LO 2.1: Students can predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views.
The increased number of oxygen atoms pulls negative charge away from the O-H bond, weakening the attraction of the proton for the electron pair and thus strengthening the acid.

The greater the size of the negative ion, the weaker its attraction for the proton, and so the stronger the acid, and the weaker the conjugate base. HI is the strongest binary acid.

+ Behaviors of Solids, Liquids, and Gases

LO 2.3: The student is able to use particulate models to reason about observed differences between solid and liquid phases and among solid and liquid materials.

+ Kinetic Molecular Theory (KMT)

LO 2.4: The student is able to use KMT and IMP’s to make predictions about the macroscopic properties of gases, including both ideal and non-ideal behaviors.
LO 2.5: 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.

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

LO 2.7: The student is able to explain how solutes can be separated by chromatography based on intermolecular interactions.
Dissolving/Dissociation: Solute and Solvent

- When drawing solute ions:
  1. Pay attention to size (Na⁺ is smaller than Cl⁻)
  2. Draw charges on ion, but not on water
  3. Draw at least 3 water molecules around each
  4. The negative dipole (oxygen side) points toward cation and the positive dipoles (H side) points toward the anion

Molarity and Particle Views

- QUESTION: Rank the six solutions above in order of increasing molarity. Pay attention to volume, and some have equal concentration

Distillation to Separate Solutions

- In the diagram above, ethanol has lower IMF's and a resulting lower boiling point than water, so it can be heated, vaporized, and condensed easily.
- Ethanol hydrogen bonds as water does and is polar, but part of the ethanol has only weaker IMF's because it's nonpolar, resulting in a lower boiling point

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

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

LO 2.10: Design/interpret the results of filtration, paper/column chromatography, or distillation in terms of the relative strength of interactions among the components.
London Dispersion Forces and Noble and Nonpolar Gases

LO 2.11: The student is able to explain the trends in properties/predict properties of samples consisting of particles with no permanent dipole on the basis of LDF’s.

Deviations from Ideal Gas Behavior

Question:
At which values of temperature and pressure will the gas N₂ behave least like an ideal gas?

<table>
<thead>
<tr>
<th>Temperature (K)</th>
<th>Pressure (atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. 300</td>
<td>100</td>
</tr>
<tr>
<td>b. 300</td>
<td>1.0</td>
</tr>
<tr>
<td>c. 700</td>
<td>0.1</td>
</tr>
<tr>
<td>d. 700</td>
<td>1.0</td>
</tr>
<tr>
<td>e. 700</td>
<td>100</td>
</tr>
</tbody>
</table>

When watching the video, don’t concern yourself with Van der Waals – AP Exam focuses on LDF’s instead.

Hydrogen Bonding

- Hydrogen bonding is seen in the following molecules: water, DNA, ammonia, HF, and alcohols. H-bonding is an attraction or force, not a true intramolecular bond.
- Hydrogen bonds are like a sandwich with N, O, and/or F as the bread, H will be in a intramolecular (same molecule) bond with one N, O, and/or F and have an intermolecular attraction (different molecule) with the other.

Remember this tip: hydrogen bonds just wanna have FON

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.
Coulomb's Law and Solubility

- Ionic compounds can dissolve in polar liquids like water because the ions are attracted to either the positive or negative part of the molecule.
- There is a sort of tug-of-war involved with species dissolved in water. The water pulls individual ions away from the solid. The solid is pulling individual ions back out of the water. There exists an equilibrium based on how strongly the water attracts the ions, versus how strong the ionic solid attracts the ions.
- We can predict the degree of solubility in water for different ionic compounds using Coulomb's law. The smaller the ions, the closer together they are, and the harder it is for the water molecules to pull the ions away from each other. The greater the charge of the ions, the harder it is for the water to pull them away as well.

**QUESTION:** Predict which of the following pairs should be more soluble in water, based on Coulombic attraction.

- LiF or NaF
- NaF or KF
- BeO or LiF

**Entropy in Solutions**

Water dissolves salts by forming a cloud of interacting water molecules around the ions. This makes electrostatic interactions between the ions and water molecules the tendency to form a crystal lattice. Dissolution of the salt is accompanied by a large increase in entropy as the individual ions become more mobile. The change in free energy of the system is overall very negative (ΔG < 0) and hence dissolution of the salt is thermodynamically highly favored.

**Physical Properties and IMF's**

**Question:** Which of the following compounds has no net dipole moment?

- a. H2O
- b. Hg
- c. CO2
- d. C6H6

**LO 2.14:** Apply Coulomb's law to describe the interactions of ions & the attractions of ions/solvents to explain the factors that contribute to solubility of ionic compounds.

**LO 2.15:** Explain observations of the solubility of ionic solids/molecules in water and other solvents on the basis of particle views that include IMF's and entropic effects.

**LO 2.16:** Explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of IMF's.
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.

+ Bonding and Electronegativity

Differences in electronegativities lead to different types of bonding:
- 0.0 – 0.4: Bond is generally considered nonpolar
- 0.5 – 1.7: Bond is generally considered polar
- > 1.7: Bond is generally considered ionic

Electronegativities are assigned values and are relative to fluorine. Electronegativity is a function of shielding / effective nuclear charge.
*Values presented are one possibility – other scales exist.

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.

+ Ranking Bond Polarity

Questions:
Which of the following bonds would be MOST polar?
- a. C−O
- b. H−O
- c. H−H
- d. C−N
- e. F−O

Ionic compounds are brittle. As the crystal structure is struck, the ions become displaced. The displaced ions will repel like charges and fracture.

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 microscopic structure to macroscopic properties (e.g., boiling point, solubility, hardness, brittleness, low volatility, lack of malleability, ductility, or conductivity).
The metallic bond is not the easiest type of bond to understand, so an analogy may help. Imagine filling your bathtub with golf balls. Fill it right up to the top. The golf balls will arrange themselves in an orderly fashion as they fill the space in the tub. Do you see any spaces between the balls? If you turn on the faucet and plug the drain, the water will fill up those spaces. What you now have is something like metallic bonding. The golf balls are the metal kernels, and the water represents the valence electrons shared by all of the atoms.

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.

Video

"The metallic bond is not the easiest type of bond to understand, so an analogy may help. Imagine filling your bathtub with golf balls. Fill it right up to the top. The golf balls will arrange themselves in an orderly fashion as they fill the space in the tub. Do you see any spaces between the balls? If you turn on the faucet and plug the drain, the water will fill up those spaces. What you now have is something like metallic bonding. The golf balls are the metal kernels, and the water represents the valence electrons shared by all of the atoms."
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.

+ Crystal Structure of Ionic Compounds

- Sodium chloride and magnesium oxide have exactly the same structure. Their melting and boiling points are:

<table>
<thead>
<tr>
<th></th>
<th>NaCl</th>
<th>MgO</th>
</tr>
</thead>
<tbody>
<tr>
<td>melting point (K)</td>
<td>1079</td>
<td>1122</td>
</tr>
<tr>
<td>boiling point (K)</td>
<td>1880</td>
<td>1973</td>
</tr>
</tbody>
</table>

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.

The +2 and -2 ions attract each other more strongly than +1 attracts -1. The ions Mg$^{+2}$ and O$^{-2}$ are smaller than Na$^{+1}$ and Cl$^{-1}$, therefore the ions can get closer together, increasing their electrostatic attractions.

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

**Alloys!**

<table>
<thead>
<tr>
<th>Type of Alloy</th>
<th>Example</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substitutional</td>
<td>Ag 31%</td>
<td>Cr 7%</td>
</tr>
<tr>
<td>Interstitial</td>
<td>Fe 95% C 5%</td>
<td>Interstitial substitution: elements commonly non-metals (H, B, C, N, O, S)</td>
</tr>
<tr>
<td>Intermetallic*</td>
<td>MgZn2</td>
<td>CuZn</td>
</tr>
<tr>
<td>Heterogeneous</td>
<td>CuSn</td>
<td>CuPb</td>
</tr>
</tbody>
</table>

*Intermetallic*: sometimes used to describe phases in heterogeneous alloys with multiple metals.

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.

**Metallic Solids - Characteristics**

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.

**Properties of Metallic Solids**

Questions:
One type of semiconductor in a germanium crystal adding some impurities can increase the conductivity of the semiconductor. Adding which of the following would create a P-type semiconductor with increased conductivity?

a. The addition of silicon.
b. The addition of phosphorus.
c. The addition of arsenic.
d. The addition of gallium.

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+ Covalent Compounds - Interactions

Graphite are sheets of carbon atoms bonded together and stacked on top of one another. The interactions between sheets is weak, much like the substance itself.

Diamond’s carbon atoms are more connected in a three-dimensional structure, adding strength to the network.

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.

+ Covalent Solids

A student places a mixture of plastic beads consisting of polyethylene (PE) and polyvinyl chloride (PVC) in a 1:1 ratio, containing distilled water. After stirring the contents of the beaker vigorously, the student observes that the beads of one type of plastic sink to the bottom of the beaker and the beads of the other type of plastic float on the water. The chemical structures of PP and PVC are represented by the diagrams below, which show segments of each polymer.

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.

+ Molecular Compounds - Interactions

Non-Polar Covalent compounds align according to London dispersion forces.

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

Which of the following are broken when water boils?

- a. Covalent bonds
- b. Hydrogen bonds
- c. Dipole-dipole interactions
- d. London Dispersion Forces

Explain why iodine is a solid with a low melting and boiling point, almost insoluble in water, but soluble in organic solvents such as hexane, and is also a non-conductor of electricity.

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.