Unit 2
From Structures to Properties
Specific Curriculum Outcomes
Suggested Time: 35 Hours

From Structures to Properties

Introduction

All matter is held together by chemical bonding. Bonding is discussed in detail in this unit. The different forces of attraction involved in matter and how it influences their properties will be studied. Questions such as why does water have the formula H_2O and why does NaCl have such a high melting point will be addressed.

Focus and Context

This unit is framed around the use of chemicals in food in an inquiry-based approach. Students will begin by identifying and describing properties of ionic and molecular compounds as well as metallic substances. Using chemicals that would be found in their own homes, students will then differentiate among and classify these compounds and substances as being ionic, molecular, or metallic.

Students should use models to build chemical structures. Through the use of laboratory investigations and research, they can investigate and compare the strengths of intermolecular and intramolecular forces.

Science Curriculum Links

There are strong links between the atomic structure unit in grade 9 and the chemical reactions unit of grade 10. The chemical reactions unit forms the foundation for the remaining grade 11 units of stoichiometry and organic chemistry as well as the grade 12 units of solutions, acids, and bases. By the end of the "From Structures to Properties" unit, students will have studied the theoretical foundation of qualitative aspects in chemistry.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
Nature of Science and Technology 114-2 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge 115-7 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced **Relationship Between Science and Technology** 116-4 analyze and describe examples where technologies were developed based on scientific understanding **Social and Environmental Contexts of Science and Technology** 117-11 analyze examples of Canadian contributions to science and technology 118-2 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology	**Initiating and Planning Skills** 212-8 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem-solving, inquiring, and decision-making **Performing and Recording** 213-5 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data 213-7 select and integrate information from various print and electronic sources or from several parts of the same source **Analysing and Interpreting** 214-2 identify limitations of a given classification system and identify alternative ways of classifying to accommodate anomalies 214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots 214-12 explain how data support or refute the hypothesis or prediction	321-4 illustrate and explain the formation of ionic, covalent, and metallic bonds 321-5 illustrate and explain hydrogen bonds and van der Waals' forces 321-7 identify and describe the properties of ionic and molecular compounds and metallic substances 321-8 describe how intermolecular forces account for the properties of ionic and molecular compounds and metallic substances 321-9 classify ionic, molecular, and metallic substances according to their properties 321-11 explain the structural model of a substance in terms of the various bonds that define it 323-7 explain the variations in the solubility of various pure substances, given the same solvent

From Structures to Properties: Classifying Compounds

Outcomes

Students will be expected to

- identify and describe the properties of ionic and molecular compounds and metallic substances (321-7)
  - observe the physical properties of representative samples of molecular, ionic and metallic substances.
  - tabulate the properties of molecular, ionic and metallic substances
- classify ionic, molecular, and metallic substances according to their properties (321-9)
  - use the periodic table as a tool for predicting the formation of ionic and molecular compounds

Elaborations—Strategies for Learning and Teaching

To introduce this unit, the teacher should provide samples of all three types of substances. The chosen samples should exhibit physical properties which differentiate between each bonding type (see the table below). Where possible, the teacher should demonstrate these properties using the samples. This activity provides the framework for the approach to the study of each bonding theory that will follow.

Compound	Properties	Samples
Molecular	solid, liquid or gas at STP; low melting point & boiling point; does not conduct electricity in aqueous solution; simple molecular compound are insoluble in water	SO_2, NH_3
Metallic	ductile; malleable; good conductors of heat and electricity; shiny when freshly cut or polished	CuZn (brass) (all metallic alloys, e.g., steel)
Ionic	crystalline solid at STP; high melting point and boiling point; conducts electricity in aqueous solutions; usually soluble in water	NaCl $CuSO_4$

The Core Lab “Properties of Ionic and Molecular Substances” in Science 1206 introduces the properties for these two types of substances.

Teachers could provide students with a variety of ionic, molecular, and metallic compounds and ask them to categorize these compounds by properties such as odour, hardness, conductivity, state, solubility, melting/boiling point. Students should recognize a concrete relationship between categories and bond types. This recognition might lead them to question “Why does a compound behave the way that it does?”

After establishing the properties of molecular, ionic and metallic substances in the above activity, students should be given a substance which has not yet been classified and perform tests and observations to classify the new substance according to its physical properties. The new substance may then be added to the previous chart of representative substances.

Teachers could have compounds available that students would find in their homes. A typical “Household Chemicals Lab” might allow students to view ionic, molecular, and metallic compounds and the properties exhibited by each. Substances such as sodium chloride, sugar, naphthalene, acetic acid, salt petre, vitamin C, an antacid, and cornstarch are good examples. Students could “link” these household chemicals to the same classifications as the “lab” chemicals. Later in the unit they might revisit their classifications and predict the bonding within the household chemicals.

From Structures to Properties: Classifying Compounds

Tasks for Instruction and/or Assessment

Presentation

- Display the bonding information you collected on the bulletin board. (321-7)
- Draw diagrams to show sodium and chloride ions being surrounded by water molecules. Draw diagrams to show sucrose molecules surrounded by water molecules. (321-9)

Performance

- Given an unknown substance, predict the type of substance and devise a test to verify your hypothesis. (321-9)
- Classify the bond types given substances based on their properties. (321-9)
- Devise criteria to classify the following substances as ionic or not ionic: C (graphite), H_2O, NaBr, Cu, $CaCO_3$. When your criteria is approved, obtain the substances and test them. (321-7)
- Identify an unknown sample(s) by comparing its properties to a set of known properties. Use the following criteria:
  - follow the recommended outline
  - use chemical and physical properties to classify or identify the unknown sample
  - observe and measure accurately
  - explain conclusions clearly (321-9)

Journal

- Sodium chloride and sugar have different bond types, yet these both dissolve in water. Explain. (321-9)
- What makes salt melt ice? (321-7)
- If you were transformed into an ionic compound, which would you be? Explain your choice. (321-7)
- What holds a salt crystal together? (321-7)

Paper and Pencil

- How do ionic compounds, molecular compounds and metallic substances differ from one another? (321-7)

Resources/Notes

www.gov.nl.ca/edu/science_ref/main.htm

MGH Chemistry, pp. 160-161

MGH Chemistry, p. 218

MGH Chemistry, pp. 161-162

Molecular Compounds

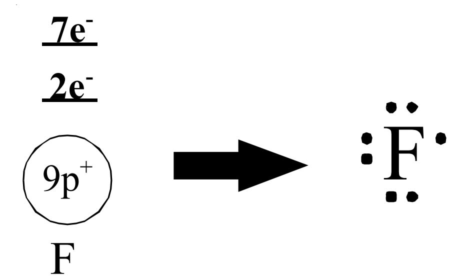
Outcomes

Students will be expected to

- illustrate and explain the formation of covalent bonds (321-4)
  - understand that chemical bonds are attractive forces that hold all substances together
  - define valence electrons, electronegativity, electron pairing, ionic bond and covalent bond
  - identify the maximum number of electrons that occupy each energy level
  - define valence energy level, bonding (unpaired electrons), nonbonding electrons (lone pairs), and bonding capacity, and be able to relate these terms to atoms of the representative elements
  - draw electron dot diagrams of atoms of the representative elements

Elaborations—Strategies for Learning and Teaching

Teachers should start from the Science 1206 coverage of bonding. Science 1206 develops simplified concepts of electron sharing or exchange in chemical bonds and how atoms bond based on their electron energy level diagrams. Students should understand how to write electron energy level diagrams and how they relate to the number of valence electrons. Some of these outcomes, therefore, may have been covered previously. The next step is to convert energy level diagrams into Lewis dot diagrams and use them successfully. See diagram below.



The periodic table could be used to introduce students to representative elements to determine valence electrons for these elements. Teachers might start with energy level diagrams and then relate these configurations to the periodic table. Students could determine the distribution of electrons in the major energy levels for the first 20 elements and for ions in groups 1 (IA), 2 (IIA), 3 (IIIA), 15 (VIA), 16 (VIIA), and 17 (VIIIA). Noble gas structures and the octet rule will be useful for students' understandings of both covalent and ionic bonding.

Energy level diagrams for main group elements should also be related to valence electrons and to electron dot symbols. A flame colour lab could be performed so that students understand energy level jumps by concrete visual examples.

Molecular Compounds

Tasks for Instruction and/or Assessment

Performance

- Design an experiment to test the flame colours of certain metals. After your procedure is approved, do the experiment. Report your results in a chart. Test an unknown. (321-4)

Paper and Pencil

- Compare the Lewis dot diagrams for elements within a specific family. (321-4)
- Compare the energy level diagrams for elements within a specific family. (321-4)

Presentation

- Design and present a poster illustrating Lewis dot diagrams and/or energy level diagrams for elements one through twenty. (321-4)

Resources/Notes

MGH Chemistry, p. 162

MGH Chemistry, pp. 162-163, p. 165, pp. 168-169

MGH Chemistry, p. 162

MGH Chemistry, pp. 162-163, p. 169

MGH Chemistry, pp. 160-163

Molecular Compounds *(continued)*

Outcomes

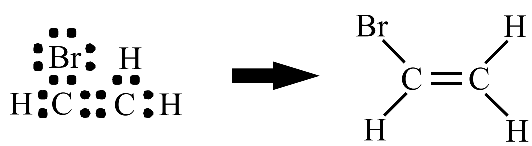
Students will be expected to

- illustrate and explain the formation of covalent bonds (321-4) (**Cont'd**)
  - explain why noble gases are unreactive and stable
  - explain the special nature of hydrogen as an exception to the octet rule
  - define single, double and triple covalent bonds
  - given the molecular formula, draw Lewis dot diagrams and structural formulas for simple molecules containing single, double and triple bonds.
- explain the structural model of a substance in terms of the various bonds that define it (321-11)
  - explain the three-dimensional nature of molecules using VSEPR theory
  - determine the shapes about central atoms in simple molecules by applying VSEPR theory
  - build models depicting the shape of simple covalent molecules
- explain, in simple terms, the energy changes of bond breaking and bond formation, and relate this to why some changes are exothermic while others are endothermic (114-2)

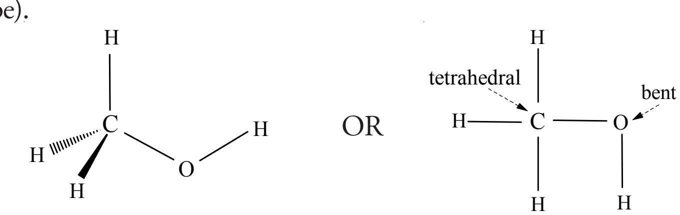
Elaborations—Strategies for Learning and Teaching

The octet rule is based upon the concept that a "filled valence level is stable" or a stable atom/ion does not have partially filled valence levels. For this reason, hydrogen may form the hydride ion (H^-) when a hydrogen atom gains an electron, as well form the more common hydrogen ion (H^+) when the hydrogen atom loses an electron and has no partially filled valence levels.

"Simple molecules" will be considered to have no more than three central atoms. It would be advantageous for teachers to select simple organic compounds for example that separately contain tetrahedral, trigonal planar and linear carbon atoms [i.e., ethane (C_2H_6), ethene (C_2H_4), ethyne (C_2H_2)] since these shapes are the basic shapes of alkanes, alkenes and alkynes to be studied later in the organic unit.



Students could determine and indicate shapes of central atoms by drawing proper structures or indicating shape by naming (labeling the central atom shape).



Teachers should note that building the shapes around atoms with more than four electron pairs is optional, but, an excellent extension for students. Students could name common substance(s) and the elements involved in it. For example; propane, methanol, ethylene glycol [$C_2H_4(OH)_2$], vinegar (acetic acid). Students might draw the substance to help give information about its structure. Students could use molecular model kits and examine the shapes of different molecules. Each student could choose a model to be built using building materials to demonstrate the bonding structure.

Students should explain the energy changes for exothermic and endothermic reactions in terms of bond breaking and bond formation. Students could look at changes that are exothermic, and endothermic but the study of the heat of reaction is done in Chemistry 3202.

Molecular Compounds *(continued)*

Tasks for Instruction and/or Assessment

Journal

- How can atoms get the noble gas electron structures? Do they become noble gases? (321-4)
- What does the gain of an electron mean in terms of an atom's charge? What is an ion and how is it formed? (321-4)

Paper and Pencil

- How is the octet rule useful? (321-4)
- What does the Roman numeral represent in a compound's name? What do the subscript Arabic numerals represent? (321-4)
- Why are most metals found in nature as ores? (321-4)
- Give examples of metals found in foods. Are they elemental or salts? (321-4)
- Select an ion that plays a role in your body. Write a report telling its function. Include recent medical information. (321-4)
- Electronegativity difference is a general guide for bond type. Explain. (321-4)
- Draw Lewis structures for H_2O, N_2F_2, CH_3COOH, H_2 (321-4)
- Explain VSEPR theory. Use diagrams if you feel these will be helpful. (321-11)

Performance

- Given unknown compounds, develop a plan to identify the bond type based on observed properties and defend the methods that you used to test for their chosen properties. (321-11)
- Play a game of joining elements to make a variety of compounds. Make a chart to keep track of the combinations and their bond types. With the element's symbol on a headband, try to find an element you can combine with to make a compound. Some elements, may have more than one combination. Keep track of the combination(s). From this, explain the bond type for your combination(s). (321-4)

Presentation

- Draw a compound that is contained in a food and explain its bonding. (321-11)

Resources/Notes

MGH Chemistry, p. 165

MGH Chemistry, pp. 168-169

MGH Chemistry, pp. 169-170, pp. 185-187

MGH Chemistry, pp. 189-193

MGH Chemistry, pp. 179-180

Molecular Compounds: Intermolecular Forces

Outcomes

Students will be expected to

- analyze an example of a Canadian contribution to bonding knowledge, the discovery of Noble Gas compounds (117-11)
- explain the evidence from an intermolecular forces experiment and from collected data. (114-2)
- illustrate and explain hydrogen bonds and van der Waals' forces (321-5)
  - compare and contrast intramolecular forces (covalent bonds) with intermolecular forces, simply in terms of strength and species involved
  - define polar and nonpolar covalent bonds
  - use bond dipoles and the shapes of molecules as predicted by VSEPR to determine if a molecule has a molecular dipole
  - define London dispersion forces, dipole-dipole forces (van der Waals' forces), and hydrogen bonding, and explain how they form
  - relate the strength of London dispersion forces to the molecular mass (number of electrons) and shape (complexity)
  - identify trends in electronegativity within periods and families of the periodic table

Elaborations—Strategies for Learning and Teaching

The CORE STSE component of this unit incorporates a broad range of Chemistry 2202 outcomes. More specifically a section of it targets 117-11. The STSE component, *Common Bonds*, can be found in Appendix A.

The Laboratory outcomes (212-8, 213-5, 214-3, 214-12) as well as 114-2, 321-5 and 321-8 are addressed by completing *Modelling Molecules*, CORE LAB #3. Students investigate several physical properties that illustrate the effect of intermolecular forces. Teachers can open this section with CORE LAB #3 or after completing the theory.

In small groups, students might join hands to represent intramolecular forces. As they move around to increase kinetic energy, they will see how intramolecular forces break first. Polarity and molecular arrangement might be demonstrated using vectors or forces in a specific direction. When a molecule is drawn, the differences in electronegativity might be written as a vector. Using bond angles for direction, vector addition for each bond could be used to determine if the molecule is polar or non-polar.

A good summary exercise is to ask students to compare intermolecular forces contained in two molecules. Teachers should use examples where only one factor varies at a time. For example:

Which has the highest boiling point?

(a) Cl_2 or F_2?

Both have the same shape, but Cl_2 (34 electrons) has a greater number of electrons, therefore it has stronger London Dispersion Forces and so a higher boiling point.

(b) Cl_2 or C_4H_{10}?

Both have the same number of electrons, but C_4H_{10} has a large, more complex shape, therefore it has stronger London Dispersion Forces and so a higher boiling point.

Molecular Compounds: Intermolecular Forces

Tasks for Instruction and/or Assessment

Paper and Pencil

- Describe the energy changes involved when two atoms come together and form a covalent bond. (321-5)
- Do atoms actually remain at the distance stated as the bond length? (321-5)
- Describe the electron distribution in a polar covalent bond and in a non-polar covalent bond. (321-5)
- Determine the shape of the compounds ClF, OF_2, and NH_3. (321-5)
- Draw the shapes of NH_4^+ and CO_3^{2-}. (321-5)
- Show, using any notation, the bond dipoles in: (i) CCl_4; (ii) ClF; (iii) H_2S; (iv) PBr_3. (321-5)

Presentation

- Design a poster illustrating VSEPR theory shapes as ball-and-stick models using molecules of your choice. (321-5)

Journal

- Discuss the potential impact upon our world if hydrogen bonding did not exist (*hint - consider water*). (321-5)

Resources/Notes

Core STSE #3: *"Common Bonds"*, **Appendix A**

Core Lab #3: *"Modelling Molecules"*, pp. 197-198

MGH Chemistry, p. 202

MGH Chemistry, p. 195

MGH Chemistry, pp. 194-196

MGH Chemistry, pp. 202-206

MGH Chemistry, p. 204

MGH Chemistry, pp. 174-175

Molecular Compounds: Intermolecular Forces *(continued)*

Outcomes

Students will be expected to

- illustrate and explain hydrogen bonds and van der Waals' forces (321-5) (**Cont'd**)
  - identify the relationship between the electronegativity difference between atoms and the degree of bond polarity
  - compare the strength of London dispersion forces, dipole-dipole forces, and hydrogen bonding
- apply bonding knowledge to a particular problem, the structure of DNA, and analyze the benefits to society to be able to solve this problem using bonding knowledge (118-2)
- select, evaluate and integrate information from experimental, print and media sources, and to present an understanding of this information in a variety of formats such as lab reports, web pages, or posters (213-7, 214-3)

Elaborations—Strategies for Learning and Teaching

Students should understand that bond polarity occurs to different degrees, however, the dipole-dipole force difference between molecules (if other intermolecular forces are constant) is very, very small. It is not expected for students to be able to predict boiling point differences based on the strength difference in dipole-dipole interactions.

Students could perform a boiling point lab activity using water, with hydrogen bonding versus a compound with non-polar bonding, such as cyclohexane, to discover the effect of hydrogen bonding. Melting points (water-ice) or camphor or salicylic acid could also be used for the lab. Students could write a report on van der Waals' forces and covalent bonding.

A supplement to the lab might be for students to research boiling points of a variety of phase change compounds with similar molecular mass but varying bond types (electronegativities). They could compare other properties of these compounds to see the effect of bonding on the other physical and chemical properties. In doing this the special nature of the three highly electronegative elements nitrogen, oxygen and fluorine could be noted. The outcomes 321-5 and 321-8 are also adressed in Core Lab #4, *Investigating the Properties of Water.* Students investigate several physical properties that illustrate the relationship between intermolecular forces and physical properties.

The CORE STSE component of this unit incorporates a broad range of Chemistry 2202 outcomes. More specifically a section of it targets 118-2, 213-7 and 214-3. The STSE component, *Common Bonds*, can be found in Appendix A.

Molecular Compounds: Intermolecular Forces *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Why is hexane non-polar? What does bond type have to do with this? (214-2, 321-8)
- Devise your own classification in a flow chart for bonding in all compounds. Use a list of supplied compounds. (214-2, 321-8)
- Describe the relationship between electronegativity and hydrogen bonding. (321-8)
- Draw and label the forces that affect atoms in a covalent bond. (321-8)

Portfolio

- Include a piece of reflective writing in your portfolio. It might analyze a particular technology useful in bonding or it might talk about risks and benefits or the use of bonding knowledge. (118-2)

Journal

- Research a chemical to report on the following:
  - What industry uses the chemical and for what purpose(s)?
  - What are the positive and negative effects of the use of this chemical on society and the environment?

  Based on this information, give your opinion as to whether you would recommend the use of this chemical. (213-7)

Presentation

- Individually or in groups, present research on a Canadian chemistry winner and his/her contribution to science locally, nationally, and globally. This could be presented orally, in written form, or developed as a multimedia presentation. (115-7, 117-11, 116-4, 118-2)
- In groups of two or four, research the contents of a mix such as brownie, cake, or soup mix. Record the names of the ingredients, including the additives and formulas for the substances. Discuss the purpose of each chemical that is used in the mix. Give a multimedia presentation about your mix, providing evidence and information in a variety of formats. (214-3)
- Make a poster or collage of food items highlighting the ingredients and additives. (213-7)
- Using diagrams, illustrate how water exists in each of the three states. (321-5)

Resources/Notes

MGH Chemistry, pp. 176-178

MGH Chemistry, pp. 209-210

Core STSE #2: *"Common Bonds"*, Appendix A

Molecular Compounds: Intermolecular Forces *(continued)*

Outcomes

Students will be expected to

- describe how the type of attractions account for the properties of molecular compounds (321-8)
  - identify the types of intermolecular forces between molecules in a substance
  - compare the melting points or boiling points of simple molecular substances by comparing the strengths of their intermolecular forces

Elaborations—Strategies for Learning and Teaching

Comparing the melting points of molecular substances could be accomplished by completing a melting point lab. Naphthalene or a similar chemical is an example of a compound to use in a melting point lab. Teachers should be firm about proper lab safety, both with the equipment and the procedure.

The solubility of molecular compounds may be discussed at this point or postponed until the chemistry of ionic compounds is covered. Leaving the discussion of solubility until after both ionic and molecular compounds have been covered, presents the teacher with the opportunity to connect the concepts of intermolecular forces and bonding to solubility.

Molecular Compounds: Intermolecular Forces *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Define bonding. Trace the development of bonding with reference to how technology helped us in our understanding of bonding. (115-7, 116-4)

Portfolio

- Keep a section of your portfolio available for issues that arise related to the relationship between science and technology. A bonding topic, such as chemical dentistry, is one that could be discussed. Follow up this discussion with a summary or piece of reflective writing for your portfolio. (115-7, 117-11, 116-4, 118-2)

Resources/Notes

MGH Chemistry, pp. 202-206, pp. 209-210

Molecular Compounds: Network Covalent Solids

Outcomes

Students will be expected to

- illustrate and explain the formation of network covalent bonding and macromolecules (321-4)
  - identify three network covalent solids (SiO_2, SiC, $C_{(diamond)}$, $C_{(graphite)}$)
  - explain the high melting points and extreme hardness of network covalent solids
  - build/design models or find images to represent network covalent bonding in order to distinguish it from ionic and molecular covalent structures
- propose possible technologies which may be developed based upon bonding (116-4)
- explain how bonding theory may evolve and become revised as new evidence arises, using the discovery of the structure of Buckminsterfullerenes (115-7)
- evaluate and select appropriate instruments for collecting evidence (212-8)
- compile and organize data, using appropriate formats to facilitate interpretation of the data (213-5)
- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, tables (214-3)
- explain how data support or refute the prediction (214-12)

Elaborations—Strategies for Learning and Teaching

To build network covalent solids teachers will need to combine many molecular model kits to produce a structure large enough for students to appreciate the structure and its properties. If this is not possible, many images exist in textbooks and the Internet. The Chime™ plug-in (free on the web at http://www.mdlchime.com/chime/) for Internet browsers will enable students to view molecules on many chemistry sites. For example; check out http://www.psrc.usm.edu/macrog/index.htm). Using the Chime™ plugin your Internet browser will be able to view 3-D graphics of molecular structures and rotate them with your mouse (just click and drag the image and it will spin in that direction).

The CORE STSE component of this unit incorporates a broad range of Chemistry 2202 outcomes. More specifically, a section of it it targets 116-4 and 115-7. The STSE component, *Common Bonds*, can be found in Appendix A.

The Laboratory outcomes (212-8, 213-5, 214-3, 214-12) as well as 321-4, 321-5 and 321-8 are addressed by completing *Modelling Molecules*, CORE LAB #3. Students will use molecular model kits to determine the shapes and polarity of molecules.

Molecular Compounds: Network Covalent Solids

Tasks for Instruction and/or Assessment

Presentation

- Silicon, a covalently bonded solid, is harder than pure metals. Research theories that explain the hardness of covalently bonded solids and their usefulness. Present your findings as a newspaper article or memo. (321-5, 213-6, 213-7, 214-3)

Resources/Notes

MGH Chemistry, p. 199

Core STSE #2: *"Common Bonds",* Appendix A

Core Lab #3: *"Modelling Molecules",* pp. 197-198

Ionic Compounds

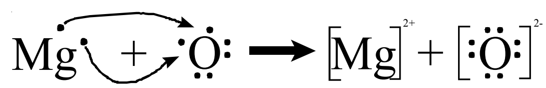
Outcomes

Students will be expected to

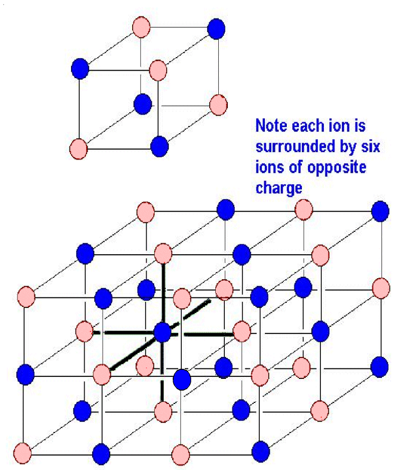
- illustrate and explain the formation of ionic bonds (321-4)
  - – predict the ionic charge for ions in the main group elements from their group number and using the octet rule.
  - – explain the importance of electron transfer in ionic bond formation
  - – define ionic crystal lattice, formula unit and empirical formulae as they apply to ionic compounds
  - – build models or find images to depict the lattice structure of an ionic compound, e.g., NaCl
  - – explain why formulae for ionic compounds refer to the simplest whole number ratio of ions that results in a net charge of zero, while the formulae for molecular compounds refer to the number of atoms of each constituent element
- describe how the type of bonding accounts for the properties of ionic compounds (321-8)
  - – use the theory of ionic bonding to explain the general properties of ionic compounds: brittleness, high melting and boiling points, and the ability to conduct electricity when molten or in aqueous solution

Elaborations—Strategies for Learning and Teaching

In Science 1206 this was covered by using energy level diagrams. Now students are expected to show how ionic bonds form. For example:



A common student misconception about ionic compounds is that they exist as separate entities similar to molecules. This does not occur. It is incorrect to say "molecules of NaCl". Teachers should emphasize that an ionic compound's formula is a ratio within a 3-D crystal lattice. See diagram below.



It is important to recall the physical properties of ionic compounds. The beginning of this unit and the Science 1206 Core Lab "Properties of Ionic and Molecular Compounds" illustrate these properties. To reinforce these, teachers could demonstrate the results of this laboratory again.

Ionic Compounds

Tasks for Instruction and/or Assessment

Paper and Pencil

- Show how ionic bonds are formed between (a) calcium and chlorine, and, (b) sodium and oxygen. (321-4)

Presentation

- Using 3-D diagrams, illustrate the different arrangements of atoms that can exist in an ionic crystal lattice. (321-4)

Journal

- Ionic and covalent bonding can be thought of in terms of simultaneous attractions. Discuss why this is true and identify the entities involved in both types of bonding. (321-4)

Resources/Notes

MGH Chemistry, p. 165

MGH Chemistry, p. 166

MGH Chemistry, pp. 167-168

MGH Chemistry, p. 168

MGH Chemistry, pp. 217-218

Ionic Compounds *(continued)*

Outcomes

Students will be expected to

- identify limitations of categorizing bond types based on differences in electronegativity between the elements of compounds (214-2)
  - recognize the relationship between electronegativities of the atoms and the type of bonding in a compound
  - describe bonding as a continuum ranging from complete electron transfer (ionic) to unequal sharing of electrons (polar covalent) to equal sharing of electrons (non-polar covalent)
- compare the strengths of ionic and covalent bonds (321-9)

Elaborations—Strategies for Learning and Teaching

Students should realize that there is a bond continuum. However, binary ionic compounds are recognized as having a metal cation (result from atoms with low electronegativities) attracted to a nonmetal(s) anion (simple anions result from atoms with high electronegativities). A compound's classification, i.e., ionic or molecular, would depend on its physical properties. For example; classify F_2, HF and NaF. F_2 and HF are molecular compounds (they do not conduct electricity as liquids and they are gases at room temperature). Based on atomic electronegativities, F_2 is nonpolar while HF is polar. The greater the difference in electronegativity the more polar (and less covalent), therefore, more ionic character a molecule has. NaF has a large electronegativity difference. It is classified as ionic because it has the physical properties of ionic compounds.

Teachers could use a diagram to illustrate the progressive nature of electron pair "sharing" - from nonpolar covalent bonding to ionic bonding.

Students could compare the strengths of ionic and covalent bonds of various common substances they have previously identified (such as table salt (NaCl) and sugar ($C_{12}H_{22}O_{11}$)).

Ionic Compounds *(continued)*

Tasks for Instruction and/or Assessment

Journal

- How does chemistry affect your life? Identify chemicals and discuss their bond type in terms of electronegativity. (214-2)

Paper and Pencil

- Which compound in each of the following pairs is more polar?
  - (a) H_2O or H_2S
  - (b) HCl or HBr
  - (c) PCl_3 or PI_3 (323-7)

Resources/Notes

MGH Chemistry, pp. 176-178

Solutions and Intermolecular Forces

Outcomes

Students will be expected to

- explain the variations in the solubility of various pure substances, given the same solvent (323-7)
  - describe the solubility of ionic and molecular compounds in polar and non-polar solvents
  - explain how molecular and ionic compounds form solutions by relating it to intermolecular forces (dipole-dipole) and forces of attraction (ion-dipole), respectively
  - understand that solutions are mixtures at the particle level and do not involve a chemical change
  - state that for different substances, solubility occurs to varying degrees

Elaborations—Strategies for Learning and Teaching

Students should be able to explain how ionic and molecular compounds form solutions by relating solutions to intermolecular forces and forces of attraction. Situations such as salt heated on a stove or soda pop in the refrigerator might be used as examples. Predictions might include whether a given solute will dissolve in a given solvent. Students should understand that solutions are mixtures formed by physically mixing at the particle level and do not involve a chemical change.

The phrase "like dissolves like" is often used to describe solubility, since polar substances (having a slight positive and slight negative charges) and ionic componds (having positive and negative charges) generally dissolve in polar solvents. Similarly, nonpolar substances generally dissolve in nonpolar solvents. Students should apply this to determine if a substance will dissolve in another substance. Teachers might wish to have a discussion about one of the following: relating it to how a solution forms: solubility of vitamins in water or oil; cleaning clothes with water and with tetrachloroethane, C_2Cl_4; and oil spills.

Polar molecular substances dissolve in polar molecular solvents because of the attraction between the oppositely charged ends of the molecular dipoles. While there are very little dipole-dipole electrostatic attractive forces between a nonpolar solute for a nonpolar solvent, there are very small electrostatic attractions within the solute and within the solvent. The kinetic molecular theory states that the particles of both the solute and solvent are in constant motion, therefore with no strong forces of attraction, the nonpolar solute will dissolve in the nonpolar solvent.

Ionic compounds have permanent positive and negative charged ions. Since polar molecular solvents have a permanent molecular dipole the positive ions attract the partially negative end of the dipole and vice versa. This is refered to as the ion-dipole attraction.

Students should be able to explain that the degree of dissolving is dependent upon the forces of attraction in the dissolving process.

Students could draw a diagram illustrating particles entering and leaving the solution phase. Students should explain, with the help of a diagram, the forces of attraction between solute and solvent particles.

Solutions and Intermolecular Forces

Tasks for Instruction and/or Assessment

Journal

- If like dissolves like, why does sodium chloride dissolve in water? (323-7)
- Why wouldn't we use water to remove a ketchup stain? (323-7)
- Draw the position of the particles to represent the following:
  - sugar dissolved in water
  - salt dissolved in water (323-7)
- Compare the forces involved when a molecular substance and an ionic substance dissolve. (323-7)

Paper and Pencil

- Which of the following substances are expected to dissolve in water? Explain your choice.

(a)	CCl_4	(d)	S_8
(b)	$Mg(NO_3)_2$	(e)	CH_2Cl_2
(c)	CH_3OH	(f)	NH_3 (323-7)

Resources/Notes

MGH Chemistry, pp. 243-247

MGH Chemistry, p. 237

Metallic Compounds

Outcomes

Students will be expected to

- illustrate and explain the formation of metallic bonds (321-4)
  - define a metallic bond, and use it to explain bonding within metals
  - build models (or find images) to represent metallic bonding in order to distinguish it from ionic and molecular covalent structures
- describe how the type of bond accounts for the properties of metallic substances (321-8)
  - using the theory of metallic bonding, explain why metals are malleable, ductile, good conductors of heat and electricity, and have a wide range of melting and boiling points
- compare the melting or boiling points of network solids, ionic compounds, metals, and molecular compounds by comparing the relative strengths of the forces of attraction between their particles (321-8)

Elaborations—Strategies for Learning and Teaching

The role of the electron "sea" is key to understanding how metallic bonding occurs (and the resulting metal physical properties). Teachers could use the "sea" analogy to explain how mobile electrons influence properties such as electrical conductivity, malleability, ductility and so on.

Teachers should emphasize that metallic bonding is dependent upon the low electronegativities of metal atoms. Since electrons are loosely held, they can become free to move into empty valence orbitals of neighboring atoms (recall metals have many empty valence orbitals).

Teachers could use the following general rule to rank substances in order of increasing melting/boiling points.

Attractive Forces

Lowest → Highest

LDF only (Varies greatly) 〉 D-D Forces 〉 Hydrogen Bonding 〉 Metallic (Varies greatly) 〉 Ionic 〉 Network Covalent

For example; SiO_2, CCl_4 and Na_2S ranked in order of increasing boiling points would be: CCl_4 (lowest), Na_2S, SiO_2 (highest).

Metallic Compounds

Tasks for Instruction and/or Assessment

Journal

- Reflect on the outcomes from this unit. Chose a title for your reflection, perhaps the "muddiest point(s)" for this unit. (114-2)

Presentation

- Students could choose a metal or metal alloy and illustrate its properties. They should include a discussion of its various uses. (321-4)

Paper and Pencil

- Rank the following substances in order of increasing boiling points.

(a)	SiC	(d)	F_2
(b)	C_2H_6	(e)	Mg
(c)	CH_3OH (323-7)		

Resources/Notes

MGH Chemistry, pp. 171-172

MGH Chemistry, p. 172, p. 219

MGH Chemistry, pp. 219-221

MGH Chemistry, p. 218