CHAPTER I
INTRODUCTION

The increase of natural gas usage in the world is one of the main guidelines to develop the energy system in several countries, due to its cheap and relatively clean combustion compared to other fossil fuels such as gasoline and diesel. From the annual forecasts of the energy outlook for the next three decades, by 2040, the natural gas consumption would rise 65 percent because companies that currently consume gasoline or diesel fuel must consider all avenues for fuel conversion (www.corporate.exxonmobil.com).

Natural gas consists primarily of methane, and varied amounts of other higher alkanes and even a lesser percentage of carbon dioxide, nitrogen, and hydrogen sulfide. Natural gas is often used for heating, cooking, and electricity generation. It is also used as fuel for vehicles. However, its major drawback as fuel is the availability of natural gas associated with offshore oil production. One of the main difficulties in large-scale natural gas usage is the long distance between oil fields and consumption sites, which sometimes do not justify constructing pipelines and pumping accessories (www.oilandgastransportationusa.com). As alternatives to transporting, storing natural gas has been considered. Three options for storing natural gas are compressed natural gas (CNG), liquefied natural gas (LNG), and adsorbed natural gas (ANG).

CNG is made by compressing natural gas. It is stored and distributed in containers at a pressure of 20 - 25 MPa, usually in cylindrical or spherical shapes. LNG is natural gas that is converted to liquid form for ease of storage and transport. The key difference between CNG and LNG is the former is stored as a gas at a high pressure, while the latter is stored at a very low temperature, becoming liquid in the process. However, the favored alternative to these two storage methods is ANG on a porous medium such as activated carbon. ANG provides better storage characteristics than CNG. Over 20 percent of the cost of CNG is related to compression, and the high performance ANG can significantly reduce this expense (www.energ2.com). ANG technology holds the promise of revolutionizing transportation fuel. ANG would allow the transition of transportation fuel to clean, abundant, and low cost

natural gas, and dramatically lowering pollution, while easing the economic burden of dependence on petroleum-based transportation systems.

The adsorption of natural gas in porous materials, in which case the gas may be stored under moderate pressures between 3.5 and 4.0 MPa, has been studied as an alternative for its storage and transport. According to Cook *et al.* (1991), activated carbon is the most adequate material for natural gas storage system due to its textural properties such as surface area and micropore volume, which may be tailored according to a given adsorbate, besides being hydrophobic and having high affinity for organic substances.

Activated carbon is considered as a versatile adsorbent. Their adsorptive properties such as high surface area, microporous structure, and high degree of surface reactivity are the main features that are utility in different applications such as purification, decolorization, deodorization, separation, catalyst supports, and also methane storage. In general, for a given starting material, several works showed that methane adsorption capacity is favored by high surface areas, high micropore volumes, and average pore sizes within the range of 8-15 Å (Biloe *et al.*, 2001; Matranga *et al.*, 1992; Parkyns and Quinn, 1995; Rubel and Stencel, 2000).

It is well known that carbon dioxide is also present in natural gas and has higher adsorption capacity than methane on microporous activated carbon, which decreases the quantity of adsorbed methane on activated carbon resulting in the low energy density (Yang *et al.*, 2011). Activated carbon can be modified with oxidative reagent, activated with a higher amount of oxygen surface groups, and consequently with less hydrophobic characteristic (Hao *et al.*, 2013). In this work, coconut shell activated carbon (CSAC) was used as a natural gas storage adsorbent. The dynamic adsorption of methane and carbon dioxide was used to study their adsorption on the modified CSAC, which was treated by alkali and applied silane coupling agent as a hydrophobic promoter to increase the methane selectivity with 3-cycle adsorption-desorption.