CHAPTER I
INTRODUCTION

Crude oil is an important material used in the production of polymers and chemicals and because of the large demand for these products, enhancing the crude oil recovery process is necessary. Crude oil is commonly divided into 4 components: saturates, aromatics, resins and asphaltenes (SARA). Asphaltenes are defined as the crude oil fraction that is soluble in aromatics, such as toluene, but insoluble in normal alkanes, such as n-heptane [Speight, J. G., 2007]. Crude oil production rates can be significantly reduced when asphaltenes are destabilized and deposit due to changes in temperature, pressure and composition [Gonzalez *et al.*, 2005]. The destabilized asphaltenes tend to precipitate and be deposited in production lines, causing plugging in pipelines and reducing capacity and productivity [Hammami *et al.*, 2007]. Asphaltene precipitation is a precursor of asphaltene deposition but it does not necessarily ensure asphaltene deposition; however, both asphaltene precipitation and deposition are major concerns in the production of crude oil.

For clear presentation and discussion of results, a few terms will be defined as follows: 1.) "destabilization" is the transition asphaltenes undergo on the nanometer length scale from stable to unstable, or from not able to grow in size to able to grow in size; 2.) "aggregation" refers to the transition of the asphaltene size from the nanometer to micrometer length scale; 3.) "precipitation" describes the entire process of asphaltenes transitioning from stable nanoaggregates to unstable material that grows to the micron length scale.

Adding precipitants (e.g., n-alkane) into crude oil is a common technique to investigate asphaltene properties and aggregation mechanisms and can be used to validate thermodynamic models [Maqbool *et al.*, 2009]. In crude oil production, methane is one of the components that causes asphaltene destabilization. However, it is difficult to study the influence of methane on the asphaltene destabilization processes in the laboratory due to the high pressure required; therefore, heptane is normally used as a precipitant to investigate asphaltene destabilization.

Previous studies [Wang *et al.*, 2003 and Maqbool *et al.*, 2009] have shown that kinetics play an important role in the asphaltene precipitation process. For example, the results from Maqbool *et al.* revealed that the time to detect unstable asphaltenes at low precipitation concentrations using optical microscopy (0.5 μm detection size) can be weeks, months, or years. Even when the instability of asphaltene at high precipitations can be immediately detected, the final value of asphaltene solubility can take weeks to measure. Moreover, a population balance model was used to estimate the particle-particle collision efficiency, β, for the asphaltene aggregation process. The collision efficiency, β, is defined as the number of successful adhesions divided by the total number of collisions, and this collision efficiency has been shown to depend significantly on the precipitant concentration [Maqbool *et al.*, 2011]. The low collision efficiency leads to a long detection time for instable asphaltenes at low precipitant concentrations.

Diverse techniques can be used to investigate asphaltene precipitation for different precipitants and precipitant concentrations such as optical microscopy [Wang *et al.*, 2003], and UV-vis spectrophotometer [Kraiwattanawong, K. 2007]. To investigate asphaltene aggregation in this study, a population balance model was used to estimate the collision efficiency. Moreover, in order to investigate asphaltene deposition, a capillary deposition apparatus was used to measure pressure drop across a capillary [Broseta *et al.*, 2000; Wang *et al.*, 2004; Hoepfner *et al.*, 2013]. This capillary deposition apparatus can detect the instability of asphaltene faster than a batch process since destabilized asphaltene is fed continuously into the capillary. Moreover, the pressure drop across the capillary increases due to asphaltene deposition inside the capillary, which can be related to the deposition rate.

Various precipitants, such as hexane, heptane, octane, nonane, and decane, and precipitation concentrations are used to investigate both asphaltene aggregation and deposition. Understanding asphaltene aggregation and deposition at different precipitants and precipitant concentrations can be altered to resemble field conditions since changing precipitants and precipitant concentrations means changing the degree of destabilization of asphaltenes. The purpose of this study is to compare trends in asphaltene aggregation and deposition, and more specifically, to relate the asphaltene aggregation particle-particle collision efficiency to the deposition rate by varying the precipitant carbon numbers and concentrations.