Learn Chemistry

The Nano Frontier

Tutor Guide

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National HE STEM Programme

RSC | Advancing the Chemical Sciences

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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.

The Nano Frontier - Suggested Texts:

Binns C., **Introduction to Nanoscience and Nanotechnology**. Wiley

Atkins P. & de Paula J., **Atkins’ Physical Chemistry**. Oxford University Press.

Schmid, G. (editor), **Nanoparticles**, Wiley

Astruc, D. (editor), **Nanoparticles and Catalysis**, Wiley

Ozin, G.A., Arsenault, A.C., Cademartiri, L., **Nanochemistry: A Chemical Approach to Nanomaterials**, RSC Publishing

Daniel, M-C., Astruc, D., *Chem. Rev*., **2004**, 104, 293-346

Wk	Session	Topics	Transferable Skills	Assessment	Preparation & Feedback
1	1 (60-90 minutes)	• Nanoparticles synthesis • MO Theory • Surface plasmon resonance • Particle in a box • Physical properties of gold nanoparticles • DNA functionalisation of gold nanoparticles	• Team working • Group discussion • Independent learning • Critical thinking • Decision making • Written communication • Independent learning	1. A two page summary of the group's recommendation on which approach to use in the detection of mercury contamination. The target audience is government ministers. 2. A one page press release summarising the course of action that will be taken by the government. The target audience for this is journalists. 3. Part of this session should be used to prepare material for the press conference.	Before session: Give students the session 1 handout In session: • Provide guidance to students during their discussion. Try to provide focus by asking facilitation questions and trying to get students to relate the questions to the research paper. • Ask students to briefly explain the contents of the paper if needed. • At the end of the session, give students oral feedback on their outline plan of action. Before next session: Receive brief written formative feedback on the summary and the press release before the next session.
2	2 (approx. 15 mins per group)	As above (this is the press conference session)	• Team working • Oral communication • Time management	A press conference to disseminate the group's chosen course of action. Given to an audience of peers who will act as members of the press.	Students should receive formal feedback on the press conference. If possible, it is useful to provide both individual and group feedback (preferably within one week of the session)
2	3 (60-90 minutes)	• Applications of nanoparticles • Magnetic nanoparticles • Nanoparticles in catalysis • Surface enhanced effects	• Team working • Group discussion • Independent learning • Critical thinking • Decision making • Written communication • Independent learning	1. Rank the four outline proposals 2. A short written summary of each proposal which outlines the background science and justifies the decision made.	Before session: Give students the session 3 handout In session: At the end of the session, give students oral feedback on their outline plan of action. After the session: • Students should receive formal feedback on the on the report. • If you choose to run the extension task, you should return this feedback before the next session.
3 **Ext**	Optional (suggest 15 mins per group – 3 or 4 groups per session)	Applications of nanoparticles (as session 3 list)	• Team working • Oral communication • Time management • Critical evaluation of the work of others	Students will give short oral presentations on the decision made in the previous session. The audience will ask questions based on the presentation. At the end of the session there will be a vote on the preferred option.	Before session: Give students the session 1 handout After the session Students should receive formal written feedback on the presentation. If possible, it is useful to provide both individual and group feedback (preferably within one week of the session). This should discuss the quality of the presentation in terms of both scientific skills

Session 1 (60-90 minutes)

Pre-Session Preparation

You should advise students that they should be prepared to discuss the following topics in the facilitation session:

- Synthesis and stabilisation of gold nanoparticles
- Molecular Orbital Theory and Band Theory in the context of the structure of metals
- Particle in a Box
- Physical and chemical properties of gold nanoparticles
- Surface plasmon resonance
- UV-Visible absorption spectroscopy
- DNA functionalised gold nanoparticles

Intended Learning Outcomes

By the end of this problem students should be able to:

- Describe and compare the different approaches used to synthesise gold nanoparticles and to evaluate these approaches in terms of what is needed to use these nanoparticles
- Describe and compare the mechanisms by which metal nanoparticles may be stabilised
- Explain why DNA functionalisation of the surface of nanoparticles can be used to produce highly selective biosensors
- Explain the origins of the differences in chemical and physical properties of gold nanoparticles with bulk metals as well as individual atoms and molecules (includes an analysis of the electronic structure of transition metal nanoparticles based on molecular orbital, band theory and particle in a box considerations)
- Relate the unique chemical and physical properties of metal nanoparticles to specific applications
- Evaluate the viability of an analytical technique based on a number of factors including sensitivity, reliability, ease of use and cost
- Perform a literature search on an active area of research in order to gain a greater understanding of fundamental scientific concepts are applied to current research
- Work in groups to produce written summaries of scientific research suitable for a range of different audiences
- Prepare for an interview (or in this case a press conference) based on the communication of a scientific concept to a specified audience type (the media in this case)

Resources

Make the following resources available to students **before** this facilitation session:

- The news article about the U-boat leaking mercury into coastal waters
- The email from the Ministry of Fisheries and Coastal Affairs requesting an evaluation of this approach (this email should include the two references that will help students research this application in more detail)

Facilitation questions

You may want to ask some of the following questions to stimulate discussion amongst groups during this session:

- How big are nanoparticles?
  The most common definition is 1-100 nm although the applications in this problem tend to focus on nanoparticles at the lower end of this size range.

- Why do their physical properties vary from those of the bulk form of the metal or individual atoms or molecules of the metal?
  Students should have encountered the fact that gold nanoparticles form coloured solutions from their pre-session reading – ask students to think about the origin of this colour. The fact that the metal nanoparticles are coloured should make the students think about the differences in electronic structure between the bulk form of them metal and the nanoparticles.
- Why are solutions of gold nanoparticles coloured?
  See answer to question below.
- Why does the colour of solutions of gold nanoparticles vary with size?
  Gold nanoparticles in aqueous solutions are typically deep-red in colour. This is due to a very broad absorption of light centred on a λ_{max} of around 520 nm. This is caused by the surface plasmon resonance which is a collective oscillation of the electron gas at the surface of the nanoparticles (i.e. the 6s electrons of the conduction band in the case of gold nanoparticles).
- Why does the surface plasmon resonance decrease for nanoparticles with core diameters of around 3 nm and below?
  This is because of the onset of quantum effects which become more significant for particles with diameters of less than 3 nm.
- What other factors can influence the colour of solutions of gold nanoparticles?
  Core charge – excess electronic charge causes shifts to higher energy, electron deficiency causes shifts to lower energy. The colour of olutions of gold nanoparticles is also affected by the interparticle spacing, the nature of the ligand shell, the shape of the nanoparticles and the solvent used.
- How are DNA functionalised gold nanoparticles commonly used?
  The synthesis and application of gold nanoparticle-oligonucleotide conjugates is currently a very active area of research. There are two primary motivations for this research – one is the ability to use the interactions between complementary DNA strands to organise individual nanoparticles into precise 3D arrangements in space. The second motivation for studying these systems is the need to develop highly sensitive biosensors due to the ability of these modified particles to act as highly selective and sensitive detectors of specific DNA sequences.

Assessment

For the first part of this problem the students should first make a recommendation about whether to use this technique or whether to stick with conventional approaches. Either way the students will produce a two page summary of the background science behind this approach which justifies their discussion. The report should include a summary of the key physical and chemical properties relevant to this application (especially the strong size-selective absorbance of light by these particles due to the surface plasmon resonance and the high degree selectivity of oligonucleotides functionalised nanoparticles for specific DNA sequences). Students will also need to discuss how this approach can be quantified by making use of UV-Visible absorption spectroscopy. Students should compare this approach with existing mercury detection approaches – this comparison should include factors such as selectivity of the technique for mercury detection, sensitivity of the technique and ease of use (perhaps including some cost factors).

Group reflection

At the end of this session give students around 10 minutes to reflect upon their discussions in this session. Students should ask themselves whether they are confident that they understand the material covered or do they need to carry out further research on some topics.

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.

Ask the students to briefly summarise their progress during the session and to present a plan of what they intend to do before the next session.

World War 2 Era Sub Threatens Northland Communities

A Northland city is facing the lethal legacy of a World War II era submarine which is gradually leaking a toxic metal into coastal waters.

The German U-boat was carrying a cargo of mercury intended for use in weapons production in Japan didn't reach its destination as it was destroyed by allied naval forces off the western coast of Northland in 1945. Although the mercury was never used in the production of weapons, it still poses a serious threat to marine and human life in Northland.

The Northland government has discovered that mercury is slowly leaking from the sunken vessel and is now concerned about sealing up the leak and evaluating the risk to human and marine life from mercury that has already been leaked. The government has decided to seal up the wreckage as it was decided that moving the remains of the boat would possibly result in collapse of the hull leading to a significant increase in the amount of mercury released into the local environment.

"We are very concerned about the impact that this contamination will have both on the local marine population and the inhabitants of the city, we need to act fast to prevent this problem from escalating into a disaster" said Northland's minister for the environment earlier today.

The remains of the U-boat were discovered by the Northland navy earlier this year; it is thought that the broken remains of the boat have been sat on the sea bed off the coast of Northland since at least 1945, possibly leaking mercury the whole time.

The government's Environmental ministry has set up an exclusion zone around the affected area and has banned fishing within a 5 mile radius. The government aims to perform more thorough tests on the levels and distribution of mercury in local waters.

The government is currently investigating a number of techniques that may be used to measure the level of mercury contamination including an experimental technique based on the use of gold nanoparticles. The government will announce more details at a press conference in a week's time.

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From: **Ann Smith [asmith@northland.gov]**

To: **Science team**

Cc:

Subject: **Mercury detection problem**

Dear Team,

As I'm sure you will already be aware, action is being taken to ensure that the no more mercury can escape from the destroyed U-Boat near the west coast of our nation. During routine investigations of mercury levels in coastal waters near Borland, abnormally high levels of the mercuric ion (Hg^{2+}) were detected. We are very concerned that this contamination will affect the local ecosystem and possibly spread into the water sources used by communities near the coast. We have investigated the levels of Hg^{2+} in rivers and streams near the west coast and no contamination has been detected, our fear is that the level of contamination is too low to be detectable by conventional means.

We need to develop a systematic process of testing contamination levels, this process must be cheap to run, portable and accurate at very low concentrations (ca. 1000 pM) of contaminant.

We are considering the use of a new technique to detect this pollution (see reference below). We need you to evaluate the viability of this process compared to existing mercury pollution techniques – remember to pay particular attention to the unique advantages that the new approach offers – a two page summary for circulation to government ministers will suffice. You will also need to write a one page press release informing journalists of what we plan to do which includes information on the background science, you will also need to answer some questions at a press conference.

1. Synthesis of Novel Nanocrystals as Fluorescent Sensors for Hg^{2+} Ions ***Chemistry Letters.***, 2004, **33 (12)** 1608-1609
2. Colorimetric Detection of Mercuric Ion (Hg^{2+}) in Aqueous Media using DNA-Functionalized Gold Nanoparticles ***Angew. Chem. Int. Ed.***, 2007, **46**, 4093 –4096

Yours faithfully,

Ann Smith

The Northland Ministry of Fisheries and Coastal Affairs

<u>Summary for the tutor:</u> This application is based on the work detailed in reference number 2 (above). This research was carried out members of the Mirkin group at Northewestern University (Evanston, Illinois, USA) which has become one of the world's leading groups in the research of DNA functionalised metal nanoparticles. The application is based on the functionalisation of complementary DNA strands with intentional T-T mismatches (i.e. DNA strands which do not hybridise under normal conditions due to the presence of a single thymidine mismatch). Hg^{2+} ions selectively bind these two types of DNA sequences at the site of the T-T mismatch (due to the selectivity of the mercuric ion for the bases that make up the T-T- mismatch) significantly stablising assemblies of gold nanoparticles formed by the interaction of these two types of DNA sequence. These assemblies have distinctly different optical properties to the individual nanoparticles (the surface plasmon resonance is affected by the interparticle spacing) which results in the apparent colour of solutions of these particles shifting from red to purple. This effect is measured by

recording the melting (i.e. dissociation) transition of the nanoparticles which is accompanied by a colour change from purple to red (as the assemblies of nanoparticles break up to reform individual nanoparticles with a characteristic colour due to the surface plasmon resonance band). Due to the stabilising effect of the mercuric ion on these assemblies of gold nanoparticles, the melting transition occurs at a higher temperature than in the absence of the mercury pollutant. This method is very selective (other metal ions of similar size and charge do not have the same stabilising effect on the assemblies of nanoparticles), very sensitive (Hg^{2+} can be detected at concentrations between 100 nM to the low micromolar range – a better sensitivity than conventional methods of detecting mercury pollution which typically have lower detection limits in the micromolar range) and offer a practical detection method – analysis only requires UV-Visible absorption spectrometer with temperature control.

Suggested questions for the press conference (for tutor only)

1. **Our readers have heard a lot about nanoparticles but nobody ever really gives the public any details about what they are, can you provide us with any more details?**

Nanoparticles are a class of chemical species which exhibit physical and chemical properties which differ from both the classical bulk properties and individual molecules. Metal nanoparticles are usually defined as very small assemblies of metal atoms with dimensions between 1-100 nm.

2. **How are the gold nanoparticles synthesised? How are these particles 'functionalised' with DNA?**

There are a number of viable synthetic approaches but the two key mechanisms that students should be familiar with are the Citrate reduction (Turkevich-Frens) and the two-phase reduction (Brust-Schiffrin) approaches. Alkanethiol stabilised gold nanoparticles (produced via the Brust-Schiffrin approach) can be coated with thiol terminating DNA strands for a number of practical applications (including the creation of specific 3D assemblies of nanoparticles and the use of nanoparticles as biosensors).

3. **How big are the nanoparticles? How do they compare in size to the mercury atoms (sic.) in the water? How big are these particles relative to the thickness of a human hair (which is about 1 μm)?**

Specifically: these nanoparticles have average core diameters between 13 and 50 nm. More generally, assemblies of gold atoms with average core diameters of between 1-100 nm are classed as gold nanoparticles. 15 nm gold nanoparticles are 66.7 times smaller than the width of a strand of hair. Ionic radius of Hg^{2+} is 116 pm (the atomic radius is 151 pm). The nanoparticles are 129.3 times bigger than the mercuric ions.

4. **Do we know what these particles look like? How can we take pictures of something so small?**

Students can talk about a number of characterisation techniques but the use of transmission electron microscopy (TEM) is possibly the most suitable technique for visualising these particles. Students should establish why optical microscopy can't be used by comparing the wavelength of visible light with average core diameter of these particles.

5. **Does introducing these nanoparticles to local water supplies pose a health risk?**

This is a very valid question (and is very typical of the type of question that one could anticipate the media asking in such a scenario) and one that is potentially tricky to answer for students. This remains an active area of research and there is still no clear answer to this question. Lethal effects have been detected in mice when sufficient doses of gold nanoparticles were used but it is still widely believed that in the quantities currently used in most research applications, these particles are effectively non-toxic.[1,2]

6. **We hear that these nanoparticles can change colour when they come into contact with mercury – how do they do this? Do we really need to use nanoparticles to achieve this effect? Surely larger particles of the same chemical substance would work just as well?**

Students should try to address the difference in properties between gold nanoparticles and bulk gold. Bulk metals are adequately described by band theory, nanoparticles are more adequately described by the particle in a box model due to confinement of the electron wavefunction in a region of space which is similar to the de Broglie wavelength of the electron. When a small spherical metal nanoparticle interacts with light, the oscillating electric field causes the conduction electrons to oscillate coherently. When the electrons are displaced from the nucleus in this way, a restoring force acts (due to Coulombic attraction between the nucleus and the electrons).

The colour of solutions of gold nanoparticle is highly dependent on size, shape and interparticle spacing – it is this property which is being exploited here. The wavelength of maximum absorption of the surface plasmon resonance is shifted to a higher wavelength when the nanoparticles are conjugated to surrounding particles – this is observed as a colour change from red to blue. Bulk gold wouldn't be suitable for this application as it does not form strongly coloured solutions due to the absence of the surface plasmon resonance band.

7. **You are using gold nanoparticles in this experiment. That seems incredibly wasteful, why not use nanoparticles produced from something less valuable? How much gold will we need? Will we have to start using our currency reserve?**

The quantity of gold required is actually very small. Students can do a very quick (and approximate!) calculation to demonstrate this – the predominant clusters of atoms formed when nanoparticles tend to correspond to a 'magic number' sizes of 8, 20, 40, etc. atoms (these numbers correspond to the filling of major electronic shells of the clusters at particular sizes). Students can determine how many gold atoms are available to form these clusters from the experimental conditions of synthetic approaches (they can get this from papers) – from this data they can determine how many nanoparticles of a particular 'magic number' size can be formed.

8. **This sounds like an expensive project – how much public money will be spent on the production of these particles and in generating the results? How long will it take us to get an accurate result from this technique?**

The result can be obtained quickly using relatively simple instruments (i.e. a UV-Visible absorption spectrometer with temperature control). The sample of water is added to the assay and the melting temperature is determined by measuring the absorption of light at the wavelength of maximum absorption of the surface plasmon resonance band (525 nm) – the melting transition occurs at 46 °C in the absence of Hg^{2+}, if Hg^{2+} is present the transition occurs at a higher temperature due to stabilisation of the gold nanoparticle conjugated due to the fact that the ion binds to the thymidine thymidine mismatch in the DNA sequence.

9. **Will these nanoparticles help us detect the minuscule quantities of mercury that we are told is present in the water?**

The technique has been demonstrated at a Hg^{2+} concentration of 20 nM which is lower than any other mercury detection method.

10. **What is meant by a melting transition? Will these nanoparticles still work if they are melted?**

Students should pick up on the fact that the melting transition refers to the transition from stable assembles of nanoparticles (held together by interactions between the complementary DNA sequences on different nanoparticles to individual nanoparticles at certain temperatures (these transitions are accompanied by significant changes to the colour of these solutions). Students should also point out that that these transitions happen at a higher temperature in the presence of mercury due to stabilisation of the assemblies of nanoparticles by the

mercuric ion which strongly binds to the mismatched thymidine groups in the DNA sequences – if students don't raise this, it may be worth adding an additional question.

1. Chen, Y-S., Hung, Y-C., I. Liau, G.S. Huang, *Nanoscale Res. Let.* ,**4**, 2009, 858-864
2. Y. Pan, S. Neuss, A. Leifert, M. Fischler, F. Wen, U. Simon, G. Schmid, W. Brandau, W. Jahnen-Dechent, *Small*, **3**, 2007, 11, 1941-1949

Guidance for writing a press release

A good scientific press release should communicate concepts and/or research to a wider audience. Press releases can often lead to wider interest from the press as well as TV & radio journalists

Press releases must be concise, they must have titles with impact (think about how many press releases newspaper editors read – your story must make an impact in the first few words!), and they must get to the point quickly. Press releases most be factual, they need to be timely (i.e. avoid producing press releases on old work and try to produce releases at a time when they will generate interest – see the BBC news story about Olympicene just before the 2012 Olympics as an example!) and they need to be well-written

The opening section should make the following clear:

- Who – did the research?/made the breakthrough?/made the decision?
- What – did they discover?/did they decide?
- When – did they do this?/what was the timescale?/when will it be of general interest?
- Where – was this work done?/will it have an impact?/is it local?
- Why – did they do it?/does this impact on the reader?
- How – was this achieved?

Feedback

Feedback on the group discussion can be given by tutors during the facilitation session. Although it is important to avoid directing the students, it is worth asking students who appear to have lost focus to think about the viability of their suggestions and to suggest alternative approaches. It is also important to encourage all group members to contribute to the discussion so if there appear to be any 'passengers' (non-contributing students) ask them what they think about the group's ideas.

It may be useful to ask students to present a short plan of action to their tutor before the end of the session. The plan should include a description of what work will be done by each member and on what timescale. Has the group considered the time needed to proof-read each other's work?

It will be very useful to students if you can set a deadline for the press release ahead of the press conference allowing you to give feedback comments before the conference. If you are holding the press conference a week after the first session, perhaps you could ask students to submit their press releases two or three days after the first facilitation.

During the trial run of this resource, this task was assessed formatively with feedback comments being added to the press releases electronically (e.g. using 'Track changes' and 'Comments' in Word).

The Press Conference

A brief description of the press conference format is given below. You may find it useful to spend 10-15 minutes at the end of this session discussing this format with all groups and asking them to think about what works and what doesn't.

A press conference is another way of communicating scientific ideas; the press release that you have prepared will form the basis of this conference. A typical press conference will start with a short address from the presenters which summarises the message that they hope to get across. This is followed by a longer period of questioning from the audience (members of the press).

It is important to remember these points:

- This is not a standard oral presentation, the majority of the time you will be answering questions. You should not prepare a PowerPoint presentation!
- Communicate your responses at an appropriate level – the audience won't be experts so it won't be much use to simply quote findings direct from a research paper!
- Critically evaluate your press release and compile a list of possible questions. Put yourselves in the shoes of the press. Some of the things that you may want to think (depending on your decision) about include:
    - Why are you proposing the use of an untested, experimental technique to solve a real-world problem? (i.e. applicable if you have decided to use this new approach)
    - Why are you using older techniques when a new, potentially quicker and more sensitive technique has been described in the research literature? (i.e. if you decide to use another approach to detect the mercury).
    - You may want to think about the timescale and the accuracy of the techniques. Will the chosen technique deliver sufficiently accurate results on a timescale that will protect the local population?

Session 2 (suggestion - 15 mins per press conference divided into 45 min sessions)

This session will be used for the press conference. You may want to call groups in one at a time in order to avoid groups who talk later in the session having an unfair advantage from hearing the questions asked earlier in the session. You may want to consider asking students at the same level who do not study this module to form an audience and possibly peer assess the groups and contribute to the questioning.

Alternatively if it is not practical to run one presentation at a time, you may prepare a large number of questions which will allow enough variation in questioning between groups to avoid making the process easier for groups who go later in the session. If students form part of the audience they should contribute to the questioning. You may need to seed each session with one or two questions but during the trials (year one chemistry) students engaged well with this scenario and asked a number of good questions.

Intended Learning Outcomes

By the end of this problem students should be able to:

- Verbally communicate scientific ideas with an audience of peers and to respond to a range of questions on the ideas presented
- Act as ambassadors of science in the community by helping the public gain a deeper understanding of scientific concepts which are often miscommunicated by the media

Notes

At this point you may find it useful to give students one or two of the example questions listed at the end of the session 1 resources.

During the trials of this resource, the press conference was both peer assessed and assessed by an academic. Students were asked to award a mark based on the quality of the answers as well as the level of communication skills from the speakers. Students were asked to consider whether the group remained in control of the press conference or whether the questioners had them 'against the ropes'.

During the trials 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)

Mark Scheme

The following mark scheme was issued to students:

Total marks available: 10

8 (or more) - The opening statement was informative, concise and clearly presented the group's argument. The group answered all questions well (and at the appropriate level for a non-expert audience) and retained control of the press conference throughout allowing them to present their case.

7 - The opening statement was sufficiently clear to allow the listener to grasp the group's case and the level of content was generally appropriate. The group responded well to most questions but may have struggled with one or two points. In general the group remained in control of the situation.

5 to 6 - The opening statement was adequate but some aspects were unclear. The group responded well to some questions but struggled with others. Some attempt was made to answer the questions at an appropriate level for a non-expert audience. The group struggled to retain control of the press conference - it felt like the questioners were steering the direction.

1 to 4 - The opening statement was difficult to follow and the group struggled with many of the questions. The level of content may have been inappropriate for the specified (non-expert) audience. It felt like the questioners were in control of the press conference.

Feedback

During the trials, peer and academic feedback was returned to groups within a week of the session.

Session 3 (60-90 minutes)

Pre-Session Preparation

You should advise students that they should be prepared to discuss the following topics in the facilitation session:

- The application of functionalised metal nanoparticles as biosensors
- Magnetic nanoparticles
- The use of magnetic nanoparticles in hyperthermic treatments of cancers
- Nanoparticle catalysts
- Surface enhanced effects of metal nanoparticles

Intended Learning Outcomes

By the end of this problem students should be able to:

- Explain the difference in chemical properties of gold nanoparticles in terms of the significantly larger surface to volume ratio of the nanoparticle form of a metal relative to that of the bulk form
- Describe how the unique physical and chemical properties of metal (specifically gold) nanoparticles are (or can potentially be) used in a number of real-world applications

Resources

Make the following resources available to students **before** this facilitation session:

- The news article about the government investment in nanoscale research
- The email from the science minister asking the team to join the research committee panel in order to allocate the funding and an email from the research council leader which the four outline proposals that the students need to consider.

Facilitation questions

Facilitation questions follow each of the outline proposals. You may want to ask students to attempt all facilitation questions before deciding which project to back. Alternatively you can ask students to back a project first and then only answer the relevant questions.

Assessment

For this part of this problem the students should agree on a ranking of the outline proposals (1 being their most favoured application and 4 being their least favoured). Students will need to identify the science necessary to explain each of these applications. The ranking of applications is subjective; the applications are all based on real research. The outline proposals have been kept intentionally short in order to encourage students to do further reading in order to find out more about similar research in the same areas. Students will be asked to submit a short report on each of these applications which includes details on the background science and justifications for their final decisions. The final part of the assessment of this problem will require students to face questioning on their 'most favoured' option from other members of the research panel

Group reflection

At the end of this session give students around 10 minutes to reflect upon their discussions in this session. Students should ask themselves whether they are confident that they understand the material covered or do they need to carry out further research on some topics?

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.

Ask the students to briefly summarise their progress during the session and to present a plan of what they intend to do before the next session.

Northland government announces massive investment in nanoscale science.

Following the recent use of DNA functionalised gold nanoparticles in the detection of mercury pollution levels the government has announced a massive package of investment in nanoscale science. The science minister commented that "this will put Northland at the forefront of this developing area of research. We project that this initiative will promote private investment in Northland and will be yet another contributing factor to the recovery of our economy".

The project was launched with the announcement of government funding for academic research projects which will be distributed by the Northland Physical Sciences Research Council (NPSRC). A research council representative stated "We have an opportunity to develop and support a network of research excellence in the nanosciences. We need to make sure that our academic output encourages the investment of private financial support in this area".

The first research activities to be funded by this project will be announced in the coming weeks.

From: **Science Minister [scienceminister@northland.gov]**

To: **Science team**

Cc:

Subject: **Research council request**

Dear Team,

As part of the recently announced strategic investment programme in fundamental scientific research, we have made a significant sum of money available for projects based on the application of nanoscience to real-world problems. We are very keen to ensure that Northland continues to be a leading force in nanoscale research in Western Europe as we are keen to attract international investment in the commercialisation of this research.

Following your recent research into the use of gold nanoparticles in the detection of mercury contamination, we have recommended that you sit on the research committee panel which will decide how some of the initial funding that we have provided will be allocated. You will be contacted by someone from the committee in due course.

Yours faithfully,

James Smith

Science Minister of Northland

Students will be presented with four very brief summaries of research proposals based on real research in the area of nanoscale science. These areas of research bring together the chemical sciences with biology, medicine and physics. Students should be encouraged to perform read more about these projects in research literature. Students should be reminded that they should assume all of this research is original – if they think the research has been previously published, it should be pointed out that these proposals are based on follow-up studies to the original research. Some of the basic concepts covered in these proposals may be new to year one and two chemistry students

(such as Hyperthermia, dendrimers, Raman spectroscopy and the conjugation of DNA sequences – students should be encouraged to research the basics of these concepts – facilitation questions designed to make this easier have been included).

From: **Alan Douglas (Prof) [a.douglas@npsrc.gov]**

To: **Science team**

Cc:

Subject: **Nanoscale projects**

Dear Team,

The government science minister has requested that we include you in the process of allocating funds to innovative nanoscience projects. The first stage of the selection process will be to rank the viability of a number of projects. Please find four outline proposals attached, we need your team to read through each of these and to write a short (approximately 600 word) summary of the science behind each of these outline proposals. It is vital that we select projects which are based on sound scientific concepts and that each project will provide benefits to both the wider scientific community and society. We also need to rank these outline proposals from 1-4 (with 1 being the proposal that you would most like to see funded).

Yours faithfully,

Prof Alan Douglas

Head of the Northland Physical Sciences Research Council

Note - You may assume all of these applications are based on original research and you need not consider financial factors when reviewing these applications.

These outline proposals represent a starting point – you will need to do more research on these topics (you may find the references at the bottom of each outline proposal helpful).

Outline Proposal 1

Dr A. Jenkins, Northland Institute for Sustainable Synthesis and Catalysis

The Development of Novel Gold Nanoparticle Based Catalysts

In spite of the long-held belief that gold is too inert to be used as a catalyst, recent research has shown that gold can behave as a highly active catalyst if it is used in nanoparticle form. The development of novel oxide supported catalysts has been applied to a number of synthetic approaches including the catalytic oxidation of CO by transition metal nanoparticles on oxide supports.[1]

The high surface area to volume ratio of transition metal nanoparticles makes these particles highly accessible for catalytic reaction and therefore increases the reaction activity and the turnover number

We propose the synthesis of a range of gold nanoparticle dendrimers composites which will be tested as catalysts in a number of diverse synthetic processes.

1 S. Galvango and G. Parravano *J. Catal*. **18**, 1978, 320-328.

This application has been left intentionally rather open in order to encourage the students to focus on the chemical properties of the nanoparticles rather than the mechanisms of the reactions that this process will catalyse. Students favouring this application should highlight the unique surface area to volume ratio (mentioned in the proposal). Transition metal nanoparticles mimic metal surface activation and catalysis at the nanoscale. The most catalytically active metal nanoparticles tend to have average core diameters of only a few nanometres

Outline Proposal 2

Dr B. Paige, Centre for Biological Chemistry, University of Northland

The Use of Functionalised Metal Nanoparticles in the Detection of Biomarkers Associated with Alzheimer's Disease

The use of oligonucleotides-metal nanoparticle conjugates in the detection of specific DNA sequences has developed into a highly active area of research in recent years. The use of metal nanoparticles in the detection of DNA and protein markers for diseases has been motivated by a drive to improve the selectivity and sensitivity of currently used approaches.

The early detection of markers is vitally important in the fight against many diseases. Current detection procedures are often complex, expensive and not portable. The development of simple (and sensitive) nanoparticle based detection methods would remove many barriers to point-of-care treatment which would have a number of benefits on both local and international levels.

The potential improvements in detection sensitivity will allow for significantly earlier detection of specific protein sequences, allowing the diagnosis of conditions (such as cancers) at an earlier stage than possible with current detection approaches, this could potentially have a major impact on the survival rate of many conditions.

Our project will focus on a study of the sensitivity of functionalised metal nanoparticles which can detect ADDL, a potential marker for Alzheimer's disease. This process will followed by monitoring the effect of the antibody concentration on the wavelength maximum of the localised surface plasmon resonance.

DNA – Gold nanoparticle conjugates are of immense potential value to chemists and biologists. These structures can act as highly sensitive and selective biosensors for specific DNA sequences. DNA strands attached to gold nanoparticles retain their ability to hybridise with complementary DNA

(this general theme was introduced in the first part of the problem – the use of DNA functionalised gold nanoparticles in the detection of mercury pollution).

The combination of the affinity of gold nanoparticles for thiol functionalised oligonucleotides with the unique optical properties of gold nanoparticles (due to the surface plasmon resonance – the collective oscillation of surface electrons due to the interaction with incoming light) make these structures ideal candidates for biosensors. When gold nanoparticles aggregate in the presence of specific DNA sequence, a distinct colour change can be observed. These aggregates can be further analysed by measuring the melting temperature of these aggregated gold nanoparticles (as previously described for the detection of mercury pollution).

Additional information from the original research paper (for the tutor): Metal nanoparticles are ideally suited to biodiagnostic approaches due to their small sizes, their ability to selectively bind to biological targets and their large surface to volume ratios. The variation of the physical properties of metal nanoparticles is easily achieved by changing the synthesis and processing conditions.

We propose to build upon recent breakthroughs by preparing a simple nanoparticle based assay for the detection of amyloid β-derived diffusible ligands (ADDLs) which have been identified as potential markers for Alzheimer's disease. Alzheimer's disease is a condition which leads to the onset of dementia in people over 65 years of age. Although there is no clear agreement on the mechanism by which the condition develops, it is thought that amyloid-β plays an important role.

Outline Proposal 3

Prof S. Patel, Solid State Physics Department, Netherley University

The Use of Magnetic Nanoparticles in the Treatment of Cancerous Cells by Hyperthermia

Due to the inherent sensitivity of biological cells to small changes in local temperature, cell death can be induced by a heat source. It has recently been demonstrated that magnetic nanoparticles which have been functionalised with an appropriate ligand to specifically bind to cancerous tissue could be used to induce cancer cell death if they are dispersed throughout the target tissue.[1,2] These nanoparticles can be 'activated' by the application of an external magnetic field which will heat the nanoparticles; this heat is then transferred to the surrounding cancerous cells. If the magnetic field results in a sufficient temperature increase for a sustained period of time, cancer cell death can be induced.

The localised heating of cancerous tissue by magnetic nanoparticles would be a major weapon in the fight against cancer. This project will produce superparamagnetic iron oxide nanoparticles which will be appropriately functionalised for binding to cancerous tissue. The hyperthermic effect of the nanoparticles will be evaluated in ex-vivo conditions to find ensure that the nanoparticles successfully bind to cancerous tissue and to measure how effectively heat is transferred from the nanoparticles to the cells when an alternating magnetic field is activated.

1 Q. A. Pankhurst, J. Connolly, S.K. Jones and J. Dobson, *J. Phys. D: Appl. Phys*. **36**, 2003, R167-R181

2 R. A. Sperling, P. R. Gill, F. Zheng, M. Zanella and W. J. Parak, *Chem. Soc. Rev*. **37**, 2008, 1896-1908.

The use of magnetic nanoparticles in hyperthemic treatments of tumorous cells has recently been investigated by a number of groups. The nanoparticles are functionalised with DNA sequences in a similar manner to that described in application 2 – the nanoparticles selectively bind to the target nuclei acid sequences. When an alternating magnetic field is applied, the particles undergo magnetic hysteresis and can heat the surrounding cancerous cells, leading to cell death.

Outline Proposal 4

Dr J Andrews, Biophysical Group, Department of Physics and Astronomy, Southborough University

The Use of Iron Oxide Nanoparticles in Surface Enhanced Raman Resonance (SERS)

Surface enhanced Raman spectroscopy (SERS) is a powerful and sensitive Raman spectroscopy technique which allows a strongly enhanced signal to be detected from analytes on certain surfaces. The enhancement of Raman signals can be described by either Physical or Chemical mechanisms. This technique will be used to identify the genes sequences in a number of different viruses including HIV and the Hepatitis virus.

Surface Enhanced Raman Scattering allows enhanced Raman signals from Raman-active molecules by adsorbing the molecules onto certain types of surfaces. Enhancement can occur via either electromagnetic or chemical enhancement. The surface enhanced Raman effect occurs due to the enhancement in the electric field provided by the surface. Localised collective plasmon absorptions are induced in gold nanoparticles when EM radiation of the appropriate frequency is incident upon the particles.

Facilitation questions

You may want to ask some of the following questions to stimulate discussion amongst groups during this session:

Catalysis

- **Why are gold based catalysts of limited use to chemists?**
  Students should know that gold is very well known for being chemically inert. It is one of the most stable metals in group 8 and is resistant to oxidation. Some limited application of gold based catalytic systems have been discovered since the 1970s but the most important gold based catalytic systems are those based on gold nanoparticles.
- **Why do the catalytic properties of gold nanoparticles vary so greatly to those of the bulk form of gold?**
  Many of the other applications discussed in this problem focus primarily on the unique physical properties of metal nanoparticles, however, this application focuses on the unique chemical properties of gold nanoparticles which occur largely due the very high surface to volume ratio.
- **What are dendrimers? How are they used to functionalise nanoparticles?**
  Dendrimers are hyperbranched macromolecules which are built around a core and feature regular branching generation after generation.[1] Dendrimers are monodisperse and highly symmetrical. When functionalising nanoparticles, dendrimers act as both polymers and ligands. Dendrimer functionalised nanoparticles can be directly synthesised by using a modified version of the Brust-Schiffrin method where the stabilising ligands are thiol functionalised dendrons which bind to the gold core to form a dendrimer.

1. **Nanoparticles and Catalysis, edited by Didier Astruc, WILEY-VCH GmbH & Co. KGaA, Weinheim, Germany. 2008.**

Biochemical applications

- **What are oligonucleotides and how do they relate to DNA?**
  An oligonucleotide is a molecule which contains just a few nucleotides a short nucleic acid polymer. If oligonucleotides are composed of 2-deoxyribonucleotides, they are effectively short DNA fragments.
- **What is meant by the term 'selectivity' in the context of biosensors and why are these functionalised nanoparticles so selective? Would these biosensors work if the same DNA sequences were applied in the absence of the metal nanoparticle? If not, why not?**
  In this context, selectivity refers to the ability of the biosensor to exclusively detect a single, specified DNA sequence and no other. Oligonucleotide functionalised gold nanoparticles are very effective as they are functionalised with a specified DNA sequence that will only be complementary to a sequence present in the biomarker that is being tested for. The assay would not work without the metal nanoparticles as it relies on the unique optical properties of metal nanoparticles to provide an indication of a positive result.
- **What approaches can be used to functionalise gold nanoparticles with DNA sequences?**
  A number of approaches are reviewed in the literature including approaches based on the Brust-Schiffrin method which are functionalised by alkanethiol-capped oligonucleotides.

Nanomedicine

- **What is meant by the term 'hyperthermia therapy'? How is this effect achieved in this research?**
  Hyperthermia therapy is a medical approach in which cancerous tissue is exposed to elevated temperaures in order to kill cancer cells. This treatment potentially allows highly localised heating to be achieved by introducing modified nanoparticles to the patient, the nanoparticles will then bind to the cancer cells (due to the fact the particles are functionalised by DNA strands which are complementary to those in the cancer cells). The patient is then exposed to alternating magnetic fields that indue magnetic hysteresis within the nanoparticles, this heat is then transferred to the surroundings (i.e. the cancer cells)
- **What makes certain nanoparticles magnetic?**
  Small iron oxide nanoparticles consist of a single magnetic domain (i.e. the region within a magnetic material which has uniform magnetisation).
- **What is paramagnetism? How is superparamagnetism different?**
  Paramagnetism is a form of magnetism in which the material is slightly attracted to an applied magnetic field but is not magnetic when the external field is switched off. It is characterised by systems with unpaired electrons (such as O_2 as shown by molecular orbital theory). Superparamagnetism is a form of magnetism seen in ferromagnetic nanoparticles. Students may discuss relaxation mechanisms of superparamegnetic materials.
- **Apart from their magnetic properties, what else makes nanoparticles particularly suitable for this application?**
  The magnetic nanoparticles are functionalised with specific nucleic acid sequences which allow selective binding to complementary sequences in the target biomarker.

Surface Enhanced Raman Sensing

- **What is Raman spectroscopy?**
  Raman spectroscopy allows the vibrational and rotational energy levels of a molecules to be studied by analysing the frequencies of radiation scattered by the molecules. If incident photons of EM radiation lose energy to the molecules, the scattered photons are referred to as Stokes radiation. If incident photons gain energy from the collision, they are referred to as anti-Stokes radiation. Students may also discuss how the data obtained from this technique complements data obtained from infrared spectroscopic analysis due to the different selection rules.
- **What is Surface Enhanced Raman Scattering?**
  Surface Enhanced Raman Scattering allows enhanced Raman signals from Raman-active molecules by adsorbing the molecules onto certain types of surfaces. Enhancement can occur via either electromagnetic or chemical enhancement.
- **How do metal nanoparticles enhance the Raman signal?**
  The surface enhanced Raman effect occurs due to the enhancement in the electric field provided by the surface. Localised collective plasmon absorptions are induced in gold nanoparticles when EM radiation of the appropriate frequency is incident upon the particles.

Extension Task

Session 4 (60-90 minutes)

This part of the problem is an optional extra if there is enough time. The groups will give short (10-15 minute) presentations on the decisions made based on the discussion in the last session. You may find it useful to break this session into a number of smaller sessions with 3 or 4 groups presenting per session. It may be useful to pick four groups which have selected different proposals as their number one choice in the previous session to speak in each session. Students can be asked to vote (individually) on their preferred proposal at both the start and the end of the session.

Intended Learning Outcomes

By the end of this problem students should be able to:

- **Give a short scientific presentation to a varied audience justifying a decision to back a research project.**
- **Justify a decision to back a given scientific project by considering the relative merits (including value for money, scientific viability, industrial/social/medical applicability, etc.) of a number of alternative courses of action.**
- **Demonstrate a clear understanding of the background science of a chosen area of scientific research**
- **Describe similar work that has been done by other groups in a chosen same research area**
- **Critically evaluate scientific presentation given by other groups and ask questions based on the viability of the decision presented by those groups.**

Assessment

The oral presentations will be assessed and detailed feedback will be given. You may choose to peer assess this activity which will generate a significant amount of peer feedback which can be sent to students.

From:	**Alan Douglas (Prof) [a.douglas@npsrc.gov]**
To:	**Science team**
Cc:	
Subject:	**RE: Nanoscale projects**

Dear Team,

Thank you for submitting your reports and your rankings. We would like to invite you to present your decision at a short seminar for government ministers (with a range of backgrounds). You will be given 15 minutes (including questions) to present your chosen proposal.

Best wishes,

Prof Alan Douglas

Head of the Northland Physical Sciences Research Council

Aim of this session:

Give a short presentation (around 10 minutes long followed by up to 5 minutes of questions from the audience) on your decision. Your presentation must make it clear what your preferred proposal is and must justify this in terms of the background science. You will be expected to ask questions to the other groups at the end of their presentations in order to

Marking Criteria

Press Conference (Session 2)

- Did the students summarise their decision in a concise and informative manner in the press conference?
- Did the group demonstrate a clear understanding of the scientific basis of their chosen course of action? Was it clear that the students had considered the points in the discussion questions from the first session?
- Did the students respond well to questioning?
- Were the students able to discuss the mechanism by which these nanoparticles can be used to detect mercury pollution?
- Did students consider the relative strengths and weaknesses of the different approaches to detection of mercury pollution (e.g. sensitivity, selectivity, ease of use in the field, cost, reliability, etc.)

Mark out of 10:

8 (or more) -The oral presentation was very well structured and clear. The group responded very well to all questions asked – responses were scientifically correct and delivered in a clear, confident manner. All of the points listed above were covered very well.

7 - The oral presentation was sufficiently clear to allow the listener to understand the key points made by the group. The group responded well to most questions – responses were scientifically correct and were delivered generally well. Most of the points listed above were covered well by the group's responses.

5 - The standard of the presentation was adequate. The group managed to cover some of the points listed above – The group struggled to respond to some of the questions and appeared to be 'against the ropes' at times .There may have been some scientific errors.

3 - The standard of presentation was very poor. The group struggled with most of the questions and failed to address many (or all) of the points listed above. The group struggled with most (or all) of the questions asked.

Written content:

- **A (1st) - Excellent** The answer contains all the things listed in the criteria and one or two extra related things
- **B (2.1) - Very Good** The answer has almost all the things listed in the criteria (only minor things missing) – any calculated values are close to the recommended values.
- **C (2.2) - Good** Most of the things listed in the criteria appear in the answer, some missing content and/or some error in written content and/or calculations.
- **D (3rd) - Modest** The answer has significant content missing. There are a number of errors throughout the answer.
- **E (Fail) - Poor** The answer contains only a few of the important points from the list. There are significant sections missing.

Presentation of written solutions

- **A (1st) - Excellent** The solution is very well structured and produced. It is easy to find the different sections and there is similar presentation on different pages. Each section is virtually free from errors in grammar, spelling and punctuation and makes good use of **referenced & labelled** diagrams.
- **B (2.1) - Very good** The solution is well structured and produced. It is clearly written apart from relatively minor aspects which would not seriously affect the understanding of the reader. The solution makes good use of referenced and labelled diagrams to clarify key points in the answer.
- **C (2.2) - Good** Though reasonably well structured and produced, the solution contains significant errors in grammar and spelling. Diagrams were provide, these were not always referenced and/or there was little attempt made to relate these to the answer.
- **D (3rd) - Modest** The solution was disorganised and disjointed and so badly produced that it would inevitably misguide the reader. There were lots of errors – spelling, grammar, lots of different fonts and little or no evidence of teamwork. There was little or no effort to provide diagrams or examples to illustrate points in the answer.

Part 1 - Echoes of the past

- Does the answer introduce the reader to the concept of nanoparticles and provide some background information on the origin of the unique physical and chemical properties of gold nanoparticles?
- **For more advanced year groups:** does the answer include a consideration of the particle in a one dimensional box model to explain the unique physical properties of nanoparticles?
- Does the report include a discussion of the surface plasmon resonance band? Has the surface plasmon band been discussed in terms of the oscillation of surface electrons following interaction with incident radiation of a particular frequency?
- Have any techniques been suggested for the functionalization of gold nanoparticles with DNA sequences? Was the term ‘complementary’ explained in terms of the DNA sequences which form part of these nanoparticles?
- Was the role of Hg^{2+} ions in the stabilisation of assemblies of gold nanoparticles discussed?
- Did the report explain what was meant by a melting transition and explain why that transition occurs at a higher temperature when mercury pollution is present?
- Does the answer compare this approach with other mercury detection techniques in terms of the detection limits, selectivity and the practicalities of this technique?

Part 2 - Peer Review

- Do the summaries of the submitted proposals include detailed explanations of the physical or chemical property that is being utilised? Has an explanation been provided for the origin of the various properties in nanoparticles?
- Do the summary reports include decisions on whether each proposal should be funded based on the scientific merit of each proposal. **(Note – each of these proposals is based on recent published research. Students may accept that all publications are worthy of funding but must give full explanations for each decision).**
- Does the ranked order of proposals include a justification of the given order which is based on a consideration of the relative merits of each proposal?

Oral Presentation (Extension Task)

- Did the group provide a valid justification for their final project choice based on the relative merits of the research proposals that they were presented with?
- Did the presentation demonstrate a clear understanding of the background science of their presented proposal?
- Did the group's presentation consider the relative merits of their chosen proposal relative to the alternatives (i.e. value for money, scientific viability, industrial/social/medical applicability, etc.)?
- Did the group refer to any similar work that had been done in the area?
- Did the group engage with the opinions of other groups by asking questions at the end of the presentations?

Mark out of 10:

8 (or more) -The oral presentation was very well structured and clear. The group responded very well to all questions asked – responses were scientifically correct and delivered in a clear, confident manner. All of the points listed above were covered very well.

7 - The oral presentation was sufficiently clear to allow the listener to understand the key points made by the group. The group responded well to most questions – responses were scientifically correct and were delivered generally well. Most of the points listed above were covered well by the group's responses.

5 - The standard of the presentation was adequate. The group managed to cover some of the points listed above – The group struggled to respond to some of the questions and appeared to be 'against the ropes' at times .There may have been some scientific errors.

3 - The standard of presentation was very poor. The group struggled with most of the questions and failed to address many (or all) of the points listed above. The group struggled with most (or all) of the questions asked.