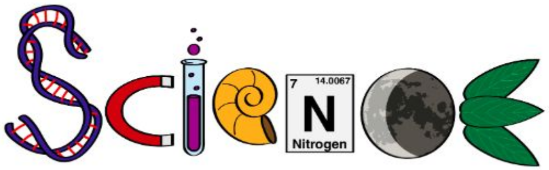

K-12 SCIENCE EDUCATION VISION

A K-12 Dublin City Schools science education engages *all students* in critical thinking and problem solving as they experience science and engineering. We believe that students can become scientifically literate citizens equipped with the knowledge and skills demanded by the ever-changing future, whether in the workforce or higher education.

We believe in developing our learners through high quality experiences that include:
- A challenging, collaborative and inquiry based environment.
- Opportunities to solve and investigate real-world problems that require critical and global thinking.
- Opportunities for students to build an identity as a scientist, able to interpret the natural world, participate productively in scientific practices and contribute to society in meaningful ways.
- Opportunities to research, generate and evaluate evidence and explanations that uphold or refute scientific data.

We believe these learning experiences will grow independent, confident students who will become creative, innovative adults that are capable of using informed scientific judgement to improve their world.

Instructional Agreements for Science Learning within the Dublin City Schools

1. Learning goals will be communicated to guide students through the expectations of science learning using a variety of instructional techniques and technology integration.
2. Teachers will ensure a safe, challenging learning environment focused on inquiry and science exploration.
3. Teachers will provide support to students as they learn to frame questions, assess and analyze data, and create and critique explanations – all important components of scientific and engineering practices.
4. Content standards will be learned in partnership with Ohio’s Cognitive Demands for Science, Science and Engineering Practices and Nature of Science practices.

<table>
<tr><th colspan="2">Nature of Science</th></tr>
<tr><td colspan="2">One goal of science education is to help students become scientifically literate citizens able to use science as a way of knowing about the natural and material world. All students should have sufficient understanding of scientific knowledge and scientific processes to enable them to distinguish what is science from what is not science and to make informed decisions about career choices, health maintenance, quality of life, community and other decisions that impact both themselves and others.</td></tr>
<tr><td>Scientific Inquiry, Practice and Applications</td><td>All students must use these scientific processes with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas.</td></tr>
<tr><td>Science is a Way of Knowing</td><td>Science assumes the universe is a vast single system in which basic laws are consistent. Natural laws operate today as they did in the past and they will continue to do so in the future. Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise and extend this knowledge.</td></tr>
<tr><td>Science is a Human Endeavor</td><td>Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes.</td></tr>
<tr><td>Scientific Knowledge is Open to Revision in Light of New Evidence</td><td>Science is not static. Science is constantly changing as we acquire more knowledge.</td></tr>
</table>

Scientific and Engineering Practices:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Ohio’s Cognitive Demands for Science

Cognitive Demand	Description
DESIGNING TECHNOLOGICAL/ ENGINEERING SOLUTIONS USING SCIENCE CONCEPTS	Requires students to solve science-based engineering or technological problems through application of scientific inquiry. Within given scientific constraints, propose or critique solutions, analyze and interpret technological and engineering problems, use science principles to anticipate effects of technological or engineering design, find solutions using science and engineering or technology, consider consequences and alternatives, and/or integrate and synthesize scientific information.
DEMONSTRATING SCIENCE KNOWLEDGE	Requires students to use scientific practices and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (Slightly altered from National Science Education Standards)
INTERPRETING AND COMMUNICATING SCIENCE CONCEPTS	Requires students to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.
RECALLING ACCURATE SCIENCE	Requires students to provide accurate statements about scientifically valid facts, concepts and relationships. Recall only requires students to provide a rote response, declarative knowledge or perform routine mathematical tasks. This cognitive demand refers to students’ knowledge of science fact, information, concepts, tools, procedures (being able to describe how) and basic principles.

CHEMISTRY

Chemistry Course Goals:

This course introduces students to key concepts and theories that provide a foundation for further study in other sciences as well as advanced science disciplines. Chemistry comprises a systematic study of the predictive physical interactions of matter and subsequent events that occur in the natural world. The study of matter through the exploration of classification, its structure and its interactions is how this course is organized. Investigations are used to understand and explain the behavior of matter in a variety of inquiry and design scenarios that incorporate scientific reasoning, analysis, communication skills and real-world applications. An understanding of leading theories and how they have informed current knowledge prepares students with higher order cognitive capabilities of evaluation, prediction and application.

STRUCTURE AND PROPERTIES OF MATTER (Atomic Structure, Electron Configurations, Periodic Trends, Chemical Bonding, Formulas, Nomenclature, Lewis Structures, Molecular Geometries, Intermolecular Forces)	
Content Statement	**Content Elaboration**
C.PM.1: Atomic structure • Evolution of atomic models/theory • Electrons • Electron configurations	● Thomson - study of electrical discharges in cathode-ray tubes led to the discovery of the electron and the development of the plum pudding model. ● Rutherford - experiment, in which he bombarded gold foil with α-particles, led to the discovery that most of the atom consists of empty space with a relatively small, positively charged nucleus. ● Bohr - used data from atomic spectra to propose a planetary model of the atom in which electrons orbit the nucleus. ● Schrödinger - used the idea that electrons travel in waves to develop a model in which electrons travel randomly in regions of space called orbitals (currently accepted quantum mechanical model). ● Atoms are usually in the ground state. ● An atom can become excited when the electrons absorb a photon with the precise amount of energy (indicated by the frequency of the photon) to move to an orbital with a higher energy. ● An atom exists in the excited state for a very short amount of time. When an electron drops back down to the lower energy level, it emits a photon that has energy equal to the energy difference between the levels. ● The amount of energy is indicated by the frequency of the light that is given off and can be measured. ● Each element has a unique emission and absorption spectrum due to its unique electron

	configuration and specific electron energy jumps that are possible for that element. ● Electron energy levels consist of sublevels (s, p, d and f) each with a characteristic number of orbitals and each orbital with a characteristic shape. ● Orbital diagrams and electron configuration are constructed to show the location of the electrons in an atom. ● Valence electrons are responsible for most of the chemical properties of elements.
C.PM.2: Periodic table • Properties • Trends	● The periodic table is divided into groups, families, periods, metals, nonmetals and metalloids ● The electron configuration of an atom can be determined from the position on the periodic table. ● The repeating pattern in the electron configuration for elements on the periodic table explains many of the trends in the properties observed. ● Atomic theory is used to describe and explain trends in properties across periods or down columns including atomic radii, ionic radii, first ionization energies, electronegativities. ● Atomic theory can help explain why the element is a solid or gas at room temperature.
C.PM.3: Chemical bonding • Ionic • Polar/covalent	● Atoms of many elements are more stable when they are bonded to other atoms. In such cases, as atoms bond, energy is released to the surroundings, resulting in a system with lower energy. An atom’s electron configuration, particularly the valence electrons, determines how an atom interacts with other atoms. ● Differences in electronegativity values are used to predict where a bond fits on the continuum between ionic and covalent bonds ● The polarity of a bond depends on the electronegativity difference and the distance between the atoms (bond length). Polar covalent bonds are introduced as an intermediary between ionic and pure covalent bonds. ● Molecules, ionic lattices and network covalent structures have different, yet predictable, properties that depend on the identity of the elements and the types of bonds formed. ● The concept of metallic bonding is used to explain many of the properties of metals (e.g., conductivity). ● Since most compounds contain multiple bonds, a substance may contain more than one type of bond. ● Carbon atoms can bond together and with other atoms, especially hydrogen, oxygen, nitrogen and sulfur, to form chains, rings and branching networks that are present in a variety of important compounds, including synthetic polymers, fossil fuels and the large molecules essential to life.

C.PM.4: Representing compounds • Formula writing • Nomenclature • Models and shapes (Lewis structures, ball and stick, molecular geometries)	● Using the periodic table, formulas of ionic compounds containing specific elements can be predicted. This can include ionic compounds made up of elements from groups 1, 2, 17, hydrogen, oxygen and polyatomic ions (given the formula and charge of the polyatomic ion). ● Given the formula, a compound can be named using conventional systems that include Greek prefixes and Roman numerals where appropriate. ● Given the name of an ionic or covalent substance, formulas can be written. ● Lewis Structures ○ Lewis structures and ball and stick models are used to visualize atoms and molecules and to predict the properties of substances. ○ Each type of representation provides unique information about the compound ○ Lewis structures are drawn to represent covalent compounds ● Molecular geometries ○ The valence shell electron pair repulsion (VSEPR) theory is used to predict the three-dimensional electron pair and molecular geometry of compounds.
C.PM.5: Quantifying matter • Average atomic mass • Measurement • Significant Figures • Dimensional Analysis	● Average atomic mass ○ The atomic mass of an element is calculated given the mass and relative abundance of each isotope of the element as it exists in nature. ● Scientific protocols for quantifying the properties of matter accurately and precisely are studied, recognizing that all measurements are associated with some error. ● Using the International System of Units (SI), significant digits or figures, scientific notation, error analysis and dimensional analysis are vital to scientific communication. ● There are three domains of magnitude in size and time: the macroscopic (human) domain, the cosmic domain and the submicroscopic (atomic and subatomic) domain. ● Measurements in the cosmic domain and submicroscopic domains require complex instruments and/or procedures. ● Macroscopic properties such as mass can reflect the number of particles present. Because the mass of an atom is very small, the mole is used to translate between the atomic and macroscopic levels. ● A mole is equal to the number of atoms in exactly 12 grams of the isotope carbon-12. ● The mass of one mole of a substance is equal to its molar mass in grams. ● The molar mass of a substance can be used in conjunction with Avogadro's number to convert between mass, moles, and number of particles of a sample.
C.PM.6: Intermolecular forces of attraction • Types and strengths	● The composition of a substance and the shape and polarity of a molecule are particularly important in determining the type and strength of bonding and intermolecular interactions. ● Types of IMF each with unique strength

• Implications for properties of substances -Melting and boiling point -Solubility -Vapor pressure	○ London dispersion forces (present between all molecules) ○ dipole-dipole forces (present between polar molecules) ○ hydrogen bonding (a special case of dipole-dipole where hydrogen is bonded to a highly electronegative atom such as fluorine, oxygen or nitrogen) ● Strength of IMF helps predict physical properties of a material (e.g., melting point, boiling point, solubility, vapor pressure) ● Energy needed for a change of state to occur depends upon the strength of the IMF between the particles. ● Ionic lattices or covalent networks tend to be solids at room temperature and have high melting and boiling points. ● Chain length and branching of organic molecules impact IMF ● Substances with similar IMF will be able to dissolve in one another, but substances with different IMF will remain separate from one another ● Water is a polar molecule and it is often used as a solvent since most ionic and polar covalent substances will dissolve in it. ● Dissolving of a solute in water is an example of a process that is difficult to classify as a chemical or physical change and it is not appropriate to have students classify it one way or another. ● Evaporation occurs when the particles with enough kinetic energy to overcome the attractive forces separate from the rest of the sample to become a gas. The pressure of these particles is called vapor pressure. ● Vapor pressure increases with temperature. Particles with larger intermolecular forces have lower vapor pressures at a given temperature since the particles require more energy to overcome the attractive forces between them. ● Molecular substances often evaporate more due to the weak attractions between the particles and can often be detected by their odor. ● Ionic or network covalent substances have stronger forces and are not as likely to volatilize. These substances often have little, if any, odor. ● Liquids boil when their vapor pressure is equal to atmospheric pressure. ● In solid water, there is a network of hydrogen bonds between the particles that gives it an open structure. This is why water expands as it freezes and why solid water has a lower density than liquid water. This has important implications for life (e.g., ice floating on water acts as an insulator in bodies of water to keep the temperature of the rest of the water above freezing).

INTERACTIONS OF MATTER
(Chemical Reactions, Stoichiometry, Gas Laws, Thermodynamics, Kinetics, Equilibrium)

Content Statement	Content Elaboration
C.IM.1: Chemical reactions • Types of reactions • Kinetics • Energy • Equilibrium • Acids/bases	● Complex reactions should be studied, classified and represented with balanced chemical equations and three-dimensional models. ● Classifications may be useful in making predictions about what happens when two substances are mixed. ● Some general types of chemical reactions are oxidation/reduction, synthesis, decomposition, single replacement, double replacement (including precipitation reactions and some acid-base neutralizations) and combustion reactions. ● Some reactions can fit into more than one category. For example, a single replacement reaction can also be classified as an oxidation/reduction reaction. ● Identification of reactions involving oxidation and reduction as well as indicating what substance is being oxidized and what is being reduced are appropriate in this course. ● Organic molecules release energy when undergoing combustion reactions and are used to meet the energy needs of society (e.g., oil, gasoline, natural gas) and to provide the energy needs of biological organisms (e.g., cellular respiration). ● When a reaction between two ionic compounds in aqueous solution results in the formation of a precipitate or molecular compound, the reaction often occurs because the new ionic or covalent bonds are stronger than the original ion-dipole interactions of the ions in solution. ● The energy change of a system can be calculated from measurements (mass and change in temperature) from calorimetry experiments in the laboratory because energy is conserved. ● Thermal energy is the energy of a system due to the movement of its particles. The thermal energy of an object depends upon the mass, temperature and chemical composition. ● Specific heat is a measure of how much energy is needed to change the temperature of a specific mass of material a specific amount. ● Specific heat values can be used to calculate the thermal energy change, the temperature (initial, final or change in) or mass of a material in calorimetry. ● Water has a particularly high specific heat capacity, which is important in regulating Earth’s temperature. ● Chemical energy is the potential energy associated with chemical systems. ● Chemical reactions involve valence electrons forming bonds to yield more stable products with lower energies. ● Energy is required to break interactions and bonds between the reactant atoms ● Energy is released when an interaction or bond is formed between the atoms in the products. ● Energy is transferred out of the system (exothermic) when the products have stronger bonds than the reactants. ● Energy is transferred into the system (endothermic) when the reactants have stronger bonds than the products.

	● Predictions of the energy requirements (endothermic or exothermic) of a reaction can be made given a table of bond energies. ● Graphic representations can be drawn and interpreted to represent the energy changes during a reaction. ● The role of energy in determining the spontaneity of chemical reactions is dealt with conceptually in this course. ● Entropy and its influence on the spontaneity of reactions are reserved for more advanced study. ● Reactions occur when reacting particles collide in an appropriate orientation and with sufficient energy. ● The rate of a chemical reaction is the change in the amount of the reactants or products in a specific period of time. Increasing the probability or effectiveness of the collisions between the particles increases the rate of the reaction. ● Changing the concentration of the reactants, changing the temperature or the pressure of gaseous reactants, or using a catalyst, can change the reaction rate. ● All reactions are reversible to a degree and many reactions do not proceed completely toward products but appear to stop progressing before the reactants are all used up. ● At equilibrium, the amounts of the reactants and the products appear to be constant and are in a state of dynamic equilibrium. ● Dynamic equilibrium means the rate of the reverse reaction is equal to the rate of the forward reaction so there is no apparent change in the reaction. ● If a system at equilibrium is disturbed by a change in the conditions of the system (e.g., increase or decrease in the temperature, pressure on gaseous equilibrium systems, concentration of a reactant or product), then the equilibrium system will respond by shifting to a new equilibrium state, reducing the effect of the change (Le Chatelier’s Principle). ● Structural features of molecules are explored to further understand acids and bases. ● Acids often result when hydrogen is covalently bonded to an electronegative element and is easily dissociated from the rest of the molecule to bind with water to form a hydronium ion (H_3O^+). ● The acidity of an aqueous solution can be expressed as pH, where pH can be calculated from the concentration of the hydronium ion. ● Bases are likely to dissociate in water to form a hydroxide ion. ● Acids can react with bases to form a salt and water in a neutralization reaction. ● Titrations should be completed.
C.IM.2: Gas laws • Pressure, volume and temperature • Ideal gas law	● The kinetic-molecular theory can be used to explain the properties of gases (pressure, temperature and volume) through the motion and interactions of its particles. ● Problems can be solved involving the changes in temperature, pressure, volume and moles of

	a gas. When two of these four are kept constant, the relationship between the other two can be quantified, described and explained using the kinetic-molecular theory. ● Equal volumes of gases at the same temperature and pressure contain an equal number of particles (Avogadro's law), so problems can be solved for an unchanging gaseous system using the ideal gas law ● (PV = nRT)
C.IM.3: Stoichiometry • Molar calculations • Solutions • Limiting reagents	● A stoichiometric calculation involves the conversion from the amount of one substance in a chemical reaction to the amount of another substance. ● The coefficients of the balanced equation indicate the ratios of the substances involved in the reaction in terms of both particles and moles. ● Once the number of moles of a substance is known, amounts can be changed to mass, volume of a gas, volume of solutions and/or number of particles. ● Molarity is a measure of the concentration of a solution that can be used in stoichiometric calculations. ● When performing a reaction in the lab, the experimental yield can be compared to the theoretical yield to calculate percent yield. ● The concept of limiting reagents should be taught conceptually, but can be taught mathematically as well.