P2.p1 Potential Energy (prerequisite)
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P2.p1A
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P2.p1B
Use the positions and arrangements of atoms and molecules in solid, liquid, and gas state to explain the need for an input of energy for melting and boiling and a release of energy in condensation and freezing. (prerequisite)

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C2.1x Chemical Potential Energy
Potential energy is stored whenever work must be done to change the distance between two objects. The attraction between the two objects may be gravitational, electrostatic, magnetic, or strong force. Chemical potential energy is the result of electrostatic attractions between atoms.

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C2.1a
Explain the changes in potential energy (due to electrostatic interactions) as a chemical bond forms and use this to explain why bond breaking always requires energy.

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C2.1b
Describe energy changes associated with chemical reactions in terms of bonds broken and formed (including intermolecular forces).

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C

C2.1c

Compare qualitatively the energy changes associated with melting various types of solids in terms of the types of forces between the particles in the solid.

C

C2.1c

Compare qualitatively the energy changes associated with melting various types of solids in terms of the types of forces between the particles in the solid.

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C2.1c

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C2.2 Molecules in Motion
Molecules that compose matter are in constant motion (translational, rotational, and vibrational). Energy may be transferred from one object to another during collisions between molecules.

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E

C2.2A
Describe conduction in terms of molecules bumping into each other to transfer energy. Explain why there is better conduction in solids and liquids than gases.

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E

C2.2B
Describe the various states of matter in terms of the motion and arrangement of the molecules (atoms) making up the substance.

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C2.2x Molecular Entropy
As temperature increases, the average kinetic energy and the entropy of the molecules in a sample increases.

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C2.2c
Explain changes in pressure, volume, and temperature for gases using the kinetic molecular model.

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C2.2d
Explain convection and the difference in transfer of thermal energy for solids, liquids, and gases using evidence that molecules are in constant motion.

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C2.2e
Compare the entropy of solids, liquids, and gases.

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C

C2.2f
Compare the average kinetic energy of the molecules in a metal object and a wood object at room temperature.

C

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Compare the average kinetic energy of the molecules in a metal object and a wood object at room temperature.

C2.3x Breaking Chemical Bonds
For molecules to react, they must collide with enough energy (activation energy) to break old chemical bonds before their atoms can be rearranged to form new substances.

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C2.3a
Explain how the rate of a given chemical reaction is dependent on the temperature and the activation energy.

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C

C2.3b

Draw and analyze a diagram to show the activation energy for an exothermic reaction that is very slow at room temperature.

C

C2.3b

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C

C2.3b

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C2.3b

Draw and analyze a diagram to show the activation energy for an exothermic reaction that is very slow at room temperature.

C2.4x Electron Movement
For each element, the arrangement of electrons surrounding the nucleus is unique. These electrons are found in different energy levels and can only move from a lower energy level (closer to nucleus) to a higher energy level (farther from nucleus) by absorbing energy in discrete packets. The energy content of the packets is directly proportional to the frequency of the radiation. These electron transitions will produce unique absorption spectra for each element. When the electron returns from an excited (high energy state) to a lower energy state, energy is emitted in only certain wavelengths of light, producing an emission spectra.

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C2.4a
Describe energy changes in flame tests of common elements in terms of the (characteristic) electron transitions.

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C

C2.4b
Contrast the mechanism of energy changes and the appearance of absorption and emission spectra.

C

C2.4b
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C

C2.4b
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C2.4b
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C2.4x Electron Movement

For each element, the arrangement of electrons surrounding the nucleus is unique. These electrons are found in different energy levels and can only move from a lower energy level (closer to nucleus) to a higher energy level (farther from nucleus) by absorbing energy in discrete packets. The energy content of the packets is directly proportional to the frequency of the radiation. These electron transitions will produce unique absorption spectra for each element. When the electron returns from an excited (high energy state) to a lower energy state, energy is emitted in only certain wavelengths of light, producing an emission spectra.

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C2.4c
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C2.4d
Compare various wavelengths of light (visible and nonvisible) in terms of frequency and relative energy.

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C2.5a
Determine the age of materials using the ratio of stable and unstable isotopes of a particular type.

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C2.r5b
Illustrate how elements can change in nuclear reactions using balanced equations. (recommended)

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C2.r5c
Describe the potential energy changes as two protons approach each other. (recommended)

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C2.r5d
Describe how and where all the elements on earth were formed. (recommended)

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P3.p1 Conservation of Energy (prerequisite)
When energy is transferred from one system to another, the quantity of energy before transfer equals the quantity of energy after transfer. (prerequisite)

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P3.p1A
Explain that the amount of energy necessary to heat a substance will be the same as the amount of energy released when the substance is cooled to the original temperature. (prerequisite)

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C3.1x Hess's Law
For chemical reactions where the state and amounts of reactants and products are known, the amount of energy transferred will be the same regardless of the chemical pathway. This relationship is called Hess's law.

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C3.1a
Calculate the ΔH for a given reaction using Hess's Law.

C

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C3.1b
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C3.1c
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C3.1d
Calculate the amount of heat produced for a given mass of reactant from a balanced chemical equation.

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P3.p2 Energy Transfer (prerequisite)
Nuclear reactions take place in the sun. In plants, light from the sun is transferred to oxygen and carbon compounds, which, in combination, have chemical potential energy photosynthesis). (prerequisite)

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P

P3.p2A
Trace (or diagram) energy transfers involving various types of energy including nuclear, chemical, electrical, sound, and light. (prerequisite)

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P

P3.p2A
Trace (or diagram) energy transfers involving various types of energy including nuclear, chemical, electrical, sound, and light. (prerequisite)

C3.2x Enthalpy
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C3.2b
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C3.3 Heating Impacts
Heating increases the kinetic (translational, rotational, and vibrational) energy of the atoms composing elements and the molecules or ions composing compounds. As the kinetic (translational) energy of the atoms, molecules, or ions increases, the temperature of the matter increases. Heating a sample of a crystalline solid increases the kinetic (vibrational) energy of the atoms, molecules, or ions. When the kinetic (vibrational) energy becomes great enough, the crystalline structure breaks down, and the solid melts.

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C3.3A
Describe how heat is conducted in a solid.

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C3.3B
Describe melting on a molecular level.

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C3.3x Bond Energy
Chemical bonds possess potential (vibrational and rotational) energy.

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C3.3c
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C3.4 Endothermic and Exothermic Reactions
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C3.4A
Use the terms endothermic and exothermic correctly to describe chemical reactions in the laboratory.

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C3.4B
Explain why chemical reactions will either release or absorb energy.

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C3.4x Enthalpy and Entropy
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C3.4c
Write chemical equations including the heat term as a part of equation or using ΔH notation.

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C3.4d
Draw enthalpy diagrams for reactants and products in endothermic and exothermic reactions.

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C3.4e
Predict if a chemical reaction is spontaneous given the enthalpy (ΔH) and entropy (ΔS) changes for the reaction using Gibb's Free Energy, $\Delta G = \Delta H - T\Delta S$ (Note: mathematical computation of ΔG is not required.)

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C

C3.4f
Explain why some endothermic reactions are spontaneous at room temperature.

C

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C3.4g
Explain why gases are less soluble in warm water than cold water.

C3.4g
Explain why gases are less soluble in warm water than cold water.

C3.4g
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C3.5x Mass Defect
Nuclear reactions involve energy changes many times the magnitude of chemical changes. In chemical reactions matter is conserved, but in nuclear reactions a small loss in mass (mass defect) will account for the tremendous release of energy. The energy released in nuclear reactions can be calculated from the mass defect using $E = mc^2$.

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C3.5a
Explain why matter is not conserved in nuclear reactions.

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P4.p1 Kinetic Molecular Theory (prerequisite)
Properties of solids, liquids, and gases are explained by a model of matter that is composed of tiny particles in motion. (prerequisite)

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P4.p1A
For a substance that can exist in all three phases, describe the relative motion of the particles in each of the phases. (prerequisite)

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P4.p1 Kinetic Molecular Theory (prerequisite)
Properties of solids, liquids, and gases are explained by a model of matter that is composed of tiny particles in motion. (prerequisite)

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P4.p1B
For a substance that can exist in all three phases, make a drawing that shows the arrangement and relative spacing of the particles in each of the phases. (prerequisite)

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P4.p1C
For a simple compound, present a drawing that shows the number of particles in the system does not change as a result of a phase change. (prerequisite)

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P4.p2 Elements, Compounds, and Mixtures (prerequisite)

Elements are a class of substances composed of a single kind of atom. Compounds are composed of two or more different elements chemically combined. Mixtures are composed of two or more different elements and/or compounds physically combined. Each element and compound has physical and chemical properties, such as boiling point, density, color, and conductivity, which are independent of the amount of the sample. (prerequisite)

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P4.p2A
Distinguish between an element, compound, or mixture based on drawings or formulae. (prerequisite)

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P

P4.p2B
Identify a pure substance (element or compound) based on unique chemical and physical properties. (prerequisite)

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P4.p2C
Separate mixtures based on the differences in physical properties of the individual components. (prerequisite)

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P4.p2D
Recognize that the properties of a compound differ from those of its individual elements. (prerequisite)

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C4.1x Molecular and Empirical Formulae
Compounds have a fixed percent elemental composition. For a compound, the empirical formula can be calculated from the percent composition or the mass of each element. To determine the molecular formula from the empirical formula, the molar mass of the substance must also be known.

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C

C4.1a
Calculate the percent by weight of each element in a compound based on the compound formula.

C

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Compounds have a fixed percent elemental composition. For a compound, the empirical formula can be calculated from the percent composition or the mass of each element. To determine the molecular formula from the empirical formula, the molar mass of the substance must also be known.

C4.1b
Calculate the empirical formula of a compound based on the percent by weight of each element in the compound.

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C

C4.1c
Use the empirical formula and molecular weight of a compound to determine the molecular formula.

C

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C4.2 Nomenclature
All compounds have unique names that are determined systematically.

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E

C4.2A
Name simple binary compounds using their formulae.

E

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E

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E

C4.2B
Given the name, write the formula of simple binary compounds.

E

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Given the name, write the formula of simple binary compounds.

E

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Given the name, write the formula of simple binary compounds.

E

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E

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C4.2x Nomenclature
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C4.2x Nomenclature
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C4.2c
Given a formula, name the compound.

C4.2c
Given a formula, name the compound.

C4.2c
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C4.2x Nomenclature
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C

C4.2d
Given the name, write the formula of ionic and molecular compounds.

C

C4.2d
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C

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C

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C4.2e
Given the formula for a simple hydrocarbon, draw and name the isomers.

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C4.3 Properties of Substances
Differences in the physical and chemical properties of substances are explained by the arrangement of the atoms, ions, or molecules of the substances and by the strength of the forces of attraction between the atoms, ions, or molecules.

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E

C4.3A

Recognize that substances that are solid at room temperature have stronger attractive forces than liquids at room temperature, which have stronger attractive forces than gases at room temperature.

E

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Recognize that substances that are solid at room temperature have stronger attractive forces than liquids at room temperature, which have stronger attractive forces than gases at room temperature.

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Differences in the physical and chemical properties of substances are explained by the arrangement of the atoms, ions, or molecules of the substances and by the strength of the forces of attraction between the atoms, ions, or molecules.

C4.3 Properties of Substances
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Differences in the physical and chemical properties of substances are explained by the arrangement of the atoms, ions, or molecules of the substances and by the strength of the forces of attraction between the atoms, ions, or molecules.

E

C4.3B
Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.

E

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Recognize that solids have a more ordered, regular arrangement of their particles than liquids and that liquids are more ordered than gases.

C4.3x Solids
Solids can be classified as metallic, ionic, covalent, or network covalent. These different types of solids have different properties that depend on the particles and forces found in the solid.

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C4.3c
Compare the relative strengths of forces between molecules based on the melting point and boiling point of the substances.

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C4.3d
Compare the strength of the forces of attraction between molecules of different elements. (For example, at room temperature, chlorine is a gas and iodine is a solid.)

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C4.3e
Predict whether the forces of attraction in a solid are primarily metallic, covalent, network covalent, or ionic based upon the elements' location on the periodic table.

C4.3e
Predict whether the forces of attraction in a solid are primarily metallic, covalent, network covalent, or ionic based upon the elements' location on the periodic table.

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C4.3f
Identify the elements necessary for hydrogen bonding (N, O, F).

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C4.3g
Given the structural formula of a compound, indicate all the intermolecular forces present (dispersion, dipolar, hydrogen bonding).

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C

C4.3h
Explain properties of various solids such as malleability, conductivity, and melting point in terms of the solid's structure and bonding.

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C4.3i
Explain why ionic solids have higher melting points than covalent solids. (For example, NaF has a melting point of 995°C, while water has a melting point of 0° C.)

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C4.4x Molecular Polarity
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C4.4a
Explain why at room temperature different compounds can exist in different phases.

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C4.4b
Identify if a molecule is polar or nonpolar given a structural formula for the compound.

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C4.5x Ideal Gas Law
The forces in gases are explained by the ideal gas law.

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C

C4.5a
Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-volume relationship in gases.

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C

C4.5b
Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the pressure-temperature relationship in gases.

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C4.5c
Provide macroscopic examples, atomic and molecular explanations, and mathematical representations (graphs and equations) for the temperature-volume relationship in gases.

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C4.6x Moles
The mole is the standard unit for counting atomic and molecular particles in terms of common mass units.

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C

C4.6a
Calculate the number of moles of any compound or element given the mass of the substance.

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C4.6b
Calculate the number of particles of any compound or element given the mass of the substance.

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C4.7x Solutions
The physical properties of a solution are determined by the concentration of solute.

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C4.7a
Investigate the difference in the boiling point or freezing point of pure water and a salt solution.

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C

C4.7b
Compare the density of pure water to that of a sugar solution.

C

C4.7b
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C4.8 Atomic Structure

Electrons, protons, and neutrons are parts of the atom and have measurable properties, including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. A kind of force that is only evident at nuclear distances holds the particles of the nucleus together against the electrical repulsion between the protons.

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E

C4.8A
Identify the location, relative mass, and charge for electrons, protons, and neutrons.

E

C4.8A
Identify the location, relative mass, and charge for electrons, protons, and neutrons.

E

C4.8A
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C4.8B
Describe the atom as mostly empty space with an extremely small, dense nucleus consisting of the protons and neutrons and an electron cloud surrounding the nucleus.

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C4.8C
Recognize that protons repel each other and that a strong force needs to be present to keep the nucleus intact.

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E

C4.8D
Give the number of electrons and protons present if the fluoride ion has a -1 charge.

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C4.8x Electron Configuration
Electrons are arranged in main energy levels with sublevels that specify particular shapes and geometry. Orbitals represent a region of space in which an electron may be found with a high level of probability. Each defined orbital can hold two electrons, each with a specific spin orientation. The specific assignment of an electron to an orbital is determined by a set of 4 quantum numbers. Each element and, therefore, each position in the periodic table is defined by a unique set of quantum numbers.

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C4.8e
Write the complete electron configuration of elements in the first four rows of the periodic table.

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C4.8f
Write kernel structures for main group elements.

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C4.8g
Predict oxidation states and bonding capacity for main group elements using their electron structure.

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C4.8h
Describe the shape and orientation of s and p orbitals.

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C4.8i
Describe the fact that the electron location cannot be exactly determined at any given time.

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C4.9 Periodic Table
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E

C4.9A
Identify elements with similar chemical and physical properties using the periodic table.

E

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C4.9x Electron Energy Levels
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C4.9b
Identify metals, non-metals, and metalloids using the periodic table.

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C4.9c
Predict general trends in atomic radius, first ionization energy, and electonegativity of the elements using the periodic table.

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C4.10 Neutral Atoms, Ions, and Isotopes
A neutral atom of any element will contain the same number of protons and electrons. Ions are charged particles with an unequal number of protons and electrons. Isotopes are atoms of the same element with different numbers of neutrons and essentially the same chemical and physical properties.

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E

C4.10A
List the number of protons, neutrons, and electrons for any given ion or isotope.

E

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E

C4.10B
Recognize that an element always contains the same number of protons.

E

C4.10B
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E

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E

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C4.10x Average Atomic Mass
The atomic mass listed on the periodic table is an average mass for all the different isotopes that exist, taking into account the percent and mass of each different isotope.

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C

C4.10c
Calculate the average atomic mass of an element given the percent abundance and mass of the individual isotopes.

C

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C4.10d
Predict which isotope will have the greatest abundance given the possible isotopes for an element and the average atomic mass in the periodic table.

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C4.10e

Write the symbol for an isotope, $^{Z}X_{A}$, where Z is the atomic number, A is the mass number, and X is the symbol for the element.

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P5.p1 Conservation of Matter (prerequisite)
Changes of state are explained by a model of matter composed of tiny particles that are in motion. When substances undergo changes of state, neither atoms nor molecules themselves are changed in structure. Mass is conserved when substances undergo changes of state. (prerequisite)

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P5.p1A
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C5.r1x Rates of Reactions (recommended)
The rate of a chemical reaction will depend upon (1) concentration of reacting species, (2) temperature of reaction, (3) pressure if reactants are gases, and (4) nature of the reactants. A model of matter composed of tiny particles that are in constant motion is used to explain rates of chemical reactions. (recommended)

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R

C5.r1a
Predict how the rate of a chemical reaction will be influenced by changes in concentration, and temperature, pressure. (recommended)

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R

C5.r1b
Explain how the rate of a reaction will depend on concentration, temperature, pressure, and nature of reactant. (recommended)

R

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C5.2 Chemical Changes

Chemical changes can occur when two substances, elements, or compounds interact and produce one or more different substances whose physical and chemical properties are different from the interacting substances. When substances undergo chemical change, the number of atoms in the reactants is the same as the number of atoms in the products. This can be shown through simple balancing of chemical equations. Mass is conserved when substances undergo chemical change. The total mass of the interacting substances (reactants) is the same as the total mass of the substances produced (products).

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E

C5.2A
Balance simple chemical equations applying the conservation of matter.

E

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E

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E

C5.2B
Distinguish between chemical and physical changes in terms of the properties of the reactants and products.

E

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E

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E

C5.2C
Draw pictures to distinguish the relationships between atoms in physical and chemical changes.

E

C5.2C
Draw pictures to distinguish the relationships between atoms in physical and chemical changes.

E

C5.2C
Draw pictures to distinguish the relationships between atoms in physical and chemical changes.

E

C5.2C
Draw pictures to distinguish the relationships between atoms in physical and chemical changes.

E

C5.2C
Draw pictures to distinguish the relationships between atoms in physical and chemical changes.

E

C5.2C
Draw pictures to distinguish the relationships between atoms in physical and chemical changes.

C5.2x Balancing Equations
A balanced chemical equation will allow one to predict the amount of product formed.

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C5.2d
Calculate the mass of a particular compound formed from the masses of starting materials.

C5.2d
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C5.2e
Identify the limiting reagent when given the masses of more than one reactant.

C5.2e
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C

C5.2f
Predict volumes of product gases using initial volumes of gases at the same temperature and pressure.

C

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C

C5.2f
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C

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C

C5.2g
Calculate the number of atoms present in a given mass of element.

C

C5.2g
Calculate the number of atoms present in a given mass of element.

C

C5.2g
Calculate the number of atoms present in a given mass of element.

C

C5.2g
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C

C5.2g
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C

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Calculate the number of atoms present in a given mass of element.

C5.3x Equilibrium
Most chemical reactions reach a state of dynamic equilibrium where the rates of the forward and reverse reactions are equal.

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C5.3a
Describe equilibrium shifts in a chemical system caused by changing conditions (Le Chatelier's Principle).

C5.3a
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C5.3x Equilibrium
Most chemical reactions reach a state of dynamic equilibrium where the rates of the forward and reverse reactions are equal.

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C5.3b
Predict shifts in a chemical system caused by changing conditions (Le Chatelier's Principle).

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C5.3c
Predict the extent reactants are converted to products using the value of the equilibrium constant.

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C5.4 Phase Change/Diagrams
Changes of state require a transfer of energy. Water has unusually high-energy changes associated with its changes of state.

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E

C5.4A
Compare the energy required to raise the temperature of one gram of aluminum and one gram of water the same number of degrees.

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E

C5.4B
Measure, plot, and interpret the graph of the temperature versus time of an ice-water mixture, under slow heating, through melting and boiling.

E

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C5.4x Changes of State
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C5.4c
Explain why both the melting point and boiling points for water are significantly higher than other small molecules of comparable mass (e.g., ammonia and methane).

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C5.4d
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C5.4e
Compare the melting point of covalent compounds based on the strength of IMFs (intermolecular forces).

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C5.5 Chemical Bonds — Trends

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E

C5.5A
Predict if the bonding between two atoms of different elements will be primarily ionic or covalent.

E

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E

C5.5B
Predict the formula for binary compounds of main group elements.

E

C5.5B
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E

C5.5B
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C5.5x Chemical Bonds
Chemical bonds can be classified as ionic, covalent, and metallic. The properties of a compound depend on the types of bonds holding the atoms together.

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C5.5c
Draw Lewis structures for simple compounds.

C5.5c
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C5.5d
Compare the relative melting point, electrical and thermal conductivity and hardness for ionic, metallic, and covalent compounds.

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C

C5.5e
Relate the melting point, hardness, and electrical and thermal conductivity of a substance to its structure.

C

C5.5e
Relate the melting point, hardness, and electrical and thermal conductivity of a substance to its structure.

C

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Relate the melting point, hardness, and electrical and thermal conductivity of a substance to its structure.

C5.6x Reduction/Oxidation Reactions
Chemical reactions are classified according to the fundamental molecular or submolecular changes that occur. Reactions that involve electron transfer are known as oxidation/reduction (or “redox”).

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C5.6a
Balance half-reactions and describe them as oxidations or reductions.

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C

C5.6b
Predict single replacement reactions.

C

C5.6b
Predict single replacement reactions.

C

C5.6b
Predict single replacement reactions.

C

C5.6b
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C

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C

C5.6c
Explain oxidation occurring when two different metals are in contact.

C

C5.6c
Explain oxidation occurring when two different metals are in contact.

C

C5.6c
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C

C5.6c
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C5.6d
Calculate the voltage for spontaneous redox reactions from the standard reduction potentials.

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C5.6e
Identify the reactions occurring at the anode and cathode in an electrochemical cell.

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C5.7 Acids and Bases
Acids and bases are important classes of chemicals that are recognized by easily observed properties in the laboratory. Acids and bases will neutralize each other. Acid formulas usually begin with hydrogen, and base formulas are a metal with a hydroxide ion. As the pH decreases, a solution becomes more acidic. A difference of one pH unit is a factor of 10 in hydrogen ion concentration.

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E

C5.7A
Recognize formulas for common inorganic acids, carboxylic acids, and bases formed from families I and II.

E

C5.7A
Recognize formulas for common inorganic acids, carboxylic acids, and bases formed from families I and II.

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C5.7 Acids and Bases
Acids and bases are important classes of chemicals that are recognized by easily observed properties in the laboratory. Acids and bases will neutralize each other. Acid formulas usually begin with hydrogen, and base formulas are a metal with a hydroxide ion. As the pH decreases, a solution becomes more acidic. A difference of one pH unit is a factor of 10 in hydrogen ion concentration.

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C5.7B
Predict products of an acid-base neutralization.

E

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C5.7C
Describe tests that can be used to distinguish an acid from a base.

E

C5.7C
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C5.7C
Describe tests that can be used to distinguish an acid from a base.

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C5.7D
Classify various solutions as acidic or basic, given their pH.

E

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E

C5.7E
Explain why lakes with limestone or calcium carbonate experience less adverse effects from acid rain than lakes with granite beds.

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C5.7x Brønsted-Lowry
Chemical reactions are classified according to the fundamental molecular or submolecular changes that occur. Reactions that involve proton transfer are known as acid/base reactions.

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C5.7f
Write balanced chemical equations for reactions between acids and bases and perform calculations with balanced equations.

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C5.7g
Calculate the pH from the hydronium ion or hydroxide ion concentration.

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C5.7h
Explain why sulfur oxides and nitrogen oxides contribute to acid rain.

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C5.r7i
Identify the Brønsted-Lowry conjugate acid-base pairs in an equation. (recommended)

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C5.8 Carbon Chemistry
The chemistry of carbon is important. Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

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E

C5.8A
Draw structural formulas for up to ten carbon chains of simple hydrocarbons.

E

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E

C5.8B
Draw isomers for simple hydrocarbons.

E

C5.8B
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E

C5.8C
Recognize that proteins, starches, and other large biological molecules are polymers.

E

C5.8C
Recognize that proteins, starches, and other large biological molecules are polymers.

E

C5.8C
Recognize that proteins, starches, and other large biological molecules are polymers.

E

C5.8C
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