CHEM-C3410 Nanomaterials: 17th October 2025

GENERAL INSTRUCTIONS

Answer to all FOUR questions **in English** (including possible (a), (b) etc. parts). Each full question can give you max. 5 points. For calculations, *remember* to show the equations, the different steps (***with substituted numbers and unit analysis***) used and the correct accuracy. As this is an Open Book type exam, the exam is evaluated based on the depth of understanding rather than a simple statement of key facts (e.g. NO bullet point list).

All text should be your own, i.e. NO copy-pasting (or adapted copying) from any sources. AI use is NOT allowed at any form. Using Grammarly or any other language tools is forbidden.

You can take the exam alone or in a group, as decided in MyCourses a week before the exam date: only one submission per group is required and everyone in the group will get the same points. Communication inside the group is allowed, but any communication outside the group is forbidden (including asking from friends, family, chats, forums, AI etc.). The same rule applies even if you take the exam alone. The exam submission box uses Turnitin tool to detect plagiarism and AI use.

It is allowed to use course material and Google/Search Engines. You can use schematics & figures (also from the books, papers etc.) to make your explanations deeper BUT you must also explain them in your written answer. About referencing in this exam:

1) Reference is not needed, if you use Course Material = lecture slides, exercises and short videos in MyCourses, the following books and papers (listed also on MyCourses' front page with links):
    1) **M.F. Ashby, P.J. Ferreira, D.L. Schodek**: *Nanomaterials, Nanotechnology and Design - An Introduction for Engineers and Architects*, Elsevier 2009.
    2) **G. Cao, Y. Wang:** *Nanostructures and Nanomaterials - Synthesis, Properties and Applications*, World Scientific 2004.
    3) **A. K. Geim, K. S. Novoselov**, The rise of graphene, *Nature Materials* **6** (2007) 183-191.
    4) **S. K. Tiwari, S. Sahoo, N. Wang, A. Huczko**, Graphene research and their outputs: Status and prospect, *Journal of Science: Advanced Materials and Devices* **5** (2020) 10-24.
    5) **H. Hu, D. Li, Y. Gao, L. Mu, Q. Zhou**, Knowledge gaps between nanotoxicological research and nanomaterial safety, *Environment International* **94** (2016) 8–23.
2) A reference is required, if you use any other sources (e.g. material found from internet).

If you take the exam in a group, the exam time is 4 h 30 mins.

If you take the exam alone, the exam time is 5 h 30 mins.

- HINT: Use the last 30 mins for finalising the submission.
- Only MyCourses submissions are graded.
- MyCourses accepts a submission only if you have selected a group (even if you would take the exam alone = a group of one person).
- MyCourses accepts only .pdf files.

You can answer by pen/pencil+paper and/or by computer (or both), but you must submit your answers as ONE single pdf file to MyCourses before the exam time ends.

- Check that all text, calculations and pictures/schematics are easily readable.
- **Pure copy-paste from Excel, calculation programs etc. is not enough as an answer** but you need to write out the equations properly with explanations and substitutions, using mathematically correct equation styles. Remember also unit analysis.

Emergency (e.g MyCourses is not responding… or other emergencies):

- CALL Kirsi Yliniemi (+358 50 592 3690)**:** you are provided a license to submit the answers by email (kirsi.yliniemi@aalto.fi**)**. Answers must be sent before the end of exam time. However, you MUST submit exam answers ALSO to MyCourses **as soon as possible**. **Only MyCourses submissions will be graded.**
- Contact only in an emergency = **NO asking for "help in understanding question X" etc.** If there is a mistake in a question, it will be taken care of in the grading: write a note about it in your answer.

After the exam questions, there is a list of physical constants, but the list is not complete.

EXAM QUESTIONS

1. MgO nanoparticles are synthetized with a hydrothermal method in $MgCl_2$ solutions so that their average diameter is 80.5 nm. Calculate the thicknesses of the electrical double layers surrounding a MgO nanoparticle (at 298.15 K) in two different aqueous solutions: 0.01 M $MgCl_2$ and 0.001 M $MgCl_2$. *Note: Simple copy-paste from Excel or any other mathematical tool leads to 0 p: instead, explain your calculation and show the equations using proper mathematical formulations, numerical substitutions and unit analysis.*

Based on these results, explain how salt concentration can be used to tune the colloidal stability of a nanoparticle solution. Explain also the theoretical background ***why*** salt can be used to tune the colloidal stability.

2. Photoluminescence emission spectra were measured for different sized carbon quantum dots (CQD) and the results are shown in Figure 1 below.

Introduce *briefly* what are carbon quantum dots. Then explain in detail the observed photoluminescence behaviour as a function of CQD size (as seen in Figure 1). Remember to explain also the underlying theories and phenomena that result in such photoluminescence behaviour.

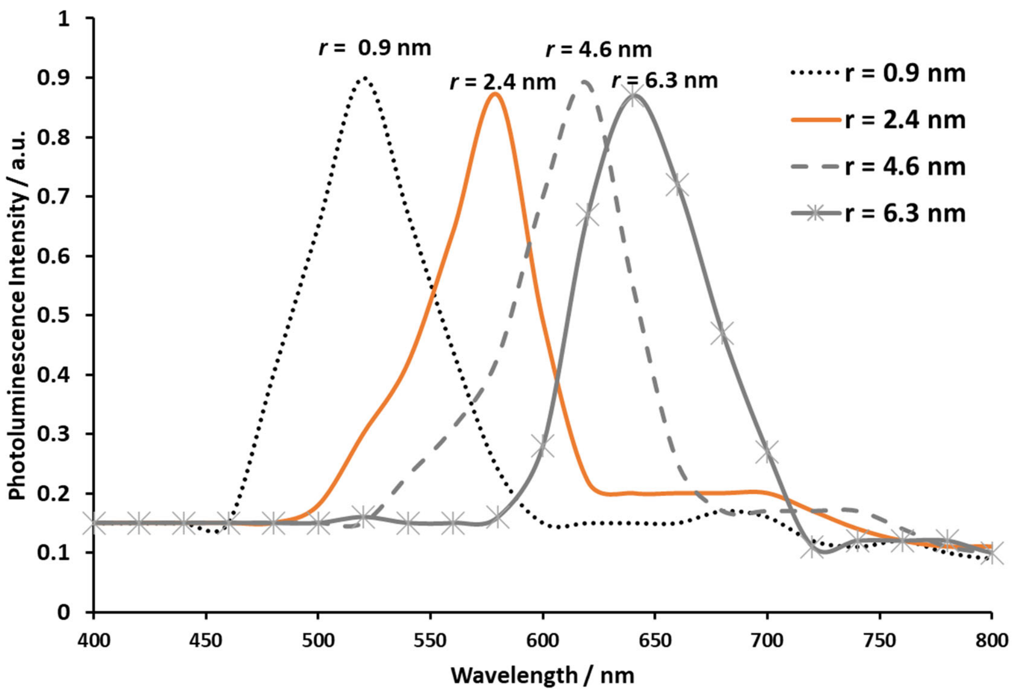

Figure 1: Photoluminescence emission spectra of carbon quantum dots (CQD) of different sizes (r=radius of CQD).

3. Coercivity field and magnetic hysteresis curves were measured at room temperature for different sized $Ni_{0.3}Zn_{0.7}Fe_2O_4$ nanoparticles. Figure 2 shows the results. Determine which hysteresis curve (curve for Particle 1, 2 or 3 in Figure 2(b)) belongs to which size range of $Ni_{0.3}Zn_{0.7}Fe_2O_4$ nanoparticles (Region 1, 2 or 3 in Figure 2(a)).

Justify your decision by explaining from a theoretical point of view, i.e. explain ***why*** coercivity changes as a function of particle size as shown in Figure 2(a) and ***why*** hysteresis behaviour changes for different sized particles as shown in Figure 2(b). *NOTE! This is an essay question = no math required.*

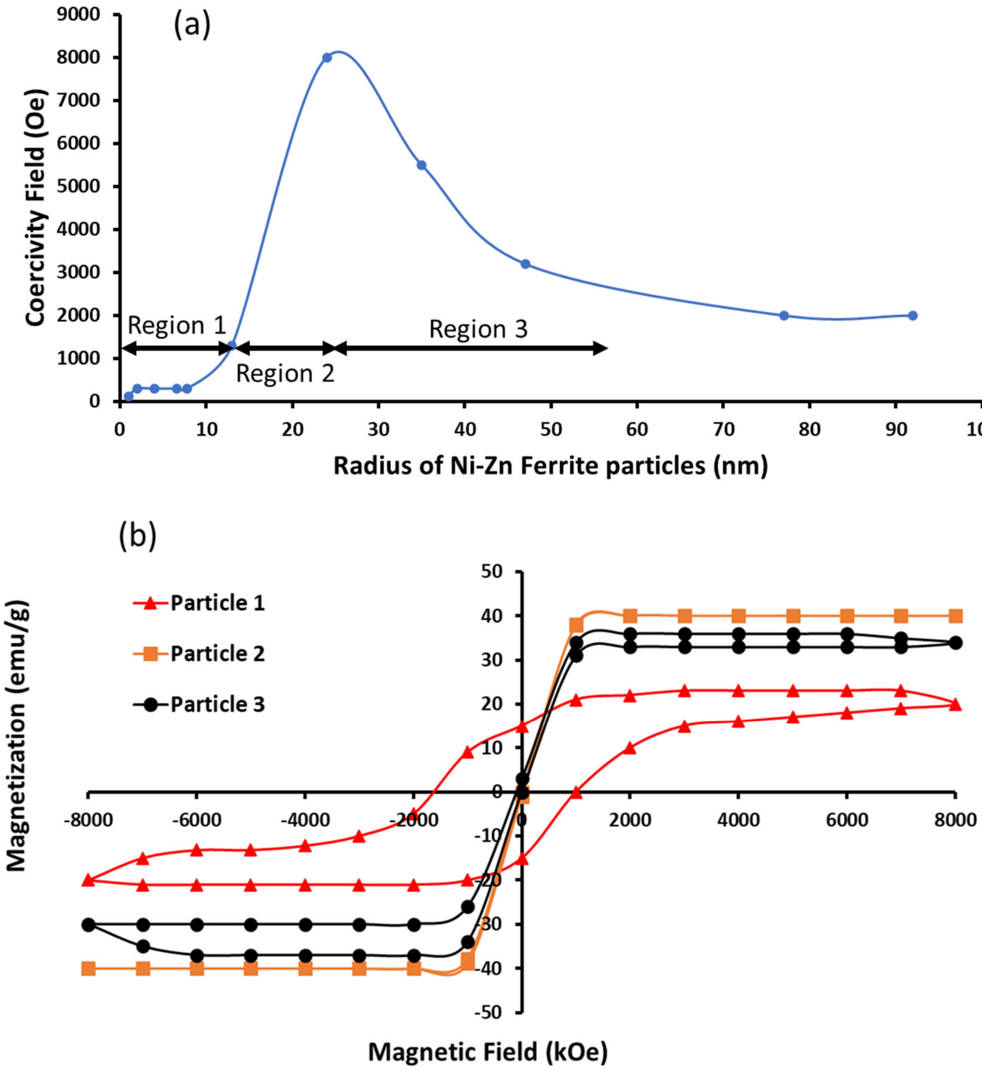

Figure 2: (a) Coercivity field determined for different sized $Ni_{0.3}Zn_{0.7}Fe_2O_4$ nanoparticles, measured at room temperature. (b) Magnetic hysteresis curves for three different sized $Ni_{0.3}Zn_{0.7}Fe_2O_4$ nanoparticles, measured at room temperature.

4. Sivakumar *et al.* [1] have studied nanotoxicity of titanium oxide nanoparticles (TiONPs). They exposed algae *Isochrysis galbana* COR-A3 cells to solution containing TiONPs and studied the cell viability after 96 h of exposure. They also measured the carbohydrate, protein and lipid content as a decrease in carbohydrate, protein and lipid levels typically indicate problems in cell viability. They also studied oxidative stress as oxygen species can detrimentally affect the photosystem II of the algae species and therefore disrupt photosynthesis; photosynthesis is algae's way to create energy for themselves.

Isochrysis galbana = a marine algae species which is crucial for other marine species as their food source.
Isochrysis galbana COR-A3 cells = a specific cell line from *Isochrysis galbana* which is used in nanotoxicity tests.
Plasmolysis = a process in which a cell loses its water content, resulting in defects in the cell membrane and even in the death of the cell.

The abstract by Sivakumar *et al.* [1] states the following:

"The widespread utilization of titanium oxide nanoparticles (TiONPs) in various industrial applications has raised concerns about their potential ecological risks in marine environment. Assessing the toxicity of TiONPs on primary producers is essential to understand their impact on marine ecosystem. This study investigates the acute toxicity effect of TiONPs on *Isochrysis galbana* COR-A3 cells, focusing on structural and physiological changes that can compromise algal viability and ecological function. Cells were exposed to TiONPs concentration of 10–50 mg/L and assessments were conducted over 96 h to evaluate cell viability, biochemical composition, photo-physiology, oxidative stress and morphological deformations. At 50 mg/L concentration, cell viability was significantly reduced by 73.42 ± 3.46% and subsequent decrease of 42.8%, 29.2%, 44.2% in carbohydrate, protein and lipid content were observed. TiONPs exposure elevates the reactive oxygen species production and thereby impairing the photosystem II efficiency and disrupting the cellular metabolism. Morphological analysis revealed significant cell membrane disruption and plasmolysis. These cascading effects reveal TiONPs ability to interfere with algal physiological process, potentially affecting the primary productivity in marine ecosystem. Our findings highlight the ecological risk associated with the TiONPs, emphasizing the need for regulatory measures to mitigate the nanoparticle pollution in aquatic environment. This study provides more insights on the TiONPs induced toxicity in marine microalgae by altering the photosynthetic performance and biochemical integrity."

Discuss about the relevance and limitations of this nanotoxicology study (as introduced in the abstract above), when considering nanosafety. *NOTE! You can base your evaluations of the study purely on the information found from the abstract and question text (= <u>no need to find and read the full paper</u>).*

[1] M. Sivakumar, I. Dhinakarasamy, S. Chakraborty, C. Clements, N. K. Thirumurugan, A. Chandrasekar, J. Vinayagam, C. Kumar, R. Thirugnanasambandam, R. Kumar V, V. N. Chandrasekaran, *Nanotoxicology* **19** (2025) 156-179. DOI: 10.1080/17435390.2025.2454267.

List of physical constants

$\varepsilon_0 = 8.8542 \cdot 10^{-12}$ F/A=$8.8542 \cdot 10^{-12}$ m^{-3} kg^{-1} s^4 A2= $8.8542 \cdot 10^{-12}$ C/(Vm)

ε(water) = 80.1

$e = 1.6022 \cdot 10^{-19}$ C

$m_{\mathrm{electron}} = 9.1094 \cdot 10^{-31}$ kg

$m_{\mathrm{proton}} = 1.6726 \cdot 10^{-27}$ kg

$h = 6.63 \cdot 10^{-34}$ Js

$\hbar = h/2\pi$

$k_B = 1.381 \cdot 10^{-23}$ J K^{-1} = $1.381 \cdot 10^{-16}$ cm^2 g s^{-2} K^{-1}

$F = 96\,485.31$ C/mol

$R = 8.31451$ J / (K mol)

$N_A = 6.02214 \cdot 10^{23}$ mol^{-1}