

Potential Revisions to Virginia's Science Standards of Learning to Include Nanoscience Concepts

*A Draft Document Developed by the MathScience Innovation Center for Use in
Advocating Revisions to the Science Standards
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Science 6

- 6.1 The student will plan and conduct investigations in which**
- a) through i) same
 - j) *Revise:* models are used to illustrate and explain phenomena and systems**
 - k) same
- 6.4 The student will investigate and understand that all matter is made up of atoms. Key concepts include**
- a) atoms are made up of electrons, protons and neutrons;
 - b) *Add:* atoms are in constant motion because of thermal energy;**
 - c) Old b – atoms of any element are alike but are different from atoms of other elements
 - d) Old c – elements may be represented by chemical symbols;
 - e) *Revise old d – two or more atoms may interact to form new substances which are held together by electrical forces (bonds);***
 - f) Old e – compounds may be represented by chemical formulas;
 - g) Old f – chemical equations can be used to model chemical changes;
 - h) *Add:* electrical forces dominate at the atomic level;**
 - i) Old g – a limited number of elements comprise the largest portion of the solid;
 - j) Earth, living matter, oceans, and the atmosphere.

6.5 The student will investigate and understand the unique properties and characteristics of water and its role in the natural and human-made environment. Key concepts include

a) water as the universal solvent;

Details for Curriculum Framework: *role of electrical charges on water molecule in solubility of substances and in cohesion, adhesion, and surface tension*

b) the properties of water in all three states;

Details for Curriculum Framework: *role of hydrogen bonding in unique properties of water*

c) the action of water in physical and chemical weathering;

d) the ability of large bodies of water to store heat and moderate climate;

e) the origin and occurrence of water on Earth;

f) the importance of water for agriculture, power generation, and public health; and

g) the importance of protecting and maintaining water resources.

Life Science

LS.1 The student will plan and conduct investigations in which

a) through c) same

d) Revise: *Models are used to illustrate structures and systems and to make predictions*

e) through j) same

LS.2 The student will investigate and understand that all living things are composed of cells. Key concepts include

a) cell structure and organelles (cell membrane, cell wall, cytoplasm, vacuole, mitochondrion, endoplasmic reticulum, nucleus, and chloroplast);

b) similarities and differences between plant and animal cells;

- c) development of cell theory;
- d) cell division (mitosis and meiosis);
- e) **Add:** *impact of surface area to volume ratio on cell division and material transport.*

Physical Science

PS.1 The student will plan and conduct investigations in which

- a) through n) – same
- o) **Add:** *models are used to visualize and understand objects and systems and to make predictions*

PS.2 The student will investigate and understand the basic nature of matter. Key concepts include

- a) the particle theory of matter;
- b) **Revise:** elements, *allotropes*, compounds, mixtures, acids, bases, and salts;

Details for Curriculum Framework: *At the macroscale, carbon allotropes include diamond, graphite, charcoal, graphene; at the nanoscale, allotropes include nanotubes and bucky-balls.*

- c) solids, liquids, and gases;
- d) characteristics of types of matter based on physical and chemical properties;
- e) **Revise:** physical properties (shape, density, solubility, odor, melting point, boiling point, color, *conductivity*);
- f) chemical properties (acidity, basicity, combustibility, reactivity);
- g) **Add:** *size and scale of matter and the dominant force at various scales*

Details for Curriculum Framework: *Scales include macro, micro, nano, atomic and subatomic; forces include gravitational, electrical, and nuclear forces.*

- h) **Add:** *changes in properties of substances at the nanoscale*

Details for Curriculum Framework: *Focus on changes in strength, conductivity, and chemical reactivity.*

PS.4 The student will investigate and understand the organization and use of the periodic table of elements to obtain information. Key concepts include

- a) symbols, atomic number, atomic mass, chemical families (groups), and periods;
- b) classification of elements as metals, metalloids, and nonmetals; and
- c) **Revise:** simple compounds (formulas and the *electrical* nature of bonding).

Details for Curriculum Framework: *ionic, covalent, metallic bonds.*

PS.5 The student will investigate and understand changes in matter and the relationships of these changes to the Law of Conservation of Matter and Energy. Key concepts include

- a) physical changes;
- b) nuclear reactions (products of fusion and fission and the effect of these products on humans and the environment);
- c) chemical changes (types of reactions, reactants, and products; and balanced equations);
- d) **Add:** *impact of surface area/volume ratio and thermal energy*

Details for Curriculum Framework: *Focus on state changes, solubility, and chemical reactivity.*

PS.9 The student will investigate and understand the nature and technological applications of light. Key concepts include

- a) the wave behavior of light (reflection, refraction, diffraction, and interference);
- b) images formed by lenses and mirrors; and
- c) **Revise:** *the electromagnetic spectrum including the relative size and scale of its components*

PS.11 The student will investigate and understand basic principles of electricity and magnetisms. Key concepts include

- a) static electricity, current electricity, and circuits;
- b) magnetic fields and electromagnets; ~~and~~
- c) motors and generators
- d) conductors, semiconductors, and insulators and changes in conductivity at various scales*

Earth Science

ES. 1 The student will demonstrate scientific reasoning and logic by

- a) through e) same
- f) Add: use of scientific notation to express relative size and scale*
- g) Add: models are used to visualize systems, make predictions, and interpret data*

ES.5 *Revise: The student will investigate and understand how to identify major minerals, the processes that produce them, and their physical and chemical properties. Key concepts include*

- a) hardness, color and streak, luster, cleavage, fracture, and unique properties:
- b) the uses of minerals
- c) Add: mineral formation through chemical and biological processes*

Details for Curriculum Framework: *Typically, minerals are formed by inorganic processes; however, through nanoscience scientists are developing an increased understanding of the role of biological processes such as the formation of minerals in fossil shells (aragonite) and in fossil teeth (apatite).*

- d) Add: changes in properties of minerals at the nanoscale*

Details for Curriculum Framework: *Focus on the impact of the surface area/volume ratio on properties used for identification (color, streak) and properties that affect behavior in the environment (solubility, transport)*

ES.10 The student will investigate and understand that many aspects of the history and evolution of the Earth and life can be inferred by studying rocks and fossils.

Key concepts include

- a) tracts and remains of ancient, often extinct, life are preserved by various means in many sedimentary rocks;
- b) superposition, cross-cutting relationships, index fossils, and radioactive decay are methods of dating bodies of rock;
- e) absolute and relative dating have different applications but can be used together to determine the age of rocks and structures; ~~and~~
- d) rocks and fossils from many different geological periods and epochs are found in Virginia;
- e) **Add:** *the interaction of geologic, oceanographic, atmospheric and biological processes.*

Details for Curriculum Framework: *Role of nanosized particles (especially iron) in formation of primitive ocean, atmosphere, and life.*

ES.12 The student will investigate and understand the origin and evolution of the atmosphere and the interrelationship of geologic process, biologic processes, and human activities on its composition and dynamics. Key concepts include

- a) scientific evidence for atmospheric changes over geologic time;
- b) current theories related to the effects of early life on the chemical makeup of the atmosphere;
- c) comparison of the Earth's atmosphere to that of other planets;
- d) **Revise:** *atmospheric regulation mechanisms including the effects of density differences, ~~and~~ energy transfer, oceanographic influences, and very small particulates;*
- e) potential atmospheric compositional changes due to human, biologic, and geologic activity.

ES.13 The student will investigate and understand that energy transfer between the sun and the Earth and its atmosphere drives weather and climate on Earth. Key concepts include

- a) observation and collection of water data;
- b) prediction of weather patterns;
- b) severe weather occurrences, such as tornadoes, hurricanes, and major storms; and
- c) *Revise: weather phenomena and the geologic, oceanographic and biological factors that affect climate ~~including radiation and convection.~~*

ES.14 The student will investigate and understand scientific concepts related to the origin and evolution of the universe. Key concepts include

- a) nebulae;
- b) the origin of stars and star systems;
- c) stellar evolution;
- d) galaxies;
- e) cosmology including the big bang theory
- f) *Add: size and scale of components of the universe and the dominant force at various scales.*

Details for Curriculum Framework: *Scales include the astronomical, macro, micro, nano, atomic, subatomic; dominant forces include gravity, electrical, and nuclear.*

Biology

BIO.2 The student will investigate and understand the history of biological concepts. Key concepts include

a) through d) same

d) **Add:** *the role of advancements in imaging techniques in creating models of structures and phenomena which were previously inaccessible because of size and scale*

Details for Curriculum Framework: *advancements include imaging techniques at the nanoscale (electron microscopy and spectroscopy) and of very large systems (satellite imaging, GPS) as well as computer-based models and simulations*

BIO.3 The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include

a) water chemistry and its impact on life processes;

b) the structure and function of macromolecules;

c) the nature of enzymes;

d) **Add:** *the role of hydrogen bonding in water chemistry and biological reactions;*

e) Old d – the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration;

f) **Add:** *the impact of surface area/volume ratio on life processes.*

BIO.5 The student will investigate and understand life functions of archaeobacteria, monerans (eubacteria), protists, fungi, plants, and animals including humans. Key concepts include

a) how their structures and functions vary between and within the kingdoms;

b) comparison of their metabolic activities;

c) analyses of their responses to the environment;

- d) maintenance of homeostasis;
- e) human health issues, human anatomy, body systems, and life functions;
- f) how viruses compare with organisms;

g) **Add:** *relative size and scale of various organisms and their components*

Details for Curriculum Framework: *organisms, cells, subcellular components, macromolecules, atoms, subatomic particles; use of scientific notation to express relative size and scale*

h) **Add:** *major forces operating at various sizes and scales and adaptive responses to these forces*

Details for Curriculum Framework: *thermal energy, Brownian Motion, viscosity, electrical forces, gravity*

BIO.6 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include

- a) cell growth and division;
- b) gamete formation;
- c) cell specialization;
- d) prediction of inheritance of traits based on the Mendelian laws of heredity;
- e) genetic variation (mutation, recombination, deletions, additions to DNA);
- f) the structure, function, and replication of nucleic acids (DNA and RNA);
- g) events involves in the construction of proteins;

h) **Add:** *self-assembly at various biological levels*

Details for Curriculum Framework: *DNA, RNA, proteins, membranes, skeletal components;*

i) Old h – use , limitations, and misuse of genetic information;

j) **Revise old I** – ~~exploration of the impact of DNA, nanoscale technologies, and new imaging tools~~

Chemistry

CH.1 The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated produce observations and verifiable data. Key concepts include:

a) through i) same

k) **Add:** *impact of new tools and instruments on increased understanding of nano, atomic and subatomic scales*

Details for Curriculum Framework: *Scanning probe microscopes, computer-based models, and simulations*

CH.2 The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The period table is a tool used for the investigations of

a) average atomic mass, mass number, and atomic number;

b) isotopes, half lives, and radioactive decay;

c) mass and charge characteristics of subatomic particles;

d) families or groups;

e) series and periods;

f) trends including atomic radii, electronegativity, shielding effect, and ionizing energy

f) electronic configurations, valence electrons, and oxidation numbers

g) **Add:** *relative size and scale of matter and dominant forces*

Details for Curriculum Framework: *Scales include macro, micro, nano, atomic, and subatomic; forces include gravitational, electrical, and nuclear forces (strong and weak).*

h) **Revise old g:** chemical and physical properties *at the macro and nanoscale*

i) Old I - historical and quantum models

CH.3 The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

- a) nomenclature
- b) balancing chemical equations
- c) writing chemical formulas (molecular, structure, and empirical; and Lewis diagram
- d) **Revise:** *the electrical nature of bonds and their relative strength*

Details for Curriculum Framework: *ionic, covalent, hydrogen bonds and van der Waals force.*

- e) reaction types (synthesis, decomposition, single and double replacement, oxidation-reduction, neutralization, exothermic, and endothermic)
- f) **Revise:** reaction rates and kinetics (activation energy, catalysis, degree of randomness, *surface area/volume ratios*)

CH.5 The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

- a) pressure, temperature and volume
- b) vapor pressure
- c) phase changes
- d) molar heats of fusion and vaporization
- e) specific heat capacity
- f) colligative properties
- g) **Add:** *thermal energy and Brownian motion*
- h) **Add:** *the impact of various types of bonds*

Details for Curriculum Framework: *ionic, covalent, hydrogen, van der Waals*

Physics

PH.1 The student will plan and conduct investigations in which

- a) through h) same
- i) **Add:** *models are used to visualize and explain phenomena and to make predictions, form hypotheses, and interpret data.*

PH.7 The student will investigate and understand properties of fluids. Key concepts include

- a) density and pressure
- b) variation of pressure with depth
- c) Archimedes' principle of buoyancy
- d) Pascal's principle
- e) **Revise:** *Fluids in motion and viscosity*
- f) Bernoulli's principle

PH.10 The student will investigate and understand that different frequencies and wavelengths in the electromagnetic spectrum are phenomena ranging from radio waves through visible light to gamma radiation. Key concepts include:

- a) **Revise:** the properties, behaviors *and relative size* of radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays;
- b) **Revise:** current applications based on the *relative size, scale*, and wave properties of each band.

PH.11 The student will investigate and understand, in describing optical systems, how light behaves in the fundamental processes of reflection, refraction, and image formation. Key concepts include

- a) application of the laws of reflection and refraction;
- b) construction and interpretation of ray diagrams;

- c) development and use of mirror and lens equations;
- d) predictions of type, size and position of real and virtual images;
- e) **Add:** *precise manipulation of light through nanoscale structures*

Details for Curriculum Framework: *quantum dots, crystal, photonic, conductive mirrors versus dielectric mirrors*

PH.14 The student will investigate and understand that extremely large and extremely small quantities are not necessarily described by the same laws as those studied in Newtonian physics. Key concepts include

- a) wave/particle duality
- b) wave properties of matter
- c) matter/energy equivalence
- d) quantum mechanics, uncertainty
- e) relativity
- f) nuclear physics
- g) **Revise:** solid state physics, *band gap, changes at various scales*
- h) superconductivity