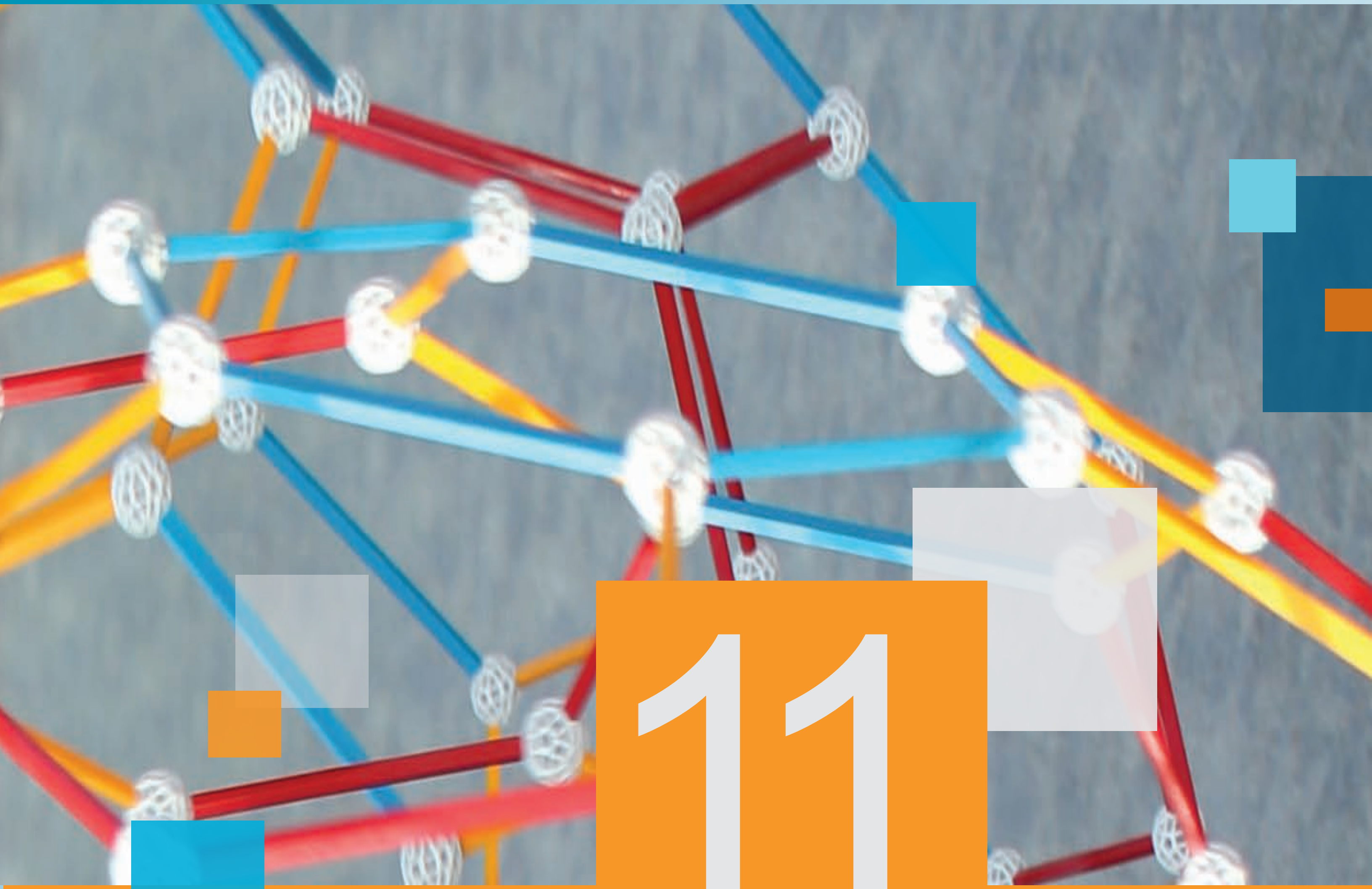
NANOTECHNOLOGY

LESSON PLAN FOR CHEMISTRY 20 (SCIENCE 24) - PUTTING IT TOGETHER



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Alberta
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Alberta Innovates Technology Futures

Science Teachers,

This lesson plan was designed for Chemistry 20 (Science 24) and meets Alberta Education curriculum learning outcomes for science (see the following page for program of studies reference). The plans are easy to understand and implement without any specialized training, additional work or study. Best of all, they make this interesting subject matter engaging to teach.

The lesson plans were focus tested in seven schools throughout Alberta, incorporating teacher's feedback, and received great reviews. These plans provide the tools necessary to guide students through interactive experiences with nanotechnology that will help them understand this aspect of science. Included in the lesson plans are:

- a short explanation on what is nanotechnology,
- an activity description,
- time requirements,
- materials,
- an assessment rubric, and
- an in-depth teacher's background for reference.

Each lesson was designed in a way that allows you to quickly adapt it to your specific class needs and/or level of knowledge. If you wish to go deeper into the material, you can use the links provided under References or Bibliography. These lesson plans are complemented by a Nano Resource DVD for additional resources such as comic strips, videos, photos and more information related to teaching and understanding nanotechnology. These resources are also available for downloading at **nanolessonplans.alberta.ca**.

Did You Know?

The University of Alberta, the University of Calgary, and the Northern Alberta Institute of Technology all offer nanotechnology programs to train the next generation of curious and bright minds.

As you can see, the subject of nanotechnology is rich with opportunities for learning. We hope you will find the lesson plans worth implementing and include this fascinating area of science in your science program for the year.

If you require more information on additional nanotechnology learning experiences, or have any questions about the information provided, please contact nanoAlberta at 780-450-5111 or email nano@albertainnovates.ca. For grades 7 to 12 check out our travelling Scanning Electron Microscope (SEM) program and book it for your school today. This free program supplies the Microscope for a week and an Alberta certified science teacher will come and work with you and your class or school. A great complement to the nano lesson plans.
Visit **nanolessonplans.alberta.ca** for more information on the SEM program.

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These lesson plans are available to view online and can be downloaded free at **nanolessonplans.alberta.ca**

Limited additional copies are available for ordering from the Learning Resource Centre at **lrc.education.gov.ab.ca**

For information, including reproduction for commercial purposes, please contact:
Alberta Innovates - Technology Futures
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Program of Studies Reference:
Chemistry 20 / Science 24 - The Diversity of Matter and Chemical Bonding

Key Concepts
- Intramolecular and intermolecular forces
- Hydrogen bonds
- Electronegativity
- Polarity
- Thermal energy

Skills
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Knowledge
- Explain intermolecular forces
- Illustrate by drawing or building models

STS
- Investigate how basic knowledge about the structure of matter is advanced through nanotechnology research and development.

NOTE:
This lesson plan also meets the learning outcomes for a chemistry component in the Science 24 curriculum. Teachers may need to modify the lesson dependent on the class.

NOTE:
Grade 9 Nano lesson plan, Carbon's Nanocaper-Matter and Chemical Change, also meets the learning outcomes for Chemistry 20, available for downloading at **nanolessonplans.alberta.ca**

Check out these other great Nanotechnology Lesson Plans

Nanotechnology: Lesson Plan for Grade 4 Science
Slippery Leaves

Nanotechnology: Lesson Plan for Grade 5 Science
Small is Different–Classroom Chemistry

Nanotechnology: Lesson Plan for Grade 6 Science
Forestry Nano Superheroes–Trees and Forests

Nanotechnology: Lesson Plan for Grade 7 Science
Nanotechnology and the Environment – Smart Dust

Nanotechnology: Lesson Plan for Grade 8 Science
Nanovision–Light and Optical Systems

Nanotechnology: Lesson Plan for Grade 9 Science
Carbon's Nanocaper–Matter and Chemical Change

Nanotechnology: Lesson Plan for Science 10
"BRANE" Work–Cycling of Matter in Living Systems

Nanotechnology: Lesson Plan for Biology 30
Medical Applications of Nanotechnology
–Cell Division, Genetics, and Molecular Biology

ACTIVITY DESCRIPTION

This activity challenges students to build self-assembling structures using LEGO® blocks and Velcro or magnets. It uses modelling to show students how intermolecular bonding and hydrogen bonds are applied in self-assembly at the nanoscale level. Students design and build these structures and present them to the class, defending their designs and describing their understanding of the self-assembly process.

Adapted from: "How Nature Builds Itself: Self-Assembly" in the book *Nanoscale Science: Activities for Grades 6-12* by M. Gail Jones, Michael R. Falvo, Amy R. Taylor, and Bethany P. Broadwell.

MATERIALS

- LEGO® blocks
- small magnets
- superglue or glue guns
- paper
- scissors
- Student Sheets (included)

GLOSSARY

- self-assembly
- lock and key
- hydrogen bond
- intermolecular force

TIME REQUIRED

90 minutes

Did You Know?

Nanotechnology opens students to a wide variety of occupations in an even wider variety of industry sectors. Consider that nanotechnology may be encountered and used in some way by:

- Applications Technician
- Bio Material Engineer
- Cancer Researcher
- Characterization Scientist
- Chemical Technologist/Engineer
- Chemist
- Coating Scientist
- Computational Physicist
- Contact Metallization Process Engineer
- Electron Microscopy Technician
- Materials/Nanotechnology Scientist
- Materials/Metallurgical Engineer
- Mechanical Engineering
- Molecular Biologist
- Molecular Imaging Technologists
- Nanobiologist
- Nanoparticle Development Scientist
- Nanotechnology Business Manager
- Nanotechnology Laboratory Technician
- Nanotoxicologist
- Optical Engineer
- Pharmacologist
- Process Quality Engineer
- Product Marketing Manager
- Tissue Engineer
- Wafer Fabrication Development/Process Engineer

INTRODUCTORY POWERPOINT PRESENTATION:

As an introduction to nanotechnology, teachers may wish to present a PowerPoint presentation created by NanoSense (SRI International) found at: http://nanosense.org/activities/sizematters/index.html, under “Lesson 1—Introduction to Nanoscience”.The information in this PPT is good but it is not particularly dynamic.

Teacher background

To get the most from this activity, students should have already investigated the structure of matter as it applies to organic (carbon-based) molecules. This may include intramolecular and intermolecular forces, hydrogen bonding, and the concept of electronegativity.

SELF-ASSEMBLY

> "Under specific conditions, some materials can spontaneously assemble into organized structures. This process provides a useful means for manipulating matter at the nanoscale."
> - *The Big ideas in Nanoscale Science and Engineering (p. 43)*

Self-assembly is the process by which materials build themselves without assistance. In the world of nanoscience, self-assembly is a "bottom-up" manufacturing process (using smaller components to build larger ones). Self-assembly is also the process by which natural materials, such as viruses, cells, and bones, are built in nature. It also plays a part in how viruses bond to a cell or how a drug finds its target. DNA replication is another example of self-assembly.

It is the intermolecular bonds that allow things at the nanoscale to stick together. These are the weaker bonds, such as hydrogen bonds, van der Waals bonding, and hydrophilic/hydrophobic interactions. It is the polarizable characteristic of molecules that gives rise to such intermolecular bonds. Some kind of intermolecular attraction will occur between any two molecules, and it is the weak character of these bonds that propels self-assembly.

The characteristics of the molecules (size, shape, and arrangement) and the environments they exist in (temperature, concentration of components, polarity, and acidity of the solvent) are critical to self-assembly processes. The process is pushed by the attracting and repelling forces between the building blocks and molecules.

Source: The Big ideas in Nanoscale Science and Engineering

LOCK AND KEY MECHANISMS

The shape of building blocks is a critical part of the self-assembly process. If the blocks have complementary shapes, it will make for easier access to the weaker non-covalent interactions (electrostatic forces, van der Waal's forces, hydrogen bonding, and hydrophobic interactions) that are the basis for self-assembly. When the shape of building blocks is complementary, the blocks are brought closer to each other and intermolecular forces can therefore take effect.

Source: http://www.physics.unc.edu/~falvo/Phys53_Spring11/Projects_Assignments/2006_Self_Assembly_How_Nature_Builds_Science_Teacher_2006.pdf

Nanotechnology Applications

Self-assembly is an example of the "bottom-up" manufacturing process used in nanoscale science and engineering. It involves building up larger structures from smaller ones at the atomic level. In this method, building blocks are purposely manipulated to form larger products. It is the net attractive forces of the components that bring and keep them together to form stable assembled structures. Bottom-up manufacturing is used to create nanotubes, nanowalls, and microfluidic channels for Lab on a Chip applications, to name just three examples.

Source:
- nanowalls: www.nanowerk.com/spotlight/spotid=9020.php
- microfluidic channels: http://pubs.acs.org/doi/abs/10.1021/cm101502n

The other method used is 'top-down". This is also called lithography, and involves taking away or "carving" away from an object to reach a final product. One example of a top-down process is photolithography. This uses a substrate surfaced with a photoresist coating. A mask (like a stencil) is placed on top and exposed to radiation. The mask only allows the desired pattern to be exposed to the radiation. The surface is then subjected to a chemical that removes either the exposed or the unexposed portion of the surface.

Source:
Stevens, S. Y., Sutherland, L., Schank, P., & Krajcik, J. (2007). T*he Big ideas in Nanoscale Science and Engineering.*

Try this neat game that illustrates some examples of self-assembly:
http://molit.concord.org/database/activities/231.html

ALBERTA RESEARCHERS

Dr. Larry Unsworth, of the University of Alberta's Department of Chemical and Materials Engineering and the National Institute for Nanotechnology (NINT), is investigating self-assembly processes in the engineering of peptides that can attach to and destroy bacterial cells. This research has the potential to create ways to combat drug resistant strains of bacteria (www.ualberta.ca/~lunswort/index.html - contact information).

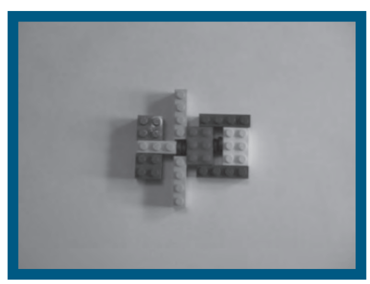
CLASS PREPARATION - Introduction

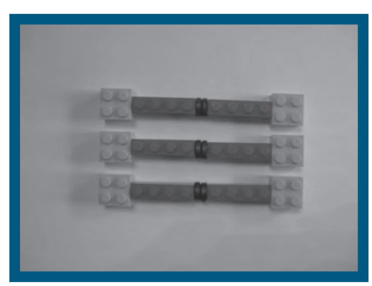
15-20 minutes

It is assumed that the basic molecular chemistry of bonding has already been presented. This activity will identify the extent to which students have grasped that content.

MODEL DESIGN

The task is to design a 3 dimensional, self-assembling model with two, three, four or more pieces that come together in a particular way—like jigsaw puzzle pieces. Students can start designing using paper cut-outs. This will help them work out the intermolecular bonds and the logic of the bonding patterns, and will help them ensure that pieces bond where they want them to. Models can be molecular models or simply geometric shapes. The trick is to use multiple weak bonds and shapes that fit together (lock and key).





MODEL-BUILDING

This step involves gluing the magnets to the LEGO® pieces. Remind students to use the polarity of the magnets to facilitate self-assembly. Superglue works best to ensure that the pieces can withstand the "thermal energy" created when shaking the reaction chamber.

REACTION CHAMBER

There are several possibilities for reaction chambers: shoeboxes (students can bring these from home), pizza boxes (a pizza store might donate some clean ones), clear plastic containers with lids (these would allow students to see the process through the sides).

The least complicated model involves shaking only from side to side. Pieces are placed inside the chamber separately and arranged randomly. The chamber is placed on a desk or table and slid back and forth in random directions. More vigorous shaking of the box represents a higher temperature, and should work to break down any bonds the students did not intend to happen. It may take a number of tries to get the result the students had planned. Reassure students that if their models work one in five times, they've built a good one.

MODEL PRESENTATION

Have students present and demonstrate their models for the class. They will need to explain the self-assembly process in their presentations, using the new concepts of weak bonds and compatibility of shape.

ASSESSMENT

SUMMATIVE ASSESSMENT

One possibility is for the teacher to create a number of models—some that self-assemble and some that don't. Students would need to explain, in terms of bonding and geometric shape, why the models work or do not.

Some questions they would need to be able to answer include:

1. Explain the role of the LEGO® in the activity.
   They are the molecules or the building blocks.

2. What do the magnets represent?
   They take the place of the receptor sites on the molecules.

3. What does the container represent?
   The environment where the reaction is happening.

4. When you shake the container, what are you simulating?
   This represents the thermal energy that happens at the nanometre scale that causes the molecules and building blocks to shake and bump around. The more quickly the box is shaken, the higher the temperature that is simulated.

5. Why do the models not self-assemble right away?
   Nature uses a combination of a number of weak bonds working together, rather than one strong one. One bond is not strong enough to withstand the shaking. The environment for self-assembly is also critical and must be just right. For instance, a temperature that is too high (too much shaking of the box) may cause the bonds to break.

FORMATIVE ASSESSMENT

Student will use the Student Learning Targets: Self-Assembly Student Sheet (see page 9), completing it as they go through the design and presentation of their self-assembly models.

STUDENT SHEET

Self-Assembly Challenge

Work in groups of three to meet the following challenge:

Your task is to design and build a three-dimensional, self-assembling model with two, three, four or more pieces that come together in a particular way—like jigsaw puzzle pieces. Use your knowledge of intermolecular forces and non-covalent bonds to build your model out of LEGO® blocks, small magnets, and superglue. The pieces need to be designed and constructed in such a way that they fit together in one, and only one, unique configuration.

Start designing using paper cut-outs. You will need to test your model and redesign the pieces until they work, using the Learning Targets Student Sheet to document your progress through the process.

Please show your model to the class, including at least the following in your presentation:

1. an explanation of the self-assembly process
2. a discussion of why your model did or did not work
3. a description of how weak bonds and geometric compatibility figure into your design

BIBLIOGRAPHY

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SELF-ASSEMBLY PLANNING SHEET

USE THIS SHEET TO DOCUMENT YOUR DESIGN PROCESS.	
DESIGN #1 ☐ worked ☐ didn't work	**MODIFICATIONS:**
DESIGN #2 ☐ worked ☐ didn't work	**MODIFICATIONS:**
DESIGN #3 ☐ worked ☐ didn't work	**MODIFICATIONS:**

USE THIS SHEET TO DOCUMENT YOUR DESIGN PROCESS.

DESIGN #4 ☐ worked ☐ didn't work	MODIFICATIONS:
DESIGN #5 ☐ worked ☐ didn't work	MODIFICATIONS:
DESIGN #6 ☐ worked ☐ didn't work	MODIFICATIONS:

STUDENT LEARNING TARGETS
Self-Assembly

CHECK OFF	OUR GROUP CAN:	WE DID THESE ACTIVITIES:	EVIDENCE:
	Develop shapes capable of self-assembly.	We discussed: ______(shape) and ______ (shape) before agreeing on:	
	Identify the role of building block shape in self-assembly.	We identified the following functions:	
	Explain the intermolecular forces that contribute to the self-assembly process.	We diagrammed or built paper models of the building blocks. We identified the forces from analyzing our diagrams or models.	
	Use combinations of techniques to cause the models to self-assemble.	We listed the bonding forces for each compound in our exotic life form.	
	Achieve a 5% success rate in getting our models to self-assemble.	We did ________trials and ________ were successful.	
	Include other concepts in our models.	Our additional concepts were:	

NOTES:

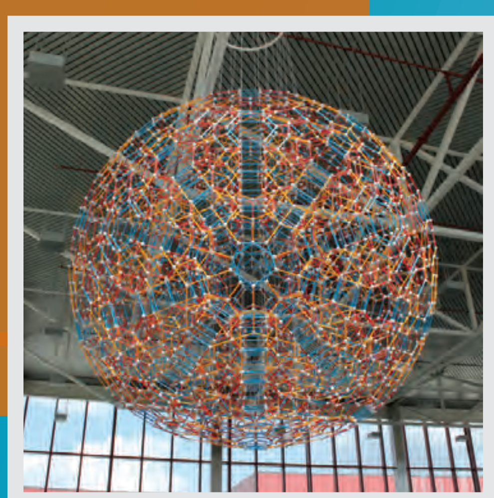
WHAT YOU'LL FIND HERE

- a "pick-up-and-go" lesson plan that will add science currency to your science program
- activities that meet science curriculum learning outcomes
- interesting subject matter that is engaging to teach
- easy to implement experiments (no specialized training needed)
- a quickly adaptable lesson with worksheets and rubrics for your class needs

Nano is... the scientific term meaning one-billionth (1/1,000,000,000). It comes from the Greek word meaning "dwarf".

Nano Science is... the discovery, research and understanding of all things nano.

Nanotechnology is... the application of science at the molecular level.



Nanotechnology is revolutionizing medicine, energy production, environmental protection, bioindustries and more!

Government of Alberta