KE-40.4150 Catalysis
Exam
December 9, 2015 at 9-13

Answer all questions, each question is worth 6 points. If you have completed the homework in 2015, one exam question can be replaced with the homework. However, you can answer all five questions, and in case the points are better in the homework, those will be taken into account in the evaluation.

No material allowed.

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1. Definition of a catalyst

   On the basis of the definition, how does the catalyst affect a chemical process? What are the requirements for an industrial catalyst? (6 points)

2. 0.5 % Pt/Al_2O_3 has been widely used as a catalyst in the catalytic reforming reaction in oil refining
   a. Describe the typical structure of the catalyst (bulk and surface structure) (3 points)
   b. When the catalyst is used in a real process, deactivation by coking is observed on this catalyst. Explain how and why the deactivation takes place, how it is observed and how it can be compensated and regenerated. (3 points)

3. 0.5 % Pt/Al_2O_3 has been widely used as a catalyst in the catalytic reforming reaction in oil refining
   a. The catalyst is prepared by wet impregnation. Explain how the preparation is done, e.g. what kind of preparation steps and procedures are included. (3 points)
   b. Tell how it can be studied that the preparation was successful i.e. that the catalyst is what is was planned to be. (3 points)

4. Compare heterogeneous and homogeneous catalysis and catalysts (6 points)

TURN!

5. a) Explain briefly how these characterization techniques are carried out and what information do they provide:

    i. H_2 chemisorption (1 point)
    ii. N_2 physisorption (1 point)
    iii. CO_2-TPD (1 point)

b) One of the most significant greenhouse gases is carbon dioxide (CO_2). The reduction of greenhouse gas emissions can be achieved by converting CO_2. In a reverse water gas shift (RWGS) reaction (R1) synthesis gas can be produced from CO_2.

$$CO_2 + H_2 \leftrightarrow CO + H_2O \qquad \text{(R1)}$$

The conversion of CO_2 (%) in RWGS was measured by the hard-working researcher over doped zirconia-based oxide catalysts (ZrO_2, Y_2O_3-ZrO_2, SiO_2-ZrO_2, CeO_2-ZrO_2, La_2O_3-ZrO_2 and CeO_2-La_2O_3-ZrO_2). Next, the researcher measured the strength of CO adsorption and the amount of basic surface sites on the catalysts. Then she plotted the conversion of CO_2 against these characteristics (Figures 1 and 2). The conversion of CO_2 decreased with increasing T_{max} temperature of CO-TPD. However, the conversion of CO_2 first increased with increasing basicity, showed a maximum and then started to decrease. Which one of the following methods should the researcher apply next to gain most insight into the reduction of CO_2 emissions by RWGS? Please explain the reasons for your selection (1 point for choosing the right method and 2 points for the reasons).

    i. H_2 chemisorption
    ii. N_2 physisorption
    iii. CO_2-TPD

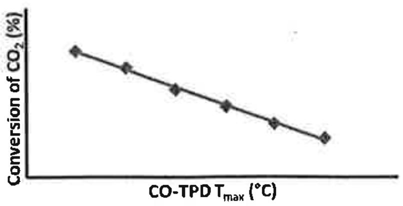

Figure 1. CO_2 conversion vs. CO-TPD T_{max} (°C).

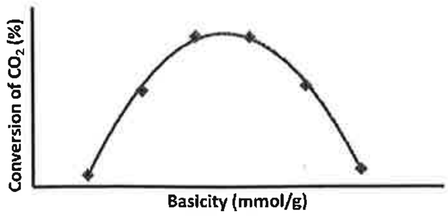

Figure 2. CO_2 conversion vs. basicity.