Plymouth Public Schools' Science and Technology/Engineering Program
High School Chemistry Learning Standards

STE0032 Chemistry Honors
STE0033 Chemistry College Prep 1

An Introduction to the Massachusetts Department of Elementary and Secondary Education Science and Technology/Engineering Curriculum Framework

Effective teaching and learning in science fosters engagement and has rigor, relevance, and coherence embedded within. It couples practice with content to give the context for performance. A program with these components encourages students to analyze and explain phenomena and experience; engages with practices to build, use, and apply knowledge; and builds a storyline over time and among disciplines. The state standards that form this program are outcomes that reflect what a student should know and be able to do as a result of instruction. Science and engineering practices, which are included in these standards, are not teaching strategies; they are important learning goals and skills to be learned, also as a result of instruction. The standards listed below are not intended to represent an exhaustive list of all that could be included in our district's science program, nor should this list prevent students from going beyond the standards where appropriate. (Excerpts from Curriculum Framework)

Disciplinary Core Ideas – Chemistry

Introductory chemistry standards build from the middle school transition of macroscopic phenomena to molecular level models. This transition establishes the foundation for high school students in chemistry to consider how structure and composition at sub-atomic scales explain structure-property relationships and influence energy transformations and dissipation of energy during chemical and physical changes. These standards emphasize science and engineering practices related to design and evaluation as well as investigation and modeling. More specifically, students are challenged to apply chemistry knowledge to designing ways to control the extent of chemical reactions for practical purposes, analyze unknown samples to determine identities and concentrations of possible pollutants, and evaluate the consequences of using different materials for household items. Students are expected to apply mathematical reasoning when considering conservation of matter in chemical reactions and in comparing strength of acid-base solutions. Disciplinary core ideas are related to matter and its interactions, motion and stability/force and interactions, and energy. (Excerpts from Curriculum Framework)

PS1. Matter and Its Interactions

HS-PS1-1. Use the periodic table as a model to predict the relative properties of main group elements, including ionization energy and relative sizes of atoms and ions, based on the patterns of electrons in the outermost energy level of each element. Use the patterns of valence electron configurations, core charge, and Coulomb's law to explain and predict general trends in ionization energies, relative sizes of atoms and ions, and reactivity of pure elements.

Clarification Statement:
Size of ions should be relevant only for predicting strength of ionic bonding.

State Assessment Boundary:
State assessment will be limited to main group (s and p block) elements.

HS-PS1-2. Use the periodic table model to predict and design simple reactions that result in two main classes of binary compounds, ionic and molecular. Develop an explanation based on given observational data and the electronegativity model about the relative strengths of ionic or covalent bonds.

Clarification Statements:

1. Simple reactions include synthesis (combination), decomposition, single displacement, double displacement, and combustion.
2. Predictions of reactants and products can be represented using Lewis dot structures, chemical formulas, or physical models.
3. Observational data include that binary ionic substances (i.e., substances that have ionic bonds), when pure, are crystalline salts at room temperature (common examples include NaCl, KI, Fe_2O_3); and substances that are liquids and gases at room temperature are usually made of molecules that have covalent bonds (common examples include CO_2, N_2, CH_4, H_2O, C_8H_{18}).

HS-PS1-3. Cite evidence to relate physical properties of substances at the bulk scale to spatial arrangements, movement, and strength of electrostatic forces among ions, small molecules, or regions of large molecules in the substances. Make arguments to account for how compositional and structural differences in molecules result in different types of intermolecular or intramolecular interactions.

Clarification Statements:

1. Substances include both pure substances in solid, liquid, gas, and networked forms (such as graphite).
2. Examples of bulk properties of substances to compare include melting point and boiling point, density, and vapor pressure.

3. Types of intermolecular interactions include dipole-dipole (including hydrogen bonding), ion-dipole, and dispersion forces.

State Assessment Boundary:
Calculations of vapor pressure by Raoult's law, properties of heterogeneous mixtures, and names and bonding angles in molecular geometries are not expected in state assessment.

HS-PS1-4. Develop a model to illustrate the energy transferred during an exothermic or endothermic chemical reaction based on the bond energy difference between bonds broken (absorption of energy) and bonds formed (release of energy).

Clarification Statement:
Examples of models may include molecular-level drawings and diagrams of reactions or graphs showing the relative energies of reactants and products.

State Assessment Boundary:
Calculations using Hess's law are not expected in state assessment.

HS-PS1-5. Construct an explanation based on kinetic molecular theory for why varying conditions influence the rate of a chemical reaction or a dissolving process. Design and test ways to slow down or accelerate rates of processes (chemical reactions or dissolving) by altering various conditions.

Clarification Statements:
1. Explanations should be based on three variables in collision theory:
    a. quantity of collisions per unit time,
    b. molecular orientation on collision, and
    c. energy input needed to induce atomic rearrangements.
2. Conditions that affect these three variables include temperature, pressure, concentrations of reactants, agitation, particle size, surface area, and addition of a catalyst.

State Assessment Boundary:
State assessment will be limited to simple reactions in which there are only two reactants and to specifying the change in only one variable at a time.

HS-PS1-7. Use mathematical representations and provide experimental evidence to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. Use the mole concept and proportional relationships to evaluate the quantities (masses or moles) of specific reactants needed in order to obtain a specific amount of product.

Clarification Statements:

1. Mathematical representations include balanced chemical equations that represent the laws of conservation of mass and constant composition (definite proportions), mass-to- mass stoichiometry, and calculations of percent yield.
2. Evaluations may involve mass-to-mass stoichiometry and atom economy comparisons, but only for single-step reactions that do not involve complexes.

HS-PS1-9(MA). Relate the strength of an aqueous acidic or basic solution to the extent of an acid or base reacting with water as measured by the hydronium ion concentration (pH) of the solution. Make arguments about the relative strengths of two acids or bases with similar structure and composition.

Clarification Statements:

1. Reactions are limited to Arrhenius and Bronsted-Lowry acid-base reaction patterns with monoprotic acids.
2. Comparisons of relative strengths of aqueous acid or base solutions made from similar acid or base substances is limited to arguments based on periodic properties of elements, the electronegativity model of electron distribution, empirical dipole moments, and molecular geometry. Acid or base strength comparisons are limited to homologous series and should include dilution and evaporation of water.

HS-PS1-11(MA). Design strategies to identify and separate the components of a mixture based on relevant chemical and physical properties.

Clarification Statements:

1. Emphasis is on compositional and structural features of components of the mixture.
2. Strategies can include chromatography, distillation, centrifuging, and precipitation reactions.
3. Relevant chemical and physical properties can include melting point, boiling point, conductivity, and density.

PS2. Motion and Stability: Forces and Interactions

HS-PS2-7(MA). Construct a model to explain how ions dissolve in polar solvents (particularly water). Analyze and compare solubility and conductivity data to determine the extent to which different ionic species dissolve.

Clarification Statement:

Data for comparison should include different concentrations of solutions with the same ionic species, and similar ionic species dissolved in the same amount of water.

HS-PS2-8(MA). Use kinetic molecular theory to compare the strengths of electrostatic forces and the prevalence of interactions that occur between molecules in solids, liquids, and gases. Use the combined gas law to determine changes in pressure, volume, and temperature in gases.

PS3. Energy

HS-PS3- 4b. Provide evidence from informational text or available data to illustrate that the transfer of energy during a chemical reaction in a closed system involves changes in energy dispersal (enthalpy change) and heat content (entropy change) while assuming the overall energy in the system is conserved.

State Assessment Boundary:
Calculations involving Gibbs free energy are not expected in state assessment.