IGC	Learning Outcomes	
1.4	**Recognize the steps of the scientific method.**	
1.1	**Classify matter.**	
1.1		Identify and describe the three states of matter.
1.1		Distinguish between substances and mixtures.
1.1		Identify substances as elements or compounds.
1.1		Identify mixtures as homogeneous or heterogeneous.
1.2	**Identify and provide examples of properties of matter.**	
1.2		Distinguish between physical and chemical changes.
1.2		Identify properties as physical or chemical.
1.2		Give examples of physical and chemical changes and chemical and physical properties.
1.2		Distinguish between intensive and extensive properties.
1.2		Produce examples of intensive and extensive properties.
1.5	**Demonstrate knowledge of units, their abbreviations, and relationships among them.**	
1.5		Identify the SI base units, including the symbol, and the quantity they are used to measure.
1.5		Recognize metric prefixes, their symbol, and their meaning.
1.5		Write relationships between quantities with different metric prefixes..
1.5		Recall the difference between mass and weight
0.2	**Determine when and how to use numbers in scientific notation.**	
0.2		Convert numbers between standard and scientific notations.
0.2		Use numbers in scientific notation in calculations.
1.5	**Describe and use derived units.**	
1.5		Identify the SI-derived unit for volume.
1.5		Give examples of common units of volume.
1.8		Define density.
1.8		Calculate density from given values of mass and volume.
1.9	**Convert temperatures between Celsius and Kelvin.**	
1.9		Identify the common scales used for temperature.
1.9		Relate how the temperature scales compare to each other.
1.6	**Apply rules of significant figures.**	
1.6		Summarize the importance of significant figures.
1.6		Label numbers in a quantity as significant or not.
1.6		Define exact number.
1.6		Classify numbers as exact or not.
1.6		State the rule for determining signifcant figures in addition and subtraction.
1.6		Complete calculations with addition and subtracting using the rules for significant figures.
1.6		State the rule for determining signifcant figures in multiplication and division.
1.6		Complete calculations with multiplication and division using the rules for significant figures.
1.6		Complete calculations that involve both addition/subtraction and multiplication/division.
1.6	**Distinguish between precision and accuracy.**	
1.6		Define precision and accuracy.
1.6		Analyze data to label as precise, accurate, neither, or both.
1.7	**Solve problems using dimensional analysis.**	
1.7		Build a problem solving plan by analyzing what is given in a chemical problem and construct a path to obtain an answer.
1.7		Apply dimensional analysis methods to convert between units in a one step process.
1.7		Apply dimensional analysis in a multi step conversions.
1.7		Apply dimensional analysis involving units raised to a power.

IGC	Learning Outcomes	
2.2-2.3	**Explain atomic theory and how the structure of the atom was determined.**	
2.2		State the law of definite proportions.
2.3		Describe the statements of Dalton's Atomic Theory.
2.3		Explain which statements of Dalton's theory are no longer accurate and why.
2.2		State the law of conservation of mass.
2.2		Perform simple problems using the law of conservation of mass.
2.3		Explain how the cathode ray tube lead to the understanding of electrons.
2.3		Describe the mass to charge ratio of the electron.
2.3		Explain the measurement of the electron's charge using the Millikan's Oil Drop Experiment.
2.3		Describe Rutherford's gold foil experiment.
2.3		Interpret the Rutherford's gold foil experiment results that lead to the conclusion that the nucleus exists as a small dense core.
2.3		Explain how the mass deficit lead to the proposal that neutrons exist.
2.4	**Describe the structure of an atom and its components.**	
2.4		Define the atomic mass unit in terms of the mass of a carbon atom.
2.4		Compare the relative mass and charge of the subatomic particles.
2.4		Define atomic number.
2.4		Describe the relationship between the atomic number and the number of protons.
2.4		Determine the atomic number for an element using the periodic table.
2.4	**Compare properties of isotopes.**	
2.4		Define isotope.
2.4		Define mass number.
2.4		Symbolize isotopes using chemical symbols, mass number, and atomic number.
2.4		Determine the number of protons, neutrons, and electrons in an atom given the isotopic symbol.
2.4		Construct the isotope symbol for atoms.
2.5	**Use isotopic masses and natural abundance in calculations.**	
2.5		Define natural abundance.
2.5		Locate the average atomic mass of an element on the periodic table.
2.5		Calculate the average atomic mass of an element given abundance and isotope masses.
2.5		Calculate the relative abundance of isotopes of an element.
2.5		Recognize the difference among the terms "atomic number", "mass number", and "atomic mass".
20.1	**Describe types of radioactive decay.**	
20.1		Identify alpha, beta, and gamma particles.
2.4	**Describe characteristics of cations and anions.**	
2.4		Define cation and anion.
2.4		Determine the number of protons and electrons in an ion.
2.4		Determine the charge of an ion given the number of protons and electrons.
2.4		Construct the isotope symbol for ions.
3.1	**Express chemical compounds using empirical, molecular and structural formulas.**	
3.1	**Differentiate between atomic and molecular elements.**	
2.6	**Describe features of the periodic table based on its layout.**	
2.1		Memorize the names and symbols of elements indicated on "Concepts to Memorize" sheet.
2.6		Recall that periods are horizontal rows in the periodic table.
2.6		Recall that groups are vertical columns in the periodic table.
2.6		Use the periodic table to classify elements as main-group elements or transition elements.
2.6		Locate noble gases, alkali metals, alkaline earth metals and halogens on the periodic table.

IGC	Learning Outcomes	
2.6		Use the periodic table to classify elements as metal, nonmetal, metalloid, transition metal, lanthanide or actinide.
3.1	**Distinguish between molecular and ionic compounds.**	
3.1		Recall that ionic bonds generally occur between metals and nonmetal.
3.1		Recall that covalent bonds general occur between nonmetals.
3.3	**Identify characteristics of monatomic and polyatomic ions.**	
3.3		Use the periodic table to predict the common charge of main group elements.
3.3		Memorize polyatomic ions and charges.
3.3		Recall the formula of the hydronium ion (H3O+, also shown as H+).
3.3, 3.4	**Write formulas and names for compounds.**	
3.3		Construct chemical formulas for ionic compounds from the known charges of the ions.
3.3		Construct chemical formulas for ionic compounds from the name of the compound.
3.4		Name ionic compounds from the chemical formula.
3.2		Name covalent compounds from the chemical formula.
3.2		Construct a chemical formula of covalent compounds given the name.
3.5		Name binary acids and provide formula from the name.
3.5		Distinguish between binary acids and oxyacids (also called oxoacids).
3.7	**Explain the meaning of mole and its relationship to mass of an atom.**	
3.7		Define mole.
3.7		Recall the magnitude of a mole is equal to Avogadro's number.
3.7		Convert between the moles and atoms of an element.
3.8		Convert between grams and moles of an element.
3.8	**Calculate formula and molar masses and relate to moles.**	
3.1		Recognize that formula units are the simplest unit for an ionic compound.
3.8		Use atomic masses of elements in a compound to calculate the formula mass (amu) and molar mass (g/mol) of the compound.
3.8		Convert between moles and mass of a compound.
3.8		Convert between moles and the number of molecules or formula units of a compound.
3.9	**Use percent by mass of a compound in calculations.**	
3.9		Calculate the percent by mass of an element in a compound.
3.9		Use percent by mass as a conversion factor to calculate mass of an element in a given quantity of a compound.
3.9		Use subscripts in a chemical formula as a conversion factor between molecules or formula units and atoms or ions.
3.10		Analyze the percent by mass of a compound and determine the empirical formula.
3.11		Determine the molecular formula if given an empirical formula and its molar mass.
4.3, 5.5	**Describe solutions qualitatively and quantitatively.**	
4.3		Define terms associated with aqueous solutions. (Solvent, solute, concentration, concentrated, dilute)
5.5		Define molarity.
5.5		Calculate molarity of a solution given moles or mass of solute and volume of solution.
5.5		Use molarity in calculations to find moles of solute, volume of solution, or mass of solute.
5.5	**Use the dilution formula in calculations.**	
5.5		State the dilution formula and identify all variables.
5.5		Use dilution formula to calculate unknown values when a solution is diluted.
5.5		Distinguish between dilute and concentrated solutions.
4.1	**Write and balance a chemical equation.**	
4.4	**Classify an ionic compound as soluble or insoluble using the solubility rules.**	
4.4		Summarize the difference between soluble and insoluble compounds.
4.4		Memorize the solublity rules.

IGC	Learning Outcomes	
4.3	**Summarize characteristics of strong, weak, and non-electrolytes.**	
4.3		Describe how an ionic compound dissolves in water.
4.3		Distinguish between strong electrolyte, weak electrolytes and nonelectrolyte solutions on the macroscopic level, that is how they behave.
4.3		Distinguish among strong electrolyte, weak electrolyte, and nonelectrolyte solutions on the molecular level, that is, what makes them.
4.3		Identify substances as strong, weak, or non-electrolytes.
4.4	**Describe precipitation reactions.**	
4.4		Define precipitation.
4.4		Predict the precipitate that may form when aqueous solutions of ionic compounds are mixed.
4.4		Write complete ionic equations.
4.4		Write net ionic equations.
4.3	**Identify strong acids and bases.**	
4.3		List the names and formulas of the six strong acids.
4.3		Write the reactions for the ionization of a strong acid or base in water.
4.3		Recognize that hydroxides of Group I metals, calcium, strontium, and barium are strong bases.
4.5	**Describe acid-base reactions.**	
4.3		Describe Arrhenius acids and bases.
4.5		Identify the products of reactions between acids and bases.
4.5		Write balanced neutralization reactions.
5.9		Define the common terms associated with a titration: titrant, equivalence point, indicator.
4.6	**Explain properties of oxidation-reduction reactions.**	
4.6		State rules for calculation of oxidation numbers.
4.6		Apply the rules to calculate the oxidation number of all atoms in a compound, for free elements, and for ions.
4.6		Recognize a redox reaction.
4.6		Define oxidation and reduction in terms of the loss or gain of electrons.
4.6		Identify what substance is oxidized and what substance is reduced.
4.6		Identify the oxidizing agent and reducing agent.
4.6		Balance redox reactions given the number of electrons in each half-reaction.
5.1-5.5	**Calculate the quantitative relationships among substances in a reaction.**	
5.1		Determine mole-to-mole ratios between substances based on a balanced chemical equation.
5.2		Given the amount of one substance (in moles or mass) and a chemical equation, calculate the amount of another substance (in moles or mass)
5.3		Identify limiting reagent problems.
5.3		Determine substances that are the limiting and excess reagents.
5.4		Calculate theoretical yield.
5.3		Calculate the amount of remaining excess reactant.
5.4		Distinguish between actual and theoretical yields.
5.4		Calculate percent yield
5.4		Use percent yield to calculate actual or theoretical yields.
5.5		Use molarity to solve stoichiometry and limiting reagent problems.
5.5		Recognize that the dilution formula is used for dilutions only and NOT for stoichiometry problems.
5.5		Distinguish between a dilution and a reaction.
5.5		Calculate quantities of reactants in a titration.
6.1-6.2	**Define terms associated with the energy of a reaction.**	
6.2		Distinguish between energy and work.
6.1		Define kinetic energy, potential energy, and thermal energy.
6.2		State the law of conservation of energy.

IGC	**Learning Outcomes**	
6.2		Define heat and work.
6.2		Define energy, system and surrounding.
6.1		Distinguish among kinetic, thermal, potential, and chemical energies.
6.1		Convert between energy units.
6.3-6.4	**Describe the basic principles of thermodynamics.**	
6.4		Explain connections between change in internal energy and change in enthalpy.
6.3		Define state functions.
6.2, 6.4	**Calcuate the change in internal energy.**	
6.2		Define internal energy.
6.2		Recall the sign convention of heat.
6.2		Recall the sign convention of work.
6.2		Explain how the sign of ΔU (internal energy) indicates the flow of energy.
6.4		Calculate work.
6.4		State the equation for the relationship between pressure, volume, and work and identify all variables.
6.4		Determine PV work.
6.5	**Distinguish between specific heat and heat capacity.**	
6.5		Define specific heat and heat capacity.
6.5		State the equation relating heat, mass, specific heat, and temperature and identify all variables.
6.5		Use the equation relating heat, mass, specific heat, and temperature in calculations.
6.5		State the equation relating heat, heat capacity, and temperature and identify all variables.
6.5		Use the equation relating heat, heat capacity, and temperature and define all variables.
6.6	**Use the principles of calorimetry to measure heat transfer between objects.**	
6.6		Recall how thermal energy is transfered between the system and surrounding.
6.6		Complete calculations for the transfer of heat between two substances.
6.6		Define calorimetry.
6.6		Recognize the components of a constant pressure calorimeter.
6.4	**Distinguish between properties of endothermic and exothermic processes.**	
6.4		Define enthalpy.
6.4		Define endothermic and exothermic.
6.7		Sketch energy diagram for endothermic and exothermic processes.
6.4		Explain the sign convention used for endothermic and exothermic processes.
6.7, 6.8	**Use enthalpy in calculations.**	
6.7		Use thermochemical equations to convert between quantity of a substance and heat.
6.7		Use measured values from a constant pressure calorimeter to calculate unknown values such as enthalpy change or heat capacity.
6.7		Describe the relationships between the chemical equation and ΔH of the reaction as the reaction is modified.
6.7		Explain the concept of Hess's Law.
6.7		Use Hess's Laws to determine the enthalpy change of a reaction.
6.8		Define standard state for gas, liquid, solid, or solution.
6.8		Define enthalpy of formation.
6.8		Express the reaction represented by a given enthalpy of formation.
6.8		Use values of enthalpy of formation to determine the enthalpy change for a given reaction.
6.8		Determine the enthalpy of formation for a substance given the enthalpy change of a reaction.
8.1	**Describe characteristics of electromagnetic radiation.**	

IGC	Learning Outcomes	
8.1		Define electromagnetic radiation.
8.1		Distinguish among amplitude, wavelength, and frequency.
8.1		Describe the general trends in the electromagnetic spectrum (frequency, wavelength, and energy).
8.1		State the colors in the visible region along with energy, frequency, and wavelength trends.
8.1		Recall that light in the visible region has wavelengths from 400-750 nm.
8.1		Classify regions of the spectrum as higher or lower in energy than visible region.
8.1		Distinguish between constructive and destructive interference.
8.1		Describe diffraction in waves.
8.1	**Complete calculations related to electromagnetic radiation.**	
8.1		Recognize that c is the speed of light.
8.1		Calculate among values of energy, frequency, and wavelength.
8.1		Relate energy to the number of photons.
8.1	**Describe the photoelectric effect.**	
8.1		Explain the concept of threshold frequency and how it affects the ejection of electrons.
8.1		Explain how intensity and wavelength affect the electrons emitted (or not) in the photoelectric effect.
8.1		Recognize that the photoelectric effect led to the understanding of the particle nature (photons) of light.
8.1		Calculate energy/frequency/wavelength associated with photoelectric effect.
8.1	**Describe the emission of electromagnetic radiation.**	
8.2		Distinguish between emission line spectra and the continuous spectrum of white light.
8.2		Relate the Bohr model to the emisson spectrum of hydrogen.
8.2		Relate the energy of the photon emitted or absorbed to the energy change of the electron.
8.2		Complete calculations for hydrogen atom using the Rydberg equation.
8.1	**Recognize the wave-particle duality of matter.**	
8.1		Explain how the interference pattern from a beam of electrons supports that electrons behave as waves.
8.3		State the deBroglie formula and identify all variables.
8.3		Use the deBroglie formula in calculations.
8.3	**Describe Heisenberg's uncertainty principle**	
8.3		Explain the inversely proportional relationship between the uncertainty of position and the uncertainty of the velocity.
8.6	**Summarize the meaning and relevance of the quantum numbers.**	
8.6		Identify each of the four quantum numbers.
8.6		Define the meaning of each of the quantum numbers.
8.6		Give the possible values for each quantum number.
8.6		Identify sets of allowed/disallowed quantum numbers.
8.6		Pair angular momentum quantum numbers with the shape of orbitals.
8.6		Describe the shape of each orbital type (s, p, d, and f).
8.6		Describe the relationship between nodes and orbitals.
8.6		Given select values of quantum numbers, determine the number of orbitals or electrons with those values.
8.4		Define degenerate.
8.4		Rank the energy level of sublevels within a principal level (s, p, d, f)
8.6		Define the Pauli exclusion principle.
8.6		Explain how the Pauli exclusion principle affects the values of quantum numbers.
8.5	**Write the electron configuration of an element.**	
8.4		Describe Hund's rule and its effect on electron arrangement.
8.4		Define aufbau principle.

IGC	Learning Outcomes	
8.4		Draw orbital diagrams of neutral atoms.
8.5		Write electron configuration of neutral atoms.
8.5, 9.1		Distinguish between valence and core electrons.
9.1		Determine the number of valence electrons in an atom.
8.5		Write electron configurations for transition metals (including exceptions for d4 and d9 elements).
8.4		Define diamagnetic and paramagnetic.
8.4		Determine if an element is diamagnetic or paramagnetic.
8.5	**Identify patterns in electron configurations based on arrangement in the periodic table.**	
8.5		Relate the electron configuration of a group of elements to their arrangement in the periodic table.
8.6		Write the quantum numbers for any electron in an atom based on its orbital diagram or electron configuration.
9.2	**Summarize periodic trends for effective nuclear charge and atomic radius.**	
9.2		Describe shielding of electrons by other electrons.
		Define effective nuclear charge.
9.2		Identify the trends in effective nuclear charge.
9.2		Define atomic radius for atoms.
9.2		Identify the trends in atomic radii.
9.2		Explain the trends in atomic radii and effective nuclear charge.
9.2		Estimate the value of the effective nuclear charge of an electron.
9.2	**Summarize periodic trends of ions and isoelectronic series.**	
9.2		Describe the size of an ion relative to its parent atom.
8.6		Define isoelectronic.
8.6		Identify isoelectronic species.
9.2		Rank isoelectronic species according to size.
9.3	**Summarize perioidic trends for ionization energy.**	
9.3		Define ionization energy.
9.3		Write the reaction that represents the first ionization of an atom.
9.3		Describe trends in first ionization energies.
9.3		Describe trends in second and successive ionization energies.
9.3		Identify element based on sequence of ionization energies.
9.3	**Summarize periodic trends for electron affinity.**	
9.3		Define electron affinity.
9.3		Write the reaction that represents the process associated with the first electron affinity.
9.3		Describe "trends" in electron affinity values.
2.3	**Summarize periodic trends for metallic character.**	
2.6		Define metallic character.
2.6		Describe trends in metallic character.
9.4	**Describe formation of ionic compounds.**	
8.6		Write the electron configuration of cations and anions.
9.4, 10.1, 12.6		Distinguish among ionic, covalent, and metallic bonding.
10.3, 10.5	**Use electronegativity to describe properties of covalent bonds.**	
10.3		Explain electronegativity of an element.
10.3		Describe the trends for electronegativity of elements.
10.5		Relate electronegativity to bond polarity.
10.5		Categorize bonds as ionic, polar, or nonpolar.
10.2-10.4	**Draw Lewis structures of compounds.**	
10.1		Draw Lewis symbols of atoms.
10.2		Draw the Lewis structure of a binary ionic compound.
10.2		Describe how electrons form single, double, or triple bonds.
10.2		Draw Lewis structures of molecules and polyatomic ions.

IGC	Learning Outcomes	
10.4		Name the three types of exceptions to the octet rule.
10.4		Draw Lewis structures of compounds that violate the octet rule.
10.3		Define resonance.
10.3		Identify when resonance is possible in a molecule or ion.
10.3		Define resonance hybrid.
10.3		Calculate formal charge of atoms in a molecule or ion.
10.3		Explain the significance of formal charge values.
10.3		Apply a formal charge explanation to determine the best Lewis structure for a compound.
10.6	**Characterize the strength of covalent bonds.**	
10.6		Define bond energy.
10.6		Discuss bond strength as a function of bond length.
10.6		Describe how the bond length changes from single to double to triple bond between atoms.
10.6		Calculate the unknown given bond energy values and/or the enthalpy of a reaction.
9.5	**Characterize the strength of ionic bonds.**	
9.5		Define lattice energy.
9.5		Describe the lattice energy trends related to ion size and charge.
9.5		Describe the steps of the Born-Haber cycle.
9.5		Write the equation for the energies associated with the Born-Haber cycle.
9.5		Calculate lattice energy using the Born-Haber cycle.
11.1	**Describe the three-dimensional shape of a molecule.**	
11.1		Describe valence shell electron pair repulsion (VSEPR) theory.
11.1		Recognize the electron group geometry of molecules.
11.1		Determine the electron group geometry based on the Lewis structure.
11.1		Determine the effect of lone pairs on the geometry of a molecule.
11.1		Name the possible electron group and molecular geometries.
11.1		Identify the electron group geometry and molecular geometry based on the number of bonding and non-bonding groups in the Lewis structure of a molecule or ion.
11.1		Determine the geometries for molecules with more than one central atom.
11.2	**Determine the polarity of a molecule.**	
11.2		Define dipole moment.
11.2		Recognize that polarity affects solubility of molecular compounds (like dissolves like).
11.3	**Describe valence bond theory in terms of orbital overlap to form bonds.**	
11.3	**Describe hybridization of atomic orbitals.**	
11.3		Pair hybridization schemes with the appropriate electron group geometry.
11.3		Compare the energy of the hybrid orbitals to the atomic orbitals from which they were formed.
11.3		Use the overlap of atomic and hybrid orbitals to explain the bonding in a molecule.
11.3		Define sigma and pi bonding according to the location of the electron density with respect to the nuclei of the atoms in the bond.
11.3		List the types of orbitals which form a sigma bond.
11.3		List the types of orbitals which form a pi bond.
11.3		Classify covalent bonds in a molecule or polyatomic ion as sigma or pi.
11.5	**Describe molecular orbital theory for homonuclear diatomic elements or ions.**	
11.5		Distinguish between bonding and antibonding orbitals.
11.5		Draw the MO diagram for homonuclear diatomics.
11.5		Calculate the bond order based on the MO diagram.
11.5		Relate the bond order to the stability of the bond.
11.5		Determine if a diatomic molecule is diamagnetic or paramagnetic based on the MO diagram.
11.5		Relate the concept of delocalized molecular orbitals to the concept of resonance.

IGC	Learning Outcomes	
11.5		Describe the linear combination of atomic orbitals that form bonding and anti-bonding molecular orbitals.
11.5		Describe how destructive and constructive interference affects molecular orbitals.
11.5		Label the components of the molecular orbital diagram of H_2.
7.1	**Identify and use units of pressure.**	
7.1		Memorize the common pressure units and the conversion factors between pressure units.
7.1		Convert between pressure units.
	Describe the simple gas laws qualitatively and quantitatively.	
7.2		Calculate values of pressure or volume using Boyle's Law.
7.3		Calculate values of volume or temperature using Charles' Law.
7.5		Calculate values of moles or volume using Avogadro's Law.
7.6		Use the ideal gas law equation to derive the simple gas laws.
	Use the ideal gas law in calculations.	
7.6		Calculate values of P, V, n or T if given the other three using the ideal gas law.
7.4		Complete calculations with the combined gas law
7.1		Define standard temperature and pressure (STP).
7.8		Combine density calculations and molar mass calculations with the ideal gas law to determine the density or molar mass of a gas.
	Define and derive molar volume.	
7.1		Use molar volume at STP as a conversion factor.
7.9		Use Avogadro's Law to do stoichiometry conversions in reactions involving gases.
7.7	**Use Dalton's Law of partial pressure to calculate total pressure of a gas if given individual gas pressures and vice versa.**	
7.7		State Dalton's law of partial pressure and define all variables.
7.7		Define mole fraction
7.7		Calculate the mole fraction of a substance in a mixture.
7.7		Calculate partial pressure in terms of mole fraction and total pressure.
7.11	**Describe the processes of diffusion and effusion of gases.**	
7.11		Define diffusion and effusion.
7.11		Compare relative speeds of molecules and rates of effusion as a function of molar mass.
7.10	**Use the kinetic molecular theory of a gas to explain the simple gas laws on the molecular level.**	
7.10		Retell the statements of the Kinetic Molecular Theory of a Gas.
7.10		Recognize the equation for kinetic energy ($1/2\ mv^2$) and identify all variables.
7.11		Describe the qualitative relationship between variables in the rms velocity equation.
7.11		Describe the qualitative relationship between molar mass and average kinetic energy of gases.
7.11		Describe the qualitative relationship between temperature and average kinetic energy of gases.
7.11		Desribe the relationship between rate of effusion and molar mass as explained by Graham's law.
7.12	**Distinguish between real and ideal gases.**	
7.12		Describe the conditions of pressure and temperature that distinguish a real gas from an ideal gas.
7.12		Explain qualitatively how the terms of the van der Waals equation account for the properties of a real gas.