**AP Chemistry: Des Moines Public Schools**

 **2017-18 CURRICULUM GUIDE SCI505/506 SCI523/524**

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| **AP Chemistry** |
| The AP Chemistry course provides students with a college-level foundation to support future advanced course work in chemistry. Students cultivate their understanding of chemistry through inquiry-based investigations, as they explore topics such as: atomic structure, intermolecular forces and bonding, chemical reactions, kinetics, thermodynamics, and equilibrium. This course requires that 25 percent of the instructional time provides students with opportunities to engage in laboratory investigations. This includes a minimum of 16 hands-on labs, at least six of which are inquiry based.**AP Chemistry** **– Course Content:** **Big Idea 1**: The chemical elements are fundamental building material of matter, and all matter can be understood in terms of arrangement of atoms. These atoms retain their identity in chemical reactions.**Big Idea 2**: Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.**Big Idea 3**: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.**Big Idea 4**: Rates of chemical reactions are determined by details of the molecular collisions.**Big Idea 5**: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.**Big Idea 6**: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.**AP Chemistry – Scientific Practices:**• Use representations and models to communicate scientific phenomena and solve scientific problems • Use mathematics appropriately• Engage in scientific questioning to extend thinking or to guide investigations • Work with scientific explanations and theories• Plan and implement data collection strategies in relation to a particular scientific question • Perform data analysis and evaluation of evidence• Connect and relate knowledge across various scales, concepts, and representations in and across domains.**AP Chemistry** **Exam: Format of Assessment – 3 Hours 15 Minutes****Section I: Multiple Choice | 60 Questions | 90 Minutes | 50% of Exam Score** • Discrete Items and Items in Sets**Section II: Free Response | 7 Questions | 105 Minutes | 50% of Exam Score** • Three long- and four short-answer questions. The seven questions ensure the assessment of the following skills: experimental design, quantitative/qualitative translation, analysis of authentic lab data and observations to identify patterns or explain phenomena, creating or analyzing atomic and molecular views to explain observations, and following a logical/analytical pathway to solve a problem.**Link to DMPS Grading Resources:** <http://grading.dmschools.org> **Link to Course Resources**: <http://science.dmschools.org> **Link to Course Information @ AP Central:** <http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/2119.html> |

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| Semester 1 Topics | College Board Curriculum Framework Alignment |
| General Chemistry, Reactions, & Stoichiometry | Big Idea 1: The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.EUs: 1.A, 1.EBig Idea 3: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.EUs: 3.A, 3.B, 3.C |
| Gas Laws & Enthalpy | Big Idea 2: Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules, and the forces between them.EUs: 2.A, 2.BBig Idea 3: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.EUs: 3.CBig Idea 5: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.EUs: 5.A, 5.B |
| Atomic Structure & Periodicity | Big Idea 1: The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.EUs: 1.B, 1.C, 1.D |
| Bonding | Big Idea 2: Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules, and the forces between them.EUs: 2.A, 2.C, 2.DBig Idea 5: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.EUs: 5.C |
| IMFs & Solutions | Big Idea 2: Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules, and the forces between them.EUs: 2.A, 2.BBig Idea 5: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.EUs: 5.D |

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| Semester 2 Topics | College Board Curriculum Framework Alignment |
| Kinetics | Big Idea 4: Rates of chemical reactions are determined by details of the molecular collisions.EUs: 4.A, 4.B, 4.C, 4.D |
| Equilibrium | Big Idea 6: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.EUs: 6.A, 6.B |
| Acid/Base | Big Idea 3: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.EUs: 3.BBig Idea 6: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.EUs: 6.C |
| Thermo & Electrochemistry | Big Idea 3: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.EUs: 3.CBig Idea 5: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.EUs: 5.EBig Idea 6: Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.EUs: 6.C, 6.D |

**Standards-Referenced Grading Basics**

The teacher designs instructional activities and assessments that grow and measure a student’s skills in the elements identified on our topic scales. Each scale features many such skills and knowledges, also called learning targets. These are noted on the scale below with letters (A, B, C) and occur at Levels 2 and 3 of the scale. In the grade book, a specific learning activity could be marked as being 3A, meaning that the task measured the A item at Level 3.

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| **The Body of Evidence in a Process-Based Course** |
| **Process-Based SRG** *is defined as an SRG course design where the same scale recurs throughout the course, but the level of complexity of text and intricacy of task increase over time.*AP Chemistry cycles students through some topics repeatedly as they progress through the course, with changing content and an increasing complexity of scientific problem-solving, analysis, and expectations throughout. To account for this, process-based courses like this have their evidence considered in a “Sliding Window” approach. When determining the topic score for any given grading topic, *the most recent evidence* determines the topic score. Teacher discretion remains a vital part of this determination, but it is hard to overlook evidence from the most recent (and therefore rigorous) assessments. |





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| General Chemistry, Reactions, and Stoichiometry |

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| **Topic** | **4** | **3** | **2** |
| **General Chemistry, Reactions, & Stoichiometry** | In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the learning goal. | 3A: Justify the observation that the ratio of the masses of the constituent elements in any pure sample of that compound is always identical on the basis of the atomic molecular theory. Use data from mass spectrometry to identify the elements and the masses of specific element. (1.14 and 1.15).3B: Select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures. Select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance. (1.2 and 1.3)3C: Connect the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively. Translate among macroscopic observations of change, chemical equations, and particle views. (1.4 and 3.1)3D: Express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings. Apply conservation of atoms to the rearrangement of atoms in various processes. (1.17, 1.18)3E: Design, and/or interpret data from, an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution. (1.19)3F: Design and/or interpret data from, an experiment that uses titration to determine the concentration of an analyte in a solution. (1.20)3G: Translate an observed chemical change into a balanced chemical equation and justify the choice of equation type (molecular, ionic, or net ionic and/or precipitation, oxidation/reduction, gas evolution and neutralization) in terms of utility for the given circumstances. (3.2)3H: Relate quantities (measured mass of substances, volumes of solutions, or volumes and pressures of gases) to identify stoichiometric relationships for a reaction, including situations involving limiting reactants and situations in which the reaction has not gone to completion. Use stoichiometric calculations to predict the results of performing a reaction in the laboratory and/or to analyze deviations from the expected results. (3.3 and 3.4)3I: Design a plan in order to collect data on the synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions. Use data from synthesis or decomposition of a compound to confirm the conservation of matter and the law of definite proportions (3.5 and 3.6)3J: Identify redox reactions and justify the identification in terms of electron transfer. Design and/or interpret the results of an experiment involving a redox titration (3.8 and 3.9)3K: Evaluate the classification of a process as a physical change, chemical change, or ambiguous change based on both macroscopic observations and the distinction between rearrangement of covalent interactions and noncovalent interactions. (3.10) | 2A: Identify and define atom, ion, isotope, atomic mass, molecule, % composition elements, atomic molecular theory.2A: Determine the number of protons, neutrons and electrons in an atom, ion or isotope of any given element.2A: Estimate the average atomic mass of an element given mass spectrometry data.2B: Identify and define chemical formula, empirical formula, molecular formula.2C: Identify and define moles, volume, reactants, products, density.2D: Identify and define law of conservation of mass.2E: Identify and define: gravimetric analysis, filtration, analyte, precipitate.2F: Identify and define titration, titrant, equivalence point, end point, concentration, molarity, strong electrolyte, weak electrolyte.2G: Identify and define molecular equation, ionic equation, net ionic equation, oxidation/ reduction reactions, neutralization reactions.2G: Use the solubility rules to predict products in a chemical reaction.2H: Identify and define stoichiometry, coefficient, mole ratio, limiting reactant, molar volume, standard temperature and pressure (STP), theoretical yield, percent yield, excess reactant.2I: Identify and define: synthesis (combination) reactions, decomposition reactions, law of definite proportions, law of multiple proportions.2J: Identify and define oxidation, reduction, oxidation numbers, half-reactions.2J: Given a reaction, identify which species is oxidized and which species is reduced using oxidation numbers. 2J: Correctly balance redox reactions in acidic and basic conditions. 2K: Identify and define chemical change, physical change.2K: Identify signs of a chemical change and physical change. |

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| Gas Laws & Enthalpy |

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| **Topic** | **4** | **3** | **2** |
| **Gas Laws & Enthalpy** | In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the learning goal. | 3A: Use KMT and concepts of intermolecular forces to make predictions about the macroscopic properties of gases, including both ideal and nonideal behaviors. Refine representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample. Apply mathematical relationships or estimation to determine macroscopic variables for ideal gases. (2.4, 2.5 and 2.6)3B: Qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions. (2.12)3C: Interpret observations regarding macroscopic energy changes associated with a reaction or process to generate a relevant symbolic and/or graphical representation of the energy changes. (3.11)3D: Relate temperature to motions of particles, either via particulate representations and/or via representations of average kinetic energy and distribution of kinetic energies of the particles, such as plots of the Maxwell-Boltzmann distribution. (5.2)3E: Generate explanations or make predictions about the transfer of thermal energy between systems based on this transfer being due to a kinetic energy transfer between systems arising from molecular collisions. (5.3)3F: Use conservation of energy to relate the magnitudes of energy changes occurring in two or more interacting systems, including identification of the systems, the type (heat vs. work), or the direction of energy flow. Use conservation of energy to relate the magnitudes of the energy changes when two non-reacting substances are mixed or brought into contact with one another. (5.4 and 5.5)3G: Use calculations or estimations to relate energy changes associated with heating/cooling a substance to the heat capacity, relate energy changes associated with a phase transition to the enthalpy of fusion/vaporization, relate energy changes associated with a chemical reaction to the enthalpy of the reaction, and relate energy changes to P [change] V work. (5.6)3H: Design and/or interpret the results of an experiment in which calorimetry is used to determine the change in enthalpy of a chemical process at constant pressure. (5.7)3I: Draw qualitative and quantitative connections between the reaction enthalpy and the energies involved in the breaking and formation of chemical bonds. (5.8) | 2A: Identify and define kinetic molecular theory (KMT), molar volume of a gas, Ideal gas law, Boyle’s Law, Charles’ Law, Avogadro’s Law, Dalton’s Law of Partial pressure, diffusion, effusion, STP (standard temperature and pressure), units of pressure. 2B: Identify and define ideal gas, real gas.2C: Identify and define: system, surroundings, endothermic and exothermic.2D: Identify and define: potential energy, average kinetic energy, Maxwell-Boltzman distribution, potential energy diagram.2E: Identify and define: kinetic energy, thermal energy.2F: Identify and define: law of conservation of energy, work, specific heat and/or capacity. 2F: Calculate the amount of heat transferred between substances (q = mcΔT).2G: Identify and define heat (enthalpy), heat (enthalpy) of fusion, heat (enthalpy) of vaporization, heat (enthalpy) of reaction.2G: Use Hess’s Law to calculate enthalpy of a reaction.2H: Identify and define calorimetry (constant-pressure and constant-volume).2I: Identify and define bond energy, endothermic, exothermic. |

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| Atomic Structure & Periodicity |

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| **Topic** | **4** | **3** | **2** |
| **Atomic Structure & Periodicity** | In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the learning goal. | 3A: Explain the distribution of electrons in an atom or ion based upon data. Analyze data relating to electron energies for patterns and relationships. (1.5 and 1.6)3B: Describe the electronic structure of the atom, using PES data, ionization energy data, and/or Coulomb’s Law to construct explanations of how the energies of electrons within shells in atoms vary. Explain the distribution of electrons using Coulomb’s law to analyze measured energies. (1.7 and 1.8)3C: Predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model. Justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity. Analyze data, based on periodicity and the properties of binary compounds, to identify patterns and generate hypotheses related to the molecular design of compounds for which data is not supplied. (1.9, 1.10 and 1.11)3D: Explain why a given set of data suggests, or does not suggest, the need to refine the atomic model from a classical shell model with the quantum mechanical model. (1.12)3E: Given information about a particular model of the atom, determine if the model is consistent with specified evidence. (1.13)3F: Justify the selection of a particular type of spectroscopy to measure the properties associated with vibrational or electronic motions of molecules. (1.15) | 2A: Identify and define frequency, electromagnetic radiation, wavelength, Planck’s constant, photon, emission spectrum, absorption spectrum.2A: Relate energy to a specific electron transition on within the atom (UV, IR, visible…).2B: Define Coulomb’s Law, photo-electric spectroscopy, core electrons, valence electrons, shielding, ionization energy, binding energy.2C: Identify and define periodicity, effective nuclear charge, period, series, family, groups, atomic radii, ionic radii, electronegativity, electron affinity, metallic character.2C: Write electron configurations.2D: Identify and define classical shell model, Bohr model, quantum mechanical model, quantum numbers.2E: Identify and define Heisenberg’s Uncertainty Principle, Pauli Exclusion Principle, Aufbau Principle.2F: Identify and define molecular rotation, electron transitions, bond vibration (molecular vibration). |

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| Bonding |

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| **Topic** | **4** | **3** | **2** |
| **Bonding** | In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the learning goal. | 3A: Predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views. (2.1)3B: 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. (2.17)3C: Rank and justify the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table. (2.18)3D: Create visual representations of ionic substances that connect the microscopic structure to macroscopic properties, and/or us representations to connect the microscopic structure to macroscopic properties (e.g., boiling point, solubility, hardness, brittleness, low volatility, lack of malleability, ductility, or conductivity). (2.19)3E: 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. (2.20)3F: Draw and use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity. (2.21)3G: Design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid. (2.22)3H: Create a representation of an ionic solid that shows essential characteristics of the structure and interactions present in the substance. Explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level. (2.23 and 2.24)3I: 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. Use the electron sea model of metallic bonding to predict or make claims about the macroscopic properties of metals or alloys. Create a representation of a metallic solid that shows essential of the structure and interactions present in the substance. Explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level. (2.25, 2.26, 2.27 and 2.28) 3J: Create a representation of a covalent solid that shows essential characteristics of the structure and interactions present in the substance. Explain a representation that connects properties of a covalent solid to its structural attributes and to the interactions present at the atomic level. (2.29 and 2.30)3K: Create a representation of a molecular solid that show essential characteristics of the structure and interactions present in the substance. Explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present at the atomic level. (2.31 and 2.32)3L: Create or use graphical representations in order to connect the dependence of potential energy to the distance between atoms and factors, such as bond order and polarity, which influence the interaction strength. (5.1) | 2A: Identify and define ionic compound, covalent compound, metallic compound.2B: Identify and define ionic bonding, covalent bonding, metallic bonding, metals, non-metals, metalloids (semi-conductors).2B: Students can predict, given a formula, the type of compound based on differences in electronegativity. 3C: Identify and define bond polarity (polar covalent, non-polar covalent and ionic bonds), bond dipole, dipole moment.2D: Identify and define: boiling point, solubility, hardness, brittleness, volatility, malleability, ductility and conductivity.2E: Identify and define electron sea model.2F: Identify and define: Lewis structures, VSEPR theory, hybridization, bond angles, electron geometry, molecular geometry (shapes), sigma bond, pi bond, resonance and resonant structures.2F: Assign formal charge.2G: Recognize the properties that can be associated with a particular type of bonding.2H: Identify and define ionic solid, crystalline (lattice) structure, lattice energy.2I: Identify and define alloy, interstitial alloy, substitutional alloy.2J: Identify and define covalent network solid, crystalline solid, amorphous solid.2K: Identify and define molecular solid.2K: Name and draw simple organic molecules.2L: Identify and define bond order, polarity. |

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| IMFs & Solutions |

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| **Topic** | **4** | **3** | **2** |
| **IMFs and Solutions** | In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the learning goal. | 3A: 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. (2.3)3B: Explain how solutes can be separated by chromatography based on intermolecular interactions. (2.7)3C: Design and/or interpret the results of a separation experiment (filtration, paper chromatography, or distillation) in terms of the relative strength of interactions among and between the components. (2.10)3D: 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. (2.11)3E: Describe the relationships between the structural features of polar molecules and the forces of attraction between the particles. (2.13)3F: 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. (2.15)3G: Explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of intermolecular forces. (2.16)3H: Make a claim or prediction regarding relative magnitudes of the forces acting within collections of interacting molecules based on the distribution of electrons within the molecules and the types of intermolecular forces through which the molecules interact. (5.9)3I: Support the claim about whether a process is a chemical or physical change (or both) based on whether the process involves changes in intramolecular versus intermolecular interactions. (5.10)3J: Identify the noncovalent interactions within and between large molecules, and/or connect the shape and function of the large molecule to the presence and magnitude of these interactions. (5.11)3K: Draw and/or interpret representations of solutions that show the interactions between the solute and solvent. (2.8)3L: Create or interpret representations that link the concept of molarity with particle views of solutions. (2.9)3M: 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. (2.14)3N: Design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in a solution. | 2A: Identify and define phases of matter.2A: Recognize heating/cooling curves for pure substances.2B: Identify and define: chromatography, solute, solvent, mobile phase, stationary phase, solvent front, retention factor (Rf).2C: Identify and define intermolecular and intramolecular forces of attraction.2D: Identify and define London Dispersion forces, dipole (permanent and temporary).2E: Identify and define polar molecules, dipole-dipole, ion-dipole, hydrogen bonding.2F: Identify and define solubility.2G: Identify and define phase, vapor pressure, viscosity, surface tension, capillary action, cohesion, adhesion.2H: Identify, given a formula, the types of intermolecular and intramolecular forces in a compound.2I: Identify and define physical change, chemical change.2J: Recognize that the functionality and properties of molecules depends strongly on the shape of the molecule.2K: Identify and define solute, solvent, solute-solute interactions, solvent-solvent interactions, solute-solvent interactions.2L: Identify and define molarity.2L: Calculate concentration.2M: Identify and define Coulomb’s Law.2M: Identify factors that affect solubility.2M: Write net ionic equations.2N: Identify and define Beer’s Law, absorption, transmittance |

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| Kinetics |

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| **Topic** | **4** | **3** | **2** |
| **Kinetics** | 4A: Evaluate alternative explanations, as expressed by reaction mechanisms, to determine which are consistent with data regarding the overall rate of a reaction. (4.7)4B: Connect the half-life of a reaction to the rate constant of a first-order reaction and justify the use of this relation in terms of the reaction being a first-order reaction. (4.3)4D: Use representations of the energy profile for an elementary reaction to make qualitative predictions regarding the relative temperature dependence of the reaction rate. (4.6) | 3A: Design and interpret the results of an experiment regarding the factors (i.e., temperature, concentration, surface area) that may influence the rate of the reaction. (4.1)3B: Analyze concentration vs. time data to determine the rate law for a zeroth, first-, or second-order reaction. (4.2)3C: Connect the rate law for an elementary reaction to the frequency and success of molecular collisions. (4.4)3D: Explain the difference between collisions that convert reactants to products and those that do not in terms of energy distributions and molecular orientation. (4.5)3E: Translate among reaction energy profile representations, particulate representations, and symbolic representations of a chemical reaction occurring in the presence and absence of a catalyst. (4.8)3F: Explain changes in reaction rates arising from the use of acid-base catalysts, surface catalysts, or enzyme catalysts, including selecting appropriate mechanisms with or without the catalyst present. (4.9) | 2A: Identify and define kinetics, reaction rate, reaction mechanism. 2B: Identify and define rate law, differentiated rate laws, integrated rate law, rate constants, zero order, first order and second order mechanisms, half-life.2C: Identify and define reaction mechanisms, intermediates, catalyst, rate-determining step.2D: Identify and define activated complex, endothermic and exothermic diagrams.2E: Identify and define activation energy, reaction profile (energy diagram).2F: Identify and define catalysts and inhibitors. |

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| Equilibrium |

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| **Topic** | **4** | **3** | **2** |
| **Equilibrium** | *In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the learning goal.*4: Use the quadratic equation to solve ICE-box/charts.  | 3A: Given a manipulation of a chemical reaction or set of reactions, determine the effects of that manipulation on Q or K. (6.2)3B: Given a set of initial conditions and the equilibrium constant, K, use the tendency of Q to approach K to predict and justify the prediction as to whether the reaction will proceed toward products or reactants as equilibrium is approached. (6.4)3C: Given a set of initials conditions and the equilibrium constant, K, use stoichiometric relationships and the law of mass action (Q equals K at equilibrium) to determine qualitatively and/or quantitatively the conditions at equilibrium for a system involving a single reversible reaction. (6.6)3D: Use Le Chatelier’s principle to design a set of conditions that will optimize a desired outcome, such as product yield. (6.9) 3E: Connect Le Chatelier’s principle to the comparison of Q to K by explaining the effects of the stress on Q and K. (6.10) | 2A: Identify and define equilibrium, Q, K, law of mass action, equilibrium constant expression, reversible reactions.2A: Determine which chemical species will have very large versus very small concentrations at equilibrium. (6.7) 2B Given data, from which the state of a system at equilibrium can be obtained, calculate the equilibrium constant, K. (6.5) 2C: Given a set of experimental observations, construct an explanation that connects the observations to the reversibility of the underlying chemical reactions or processes. (6.1) 2D: Identify and define Le Chatelier’s principle.2D: Connect kinetics to equilibrium using reasoning about equilibrium, such as Le Chatelier’s principle, to infer the relative rates of the forward and reverse reactions. (6.3)2E: Use Le Chatelier’s principle to predict the direction of the shift resulting from various possible stresses on a system at chemical equilibrium. (6.8) |

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| Acid/Base |

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| **Topic** | **4** | **3** | **2** |
| **Acid/Base** | *In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the learning goal.*4: Predict the solubility of a salt, or rank the solubility of salts, given the relevant Ksp values. 6.214: Interpret data regarding solubility of salts to determine, or rank, the relevant Ksp values. 6.224: Interpret data regarding the relative solubility of salts in terms of factors (common ions, pH) that influence the solubility. 6.23 | 3A: Explain the relative strengths of acids and bases based on molecular structure, interparticle forces, and solution equilibrium. Interpret titration data for monoprotic and polyprotic acids involving titration of a weak or strong acid by a strong base (or a weak or strong base by a strong acid) to determine the concentration of the titrant and the pK, for a weak acid, or the pK, for a weak base. (2.2 and 6.13)3B: Reason, based on the dependence of K on temperature, that neutrality requires [H+] = [OH-] as opposed to requiring pH = 7, including especially the applications to biological systems. (6.14) 3C: Identify a given solution as being the solution of a monoprotic weak acid or base (including salts in which one ion is a weak acid or base), calculate the pH and concentration of all species in the solution, and/or infer the relative strengths of the weak acids or bases from given equilibrium concentrations. (6.15)3D: Given an arbitrary mixture of weak and strong acids and bases, determine which species will react strongly with one another and what species will be present in large concentrations at equilibrium. (6.17)3E: Design a buffer solution with a target pH and buffer capacity by selecting an appropriate conjugate acid-base pair and estimating the concentrations needed to achieve the desired capacity. (6.18) 3F: Relate the predominant form of a chemical species involving a labile proton to the pH of a solution and the pK associated with the labile proton. (6.19)  | 2A: Identify and define: Arrhenius, Bronsted-Lowry, Lewis acids and bases; conjugate acid-base pairs; hydronium ion, hydroxide ion, percent ionization, amphoterism, pH, pOH, Ka, Kb, Kw, Ksp; monoprotic, diprotic, polyprotic, % dissociation, % ionization.2A: Identify a given solution as containing a mixture of strong acids and/or bases and calculate or estimate the pH in the resulting solution. (6.15) 2B: Identify acids and bases on a pH scale. 2B: Generate or use a particulate representation of an acid and a strong base to explain the species that will have large versus small concentrations at equilibrium. 6.112C: Identify and define titration, equivalence point, indicator, monoprotic, diprotic, polyprotic.2C: Distinguish between strong and weak acid solutions with similar values of pH, including the percent ionization of the acids, the concentrations needed to achieve the same pH, and the amount of base needed to reach the equivalence point in a titration. 6.12 2D: Identify and define weak acid, strong acid, weak base, strong acid.2D: Identify and define acid/base indicators.2D: Determine the appropriate indicator for use in a titration2E: Identify and define conjugate acid/base pairs, buffer, buffer capacity.2E: Identify a solution as being a buffer solution and explain the buffer mechanism in terms of the reactions that would occur on addition of acid or base. 2F: Identify and define pKa, Henderson-Hasselbalch equation. |

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| Thermo & Electrochemistry |

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| **Topic** | **4** | **3** | **2** |
| **Thermo & Electro- Chemistry** | *In addition to score 3.0 performance, the student demonstrates in-depth inferences and applications that go beyond the learning goal.* | 3A: Use representations and models to predict the sign and relative magnitude of the entropy change associated with chemical or physical processes. (5.12)3B: Predict whether or not a physical or chemical process is thermodynamically favored by determination of the signs of both Ho and So and calculation or estimation of Go when needed. (5.13)3C: Determine whether a chemical or physical process is thermodynamically favorable by calculating the change in standard Gibbs free energy. (5.14)3D.1: Use Le Chatelier’s principle to make qualitative predictions for systems in which coupled reactions that share a common intermediate drive formation of a product. (5.16)3D.2: Make quantitative predictions for systems involving coupled reactions that share a common intermediate, based on the equilibrium constant for the combined reaction. (5.17)3D.3: Express the equilibrium constant in terms of Go and RT and use this relationship to estimate the magnitude of K and, consequently, the thermodynamic favorability of the process. (6.25)3E: Explain why a thermodynamically favored chemical reaction may not produce large amounts of product or why a thermodynamically unfavored chemical reaction can produce large amounts of product for certain sets of initial conditions. (5.18)3F: Analyze the enthalpic and entropic changes associated with the dissolution of a salt, using particulate level interactions and representations. (6.24)  | 2A: Identify and define entropy, systems, surroundings and universe.2B. Identify and define endothermic, exothermic, enthalpy (H), entropy (S), Gibbs’ Free Energy (G), spontaneity, thermodynamically favored.2C: Calculate $Δ$ G using $Δ$H, temperature (in Kelvin) and $Δ$S to determine spontaneity. $Δ$ G = $Δ$ H - T$Δ$S.2C: Calculate $Δ$ G, $Δ$ H and $Δ$ S of a reaction using $Δ$ = products – reactants.2C: Calculate $Δ$ G using multiple combinations and rearrangements of stepwise equations.2D: Calculate $Δ$G using $Δ$G = -RTlnK2E: Identify conditions that must be considered when enthalpy and entropy and Gibbs’ Free Energy are thermodynamically favorable.2E: Identify conditions that must be considered when enthalpy, entropy and Gibbs Free Energy are not thermodynamically favorable.2F: Identify and define a salt, dissolution, particulate level interactions. |

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| **SRG Scale Score** | **Topic:****AP-Style Assessments** | **AP Exam** **Score Conversion** |
| **4** | In addition to meeting the learning goal, the student demonstrates in-depth inferences and applications that go beyond the goal. | **90-100%** |
| **3.5** | Student’s performance reflects exceptional facility with **some**, but not all Level 4 learning targets. | **80-89%** |
| **3****Learning Goal** | Student’s performance reflects success on **all Level 3** learning targets. | **70-79%** |
| **2.5** | Student’s performance reflects success on **some**, but not all, Level 3 learning targets | **60-69%** |
| **2** | Student’s performance reflects success on **all Level 2** learning targets. | **50-59%** |
| **1.5** | Student’s performance reflects success on **some** but not all Level 2 learning targets | **40-49%** |
| **1** | Student’s performance reflects insufficient progress towards foundational skills and knowledge. | **20-39%** |