**INTRO TO NANOTECHNOLOGY AND BIOSENSORS**

**5E Inquiry Lesson Plans - Grade 10-11 CHEMISTRY**

**Lesson Plan #6: Carbon NanoTubes, their structure, bonding & potential uses**

2 block days and a speed day

**ENGAGE:** “What are the similarities and differences in Diamonds, Coal, Graphite and Carbon Nanotubes (CNT’s)?” This question should be put on the board or overhead as a starter or engage question. A class discussion should ensue allowing the teacher to create some lists/notes on the board/overhead.

<table>
<thead>
<tr>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>They are all made of Pure Carbon</td>
<td>Uses are different</td>
</tr>
<tr>
<td></td>
<td>look and feel different</td>
</tr>
<tr>
<td></td>
<td>All occur naturally except the CNT’s</td>
</tr>
<tr>
<td>HOW? WHY?? Emphasize this question!!</td>
<td>Hard &amp; clear (diamond)</td>
</tr>
<tr>
<td></td>
<td>Soft &amp; dirty (coal/graphite)</td>
</tr>
<tr>
<td></td>
<td>They must Bond Differently – HOW?</td>
</tr>
<tr>
<td></td>
<td>Different Bonding must occur under different</td>
</tr>
<tr>
<td></td>
<td>temperatures and pressures</td>
</tr>
</tbody>
</table>

To continue the Engage Process – show them the power point on the Biosensors & the Allotropes of Carbon. Their assignment is on slide #25.

**EXPLORE:** To do the assignment on Slide #25 as stated above. The assignment is as follows:

- Choose one of the following four allotropes: Diamond, Graphite, Fullerenes or Carbon Nanotubes and break into groups of 2-3 students.
- Make a 3-d model of the C-C specific allotrope (diamond, graphite, CNT or Fullerene).
- Design a poster board with diagrams & photos to include all of the following:
  - The Electron Configuration of Carbon along with the electron arrows
  - An explanation of hybridization in addition to your allotropes specific sp2 or sp3 hybridization
  - The angles of the bond & how it strengthens or weakens your Carbon Allotrope
  - Explain the Heat & Pressure requirements for your Allotrope

Some of the parameters above will push the students beyond EXPLORE and into the **ELABORATE** phase.

**Michigan Benchmarks:**

I.1.1 Understanding the need to build upon existing knowledge.
I.1.2 Suggesting tests of hypothesis, prediction, testing and conclusions
I.1.3 Conducting scientific investigations. Hypothesis, theory, observation, conclusion, law, data, generalization, aspects of field research.
I.1.6 Designing an experiment using quantitative data, recognizing and explaining the limitations of measuring devices (current sensing technology & microscopes).
I.1.8 Discuss topics in groups, restating or summarizing what others have said, elaboration, alternative perspectives on research.
I.1.9 Reconstruct previously learned knowledge (LP’s 1-3) in real world contexts.
II.1.1 Justify plans and explanations, aspects of logical argument including evidence, observations and conclusions in real world contexts.
II.1.3 Show how common themes of science, mathematics and technology apply in the real world.
This will take some time to complete. I'm estimating approximately 2 block days. Below are some websites that may help the students in their research:

http://invsee.asu.edu/nmodules/Carbonmod/bonding.html
http://www.ecsel.psu.edu/~snathan/jb/JB_1Bonding/sld019.htm
http://www.forskninng.no/Artikler/2006/juni/1149432180.36
http://students.chem.tue.nl/ifp03/synthesis.html

**EXPLAIN:** Students can present their findings in the manner the teacher deems appropriate for the class.

**EVALUATE:** Evaluation of their project & presentation should be pertinent to the parameters set above.

**ELABORATE:** Show the Chemistry & Physics of the Biosensor power point (Lesson Plan 7) through slide 8 to re-engage the students into the biosensor project. At the end they will do a refresher of what they did earlier in science on the pH and Conductivity of the Polyaniline.

Contact Michigan State University to arrange a field trip to the Biosensor Lab. Perhaps the students can assist in binding the CNT's to the Polyaniline or attaching the antibodies to the Polyaniline. They could also boil PANI and CNT's to see what temperatures they are no longer conductive. The students would also be interested in seeing the biosensor actually capture a bacteria and see the alarm go off! The students already know they will get to build a large scale biosensor the next year in physics class.

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**Michigan Benchmarks, Con’t.**

III.2.5 Describe technology used in the prevention and diagnosis of diseases.

IV.1.2 Explain how families of elements are related by common properties.

IV.1.4 Describe and explain the structural parts of atoms.

IV.2.4 Describe how materials are made with descriptions of physical and chemical changes.

IV.2.5 Explain chemical changes in terms of the arrangement of Carbon atoms.

IV.2.6 Describe, compare and contrast changes in Carbon atoms during heat & pressure changes.
Slide 1

Biosensors, Polyaniline & Carbon NanoTubes

Slide 2

A Biosensor will be used for detecting bacteria & viruses within only a few minutes.

Analyte is the liquid to be tested and is put on the application membrane.

Slide 3

Main components on the biosensor not seen include the use of polyaniline and carbon nanotubes (CNT's).

Analyte is the liquid to be tested and is put on the application membrane.
Slide 4

CNT's and Polyamine are used in the Capture Membrane

Slide 5

CNT’s are a special Carbon Allotrope. There are 8 Allotropes.

Slide 6

DIAMONDS are forever!
- Each black ball is a carbon atom
- It tends to form a cubic lattice
- It’s the hardest known natural mineral
- It has a high dispersion of light
- 80% of mined diamonds are for industrial use as they are not of jewelry quality
- What do they use them for in industry?
Graphite

- In Greek: “to draw/write”
- A conductor
- The most stable
- Is used in pencils
- Carbon forms in Hexagonal planes
**Slide 10**

Lonsdaleite

- Identified in 1967 in a meteorite found in an Arizonan crater
- Believed to be originally graphite due to the heat and pressure upon impact, it turned to diamond but kept the crystal structure of graphite.

**Slide 11**

FULLERENES

- Discovered in 1985 by a team of scientists from the US and England
- Shape of a hollow sphere
- Referred to as "buckyballs"
- Also known as C60. Why?
- Use nano-technology to combine the atoms in this way
- Hopeful for use in tackling melanoma and other tough cancers

**Slide 12**
Like all fullerenes, C540 is a hollow spherical shape created using nanotechnology.

How many atoms of carbon are in it?

Another Nanotech creation

What do all Fullerenes have in common?
Amorphous Carbon (Coal & soot)

- Does not have any visible crystal structure or atomic arrangement of carbon atoms
- Is found containing crystallites of graphite and diamond (so small, it's often nano size)
- Coal has different grades ranging from 55% - 90% pure carbon
Slide 19

**CARBON NANO-TUBES**

- Stronger than diamonds
- Conduct heat well
- Can be made as either a conductor or a semiconductor

Slide 20

**CNT’s (Carbon NanoTubes) are now used for or being researched for……**

- **Clothes** – waterproof, tear resistant cloth fibers
- **Military Combat Jackets** – the ultra strong CNT fibers will monitor the condition of the soldier
- **Concrete** – increases tensile strength and eliminates cracks
- **Sports equipment** – lighter & stronger equipment as seen previously
- **Nano wires** – possibly! It’s in the planning stages
- **Computer circuits**
- **Air and water filters**
- **BIOSENSORS!!!!**

Slide 21
What is the difference between each of the Allotropes?

- They look and feel different
- Uses are obviously different
- Some occur naturally, some are made using nanotechnology
- They are all made of CARBON - so what about the development could cause Diamonds & CNT’s to be the strongest things known and Graphite & Coal the weakest?!

BONDING – what is the difference?

- This is the first question in your project!

Temperature & Pressure Conditions?

- This is the second question in your project!

Phase Diagram for Carbon
Your Assignment!

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