Using a Materials Course to Teach AP Chemistry Unit "States of Matter"

Subject Area(s) Chemistry

Associated Unit States of Matter

Lesson Title Using a Materials Course to Teach AP Level States of Matter

Grade Level 9-12

Time Required 7, 50 minute periods with an optional field trip

Summary

Students will deepen their understanding of how atomic structure relates to the use and function of materials in our lives. The classes of materials covered in depth are metals, polymers and ceramics. For each materials class students will do some kind of hands on activity and the evaluation will be the student's ability to explain what they are observing based on what they learn about atomic structure. As an idea, an optional field trip connecting science with the arts is suggested.

Engineering Connection

Students will be trying various hands on activities that they must then explain using their knowledge of atomic structure. Some of the activities require students to think critically and try various proportions of chemicals to get a desired effect. Additionally there is a research component where students will delve into modern uses of polymers. The goal is to expose students to engineering and research that affects their lives.

Engineering Category =

Choose the category that best describes this lesson's amount/depth of engineering content:

1. Relating science and/or math concept(s) to engineering

Keywords

Metals, crystalline structure, grain size, alloys, bismuth crystals, metal recycling, polymers, elastomers, oobleck, slime, gluep, polystyrene, d-limonene, monomer, co-polymer, branching, cross linking, electrospinning, intermolecular forces, recycling plastics, ceramics, glass, super conductors, glass blowing, pottery, arts

Educational Standards **(List 2-4)**

State STEM Standard (required)

Source, year, standard number(s)/letter(s), grade band and text (its unique ID# is optional)

AP Chemistry Curriculum, College Board, 2013:

Enduring understanding 2.A: Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.

Enduring understanding 2.B: Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.

Enduring understanding 2.D: The type of bonding in the solid state can be deduced from the properties of the solid state.

Enduring understanding 5.D: The Electrostatic forces exist between molecules as well as between atoms or ions, and breaking the resultant intermolecular interactions requires energy.

LO 2.1 Students can predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views.

LO 2.3 The student is able to use aspects of particulate models (i.e., particle spacing, motion, and forces of attraction) to reason about observed differences between solid and liquid phases and among solid and liquid materials.

LO 2.11 The student is able to explain the trends in properties and/or predict properties of samples consisting of particles with no permanent dipole on the basis of London dispersion forces.

LO 2.12 The student can qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions.

LO 2.13 The student is able to describe the relationships between the structural features of polar molecules and the forces of attraction between the particles.

LO 2.14 The student is able to apply Coulomb's law qualitatively (including using representations) to describe the interactions of ions, and the attractions between ions and solvents to explain the factors that contribute to the solubility of ionic compounds.

LO 2.15 The student is able to explain observations regarding the solubility of ionic solids and molecules in water and other solvents on the basis of particle views that include intermolecular interactions and entropic effects.

LO 2.16 The student is able to explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of intermolecular forces.

LO 2.29 The student can create a representation of a covalent solid that shows essential characteristics of the structure and interactions present in the substance.

LO 2.30 The student is able to explain a representation that connects properties of a covalent solid to its structural attributes and to the interactions present at the atomic level.

LO 5.9 The student is able to make claims and/or predictions regarding relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within the molecules and the types of intermolecular forces through which the molecules interact.

LO 5.10 The student can support the claim about whether a process is a chemical or physical change (or may be classified as both) based on whether the process involves changes in intramolecular versus intermolecular interactions.

LO 5.11 The student is able to identify the noncovalent interactions within and between large molecules, and/or connect the shape and function of the large molecule to the presence and magnitude of these interactions.

2.A.1: The different properties of solids and liquids can be explained by differences in their structures, both at the particulate level and in their supramolecular structures.

2.B.1: London dispersion forces are attractive forces present between all atoms and molecules. London dispersion forces are often the strongest net intermolecular force between large molecules.

2.B.2: Dipole forces result from the attraction among the positive ends and negative ends of polar molecules. Hydrogen bonding is a strong type of dipole-dipole force that exists when very electronegative atoms (N,O, and F) are involved.

2.B.3: Intermolecular forces play a key role in determining the properties of substances, including biological structures and interactions.

2.D.3: Covalent network solids generally have extremely high melting points, are hard, and are thermal insulators. Some conduct electricity.

5.D.1: Potential energy is associated with the interaction of molecules; as molecules draw near each other, they experience an attractive force.

5.D.2: At the particulate scale, chemical processes can be distinguished from physical processes because chemical bonds can be distinguished from intermolecular interactions.

5.D.3: Noncovalent and intermolecular interactions play important roles in many biological and polymer systems.

Pre-Requisite Knowledge
Students will need to have fundamental knowledge of atomic structure, basic bond types and intermolecular forces.

Learning Objectives
After this lesson, students should be able to:

- Connect man's development and use of various materials with developing technologies.
- Explain various phenomenon using knowledge of atomic structure, bond type, properties of materials and intermolecular forces.

Overall Unit Plan

Day 1	• Discuss evolution of man's use of materials
	• Present four classes of materials
	  ○ Metals
	    ▪ Engage
	      • Compare…bending a paperclip with bending a bobbypin (similar compositions, why are th different?)
	      • Holding gallium
	    ▪ Explore
	      • Content
	        ○ Crystalline structures
	        ○ Grain size and it's functional properties
	        ○ Cold working & annealing
	          ▪ look at blacksmithing
	        ○ Alloys

Day 2	▪ Explain
	      • Growing bismuth crystals activity
	    ▪ Extend
	      • Metal Recycling Process/ Energy

	o Discuss 2015 FRQ dealing with this idea! ▪ Evaluate • Explain why bismuth crystals grow in the shape they do and relate this to another crystal yo like to try and grow.
Day 3	o Polymers & elastomers ▪ Engage • Create a slime and explain the polymers involved and the interaction of the molecules and intermolecular forces causing it's particular properties o Slime--Polyvinyl Alcohol/Borax Gel o Gluep o Oobleck ▪ Explore • Creating polymer fibers using polystyrene dissolved in d-limonene and stretch fibers on glo ▪ Explain • Content o What are polymers? o How do you make a monomer into a polymer? o Discuss real life examples and uses of polymers o Co-polymers o Branching & Cross-linking
Day 4	▪ Extend • Presentations on polymers o Possible topics: ▪ Discovery of various polymers--polyester, Nylon, Rayon, Acrylonitrile or s rubber ▪ Polymer Industry--historical or economic approach ▪ Uses of polymers in industry, consumer goods, biomedical research ▪ Natural polymers--DNA, starch or vitamins ▪ Manipulation of polymers (electrospinning, fabrication of materials, etc) • Requirements o All students will make 3 minute presentations o Must cite all materials o Must cite at least 3 different sources
Day 5	• Extend cont'd: o Student presentations • Evaluate o FRQ Practice explaining topics related to material structure ▪ Discuss electrospinning…how does a process like this work? Think about IMF at play. ▪ Recycling plastics • What the codes mean • Process • Issues related to structure

Day 6	○ Ceramics & Glass ▪ Engage • Classroom discussion: Urban Legend: Glass is a liquid. True of false? ○ http://dwb.unl.edu/Teacher/NSF/C01/C01Links/www.ualberta.ca/~bderksen/florin. ▪ Explore • Pull glass rods using blow torch in classroom…let students try?? • Show renovation of old stained glass (melting!) ▪ Explain • Content ○ What are ceramics ○ Characteristics of ceramics ○ Compare to other materials ○ Relate characteristics to crystalline structure ○ Super conductors
Day 7	▪ Extend • Video clip of ceramic artists…process …visit art teacher is field trip isn't an option • Field trip to Chihuly Glass Museum and see Glass blowing demo/ceramics ▪ Evaluate • Connect what they learned about ceramics with material structure via an art piece analysis. • After the field trip students will be asked to analyze one piece of art and apply the scientific information they have learned about materials and structure as part of their analysis.

Introduction / Motivation (5E – Engage)

- Each class of materials has its own small "engage" activity. See daily overview below for further details.
  - Metals
    - Compare…bending a paperclip with bending a bobbypin (similar compositions, why are they different?)
    - Holding gallium
  - Polymers
    - Create a slime and explain the polymers involved and the interaction of the molecules and intermolecular forces causing it's particular properties
      - Slime--Polyvinyl Alcohol/Borax Gel
      - Gluep
      - Oobleck
  - Ceramics
    - Pull glass rods using blow torch in classroom…let students try
    - Show renovation of old stained glass (melting!)

Associated Activities (5E – Explore)

- Each class of materials has its own "explore" and "extend" content. See daily overview below for further details.
  - Metals
    - Growing Bismuth Crystals
  - Polymers
    -

- Ceramics
  - Connecting science education with arts education.
    - In this plan it is a field trip to a famous glass artist's museum located locally. Other ideas might include:
      - Glass blowing
      - Ceramic studios
      - Get together with on campus ceramic teacher and create classroom activity

Lesson Background & Concepts for Teachers (5E – Explain)

Much of the lecture material was based off of information from a Materials Course taught by Dr. Scott Campbell at the University of South Florida. The following websites are helpful resources for teachers who need more information on the various classes of materials.

- http://matse1.matse.illinois.edu
- http://chemwiki.ucdavis.edu/Inorganic_Chemistry

Vocabulary / Definitions

Word	Definition
Metal	a solid material that is typically hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity
Crystalline Structure	a unique arrangement of atoms, ions or molecules in a crystalline liquid or solid. It describes a highly ordered structure, occurring due to the intrinsic nature of its constituents to form symmetric patterns.
Polymer	a substance that has a molecular structure consisting chiefly or entirely of a large number of similar units bonded together, e.g., many synthetic organic materials used as plastics and resins.
Grain size/boundaries	Most metals are crystalline in nature and contain internal boundaries, commonly known as "grain boundaries". When a metal or alloy is processed, the atoms within each growing grain are lined up in a specific pattern, depending on the crystal structure of sample.
Alloy	a metal made by combining two or more metallic elements, especially to give greater strength or resistance to corrosion.
Elastomer	a natural or synthetic polymer having elastic properties, e.g., rubber.
Monomer	a molecule that can be bonded to other identical molecules to form a polymer.
Co-polymer	a polymer made by reaction of two different monomers, with units of more than one kind.
Branching	A branched polymer is a polymer containing secondary polymer chains branching off the main chain.
Crosslinking	Crosslinks tie many polymer molecules together. Because they are tied together, when something like vulcanized rubber for example, gets hot, the polymers can't flow past each other, nor around each other, so they don't melt easily in this case.
Electrospinning	Uses an electrical charge to draw very fine (typically on the micro or nano scale) fibers from a liquid.
Intermolecular forces	Intermolecular forces are forces of attraction or repulsion which act between neighboring particles (atoms, molecules or ions). They are weak compared to the intramolecular forces, the forces which keep a molecule together.
Ceramics	A ceramic material may be defined as any inorganic crystalline material,

	compounded of a metal and a non-metal. It is solid and inert. Ceramic materials are brittle, hard, strong in compression, weak in shearing and tension.
Glass	A glass is an amorphous solid. The term is usually applied to inorganic solids and not to plastics or other organics. Glasses do not have crystalline internal structure. They usually are hard and brittle solids.
Super conductor	Superconductivity is a phenomenon of exactly zero electrical resistance and expulsion of magnetic fields occurring in certain materials when cooled below a characteristic critical temperature.

Assessment (5E – Evaluate)

- Each class of materials has its own smaller method evaluation. See daily overview below for further details.
  - Metals
    - Explain why bismuth crystals grow in the shape they do and relate this to another crystal you would like to try and grow on your own.
    - Analyze energy associated with metal recycling processes and specifically look at 2015 Free Response Question on this topic
  - Polymers
    - Student presentations will be graded
    - Students will also be given a free response question on polymers (2013). It requires them to apply and explain what they have learned about polymers.
  - Ceramics
    - After the field trip students will be asked to analyze one piece of art and apply the scientific information they have learned about materials and structure as part of their analysis.

Contributors

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Classroom Testing Information

The goal of this unit was to have students explain and apply their knowledge as they learn. All assessments in this unit have students writing and explaining their thoughts as they are learning the information. The goal is to have students do so throughout the unit so the teacher is not overwhelmed at the very end with long wordy essays or a giant multiple-choice test.