Science Standard 2
Materials and Their Properties

Materials exist throughout our physical world. The structures of materials influence their physical properties, chemical reactivity and use.

Strand	Grades K-3	Grades 4-5	Grades 6-8	Grades 9-12
Properties and Structure of Materials Enduring Understanding: The structures of materials determine their properties. Essential Question: How do the properties of materials determine their use? (Grades K-8) Essential Question: How do the properties and structures of materials determine their uses? (Grades 9-12)	A. Materials can be described and classified according to the following physical properties: size, shape, mass, texture, color, and material composition. Students can observe materials' physical properties by using tools that include rulers, balances, thermometers and hand lenses. **Level: Essential** B. Materials exist in one of three states – solid, liquid, or gas. Solids and liquids have easily observable properties and may change from one form to the other. **Level: Essential** C. Physical properties of materials can be changed by exposure to water, heat, light, or by cutting, mixing, and grinding. **Level: Essential**	A. Observable physical properties can be used to classify materials. These physical properties may include solubility, mass, magnetism, and electrical conductivity. Tools such as graduated cylinders, balances, rulers, magnifiers, simple circuits, and magnets are used to study the physical properties. **Level: Essential** B. Heating and cooling of materials may produce changes in the state of solids, liquids and gases. **Level: Important**	A. All matter consists of particles too small to be seen with the naked eye. The arrangement, motion, and interaction of these particles determine the three states of matter (solid, liquid, and gas). Particles in all three states are in constant motion. In the solid state, tightly packed particles have a limited range of motion. In the liquid state, particles are loosely packed and move past each other. In the gaseous state, particles are free to move. **Level: Essential** B. A phase change may occur when a material absorbs or releases heat energy. Changes in phase do not change the particles but do change how they are arranged. **Level: Important** C. Some physical properties, such as mass and volume, depend upon the amount of material. Other physical properties, such as density and melting point, are independent of the quantity of material. Density and melting point are unique physical properties for a material. Tools such as microscopes, scales, beakers, graduated cylinders, Celsius thermometers, and metric rulers are used to measure physical properties. **Level: Essential**	A. All matter is composed of minute particles called atoms. Most of the mass of an atom is concentrated in the nucleus. In the nucleus, there are neutrons with no electrical charge and positively charged protons. Negatively charged electrons surround the nucleus and overall, the atom is electrically neutral. **Level: Essential** B. Elements and compounds are pure substances. Elements cannot be decomposed into simpler materials by chemical reactions. Elements can react to form compounds. Elements and/or compounds may also be physically combined to form mixtures. **Level: Essential** C. Isotopes of a given element differ in the number of neutrons in the nucleus. Their chemical properties remain essentially the same. **Level: Important** D. The periodic table arranges the elements in order of atomic number (the number of protons). The elements are grouped according to similar chemical and physical properties. Properties vary in a regular pattern across the rows (periods) and down the columns (families or groups). *(Continued on next page)*

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Properties and Structure of Materials *(Continued from previous page)*			D. An important property of materials is their ability to conduct heat. Some materials, such as certain metals, are excellent conductors of heat while other materials, such as glass, are poor conductors (good thermal insulators). **Level: Important** E. Exposure to energy, such as light and heat, may change the physical properties of materials. **Level: Compact**	As a result, an element's chemical and physical properties can be predicted knowing only its position on the periodic table. **Level: Important** E. An atom's electron structure determines its physical and chemical properties. Metals have valence electrons that can be modeled as a sea of electrons where the valence electrons move freely and are not associated with individual atoms. These freely moving electrons explain the metallic properties such as conductivity, malleability, and ductility. **Level: Essential** F. Ionic compounds form when atoms transfer electrons. Covalent compounds form when atoms share electrons. Both types of interactions generally involve valence electrons and produce chemical bonds that determine the chemical property of the compound. **Level: Essential** G. A change in physical properties does not change the chemical composition of the substance. The physical properties of elements and compounds (such as melting and boiling points) reflect the nature of the interactions among their atoms, ions, or molecules and the electrical forces that exist between. **Level: Important**

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Properties and Structure of Materials *(Continued from previous page)*				H. A change of phase may occur when there is a change in the potential energy of the atoms or molecules of a substance. **Level: Compact** I. Temperature, pressure, and volume are important properties of a gas. A change in two of these properties results in predictable changes in the third. **Level: Compact**
Mixtures and Solutions Enduring Understanding: The properties of a mixture are based on the properties of its components. Essential Questions: How can the properties of the components of a mixture be used to separate the mixture? How do the components determine the properties of mixtures?		A. Most materials are physical mixtures. Physical mixtures can be composed of different kinds of materials, each having distinct physical properties. These physical property differences can be used to separate, sort, and group the materials of the mixture. **Level: Essential** B. Mixtures can consist of different combinations of solids and/or liquids. The characteristics of these resulting mixtures depend on the relative amounts and properties of the components. **Level: Essential** C. Physical properties can be used to separate mixtures through techniques such as filtration and evaporation. **Level: Essential** D. When a solid is dissolved in a liquid, a solution is formed that can be separated through the process of evaporation. **Level: Essential**	A. Mixtures can be homogeneous or heterogeneous. Mixtures may be solids, liquids, and/or gases. Most materials are physical mixtures consisting of different components in varying concentrations. The individual components can be separated using the components' unique physical properties. **Level: Essential** B. Solutions are homogenous mixtures of two or more components. The properties of a solution depend on the nature and concentration of the solute(s) and the nature of the solvent(s). **Level: Important** C. The rate of solubility is influenced by temperature and the surface area of the solute. **Level: Essential** D. Temperature of the solvent can affect the saturation point of the solution. **Level: Important**	A. Properties of solutions, such as pH, solubility, and electrical conductivity depend upon the concentration and interactions of the solute and solvents. **Level: Important** B. A variety of methods can be used to separate mixtures into their component parts based upon the chemical and physical properties of the individual components. **Level: Important**

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Mixtures and Solutions *(Continued from previous page)*			E. In mixtures, individual components move from areas of higher concentration to areas of lower concentration to eliminate concentration differences. Diffusion is the movement of individual components. **Level: Compact**	
Conservation of Matter Enduring Understanding: When materials interact within a closed system, the total mass of the system remains the same. Essential Questions: How does conservation of mass apply to the interaction of materials in a closed system?		A. The mass of an object remains unchanged when broken into parts. The sum of the parts equals the whole. **Level: Essential**	A. The total mass of the mixture is equal to the sum of the masses of the components. Total mass is conserved when different substances are mixed. **Level: Important**	A. The total mass of the system remains the same regardless of how atoms and molecules in a closed system interact with one another, or how they combine or break apart. **Level: Essential** B. Radioactive isotopes are unstable and undergo spontaneous and predictable nuclear reactions emitting particles and/or radiation, and become new isotopes that can have very different properties. In these nuclear changes, the total of the mass and energy remains the same. **Level: Important**
Chemical Reactions Enduring Understanding: There are several ways in which elements and/or compounds react to form new substances and each reaction involves energy. Essential Question: What determines the type and extent of a chemical reaction?				A. Chemical reactions result in new substances with properties that are different from those of the component parts (reactants). **Level: Essential** B. There are different types of chemical reactions. Precipitation reactions produce insoluble substances (e.g., double replacement). *(Continued on next page)*

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Chemical Reactions *(Continued from previous page)*				The transfer of electrons between atoms is a reduction-oxidation (redox) reaction (e.g., single-replacement combustion, synthesis, decomposition). Some acid/base reactions involve the transfer of hydrogen ions. **Level: Important** C. The rate of a chemical reaction depends on the properties and concentration of the reactants, temperature, and the presence or absence of a catalyst. **Level: Essential** D. Energy is transformed in chemical reactions. Energy diagrams can illustrate this transformation. Exothermic reactions release energy. Endothermic reactions absorb energy. **Level: Essential** E. A catalyst lowers the activation energy of a chemical reaction. The catalyst remains unchanged and is not consumed in the overall reaction. Enzymes are protein molecules that catalyze chemical reactions in living systems. **Level: Important** F. Certain small molecules (monomers) react with one another in repetitive fashion (polymerization) to form long chain macromolecules (polymers). *(Continued on next page)*

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Chemical Reactions *(Continued from previous page)*				The properties of the macromolecules depend on the properties of the molecules used in their formation and on the lengths and structure of the polymer chain. Polymers can be natural or synthetic. **Level: Compact**
Material Technology Enduring Understanding: People develop new materials as a response to the needs of society and the pursuit of knowledge. This development may have risks and benefits to humans and the environment. Essential Questions: How do you know which material is best for a particular product or need? What determines if new materials need to be developed? Why should people consider the risks and benefits before the production of new materials and/or the implementation of a new process?	A. The properties of materials influence their use. Some materials are more suitable for making a particular product or device. **Level: Compact** B. Technology has created new materials that can help people solve problems. **Level: Compact**	A. Many materials can be recycled and used again (sometimes in different forms). **Level: Compact**	A. Synthetic materials and/or modified natural materials are produced to make products used in everyday life. **Level: Compact** B. The production of new materials has social, environmental, and other implications that require analyses of the risks and benefits. **Level: Compact**	A. Materials' properties determine their use. New materials can improve the quality of life. However, their development and production often raise social, economic, and environmental issues that require analyses of the risks and benefits. **Level: Compact**