Ohio Science

Chemistry Content Statements: Grades 9-12

Adopted 2018

Chemistry

1. **Atomic structure** C.PM.1

   a. Using knowledge and/or understanding of various ions and their electron location, construct a plan or proposal for a community firework show. Proposal must contain a list of materials, including the chemicals, safety procedures, environmental impact and possible cost. C.PM.1.DTES.A

   b. Design a toy that is based on the idea of excited electrons. C.PM.1.DTES.B

   a. Design an investigation using group 2 elements that illustrates the reactivity of the elements as you move down the group. Interpret data to explain this reasoning based on the electron configurations of each element. C.PM.1.DSK.A

   a. Compare the nature of protons, neutrons and electrons among different atomic models. C.PM.1.ICSC.A

   b. Compare the strengths and limitations of particular atomic models. C.PM.1.ICSC.B

   c. Investigate the principles used to develop atomic models (e.g. a black-box problem). C.PM.1.ICSC.C

   d. Create a timeline that shows major discoveries in atomic history. C.PM.1.ICSC.D

   e. Predict which isotope is most abundant given an element's atomic mass and the mass numbers of its isotopes. C.PM.1.ICSC.E

   f. Compare the electron configuration of various ions based on data from an experiment (e.g., flame test, spectral tubes). Explore the color of various salts by looking at the electromagnetic spectrum. C.PM.1.ICSC.F

   a. Identify atomic models (e.g., Dalton's, Thomson's, Rutherford's, Bohr's) and the work used to produce each of these models. C.PM.1.RAS.A

   b. Interpret the classic historical experiments that were used to identify the components of an atom and behavior of electrons. C.PM.1.RAS.B

   c. Calculate atomic mass given the abundance of various isotopes. C.PM.1.RAS.C

   d. Determine the atomic number, mass number, number of protons, neutrons and electrons. C.PM.1.RAS.D

   e. Identify the extended and noble gas notation electron configurations for elements in the first three periods. C.PM.1.RAS.E

   f. Using the periodic table, determine the electron configuration of an atom. C.PM.1.RAS.F

   g. Construct an orbital diagram or electron configuration to show the probable arrangement of electrons in an atom. C.PM.1.RAS.G

2. **Periodic table** C.PM.2

   a. Develop a proposal for the construction of an outdoor art installation in various environments/climates. Determine which metal(s) would have the optimal properties for your project. Present and defend your proposal to a panel of experts. C.PM.2.DTES.A

   a. Predict the placement of an element on the periodic table given only a list of its properties. C.PM.2.ICSC.A

   b. Given a metalloid, judge whether the metalloid is more likely to behave as a metal or nonmetal. Defend your choice. C.PM.2.ICSC.B

   c. Create a graphic to show the relationships between the trends of the periodic table and electron configurations. C.PM.2.ICSC.C

   a. Create a product that explains the organization of the periodic table (e.g., increasing atomic number, groups, periods, metals, metalloid, nonmetals) to middle school students C.PM.2.RAS.A

   b. Describe ionization energy and relate it to atomic structure. C.PM.2.RAS.B

   c. Describe electronegativity and relate it to atomic structure. C.PM.2.RAS.C

   d. Describe periodic trends in ionic radii and electron affinity and relate them to atomic structure. C.PM.2.RAS.D

   e. Describe atomic radius and relate to atomic structure. C.PM.2.RAS.E

   f. Describe how shielding effect explains the trend in atomic size. C.PM.2.RAS.F

   g. For two atoms, identify the one that is larger, more electronegative, or more easily ionized based on where they are on the periodic table. Justify your answer. C.PM.2.RAS.G

3. **Chemical bonding** C.PM.3

    a. Design a theoretical pharmaceutical with an appropriate shape to interact with a provided enzyme or receptor designed by the teacher. The designed molecule would need to contact the enzyme or receptor in three different loci. C.PM.3.DTES.A

    b. Design an investigation to evaluate the claims of a commercial product (e.g., ionic-tourmaline, a mineral that is said to emit quick-drying ions; a hair dryer; a shake weight dumbbell; a type of strong-bond glue). Determine function, intent and any potential bias with the product. Present findings in multiple formats. C.PM.3.DTES.B

    c. Propose a method to evaluate the ability of plastics to be recycled based on the understanding of the plastic's polarity. C.PM.3.DTES.C

    d. Evaluate and critique the impact of a synthetic polymer, fossil fuel or biological macromolecule on society, the environment or health. C.PM.3.DTES.D

    e. Critique the advantages and disadvantages of different metals and alloys for bridge construction. C.PM.3.DTES.E

    a. Design and conduct an investigation to distinguish between ionic, polar covalent, nonpolar covalent and metallic bonds based on material properties (e.g., melting point, solubility, conductivity). C.PM.3.DSK.A

    b. Design an experiment to test the effectiveness of a water softener system's ability to remove ions from water. C.PM.3.DSK.B

    c. Devise a procedure to evaluate physical and chemical properties to develop predictions and support claims about compounds' classification as ionic, polar or covalent. C.PM.3.DSK.C

    d. Evaluate the properties of DNA based on the bonds (polar and nonpolar) within its chemical structure and how it relates to DNA sequencing and/or forensic/medical applications. C.PM.3.DSK.D

    a. Compare the stability of ions when they are separated vs. when they are in their lattice. C.PM.3.ICSC.A

    b. Construct models or diagrams (e.g., Lewis dot structures, ball and stick models) of common compounds and molecules (e.g., NaCl, SiO₂, O₂, H₂, CO₂) and distinguish between ionically and covalently bonded compounds. C.PM.3.ICSC.B

    c. Using electron configurations, hypothesize how an atom becomes a cation or anion and illustrate how and why they would form ionic compounds. C.PM.3.ICSC.C

    d. Determine if bonds and molecules are polar by determining the direction of dipole moment of the individual bonds. C.PM.3.ICSC.D

    e. Using electron dot diagrams, generate models showing that molecular compounds result from atoms sharing electrons. Include carbon bonds showing the formation of chains, rings and branching networks. C.PM.3.ICSC.E

    f. Distinguish between bond polarity and molecular polarity. Construct models illustrating how a nonpolar molecule can be formed from polar bonds. C.PM.3.ICSC.F

g. Compare the stability of atoms when they are separated vs. when they are bonded. C.PM.3.ICSC.G

h. Using experimental evidence, explain how the properties of macromolecules depend on the properties of the molecules used in their formation and the length and structure of the polymer chain. C.PM.3.ICSC.H

i. Illustrate how freely moving electrons in metallic bonds affect properties such as conductivity, malleability and ductility. C.PM.3.ICSC.I

j. Explain how the structure of metal atoms give them the ability to conduct heat and electricity. C.PM.3.ICSC.J

k. Explore the extent to which a variety of solid materials conduct electricity and rank the materials from good conductors to poor conductors. Based on the conductivity data, determine patterns of location on the Periodic Table for the good conductors vs. the poor conductors. C.PM.3.ICSC.K

a. Define bond energy and recognize that bond-breaking is an endothermic process and bond-forming is an exothermic process. C.PM.3.RAS.A

b. Represent the formation of a bond using electron configurations of individual atoms. C.PM.3.RAS.B

c. Explain the tendency of elements to transfer or share electrons based on their location on the periodic table. C.PM.3.RAS.C

d. Identify valence electrons as the highest energy electrons in the atom and use the octet rule to predict the most stable ion formed. C.PM.3.RAS.D

e. Distinguish between ionic and polar/nonpolar covalent bonds based on their electronegativity values. C.PM.3.RAS.E

f. Write equations for covalent bond formation between two atoms using Lewis structures. C.PM.3.RAS.F

g. Explain the difference between a single, double and triple bond in terms of electrons shared. C.PM.3.RAS.G

h. Compare the bond energies and lengths for single, double and triple bonds conceptually (no numbers). C.PM.3.RAS.H

i. Explain how polymerization forms long chains of macromolecules (polymers) from small molecules (monomers). Provide examples of natural and synthetic polymers. C.PM.3.RAS.I

j. Compare electrons in a metallic bond and in a covalent bond. C.PM.3.RAS.J

4. **Representing compounds** C.PM.4

    a. Develop the formulas for chemical compounds in household items based on their names. C.PM.4.ICSC.A

    b. Construct a prototype of a game to enhance the understanding of formula writing and nomenclature. Allow other students to evaluate and critique the appropriateness of the game. C.PM.4.ICSC.B

    c. Determine which type of model (e.g., chemical formula, Lewis structure, ball-and-stick model) is the best representation for a variety of compounds. C.PM.4.ICSC.C

    d. Implementing VSEPR identify the different shapes within a large macromolecule (e.g., caffeine, dopamine, serotonin). C.PM.4.ICSC.D

    a. Given elements from the periodic table and/or polyatomic ions, predict the formula of a compound. C.PM.4.RAS.A

    b. Write a formula from the name of an acid. C.PM.4.RAS.B

    c. Given the formula of an ionic compound or a binary covalent compound, determine the compound's name. C.PM.4.RAS.C

    d. Name an acid based on its chemical formula. C.PM.4.RAS.D

    e. Construct simple Lewis structures of compounds made up of hydrogen, carbon, nitrogen, oxygen, phosphorus, sulfur and the halogens. C.PM.4.RAS.E

    f. Predict the three-dimensional shapes of simple Lewis structures using valence shell electron pair repulsion (VSEPR) theory. C.PM.4.RAS.F

    g. Construct three-dimensional ball-and-stick models to determine the shapes of simple covalent compounds. C.PM.4.RAS.G

5. **Quantifying matter** C.PM.5

   a. Devise a method to indirectly determine the value of a measurement that common laboratory tools cannot provide (e.g., thickness of aluminum foil, number of sand particles, moles of chalk used to write your name, drop from a pipet). C.PM.5.DTES.A

   a. Design a method to determine the empirical formula or percent composition of an unknown hydrate/compound. C.PM.5.DSK.A

   b. Determine the percent by mass of water content in popcorn. Correlate its effect on the amount of popcorn produced (or time it takes to start the batch popping). Compare three brands, isolate other variables (e.g., popping method, use of different types of oil) and present findings in multiple formats. C.PM.5.DSK.B

   a. Using a Socratic seminar, research and discuss the pros and cons of the International System of Units (SI) vs. the English measuring system. C.PM.5.ICSC.A

   b. Use calculations to compare the ratios of the size of the atom to the size of different objects (e.g., cell, person, tree). C.PM.5.ICSC.B

   c. Compare moles and mass. Identify situations where each is most appropriate to use. C.PM.5.ICSC.C

   d. Design an investigation to show that the volume of any liquid sample is constant when divided by its mass. C.PM.5.ICSC.D

   a. Measure the volume of an irregular solid using SI units. Provide your answer using correct significant figures and unit. C.PM.5.RAS.A

   b. Distinguish accuracy from precision. C.PM.5.RAS.B

   c. Carry out laboratory measurements with a variety of equipment (e.g., graduated cylinders, beakers, balances) and report measurements to the correct number of significant figures. Compare the accuracy of each measuring device. C.PM.5.RAS.C

   d. Apply the rules for determining significant digits when performing mathematical operations. C.PM.5.RAS.D

   e. Determine the average atomic mass of an element based on the percent abundance of its naturally occurring isotopes. C.PM.5.RAS.E

   f. Convert between mass, moles, volume and number of representative particles using Avogadro's number, molar mass and density using dimensional analysis. C.PM.5.RAS.F

6. **Intermolecular forces of attraction** C.PM.6

   a. Make a soap and evaluate its effectiveness on hard water. Compare the effectiveness of various soaps. C.PM.6.DTS.A
   b. Evaluate the composition of shampoo samples using properties (e.g., viscosity, pH) to determine their effectiveness. C.PM.6.DTS.B
   a. Design an investigation to identify which solvent would be best to dissolve a particular solute. C.PM.6.DSK.A
   b. Design a procedure to determine the polarity of a substance. C.PM.6.DSK.B
   c. Investigate why water doesn't follow predicted trends (e.g., surface tension, density, vapor pressure, boiling point) based on its intermolecular interactions (e.g. drops on a penny, capillary tube, mixing oil and water, water on glass vs. wax paper). Summarize your findings. C.PM.6.DSK.C
   d. Evaluate the properties of sweeteners (e.g., regular table sugar, high fructose corn syrup, stevia, aspartame, saccharin, sucralose, honey, agave). Research these products and potential impacts. A variation for this could be evaluating oils (e.g., canola, coconut, olive, vegetable). C.PM.6.DSK.D
   e. Design an investigation to determine if a molecule is polar or nonpolar. C.PM.6.DSK.E
   f. Devise an investigation to show that the addition of a solute affects the density of a liquid. C.PM.6.DSK.F
   a. Apply the idea of intermolecular forces to biological implications (e.g., hydrogen bonding between two DNA strands, cell membrane formation of lipids). C.PM.6.ICSC.A
   b. Construct a chromatography technique to separate the components of different dyes (e.g., hair color, food additives, skittles) applying principles of inter- and intra-molecular forces. C.PM.6.ICSC.B
   c. Illustrate the differences between intermolecular forces. C.PM.6.ICSC.C
   d. Represent the cause of intermolecular forces between molecules using models. C.PM.6.ICSC.D
   e. Explain the effect that branching has on London dispersion forces in nonpolar organic molecules (e.g., long chains have greater forces and branching decreases the forces). Identify real-world implications. C.PM.6.ICSC.E
   f. Explain how a graph of vapor pressure vs. temperature can be used to determine boiling point and strength of intermolecular forces. C.PM.6.ICSC.F
   g. Demonstrate the effect the strength of intermolecular forces has on various properties (e.g., change in evaporation temperature, polarizability, viscosity). C.PM.6.ICSC.G
   h. Predict which compound will have the highest/lowest vapor pressure and melting/boiling point based on intermolecular forces. C.PM.6.ICSC.H
   i. Sketch the solvation of a solute in an appropriate solvent and explain how the solute separates and interacts with the solvent. C.PM.6.ICSC.I

a. Explain the importance of molecular-level structure in the functioning of designed materials (e.g., why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, pharmaceuticals are designed to interact with specific receptors). C.PM.6.RAS.A

b. Describe intermolecular forces for molecular compounds.
H-bond as attraction between molecules when H is bonded to O, N, or F.
Dipole-dipole attractions between polar molecules.
London dispersion forces (electrons of one molecule attracted to nucleus of another molecule) – i.e. liquefied inert gases.
Relative strengths (H>dipole>London/van der Waals). C.PM.6.RAS.B

c. Explain why intermolecular forces are weaker than ionic, covalent or metallic bonds. C.PM.6.RAS.C

d. Identify the intermolecular forces that exist in a given compound. C.PM.6.RAS.D

e. Differentiate between bond polarity and molecular polarity. C.PM.6.RAS.E

f. Explain why greater solubility occurs when dissolving a substance in a solvent with similar intermolecular forces ("like dissolves like"). C.PM.6.RAS.F

1. **Chemical reactions** C.IM.1

   a. Evaluate oxidation-reduction reactions occurring in real-world settings (e.g., rusting, electroplating) that cause engineering/manufacturing challenges and propose a solution. C.IM.1.DTES.A

   b. Critique the effects of a catalyst on everyday chemical reactions (e.g., biological enzymes, catalytic converters). Redesign a process which is more cost effective and/or environmentally friendly. C.IM.1.DTES.B

   c. Design a better (e.g., less expensive, more environmentally friendly) safe hand warmer using ionic substances. C.IM.1.DTES.C

   d. Propose a procedure to shift a commercial equilibrium process to maximize a desired product and construct a risk assessment for its implications on society (e.g., Haber process). C.IM.1.DTES.D

   e. Conduct an experiment to determine what type of roof materials would be appropriate in areas with high acid rain. C.IM.1.DTES.E

   f. Evaluate and critique why lakes with limestone or calcium carbonate experience less adverse effects from acid rain than lakes with granite beds. Then invent a product or process to minimize these effects. C.IM.1.DTES.F

   a. Generate a process for recycling a metal including the uses and possible limitations of the recycled metal. C.IM.1.DSK.A

   b. Design an experiment to determine the effect of concentration, surface area or temperature on reaction rate. C.IM.1.DSK.B

   c. Design a method to determine the identity of a metal by calculating the heat transfer from the hot metal to cold water. C.IM.1.DSK.C

   d. Design an investigation to determine the effective pH range of natural and synthetic indicators. C.IM.1.DSK.D

   e. Devise a method to evaluate the Vitamin C content of commercial products. C.IM.1.DSK.E

   f. Design an investigation to determine the most effective antacid (e.g., baking soda (NaHCO₃) or magnesium hydroxide (Mg (OH)₂) per gram for neutralizing stomach acid (HCl). C.IM.1.DSK.F

   a. Apply knowledge of reactions to determine the appropriate fire extinguisher for a given scenario. C.IM.1.ICSC.A

   b. Examine living organisms to identify and explain biological chemical reactions (e.g., metabolism, respiration, photosynthesis) within the organism. C.IM.1.ICSC.B

   c. Compare different reaction types. C.IM.1.ICSC.C

   d. Explain the energy changes in photosynthesis and in the combustion of sugar in terms of bond breaking and bond formation. C.IM.1.ICSC.D

   e. Using activity series and solubility rules construct an outcome for single replacement and double replacement reactions. C.IM.1.ICSC.E

f. Draw a particle diagram representing the interactions of particles in a chemical reaction. C.IM.1.ICSC.F

g. Apply scientific principles and evidence to provide an explanation about the effects of changing concentration, temperature and pressure on the rate of a chemical reaction. C.IM.1.ICSC.G

h. Through experimentation, generate qualitative potential energy diagrams for endothermic and exothermic reactions with and without the presence of a catalyst (e.g., decomposition of H₂O₂ with KI and without KI). Include reactants, products and activated complex. C.IM.1.ICSC.H

i. Illustrate collision theory using particle diagrams showing that molecules must collide in the proper orientation and with sufficient energy to equal or exceed the activation energy in order to react. C.IM.1.ICSC.I

j. Compare how the specific heat of different substances impacts temperature change. C.IM.1.ICSC.J

k. Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. C.IM.1.ICSC.K

l. Use household materials to show the difference between endothermic and exothermic reactions. C.IM.1.ICSC.L

m. In a laboratory setting, illustrate equilibrium shift due to disturbances. C.IM.1.ICSC.M

n. Indicate whether the forward or reverse reaction is favored to reach equilibrium based on different disturbances (e.g., increase or decrease in temperature, pressure on gaseous equilibrium systems, change in concentration of a reactant or product). C.IM.1.ICSC.N

o. Evaluate neutralization reactions quantitatively by performing titration experiments. C.IM.1.ICSC.O

a. Classify a chemical reaction as synthesis, decomposition, single-replacement, double replacement or organic combustion. C.IM.1.RAS.A

b. Identify which substance is oxidized and which substance is reduced in an oxidation/reduction reaction. C.IM.1.RAS.B

c. Identify the ways the rate of a chemical reaction can be affected (e.g., concentrations of reactions, surface area, changing temperature or pressure of gaseous substances, using a catalyst). C.IM.1.RAS.C

d. Calculate the thermal energy change (q), the change of temperature (ΔT), initial or final temperature and mass of a material using specific heat. C.IM.1.RAS.D

e. Given a table of bond energies, determine whether a given reaction is exothermic or endothermic. C.IM.1.RAS.E

f. Track the flow of energy and explain why a reaction is an exothermic or endothermic process. C.IM.1.RAS.F

g. Show that equilibrium is dynamic and that the rates of the forward and reverse reactions are equal. C.IM.1.RAS.G

h. Describe key features of equilibrium (two opposing processes occur simultaneously at the same rate). C.IM.1.RAS.H

i. Perform calculations relating pH to hydronium ion concentration. C.IM.1.RAS.I

j. Identify acids based on the formation of the hydronium ion in water. C.IM.1.RAS.J

k. Identify bases by their dissociation in water to form the hydroxide ion. C.IM.1.RAS.K

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2. **Gas laws** C.IM.2

   a. Design a device that measures tire pressure under changing temperature conditions. C.IM.2.DTES.A

   b. Design a toy that is an application of a gas law. C.IM.2.DTES.B

   a. Using simulations and/or laboratory experiences, determine the relationships between pressure and volume, pressure and temperature, and temperature and volume. C.IM.2.DSK.A

   b. Create a model airbag with baking soda and vinegar in a plastic bag. Use the ideal gas law to figure the amount of the reactants necessary to fill a given plastic bag. Test the prediction and provide possible explanations for any discrepancy between the theoretical and actual results. C.IM.2.DSK.B

   c. Detect and measure the volume of a gas produced during a chemical reaction and relate to molar volume at standard temperature and pressure. C.IM.2.DSK.C

   a. Explain both the quantitative and qualitative relationships between pressure, volume and temperature. C.IM.2.ICSC.A

   b. Construct models representing the relationship of pressure, volume and temperature related to collisions and energy of particles. C.IM.2.ICSC.B

   c. Apply gas laws to common scenarios (e.g. hot air balloons, tire blowouts) C.IM.2.ICSC.C

   d. Use the kinetic molecular theory to explain the motion of gas particles and how they are affected by changes in pressure, temperature and/or volume. C.IM.2.ICSC.D

   e. Use an Ideal Gas Law Simulator to represent and interpret the connection between pressure, volume, temperature and number of particles. C.IM.2.ICSC.E

   a. Identify units of pressure, volume and temperature. C.IM.2.RAS.A

   b. Convert between different pressure units. C.IM.2.RAS.B

   c. Solve problems using appropriate gas law equations. C.IM.2.RAS.C

   d. Determine whether pressure, temperature and volume are increasing or decreasing in a given situation. C.IM.2.RAS.D

   e. Apply the ideal gas law to solve for an appropriate variable. C.IM.2.RAS.E

3. Stoichiometry C.IM.3

a. Evaluate the efficiency, cost and environmental impacts of multiple possible chemical processes to determine which process would be best to use. Sustainability and green chemistry should be considered. C.IM.3.DTES.A

b. Evaluate an environmental problem through the lens of limiting reagents (e.g., algae growths impacted by available phosphates and nitrates). C.IM.3.DTES.B

c. Investigate the role that limiting reagents play in an industrial process (e.g., pharmacology, cosmetics, chemical industries). Evaluate techniques to optimize production, including how costs and waste products are taken into consideration. C.IM.3.DTES.C

a. Calculate the reactants needed to produce an exact amount of a product (e.g., produce silver through the reaction of silver nitrate and copper or zinc and hydrochloric acid). Produce the product in the laboratory. Calculate the percent difference between the theoretical amount and the amount actually produced. Provide possible explanations for the discrepancy. C.IM.3.DSK.A

b. Plan and implement a process to test concentration of pollutants in water (e.g., lead, mercury). C.IM.3.DSK.B

c. Plan and carry out an investigation to demonstrate the conceptual principle of limiting reactants. C.IM.3.DSK.C

a. Explain how the creation of a standardized solution (a solution of known molarity) allows you to determine the concentration of an unknown solution. C.IM.3.ICSC.A

b. Compare limiting to excess reagents in a chemical reaction (e.g., copper (II) sulfate and an iron nail). C.IM.3.ICSC.B

a. Using data collected from a multi-step chemical reaction, calculate percent yield. C.IM.3.RAS.A

b. Use mole ratios from a balanced equation to calculate the quantity of one substance in a reaction, given the quantity of another substance in the reaction (e.g., given moles, particles, mass or volume and ending with moles, particles, mass or volume of the desired substance). C.IM.3.RAS.B

c. Interpret the coefficients of a balanced equation in terms of moles and particles. C.IM.3.RAS.C

d. Create a solution and a dilution of a known concentration. C.IM.3.RAS.D

e. Calculate the molarity of an aqueous solution. C.IM.3.RAS.E

f. Distinguish between solute, solvent and solution. C.IM.3.RAS.F

g. Determine the concentration of an unknown solution through titration. C.IM.3.RAS.G

h. Determine which reactant is limited using particle diagrams. C.IM.3.RAS.H

i. Use BCA tables to calculate the quantities of products and excess reactants. C.IM.3.RAS.I