

CHAPTER VII

INDUSTRIAL APPLICATIONS AND RECOMMENDATIONS FOR FUTURE WORK

7.1 Industrial Applications

7.1.1 Degradation Analytical Techniques

Applications of the analytical techniques for the identification and quantification of MEA and degradation products developed in this study could be found for the industry. Information extracted from the GC-MS could guide the analysis of the CO₂ capture process for solvent quality in terms of chemical stability by selection of appropriate GC columns to match the required analysis (i.e. MEA, degradation products, MEA + degradation products). HPLC-RID with the tested condition could also be applied since it showed capability in detection of MEA and some degradation products in a single analysis. CE-DAD technique, although required heavy sample dilution, was simple enough for the degradation products analysis. GC-MS, HPLC-RID and CE-DAD techniques, if combined, could be used to verify results obtained from one another. This could be advantageous over the existing analytical techniques used in real applications where a single technique is often used.

7.1.2 O₂-SO₂ Induced Degradation Kinetic Rate Model

The kinetic model was formulated using CO₂ removal operating conditions by taking into account the presence of MEA, O₂, SO₂ and CO₂. In addition to the natural gas power plant flue gas, coal-fired power plant flue gas purification for CO₂ capture could also benefit from the kinetic equation because the SO₂ term was incorporated in the model. The incorporation of the SO₂ term makes the kinetics more applicable to the real life CO₂ capture from coal-derived flue gases. The model could be used to estimate the degradation rate of MEA. This rate information then allows the calculation of amine make up rate needed for maintaining the absorption capacity during CO₂ capture operation. The kinetic model also contains mechanistic information since it was developed based on a consistent

mechanism. This helps to elucidate the degradation roles of MEA, O₂, SO₂ and CO₂. In addition, this mechanistic knowledge can be certainly applied to assist in formulating a degradation prevent technique.

7.1.3 Preliminary Inhibitor Study

Results obtained from degradation inhibitor study could find applications in industry. Since Inhibitor UR-A has been found to reduce the MEA oxidative degradation rate in systems with and without SO₂. It can be applied to minimize the degradation in both natural gas and coal flue gas purification.

7.2 Recommendations for Future Work

Since mechanistic knowledge provides a better understanding of the degradation behaviour in MEA system with and without SO₂ and helps to formulate degradation prevention techniques, verification of major degradation products must be done using the analytical techniques developed in this study. The development of more advanced analytical techniques such as NMR or combined HPLC-NMR is also recommended to help identify structures of the degradation products for complete elucidation of the degradation pathways.

Isotopic labelling technique is also recommended for ultimate verification of degradation mechanism. This technique can be done by replacement of one or more atoms of interest with its isotope, in one of the following molecules of MEA, O₂, SO₂ and CO₂ prior to oxidative degradation experiments. Deuterium (D) and carbon 13 (¹³C) are considered for the respective replacement of ¹H, ¹²C in MEA. Oxygen 18 (¹⁸O) is to replace ¹⁶O in O₂ and SO₂. ¹³C is for replacing ¹²C in CO₂. Examples of isotopically labelled MEA, O₂, SO₂ and CO₂ are tabulated in Table 7.1.

Table 7.1 Isotopic labeled MEA, O₂, SO₂, and CO₂

Original	Labelled
D replacement	
$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{O}-\text{C}-\text{C}-\text{N}-\text{H} \\ \quad \quad \diagdown \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{D} \quad \text{D} \\ \quad \\ \text{H}-\text{O}-\text{C}-\text{C}-\text{N}-\text{H} \\ \quad \quad \diagdown \\ \text{D} \quad \text{D} \quad \text{H} \end{array}$
¹³ C replacement	
$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{O}-\text{C}-\text{C}-\text{N}-\text{H} \\ \quad \quad \diagdown \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{O}-\text{C}-\text{C}-\text{N}-\text{H} \\ \quad \quad \diagdown \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$
O ₂	¹⁸ O ₂
SO ₂	S ¹⁸ O ₂
CO ₂	¹³ CO ₂

The use of one or a combination of isotopically-labelled compounds listed in Table 7.1 allows details of oxidative degradation pathways to be revealed. For instance, the pathway and role of both α - and β -hydrogen of MEA for the system of MEA-O₂-SO₂-CO₂ can be traced. To achieve this, deuterium-labelled MEA is used whereas O₂ and SO₂ are kept in their original forms. With this arrangement, the MEA's α - and β -hydrogens are made distinguishable from the rest of the hydrogen atoms (e.g. H₂O) within the system. Therefore, identification of their pathways is possible. To establish the role of O₂ in the same system, a similar technique is employed but the labelled-compound is switched to ¹⁸O₂ and the remaining MEA, SO₂, and CO₂ are used as their originals. GC-MS developed in this study can be used in combination with NMR and HPLC-NMR to distinguish the differences between original and labeled species. Verification of degradation mechanism proposed for kinetic formulation in Chapter 5 is also needed and can also be done using this isotopic labeling technique.

More potential degradation inhibitors such as antioxidants and O₂ scavengers must be screened and tested for performances in minimizing the

degradation of MEA-O₂-SO₂-CO₂ system. Evaluation of blends of two or more additives is also recommended since each might enhance the inhibition effects of the other in the degradation system.