Loughborough University

24MPC312
Nanomaterials

Semester 1 2024/25 In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

Answer **ALL** questions. Each question carries 20 marks.

A formula sheet is provided at the end of the paper.

1. (a) Define two-dimensional (2D) nanomaterials and give an example thereof. [2 marks]

(b) Carbon nanomaterials such as fullerenes, carbon nanotubes and graphene, have similar properties.

(i) Explain why carbon nanomaterial properties are similar. [2 marks]

(ii) Explain the process for generating graphene oxide from graphene. State which properties change during this process and explain why they change. [6 marks]

(iii) Carbon nanotube transparent thin films have been proposed as a replacement for indium tin oxide transparent electrodes. Discuss the advantages and disadvantages of using carbon nanotube thin films compared with indium tin oxide transparent electrodes. [6 marks]

(c) Nanomaterials are used in many electronic applications, for example, quantum dots are widely used in display screens for televisions and smart phones.

(i) Explain why different colours of light are observed for quantum dots of different sizes. [2 marks]

(ii) Suggest two drawbacks of using quantum dots. [2 marks]

2. You work for a materials development company and have been asked to investigate various nanomaterials for their performance as catalysts, considering catalytic activity, specific surface area and cost. After researching a selection of commercially available spherical nanoparticles you have shortlisted the following options given in Table Q1.

Table Q1

Type of material	**Nanoparticle diameter (nm)**	**Density (g cm^{-3})**	**Specific surface area (m^2 g^{-1})**	**Catalytic activity**	**Cost per gram (£)**
Iron oxide, Fe_2O_3	40	5.2	28.8	Low	5.2
Gold, Au	15	19.3	?	High	450
Zinc oxide, ZnO	20	5.6	53.6	Medium	10.6

(a) Calculate the specific surface area for the gold nanoparticles for 1 gram of material. [6 marks]

(b) Discuss the differences observed between the specific surface areas for the different nanoparticles and explain why the smallest particles may not necessarily have the largest specific surface area. [3 marks]

(c) Which nanomaterial would you select to use as a catalyst? Justify your answer. [4 marks]

(d) You decide to produce the nanomaterials in house.

(i) Suggest an appropriate 'bottom up' method to fabricate the gold nanoparticles. [1 mark]

(ii) Explain how the particle size is controlled in your chosen method. [2 marks]

(e) Discuss issues which may arise from accidental release of these nanoparticles into the environment. [4 marks]

3. Nanomaterials are often heralded as wonder materials due their improved properties compared with bulk materials.

(a) Explain how and why the large surface area alters the melting point of a material. [3 marks]

(b) Explain why nanomaterials are prone to aggregation, discuss a negative consequence of aggregation, and suggest a method to prevent this. [3 marks]

(c) You are tasked with selecting a nanoparticle for use in drug delivery applications. Identify two nanoparticle properties which are important for this application, explaining why they are important. [4 marks]

(d) Titanium dioxide, TiO_2, nanoparticles are used in water purification and prepared on a large scale using the flame aerosol process.

(i) Explain why TiO_2 can be used in this application and discuss the importance of nanoparticle size. [5 marks]

(ii) Discuss the advantages and disadvantages of using TiO_2 nanoparticles for water purification. [4 marks]

(iii) Suggest another application for TiO_2 nanoparticles. [1 mark]

END OF PAPER

Dr F Hatton

List of equations

Volume of a sphere, $v = \frac{1}{6}\pi D^3$

Surface area of a sphere, $SA\ sphere = \pi D^2$