Learn Chemistry

Chemistry's Interfaces: The Nano Frontier

Resource Overview

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Introduction

This resource is designed as an introduction to the science of metal and semiconductor nanoparticles. The resource is focussed at level 1 and 2 students so it places a particular emphasis on the difference between the physical and chemical properties of the bulk form of materials, individual molecules and nanoparticles in the 1-100 nm diameter range.

Many of the underlying concepts that students should understand in order to do this problem are covered in many year one chemistry courses such as quantisation, particle in a box, band theory and molecular orbital theory. An understanding of the underlying principles of electronic spectroscopy and intermolecular forces will also be useful. If students are yet to study some (or all) of these concepts, this problem could also be used to introduce the concepts alongside lectures – the problem will give students an opportunity to see how some of these (occasionally abstract) concepts can be applied in real applications.

Although the problem has been primarily designed with year 1 and 2 students in mind, with some modifications it could be used with year 3 or 4 students, especially in courses which include final year modules on nanoscience or nanochemistry.

The range of applications covered in this problem brings together a number of different areas of overlap between chemistry and the physical and life sciences. The first part of the problem ties together the functionalisation of gold nanoparticles with complementary DNA sequences (which involves both inorganic chemistry and biochemistry) with a consideration of the unique size and shape dependent optical properties of transition metal nanoparticles (which requires students to explore aspects of both chemistry and physics).

We recommend that this problem is used with small groups of students (typically group sizes of 4-6 work best). We also recommend that each facilitator guides no more than 2 or 3 groups – if a facilitator has to work with any more groups than this, it is likely to mean that very little time is spent with each group.

We have found that postgraduate students can make good PBL/CBL facilitators if they are given guidance in this style of teaching and the nature of the problem before the start of the module.

Criterion	Value
Intended level	Year 1-2
Subject area	Nanoscience
Contact Hours	3-4 hours
Group size	4-6

Tutor text has been included in this version of the problem. The tutor text is shown in red; this text should not be shown to students.

Outline tutor answers have been provided for the facilitation questions. Please note that these are neither model answers nor guidelines to the amount of content that students should produce. These answers only provide a minimal outline of the concepts being asked and students should go into more detail and provide examples of each of these concepts.

Background

This primary inspiration for the context of this resource is the author's interest in this truly interdisciplinary research area which is underpinned by a number of core aspects of chemistry. It is hoped that this resource will allow students to engage with a very active area and interesting of research while developing an understanding of the background science (e.g. quantum mechanics).

It is worth noting that during the pilot testing of this resource, foundation year and year one students had some difficulty with the quantum mechanical aspects of the nanoscience but coped well with the following concepts: chemical synthesis of nanoparticles, applications of nanoparticles and the unique physical properties of nanoparticles (although the students were less certain on how to explain this in terms of quantum mechanics). Press conference sessions tended to work very well but occasionally required the academic to deliver the first one or two questions. It was found that this activity works well if press conferences are limited to 10-15 minutes and with no more than 3 groups giving a press conference in each session (parallel sessions and a number of successive sessions have both been used to allow all groups to be assessed). Different lengths of press conference may be appropriate for students at later stages of their education.

Transferable Skills Development

This resource makes use of a number of types of assessment which share a common theme of communication. The authors have found that the use of C/PBL resources can be an ideal way of teaching communication skills in a scientific context and it is hoped that this resource will raise awareness of the relevant issues when communicating science to a range of audience types. The following transferable skills are encountered in this problem:

- Working in a small group on a mini-project **- Relevant throughout the problem**
- Critical thinking, decision making and independent learning **– Relevant throughout the problem**
- Preparing concise written critiques of active areas of scientific research - **Session 1.**
- Writing a scientific press release – **Session 1.**
- Orally communicate an understanding of an area of scientific research in an interview scenario (such as a press conference) – **Groups prepare for this between sessions 1 and 2 and are interviewed in session 2.**
- Working within a group to critically evaluate a number of different courses of action and justifying the decision made in a short written report – **Session 4 (and to some extent, session 1).**

The Scenario

The scenario places the students in the role of a chemistry advisory team to the government of Northland (a fictitious nation in North West Europe). They will be working with politicians, scientific advisors with different specialist areas.

Part 1 – Echoes of the past

The first part of the problem requires all students to work on the same task. The government of Northland has detected mercury contamination off the coast of one of the nation's most heavily populated areas. The students are asked to evaluate a new technology for mercury detection which is based on the use of functionalised gold nanoparticles (this approach is based on some research: Synthesis of Novel Nanocrystals as Fluorescent Sensors for Hg^{2+} Ions **Chemistry Letters**. Mirkin *et al.*, 2004, 33 **(12)** 1608-1609 – students have been informed of this approach in an email from the science minister but have also been given two references for articles which they should read). Students are asked to write a short recommendation to the government on whether this technology is suitable for the task; the report must include a description of the relevant physical and chemical properties of these nanoparticles. The report must also include a decision on whether this approach is better than other, currently available approaches for mercury detection – this will require the students to consider the sensitivity, the portability and the cost of this technique compared to currently available alternatives. The second part of the assessment of this task takes the form of a press conference. Students will answer questions from members of the press in their groups – the press will be formed of their peers and a few members of staff to seed the questioning if the students are unable (or unwilling!) to question the group. A list of suggested questions has been provided for tutors – you may want to encourage students to think about some of these themes when they are writing their report. Obviously it is very easy for students to write a very short recommendation with little background information but students who do this will find the press conference particularly tough!

Part 2 – Peer Review

The second part of the problem gives students a taste of the scientific peer review process. The students have been assigned to help a research council review a number of research applications based on the application of metal and/or semiconductor nanoparticles. In order to make this task possible for students with little experience of either the peer review process or this area of research, students are presented with very short 'summary proposals' and are asked to evaluate the ideas based on a consideration of the merit of the research and the potential benefits to both society and the scientific community. Students are asked to read through each of the applications and write a short summary of the project which includes a summary of the underlying science (i.e. details of the physical or chemical properties of nanoparticles that the project will make use of). Students are also asked to include a brief section on the potential benefit to society and the scientific community that this project will bring if successfully completed. Students have also been asked to rank the proposals in order of preference. As the nature of the applications is rather diverse (from the hyperthermic treatment of tumour cells by magnetic nanoparticles to the use of functionalised metal nanoparticles as catalysts in inorganic synthetic processes), it is likely that different groups of students will pick different applications as their most preferred option.

The next part of the task asks students to give a short presentation on their most preferred option. It is possible that one project will be picked by a number of groups, if you would like to avoid this in your implementation of this resource, you may prefer to assign the projects before the students read through them or you may want to ask the students to submitted their rankings of the proposals and assign projects to groups accordingly.

All of the research proposals that the students are presented with are closely based on real examples of research in nanoscience so students have been asked to assume that all applications are based on original projects. Students have also been told not to consider financial factors in order to ensure they don't get side-tracked away from the scientific content of the problem.

Advanced Students

If you are running this problem with students from later year groups (years 3 or 4), you should expect a higher level of answer to the facilitation questions and the problem solutions. For example, when discussing the electronic structure of gold nanoparticles, students should discuss the particle in a 1-D box model and show how the energy levels can be derived.

Tutor text

The red text in this version of the guide is meant to be seen by the tutor only. This text includes guidance on how the problem can be run, marking criteria, feedback from the trials and some (where appropriate) example answers.

Feedback from Trials

Trials of the resource revealed that students engaged well with the scenario and appreciated the opportunity to develop their communication skills:" Very useful part of the module to be taught as this is so important in later life". 80 % of respondents to an end of course questionnaire also stated that they appreciated the opportunity to receive feedback on science communication activities.