**Big Idea 1 - (SPQ) 10 points**

**SPQ-2.A.3** The chemical formula that lists the lowest whole number ratio of atoms of the elements in a compound is the empirical formula.

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**Big Idea 1 - (SPQ) 20 points**

**SPQ-3.C.1** The components of a liquid solution cannot be separated by filtration. They can, however, be separated using processes that take advantage of differences in the intermolecular interactions of the components.

1. Chromatography (paper, thin-layer, and column) separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components of the solution (the mobile phase) and with the surface components of the stationary phase.
2. Distillation separates chemical species by taking advantage of the differential strength of intermolecular interactions between and among the components and the effects these interactions have on the vapor pressures of the components in the mixture

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**Big Idea 1 - (SPQ) 30 points**

**SPQ-4.A.2** Coefficients of balanced chemical equations contain information regarding the

proportionality of the amounts of substances involved in the reaction. These values can be used in chemical calculations involving the mole concept.

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**Big Idea 1 - (SPQ) 40 points**

**SPQ–5.C.1** The solubility of a salt is pH sensitive when one of the constituent ions is a weak acid or base. These effects can be understood qualitatively using Le Châtelier’s principle.

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**Big Idea 1 - (SPQ) 50 points**

**SPQ-1.A.1** One cannot count particles directly while performing laboratory work. Thus, there must be a connection between the masses of substances reacting and the actual number of particles undergoing chemical changes.

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**Big Idea 2 - (SAP) 10 points**

**SAP-1.B.1** The energies of the electrons in a given shell can be measured experimentally with photoelectron spectroscopy (PES). The position of each peak in the PES spectrum is related to the energy required to remove an electron from the corresponding subshell, and the height of each peak is (ideally) proportional to the number of electrons in that subshell.

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**Big Idea 2 - (SAP) 20 points**

**SAP-2.A.2** Trends in atomic properties within the periodic table (periodicity) can be qualitatively understood through the position of the element in the periodic table, Coulomb’s law, the shell model, and the concept of shielding/effective nuclear charge. These properties include:

**a.** Ionization energy **b.** Atomic and ionic radii

1. **c.** Electron affinity **d.** Electronegativity.

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**Big Idea 2 - (SAP) 30 points**

**SAP–8.C.1** The Beer–Lambert law relates the absorption of light by a solution to three variables according to the equation:EQUATION: *A* = ε*bc*.

The molar absorptivity ε describes how intensely a sample of molecules or ions absorbs light of a specific wavelength. The path length *b* and concentration *c* are proportional to the number of absorbing species.

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**Big Idea 2 - (SAP) 40 points**

**SAP-8.A.1** Differences in absorption or emission of photons in different spectral regions are related to the different types of molecular motion or electronic transition:

**a.** Microwave radiation is associated with transitions in molecular rotational levels.

**b.** Infrared radiation is associated with transitions in molecular vibrational levels.

**c.** UV/Visible radiation is associated with transitions in electronic energy levels.

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**Big Idea 2 - (SAP) 50 points**

**SAP-3.D.2** Interstitial alloys form between atoms of different radii, where the smaller atoms fill the interstitial spaces between the larger atoms (e.g., with steel in which carbon occupies the interstices in iron).

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**Big Idea 3 - (TRA) 10 points**

**TRA-1.A.2** A chemical change occurs when substances are transformed into new substances, typically with different compositions. Production of heat or light, formation of a gas, formation of a precipitate, and/or color change provide evidence that a chemical change has occurred.

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**Big Idea 3 - (TRA) 20 points**

**TRA–2.C.1** Balanced chemical equations for redox reactions can be constructed from half- reactions.

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**Big Idea 3 - (TRA) 30 points**

**TRA–3.B.1** Experimental methods can be used to monitor the amounts of reactants and/or products of a reaction and to determine the rate of the reaction.

**TRA–3.B.2** The rate law expresses the rate of a reaction as proportional to the concentration of each reactant raised to a power.

**TRA–3.B.3** The power of each reactant in the rate law is the order of the reaction with respect to that reactant. The sum of the powers of the reactant concentrations in the rate law is the overall order of the reaction.

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**Big Idea 3 - (TRA) 40 points**

**TRA–3.C.5** Half-life is a critical parameter for first order reactions because the half-life is constant and related to the rate constant for the reaction by the equation:EQUATION: *t*½ = 0.693/*k*

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**Big Idea 3 - (TRA) 50 points**

**TRA-8.B.1** A disturbance to a system at equilibrium causes *Q* to differ from *K*, thereby taking the system out of equilibrium. The system responds by bringing *Q* back into agreement with *K*, thereby establishing a new equilibrium state.

**TRA-8.B.2** Some stresses, such as changes in concentration, cause a change in *Q* only. A change in temperature causes a change in *K*. In either case, the concentrations or partial pressures of species redistribute to bring *Q* and *K* back into equality.

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**Big Idea 3 - (ENE) 10 points**

**ENE–6.B.2** The standard cell potential of electrochemical cells can be calculated by identifying the oxidation and reduction half-reactions and their respective standard reduction potentials.

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**Big Idea 3 - (ENE) 20 points**

**ENE–6.C.3** The standard cell potential *E*o corresponds to the standard conditions of *Q* = 1. As the system approaches equilibrium, the magnitude (i.e., absolute value) of the cell potential decreases, reaching zero at equilibrium (when *Q* = *K*). Deviations from standard conditions that take the cell further from equilibrium than *Q* = 1 will increase the magnitude of the cell potential relative to *E*o. Deviations from standard conditions that take the cell closer to equilibrium than *Q* = 1 will decrease the magnitude of the cell potential relative to *E*o. In concentration cells, the direction of spontaneous electron flow can be determined by considering the direction needed to reach equilibrium.

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**Big Idea 3 - (ENE) 30 points**

**ENE-2.D.1** The heating of a cool body by a warmer body is an important form of energy transfer between two systems. Calorimetry experiments are used to measure the transfer of heat. The amount of heat transferred between two bodies may be quantified by the heat transfer equation: EQUATION: q = m x C x T

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**Big Idea 3 - (ENE) 40 points**

**ENE–4.C.6** In general, the temperature conditions for a process to be thermodynamically favored (Δ*G*o < 0) can be predicted from the signs of Δ*H*o and Δ*S*o as shown in the table below:

|  |  |  |  |
| --- | --- | --- | --- |
| Δ*H*o | ΔSo | Symbols | Δ*G*o < 0  favored at: |
| < 0 | > 0 | < > | all *T* |
| > 0 | < 0 | > < | no *T* |
| > 0 | > 0 | > > | high *T* |
| < 0 | < 0 | < < | low *T* |

In cases where Δ*H*o < 0 and Δ*S*o > 0, no calculation of ∆*G*o is necessary to determine that the process is thermodynamically favored (Δ*G*o < 0). In cases where Δ*H*o > 0 and Δ*S*o < 0, no calculation of ∆*G*o is necessary to determine that the process is thermodynamically unfavored (Δ*G*o > 0).

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**Big Idea 3 - (ENE) 50 points**

**ENE–6.D.1** Faraday’s laws can be used to determine the stoichiometry of the redox reaction occurring in an electrochemical cell with respect to the following:

**a.** Number of electrons transferred

**b.** Mass of material deposited on or removed from an electrode

**c.** Current

**d.** Time elapsed

**e.** Charge of ionic species

EQUATION: *I* = *q*/*t*

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**Even More Big Idea 2 - (SAP) 10 points**

**SAP–3.B.3** Coulomb’s law can be used to understand the strength of interactions between cations and anions.

**a.** Because the interaction strength is proportional to the charge on each ion, larger charges lead to stronger interactions.

**b.** Because the interaction strength increases as the distance between the centers of the ions (nuclei) decreases, smaller ions lead to stronger interactions.

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**Even More Big Idea 2 - (SAP) 20 points**

**SAP-7.C.1** The ideal gas law does not explain the actual behavior of real gases. Deviations from the ideal gas law may result from interparticle attractions among gas molecules, particularly at conditions that are close to those resulting in condensation. Deviations may also arise from particle volumes, particularly at extremely high pressures.

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**Even More Big Idea 2 - (SAP) 30 points**

**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.

**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”).

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**Even More Big Idea 2 - (SAP) 40 points**

**SAP–5.A.1** London dispersion forces are a result of the Coulombic interactions between temporary, fluctuating dipoles. They are often the strongest net intermolecular force between large molecules.

**a.** Dispersion forces increase with increasing contact area between molecules and with increasing polarizability of the molecules.

**b.** The polarizability of a molecule increases with an increasing number of electrons in the molecule, and the size of the electron cloud. It is enhanced by the presence of pi bonding.

**c.** “London dispersion forces” should **NOT** be used synonymously with “van der Waals forces."

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**Even More Big Idea 2 - (SAP) 50 points**

**SAP–10.A.1** The protonation state of an acid or base (i.e., the relative concentrations of HA and A–) can be predicted by comparing the pH of a solution to the p*K*a of the acid in that solution. When solution pH < acid p*K*a, the acid form has a higher concentration than the base form. When solution pH > acid p*K*a, the base form has a higher concentration than the acid form.

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