

J. Wolf

Big Idea 2: Structure and Properties of Matter

Chemical and physical properties of materials can be explained by the structure and the arrangements of atoms, ions, or molecules and the forces between them.

When all else fails, remember the INTERmolecular forces and INTRAmolecular forces. The intramolecular forces are the bonds within molecules (covalent, polar, ionic). Intramolecular forces (bonds) are broken and re-formed in reactions. The intermolecular forces are the interactions between molecules of a sample. They contribute to the melting point, boiling point, vapor pressure, and other properties related to the phase of matter that the substance exists.

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

This could be solid, liquid, and gas on the particle level or it could refer to ionic, covalent, and those kinds of particles.

Example:

Which of the following will be more soluble at lower temperatures than at higher temperatures?

- a) $\text{KNO}_3(\text{s})$
 - b) $\text{O}_2(\text{g})$
 - c) $\text{C}_6\text{H}_{14}(\text{l})$
 - d) $\text{NaCl}(\text{s})$
- ← Only gas and gas solubility ↑ as T ↓

LO 2.2 The student is able to explain the relative strengths of acids and bases based on molecular structure, interparticle forces, and solution equilibrium.

Be able to explain why a strong acid is a strong acid, not just because my teacher told me so.

Example:

Which of the following is the strongest acid?

- a) HClO_2
 - b) HClO
 - c) HClO_3
 - d) HClO_4
- Both strong acids, but HClO_4 has more O, so more e⁻ withdrawing oxygen and that makes H easier to ionize

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.

Be able to describe what a solid and liquid look like, on the particle level.

Example: Describe why a gas is able to expand to fill its container.

Gas particles are freely moving

LO 2.4 The student is able to use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and nonideal behaviors.

Kinetic molecular theory describes how particles move and interact (or more properly, don't interact). Students need to be able to describe how the IMF for a gas contribute to deviation from ideal behavior.

Example:

Under what conditions are the assumptions of Kinetic Molecular theory most likely to fail?

- a) High pressure and high temperature
 - b) High pressure and low temperature
 - c) Low pressure and low temperature
 - d) Low pressure and high temperature
- squishes particles together and slowly moving → start to feel attraction and not mostly empty space*

LO 2.5 The student is able to refine multiple representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample.

Use models to represent changes in volume, pressure, and temperature on a sample of a gas.

Example:

Use the kinetic molecular theory model to predict what would happen to a closed sample of a gas if the temperature decreased while its pressure ~~decreased~~ *increased*.

- a) The volume would increase
 - b) The volume would decrease
 - c) The average kinetic energy of the molecules would increase
 - d) The moles of gas molecules would increase
- PV = nRT As particles slow and are compressed, the space they occupy decreases*

LO 2.6 The student can apply mathematical relationships or estimation to determine macroscopic variables for ideal gases.

Use the Ideal Gas law in calculations

Example:

Calculate the number of molecules in a deep breath of air whose volume is 2.25 L at a body temperature of 37 °C and a pressure of 735 torr

$$PV = nRT \quad (735 \text{ torr})(2.25 \text{ L}) = n(62.36 \frac{\text{torr} \cdot \text{L}}{\text{mol} \cdot \text{K}})(310 \text{ K}) \quad n = 0.0855 \text{ mol}$$
$$0.0855 \text{ mol} \times 6.02 \times 10^{23} \text{ molecules/mol} = 5.15 \times 10^{22} \text{ molecules}$$

LO 2.7 The student is able to explain how solutes can be separated by chromatography based on intermolecular interactions.

Describe how chromatography works on the particle level, describe the relationship of the solute with the solvent and the stationary phase, as well as the size of the particles.

Example:

Chromatography is a good way to separate the

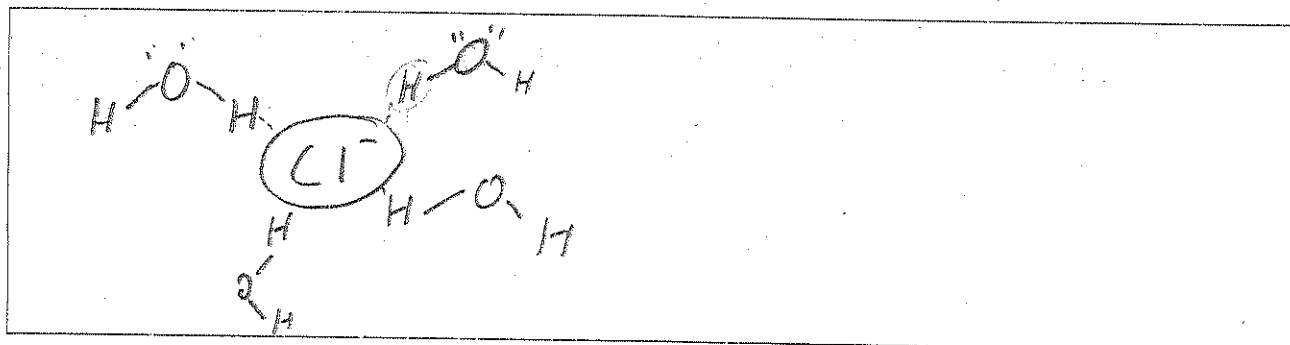
- a) elements in a compound
- b) the components in a mixture
- c) the atoms in an element
- d) the phases of a pure substance

LO 2.8 The student can draw and/or interpret representations of solutions that show the interactions between the solute and solvent.

Students can draw solute particles and the solvent interactions, based on the polarity of the particles or the ldf.

Example:

In the box below, draw a particle representation of how water molecules would interact with a Chloride ion.

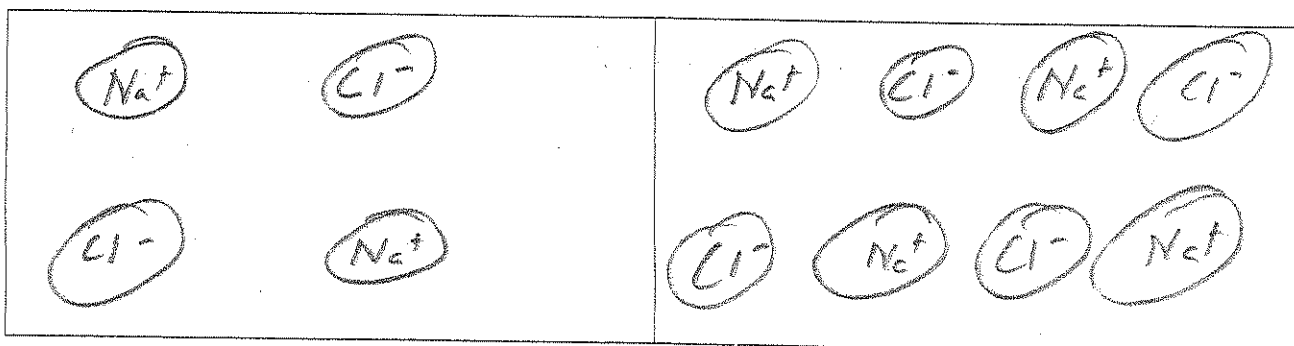


LO 2.9 The student is able to create or interpret representations that link the concept of molarity with particle views of solutions.

Be able to draw a dilute solution and a concentrated solution in terms of the number of particles of solute vs. solvent.

Example:

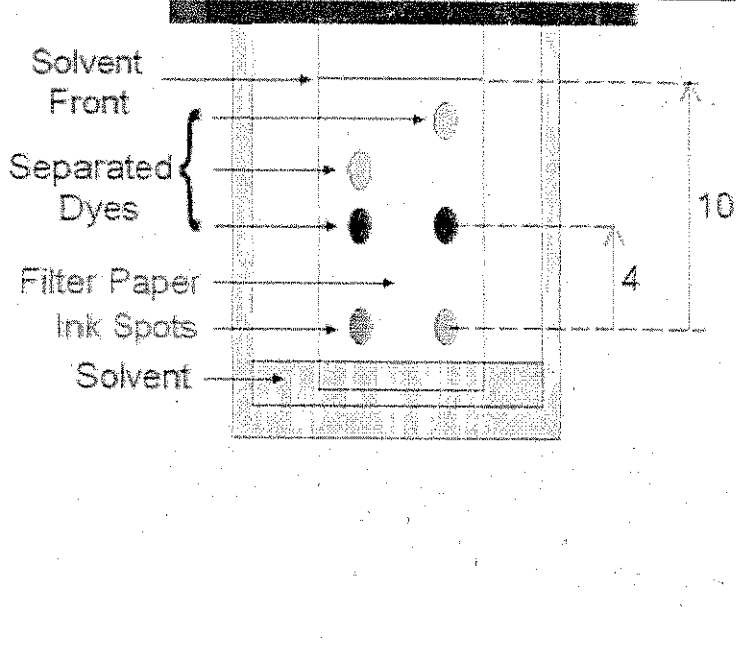
In the box below, draw a representation of two NaCl solutions. On the left, represent a 1M solution and on the right, represent a 2M solution.



LO 2.10 The student can design and/or interpret the results of a separation experiment (filtration, paper chromatography, column chromatography, or distillation) in terms of the relative strength of interactions among and between the components.

Chromatography is affected by the attraction for the mobile phase as well as the stationary phase.

Example:

	<p>On the illustration on the left, you have a diagram of paper chromatography. The ink spots are represented at the bottom of the paper and the separated dyes are at different distances towards the top of the paper. Why do the components of the dyes move to different heights?</p> <ul style="list-style-type: none">a) Different molecules that make up dyes have different particle sizes and affinity for the paper and solvent.b) Different dyes are made of a single molecule that breaks apart in the solutionc) Dyes separate on paper when they get wetd) Filter paper has special properties that separates dye
--	--

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.

Students need to know ldf and how that affects the properties of a sample of the substance. This would apply to nonpolar substances.

Example:

Methane, ethane, propane, and butane are gases at room temperature, while pentane, hexane, and heptane are liquids. In terms of ldf, why does boiling point of hydrocarbons increase as more carbons are added to the molecule?

- a) Molar mass increases and boiling point increases because the molecules are heavier and more likely to be liquids
- b) As the molecules become larger, there are more electrons per molecule, which makes the larger molecules more polarizable and have stronger ldf forces.
- c) As the molecules become smaller, there are more electrons per molecule, which makes the larger molecules more polarizable and have stronger ldf forces.
- d) As molar mass decreases, boiling point increases.

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

The ideal gas law does not take into account the IMF between the particles of a gas. Gases

Example:

<p>According to the graph to the right, what are the ideal conditions, when a gas behaves most like an ideal gas?</p> <p>a) High pressure, high volume b) Low pressure, high volume c) Low pressure, low volume d) High pressure, low volume</p>	
--	--

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.

Example:

<p>Draw a particle-level representation of methanol, CH_3OH, and differentiate between the intermolecular forces (attractions) and intramolecular forces (bonds). Draw at least 3 molecules in the box to the right.</p>	
---	--

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.

Example:

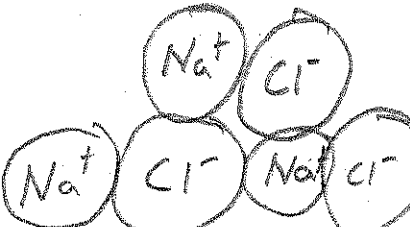
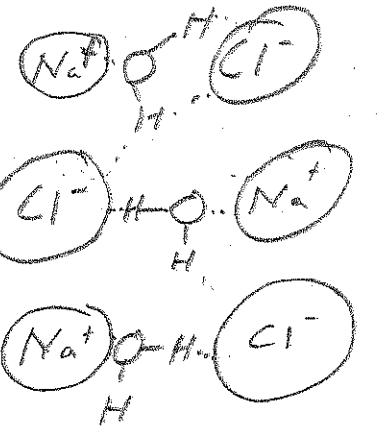
smallest
 Based on size and charge, which of the following would be the most soluble in water?

- a) RbCl
b) MgCl_2
 c) AgCl
 d) ScCl_3

most charged

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.

Example:

	<p>In the box on the left, draw a salt crystal with at least 3 formula units. In the box on the right, draw the same salt crystal dissolved in water. Which sample allows for more freedom of movement? Which box represents a sample with a higher entropy value?</p> <p>a) <u>Left</u> b) <u>Right</u> c) Both d) Neither</p>	
---	--	---

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.

Example:

Which of the following molecules would be expected to have the lowest viscosity (resistance to flow)?

- a) H_2O
- b) Hg
- c) CF_4
- d) $C_{12}H_{26}$

smallest and nonpolar overall

lowest IMF

LO 2.17 The student can predict the type of bonding present between two atoms in a binary compound based on position in the periodic table and the electronegativity of the elements.

Example:

Which of the following molecules would be expected to be the most nonpolar?

- a) F_2 — *same element*
- b) NF_3
- c) SF_2
- d) CH_2F_2

LO 2.18 The student is able to rank and justify the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table.

Example:

Which of the following bonds has the highest electronegativity difference?

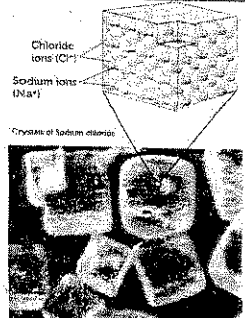
- a) C - O
- b) Si - O
- c) Ge - O
- d) Sn - O

LO 2.19 The student can create visual representations of ionic substances that connect the microscopic structure to macroscopic properties, and/or use representations to connect the microscopic structure to macroscopic properties (e.g., boiling point, solubility, hardness, brittleness, low volatility, lack of malleability, ductility, or conductivity).

Example:

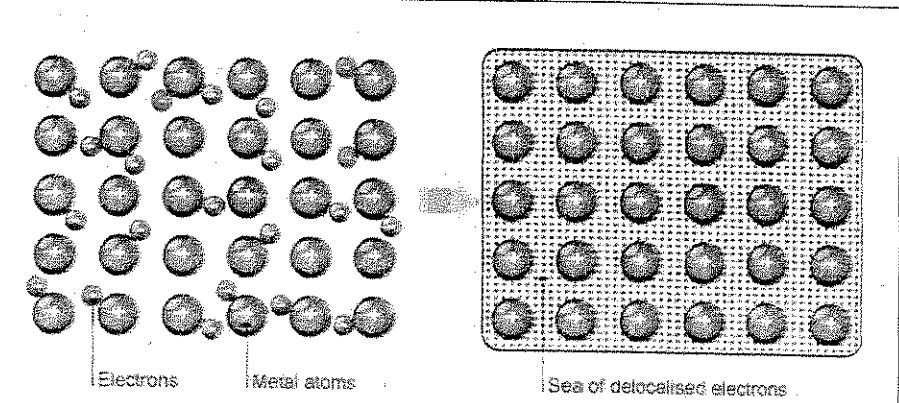
Would the substance illustrated on the right be hard and brittle or soft and malleable? Explain.

Ionic bonds are strong and close as possible



Chloride ions (Cl⁻)
Sodium ions (Na⁺)
Crystal of sodium chloride

LO 2.20 The student is able to explain how a bonding model involving delocalized electrons is consistent with macroscopic properties of metals (e.g., conductivity, malleability, ductility, and low volatility) and the shell model of the atom.



Electrons Metal atoms

Sea of delocalised electrons

Sea of e⁻ allows e⁻ to move and be transferred

The representation on the left shows a particle view of metal atoms. In order to conduct electricity, a substance must be able to carry a charged particle and move. Describe how the illustration shows that a metal satisfies the requirements of being a conductor of electricity.

LO 2.21 The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity.

Example:

Which of the following molecules would be the most polar overall?

- a) CH_4 *→ all nonpolar overall*
b) CF_4
c) H_2O
d) BeH_2

LO 2.22 The student is able to design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid.

Example:

You are given a set of white solids and are asked to determine whether the substances are ionic or covalent compounds. Describe the steps you would take to determine whether the substances were ionic or covalent, including expected results.

*dissolve in water then test conductivity - ionic will conduct
covalent will not
attempt to melt - ionic will be much higher than covalent*

LO 2.23 The student can create a representation of an ionic solid that shows essential characteristics of the structure and interactions present in the substance.

Example:

Describe how Coulomb's Law is related to the formation and properties of an ionic crystal lattice.

*opposites attract, forces are stronger the closer the particles
(like repel)*

makes ionic lattice strong, hard, brittle, stable

LO 2.24 The student is able to explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level.

Example:

Consider three hypothetical ionic compounds; one is composed of $1+$ and $1-$ ions, another is $2+$ and $2-$, and a third is $3+$ and $3-$. Which of the three would you expect to have the highest melting point?

- a) The $1+$ and $1-$
b) The $2+$ and $2-$
c) The $3+$ and $3-$
d) None of the above

Coulomb's Law!

LO 2.25 The student is able to compare the properties of metal alloys with their constituent elements to determine if an alloy has formed, identify the type of alloy formed, and explain the differences in properties using particulate level reasoning.

Example:

Bronze and brass are 2 alloys of copper. Bronze is a mixture of copper and tin, while brass is copper and zinc. Based on the components of the alloys, which alloy would be more resistant to corrosion and why?

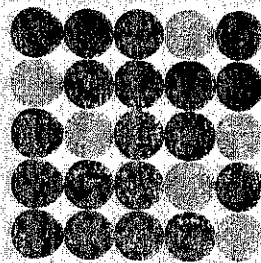
Bronze would be more resistant to corrosion b/c tin is lower on activity series than zinc

LO 2.26 Students can use the electron sea model of metallic bonding to predict or make claims about the macroscopic properties of metals or alloys.

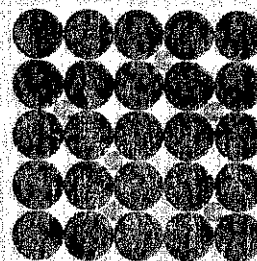
Example:

Of the two types of alloys pictured on the right, which one would you expect to have an increased density and melting point? Why?

Interstitial would have increased density and MP b/c it has more particles in a closer space to each other. More particles also means more attraction



SUBSTITUTION ALLOY



INTERSTITIAL ALLOY

LO 2.27 The student can create a representation of a metallic solid that shows essential characteristics of the structure and interactions present in the substance.

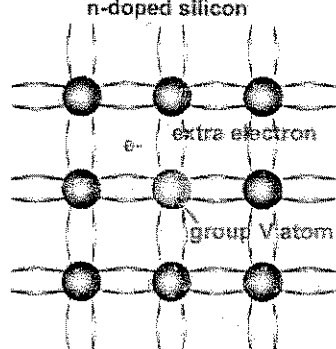
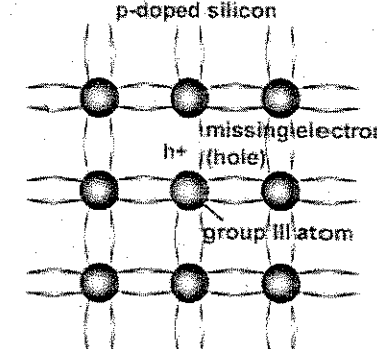
Example:

Of the two types of alloys, substitution and interstitial, which would tend to take on an average of the properties of the component metals? Why?

A substitution alloy would average the properties since the different components would tend to be closer in size and amount.

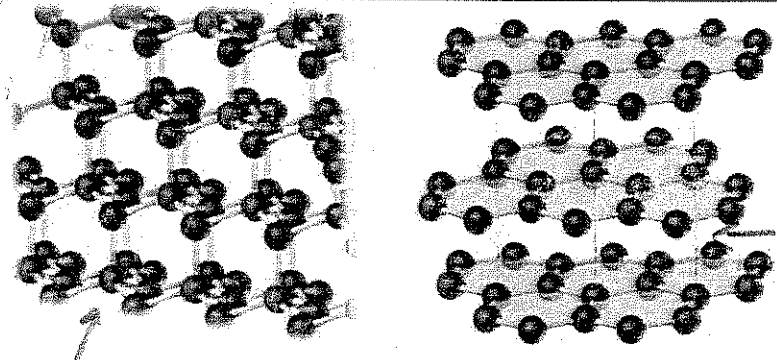
LO 2.28 The student is able to explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level.

Example:

<p>n-doped silicon</p>  <p>extra electron e^- group V atom</p>	<p>p-doped silicon</p>  <p>missing electron h^+ (hole) group III atom</p>	<p>Two types of doping for semiconductors are shown in the image on the left. Which element of the following would make a good p-doping element for silicon?</p> <p>a) P $> 5e^-$ is 1 extra e^- b) N $> 5e^-$ is 1 extra e^- c) B - missing an electron ($3e^-$) d) C - $4e^-$ = full</p>
--	---	---

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.

Example:

<p>The illustration on the right shows two covalent network solids, diamond(a) and graphite(b). With regards to intermolecular forces (attractions) and intramolecular forces (bonds), which is a harder solid, <u>diamond</u> or graphite? How is that illustrated in the model to the right?</p> <p>Diamond is harder b/c it has 3-D</p>	 <p>(a) Diamond</p> <p>(b) Graphite</p> <p>all bonds</p> <p>left interactions</p>
--	--

covalent bonding, while graphite has covalently bonded layers with ldf interactions holding the layers together

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.

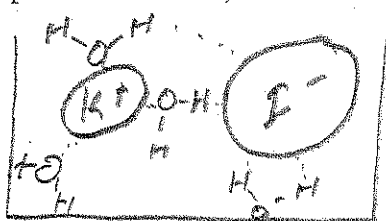
Example:

<p>The diagram shows three polymer skeletons labeled A, B, and C. Structure A is a single, continuous zigzag line representing a linear polymer. Structure B is a zigzag line with several shorter lines branching off it, representing a branched polymer. Structure C consists of two zigzag lines connected by several vertical lines, representing a cross-linked polymer.</p>	<p>Three basic structures of polymers are shown on the left. Linear(A), branched(B), and cross-linked(C) polymer skeletons are shown. If you wanted a polymer with a <u>high density</u>, which would you choose and why?</p> <p><i>A, linear, would be able to be made in high density b/c you could fit lots of particles much closer than the others</i></p>
--	---

LO 2.31 The student can create a representation of a molecular solid that shows essential characteristics of the structure and interactions present in the substance.

Example:

Solid iodine, I_2 , is slightly soluble in water, but if the iodine is mixed with potassium iodide, KI, it becomes much more soluble. Draw an illustration of the interactions between water molecules and a sample of potassium iodide, dissolved in water.



LO 2.32 The student is able to explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present at the atomic level.

Example:

Iodine readily sublimates, goes straight from a solid to a gas. What forces are broken when iodine sublimates?

- a) Covalent bonds
- b) Hydrogen bonds
- c) Dipole-dipole interactions
- d) London dispersion forces

*Intermolecular forces
vs
Intramolecular bonds*