CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The densities of binary mixtures of water with piperazine, water with DEA, DEA with piperazine and the ternary mixture of water + piperazine + DEA have been measured in the temperature range from 30 to 80 °C with piperazine concentration varying from 0.01 to 1 M. The results of these measurements show that the binary and ternary systems exhibit different trends of the density curves. Based on the density data collected, a generalized set of interaction parameters to calculate the density were determined for the aqueous piperazine, DEA, DEA + PZ mixtures and activated DEA solutions. The overall deviation of the experimental and calculated density values for the PZ + H₂O, DEA + H₂O, DEA + PZ mixtures and activated DEA solutions for 2 M and 4 M are 0.02 %, 0.04 %, 0.07 %, 0.24 % and 0.37 % respectively.

Investigations on equilibrium solubility of carbon dioxide into aqueous piperazine and activated solution have been conducted in a double jacketed stirred cell reactor at CO₂ partial pressures ranging from 0.4 to 96 kPa and temperatures from 20 to 50 °C. The concentration of piperazine varied from 0.1 to 1 M and 0.05 to 1 M in aqueous piperazine and activated DEA solution respectively. It was observed that the
solubility of CO₂ in both aqueous piperazine and activated DEA solution exhibit the
same trend as other typical amines, whereby the solubility of CO₂ increases with
increase in CO₂ partial pressure. However, increasing either the temperature or
piperazine concentration will cause the CO₂ loading to decrease. The aqueous
piperazine solution exhibits an interesting behavior at high partial pressure with low
piperazine concentrations where the solubility of CO₂ exceeds the theoretical value.
This is due to the dominant role of physical absorption.

In the activated DEA solution of equal molarity, the solubility of CO₂ decreases as
the concentration of piperazine increases at high CO₂ partial pressure and a small
increase at low CO₂ partial pressure which is not significant in enhancing the CO₂
loading. Compared to amine mixtures of DEA + MDEA and MEA + MDEA,
activated DEA solutions show better CO₂ absorption capacity especially at low CO₂
partial pressure. This indicates that the aqueous activated DEA is a potential solvent
to be used in gas treatment industries.

Generally, for CO₂ absorption in the aqueous piperazine solution, the Kent and
Eisenberg model fairly well with the experimental data except at high CO₂ partial
pressures and low piperazine concentrations which is due to the dominant role of
physical absorption. Beside, the small amount of the CO₂ loading measured may also
have generated error. Thus, the model is expected to be unreliable at these two
conditions. The Kent and Eisenberg model was also applied to the activated DEA
system and it also predicts the CO₂ loading fairly well. Only at low CO₂ partial
pressures and high temperature conditions did the predicted CO₂ loading values
deviate more than 50% from the experimental data which may be due to the limitation of Henry’s Constant and equilibrium constants used in this region.

6.2 Recommendations

A more comprehensive study on physical properties of the activated amine system would be interesting to explore in order to provide quantitative estimates of equilibrium properties for amine mixtures which are required in chemical production and process design.

Based on the experimental data, at high CO$_2$ partial pressures and low piperazine concentrations, the solubility of CO$_2$ in the aqueous piperazine solution exceeds the theoretical value. This highlights the necessity to determine the physical solubility and diffusivity experimentally in order to obtain fundamental understanding of absorption mechanism in this system.

The large deviations of CO$_2$ loading between the model and the experimental data at certain conditions suggest that an improved model is desirable for quantitative prediction of CO$_2$ loading. The model should take into account the ionic parameters to represent the non-ideality of the system. The Kent and Eisenberg model may also have some deficiencies. It is only applicable to a limited loading range and its extension to acid gas mixtures is less successful (Liu et al., 1999a). Therefore, this model may not be able to represent the CO$_2$-activated system accurately in a wider range due to the complicated reaction which occurs in the CO$_2$-H$_2$O-PZ-DEA system.

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The results from this work also identify that activated DEA is a potential solvent to be used in the gas treatment industries. Therefore, future works on degradation and corrosion effects of activated DEA in stripping process is recommended, since it contributes major problems in operating gas treatment plants. Extension work on kinetic and scale-up is desirable to ensure the ability of this solvent to absorb CO₂ effectively and efficiently at lower cost.