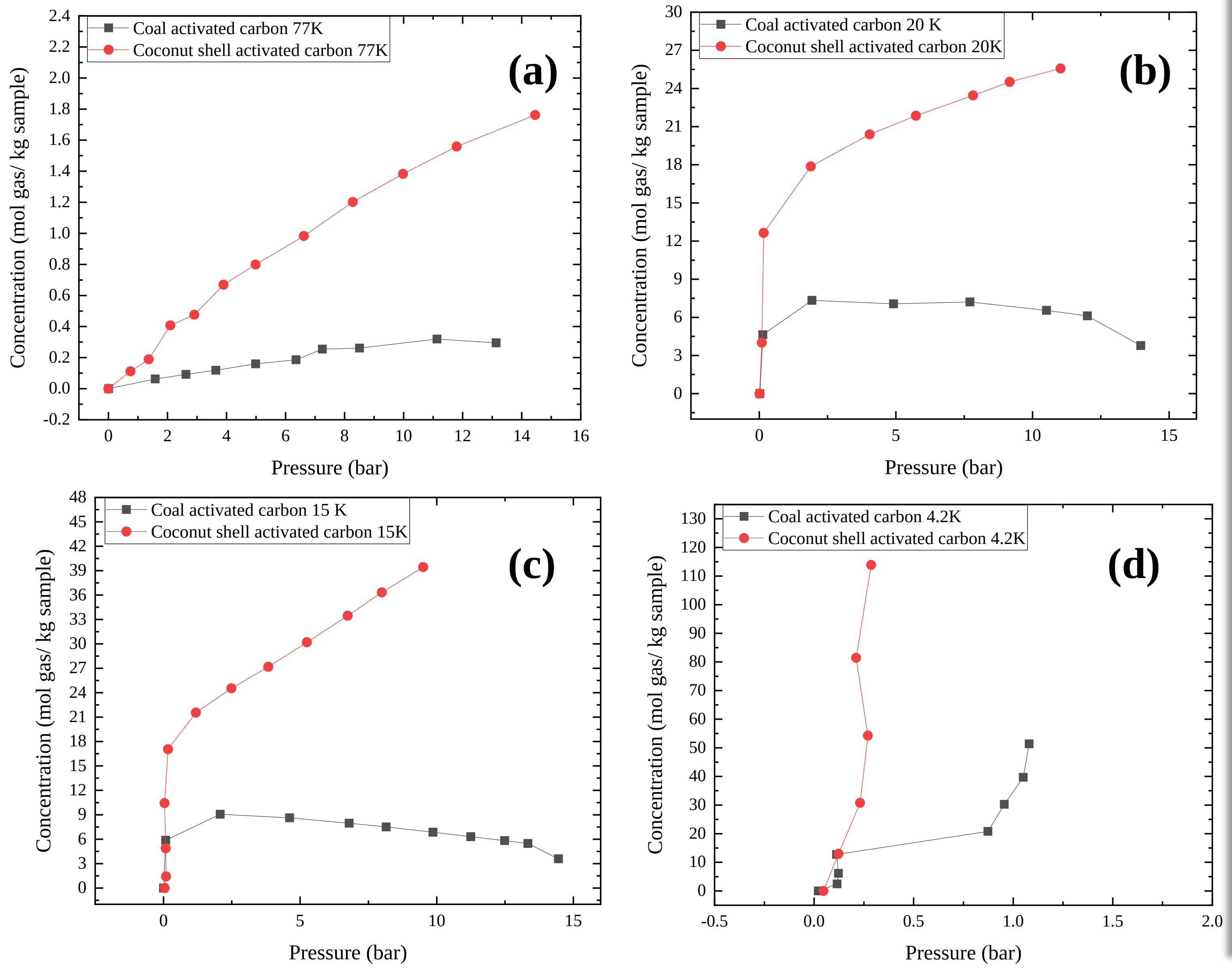
3. Material characteristics

- In this paper, coconut shell and coal activated carbon supplied by Chinese activated carbon manufacturers were tested.
- The specific surface area were calculated by using Brunauer-Emmett-Teller (BET) method based on nitrogen adsorption tests at 77K.
- The pore characteristics were calculated by Barrett-Joyner-Halenda (BJH) model.

Activated carbon	Coconut shell	Coal
Total BET surface area (m2/g)	973	906
Total pore volume (cm3/g)	0.45	0.51
Ture density (g/cm3)	1.4	1.5
Iodine adsorption value (mg/g)	1022	1000
D10(nm)	1.74	1.82
D90(nm)	6.96	111.88
BJH average pore diameter (nm)	2.36	4.29

4. Results and discussion

➢ Comparison of helium adsorption isotherms for coconut shell and coal activated carbon.



➢ Analysis

- The steep uptake at low pressure of the adsorption isotherms at 15K and 20K have been observed on both adsorbents, which primarily due to enhanced adsorption interactions in narrow micropores, resulting in micropore filling at low pressure.
- At 4.2K, within the test range below the saturation pressure of helium, the adsorption capacity of coconut shell activated carbon significantly increases with pressure.

T（K）	P（bar）
4.2	0.99
5.0	1.96

5. Conclusion

- The experiments have demonstrated the capability of the apparatus for selecting the suitable adsorbents which can be used in the system of helium separation project.
- The coconut shell activated carbon is found to be a much better adsorbent of helium when at low temperatures under same pressures.
- The characterization parameters of the selected coconut shell and coal activated carbons in this study are similar, while differences in adsorption isotherms are likely due to variations in micropore distribution and proportions.
- More types of adsorbents such as MOFs are to be tested.