

Core Idea PS1

Matter and Its Interactions

How can one explain the structure, properties, and interactions of matter?

- existence
- atoms
- evidence
- postulate
- model
- qualitative
- quantitative
- observations
- matter
- Brownian motion
- ratio
- reactant(s)
- product(s)
- chemical reactions
- atom(s)
- states of matter (i.e., solid, liquid, gas, or plasma)
- properties of matter (e.g., hardness, conductivity)
- reactions (both physical and chemical)
- matter (types, interactions, and motions of the atoms)
- chemical reaction
- living and nonliving systems
- molecules
- nuclear reactions
- atomic nuclei
- energy
- isotopes

PS1.A: STRUCTURE AND PROPERTIES OF MATTER

How do particles combine to form the variety of matter one observes?

- visible light
- atoms
- nucleus—containing protons and neutrons
- electrons
- atomic nucleus
- atomic number
- element

- isotope
- neutron
- chemical property
- periodic table
- families of elements
- valence electron(s)
- chemical reactivity
- bond formation
- atomic substructure
- electrical attraction
- electrical repulsion
- charged particles (i.e., atomic nuclei and electrons)
- matter
- forces between atoms
- chemical bonds
- biological molecules
- proteins
- crystals
- metals
- physical properties of matter/minerals (e.g., hardness, conductivity)
- kinetic theory
- motion
- state of matter (e.g., solid, liquid)
- chemical composition
- temperature
- pressure
- properties materials (e.g., density, elasticity, viscosity)
- properties materials (e.g., volume, mass)
- measureable properties
- plastics
- nanoparticles
- physical functioning
- chemical functioning
- biological systems

Grade Band Endpoints for PS1.A

By the end of grade 2.

- kinds of matter exist (e.g., wood, metal, water)
- solid
- liquid
- temperature
- matter

- observable properties (e.g., visual, aural, textural)
- properties can be described and measured. (Boundary: volume is introduced only for liquid measure.)
- weight
- weigh/mass

By the end of grade 5.

- matter
- particles (that are too small to see, but even then the matter still exists and can be detected by other means (e.g., by weighing or by its effects on other objects))
- model
- gas(es)
- space
- inflation
- shape
- visible
- scale
- water droplets
- condensation
- fog
- clouds
- contrails of a jet
- weight (the amount of matter)
- conservation of matter
- dissolution/dissolve
- evaporation
- measurement
- properties of matter (e.g., hardness, reflectivity) (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.)

By the end of grade 8.

- substance
- atom
- combine
- molecule
- pure substance
- physical properties
- chemical properties
- gas(es)

- liquid(s)
- inert atom(s)
- solids
- crystals(s)
- changes of state (occur with variations in temperature or pressure)
- prediction
- models of matter. (Boundary: Predictions here are qualitative, not quantitative.)

By the end of grade 12.

- atom
- nucleus
- proton
- neutrons
- electron
- periodic table
- periods (orders elements horizontally by the number of protons in the atom's nucleus)
- families (place those with similar chemical properties in columns)
- valence (reflect patterns of outer electron states)
- structure and interactions of matter
- bulk scale
- electrical forces (within and between atoms)
- stable forms of matter
- electric field energy
- magnetic field energy
- stable molecule (has less energy, by an amount known as the binding energy, than the same set of atoms separated)

PS1.B: CHEMICAL REACTIONS

How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?

- chemical reactivity
- chemical properties
- substance
- atom
- conservation of matter
- conservation of mass
- element(s)
- molecule(s)
- solution

Understanding chemical reactions and the properties of elements is essential not only to the physical sciences but also is foundational knowledge for the life sciences and the earth and space sciences.

- change of state
- reversible Δ (return to original conditions)
- nonreversible Δ (chemical change)
- collision theory
- qualitative model
- rate of chemical reaction
- kinetic theory of matter
- solution
- gas
- chemical composition—that is, be in a steady state
- dynamic balance
- chemical process
- chemical bonds
- bond energies
- chemical binding energy
- total kinetic energy
- reactant molecule(s)
- product molecule(s)
- collision
- conservation of energy
- chemical reactions that release energy (e.g., burning fuel in the presence of oxygen),
- chemical reactions that require energy input (e.g., synthesis of sugars from carbon dioxide and water).
- physical sciences
- life sciences
- earth and space sciences
- cycling of matter
- transfers of energy in systems
- scale
- physical processes
- chemical processes
- reactivity
- hydrogen
- ion(s)
- biological and geophysical phenomena

- carbon atoms
- backbone of carbon
- chemistry of life
- carbon cycle
- atmospheric carbon
- atmosphere
- carbon dioxide—and carbon in living matter or formerly living matter (including fossil fuels)
- proportion
- oxygen (i.e., oxygen in the form O₂)
- oxygen cycle

Grade Band Endpoints for PS1.B

By the end of grade 2.

- heat(ing)
- cool(ing)
- observation
- reversible change (Δ) (e.g., melting and freezing)
- non-reversible change (e.g., baking a cake, burning fuel).

By the end of grade 5.

- substance(s)
- mix (mixture)
- property
- temperature
- reaction

By the end of grade 8.

- Substance(s)
- chemically react
- chemical process
- atoms
- reactant
- conservation of energy
- mass
- chemical reaction
- energy
- store energy

By the end of grade 12.

- chemical process(es)
- rate(s)
- whether
- energy
- stored energy
- released energy
- collision(s)
- molecule(s)
- atoms
- total binding energy (i.e., the sum of all bond energies in the set of molecules)
- kinetic energy
- dynamic balance
- condition-dependent balance
- reaction
- reverse reaction
- fact
- atoms (all matter) are/is conserved
- chemical properties of the elements
- chemical reaction(s)
- chemical processes
- biological phenomena
- geophysical phenomena.

PS1.C: NUCLEAR PROCESSES

What forces hold nuclei together and mediate nuclear processes?

- nuclei
- element
- radioactivity
- energy
- sun
- stars
- nuclear power
- explain
- predict
- nuclear processes
- strong nuclear interactions (provides the primary force that holds nuclei together and determines nuclear binding energies)
- weak nuclear interactions
- nuclei
- nuclear process(es)

- fusion
- fission
- radioactive decay
- unstable nuclei.
- changes in nuclear binding energies
- changes in nuclear masses (as described by $E = mc^2$)
- star (cores)
- Big Bang
- Matter
- Hydrogen
- Helium
- Lithium
- supernova explosions
- primordial low-mass elements (like hydrogen)
- alpha particle
- radiation
- beta particles
- gamma particles
- electron
- positrons
- photons (i.e., high-frequency electromagnetic radiation)
- ionize
- tissue
- stable isotope
- spontaneous radioactive decay
- exponential decay law
- nuclear decay
- rock
- mineral
- radiometric dating
- isotope ratios

Grade Band Endpoints for PS1.C

By the end of grade 2. [Intentionally left blank.]

By the end of grade 5. [Intentionally left blank.]

By the end of grade 8.

- nuclear fusion
- nuclei
- energy
- atom

- chemical process
- temperature
- pressure
- star cores
- light
- primordial hydrogen
- element
- Earth
- Universe
- Helium
- supernovas

By the end of grade 12.

- Nuclear processes
- Fusion
- Fission
- radioactive decay
- unstable nuclei
- nuclear binding energies
- neutrons
- protons
- strong nuclear interactions
- weak nuclear interactions
- spontaneous radioactive decay
- exponential decay law
- nuclear lifetime
- radiometric dating
- rock(s)
- isotope ratios
- star
- carbon
- iron
- elements
- supernova explosion