

## UNIT 2: MOLECULAR & IONIC COMPOUND STRUCTURE & PROPERTIES--Unit Guide

### TOPIC 2.1: TYPES OF CHEMICAL BONDS

#### ENDURING UNDERSTANDING:

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| SAP-3 | Atoms or ions bond due to interactions between them, forming molecules |
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#### LEARNING OBJECTIVE:

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| SAP-3.A | Explain the relationship between the types of bonding and the properties of the elements participating in the bond |
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#### ESSENTIAL KNOWLEDGE:

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| SAP-3.A.1 | Electronegativity values for the representative elements increase going from left to right across a period and decrease going down a group. These trends can be understood qualitatively through the electronic structure of the atoms, the shell model, and Coulomb's law |
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| SAP-3.A.2 | Valence electrons shared between atoms of similar electronegativity constitute a nonpolar covalent bond. For example, bonds between carbon and hydrogen are effectively nonpolar even though carbon is slightly more electronegative than hydrogen. |
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| SAP-3.A.3 | Valence electrons shared between atoms of unequal electronegativity constitute a polar covalent bond. <ol style="list-style-type: none"> <li>The atom with a higher electronegativity will develop a partial negative charge relative to the other atom in the bond.</li> <li>In single bonds, greater differences in electronegativity lead to greater bond dipoles.</li> <li>All polar bonds have some ionic character, and the difference between ionic and covalent bonding is not distinct but rather a continuum.</li> </ol> |
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| SAP-3.A.4 | The difference in electronegativity is not the only factor in determining if a bond should be designated as ionic or covalent. Generally, bonds between a metal and a nonmetal are ionic, and bonds between two nonmetals are covalent. Examination of the properties of a compound is the best way to characterize the type of bonding. |
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| SAP-3.A.5 | In a metallic solid, the valence electrons from the metal atoms are considered to be delocalized and not associated with any individual atom |
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### TOPIC 2.2: INTRAMOLECULAR FORCE AND POTENTIAL ENERGY

#### ENDURING UNDERSTANDING:

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| SAP-3 | Atoms or ions bond due to interactions between them, forming molecules |
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#### LEARNING OBJECTIVE:

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| SAP-3.B | Represent the relationship between potential energy and distance between atoms, based on factors that influence the interaction strength |
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#### ESSENTIAL KNOWLEDGE:

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| SAP-3.B.1 | A graph of potential energy versus the distance between atoms is a useful representation for describing the interactions between atoms. Such graphs illustrate both the equilibrium bond length (the separation between atoms at which the potential energy is lowest) and the bond energy (the energy required to separate the |
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|           | atoms)   |
| SAP-3.B.2 | <i>In a covalent bond, the bond length is influenced by both the size of the atom's core and the bond order (i.e. single, double, triple). Bonds with higher order are shorter and have larger bond energies</i>   |
| SAP-3.B.3 | <p>Coulomb's law can be used to understand the strength of interactions between cations and anions.</p> <ol style="list-style-type: none"> <li>Because the interaction strength is proportional to the charge of each ion, larger charges lead to stronger interactions</li> <li>Because the interaction strength increases as the distance between the centers of the ions (nuclei) decreases, smaller ions lead to stronger interactions.</li> </ol> |

## TOPIC 2.3: STRUCTURE OF IONIC SOLIDS

### ENDURING UNDERSTANDING:

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| SAP-3 | Atoms or ions bond due to interactions between them, forming molecules |
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### LEARNING OBJECTIVE:

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| SAP-3.C | Represent an ionic solid with a particulate model that is consistent with Coulomb's law and the properties of the constituent ions |
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### ESSENTIAL KNOWLEDGE:

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| SAP-3.C.1 | The cations and anions in an ionic crystal are arranged in a systematic, periodic 3D array that maximizes the attractive forces among cations and anions while minimizing repulsive forces                |
|           | <p>KNOWLEDGE OF SPECIFIC TYPES OF CRYSTAL STRUCTURES WILL NOT BE ASSESSED ON THE AP EXAM</p> <p>Rationale: study of specific crystal structures is not essential to an understanding of the big ideas</p> |

### EQUATION(S):

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| Coulomb's Law | $F = \frac{k \cdot q_1 \cdot q_2}{r^2}$ |
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## TOPIC 2.4: STRUCTURE OF METALS AND ALLOYS

### ENDURING UNDERSTANDING:

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| SAP-3 | Atoms or ions bond due to interactions between them, forming molecules |
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### LEARNING OBJECTIVE:

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| SAP-3.D | Represent a metallic solid and/or alloy using a model to show essential characteristics of the structure and interactions present in the substance |
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### ESSENTIAL KNOWLEDGE:

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| SAP-3.D.1 | Metallic bonding can be represented as an array of positive metal ions surrounded by delocalized valence electrons (i.e. a "sea of electrons")  |
| SAP-3.D.2 | Interstitial alloys form between atoms of different radii, where smaller atoms fill the interstitial spaces between the larger atoms (e.g. with steel in which carbon occupies the interstices in iron) |
| SAP-3.D.3 | Substitutional alloys form between atoms of comparable radius, where one atom substitutes for the other in the lattice. (In certain brass alloys, other elements, usually zinc, substitute for copper.) |

| TOPIC 2.5: LEWIS DIAGRAMS |   |
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| ENDURING UNDERSTANDING:   |   |
| SAP-4                     | Molecular compounds are arranged based on Lewis diagrams and Valence Shell Electron Pair Repulsion (VSEPR) theory |
| LEARNING OBJECTIVE:       |   |
| SAP-4.A                   | Represent a molecule with a Lewis diagram   |
| ESSENTIAL KNOWLEDGE:      |   |
| SAP-4.A.1                 | Lewis diagrams can be constructed according to an established set of principles                                   |

| TOPIC 2.6: RESONANCE & FORMAL CHARGE |   |
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| ENDURING UNDERSTANDING:              |   |
| SAP-4                                | Molecular compounds are arranged based on Lewis diagrams and Valence Shell Electron Pair Repulsion (VSEPR) theory.  |
| LEARNING OBJECTIVE:                  |   |
| SAP-4.B                              | Represent a molecule with a Lewis Diagram that accounts for resonance between equivalent structures or that uses formal charge to select between nonequivalent structures   |
| ESSENTIAL KNOWLEDGE:                 |   |
| SPQ-1.A.1                            | In cases where more than one equivalent Lewis structure can be constructed, resonance must be included as a refinement to the Lewis structure. In many such cases, this refinement is needed to provide qualitatively accurate predictions of molecular structure and properties. |
| SAP-4.B.2                            | The octet rule and formal charge can be used as criteria for determining which of several possible valid Lewis Diagrams provides the best model for predicting molecular structure and properties.  |
| SAP-4.B.3                            | As with any model, there are limitations to the use of the Lewis structure model, particularly in cases with an odd number of valence electrons   |
| EQUATION(S):                         |   |
|                                      | $\text{Formal charge} = (\# \text{ of valence } e^-) - (\# \text{ of lone } e^- + \# \text{ bonds connected})$ *NOT on equation sheet   |

| TOPIC 2.7: VSEPR & BOND HYBRIDIZATION |   |
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| ENDURING UNDERSTANDING:               |   |
| SAP-4                                 | Molecular compounds are arranged based on Lewis diagrams and Valence Shell Electron Pair Repulsion (VSEPR) theory.  |
| LEARNING OBJECTIVE:                   |   |
| SAP-4.C                               | Based on the relationship between Lewis diagrams, VSEPR theory, bond orders, and bond polarities: a. Explain Structural properties of molecules. b. Explain electron properties of molecules. |

**ESSENTIAL KNOWLEDGE:**

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| SAP-4.C.1 | VSEPR theory uses the Coulombic repulsion between electrons as a basis for predicting the arrangement of electron pairs around a central atom.  |
| SAP-4.C.2 | Both Lewis diagrams and VSEPR theory must be used for predicting electronic and structural properties of many covalently bonded molecules and polyatomic ions, including the following: <ul style="list-style-type: none"><li>a. Molecular geometry.</li><li>b. Bond angles.</li><li>c. Relative bond energies based on bond order</li><li>d. Relative bond lengths (multiple bonds, effects of atomic radius)</li><li>e. Presence of a dipole moment</li><li>f. Hybridization of valence orbitals of the molecule</li></ul>                                    |
| SAP-4.C.3 | The terms “hybridization” and “hybrid atomic orbital” are used to describe the arrangement of electrons around a central atom. When the central atom is $sp$ hybridized, its ideal bond angles are $180^\circ$ ; for $sp^2$ hybridized atoms the bond angles are $120^\circ$ ; and for $sp^3$ hybridized atoms the bond angles are $109.5^\circ$  |
|           | AN UNDERSTANDING OF THE DERIVATION AND DEPICTION OF HYBRID ORBITALS WILL NOT BE ASSESSED ON THE AP EXAM.<br>Rationale: The course includes the distinction between sigma and pi bonding, the use of VSEPR to explain the shapes of molecules and the $sp$ , $sp^2$ , and $sp^3$ nomenclature. Additional aspects related to hybridization are both controversial and do not substantially enhance understanding of molecular structure.   |
|           | HYBRIDIZATION INVOLVING D ORBITALS WILL NOT BE ASSESSED ON THE AP EXAM. WHEN AN ATOM HAS MORE THAN FOUR PAIRS OF ELECTRONS SURROUNDING THE CENTRAL ATOM, STUDENTS ARE ONLY RESPONSIBLE FOR THE SHAPE OF THE RESULTING MOLECULE.<br>Rationale: Current evidence suggests that main-group hybridization involving d orbitals does not exist, and there is controversy about the need to teach any hybridization. Until agreement is reached in the chemistry community, we will continue to include only $sp$ , $sp^2$ , and $sp^3$ hybridization on the AP Exam. |
| SAP-4.C.4 | Bond formation is associated with overlap between atomic orbitals. In multiple bonds, such overlap leads to the formation of both sigma and pi bonds. The overlap is stronger in sigma than pi bonds, which is reflected in sigma bonds having greater bond energy than pi bonds. The presence of a pi bond also prevents the rotation of the bond and leads to structural isomers.   |
|           | MOLECULAR ORBITAL THEORY IS RECOMMENDED AS A WAY TO PROVIDE DEEPER INSIGHT INTO BONDING. HOWEVER, THE AP EXAM WILL NEITHER EXPLICITLY ASSESS MOLECULAR ORBITAL DIAGRAM, FILLING OF MOLECULAR ORBITALS, NOR THE DISTINCTION BETWEEN BONDING, NONBONDING, AND ANTIBONDING ORBITALS.<br>Rationale: As currently covered in general chemistry college textbooks, molecular orbital theory is limited to homonuclear molecules in the second period.   |