On-line Exam 1, 23.2.2021 (period III), 14:00-18:00 (4 h)

CHEM-E1130 Catalysis on-line Exam 23.2.2021

- Open book exam = all materials allowed (Covid-19 necessity)
- Download the exam materials in advance from MyCourses; make sure that you have access to a Periodic Table of the Elements

- Answer in clear English language.
- Include all text answers in the answering boxes of MyCourses.
- In some questions, an optional uploading of an image file has been added, for those who wish to support your text-based answer by a (self-made!) drawing.
- At the end of the exam, you may write feedback to the teachers.

Good luck for the exam!

Question **1**

Flag question Marked out of 9.00 Complete

Definition of catalysis and catalyst

Give the definition of a catalyst. On the basis of the definition, how does the catalyst affect a chemical process? What kinds of requirements are there for industrial catalysts?

Question **2**

Flag question Marked out of 3.00 Complete

Brief question - IUPAC pore size classification (3 pt)

Pore sizes in heterogeneous catalysts are classified in several ranges by IUPAC, the International Union of Pure and Applied Chemistry. What are the different pore size categories relevant to heterogeneous catalysis? Please describe the names and numerical ranges. Why is there such a classification?

Question **3**

Flag question Marked out of 3.00 Complete

Brief question: Catalyst components (3 pt)

What are the different typical components of a heterogeneous catalyst? Give the name and examples of each kind. Are all types of components always present in a catalyst? Why, or why not?

Question **4**

Flag question Marked out of 3.00 Complete

Brief question: 18-electron rule (3 pt)

Consider the following palladium complex: **HPd(CO)(PPh3)2**.

Question in three parts (please use the respective numbers in your answer, for clarity):

1. What is the oxidation state of palladium in the complex?
2. Is the complex saturated or not? Answer clearly with YES/NO, along with justification.
3. Do you expect the complex to be catalytically active?

For background information, the ligands are explained here:

- H hydride
- CO carbonyl
- PPh3 triphenylphosphine

Question **5**

Flag question Marked out of 9.00 Complete

Catalyst deactivation

Hydrogenation of toluene is investigated in a continuous flow reactor using the reactant (toluene) diluted in a solvent (hexane). The solvent's impurity level is less than 0.01 wt-%; detailed impurities are unknown. Hydrogenation is made with an palladium catalyst supported on mesoporous aluminium oxide. The reaction temperature is 200°C, pressure is 10 bar, hydrogen is present in the gas phase. The catalyst is observed to slowly deactivate with time. What could be the reasons behind this deactivation? Describe (a) with justification, which deactivation mechanism(s) you consider likely, and which you consider unlikely; and (b) how you think deactivation could be postponed or prevented.

Question **6**

Flag question Marked out of 9.00 Complete

Catalyst characterization (applied) - mind the mistakes!

An enthusiastic Master's thesis student has prepared platinum catalysts on mesoporous titania (TiO_2) and zirconia (ZrO_2) supports for testing in catalytic hydrodeoxygenation, using gamma-nonalactone as a model compound. The targeted metal concentration was 1.0 wt-%.

Before proceeding to test the catalytic activity in high-pressure batch reactor runs, the student will make basic characterization for the prepared catalysts. The student is planning to measure (i) the surface area of the support by hydrogen chemisorption at 30°C, (ii) active platinum surface area by nitrogen physisorption at 77 K, (iii) the total metal content by x-ray diffraction, (iv) pore size distribution by scanning electron microscopy, and (v) crystal size by infrared spectroscopy.

The student makes a detailed experimental plan and shows it to the thesis advisor before agreeing the final details with the supervising professor. Luckily so! The thesis advisor notices that there are many mix-ups in the student's experimental plan related to concepts of catalyst characterization.

Which mix-ups did the student make? List and justify at least three mistakes in the student's plan, and also how the student could instead measure the targeted properties.

Question **7**

Flag question Marked out of 3.00 Complete

Catalyst preparation 1 - Choosing the support (3 pt)

You need to make a catalyst with nickel on a mesoporous support for high-temperature steam reforming reaction.

The targeted reaction temperature is 800°C. Which kinds of materials can you use as support? Propose suitable support material candidates, with justification.

Question **8**

Flag question Marked out of 3.00 Complete

Catalyst preparation 2 - Active component (3 pt)

You need to make a catalyst with nickel on a mesoporous support for high-temperature steam reforming reaction.

Targeted metal amount is 10 wt-%. Propose and describe a suitable method for how to make the catalyst.

Question **9**

Flag question Marked out of 3.00 Complete

Catalyst preparation 3 - Overlayers (3 pt)

You have been requested to make an thin overlayer of aluminium oxide on top of a metal catalyst, to protect it against sintering. Which catalyst preparation method could you use to create such overlayer? Briefly describe an applicable method, including its name and principles.