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Analysis of error sources and impacts in determining the free space of sample vessels in isothermal adsorption experiments

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Abstract

The isothermal adsorption experiment is widely used in areas such as shale gas reservoir quality evaluation, coal sample adsorption capacity, and gas disaster prevention. However, when the volumetric method is used for coal rock isothermal adsorption experiments and the adsorption amount is calculated using the free space volume, anomalous results with negative adsorption values occur. This paper focuses on the impact of free space volume on adsorption capacity. Four methods which drainage and gas collection method, injection method, steel ball method, and low-pressure adsorption method are used to measure the free space volume. The study systematically explores the sources of error in each method and analyzes their effects on the calculation of adsorption capacity. The aim is to identify an accurate, convenient, and universal method for determining free space volume. Additionally, with accurate free space measurement, the pore space, porosity, and density of the sample can be directly calculated based on the sample's apparent volume and mass. Experimental comparison results show that the free space measurement by the drainage and gas collection method has a minimal range of 0.58 ml, with good repeatability, and demonstrates excellent accuracy and universality across different scenarios. The injection method also yields stable results due to the stable reference tank volume. In contrast, the steel ball method is significantly affected by the reference container volume measurement, with a fluctuation of up to 6.35 ml, confirming the direct influence of the reference container volume on free space determination. The low-pressure adsorption method, constrained by the instrument's design, leads to adsorption in the coal sample and results in larger measurement errors. Furthermore, the comparison of porosity and density measurements indicates that fluctuating free space values significantly affect the accuracy and repeatability of porosity and density calculations. This paper analyzes the differences in results and sources of error from various measurement methods, proposing a relatively accurate, convenient, and efficient method for determining free space volume. This approach improves the accuracy of free space volume measurement and provides a reference for its standardized determination. Additionally, based on the measurement process, it offers new insights for determining the porosity and density of samples.

1. Introduction

Isothermal adsorption experiments investigate the equilibrium relationship between an adsorbent and adsorbate at a constant temperature, providing essential data for understanding the adsorption characteristics of materials [1]. For instance, conducting isothermal adsorption experiments on coal