You can **use up to 8 pages** (2 exam sheets) for the answers but be concise. The answers can contain drawn images and written text. If you decide to draw accompany your drawing with a written description, i.e. drawings can only support your answer, they are not the answer itself.

You should have 2 scientific papers (Material development, LCA) with you at the exam that are used in questions Q4 and Q5. When you have finished, please return these scientific papers along with your answer papers. If you do not have scientific papers with you, contact staff immediately.

Each questions provides you 10 points:

Q1) Explain the following concepts:

- **Task 1.1** (4 points): What are the challenges in state of art material used in your own technology? Explain two in more detail.
- **Task 1.2** (3 points): Define what is work function for a metal.
- **Task 1.3** (3 points): Define Energy Stored on Energy Invested (ESOI)

Q2) Answer to the following questions:

- **Task 2.1** (5 points): Analyse the following image and answer to the questions below:
  a) Have these values been measured in 2 or 3 electrode set-up and how can you know that?
  b) Which of these catalyst materials you consider is the most active for this reaction and why?

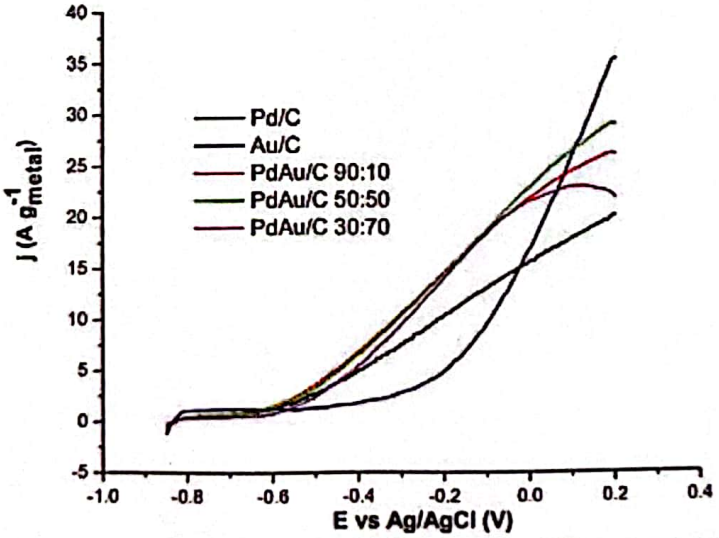

Figure 1 - *Ethanol oxidation in alkaline media (1 M KOH) on different catalyst. Au/C is gold nanoparticle catalyst on carbon support.*

- **Task 2.2** (5 points): Lead acid battery has only 4 components: 2 lead electrodes (100 % Lead), sulphuric acid electrolyte and plastic container. How would you recycle this battery most efficiently with recycling unit operation if the cost is not a limitation?

Q3) Answer to the following questions:

- **Task 3.1** (5 points): What is an Eco-design? Is the Eco-design for energy storage systems described in EU legislation already?
- **Task 3.2** (5 points): Describe an eco-design proposal from the **poster 3** – this can be from your own poster or from some other poster in your sub-group. Critically evaluate whether this would be possible to implement. (You can propose new solution if you have better idea in your mind?)

Q4) Use your **Material development scientific paper** as reference for the following question:

- **Task 4.1** (5 points): Select from your paper a physical characterization Figure (please start the answer by telling which Figure you are referring to) of the material and answer for the following questions:
  a) What physical characterization method is it and what information it provides about the material?
  b) Is the new material being compared to other materials (some state of art material)?
  c) Critically evaluate the new material suggestion in this Figure. (is it new?, is it helpful? Etc.)
- **Task 4.2 (5 points):** Select from your paper a Figure that is describing the property improvement of the material (activity/durability). Please start the answer by telling which Figure you are referring to an answer to the following questions:
  a) What Figure this is and how relevant this property is for this application?
  b) Critically evaluate if the new material provides improvement for this technology.

Q5) Please use your **Life Cycle Assessment scientific paper** along with this answer.

- **Task 5.1 (5 points):** Find in your paper following essential parts of any LCA and list them as your answer:
  a) What is the Functional unit?
  b) What are the System boundaries?
- **Task 5.2 (5 points):** Select from your paper a Life Cycle Impact category and answer the following questions.
  a) Describe what is meant by this impact category in general?
  b) Which operation and/or part of the system contributes most to this impact category? Why?
  c) Provide one way how the impact could be reduced.