

LEGACY LEARNING CENTER

CHEMISTRY I

HIGH SCHOOL — COMPREHENSIVE CURRICULUM, SYLLABUS & LESSON PLANS

Standards: 2023 Indiana Academic Standards for Chemistry I — NGSS-Based — 3-Dimensional (SEP + CCC + DCI)

Indiana Standards Source: secure.in.gov/doi/students/indiana-academic-standards/science-and-computer-science/ | media.doe.in.gov/news/chemistry-standards.pdf

Primary Free Curriculum: OpenSciEd HS Chemistry (EdReports ALL-GREEN — Aug. 2025) — opensci.ed.org/curriculum/high-school/

7 Units | 16 Detailed 5E Lesson Plans | Labs | Safety Protocols | Resources | Assessments | Tracking Tools
Performance Expectations: HS-PS1-1 through HS-PS2-6 | Indiana Chemistry I Standards C.1–C.9 | ETS Engineering
Legacy Learning Center | 2025–2026 | Indiana 2023 IAS Compliant

Unit	Unit Title	Key Standards	Weeks	Primary Free Resource
Unit 1	Atomic Structure & the Periodic Table	HS-PS1-1 HS-PS1-3 C.1 C.2	4 wks	OpenSciEd HS-C + PhET Build an Atom Atomic Spectra
Unit 2	Chemical Bonding & Molecular Structure	HS-PS1-3 HS-PS2-6 C.3	4 wks	OpenSciEd HS-C PhET Molecule Shapes VSEPR resources
Unit 3	Chemical Reactions & Stoichiometry	HS-PS1-2 HS-PS1-7 C.4 C.4.4	5 wks	OpenSciEd HS-C PhET Balancing Equations HS Sci 4 All
Unit 4	Thermochemistry & Energy in Reactions	HS-PS1-4 HS-PS3-1 C.5	4 wks	OpenSciEd HS-C PhET Energy Forms Calorimetry lab
Unit 5	Reaction Kinetics & Chemical Equilibrium	HS-PS1-5 HS-PS1-6 C.6	4 wks	OpenSciEd HS-C PhET Reactions & Rates SFUSD Chemistry
Unit 6	Solutions, Acids & Bases	HS-PS1-3 HS-PS1-5 C.7 C.8	4 wks	OpenSciEd HS-C PhET Acid-Base Solutions Khan Academy
Unit 7	Gas Laws, Nuclear & Modern Chemistry	HS-PS1-8 C.9 Gas Laws	3 wks	PhET Gas Properties Khan Academy HHMI Radiocarbon Dating

Section 1: Chemistry I — Course Syllabus

Course Information

Element	Details
Course Title	Chemistry I — High School Legacy Learning Center 2025–2026
Indiana Course Code	Chemistry I (IDOE Course Titles & Descriptions 2025–2026)
Prerequisites	Biology (recommended) Algebra I required Algebra II concurrent recommended
Credit	1.0 credit — Core 40 / Academic Honors Diploma lab science requirement
Standards Framework	2023 Indiana Academic Standards for Chemistry I — NGSS-Based (HS-PS1, HS-PS2, HS-PS3 segments) — Adopted SBOE June 7, 2023
Indiana Chemistry Standards	HS-PS1-1 through HS-PS2-6 (NGSS Performance Expectations) + Indiana Chemistry course standards C.1–C.9 (mole concept, gas laws, solutions, acids/bases, electrochemistry, organic) Source: media.doe.in.gov/news/chemistry-standards.pdf
Three Dimensions	Dim. 1 — Science & Engineering Practices (SEP) Dim. 2 — Crosscutting Concepts (CCC) Dim. 3 — Disciplinary Core Ideas (DCI)
Primary Curriculum	OpenSciEd High School Chemistry (FREE — EdReports ALL-GREEN August 2025) — opensci.org/curriculum/high-school/
Supplemental Resources	PhET Simulations (phet.colorado.edu) Khan Academy Chemistry Crash Course Chemistry (YouTube) HHMI BioInteractive HS Science for All (hsscience4all.org) SFUSD NGSS Chemistry (sfusd.edu) CK-12 Chemistry
Lab Component	Minimum 1 lab investigation per unit — all labs require safety protocols, MSDS/SDS review, proper PPE — labs are essential for 3D learning
Lab Safety	Indiana OSHA compliance required — eye protection, aprons, gloves — no open-toed shoes — all labs must be pre-approved by principal — emergency procedures posted
Science Notebook	All students maintain chemistry science notebooks — updated every class — includes: observations, models, data tables, calculations, CER responses
Mathematics	Algebra-based: mole calculations, stoichiometry, pH (logarithms), gas law equations, solution concentration (molarity) — graphing required
Grading	Unit Tests (40%) Lab Reports & Notebook (30%) Formative / Exit Tickets (15%) Engineering Design / Capstone (15%)
Total Duration	30 weeks 7 units 16 detailed lesson plans Full school year (August–May)

All Indiana Chemistry I Standards — Complete List (Source: NGSS / IDOE 2023 IAS)

Source: Indiana 2023 IAS for Chemistry I (media.doe.in.gov/news/chemistry-standards.pdf) aligned to NGSS HS Physical Science Performance Expectations (nextgenscience.org). Adopted by SBOE June 7, 2023.

PE Code	Indiana Chemistry I Standard — Full Performance Expectation (NGSS / Indiana 2023 IAS)	SEP	Unit
HS-PS1-1	Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. [Clarification: Properties include reactivity of metals, types of bonds formed, numbers of bonds, reactions with oxygen. Assessment limited to main group elements; no quantitative ionization energy beyond relative trends.]	<i>Developing & Using Models</i>	Unit 1
HS-PS1-3	Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. [Clarification: Emphasis on strength of forces between particles, not specific intermolecular force]	<i>Planning Investigations</i>	Units 1–2

	names. Examples: ions, atoms, molecules, networked materials. Bulk properties: melting/boiling point, vapor pressure, surface tension. Assessment: no Raoult's law.]		
HS-PS2-6	Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.* [Clarification: Emphasis on attractive and repulsive forces determining material function. Examples: metals for conductivity, long-chain molecules for flexibility/durability, pharmaceuticals designed to interact with specific receptors. Assessment: limited to provided molecular structures of specific designed materials.]	<i>Communicating Information</i>	Unit 2
HS-PS1-2	Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. [Clarification: Examples: $\text{Na} + \text{Cl}$, $\text{C} + \text{O}$, $\text{C} + \text{H}$. Assessment limited to main group elements and combustion reactions.]	<i>Constructing Explanations</i>	Unit 3
HS-PS1-4	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. [Clarification: Emphasis on the idea that a chemical reaction is a system affecting energy change. Models: molecular-level drawings, energy diagrams, representations showing energy conservation. Assessment: no calculation of bond energy changes from bond energies.]	<i>Developing & Using Models</i>	Unit 4
HS-PS1-5	Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. [Clarification: Emphasis on number and energy of collisions between molecules. Assessment: simple reactions with only two reactants; qualitative relationships between rate and temperature.]	<i>Constructing Explanations</i>	Unit 5
HS-PS1-6	Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.* [Clarification: Emphasis on Le Chatelier's Principle and refining designs of chemical reaction systems, including molecular-level changes. Examples: adding reactants or removing products. Assessment: change in only one variable at a time; no equilibrium constant calculations.]	<i>Designing Solutions</i>	Unit 5
HS-PS1-7	Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. [Clarification: Emphasis on mathematical ideas to communicate proportional relationships between masses of atoms in reactants and products, and translation to macroscopic scale using mole as the conversion factor. Emphasis on mathematical thinking, not rote problem-solving techniques. Assessment: no complex reactions.]	<i>Using Math & Computation</i>	Unit 3
HS-PS1-8	Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay. [Clarification: Simple qualitative models — pictures or diagrams; scale of energy released in nuclear processes relative to other transformations. Assessment: alpha, beta, gamma decays only; no quantitative energy calculations.]	<i>Developing & Using Models</i>	Unit 7
HS-PS3-1	Create a computational model to calculate the change in energy of one component in a system when the change in energy of other component(s) and energy flows in and out of the system are known. [Assessment: basic algebraic expressions; systems of two or three components; thermal, kinetic, and/or gravitational/magnetic/electric field energy.]	<i>Using Math & Computation</i>	Unit 4
HS-PS3-2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with motions of particles (objects) and energy associated with the relative position of particles (objects).	<i>Developing & Using Models</i>	Unit 4
C.1 (Atomic Structure)	Describe the atomic structure of matter including subatomic particles, electron configuration, atomic number, mass number, isotopes, and how quantum mechanical model describes electron energy levels.	<i>Developing Models</i>	Unit 1

C.2 (Periodic Table)	Explain the organization of the periodic table including periods, groups, and periodic trends (electronegativity, ionization energy, atomic radius, electron affinity) and use the table to predict element properties and behavior.	<i>Analyzing Data</i>	Unit 1
C.3 (Bonding)	Describe, classify, and compare different types of chemical bonds (ionic, covalent, metallic) including Lewis structures, VSEPR theory, molecular geometry, polarity, and intermolecular forces and relate these to the macroscopic properties of substances.	<i>Developing Models</i>	Unit 2
C.4 (Reactions)	Describe, classify, and balance chemical equations for major reaction types (synthesis, decomposition, single/double displacement, combustion, acid-base, redox); apply the law of conservation of mass; predict products.	<i>Constructing Explanations</i>	Unit 3
C.4.4 (Stoichiometry)	Apply the mole concept to chemical calculations including mass-mass, mass-mole, and mole-mole stoichiometry; determine limiting reagents and excess reagents; calculate percent yield and theoretical yield for reactions.	<i>Using Math & Computation</i>	Unit 3
C.5 (Thermochemistry)	Describe and calculate energy changes in chemical reactions including exothermic vs. endothermic reactions, enthalpy (ΔH), calorimetry calculations using $Q = mc\Delta T$, and Hess's Law for enthalpy of reaction.	<i>Using Math & Computation</i>	Unit 4
C.6 (Kinetics & Equilibrium)	Explain reaction rate in terms of collision theory; describe factors affecting reaction rate (temperature, concentration, surface area, catalysts); explain chemical equilibrium and apply Le Chatelier's Principle to predict shifts in equilibrium.	<i>Applying Principles</i>	Unit 5
C.7 (Solutions)	Describe the process of dissolution including solubility rules, factors affecting solubility (temperature, pressure, polarity); calculate solution concentration in terms of molarity ($M = \text{mol/L}$); prepare and dilute solutions.	<i>Using Math & Computation</i>	Unit 6
C.8 (Acids & Bases)	Classify solutions as acids or bases using Arrhenius, Brønsted-Lowry definitions; calculate pH and pOH from $[\text{H}^+]$ and $[\text{OH}^-]$; compare strong vs. weak acids/bases; describe neutralization reactions and acid-base titrations.	<i>Using Math & Computation</i>	Unit 6
C.9 (Gas Laws)	Describe the behavior of gases using kinetic molecular theory; apply Boyle's Law, Charles's Law, Gay-Lussac's Law, Combined Gas Law, Avogadro's Law, and Ideal Gas Law ($PV = nRT$) to solve gas problems.	<i>Using Math & Computation</i>	Unit 7

Standards marked with asterisk integrate science content with engineering. Source: Indiana 2023 IAS Chemistry I — media.doe.in.gov/news/chemistry-standards.pdf + NGSS HS Physical Science — nextgenscience.org

Section 2: 3D Framework & Chemistry Resources

Free Chemistry Resources — Verified May 2026

Resource	Cost	Best For	Description + URL
OpenSciEd HS Chemistry (ALL-GREEN EdReports Aug. 2025)	FREE	All units — primary curriculum	Complete NGSS HS Chemistry — field-tested — EdReports All-Green — real-world phenomena anchoring every unit (climate change, water quality, material design) — teacher + student materials + assessments. opensci.ed.org/curriculum/high-school/
PhET Interactive Simulations	FREE	All units — virtual labs	Build an Atom, Isotopes & Atomic Mass, Molecule Shapes, Balancing Chemical Equations, Reactions & Rates, Acid-Base Solutions, Gas Properties, Concentration, pH Scale, Blackbody Spectrum. phet.colorado.edu
HS Science for All (hsscience4all.org)	FREE	Unit 3 — Stoichiometry	Complete free NGSS Chemistry units including stoichiometry — aligned to HS-PS1-7 — teacher + student materials. hsscience4all.org/chemistry
Khan Academy — Chemistry	FREE	All units — videos + practice	Complete HS Chemistry video library + practice aligned to all Indiana Chemistry I standards — teacher dashboard — khanacademy.org/science/chemistry
Crash Course Chemistry (YouTube)	FREE	All units — supplemental videos	47 chemistry episodes (10–12 min each) by Hank Green covering all Indiana Chemistry I topics — engaging for HS students. youtube.com/crashcourse — Chemistry playlist
SFUSD NGSS Chemistry Curriculum	FREE	All units — NGSS phenomena	Complete free NGSS Chemistry course from San Francisco Unified School District — phenomena-based — units on atomic structure, bonding, reactions, climate, solutions, acids/bases. sfusd.edu/high-school-ngss-chemistry
HHMI BioInteractive — Chemistry Connections	FREE	Units 4–7 (energy, nuclear)	Real-world chemistry applications — photosynthesis & energy, radiocarbon dating, climate & CO ₂ — biointeractive.org
CK-12 Chemistry FlexBook	FREE	All units — digital textbook	Free customizable HS Chemistry digital textbook + simulations + quizzes — NGSS aligned — students access on any device. ck12.org
Flinn Scientific — Free Resources	FREE teacher resources	All labs	Free lab protocols, safety guides, and chemical storage guidelines — flinnsci.com — free Teacher SDS/MSDS access
Chemistry Coach (chemistrycoach.com)	FREE	Indiana-specific standards	Indiana-aligned chemistry standards explanations and practice problems — covers Indiana Chemistry I standards C.1–C.9 — chemistry.coach
New Visions Science — Chemistry	FREE	All units	Free NGSS HS Chemistry lessons — newvisions.org/curriculum/science/chemistry — NYC-developed, nationally used
Chemthink (simulations)	FREE	Units 1–3 — concepts	Free interactive chemistry simulations: atomic structure, ionic bonding, gas laws — sciencegeek.net/chemthink/
Pivot Interactives	~\$12/student /yr	Labs	Video-based real chemistry investigations — students collect real lab data — used in top Indiana HS science programs. pivotinteractives.com
Savvas Chemistry (Pearson)	Paid — school license	Core program alternative	NGSS HS Chemistry — phenomenon-based — Flinn Scientific lab kits — Indiana-aligned — savvas.com
Kognity NGSS Chemistry	Paid (~\$30/student)	Digital textbook	NGSS HS Chemistry digital textbook + 600+ videos + interactive models + simulations. kognity.com

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Lab Safety — Required for ALL Chemistry Labs

ALL chemistry labs must be pre-approved by principal and teacher with completed risk assessment before students conduct the investigation.

PPE (Personal Protective Equipment) required for every lab: safety goggles/glasses + lab apron + gloves when handling chemicals. No exceptions.

No open-toed shoes in the chemistry lab — ever. Closed-toe shoes required on lab days.

Safety Data Sheet (SDS) — formerly MSDS — must be reviewed for every chemical used. Free SDS access: flinnsci.com/sds or chemicalsafety.com.

Know the location of: eyewash station, safety shower, fire extinguisher, first aid kit, and emergency shutoffs BEFORE any lab begins.

Dispose of chemicals per Indiana IDEM regulations and school policy — NEVER pour chemicals down the drain without verifying they are approved for drain disposal.

Indiana lab safety compliance: indiana.gov/OSHA + National Science Teachers Association Lab Safety guidelines: nsta.org/safety.

Legacy Learning Center · Chemistry I — High School · 2025–2026

UNIT 1 — 4 Weeks | August–September

ATOMIC STRUCTURE & THE PERIODIC TABLE

Standards: HS-PS1-1 | HS-PS1-3 | C.1 | C.2

Anchoring Phenomenon: A bright orange glow appears when a sample is held in a flame. Scientists 200 years ago discovered that every element produces a unique color pattern when energized — the spectral fingerprint. How can electrons inside an atom produce light — and why is each element's pattern unique?

LESSON PLAN 1.1 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Inside the Atom — Subatomic Particles, Electron Configuration & the Quantum Model

Anchoring Phenomenon: When scientists shine white light through a glass prism, they get a rainbow. But when they heat hydrogen gas and pass THAT light through a prism, they get only four specific colored lines — not a rainbow. Why do atoms only emit specific colors of light?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-1: Use the periodic table as a model to predict element properties based on patterns of electrons in outermost energy levels. C.1 (Indiana): Describe atomic structure including subatomic particles, electron configuration, atomic number, mass number, isotopes, and the quantum mechanical model of electron energy levels.
Objectives	(1) Identify protons, neutrons, electrons — their mass, charge, and location; (2) Calculate atomic number, mass number, and determine the number of neutrons for any element or isotope; (3) Write electron configurations for elements 1–36 using the Aufbau principle; (4) Explain why hydrogen's emission spectrum shows only four colored lines using the Bohr model; (5) Describe how the quantum mechanical model improves on the Bohr model.
Key Vocabulary	Atom, Proton, Neutron, Electron, Atomic Number (Z), Mass Number (A), Isotope, Atomic Mass (weighted average), Electron Configuration, Energy Level, Subshell (s, p, d, f), Orbital, Aufbau Principle, Pauli Exclusion Principle, Hund's Rule, Quantum Mechanical Model, Bohr Model, Ground State, Excited State, Emission Spectrum
Materials	PhET 'Build an Atom' simulation (phet.colorado.edu) PhET 'Isotopes and Atomic Mass' Spectroscope or diffraction grating (per group) Gas discharge tubes (H, He, Ne) or YouTube flame test video Periodic table (laminated per student) Science notebooks

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	10 min	Display side-by-side: white light spectrum (rainbow) vs. hydrogen emission spectrum (4 colored lines). 'Why does hydrogen only produce THESE four colors? What is happening inside the atom?' Students write initial ideas. Anchor: 'Today we go inside the atom to understand where these colors come from.'
Explore	20 min	PhET 'Build an Atom': Students add protons, neutrons, electrons to a nucleus. Discover: (1) adding protons changes the element; (2) adding/removing neutrons creates isotopes; (3) electron configuration determines chemical behavior. Students: 'How does the number of electrons relate to the number of protons in a neutral atom?'
Explain	15 min	Teacher: subatomic particles table (mass, charge, location). Electron configuration using s, p, d subshell notation — Aufbau, Pauli, Hund's rules. Then: Bohr model for hydrogen — electrons can only exist at specific energy levels. When an electron drops from excited state to ground state: $\Delta E = hf$ — it emits a photon of that specific frequency. THAT is why we see only 4 lines.
Elaborate	12 min	Flame test demonstration (or video): Li = red, Na = yellow/orange, Cu = green,

		K = violet. Students: 'Each element produces a unique emission spectrum — this is a chemical fingerprint. How do astronomers use this to identify elements in distant stars?' Quick research activity.
Evaluate	8 min	Exit ticket: (1) Write the electron configuration for Ca (Z=20). (2) An electron in hydrogen drops from n=3 to n=2 — will the emitted photon be visible light, UV, or IR? (3) A sample gives a bright yellow flame — what element is likely present?

<p>Lab / Investigation</p> <p>Lab: Atomic Emission Spectra — Flame Test. Students: (a) use a platinum wire loop to introduce metal salt solutions (LiCl, NaCl, KCl, CuCl₂, CaCl₂) into a flame; (b) record the observed color for each element; (c) use a spectroscope or diffraction grating to observe the discrete line spectrum. Lab report: data table, spectral diagram, CER: 'Each element produces a unique flame color because _____. This supports the quantum model because _____.' SAFETY: flame-resistant lab aprons required, tie back hair, use caution with open flame.</p>	<p>Assessment</p> <p>Electron configuration exit ticket. Flame test lab report with CER. Quiz: subatomic particles, atomic number/mass number, isotopes, electron configuration for elements 1–36, Bohr model vs. quantum model.</p>	<p>Differentiation & Resources</p> <p>ELL: bilingual atomic structure diagram with all particles labeled Below level: PhET Build an Atom with guided questions only; electron configuration limited to periods 1–3 Above level: calculate energies of Balmer series lines using $E = hc/\lambda$; explain why quantum model (orbital probability clouds) replaces Bohr orbits Free: phet.colorado.edu/en/simulations/build-an-atom <i>PhET Build an Atom + Isotopes:</i> phet.colorado.edu <i>Khan Academy Atomic Structure:</i> khanacademy.org <i>Crash Course Chemistry #1–5:</i> youtube.com <i>CK-12 Atomic Theory:</i> ck12.org <i>OpenSciEd HS Chemistry Unit:</i> opensci.ed.org</p>
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LESSON PLAN 1.2 | Legacy Learning Center | Chemistry I — High School | 2025–2026

The Periodic Table — Patterns, Trends & Predicting Properties (HS-PS1-1 + C.2)

Anchoring Phenomenon: Francium (Fr), at the bottom of Group 1, has never been seen by the naked eye — its most stable isotope has a half-life of 22 minutes. Yet chemists can predict with certainty that it is the most reactive metal, has the largest atomic radius of any element, and the lowest ionization energy. How can we know all this without directly observing it?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on patterns of electrons in outermost energy level of atoms. C.2 (Indiana): Explain organization of the periodic table including periodic trends (electronegativity, ionization energy, atomic radius, electron affinity) and use it to predict element properties.
Objectives	(1) Explain how the periodic table is organized by atomic number and how period and group reflect electron configuration; (2) Identify periodic trends: atomic radius, ionization energy, electronegativity, electron affinity — with direction of increase; (3) Predict element properties from table position; (4) Distinguish metals, metalloids, and nonmetals; (5) Use the periodic table as a predictive model.
Key Vocabulary	<i>Period, Group (Family), Representative Elements, Transition Metals, Lanthanides, Actinides, Alkali Metals, Alkaline Earth Metals, Halogens, Noble Gases, Metals/Metalloids/Nonmetals, Atomic Radius, Ionization Energy (IE), Electronegativity (EN), Electron Affinity (EA), Periodic Trend, Valence Electrons</i>
Materials	Large periodic table (projected or poster) PhET 'Periodic Table' activity or printed trend worksheet Colored pencils (for trend mapping) Science notebooks Indiana periodic table (allowed on most chemistry assessments)

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
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Engage	10 min	Display the Francium scenario. 'We can predict all these properties without ever observing Francium directly. The periodic table is so powerful it acts like a crystal ball for chemistry. Why?' Students: 'What patterns do you already notice in the periodic table?' Chart initial observations.
Explore	18 min	Trend mapping: Students receive a printed periodic table and colored pencil. Task: (a) Shade atomic radius — largest in bottom-left, smallest in top-right; (b) Shade ionization energy — opposite pattern; (c) Shade electronegativity — highest top-right (except noble gases). Students derive the rules for each trend from patterns. 'Why do these trends exist — what is causing them?'
Explain	15 min	Teacher: explain trends using nuclear charge and shielding; (1) Going DOWN a group → atomic radius increases (more electron shells); (2) Going RIGHT across a period → atomic radius decreases (more protons pulling electrons closer); (3) Ionization energy is opposite of radius; (4) Electronegativity highest at top-right — fluorine is most electronegative element. Apply to Francium: bottom-left = largest radius, lowest IE, most reactive.
Elaborate	12 min	HS-PS1-1 application: 'Use the periodic table to predict: (a) Which will form 2+ ions — Mg or Ca? (b) Which is more electronegative — Cl or Br? (c) Which element in Period 3 will react most vigorously with water?' Students answer using trend maps, not memorization. Connect to bonding (Unit 2): electronegativity determines bond type.
Evaluate	10 min	Exit ticket: (1) Rank these elements in order of increasing atomic radius: Na, K, Mg, Cl. (2) Which has higher ionization energy: O or S? Explain. (3) Predict two properties of element 119 (oganesson + 1) if it were synthesized. Students use trend maps — justify with reasoning.

<p>Lab / Investigation</p> <p>Lab: Periodic Trends — Data Analysis. Students receive a data table of atomic radii, ionization energies, and electronegativities for periods 2 and 3. Tasks: (a) graph IE vs. atomic number for period 3 — identify anomalies (B, O) and explain; (b) graph atomic radius vs. atomic number — identify trend; (c) CER: 'The data shows that ionization energy generally ___ across a period because ___.' Virtual option: PhET Periodic Table or ptable.com interactive data.</p>	<p>Assessment</p> <p>Trend map accuracy. IE graph + anomaly explanation. Exit ticket. Quiz: periodic trends (direction + explanation for each), predicting element properties from table position, valence electrons, metal/nonmetal/metalloid classification.</p>	<p>Differentiation & Resources</p> <p>ELL: trend direction mnemonic chart — arrows showing direction of increase for each trend Below level: pre-drawn graphs with trend lines — students only annotate and explain Above level: explain anomalies in IE trends (B < Be because 2p > 2s shielding; O < N because paired 2p electron repulsion) Free: ptable.com interactive periodic table Khan Academy Periodic Trends: khanacademy.org</p> <p><i>PhET Periodic Table resources:</i> phet.colorado.edu ptable.com (interactive data) Khan Academy Periodic Trends: khanacademy.org Crash Course Chemistry #3–4: youtube.com CK-12 Periodic Table: ck12.org</p>
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UNIT 2 — 4 Weeks | October

CHEMICAL BONDING & MOLECULAR STRUCTURE

Standards: HS-PS1-3 | HS-PS2-6 | C.3

Anchoring Phenomenon: Kevlar — a material 5 times stronger than steel by weight — is used in bulletproof vests. Aerogel is 99.8% air yet supports 4,000 times its own weight. Diamond is the hardest natural substance. All three are made of carbon, nitrogen, oxygen, and hydrogen. How can the same elements arranged differently produce such radically different properties?

LESSON PLAN 2.1 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Chemical Bonds — Ionic, Covalent & Metallic | Lewis Structures | VSEPR

Anchoring Phenomenon: Salt (NaCl) dissolves in water and conducts electricity. Sugar (C H O) dissolves in water but does NOT conduct electricity. Both are white crystalline solids. Both dissolve in water. What is different at the molecular level that explains this behavior difference?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles. C.3 (Indiana): Describe, classify, and compare ionic, covalent, and metallic bonds; Lewis structures; VSEPR; molecular geometry; polarity; intermolecular forces.
Objectives	(1) Predict bond type (ionic, covalent, metallic) from electronegativity difference; (2) Draw Lewis electron-dot structures for elements and simple molecules; (3) Apply VSEPR theory to predict molecular geometry (linear, bent, trigonal planar, tetrahedral, trigonal pyramidal); (4) Determine molecular polarity from geometry + bond polarity; (5) Connect molecular-level structure to bulk macroscopic properties.
Key Vocabulary	<i>Ionic Bond, Covalent Bond (polar/nonpolar), Metallic Bond, Lewis Structure, Octet Rule, Formal Charge, VSEPR Theory, Molecular Geometry, Bond Angle, Polar Molecule, Dipole Moment, Electronegativity Difference (ΔEN), Intermolecular Forces (IMF), London Dispersion, Dipole-Dipole, Hydrogen Bond, Network Covalent Solid</i>
Materials	PhET 'Molecule Shapes' simulation PhET 'Electronegativity' exploration Molecular model kits (or ball-and-stick models) Conductivity tester (battery + LED + wires) Salt, sugar, distilled water solutions Science notebooks

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	10 min	Demonstration: Dip conductivity tester into (a) pure water — no glow; (b) saltwater — glows; (c) sugar water — no glow. 'Salt conducts electricity dissolved in water. Sugar does not. Both are dissolved. What is the molecular-level difference?' Students predict. Anchor: 'Today we go to the molecular level to understand how bonding determines ALL the properties of a substance.'
Explore	20 min	Part A — Bond type from ΔEN : Students calculate ΔEN for 6 pairs and classify as ionic (>1.7), polar covalent (0.5–1.7), or nonpolar covalent (<0.5). Part B — PhET Molecule Shapes: Students build H ₂ O, CH ₄ , NH ₃ , CO ₂ , BF ₃ . Record: number of bonding pairs, lone pairs, geometry, bond angles. 'What determines the shape? What determines polarity?'
Explain	15 min	Teacher: Lewis structures → VSEPR → geometry → polarity. Key examples: H ₂ O (bent, polar), CO ₂ (linear, nonpolar despite polar bonds), CH ₄ (tetrahedral, nonpolar), NH ₃ (trigonal pyramidal, polar). Connect to salt/sugar: NaCl forms free ions in solution → conducts; C ₆ H ₁₂ O ₆ stays as neutral molecules → no ions → no conductivity. HS-PS2-6 : pharmaceutical molecules designed to fit receptor sites.

Elaborate	12 min	HS-PS2-6 — Designed Materials: Students research one designed material from 3 choices: (a) Kevlar (hydrogen bonding between chains → extraordinary strength); (b) PTFE/Teflon (nonpolar molecules → nothing sticks); (c) Aspirin (polar groups designed to interact with specific enzyme). Explain the molecular-level structure that determines the function. Present to class in 2 minutes.
Evaluate	8 min	Exit ticket: (1) Draw the Lewis structure and predict geometry of SO_2 . (2) Is SO_2 polar or nonpolar? Explain. (3) Why does NaCl conduct electricity in solution but not in solid form? Students show work.

<p>Lab / Investigation</p> <p>Lab A: Conductivity Investigation (HS-PS1-3) — Students dissolve 6 different substances (NaCl, KNO_3, glucose, ethanol, CaCO_3, acetic acid) in distilled water and test conductivity with LED tester. Record: (a) whether each conducts; (b) bond type predicted from ΔEN; (c) CER linking conductivity to bond type and particle type in solution. Lab B: PhET Molecule Shapes — draw 6 molecule geometries with bond angles. Combined lab report with CER connecting molecular structure to macroscopic properties (HS-PS1-3).</p>	<p>Assessment</p> <p>Lewis structure + geometry exit ticket. Conductivity lab report with CER (HS-PS1-3). HS-PS2-6 designed material research brief. Quiz: bond type prediction from ΔEN, Lewis structures for 6 molecules, VSEPR geometry and bond angles, polarity determination, IMF ranking.</p>	<p>Differentiation & Resources</p> <p>ELL: VSEPR geometry chart with 3D images and bond angle values labeled Below level: Lewis structures limited to molecules with no formal charge; conductivity lab only Above level: resonance structures for NO and SO_2; formal charge calculations; MO theory introduction Free: phet.colorado.edu/en/simulations/molecule-shapes PhET Electronegativity: phet.colorado.edu <i>PhET Molecule Shapes + Electronegativity: phet.colorado.edu Khan Academy Bonding: khanacademy.org Crash Course Chemistry #12–16: youtube.com OpenSciEd HS Chemistry materials design unit: opencied.org</i></p>
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Legacy Learning Center · Chemistry I — High School · 2025–2026

UNIT 3 — 5 Weeks | November–December

CHEMICAL REACTIONS & STOICHIOMETRY

Standards: HS-PS1-2 | HS-PS1-7 | C.4 | C.4.4

Anchoring Phenomenon: A baker follows a recipe: 2 cups flour + 1 cup sugar + 3 eggs → 12 cookies. If she has 5 cups of flour, 2 cups of sugar, and 6 eggs — how many cookies can she make? And what ingredient runs out first? This is exactly the problem a chemist faces when calculating how much product a reaction will yield. How do chemists count atoms they can't see?

LESSON PLAN 3.1 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Types of Chemical Reactions & Balancing Equations — Law of Conservation of Mass

Anchoring Phenomenon: A steel bridge slowly rusts over decades. A firework explodes in milliseconds. An antacid tablet fizzes when dropped in water. All three involve chemical reactions — but they look completely different. What makes a chemical reaction a chemical reaction, and how do we write them?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on outermost electron states of atoms and periodic table trends. HS-PS1-7: Use mathematical representations to support the claim that atoms — and therefore mass — are conserved during a chemical reaction. C.4 (Indiana): Describe, classify, and balance equations for major reaction types; predict products.
Objectives	(1) Identify evidence of chemical reactions (color change, gas production, precipitate, temperature change, light); (2) Classify reactions as synthesis, decomposition, single displacement, double displacement, combustion, or acid-base; (3) Balance chemical equations using the law of conservation of mass; (4) Use mathematical representations to support that atoms are conserved; (5) Predict products of simple reactions.
Key Vocabulary	<i>Chemical Reaction, Reactant, Product, Chemical Equation, Balanced Equation, Law of Conservation of Mass (atoms), Coefficient, Subscript, Synthesis, Decomposition, Single Displacement, Double Displacement, Combustion, Acid-Base Reaction, Precipitate, Activity Series, Solubility Rules</i>
Materials	PhET 'Balancing Chemical Equations' simulation Mass of reactants/products demonstration materials (baking soda + vinegar in sealed container on balance) Printed reaction type identification worksheet Science notebooks Activity series chart

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	10 min	Mass conservation demonstration: Add baking soda to vinegar in a SEALED bag on a balance. Read mass before and after reaction. 'The mass didn't change — even though gas was produced! How is that possible?' Anchor: 'Can we account for every atom before and after a chemical reaction? How?'
Explore	18 min	PhET 'Balancing Chemical Equations': Students balance 8 equations, observing that: (a) atoms on both sides must be equal; (b) only coefficients may change (not subscripts); (c) 'balanced' means all atoms are conserved. Students also physically model: $2\text{H} + \text{O} \rightarrow 2\text{H O}$ using colored sticky dots representing atoms — count all atoms before and after.
Explain	15 min	Teacher: six reaction types with examples, balancing strategies, and product prediction rules. Key: HS-PS1-2 — predict products using periodic table (single displacement requires activity series; double displacement requires solubility rules). HS-PS1-7: mathematically confirm conservation: 'Total mass of products = total mass of reactants always.' Students balance 5 equations independently.
Elaborate	12 min	Real-world applications: (1) Rust: $4\text{Fe} + 3\text{O} \rightarrow 2\text{Fe O}$ — classify and balance; (2) Fireworks — combustion of metal salts — classify and balance;

		(3) Antacid tablet — $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$ — classify, balance, calculate mass of CO_2 produced (preview stoichiometry). Connect HS-PS1-2: outermost electrons drive what products form.
Evaluate	8 min	Exit ticket: (1) Balance: $___ \text{Al} + ___ \text{O}_2 \rightarrow ___ \text{Al}_2\text{O}_3$. (2) Classify this reaction type. (3) If 54 g of Al reacts completely, predict whether the mass of Al_2O_3 produced is MORE, LESS, or EQUAL to 54 g. Explain using conservation of mass. Students show atom counting.

<p>Lab / Investigation</p> <p>Lab: Conservation of Mass in a Chemical Reaction. Students react sodium bicarbonate (NaHCO_3) with hydrochloric acid (HCl) in an OPEN flask and a SEALED flask (Ziploc bag). Measure total mass before and after each setup. Tasks: (a) Compare mass change in open vs. sealed; (b) Balance the equation; (c) CER: 'The mass changed in the open flask because _____. The data supports conservation of mass because _____.' SAFETY: dilute HCl (0.1M or less); goggles required; gas is CO_2 (non-toxic at these concentrations).</p>	<p>Assessment</p> <p>Equation balancing exit ticket. Conservation of mass lab report with CER (HS-PS1-7). Reaction type identification and product prediction quiz. Unit 3.1 quiz: balancing equations, classifying 6 reaction types, predicting products using activity series and solubility rules.</p>	<p>Differentiation & Resources</p> <p>ELL: six reaction type reference card with equation examples Below level: PhET Balancing Equations only; balancing limited to single-replacement reactions Above level: net ionic equations for all reaction types; predict whether precipitate forms using Ksp values Free: phet.colorado.edu/en/simulations/balancing-chemical-equations HS Science for All: hsscience4all.org/chemistry PhET Balancing Equations: phet.colorado.edu HS Sci for All Chemistry: hsscience4all.org Khan Academy Balancing Equations: khanacademy.org Crash Course Chemistry #10–12: youtube.com</p>
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LESSON PLAN 3.2 | Legacy Learning Center | Chemistry I — High School | 2025–2026

The Mole Concept & Stoichiometry — Mass-Mole-Particle Calculations (C.4.4, HS-PS1-7)

Anchoring Phenomenon: A pharmaceutical company needs to manufacture exactly 500 kg of aspirin ($\text{C}_9\text{H}_8\text{O}_4$, MW = 180 g/mol) for a hospital order. They must know: how many molecules of salicylic acid to start with, how much acetic anhydride they need, and how much aspirin they'll theoretically produce. Without the mole concept, this calculation is impossible. How do chemists 'count' 10^{23} particles?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-7: Use mathematical representations to support the claim that atoms and mass are conserved during a chemical reaction. C.4.4 (Indiana): Apply the mole concept — mass-mole-particle stoichiometry; limiting and excess reagents; percent yield; theoretical yield.
Objectives	(1) Define the mole and Avogadro's number (6.022×10^{23}); (2) Perform mole-mass-particle conversions using molar mass as a conversion factor; (3) Calculate molar mass from chemical formula; (4) Use mole ratios from balanced equations for stoichiometric calculations; (5) Identify limiting and excess reagents; (6) Calculate theoretical yield and percent yield.
Key Vocabulary	<i>Mole (mol), Avogadro's Number (6.022×10^{23}), Molar Mass (g/mol), Stoichiometry, Mole Ratio, Limiting Reagent (Reactant), Excess Reagent (Reactant), Theoretical Yield, Actual Yield, Percent Yield = (actual/theoretical) \times 100%, Mass-Mass Calculation</i>
Materials	Scale (balance) Known substances with calculated molar masses (NaCl, sugar, water) Calculators Stoichiometry problem set worksheets Science notebooks Aspirin synthesis kit (optional — Flinn Scientific) or virtual aspirin synthesis (virtual-chemistry-lab.com)

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	10 min	Display the aspirin manufacturing scenario. 'How do chemists figure out how much of each chemical to use to make exactly 500 kg of aspirin — without going massively over or under?' Anchor: 'Chemists don't count individual molecules — there are 10^{23} of them in just a few grams. They count by

		MOLES. Today we learn why this is the most powerful unit in chemistry.'
Explore	20 min	Mole concept investigation: Students receive 1 mole of 4 different substances (NaCl = 58.44 g, H ₂ O = 18.02 g, Cu = 63.55 g, C ₆ H ₁₂ O ₆ = 180.16 g) pre-weighed. 'All these samples contain the same NUMBER of formula units (6.022 × 10 ²³). Why are the masses different?' Students discover: different molar masses because atoms have different masses. Derive: mole = bridge between atomic world and gram world.
Explain	15 min	Teacher: mole-mass-particle conversion map (3-step: grams ÷ molar mass = moles; moles × mole ratio = moles of product; moles × molar mass = grams of product). Stoichiometry: N ₂ + 3H ₂ → 2NH ₃ . 'If I start with 28 g of N ₂ , how many grams of NH ₃ can I make?' Walk through all steps. Then limiting reagent: 'What if I have 28 g N ₂ AND 9 g H ₂ — which runs out first?' Calculate both theoretical yields; smaller = limiting reagent.
Elaborate	12 min	Aspirin synthesis scenario: C ₆ H ₆ O ₃ + C ₆ H ₄ O ₃ → C ₆ H ₄ O ₂ + CH ₃ COOH. Students: (a) calculate theoretical yield of aspirin from 14.0 g salicylic acid; (b) if actual yield is 11.2 g, calculate percent yield; (c) identify: what would the limiting reagent be if both reactants were present in equimolar amounts? Optional: virtual aspirin synthesis.
Evaluate	10 min	Exit ticket: 2H ₂ + O ₂ → 2H ₂ O. Given: 4.0 g H ₂ and 32.0 g O ₂ . (1) Calculate moles of each reactant. (2) Identify the limiting reagent. (3) Calculate the theoretical yield of water in grams. (4) If 34.0 g of water is produced, what is the percent yield?

<p>Lab / Investigation</p> <p>Lab: Stoichiometry — Baking Soda + Acetic Acid Reaction. Students: (a) measure 5.0 g NaHCO₃ + 30 mL of 1M CH₃COOH; (b) collect and measure mass of CO₂ released (mass before – mass after); (c) calculate theoretical yield of CO₂ using stoichiometry; (d) calculate percent yield; (e) CER identifying limiting reagent. Lab report: balanced equation, stoichiometry calculations, percent yield calculation, CER with sources of error discussion.</p>	<p>Assessment</p> <p>Stoichiometry exit ticket (all 4 parts). Lab report with calculations and CER. Unit 3.2 quiz: mole conversions, molar mass calculation, mass-mass stoichiometry, limiting/excess reagent identification, percent yield calculation.</p>	<p>Differentiation & Resources</p> <p>ELL: stoichiometry conversion map with labels in both English and student's language Below level: mole conversion only (no limiting reagent); calculator provided for all problems Above level: multi-step stoichiometry with solution concentration; design an experiment to determine the limiting reagent of an unknown mixture Free: HS Science for All stoichiometry unit: hsscience4all.org Khan Academy Stoichiometry: khanacademy.org</p> <p><i>HS Science for All Stoichiometry:</i> hsscience4all.org <i>Khan Academy Moles + Stoichiometry:</i> khanacademy.org <i>Crash Course Chemistry #9–10:</i> youtube.com <i>Chemistry Coach Indiana:</i> chemistry.coach <i>OpenSciEd HS-C:</i> opensci.ed.org</p>
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Legacy Learning Center · Chemistry I — High School · 2025–2026

UNIT 4 — 4 Weeks | January

THERMOCHEMISTRY & ENERGY IN REACTIONS

Standards: HS-PS1-4 | HS-PS3-1 | HS-PS3-2 | C.5

Anchoring Phenomenon: Hand warmers get hot when you shake them. Cold packs get cold when you squeeze them. Both involve chemical reactions — but one releases energy and one absorbs it. Where does the energy come from — and where does it go? Can we design a better hand warmer?

LESSON PLAN 4.1 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Thermochemistry — Bond Energy, Enthalpy, Calorimetry & Hess's Law

Anchoring Phenomenon: A chemical hand warmer reaches 54°C in 30 seconds when activated. A chemical cold pack drops to 1°C in 20 seconds when squeezed. Both fit in the palm of your hand. How do chemical reactions store and release thermal energy — and how do we measure it?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-4: Develop a model to illustrate that the release or absorption of energy from a chemical reaction depends on changes in total bond energy. HS-PS3-1: Create a computational model to calculate energy change in a system. C.5 (Indiana): Describe and calculate energy changes in chemical reactions including enthalpy, calorimetry ($Q = mc\Delta T$), and Hess's Law.
Objectives	(1) Distinguish exothermic ($\Delta H < 0$) from endothermic ($\Delta H > 0$) reactions using energy diagrams; (2) Connect enthalpy change to bond breaking (requires energy) vs. bond forming (releases energy); (3) Calculate heat absorbed or released using $Q = mc\Delta T$; (4) Apply Hess's Law to calculate ΔH for multi-step reactions; (5) Create a computational model tracking energy in a calorimetry system.
Key Vocabulary	<i>Thermochemistry, Exothermic ($\Delta H < 0$), Endothermic ($\Delta H > 0$), Enthalpy (H), Enthalpy Change (ΔH), Bond Energy (bond dissociation energy), Calorimetry, Specific Heat Capacity (c), $Q = mc\Delta T$, Joule (J), Calorie, Hess's Law, Heat of Formation ($\Delta H^{\circ}f$), Energy Diagram (reaction progress diagram), Activation Energy (E_a), Catalyst</i>
Materials	Styrofoam calorimeters (nested cups) Thermometers or temperature probes Hot water + room-temp water NaOH + HCl (dilute) for neutralization enthalpy Hand warmer (commercial) + cold pack (commercial) for demonstration Calculators Energy diagram template Science notebooks

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	8 min	Activate a hand warmer + cold pack simultaneously. Pass around. 'Both are chemical reactions. One releases energy to the surroundings. One absorbs energy from the surroundings. Where does the energy come from?' Anchor: 'Today we track energy at the molecular level — inside the chemical bonds.'
Explore	20 min	Part A: PhET Energy Forms and Changes (or actual hot/cold water mixing) — students mix equal masses of hot and cold water. Record temperature of each and final temperature. Calculate Q for hot water and Q for cold water: $Q = mc\Delta T$. 'Was energy created or destroyed?' Part B: Bond energy model — teacher provides bond energies table. Students calculate ΔH for $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ by summing: (bonds broken = energy IN) and (bonds formed = energy OUT). Net $\Delta H = \text{IN} - \text{OUT}$.
Explain	15 min	Teacher: $\Delta H = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed})$. Exothermic: more energy released forming bonds than absorbed breaking them → negative ΔH . Endothermic: opposite. Energy diagrams: draw reaction progress on x-axis, energy on y-axis; identify reactants, products, ΔH , activation energy. Hess's Law: ΔH of overall reaction = sum of ΔH of individual steps. Computational

		model (HS-PS3-1): $Q_{\text{system}} + Q_{\text{surroundings}} = 0$ in isolated system.
Elaborate	12 min	Design application: 'You are designing the next generation hand warmer. Using the bond energy table, identify which reaction would release the most heat per gram of reactant. Specify: the reaction, ΔH , and how you would activate it safely.' Students work in pairs, present recommendations. Connect to engineering design (ETS).
Evaluate	10 min	Exit ticket: 100.0 g of water is heated from 22°C to 78°C. (1) Calculate Q using $c(\text{water}) = 4.18 \text{ J/g}^\circ\text{C}$. (2) Is this process exothermic or endothermic FROM THE WATER'S PERSPECTIVE? (3) Draw the energy diagram for an exothermic reaction. Label: reactants, products, ΔH , E_a .

<p>Lab / Investigation</p> <p>Lab: Calorimetry — Measuring Enthalpy of Neutralization. Students: (a) add 50 mL of 1M HCl to 50 mL of 1M NaOH in a Styrofoam calorimeter; (b) measure initial T of each solution and final T of mixture; (c) calculate $Q = mc\Delta T$ for the neutralization reaction; (d) express ΔH per mole of H_2O produced; (e) compare to accepted value (-57.1 kJ/mol) and calculate % error. Lab report: calculations, energy diagram, CER, sources of error. SAFETY: dilute 1M concentrations; goggles required; avoid skin contact with NaOH.</p>	<p>Assessment</p> <p>Calorimetry exit ticket ($Q = mc\Delta T +$ energy diagram). Neutralization lab report with ΔH calculation and % error. Quiz: exothermic vs. endothermic, bond energy calculations, ΔH from bond energies, Hess's Law, $Q = mc\Delta T$ problems, energy diagrams with E_a and ΔH labeled.</p>	<p>Differentiation & Resources</p> <p>ELL: energy diagram template pre-labeled with all variables; $Q = mc\Delta T$ step-by-step scaffold Below level: calorimetry only (no bond energy calculations or Hess's Law); $Q = mc\Delta T$ problems with given specific heat values Above level: Hess's Law multi-step calculations; calculate standard enthalpy of formation from bond energies vs. tabulated values; research Hess's Law applications in industrial chemistry Free: phet.colorado.edu/en/simulations/energy-forms-and-changes Khan Academy Thermochemistry: khanacademy.org</p> <p><i>PhET Energy Forms and Changes:</i> phet.colorado.edu <i>Khan Academy Thermochemistry:</i> khanacademy.org <i>Crash Course Chemistry #17–18:</i> youtube.com <i>OpenSciEd HS Chemistry energy units:</i> opencscied.org <i>CK-12 Thermochemistry:</i> ck12.org</p>
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Legacy Learning Center · Chemistry I — High School · 2025–2026

UNIT 5 — 4 Weeks | February

REACTION KINETICS & CHEMICAL EQUILIBRIUM

Standards: HS-PS1-5 | HS-PS1-6 | C.6

Anchoring Phenomenon: The Haber-Bosch process converts nitrogen gas and hydrogen gas into ammonia — the basis for nearly all fertilizer on Earth, feeding half the world's population. But the reaction is slow at room temperature and the equilibrium favors the reactants. Fritz Haber won the Nobel Prize for figuring out how to make it work. How do chemists control the speed and outcome of chemical reactions?

LESSON PLAN 5.1 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Reaction Rate & Factors Affecting Kinetics — Collision Theory (HS-PS1-5)

Anchoring Phenomenon: A potato chip left out at room temperature stays fresh for weeks. In a hot fryer at 185°C it browns in 3 minutes. In a freezer at -18°C it lasts months. The same organic molecules, the same chemical reactions — but rate changes by orders of magnitude with temperature. Why?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-5: Apply scientific principles and evidence to provide an explanation about the effects of changing temperature or concentration of reacting particles on the rate of a chemical reaction. [Emphasis on number and energy of collisions. Assessment: simple two-reactant reactions; qualitative relationships between rate and temperature.] C.6 (Indiana): Explain reaction rate in terms of collision theory; factors affecting rate (temperature, concentration, surface area, catalysts).
Objectives	(1) State collision theory — rate depends on frequency and energy of effective collisions; (2) Explain how temperature increases rate (more collisions, greater energy); (3) Explain how concentration increases rate (more frequent collisions); (4) Explain how surface area increases rate (more exposed particles); (5) Explain catalysts — lower E_a without being consumed; (6) Construct an evidence-based explanation connecting molecular behavior to macroscopic rate observation.
Key Vocabulary	Reaction Rate, Collision Theory, Effective Collision, Activation Energy (E_a), Frequency Factor, Temperature Effect on Rate, Concentration Effect on Rate, Surface Area Effect on Rate, Catalyst, Enzyme (biological catalyst), Inhibitor, Rate Law (qualitative), Doubling Time
Materials	PhET 'Reactions and Rates' simulation Effervescent tablets (Alka-Seltzer) + water at 3 temperatures (cold, room temp, hot) + whole vs. crushed tablet Stopwatch Science notebooks Printed collision theory diagram Energy diagram template

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	8 min	Display the potato chip scenario side-by-side with temperature data. 'The SAME reaction. The SAME molecules. A 165°C difference changes the time from 3 minutes to months. What is happening at the molecular level when we change temperature?' Students predict. Anchor: 'Collision theory explains all of this — and it is the foundation of all reaction kinetics.'
Explore	20 min	Lab — Effect of Temperature + Surface Area on Reaction Rate: Groups test Alka-Seltzer tablet in water at 3 temperatures (5°C, 25°C, 50°C). Record time until fizzing stops. Also: compare whole tablet vs. same-mass crushed tablet at 25°C. Data table: temperature, time, rate (1/time). 'What patterns do you observe? Rank from fastest to slowest.' PhET Reactions and Rates: vary temperature, observe collision frequency and energy.
Explain	15 min	Teacher: collision theory — molecules must collide with sufficient energy ($\geq E_a$) AND proper orientation. At higher T: molecules move faster → more collisions/second + more energy per collision → higher % of effective collisions. Higher concentration: more particles in same volume → more

		frequent collisions. Greater surface area: more particles exposed for collision. Catalyst: provides alternate reaction pathway with lower E_a — shown on energy diagram. HS-PS1-5: apply to the Haber-Bosch scenario.
Elaborate	12 min	Apply to real systems: (1) Food refrigeration: lower T → lower reaction rates → slower spoilage; (2) Enzyme catalysts: biological catalysts that work at body temperature; (3) Automotive catalytic converter: Pt/Pd catalyst converts CO, NO _x to CO ₂ , N ₂ . Students: write a CER for each explaining HOW collision theory explains the phenomenon.
Evaluate	10 min	Exit ticket: (1) A reaction doubles in rate when temperature increases by 10°C. Explain using collision theory (not just 'more collisions'). (2) Adding a catalyst to a reaction (increases/decreases/doesn't change) the activation energy — explain. (3) Draw the energy diagram for the same reaction with and without a catalyst.

Lab / Investigation Lab: Rates of Reaction — Alka-Seltzer Investigation (HS-PS1-5 Investigation). Full lab report: (a) data table with temperature, reaction time, and calculated rate (1/time s ⁻¹); (b) graph rate vs. temperature; (c) graph comparing whole vs. crushed tablet; (d) CER: 'Increasing temperature increases reaction rate because _____. The data shows _____. This connects to collision theory because _____.' Additional inquiry extension: does stirring change the rate? Students design and test.	Assessment Collision theory exit ticket + energy diagram. Reaction rate lab report (HS-PS1-5 evidence-based explanation). Quiz: collision theory factors (temperature, concentration, surface area, catalyst), energy diagram with/without catalyst, CER applying collision theory to novel scenario.	Differentiation & Resources ELL: collision theory visual with molecular animation description Below level: Alka-Seltzer lab only — two variables at a time; guided CER scaffold Above level: Arrhenius equation ($k = Ae^{(-E_a/RT)}$) — calculate activation energy from rate-temperature data; research enzyme kinetics and Michaelis-Menten model Free: phet.colorado.edu/en/simulations/reactions-and-rates Khan Academy Kinetics: khanacademy.org <i>PhET Reactions and Rates:</i> phet.colorado.edu Khan Academy Chemical Kinetics: khanacademy.org SFUSD NGSS Chemistry kinetics unit: sfusd.edu Crash Course Chemistry #20–21: youtube.com
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LESSON PLAN 5.2 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Chemical Equilibrium & Le Chatelier's Principle — Engineering Equilibrium (HS-PS1-6)

Anchoring Phenomenon: Fritz Haber discovered that $N_2 + 3H_2 \rightleftharpoons 2NH_3$ reaches equilibrium with less than 10% ammonia at 500°C. The reaction favors the reactants. Yet today the Haber-Bosch process produces 150 million tons of ammonia per year — the source of most nitrogen fertilizer. How did engineers solve a problem that chemistry seemed to prevent?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-6 : Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium. [Emphasis: Le Chatelier's Principle — macroscopic changes at molecular level. Assessment: one variable at a time; no Keq calculations.] C.6 (Indiana): Explain chemical equilibrium and apply Le Chatelier's Principle.
Objectives	(1) Describe chemical equilibrium as a dynamic state where forward and reverse reaction rates are equal; (2) Apply Le Chatelier's Principle to predict how changes in concentration, temperature, and pressure shift equilibrium; (3) Design a modification to a chemical system to increase product yield (HS-PS1-6); (4) Connect equilibrium principles to industrial chemical processes; (5) Explain why equilibrium is 'dynamic' not 'static'.
Key Vocabulary	<i>Chemical Equilibrium, Dynamic Equilibrium, Equilibrium Constant (Keq — conceptual only), Le Chatelier's Principle, Stress, Shift, Forward Reaction, Reverse Reaction, Equilibrium Expression, Q vs. K (conceptual), Haber-Bosch Process, Industrial Chemistry, Optimization, Yield</i>
Materials	PhET 'Reactions and Rates' simulation (equilibrium mode) Large whiteboard for class

equilibrium model | Printed Le Chatelier's Principle practice problems | Haber-Bosch process diagram (printed or projected) | Science notebooks

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	8 min	Display the Haber-Bosch problem: 'At 500°C, the equilibrium gives < 10% ammonia. At 200°C, the % is higher — but the reaction is too slow. High pressure favors ammonia formation. Iron catalyst lowers activation energy. Haber spent 10 years solving this optimization problem. Today YOU will solve it.' Anchor: 'Le Chatelier's Principle is the tool that explains every industrial chemical engineering decision.'
Explore	18 min	PhET Reactions and Rates (equilibrium mode): Students perturb the equilibrium by: (a) adding more reactant; (b) removing product; (c) increasing temperature; (d) increasing pressure (for gas-phase reactions). For each: observe which direction equilibrium shifts, record in table, identify the 'stress' and the system's 'response.'
Explain	15 min	Teacher: Le Chatelier's Principle — 'If a system at equilibrium is subjected to a stress, the system responds in the direction that relieves the stress.' Four stresses: (1) add reactant → shift right; (2) remove product → shift right; (3) increase temperature for endothermic → shift right; for exothermic → shift left; (4) increase pressure → shift toward fewer moles of gas. Apply to Haber-Bosch: remove ammonia as it forms → shift right. High pressure (150 atm) → shift right. Iron catalyst → reaches equilibrium faster.
Elaborate	20 min	HS-PS1-6 Engineering Design Task: 'You are an industrial chemist. Design the optimal conditions for the reaction: $\text{CO(g)} + 2\text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$ $\Delta H = -128 \text{ kJ/mol}$. The goal is maximum methanol yield in minimum time. Specify: temperature (high or low? why?), pressure (high or low? why?), should you add more CO or H ₂ ? Should you remove methanol as it forms? Write a justified recommendation using Le Chatelier's Principle for each decision.'
Evaluate	10 min	Exit ticket: For $\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)}$ $\Delta H = -92 \text{ kJ/mol}$ — predict the effect on equilibrium of each change and explain: (1) Add more H ₂ ; (2) Remove NH ₃ as it forms; (3) Increase temperature; (4) Decrease pressure (volume increases). Students must state direction of shift AND explain in terms of Le Chatelier.

<p>Lab / Investigation</p> <p>Lab: Le Chatelier's Principle — Cobalt Equilibrium Investigation. Students add CoCl₂ to ethanol — clear blue solution. Add HCl → shifts to blue [CoCl₄]²⁻; add AgNO₃ → precipitates Cl⁻, shifts to pink [Co(H₂O)₆]²⁺; heat → shifts to blue; cool → shifts to pink. Students: (a) record observations for each perturbation; (b) identify the stress and shift direction; (c) CER: 'When AgNO₃ was added, the solution turned pink because _____. Le Chatelier's Principle explains this shift because _____. SAFETY: goggles + gloves; cobalt compounds are irritants — minimal quantities.'</p>	<p>Assessment</p> <p>Le Chatelier exit ticket (4 predictions with explanations). Engineering design task (HS-PS1-6) with justified recommendations. Cobalt equilibrium lab report with CER. Quiz: dynamic equilibrium, Le Chatelier predictions for 4 stress types, Haber-Bosch optimization analysis.</p>	<p>Differentiation & Resources</p> <p>ELL: Le Chatelier's Principle template — 'When ____ is added/removed, the equilibrium shifts ____ because ____.' Below level: PhET equilibrium simulation only; Le Chatelier predictions for concentration changes only Above level: write equilibrium expression K_{eq}; calculate Q vs. K to predict shift direction; research industrial applications of equilibrium control Free: phet.colorado.edu/en/simulations/reactions-and-rates SFUSD Chemistry equilibrium: sfusd.edu</p> <p><i>PhET Reactions and Rates:</i> phet.colorado.edu <i>Khan Academy Equilibrium:</i> khanacademy.org <i>SFUSD NGSS Chemistry:</i> sfusd.edu <i>Crash Course Chemistry #28–29:</i> youtube.com <i>OpenSciEd HS Chemistry:</i> opensci.ed.org</p>
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Legacy Learning Center · Chemistry I — High School · 2025–2026

UNIT 6 — 4 Weeks | March–April

SOLUTIONS, ACIDS & BASES

Standards: HS-PS1-3 | C.7 | C.8

Anchoring Phenomenon: Ocean acidification has lowered ocean pH from 8.2 to 8.1 since industrialization — a 26% increase in acidity. This seemingly small change is dissolving the calcium carbonate shells of oysters, clams, and coral. How can such a small pH change cause such massive damage — and what does pH really measure?

LESSON PLAN 6.1 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Solutions & Concentration — Molarity, Dilution, Solubility (C.7)

Anchoring Phenomenon: Seawater is about 3.5% NaCl by mass — yet drinking it makes you more dehydrated. Freshwater fish die in saltwater. Ocean plants thrive in saltwater but die in freshwater. The concentration of dissolved substances in water determines survival for aquatic life. How do chemists precisely describe and control concentration?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer strength of electrical forces between particles. C.7 (Indiana): Solubility rules, factors affecting solubility, molarity ($M = \text{mol/L}$), preparing and diluting solutions.
Objectives	(1) Explain the dissolving process using like-dissolves-like principle and IMF; (2) Identify factors affecting solubility (temperature, pressure, polarity); (3) Calculate solution concentration in molarity ($M = \text{mol/L}$); (4) Prepare a solution of given molarity from a pure substance; (5) Calculate concentration after dilution using $C_1 V_1 = C_2 V_2$; (6) Use solubility rules to predict whether a precipitate forms.
Key Vocabulary	<i>Solution, Solvent, Solute, Dissolving, Solubility, Miscible/Immiscible, Like Dissolves Like, Molarity ($M = \text{mol/L}$), Concentration, Saturated/Unsaturated/Supersaturated, Dilution ($C_1 V_1 = C_2 V_2$), Electrolyte/Nonelectrolyte, Solubility Rules, Precipitation Reaction, Ions in Solution</i>
Materials	PhET 'Concentration' simulation Graduated cylinders + volumetric flasks Salt, sugar, food coloring Distilled water Conductivity tester Beakers Solubility rules chart Science notebooks

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	10 min	Display seawater scenario + photo of ocean acidification affecting coral. 'Seawater is 35 g of dissolved salt per liter. This concentration is so precisely controlled by ocean chemistry that most marine life cannot survive even 1g/L change. How do chemists describe and measure concentration precisely?' Anchor: 'Molarity is the chemist's way of describing the exact concentration of any solution.'
Explore	20 min	PhET 'Concentration' simulation: Students add different amounts of KMnO_4 to different volumes of water. Record $M = n/V$ for each. Observe: (a) how color intensity relates to concentration; (b) what happens when you add more solvent (dilution); (c) confirm $C_1 V_1 = C_2 V_2$ for dilution. Physical investigation: students test conductivity of: pure water, 0.1M NaCl, 1.0M NaCl, 0.1M sucrose — confirm electrolytes conduct; nonelectrolytes do not (HS-PS1-3).
Explain	15 min	Teacher: $M = \text{mol/L}$ — the central unit of solution chemistry. Preparation: $m = M \times V \times MW$ (mass needed to make a solution). Dilution: $C_1 V_1 = C_2 V_2$ — water is added, moles stay constant. Solubility rules: soluble vs. insoluble — used to predict precipitates. 'Like dissolves like' at molecular level: polar solvents dissolve ionic and polar solutes; nonpolar solvents dissolve nonpolar solutes. Connection to HS-PS1-3: ion interactions (IMF strength) determine solubility.

Elaborate	12 min	Solution preparation challenge: 'Prepare 250 mL of 0.500M NaCl. Show all calculations: (a) moles of NaCl needed; (b) mass of NaCl needed; (c) step-by-step procedure.' Students design and execute (time permitting). Ocean concentration context: 'Normal seawater: 0.60M NaCl. How many grams of NaCl in 1 liter of seawater?'
Evaluate	8 min	Exit ticket: (1) Calculate the molarity of a solution prepared by dissolving 11.7 g NaCl (MW = 58.44 g/mol) in enough water to make 500 mL. (2) What volume of this solution contains 0.050 mol NaCl? (3) If you dilute 25 mL of 2.0M HCl to 100 mL, what is the new concentration?

<p>Lab / Investigation</p> <p>Lab: Solution Preparation and Dilution. Students: (a) calculate mass of NaCl needed to prepare 100 mL of 1.0M NaCl; (b) prepare the solution using a volumetric flask; (c) take 25 mL aliquots and dilute to 0.25M, 0.50M, 0.75M; (d) test conductivity of each — graph conductivity vs. concentration; (e) CER: 'As NaCl concentration increases, conductivity increases because ____.' Lab report: all calculations, data table, conductivity graph, CER with IMF explanation (HS-PS1-3).</p>	<p>Assessment</p> <p>Molarity calculation exit ticket (3 parts). Solution preparation lab report with conductivity graph and CER. Quiz: $M = \text{mol/L}$ problems, dilution $C_1V_1 = C_2V_2$ problems, solubility rules, precipitate prediction, like-dissolves-like application.</p>	<p>Differentiation & Resources</p> <p>ELL: solution preparation procedure in numbered steps with diagrams Below level: molarity calculation only (given moles, solve for volume or concentration); no dilution problems Above level: solution stoichiometry — calculate what volume of one solution reacts with another; research reverse osmosis desalination process Free: phet.colorado.edu/en/simulations/concentration Khan Academy Solutions: khanacademy.org</p> <p><i>PhET Concentration: phet.colorado.edu Khan Academy Solutions: khanacademy.org Crash Course Chemistry #27: youtube.com CK-12 Solutions: ck12.org</i></p>
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LESSON PLAN 6.2 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Acids, Bases & pH — Definitions, Calculations & Titrations (C.8)

Anchoring Phenomenon: Ocean pH has dropped from 8.2 to 8.1 since industrialization began. This seems like a tiny change — only 0.1 pH units. But scientists report that ocean acidity has increased by 26%. How can a 0.1 change in pH equal a 26% change in acidity? What IS pH really measuring?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	C.8 (Indiana): Classify solutions as acids/bases; calculate pH and pOH; compare strong vs. weak acids/bases; describe neutralization reactions and acid-base titrations.
Objectives	(1) Apply Arrhenius and Brønsted-Lowry definitions of acids and bases; (2) Explain the pH scale as a logarithmic scale measuring $[H^+]$; (3) Calculate pH from $[H^+]$ and $[OH^-]$ from pH; (4) Calculate pOH and use $K_w = [H^+][OH^-] = 10^{-14}$; (5) Distinguish strong (100% dissociated) from weak acids/bases; (6) Describe neutralization reactions; (7) Calculate unknown concentration from titration data.
Key Vocabulary	<i>Acid, Base, Arrhenius Acid/Base, Brønsted-Lowry Acid (proton donor) / Base (proton acceptor), Conjugate Acid-Base Pair, $pH = -\log[H^+]$, $pOH = -\log[OH^-]$, $pH + pOH = 14$, $K_w = 1.0 \times 10^{-14}$, Strong Acid (HCl, HNO₃, H₂SO₄, HBr, HI, HClO₄), Weak Acid (CH₃COOH), Neutralization, Salt, Titration, Equivalence Point, Indicator, Buffer</i>
Materials	PhET 'Acid-Base Solutions' simulation PhET 'pH Scale' Universal indicator solution or pH paper Dilute HCl solutions (1M, 0.1M, 0.01M, 0.001M) NaOH for neutralization Phenolphthalein indicator Burettes (or syringes) + Erlenmeyer flasks Science notebooks Logarithm reference guide

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	10 min	Display the ocean acidification data: 'pH dropped from 8.2 to 8.1. Scientists say acidity increased 26%.' Students calculate: $[H^+]$ at pH 8.2 = 6.3×10^{-9} M. At pH 8.1 = 7.9×10^{-9} M. Ratio = $7.9/6.3 = 1.26 = 26\%$ increase. 'The pH

		scale is LOGARITHMIC. A 0.1 change in pH = 26% change in actual concentration.' Anchor: 'Understanding pH requires understanding logarithms — and what they mean for chemistry.'
Explore	18 min	PhET 'pH Scale': Students measure pH of 8 substances (pure water, coffee, orange juice, bleach, rainwater, seawater, battery acid, baking soda). Record pH, identify acid/base/neutral. PhET 'Acid-Base Solutions': observe particle diagrams for strong acid (100% ions) vs. weak acid (partial dissociation). 'What is different at the particle level between HCl and acetic acid at the same concentration?'
Explain	15 min	Teacher: $\text{pH} = -\log[\text{H}_3\text{O}^+]$. Key examples: $[\text{H}_3\text{O}^+] = 0.01 \text{ M}$ gives $\text{pH} = 2$. $\text{pH} = 9$ means $[\text{H}_3\text{O}^+] = 10^{-9} \text{ M}$. $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 10^{-14}$, so $\text{pH} + \text{pOH} = 14$. Strong acids: 100% dissociated, so $[\text{H}_3\text{O}^+] = \text{M}$ of acid. Weak acids: partial dissociation — must use K_a . Neutralization: $\text{H}_3\text{O}^+ + \text{OH}^-$ gives $2\text{H}_2\text{O}$. Titration: use known concentration to find unknown. At equivalence point: moles acid = moles base.
Elaborate	12 min	Titration calculation: 'A 25.0 mL sample of HCl reaches equivalence point when 18.5 mL of 0.125M NaOH is added. Calculate the molarity of the HCl.' Students work through: $n(\text{NaOH}) = 0.125 \times 0.0185 = 2.3 \times 10^{-3} \text{ mol} = n(\text{HCl})$. $M(\text{HCl}) = 2.3 \times 10^{-3} / 0.025 = 0.093\text{M}$. Connect back to ocean: 'What natural buffer system protects the ocean from rapid pH changes?'
Evaluate	10 min	Exit ticket: (1) Calculate the pH of 0.050M HCl. (2) Calculate $[\text{OH}^-]$ in a solution with $\text{pH} = 3.5$. (3) What volume of 0.200M NaOH is needed to neutralize 50.0 mL of 0.150M HCl? Show all work.

<p>Lab / Investigation</p> <p>Lab: Acid-Base Titration — Determining the Concentration of an Unknown Acid. Each group receives a sample of 'unknown concentration' HCl. Students: (a) fill burette with 0.100M NaOH; (b) titrate 25.0 mL of unknown HCl using phenolphthalein indicator; (c) record volume of NaOH at equivalence point; (d) calculate $[\text{HCl}]$; (e) run 3 trials, calculate average. Lab report: data table with 3 trials, molarity calculation for each, average, % error vs. teacher-provided actual concentration, CER.</p>	<p>Assessment</p> <p>pH calculation exit ticket (3 parts). Titration lab report with 3-trial data, molarity calculations, and % error. Quiz: pH from $[\text{H}_3\text{O}^+]$ and vice versa, pOH, K_w calculations, strong vs. weak acid comparison, titration calculation, neutralization equation writing.</p>	<p>Differentiation & Resources</p> <p>ELL: $\text{pH} \leftrightarrow [\text{H}_3\text{O}^+]$ conversion table; step-by-step titration calculation scaffold Below level: pH scale visual only; strong acid calculations only (no titration calculations); guided PhET exploration Above level: calculate K_a for weak acid given pH; buffer capacity calculations; Henderson-Hasselbalch equation for pH of buffer systems Free: phet.colorado.edu/en/simulations/acid-base-solutions Khan Academy Acids & Bases: khanacademy.org <i>PhET Acid-Base Solutions + pH Scale:</i> phet.colorado.edu <i>Khan Academy Acids and Bases:</i> khanacademy.org <i>Crash Course Chemistry #30–31:</i> youtube.com <i>SFUSD NGSS Chemistry acids/bases unit:</i> sfusd.edu <i>CK-12 Acids and Bases:</i> ck12.org</p>
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Legacy Learning Center · Chemistry I — High School · 2025–2026

UNIT 7 — 3 Weeks | April–May

GAS LAWS, NUCLEAR PROCESSES & MODERN CHEMISTRY

Standards: HS-PS1-8 | C.9

Anchoring Phenomenon: A fully inflated car tire on a cold January morning in Indianapolis has a pressure of 35 psi. After driving on the highway, the tire pressure reads 38 psi — you didn't add air, and the tire didn't visibly change. Where did the extra 3 psi come from? And in a nuclear power plant, how does splitting uranium atoms produce enough energy to power a city?

LESSON PLAN 7.1 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Gas Laws — Boyle's, Charles's, Gay-Lussac's, Combined, Avogadro's & Ideal Gas Law

Anchoring Phenomenon: A scuba diver's lungs hold 6 L of air at the surface (1 atm). At 30 meters underwater (4 atm), that same amount of air occupies only 1.5 L. If a diver holds their breath and ascends too quickly, the expanding air can rupture the lungs. How do pressure, temperature, and volume relate for gases?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	C.9 (Indiana): Describe behavior of gases using kinetic molecular theory; apply Boyle's, Charles's, Gay-Lussac's, Combined Gas Law, Avogadro's Law, and Ideal Gas Law ($PV = nRT$) to solve problems.
Objectives	(1) State the postulates of kinetic molecular theory; (2) Apply Boyle's Law ($P_1 V_1 = P_2 V_2$ at constant T and n) to gas pressure-volume problems; (3) Apply Charles's Law ($V_1 / T_1 = V_2 / T_2$ at constant P) to temperature-volume problems; (4) Apply Gay-Lussac's Law to pressure-temperature problems; (5) Solve problems using the combined gas law; (6) Apply the Ideal Gas Law $PV = nRT$ to calculate P, V, n, or T; (7) Connect gas behavior to molecular-level kinetic energy.
Key Vocabulary	<i>Kinetic Molecular Theory (KMT), Pressure (P — atm, kPa, mmHg, torr), Volume (V), Temperature (T — must use Kelvin), n (moles), R = 0.0821 L·atm/mol·K (or 8.314 J/mol·K), STP (0°C, 1 atm), Boyle's Law, Charles's Law, Gay-Lussac's Law, Combined Gas Law, Avogadro's Law, Ideal Gas Law (PV = nRT), Molar Volume at STP = 22.4 L</i>
Materials	PhET 'Gas Properties' simulation Syringes + stoppers for Boyle's Law demo Balloons + liquid nitrogen (if available) for Charles's Law Tire pressure gauge Calculators Gas Laws reference card Science notebooks

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	8 min	Scuba diver scenario: 'A diver at 30 m underwater breathes compressed air at 4 atm. If they hold their breath and ascend to the surface (1 atm) — what happens to the volume of air in their lungs? Use $P_1 V_1 = P_2 V_2$ to calculate.' Students: $6 \times 4 = V_2 \times 1 \rightarrow V_2 = 24$ L. 'Their lungs would expand to 24 L. Lungs hold 6 L max. That's the danger.' Anchor: 'All four gas laws connect back to the kinetic molecular theory — and they can save your life or harm you.'
Explore	18 min	PhET 'Gas Properties': Students: (a) add 100 gas molecules; change volume with constant T — observe pressure change (Boyle's Law); (b) keep volume and n constant; change temperature — observe pressure change (Gay-Lussac's Law); (c) keep pressure constant; change temperature — observe volume change (Charles's Law). Record data, derive each relationship algebraically from data.
Explain	15 min	Teacher: KMT postulates → gas particles in constant random motion; collisions with walls = pressure; temperature = average KE. Derive all laws from KMT. Introduce Ideal Gas Law: $PV = nRT$. Key: T must be in Kelvin!

		Apply: 'A 3.0 mol gas sample at 25°C is contained in an 80.0 L container. Calculate the pressure.' Students solve 5 gas law problems — identify which law applies, convert units, solve.
Elaborate	10 min	Real-world applications: (1) Tire pressure in winter vs. summer (Gay-Lussac); (2) Hot air balloon (Charles's Law); (3) Scuba tank with 2,000 L of air compressed to 12 L (Boyle's); (4) Weather balloons that expand as they rise (combined gas law). Students calculate answer for each, explain using KMT.
Evaluate	12 min	Exit ticket: (1) A gas occupies 4.0 L at 300 K and 1.0 atm. What volume will it occupy at 400 K and 2.0 atm? (2) How many moles of gas are in a 10.0 L container at 27°C and 1.5 atm? (3) A tire is inflated to 35 psi at 20°C. What is the pressure after driving when temperature reaches 50°C? (All must show R value used and units.)

Lab / Investigation Lab: Boyle's Law Verification — Syringe Method. Students: (a) use syringe with trapped air; apply different forces (via calibrated weights) to compress gas; record volume and calculate pressure from force/area; (b) plot P vs. V and P vs. 1/V; (c) confirm Boyle's Law from graph linearity of P vs. 1/V; (d) calculate PV for each data point — should be constant; (e) CER: 'The data supports Boyle's Law because ____.' Virtual option: PhET Gas Properties Boyle's Law investigation. Lab report with graphs and CER.	Assessment Gas law exit ticket (3 calculations). Boyle's Law lab report with P vs. V and P vs. 1/V graphs and CER. Quiz: all five gas laws applied to problems (identify which law, unit conversions, solve), Ideal Gas Law $PV = nRT$ calculation, KMT explanation of gas behavior.	Differentiation & Resources ELL: gas laws reference card with formulas, units, and when to use each law Below level: Boyle's Law and Charles's Law only; Ideal Gas Law given R value and guided unit conversion Above level: Dalton's Law of Partial Pressures; van der Waals equation for real gas deviations; derive ideal gas law from KMT equations Free: phet.colorado.edu/en/simulations/gas-properties Khan Academy Gas Laws: khanacademy.org <i>PhET Gas Properties:</i> phet.colorado.edu <i>Khan Academy Gas Laws:</i> khanacademy.org <i>Crash Course Chemistry #23–25:</i> youtube.com <i>CK-12 Gas Laws:</i> ck12.org <i>Chemistry Coach Indiana C.9:</i> chemistry.coach
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LESSON PLAN 7.2 | Legacy Learning Center | Chemistry I — High School | 2025–2026

Nuclear Chemistry — Radioactive Decay, Fission, Fusion & Half-Life (HS-PS1-8) + Chemistry Capstone

Anchoring Phenomenon: The USS Enterprise aircraft carrier (CVN-65) operated for 51 years on 8 nuclear reactors — without ever refueling. It traveled over 2 million miles. Its fuel was enriched uranium-235. Burning the same energy from coal would require 1 million tons of coal. How does fission of just a few kilograms of uranium release such extraordinary energy?

Indiana Standards	Performance Expectations (Indiana 2023 IAS Chemistry I / NGSS HS Physical Science)
Standards	HS-PS1-8: Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during fission, fusion, and radioactive decay. [Assessment: alpha, beta, gamma decays only; qualitative models; scale of energy relative to chemical transformations. No quantitative energy calculations.]
Objectives	(1) Model alpha, beta, and gamma radioactive decay using nuclear equations; (2) Distinguish fission (splitting heavy nucleus) from fusion (combining light nuclei); (3) Explain why nuclear reactions release millions of times more energy than chemical reactions (mass-energy equivalence: $E=mc^2$); (4) Calculate remaining amount after n half-lives; (5) Evaluate evidence for nuclear energy as a low-carbon electricity source; (6) Apply course-long chemistry concepts to a capstone engineering or research project.
Key Vocabulary	<i>Radioactive Decay, Alpha Particle (^4_2He), Beta Particle ($^0_{-1}\text{e}$), Gamma Ray (γ), Nuclear Equation, Half-Life ($t_{1/2}$), Parent/Daughter Nuclide, Nuclear Fission, Nuclear Fusion, Mass-Energy Equivalence ($E=mc^2$), Mass Defect, Chain Reaction, Critical Mass, Nuclear Power, Enriched Uranium, Plutonium, Carbon-14 Dating</i>
Materials	Nuclear decay model cards Half-life M&M/penny simulation PhET 'Nuclear Fission' simulation PhET 'Radioactive Dating Game' HHMI 'Radiocarbon Dating' activity Capstone

project materials (per group — varies by track) | Science notebooks

5E Lesson Schedule

Phase	Time	Teacher & Student Actions
Engage	8 min	Display USS Enterprise scenario + energy comparison table (nuclear vs. coal). 'One U-235 fission releases 200 MeV of energy. Burning one molecule of methane releases 9 eV — about 20 million times less energy per particle. Why? The answer is at the level of the nucleus.' Anchor: 'Nuclear chemistry deals with changes IN the nucleus itself — far more powerful than electron rearrangements in chemical reactions.'
Explore	20 min	Part A: Nuclear decay model cards — Students write balanced nuclear equations for: (1) alpha decay of U-238; (2) beta decay of C-14; (3) gamma emission of Co-60. Count protons + neutrons before and after — confirm conservation. Part B: Half-life M&M simulation — 100 M&Ms; remove all M-side-up each round (= decayed). Plot: N vs. rounds. Identify half-life graphically.
Explain	15 min	Teacher: Alpha/beta/gamma properties (mass, charge, penetration). HS-PS1-8 model: nucleus before → decay products + energy released. Fission: $^{235}\text{U} + \text{n} \rightarrow \text{Ba} + \text{Kr} + 2-3 \text{n} + \text{energy}$ (chain reaction). Fusion: $^2\text{H} + ^3\text{H} \rightarrow \text{He} + \text{n} + \text{energy}$ (requires extreme temperature). $E=mc^2$: mass defect $\times c^2 = \text{enormous energy released}$. HHMI Radiocarbon Dating: C-14 half-life 5,730 years — calculate age of artifact from activity ratio.
Elaborate + Capstone	30 min	Capstone Engineering Design: Groups select one track and work on it for this lesson + additional time: Track A — Design a process to extract maximum energy from a chemical system (thermochemistry + equilibrium application); Track B — Create a comprehensive research report on nuclear power as a climate solution (safety, waste, cost, energy output calculations); Track C — Design a water treatment process using acids, bases, and precipitation reactions for a contaminated water sample; Track D — Full stoichiometry optimization for a proposed industrial chemical process (Haber-Bosch, aspirin synthesis, or biodiesel).
Evaluate	12 min	Nuclear chemistry exit ticket: (1) Write the nuclear equation for beta decay of ^{14}C . (2) A fossil has 1/8 of its original C-14 activity. How many half-lives have elapsed? How old is it? (3) Explain in 2 sentences why nuclear fission releases millions of times more energy than chemical combustion.

Lab / Investigation	Assessment	Differentiation & Resources
Lab A: Half-Life Simulation (M&Ms or pennies) — complete data table, exponential decay graph, half-life determination, CER. Lab B: HHMI Radiocarbon Dating Activity — students use C-14 half-life data to date 3 artifacts; compare calculated age to accepted value; calculate % error. Capstone project is also a lab artifact (ongoing). Combined lab report: half-life simulation + HHMI dating calculations.	Nuclear equation writing quiz (alpha, beta, gamma for 4 isotopes). Half-life calculation (after n half-lives). HHMI dating lab report. Capstone project final presentation rubric (Indiana standards demonstrated, quantitative calculations, real-world application, chemical concepts). Cumulative Chemistry Final Assessment.	ELL: nuclear decay equation template; HHMI radiocarbon dating worksheet in student's language (available in Spanish at biointeractive.org) Below level: alpha and beta decay only; half-life problems: $N = N_0 \times (\frac{1}{2})^n$ given n Above level: calculate binding energy per nucleon; compare to chemical bond energies; research ITER fusion reactor project and calculate breakeven conditions Free: phet.colorado.edu/en/simulations/nuclear-fission HHMI Radiocarbon Dating: biointeractive.org <i>PhET Nuclear Fission + Radioactive Dating Game: phet.colorado.edu HHMI BioInteractive Radiocarbon Dating: biointeractive.org Khan Academy Nuclear Chemistry: khanacademy.org Crash Course Chemistry #38–40: youtube.com Chemistry Coach Indiana: chemistry.coach</i>

Section 4: Capstone Project, Tracking & Authorization

Chemistry I Capstone Engineering Design Project

Capstone Overview — Final 2 Weeks of Course

DRIVING QUESTION: How can we apply chemistry principles to address a real-world problem in our community or the world?

Students work in groups of 2–3. Each group selects ONE track based on the chemistry they found most compelling during the course.

Track A — Thermochemistry/Energy: Design a next-generation hand warmer or chemical cold pack using reaction enthalpy data. Specify: reaction choice (HS-PS1-4), ΔH calculation, safe activation mechanism, optimal temperature range, cost-per-use estimate. Test and evaluate design.

Track B — Nuclear Power vs. Fossil Fuels: Research report — use HS-PS1-8 principles + energy calculations to evaluate nuclear power as a climate solution. Compare: energy per kg of fuel (nuclear vs. coal vs. natural gas), carbon emissions, safety record, waste management. Recommend a state energy policy for Indiana.

Track C — Water Treatment Engineering: A local water sample contains elevated concentrations of lead ions, high acidity (pH 4.5), and a bacterial contamination. Design a multi-step treatment process using: precipitation reactions (solubility rules), acid-base neutralization (C.8), concentration calculations (C.7). Present to 'city council' (class).

Track D — Industrial Chemical Process Optimization: Optimize one industrial reaction (Haber-Bosch, aspirin synthesis, or biodiesel production) using Le Chatelier's Principle (HS-PS1-6), stoichiometry (C.4.4), kinetics (HS-PS1-5), and thermochemistry (C.5). Calculate theoretical yield for proposed production scale.

Deliverables: (1) Chemistry design/research notebook; (2) Prototype or detailed technical proposal with calculations; (3) 8-minute class presentation with Indiana chemistry standards cited; (4) CER written report connecting project to specific PE codes.

Year-Long Chemistry Pacing Guide

Quarter	Months	Units	Major Assessments	Key Labs
Q1	Aug–Oct	Unit 1: Atomic Structure & Periodic Table (4 wks) Unit 2: Chemical Bonding (4 wks)	Unit 1 Test Unit 2 Test Flame Test Lab Report Conductivity Investigation (HS-PS1-3) Designed Materials Brief (HS-PS2-6)	Flame Test Spectroscopy PhET Build an Atom Molecule Shapes Conductivity Tester
Q2	Nov–Jan	Unit 3: Reactions & Stoichiometry (5 wks) Unit 4: Thermochemistry (4 wks)	Unit 3 Test Unit 4 Test Conservation of Mass Lab Stoichiometry Lab Calorimetry Lab Mid-Year Portfolio	Conservation of Mass Alka-Seltzer Stoichiometry (Baking Soda) Calorimetry (Neutralization)
Q3	Feb–Mar	Unit 5: Kinetics & Equilibrium (4 wks)	Unit 5 Test Reaction Rate Lab (HS-PS1-5) Le Chatelier Lab Engineering Design Task (HS-PS1-6)	Alka-Seltzer Rate Cobalt Equilibrium PhET Reactions & Rates
Q4	Apr–May	Unit 6: Solutions & Acids/Bases (4 wks) Unit 7: Gas Laws & Nuclear (3 wks) Capstone (2 wks)	Unit 6 Test Unit 7 Test Titration Lab Half-Life Lab HHMI Dating Capstone Presentation Cumulative Final	Titration Solution Preparation PhET pH Scale Half-Life M&Ms HHMI Radiocarbon Dating

Weekly Chemistry Fidelity Checklist

Chemistry Instructional Expectation	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8
Phenomenon-based 5E lesson delivered — driving question anchored for unit								
All three NGSS dimensions integrated: SEP (practice) + CCC (concept) + DCI (content)								
Math and quantitative reasoning embedded (stoichiometry, mole calculations, pH, etc.)								
Lab investigation or PhET/virtual lab simulation used this week								
Lab safety protocols followed — MSDS/SDS reviewed for all chemicals used								
Science notebook / lab report updated by students — claim, evidence, reasoning								
Formative assessment or exit ticket used ≥ 2 times this week								
Claim-Evidence-Reasoning (CER) written response completed at least once								
Week of (date): →	__/__/__	__/__/__	__/__/__	__/__/__	__/__/__	__/__/__	__/__/__	__/__/__

Quarterly Chemistry Data Review

Q1 — Aug–Oct

Coverage: Units 1–2: Atomic Structure + Bonding

Assessments: Unit 1 Test: Atoms & Periodic Table | Unit 2 Test: Bonding | Lab Reports: Flame Test + Molecular Model | Spectroscopy investigation

Data Point	Result	% Meeting Target	Action
% Students scoring $\geq 70\%$ on unit test			
Lab report average score (out of rubric max)			
% Students completing stoichiometry calculations accurately			
# Students needing Tier 2 Chemistry support			
% Students completing science notebook entries			

Key adjustments:

- _____
- _____

Teacher Signature: _____ Date: _____

Principal Signature: _____ Date: _____

Q2 — Nov–Jan

Coverage: Units 3–4: Stoichiometry + Thermochemistry

Assessments: Unit 3 Test: Chemical Reactions & Stoichiometry | Unit 4 Test: Thermochemistry | Lab: Mass Conservation + Calorimetry | Mid-year portfolio

Data Point	Result	% Meeting Target	Action
% Students scoring $\geq 70\%$ on unit test			
Lab report average score (out of rubric max)			
% Students completing stoichiometry calculations accurately			
# Students needing Tier 2 Chemistry support			
% Students completing science notebook entries			

Key adjustments:

- _____
- _____

Teacher Signature: _____ Date: _____

Principal Signature: _____ Date: _____

Q3 — Feb–Mar

Coverage: Unit 5: Kinetics & Equilibrium

Assessments: Unit 5 Test: Reaction Rates & Equilibrium | Lab: Reaction Rate Investigation + Le Chatelier's experiment | Engineering design task

Data Point	Result	% Meeting Target	Action
% Students scoring $\geq 70\%$ on unit test			
Lab report average score (out of rubric max)			
% Students completing stoichiometry calculations accurately			
# Students needing Tier 2 Chemistry support			
% Students completing science notebook entries			

Key adjustments:

- _____
- _____

Teacher Signature: _____ Date: _____

Principal Signature: _____ Date: _____

<p>% Students completing science notebook entries</p>	
<p>Key adjustments:</p> <p>1. _____</p> <p>2. _____</p>	
<p>Teacher Signature: _____ Date: _____</p> <p>Principal Signature: _____ Date: _____</p>	

Chemistry I Plan Authorization

<p>TEACHER — CHEMISTRY PLAN Chemistry I — High School Legacy Learning Center 2025–2026 <i>I have read this Chemistry I curriculum in full and commit to implementing it with fidelity for 2025–2026.</i></p> <p>Teacher Signature: _____</p> <p>Date: _____</p>	<p>PRINCIPAL AUTHORIZATION Principal — Legacy Learning Center <i>This Chemistry I curriculum has been reviewed and approved for 2025–2026.</i></p> <p>Principal Signature: _____</p> <p>Date Issued: _____</p>
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All Free Chemistry Resources — Quick Reference Links

Verified Direct URLs — May 2026

Indiana 2023 Chemistry I Standards: secure.in.gov/doe/students/indiana-academic-standards/science-and-computer-science/

Indiana Chemistry Standards PDF: media.doe.in.gov/news/chemistry-standards.pdf

NGSS HS Chemistry Performance Expectations: nextgenscience.org/high-school-domains-model-course-1-chemistry

OpenSciEd HS Chemistry (FREE — ALL-GREEN EdReports Aug. 2025): opensci.ed.org/curriculum/high-school/

PhET Simulations — ALL FREE: phet.colorado.edu | Build an Atom | Isotopes | Molecule Shapes | Balancing Equations | Reactions & Rates | Acid-Base Solutions | Gas Properties | Concentration | pH Scale | Nuclear Fission | Radioactive Dating

Khan Academy Chemistry (FREE): khanacademy.org/science/chemistry

Crash Course Chemistry — Full Playlist (FREE): [youtube.com](https://www.youtube.com) (search: Crash Course Chemistry)
HS Science for All — Stoichiometry + Chemistry (FREE): hsscience4all.org/chemistry
SFUSD NGSS Chemistry Curriculum (FREE): sfusd.edu/high-school-ngss-chemistry
HHMI BioInteractive — Chemistry connections + Radiocarbon Dating (FREE): biointeractive.org
CK-12 Chemistry FlexBook (FREE): ck12.org
ptable.com — Interactive Periodic Table with data (FREE): ptable.com
New Visions Science Chemistry (FREE): newvisions.org/curriculum/science/chemistry
Flinn Scientific — Free SDS/Safety Resources (FREE): flinnsci.com/sds
Chemistry Coach Indiana Standards (FREE): chemistry.coach
Chemthink Simulations (FREE): sciencegeek.net/chemthink/
IDOE IN Learning Lab — Chemistry Frameworks: inlearninglab.com
IDOE Chemistry Standards Source: secure.in.gov/doe/students/indiana-academic-standards/science-and-computer-science/
IDOE DCI Vertical Articulation: secure.in.gov/doe/files/Disciplinary-Core-Ideas-9.23.pdf
IDOE Teaching and Learning: teachingandlearning@doe.in.gov | General: 1-317-232-6610