Intermolecular Forces (IMFs) and Johnstone's Triangle ASSR

	Expert (4)	**Proficient (3)**	**Emerging (2)**	**Novice (1)**
A. Macroscopic *Ability to utilize Johnstone's Triangle to predict observable, macroscopic outcomes of intermolecular forces.* ***See questions 3(a), 3(b), and 4.**	Effectively draws macroscopic conclusions from sub-microscopic and symbolic evidence. Utilizes molecular characteristics like predominant IMFs, charge, and size to assess observable outcomes. *For example, in Question 4, a student would connect the predominant IMFs in octanol to its subsequent immiscibility in water. He or she could further examine these macroscopic results from the perspective of the "5-6 Carbon Rule."*	Correctly predicts macroscopic phenomena based on particle-level evidence. Identifies how IMFs will impact overall intermolecular structure and orientation but fails to comprehensively attribute additional molecular characteristics to chemical observations. *For example, in Question 4, a student would identify DCM as immiscible in water due to its violation of the idea of "like dissolves like," but he or she might fail to denote predominant IMFs.*	Possesses a general understanding of macroscopic observations as demonstrated through unidimensional explanations of concepts. Fails to comprehensively apply sub-microscopic molecular characteristics to subsequent macroscopic outcomes. *For example, in Question 3(b), a student would correctly identify the molecule with the higher boiling point, but he or she would explain this concept through only the formation of hydrogen bonds without consideration for electronegativity, atomic size, predominant IMFs, etc.*	Fails to predict the macroscopic implications (i.e. boiling point, freezing point, miscibility, immiscibility, etc.) of sub-microscopic intermolecular interactions. Cannot explain why observable, macroscopic phenomena occur.
B. (Sub)microscopic *Ability to connect intermolecular forces to phenomena on the particle level.* ***See questions 1, 2, and 5.**	Provides both correct identifications of all intermolecular forces and, when prompted, comprehensive explanations as to why given molecules form specific bond types. *For example, in Question 3(b), a student would explore the concept of boiling point based on electronegativity, predominant IMFs, and subsequent influence over bond-dissociation enthalpy.*	Able to identify all intermolecular forces present between given molecules based on their electronegativity, polarity, size, etc, but may fail to consider factors like predominant IMFs. *For example, in Question 2, a student would correctly state that none of the molecular pairings would form hydrogen bonds.*	Demonstrates a fundamental knowledge of intermolecular forces as pertaining to bond types and molecular characteristics. *For example, in Question 1, a student may identify the majority of intermolecular forces between propan-2-one and water while excluding others.*	Fails to justify intermolecular forces through the examination of atoms, molecules, and chemical reactions. Cannot predict molecular interactions based on the properties of given chemical species.

C. <u>Symbolic</u> *Ability to properly represent intermolecular interactions and apply mathematical formulae.* ****See questions 1, 2, and 5.***	Comprehensively represents intermolecular attraction through correct molecular structure, orientation, and formal charge without direct trigger words. When prompted, the student is able to verbally justify their symbolic reasoning. *For example, in Question 5, a student would demonstrate the hydration of NaCl, designated as ionic, with regard to the partial charge of water and its subsequent impact on orientation.*	Consistently denotes proper molecular structure and orientation, but lacks consideration for symbolic representation of characteristics like partial charge based on uneven distribution of electrons. *For example, in Question 5, a student would indicate the formal charges relative to the intramolecular forces of NaCl, but he or she would not recognize the partial charges of H_2O.*	Generally able to represent bond formation, charged species, and molecular structure. Struggles to apply these concepts to subsequent impacts on molecular orientation during the formation of IMFs. *For example, in Question 5, a student would indicate the charged, ionic nature of NaCl. However, they may incorrectly represent the overall process of hydration of NaCl based on improper molecular orientation.*	Lacks a fundamental understanding of symbolic representations of intermolecular forces, molecular structure, and molecular orientation. Fails to properly represent the formation of intermolecular forces.
D. <u>Synthesis</u> *Ability to implement all three parameters of Johnstone's Triangle to application-based problems.* ****See questions 3(a), 3(b), and 5.***	Effectively applies all three dimensions of Johnstone's Triangle to provide a comprehensive analysis of application-based problems. Demonstrates an understanding of the role of sub-microscopic phenomena in instigating macroscopic results, and successfully represents these processes through proper symbolism. *For example, in Question 3(a), a student would explain the concept of density within ice by analyzing and representing hydrogen bond formation through sub-microscopic and symbolic means and, subsequently, relating these concepts to the formation of a crystal lattice observable through the ability of ice to float on water.*	Generally applies all three dimensions of Johnstone's Triangle to a given question. Offers an understanding of sub-microscopic interactions, but does not explore them with full depth in his or her symbolic representations. Overarchingly is able to predict macroscopic outcomes. *For example, in Question 5, a student would accurately depict the process of NaCl hydration through molecular structure and orientation, but they may lack consideration for the role of partial charges in the formation of a hydration sphere. However, they would successfully designate the dissociation of NaCl with proper formal charges.*	Attempts to apply the parameters of Johnstone's Triangle to multidimensional concepts, but struggles to fully define macroscopic observations through symbolic representations of sub-microscopic interactions. *For example, in Question 3(a), a student would relate the density of ice to the presence of hydrogen bonding, but he or she would not apply this to the formation of a crystal lattice.*	Struggles to connect each dimension of Johnstone's Triangle and explore chemical phenomena across observable and non-observable scales. Attempts to address application-based problems with singular dimensions of Johnstone's Triangle.