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Enhancing hydrogen adsorption through optimized magnesium dispersion on fibrous nano-silica scaffold: Kinetic and thermodynamic studies

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ABSTRACT

Silica material, particularly, fibrous nano-silica (FNS) is one of the potential scaffolds for hydrogen storage, however, low hydrogen adsorption limits its application. To improve its adsorption capacities, the incorporation of active metal, particularly magnesium (Mg), was prepared. FNS with well-developed pore structures and a good surface area were synthesized. Various amounts of Mg (1–5 wt%) were infiltrated into the FNS. To study the effect of metal loading, the adsorbents were characterized by their chemical structure, crystal phase, morphology/elemental composition, and textural properties. Subsequently, hydrogen adsorption studies were conducted where different reaction conditions, including metal loading, catalyst loading, and temperature were studied. Furthermore, kinetic and thermodynamic studies were conducted based on the Langmuir and Van't Hoff models. The results of the characterizations show that the Mg metal was well dispersed into the porous FNS with no significant changes in the original structure. The optimum adsorption of 1.90 wt% was achieved at 1.0 wt% Mg loading, 0.1 g catalyst loading, and 423 K temperature. Kinetic studies demonstrated that the adsorption process fits the pseudo-second-order reaction. The 1%Mg/FNS adsorbents showed good reusability where 5 runs were conducted with <5 % loss in activity. Therefore, this result indicated that infiltration of Mg into the silica is one of the most active approaches in improving the hydrogen adsorption capacities of FNS.

1. Introduction

As fossil fuel reserves deplete rapidly and the exhaust from combustion engines poses significant environmental threats, the search for alternative energy sources has intensified in recent times. The use of fossil fuels has a negative impact on international politics and peace. By 2040, the International Energy Agency (IEA) predicts that fossil fuels will supply more than 80 % of the world's energy needs. However, the use of fossil fuels has contributed to greenhouse gas (GHG) emissions, which have led to record a high carbon dioxide (CO_2) emission of 411 ppm [1]. To lessen the amount of greenhouse gases released into the environment, it is urgent to stop the effects of global warming and prepare for the impending energy deficit caused by depleting petroleum supplies. Efforts must be made to reduce GHG emissions while supplying the rising energy demand. To meet the 2 °C targets by the year 2100, a selection of low-carbon technologies, like a switch to a renewable energy source, should be used for energy storage and generation [2]. This demand for alternative sources of energy has resulted in discovering and researching renewable and sustainable different sources of energy, which are effective, affordable, and cut vehicle emissions.

One of the most potentially sustainable and clean energy carriers to substitute fossil fuels is hydrogen owing to its high energy density (142 kJ/kg), environmental friendliness, and renewability [3,4]. Hydrogen has an energy content of 122 kJ/g that is greater than that of fuels-based hydrocarbons and is expected to supply 34 % of all renewable sources by 2050 [5]. On Earth, hydrogen is a plentiful energy carrier that may be created from basic energy source, including coal, nuclear energy, natural gas, and grid power. After combustion, hydrogen has a massive calorific value that is greater than that of petrol (43 MJ/kg). Furthermore, pure, and non-toxic water is the main combustion byproduct of

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