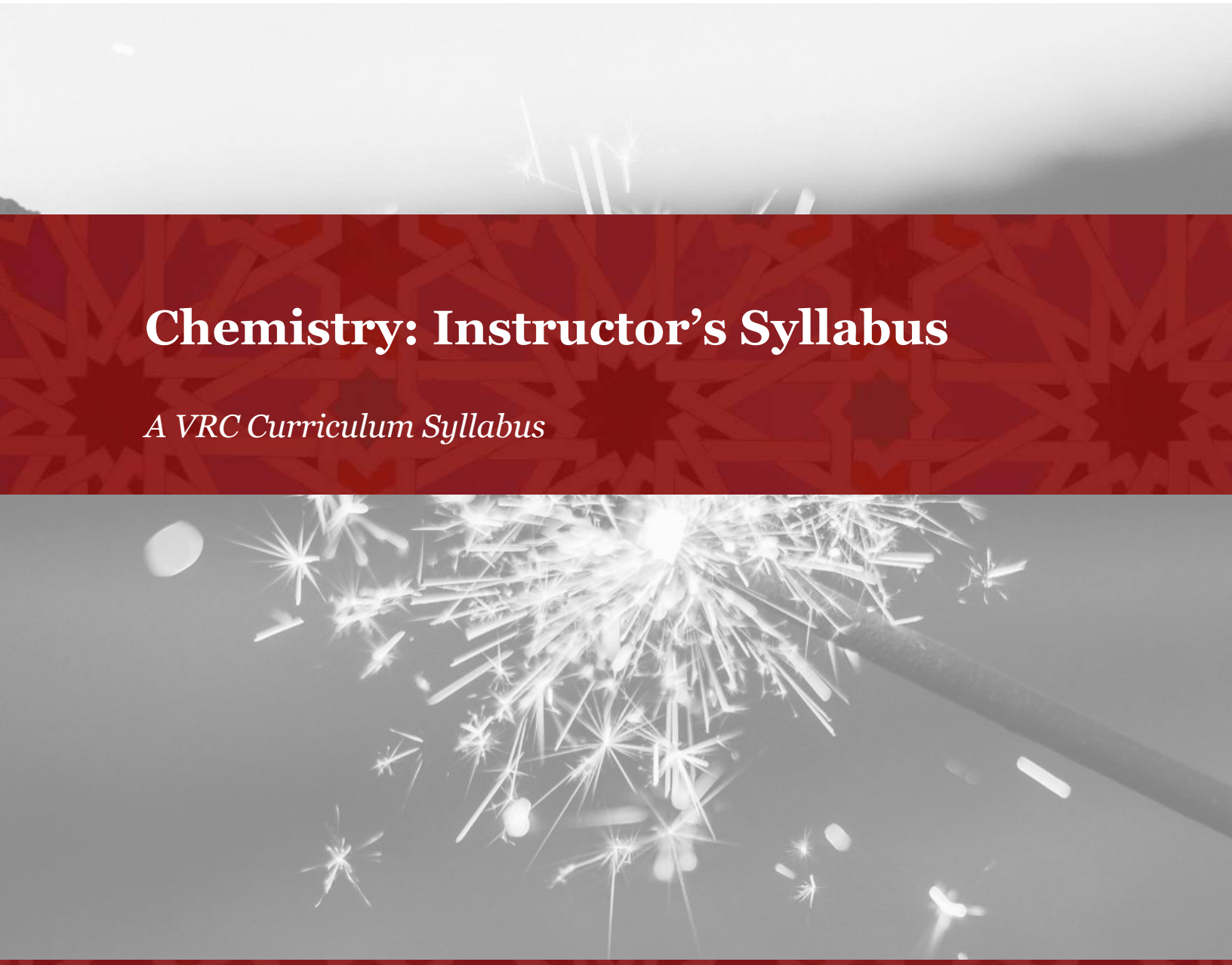
Verification and Renewal Curriculum



Chemistry: Instructor's Syllabus

A VRC Curriculum Syllabus

Written by: Sarah Kazmi, Ibrahim Qureshi, Justin Poe, Aaron Spevack

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The American Society of Islamic Philosophy and Theology

Chemistry Syllabus

A Verification and Renewal Curriculum (VRC) Syllabus

Written by Sarah Kazmi, Ibrahim Qureshi, Justin Poe, Aaron Spevack

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Course Description:

Dear Students,

Welcome to Chemistry! Chemistry comes from the Arabic word '*al-kīmīʿa*'. It is the science that studies the composition of matter from basic elements and the properties of how matter changes based on its composition. In this course you will be learning about atoms, molecules, the periodic table, solids, liquids, gasses, chemical reactions, heat, motion, acids & bases, and oxidation.

Course Overview:

Term	*Content*	*Science Fair*	*Interdisciplinary Integration*
Term 1	1. Introduction to Chemistry 2. Matter and Change 3. Scientific Measurement 4. Atomic Structure 5. Electrons in an Atom 6. Periodic Table 7. Chemical Nomenclature 8. Ionic and Metallic Bonding	<u>Developing Your Topic</u> • Class discussions about various science fair topics • Brainstorming possible **research** or **engineering** design questions • Conducting literature search • Finalizing a research or engineering design topic and question • Writing a project proposal	• Contributions of Muslims Alchemists and Chemists • Ethics of Green Chemistry • *Istiḥāla* in Islamic Law • Muslim Atomism • The Ethics of Nanotechnology • Metals and Ions in the Qur'an
Term 2	9. Covalent Bonding 10. Chemical Quantities 11. Chemical Reactions 12. Stoichiometry 13. States of Matter 14. Behavior of Gases 15. Water and Aqueous Systems 16. Solutions	<u>Science Fair</u> • Conducting experiments or building and testing prototypes • Finalizing results • Writing research paper and presenting science fair project	• Chemical Composition of Man and Clay

Term 3	17. Thermochemistry 18. Kinetics 19. Equilibrium 20. Entropy & Free Energy 21. Acids & Bases 22. Oxidation-Reduction Reactions		• Clay as the Cradle of DNA

Course Outcomes:

Transportable knowledge that students will gain:

1. Students will become familiar with basic chemical terminology of atomic and molecular structure, using the periodic table, understanding nuclear phenomena, understanding chemical processes, predicting chemical reactions, understanding bonding and behavior and states of matter.
2. Students will continue to understand crosscutting concepts such as patterns, energy and matter, structure and function, cause and effect, and systems and system models.
3. Students will reflect deeply about the wisdom, complexity, patterns and interconnectedness of Allah's creation.
4. Students will continue to gain familiarity with basic laboratory skills of safety, following instructions, making observation, measurement and conversions, using algebra to solve chemical problems, instrumentation and data analysis and interpretation.
5. Students will continue to gain familiarity with some primary literature researches, following the scientific method to conduct their own research and writing scientific reports using APA format

Course Materials:

- CK-12 Online
    - Textbook: https://flexbooks.ck12.org/user:78aa16ce4b61/cbook/vrc-ck-12-chemistry-for-high-school/
    - Textbook Integrations: *see end of syllabus*
- 2 Composition Notebooks
    - Class Notes
    - Lab Notebook/Science Fair Log
- Lab Safety Contract
- Shared folder/Google Drive (for keeping corrected assignments and tests)

Additional Teacher Resources:

- CK-12 Resources: https://www.ck12.org/c/chemistry/
- Alchemy and Chemistry in Islam: https://www.chemeurope.com/en/encyclopedia/Alchemy_%28Islam%29.html
- https://islamic-study.org/chemistry/
- Suparjo, S., Hanif, M., & Senja, D. I. (2021). Developing Islamic science based integrated teaching materials for Islamic religious education in Islamic high schools. *Pegem Journal of Education and Instruction*, *11*(4), 282-289. https://files.eric.ed.gov/fulltext/EJ1320304.pdf

Class Breakdown and Expectations:

This course engages students holistically using all of their faculties to facilitate understanding. This course follows three stages: deep reading (*mutala'a*), class sessions (*dars*), and review (*mudhakara*).

- Deep Reading (*mutala'a*): Students should closely prepare all required sections prior to class sessions and identify key topics and terms. Optionally, students may benefit from preparing an outline of the topics covered and a list of key terms and definitions.

  The method of deep reading trains students to begin to "self-teach" themselves from a textbook and to engage it critically: jotting down questions to be asked, noting places of inconsistency, and challenging evidence. Traditionally, deep reading only involved books and commentaries; however, in biology, deep engagement may also involve watching assigned videos and participating in hands-on activities where appropriate.

  The purpose of preparation is for students to familiarize themselves with the material and to grasp the structure of the upcoming lesson. When preparation is done well, a student is able to intelligently engage with the teacher in class sessions so that everything a teacher discusses is familiar to the ear and easily able to be placed within the larger study of biology.
- Class Sessions (*dars*): Students should keep a class notebook in addition to their textbook where they add notes (*mulahaza*) based on the class lecture and discussion. Students are encouraged to ask questions.
- Review (*mudhakara*): Students should gather in person or virtually for group review outside of class hours before the next class session. They should read through the material together and take turns reteaching the material from their notes to their peers. This is a place for students to work with each other to seek clarity and engage in deeper conversation and independent research around the material.

In this course, students are expected to:

1. Actively & constructively participate in class discussions
2. Work collaboratively during laboratory investigations
3. Accurately and effectively report the results of laboratory investigations
4. Complete all the assigned homework in a timely and presentable manner
5. Utilize class notes, homework assignments, and reading notes in preparation for quizzes and tests.

Evaluation:

Homework (every day)	*20%*
Quizzes (once a week)	*20%*
Tests (midterm and final)	*20%*
Labs	*15%*
Class Participation	*10%*
Science Fair (Term 1 & Term 2)	*15%*

Homework

The purpose of daily homework assignments is to reinforce classroom learning and to encourage application of the concepts learned. This also serves as feedback for the instructor to assess students' level of comprehension of the material.

Quizzes

Quizzes will be short assessments about recent homework or class work.

In-Class Activities & Projects

These may include model building activities, short experiments, or problem-solving sessions.

Tests

Tests will emphasize understanding of concepts, not memorization.

Lab

Lab is an integral part of this class as it affords students the opportunity to apply the scientific method for themselves as biologists have done in the past. All students must complete any pre-lab assignments before they may participate in the lab. Students will take lab notes and present a completed lab report in their notebook one week after the lab is performed.

Science Fair

- MA Science and Engineering Fair: https://scifair.com/
- Standards: https://www.doe.mass.edu/frameworks/scitech/2016-04/STE-Standards.pdf (pages 69-72)

- Timeline for Experiment-Based Project:Science Fair Timeline - Experiment based Project 202324.docx
- Timeline for Engineering Design Project:Science Fair Timeline - Engineering Design Project 202324.docx

Honors/AP Level:

Students in the honors/AP level will have additional assignments. Choices of research or experiment based science articles are provided for students to get used to reading primary literature and use APA citation to respond according to a rubric.

Resources

- https://nhsjs.com/?mainpage
- https://www.sciencejournalforkids.org/articles/reading_level/high-school-upper/
- https://www.snexplores.org/

Student should reflect on:

- Islamic components
- bias in research
- qualitative/quantitative research method

This is the rubric for grading:

Science Article Summary Rubric Name: _____ Date: _____ Class: _____

Category	5 – Exemplary	4 – Accomplished	3 – Developing	2 – Beginning	0 – Incomplete	Score
Article Summary Summarize what you read into **5 paragraphs** sentences.	Article summary is accurate, well organized, coherent and well written. No spelling mistakes. Capitalization and punctuation used.	Summary is accurate, but organization could be improved. No more 2 capitalization or spelling errors.	Summary is reasonably accurate (some minor errors) or organization is poor. No more than 4 capitalization or spelling errors.	Summary is inaccurate (contains important errors) 5 or more capitalization or spelling errors.	No summary provided.	
Reading Strategies & Impact of Science and Technology (Answer questions on paper with summary)	Reaction clearly shows critical analysis of article; All nine questions addressed.	Reaction to article shows thought and provides an idea of writer's position on the issue; 8 of the 9 questions are addressed.	Reaction to article provides some evidence of thought; 7 of the 9 questions are addressed.	Reaction to article very vague and lacks obvious critical thought; 5 of the 9 questions are addressed	Reaction to article not included or 5 or more questions are not addressed	
Article Verification/Citation	Article has a correct citation.	No more than one citation error.	No more than 2 citation errors.	More than 2 citation errors.	No citation is given.	
List of 10 new vocabulary words with definitions	List is complete and has full definitions		Only half the number of vocab words are given		No vocab words Total Score: _____/20	

1. **Predict**: What can you predict from the title/headline? Or what do you predict will happen next in the passage?
2. **Clarify**: Ask yourself questions when you are confused about the information the author is trying to tell you. What did you have to reread in order for it to make sense? OR what did you read that didn't make sense at first, but by the end of the passage you understood what the author meant?
3. **Visualize**: What did you visualize when you read the passage?
4. **Evaluate**: What is your opinion of what you read? Be sure to include reasons as to why or why not you feel the author was successful in persuading, informing, or entertaining the reader.
5. **Connect**: How did the passage connect to your life? OR what did you already know about this topic before you read this passage?
6. **Question**: What is a question you still have after reading the passage?
7. How does this affect society -what are the drawbacks/benefits?
8. Why was there a need for this research?
9. Why did you choose this particular article?

Weekly Schedule

TERM 1			
Week	*Topics (to read & watch)*	*Activities (to do)*	*Additional Resources*
1	*Unit 1: Introduction*		
	1.1-1.6. Introduction to Chemistry *Read:* • 1.1. Scope of Chemistry • 1.2. History of Chemistry • 1.3. Alchemy • 1.4. Areas of Chemistry • 1.5. Pure & Applied Chemistry • 1.6. Energy in Chemistry	*Exercises:* • Lab Safety • Writing a Lab Report • Design an Experiment	*Watch:* • Lab Safety • Map of Chemistry • Science and Islam Documentary • Inside the Mind of an Alchemist *Read:* • Synthetic Dyes and Chemical Industry
	Unit 2: Matter and Change		
	2.1-2.6. Properties of Matter *Read:* • 2.1. Matter, Mass, and Volume • 2.2. Pure Substance • 2.3. Physical Properties • 2.4. Extensive & Intensive Properties • 2.5. States of Matter • 2.6. Physical Change	*Exercises:* • Classifying Matter Interactive • Discovering Extensive and Intensive Properties • States of Matter Interactive	*Watch:* • Types of Matter
2	2.7-2.12. Classification of Matter *Read:* • 2.7. Mixture • 2.8. Homogenous Mixture • 2.9. Heterogenous Mixture • 2.10. Separating Mixtures • 2.11. Element • 2.12. Compound 2.13-2.18. Changes in Matter *Read:* • 2.13. Chemical Reaction • 2.14. Chemical Change • 2.15. Chemical Symbols & Formulas	*Exercises:* • Camping Interactive • 2.8. Lemonade Interactive • Observing Bubbles *Lab:* • Bubbles • Physical/Chemical Change • Heating Ice	*Watch:* • Computer Chips from Silicon • What is a Chemical Compound? • Physical & Chemical Changes • Identifying a Chemical Formula from a Particle Diagram • Types of Chemical Reactions *Read:* • Mixture: Blood

	• 2.16. Chemical Properties & Reactions • 2.17. Reactants & Products • 2.18. Recognition Chemical Reactions		• The Importance of Nomenclature
	Unit 3: Measurements		
3	3.1-3.7. International System of Units *Read:* • 3.1. SI Base Units • 3.2. Metric Prefixes • 3.3. Scientific Notation • 3.4. Length & Volume • 3.5. Mass & Weight • 3.6. Kinetic Energy • 3.7. Temperature 3.8-3.11. Unit Conversions *Read:* • 3.8. Dimensional Analysis • 3.9. Metric Unit Conversions • 3.10. Derived Units • 3.11. Density 3.12-3.16. Uncertainty in Measurement *Read:* • 3.12. Accuracy & Precision • 3.13. Percent Error • 3.14. Measurement Uncertainty • 3.15. Rounding • 3.16. Significant Figures • 3.17. Significant Figures in Addition & Subtraction • 3.18. Significant Figures in Multiplication and Division	*Lab:* • Observing a Candle *Exercise:* • Unit Conversion Worksheet • 3.1. SI Base Units Interactive • 3.2 Metric Prefixes Interactive • Mass and Density Interactive • Temperature Scales Interactive • 3.8. Mole Carnival • 3.11. Going Fishing Interactive • 3.12. Accuracy and Precision Interactive	*Watch:* • Measurements • SI Units and Density • Is Mass the Same as Weight? • Percent Error Made Easy! *Read:* • How to Crash a Space Vehicle • Clouds and Density
	Unit 4: Atomic Structure		
	4.1-4.6. Atomic Models and Theories *Read:* • 4.1. The History of Atoms • 4.2. Law of Conservation of Mass		*Watch:* • History of Atomic Chemistry *Read:* • Better Late than Never

	• 4.3. Law of Multiple Proportions • 4.4. Law of Definite Proportions • 4.5. Mass Ratio Calculation • 4.6. Dalton's Atomic Theory		
4	4.7-4.10. The Nuclear Model of the Atom *Read:* • 4.7. Atom • 4.8. Electron • 4.9. Proton • 4.10. Neutron 4.11-4.15. History of the Nuclear Model *Read:* • 4.11. Cathode Ray Tube • 4.12. Oil Drop Experiment • 4.13. Plum Pudding Atomic Model • 4.14. Gold Foil Experiment • 4.15. Atomic Nucleus 4.16-4.20. Isotopes & Atomic Mass *Read:* • 4.16. Atomic Number • 4.17. Mass Number • 4.18. Isotope • 4.19. Atomic Mass Unit • 4.20. Calculating Average Atomic Mass	*Exercise:* • Atomic Structure Worksheet • Atomic Structure Tutorial • Nanotech in Food • Rutherford's Gold Foil Experiment Simulation • Writing the Periodic Table • Atomic Number Interactive • Isotope Notation Interactive	*Watch:* • Law of Multiple Proportions • Atomic Theory • Subatomic Particles • Rutherford's Experiment • Cathode Ray Tube • Oil Drop Experiment • Atomic Mass: Introduction *Read:* • Conservation of Mass & Energy • Nanotechnology • Holding Things Together • Fingerprint Detection • Seeing the Unseeable • How to Destroy an Island • Radiocarbon Dating
5	5.1.-5.7. Light and the Bohr Model *Read:* • 5.1. Electromagnetic Spectrum • 5.2. Wavelength & Frequency Calculations • 5.3. Quantization of Energy • 5.4. Photoelectric Effect • 5.5. Atomic Emission Spectra • 5.6. Bohr's Atomic Model	*Exercise:* • Neon Lights Interactive • Visible Spectrum Interactive • Bohr's Atomic Model Interactive	*Watch:* • Light: Particle or Wave? • Flame Tests Experiment • Electrons • Atomic Emission Spectrum • de Broglie Waves • Heisenberg's Uncertainty Principle

	• 5.7. Spectral Lines of Hydrogen 5.8-5.14. The Quantum Mechanical Model Read: • 5.8. de Broglie Wave Equation • 5.9. Quantum Mechanics • 5.10. Heisenberg Uncertainty Principle • 5.11. Quantum Mechanical Atomic Model		*Read:* • Sodium Vapor Lights • Deciphering the Sun
6	• 5.12. Energy Level • 5.13. Orbital • 5.14. Quantum Numbers 5.15-5.20. Electron Arrangement in Atoms *Read:* • 5.15. Aufbau Principle • 5.16. Pauli Exclusion Principle • 5.17. Hund's Rule and Orbital Filling Diagrams • 5.18. Electron Configurations • 5.19. Valence Electrons • 5.20. Noble Gas Configuration	*Exercises:* • Orbitals Interactive	*Watch:* • The Electron • Electron Configuration • Noble Gases *Read:* • A Strange New World • In the Clouds • Where Did I Put That Electron?
7	*Unit 5: The Periodic Table*		
	6.1-6.7. History of the Periodic Table *Read:* • 6.1. Early History of the Periodic Table • 6.2. Mendeleev's Periodic Table • 6.3. Periodic Law • 6.4. Modern Periodic Table • 6.5. Metals • 6.6. Non-Metals • 6.7. Metalloids 6.8-6.14. Electron Configuration in the Periodic Table	*Exercise:* • Periodic Table Interactive • The Size of an Atom • Bonding and Electronegativity *Lab:* • Predicting Density	*Exercise:* • Periodic Table Interactive (PBS) *Watch:* • Valence Electrons • Group 1 • Argon • Ionic Bond • Tutorial: Metallic & Nonmetallic Character *Read:*

	Read: • 6.8. Blocks of the Periodic Table • 6.9. Hydrogen and Alkali Metals • 6.10. Alkaline Earth Metals • 6.11. Noble Gases • 6.12. Halogens • 6.13. Transition Metals • 6.14. Lanthanides & Actinides 6.15-6.22. Periodic Trends *Read:* • 6.15. Atomic Radius • 6.16. Ion • 6.17. Ionization Energy • 6.18. Electron Shielding • 6.19. Electron Affinity • 6.20. Ionic Radii • 6.21. Electronegativity • 6.22. Metallic & Non Metallic Character		• Finding Patterns in Elemental Behavior • Metals with Memories • Properties of Metals, Metalloids, and Nonmetals • Hard Water • Depletion of Ozone • Electron Shielding
8	*Unit 6: Chemical Names and Formulas*		
	7.1-7.2. Ionic Compounds *Read:* • 7.1. Molecular Formula • 7.2. Empirical Formula 7.3-7.5. Monoatomic Ions *Read:* • 7.3. Cation • 7.4. Anion • 7.5. Transition Metal Ions 7.6-7.8. Binary Ionic Compounds *Read:* • 7.6. Stock Name of Nomenclature • 7.7. Binary Ionic Compounds: Naming • 7.8. Binary Ionic Compounds: Formulas 7.9-7.10. Ternary Ionic Compounds	*Quiz:* • Naming Ionic Compounds *Exercise:* • Matching Molecules Interactive • Empirical Formula Interactive • Cations and Anions Interactive • Binary Ionic Compounds Interactive • 7.11. Train Cars • Naming Acids Interactive	*Watch:* • Chemical Formulas • Writing Ionic Formulas • Ternary Compounds • Bases: Naming and Writing *Read:* • How Formulas are Discovered? • How Table Salt Forms • Anions in Health and Disease • Tracing the Family Tree • The Role of Fluoride

	Read: • 7.9. Polyatomic Ions • 7.10. Ternary Ionic Compounds 7.11. Molecular Compound Names & Formulas *Read:* • 7.11. Binary Molecular Compounds 7.12-7.13. Acid & Base Names & Formulas *Read:* • 7.12. Acids • 7.13. Bases		
Unit 7: Ionic and Metallic Bonding			
9	8.1-8.5. Ions *Read:* • 8.1. Electron Dot Diagrams • 8.2. Octet Rule • 8.3. Cation Formation • 8.4. Anion Formation • 8.5. Transition Metal Ion Formation	*Exercise:* • Ionic Bonding Interactive • Octet Rule Interactive	*Watch:* • Ionic Compounds • Lewis Diagrams Made Easy • The Octet Rule *Read:* • Metal Ions and Diet
10	8.6-8.9. Ionic Bonds and Compounds *Read:* • 8.6. Ionic Bond • 8.7. Ionic Crystal Structure • 8.8. Coordination Number • 8.9. Physical Properties of Ionic Compounds 8.10-8.12. Metallic Bonds and Properties *Read:* • 8.10. Metallic Bond • 8.11. Crystal Structure of Metals • 8.12. Alloys	*Exercise:* • Covalent and Ionic Bonding Interactive	*Watch:* • Ionic Compound Formation *Read:* • Sapphire Screens? • To the Center of the Earth

TERM 2			
Week	*Topics*	*Lab*	*Additional Resources*
	Unit 8: Covalent Bonding		
11	9.1. Nature of the Chemical Bond *Read:* • 9.1. Chemical Bond 9.2-9.12. The Covalent Bond *Read:* • 9.2. Covalent Bond • 9.3. Molecular Compounds • 9.4. Energy & Covalent Bond Formation • 9.5. Lewis Electron-Dot Structures • 9.6. Single Covalent Bonds • 9.7. Multiple Covalent Bonds • 9.8. Coordinate Covalent Bond • 9.9. Covalent Bonding in Polyatomic Ions • 9.10. Resonance • 9.11. Exceptions to the Octet Rule • 9.12. Bond Energy	*Lab:* • Identifying Ionic & Molecular Compounds *Exercise:* • Building Molecules • Aspartame Molecule • Lewis Electron-Dot Structures Interactive • Ozone Resonance Interactive	*Watch:* • Covalent Compounds • Covalent vs Ionic Compounds • Single Covalent Bonds • Multiple Covalent Bonds *Read:* • Chemical Bonds • Molecular Bonds for Life • Silica Gel in Clothing
12	9.13-9.15. Molecular Geometry *Read:* • 9.13. VSEPR Theory • 9.14. Molecular Shapes: No Lone Pairs on Central Atom • 9.15. Molecular Shapes: Lone Pairs on Central Atom 9.16-9.20. Polarity & Intermolecular Forces *Read:* • 9.16. Bond Polarity • 9.17. Polar Molecules • 9.18. Van Der Waals Forces • 9.19. Hydrogen Bonding • 9.20. Physical Properties & Intermolecular Forces	*Lab:* • Dripping Droplets *Exercise:* • Molecular Shapes Interactive • Electronegativity Interactive • Soap Chemistry • 9.20. Intermolecular Forces Interactive	*Watch:* • VSEPR Model Overview • Bond Polarity *Read:* • Molecules in Computer Design • Lotus Leaves Repel Water • Sauna Survival • Hybrid Orbitals Limits

	9.21-9.24. Hybridization & Molecular Orbitals *Read:* • 9.21. Valence Bond Theory • 9.22. Hybrid Orbitals - sp3 • 9.23. Hybrid Orbitals - sp and sp2 • 9.24. Sigma and Pi Bonds		
	Unit 9: Chemical Reactions		
13	10.1-10.5. The Mole Concept *Read:* • 10.1. Avogadro's Number • 10.2. Conversions Between Moles and Atoms • 10.3. Molar Mass • 10.4. Conversions Between Moles and Mass • 10.5. Conversions Between Mass and Number of Particles 10.6-10.9. Mass, Volume, and the Mole *Read:* • 10.6. Avogadro's Hypothesis and Molar Volume • 10.7. Conversions Between Moles and Gas Volume • 10.8. Gas Density • 10.9. Mole Road Map 10.10-10.13. Chemical Formulas *Read:* • 10.10. Percent Composition • 10.11. Percent of Water in a Hydrate • 10.12. Determining Empirical Formulas • 10.13. Determining Molecular Formulas	*Exercise:* • Mole Carnival • Conversions Between Moles and Atoms Interactive • Conversions Between Moles and Mass Interactive • Molecules in the Balloon • Percent Composition Interactive	*Watch:* • Avogadro's Hypothesis • Determining Molecular Formulas *Read:* • The Composition of Petroleum
14	11.1-11.3. Chemical Equations *Read:* • 11.1. Word Equations	*Lab:* • **combination -** burning magnesium	*Watch:* • Chemical Reactions • Types of Chemical Reactions

	• 11.2. Writing Chemical Equations • 11.3. Balancing Chemical Equations 11.4-11.9. Types of Chemical Reactions *Read:* • 11.4. Combination Reactions • 11.5. Decomposition Reactions • 11.6. Combustion Reaction • 11.7. Single Replacement Reactions • 11.8. Activity Series • 11.9. Double Replacement Reactions	• **decomposition** - copper sulfate hydrate • **single replacement** - zinc with hydrochloric acid • **double replacement** - sodium hydroxide and hydrochloric acid • **combustion** - candle burning *Exercise:* • Balancing Chemical Equations • Writing Combination Reaction Equations • Decomposition Reactions in an Airbag	• Writing Chemical Equations *Read:* • Fire in the Hole • The Heat of Thermite Reactions
15	*Unit 10: Stoichiometry*		
	12.1-12.6. Stoichiometric Calculations *Read:* • 12.1. Everyday Stoichiometry • 12.2. Mole Ratios • 12.3. Mass-Mole Stoichiometry • 12.4. Mass-Mass Stoichiometry • 12.5. Volume-Volume Stoichiometry • 12.6. Mass-Volume Stoichiometry 12.7-12.9. Limiting Reactant and Percent Yield *Read:* • 12.7. Limiting Reactant • 12.8. Determining the Limiting Reactant • 12.9. Theoretical Yield and Percent Yield	*Exercise:* • Mashed Potatoes Interactive • Running Out of Reactants Interactive • Limiting Reactant Interactive	*Watch:* • Stoichiometry • Sandwich Stoichiometry *Read:* • Stocking the Sand • Issues in Improving Yield • Manufacturing Rocket Fuel
16	*Unit 11: States of Matter*		
	13.1-13.5. Gases *Read:*	*Exercise:*	*Watch:*

	• 13.1. Kinetic Molecular Theory • 13.2. Gas Pressure • 13.3. Atmospheric Pressure • 13.4. Pressure Units and Conversions • 13.5. Average Kinetic Energy & Temperature 13.6-13.10. Liquids *Read:* • 13.6. Surface Tension • 13.7. Evaporation • 13.8. Vapor Pressure • 13.9. Boiling • 13.10. Vapor Pressure Curves	• States of Matter Interactive (States & Phase Changes) • Building Bridges Simulation • Average Kinetic Energy Interactive • Boiling Water on Mt. Everest Interactive *Lab:* • Matter on the Move	• Postulates of Kinetic Molecular Theory • States of Matter • Gas Pressure: The Basics • Biggest Mistakes in Chemistry • Non-Newtonian Fluids *Read:* • Exploding Marshmallows • Gas Pressure and Dissolvability • Enriching Uranium • How Did the Fire Start?
17	13.11-13.16. Solids *Read:* • 13.11. Melting • 13.12. Sublimation • 13.13. Crystal Systems • 13.14. Unit Cells • 13.15. Classes of Crystalline Solids • 13.16. Amorphous Solid 13.17-13.20. State Changes *Read:* • 13.17. Change of State • 13.18. Heating & Cooling Curves • 13.19. Phase Diagrams • 13.20. Phase Diagram for Water	*Exercise:* • Phase Change Simulation • Heating Curve of Water Interactive • General Phase Diagram Interactive	*Watch:* • The Highest Melting Point • Sublimation • Rolling Glass Read: • Why Won't My Salt Melt? • Crystal Structures • Carbon Fiber in Hockey • All Three Phases at Once!
	Unit 12: Behavior of Gases		
18	14.1-14.2. Gas Properties *Read:* • 14.1. Compressibility • 14.2. Factors Affecting Gas Pressure 14.3-14.7. Gas Laws	*Lab:* • Balloon Lab *Exercise:* • States of Matter Interactive (Interaction)	*Watch:* • Gas Law • Factors that Influence Gas Pressure • Boyle's Law of Ideal Gases • Real Gases

	Read: • 14.3. Boyle's Law • 14.4. Charles's Law • 14.5. Gay-Lussac's Law • 14.6. Combined Gas Law • 14.7. Avogadro's Law 14.8-14.11. Ideal Gases *Read:* • 14.8. Ideal Gas Law • 14.9. Calculating the Molar Mass of a Gas • 14.10. Gas Stoichiometry • 14.11. Real and Ideal Gases 14.12-14.15. Gas Mixtures & Molecular Speeds *Read:* • 14.12. Dalton's Law of Partial Pressures • 14.13. Mole Fraction • 14.14. Gas Collection by Water Displacement • 14.15. Diffusion, Effusion, and Graham's Law	• Compressibility Interactive • Piston Pressure Interactive • Charles's Law Interactive • Gay-Lussac's Law Interactive • Partial and Combined Pressures Interactive • Mole Fraction Interactive	• Collecting Oxygen Through Water Displacement *Read:* • Hot Tires and Cold Drinks • Mole Fractions and Experiments
	Unit 13: Water & Solutions		
19	15.1-15.3. Properties of Water *Read:* • 15.1. Structure of Water • 15.2. Structure of Ice • 15.3. Physical Properties of Water 15.4-15.9. Aqueous Solutions *Read:* • 15.4. Solute and Solvent • 15.5. Dissolving Process • 15.6. Liquid-Liquid Solutions • 15.7. Electrolytes and Nonelectrolytes • 15.8. Dissociation • 15.9. Strong and Weak Electrolytes 15.10-15.11. Colloids and Suspensions	*Exercise:* • Structure of Water Interactive • Structure of Ice Interactive • Dissolving Process Interactive • Conductive Solutions Interactive • Solid on Land, Ion in Water • Tyndall Effect	*Watch:* • Why Does Ice Float in Water? • Aqueous Solutions • Pepper and Water Trick *Read:* • Contaminants in the Water Supply • Lowering the Freezing Point • Am I Drinking Electricity? • The Composition of Inks

	Read: • 15.10. Suspensions • 15.11. Colloids		
20	16.1-16.7. Solubility Overview *Read:* • 16.1. Solution • 16.2. Solute-Solvent Combinations • 16.3. Rate of Dissolving • 16.4. Saturated and Unsaturated Solutions • 16.5. Solubility • 16.6. Supersaturated Solutions • 16.7. Henry's Law of Solubility 16.8-16.12. Solution Concentration *Read:* • 16.8. Percent Solutions • 16.9. Molarity • 16.10. Molality • 16.11. Preparing Solutions • 16.12. Dilution 16.13-16.17. Colligative Properties *Read:* • 16.13. Vapor Pressure Lowering • 16.14. Freezing Point Depression • 16.15. Boiling Point Elevation • 16.16. Electrolytes and Colligative Properties • 16.17. Calculating Molar Mass Using Colligative Properties	*Exercise:* • Dissolving Sugars • Rock Candy Simulation • Saturated and Unsaturated Solutions • Flat Soda Interactive • Percent Solutions Interactive • Dilution Interactive • Salty Roads Simulation	*Watch:* • Solutions • The Solutions Song • Temperature and the Solubility of Minerals • Solution Preparation • Boiling Point Elevation • Determining Molar Mass of an Unknown *Read:* • Dealing with Aches and Pains • Seeding Clouds for Rain • Industrial Production of Aspirin • Dilution in Homeopathy • How Pressure Cookers Work • Salt in Ice Cream

TERM 3			
Week	*Topics*	*Lab*	*Additional Resources*
	Unit 14: Thermochemistry		
21	17.1-17.7. Heat Flow *Read:* • 17.1. Chemical Potential Energy • 17.2. Heat • 17.3. Exothermic Reaction • 17.4. Endothermic Reaction • 17.5. Exothermic & Endothermic Processes • 17.6. Heat Capacity & Specific Heat • 17.7. Specific Heat Calculations 17.8-17.11. Thermochemical Equations Overview *Read:* • 17.8. Enthalpy • 17.9. Calorimetry • 17.10. Thermochemical Equation • 17.11. Stoichiometry & Thermochemical Equations	*Lab:* • Specific Heat and Metals • Thermal Energy *Exercise:* • Change in Temperature Interactive • Hot Pack Cold Pack Simulation • Chasing the Heat Interactive • Burning Stuff Interactive	*Watch:* • Thermochemistry • Energy Considerations in Biofuels • Chemical Heat • Exothermic and Endothermic Reactions • Heat Capacity of Water Balloon • Specific Heat Calculation *Read:* • When Lightning Strikes • Stay Warm for Life • Properties and Sources of Propane Gas
22	17.12-17.15. Heat and Changes of State *Read:* • 17.12. Heats of Fusion and Solidification • 17.13. Heats of Vaporization and Condensation • 17.14. Multi-Step Problems with Changes of State • 17.15. Heat of Solution 17.16-17.19. Hess's Law *Read:* • 17.16. Hess's Law of Heat Summation • 17.17. Heat of Combustion		*Watch:* • Heat of Fusion & Heat of Vaporization • Enthalpy and Phase Changes • Hess's Law • Enthalpies of Formation: Tutorial *Read:* • Water to the Wadi • Properties of Rocket Propellants

	• 17.18. Standard Heat of Formation • 17.19. Heat of Reaction		
	Unit 15: Kinetics and Equilibrium		
23	18.1-18.7. Rates of Reactions *Read:* • 18.1. Reaction Rate • 18.2. Collision Theory • 18.3. Activation Energy • 18.4. Potential Energy Diagrams • 18.5. Activated Complex • 18.6. Factors Affecting Reaction Rate • 18.7. Catalyst 18.8-18.10. Rate Laws *Read:* • 18.8. Rate Law and Rate Constant • 18.9. Reaction Order • 18.10. Determining the Rate Law from Experimental Data	*Lab:* • Reaction Rates and Surface Area *Exercise:* • Factors Affecting Reaction Rates Interactive • Collision Theory Interactive • Potential Energy Diagrams	*Watch:* • Collision Theory Animation • Potential Energy Diagram Basics • Activated Complex Demonstration • How to Speed Up Chemical Reactions • Reaction Rate: Introduction *Read:* • Collision Theory and Football Fumbles • Activation Energy in Fireflies • Catalysts and Carbon Dioxide
24	18.11-18.15. Mechanisms *Read:* • 18.11. Reactions Mechanisms and the Elementary Step • 18.12. Reaction Intermediate • 18.13. Molecularity • 18.14. Rate-Determining Step • 18.15. Reaction Mechanisms and Potential Energy Diagrams 19.1-19.5. The Nature of Equilibrium *Read:* • 19.1. Reversible Reaction • 19.2. Chemical Equilibrium • 19.3. Equilibrium Constant • 19.4. Calculations with Equilibrium Constants • 19.5. Nonreversible Reactions	*Exercise:* • Reversible Reaction Interactive	*Watch:* • The Difference Between and Catalyst and an Intermediate • Equilibrium • Reactions and Equilibrium • If Molecules Were People • Irreversible Reactions *Read:* • Reaction Mechanisms • Order of Reaction • No Going Back • Equilibrium in Everyday Life
25	19.6-19.10. Equilibrium and Le Chatelier's Principle	*Exercise:* • Flat vs. Fizzy Soda	*Watch:*

	Read: • 19.6. Le Chatelier's Principle • 19.7. Effect of Concentration • 19.8. Effect of Temperature • 19.9. Effect of Pressure • 19.10. Le Chatelier's Principle and the Equilibrium Constant 19.11-19.15. Solubility Equilibrium *Read:* • 19.11. Solubility Product Constant • 19.12. Calculating Solubility from Ksp • 19.13. Calculating Ksp from Solubility • 19.14. Predicting Precipitates • 19.15. Common Ion Effect	• Concentrating on Le Chatelier's Principle • Pressing Them Together Interactive	• Effect of Temperature in NO_2 Equilibrium • Concentration Change • Predicting Whether a Precipitate Will Form *Read:* • Equilibrium Between Carbon Dioxide and Hydrogen • A Cure for Acid Indigestion • Water Purification with Seashells
	Unit 16: Entropy and Free Energy		
26	20.1-20.2. Entropy *Read:* • 20.1. Entropy Overview • 20.2. Standard Entropy 20.3-20.5. Spontaneous Reactions and Free Energy *Read:* • 20.3. Spontaneous & Nonspontaneous Reactions • 20.4. Free Energy • 20.5. Calculating Free Energy Change 20.6-20.8. Free Energy and Equilibrium *Read:* • 20.6. Temperature and Free Energy • 20.7. Changes of State and Free Energy • 20.8. Calculations of Free Energy and Keq	*Exercise:* • Entropy Interactive	*Watch:* • Calculate the Standard Entropy of Reaction • What are Spontaneous/Nonspontaneous Reactions? • Free Energy Analogies • Entropy Change of Phase Transition *Read:* • Order and Chaos • Burgers and Charcoal Manufacturing • Kelvin 506 • How Does Your Garden Grow?
	Unit 17: Acids & Bases		

27	21.1-21.7. Properties of Acids and Bases *Read:* • 21.1. Acid • 21.2. Base • 21.3. Arrhenius Acids • 21.4. Arrhenius Bases • 21.5. Bronstead-Lowry Acids and Bases • 21.6. Bronstead-Lowry Acid-Base Reactions • 21.7. Lewis Acids and Bases	*Lab:* • pH Analysis *Exercise:* • Arrhenius Base Interactive	*Watch:* • Acids and Bases • Properties of Acids • Salts • Lewis Acids and Bases *Read:* • Can a Weak Acid Dissolve Glass? • Alkaline Mineral Springs • Grandma's Lye Soap • Soda and Dissolving Teeth
28	21.8-21.11. pH Concept *Read:* • 21.8. Self-Ionization of Water • 21.9. pH • 21.10. Calculating pH • 21.11. pOH Scale and Calculations 21.12-21.15. Acid and Base Strength *Read:* • 21.12. Strong and Weak Acids and Acid Ionization Constant • 21.13. Strong and Weak Bases and Base Ionization Constant • 21.14. Calculating Ka and Kb • 21.15. Calculating pH of Weak Acid and Base Solutions	*Exercise:* • The pH Scale Interactive • The pOH Concept Interactive	*Watch:* • pH and pOH • Acids, Bases, and pH • pH Calculations of Weak Bases *Read:* • Acid-Base Issues and Definitions • How Strong
29	21.16-21.20. Acid-Base Neutralization *Read:* • 21.16. Neutralization Reaction and Net Ionic Equations • 21.17. Titration Experiment • 21.18. Titration Calculations • 21.19. Titration Curves • 21.20. Indicators 21.21-21.23. Salt Solutions *Read:* • 21.21. Salt Hydrolysis	*Exercise:* • Titration Curves Interactive	*Watch:* • Neutralization Reaction Overview • Titration Experiment • Basic Titrations: Tutorial • Titration Roundup • Hydrolysis of Salts *Read:* • Fries and Fuel • Pool Water

	• 21.22. Calculating pH of Salt Solutions • 21.23. Buffers		• Chemistry of Bread Making
	Unit 18: Oxidation-Reduction Reactions		
30	22.1-22.5. The Nature of Oxidation and Reduction *Read:* • 22.1. Oxygen in Reactions • 22.2. Redox Reactions and Ionic Compounds • 22.3. Redox Reactions and Molecular Compounds • 22.4. Oxidizing and Reducing Agents • 22.5. Corrosion 22.6-22.8. Oxidation Numbers *Read:* • 22.6. Assigning Oxidation Numbers • 22.7. Oxidation-Number Changes in Reactions • 22.8. Identifying Redox Reactions 22.9-22.11. Balancing Redox Reactions *Read:* • 22.9. Oxidation Number Change Method • 22.10. Half-Reaction Method • 22.11. Half-Reaction Method in Basic Solution	*Lab:* • Series of Metals	*Watch:* • Why is Mars Red? • Electrolysis of Water • Oxidation and Reduction • Reaction of Magnesium in Oxygen • Redox Reactions • Water Purification by Oxidation • Corrosion and Prevention *Read:* • Too Much Sugar • Recycling Metals • Why is the Sky Yellow? • The Chemistry of Batteries

Curriculum Standards for Chemistry:

- taken from NGSS - Next Generation Science Standards and Massachusetts State Curriculum Guidelines
- based on NGSS pages 53-58

Domain/Standards	*Topic*	*Main Ideas*
Structure and Properties of Matter **HS-PS1-1.** **HS-PS1-3.** **HS-PS1-8.** **HS-PS2-6.**	Matter and Its Interactions	
	Nuclear Processes	
	Types of Interactions	
Chemical Reactions **HS-PS1-1.** **HS-PS1-2.** **HS-PS1-4.** **HS-PS1-5.** **HS-PS1-6.** **HS-PS1-7.** **HS-PS1-9 (MA)** **HS-PS1-10(MA)** **HS-PS1-11(MA)**	Structure and Properties of Matter	
	Chemical Reactions	
	Optimizing the Design Solutions	
	Acid/Base Solutions	
	Oxidation/Reduction	
	Separation of Mixtures based on Chemical and Physical Properties	
Forces and Interactions (physics) **HS-PS2-1.** **HS-PS2-2.** **HS-PS2-3.** **HS-PS2-4.** **HS-PS2-5.**	Forces and Motion	
	Types of Interactions	
	Definitions of Energy	
	Defining and Delimiting an engineering problem	
	Optimizing the Design Solution	
Forces and Interactions	Molecular-Level Structures of	

(chemistry) **HS-PS2-6.** **HS-PS2-7.(MA)** **HS-PS2-8.(MA)**	Polymers, Ionic Compounds, Acids and Bases, and Metals	
	Solubility and Conductivity	
	Kinetic Molecular Theory	
Energy (physics) **HS-PS3-1** **HS-PS3-2.** **HS-PS3-3.** **HS-PS3-4.** **HS-PS3-5.**	Definitions of Energy	
	Conservation of Energy and Energy Transfer	
	Relationship between Energy and Forces	
	Energy and Chemical Processes	
	Defining and Delimiting an engineering problem	
Energy (chemistry) **HS-PS3-4b.**	Transfer of Energy during a Chemical Reaction	
	Gibbs Free Energy	
Waves and Electromagnetic Radiation (physics) **HS-PS4-1.** **HS-PS4-2.** **HS-PS4-3.** **HS-PS4-4.** **HS-PS4-5.**	Energy in Chemical Processes	
	Wave Properties	
	Electromagnetic Radiation	
	Information Technology and Instrumentation	

CHEMISTRY VRC INTEGRATIONS

1. INTRODUCTION TO CHEMISTRY

1.2 History of Chemistry

Chemistry in the Muslim World

Most historians of science consider Muslims scientists as the founders of chemistry. Many early Muslims were engaged in in both traditional alchemy – the quest to turn base metals into gold – and in early practical chemistry. Chemistry formed an important part of industries such as metal-working, ceramic manufacture, pharmacy and dyeing. A huge amount of practical knowledge of substances and processes was gained. Important methods such as distillation were developed by Islamic scientists, as well as new approaches to experimentation. Islamic scientists were also the first to describe the properties of acids and alkalis.

Abu Bakr al-Razi wrote *Doubts about Galen* to question classical Greek theories of the elements only consisting of heat, coldness, wetness and dryness. His chemical experiments led him to conclude that qualities such as "oiliness", "sulfurousness", inflammability, and salinity were unique qualities. In addition, Razi was the first to distill petroleum, invent kerosene for lamps, invent soap bars, produce antiseptics, and discover the chemical process of sublimation.

Early Muslim chemists also invented different kinds of laboratory equipment. Al-Biruni invented the conical measure, the laboratory flask, and the pycnometer. Jabir ibn al-Hayyan invented the alembic, retort, and still all for the purpose of distillation. Avicenna was the first to use a thermometer in his experiments in physics. [Source]

1.3. Alchemy

Alchemy in the Muslim World

Our word 'chemistry' is taken from 'alchemy' which comes from the Arabic '*al-kimi'a'*. Famous Muslim alchemists include Jabir ibn Hayyan ("Jabir" is where we get the word "algebra" from!) and Abu Bakr al-Razi (known in the West as Rhazes). Their key chemical discoveries include:

- inventing a distillation apparatus (*taqtir*) that could fully purify chemical substances
- inventing the chemical process of filtration
- discovering hydrochloric, sulfuric, nitric, and acetic acids

- mixing perfumery
- identifying sodium (*natrun*) and potassium (*qali*). The periodic symbol for sodium (Na) and potassium (Ka) come from their Arabic names.
- the discovery of 'royal water' (*aqua regia*) which can dissolve the noblest metal, gold

Beginning in the 9th century, a number of Muslim scientists including al-Kindi, the astronomer al-Biruni, Avicenna, and Ibn Khaldun began opposing the traditional quest of alchemy to transform some metals into other metals, arguing that this was impossible. Instead, the fascination with alchemy in the Muslim world continued not literally as a physical science but symbolically as a science of the soul. Imam al-Ghazali, for example, wrote a short work in Persian entitled "The Alchemy of Happiness" about how to transform the state of the heart to turn to God and earn true happiness. The Prophet ﷺ said, "People are like minerals," (Muslim 2638) and so Ghazali's book is about transforming people's heart to "gold". [Source]

1.5. Pure and Applied Chemistry

Principles of Green Chemistry

We, human beings, were created as custodians (*khulafa*) of God's earth. God says that "He set a balance. So that you do not go to excess beyond the balance. Uphold the scales justly and do not fall short of the balance," (Qur'an, al-Rahman 55:9). As such, believers are required to engage with nature in a manner that maintains the divine order of the universe. Consistent with this responsibility are the principles set by green chemistry. As opposed to regular industrial applications of chemistry, green chemistry aims at creating biodegradable products that do not persist in the environment, products that do not cause toxic harm to humans, and products made from renewable resources that do not leave an environmental mess for later generations.

There are twelve principles to practicing green chemistry:

1. Waste Prevention: It is better to prevent waste than to treat or clean up waste after it has been created.
2. Atom Economy: Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. Less Hazardous Chemical Syntheses: Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4. Designing Safer Chemicals: Chemical products should be designed to effect their desired function while minimizing their toxicity.
5. Safer Solvents and Auxiliaries: The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used (minimize the use of auxiliary substances).
6. Design for Energy Efficiency: Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.
7. Use of Renewable Feedstocks: A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.
8. Reduce Derivatives: Unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.
9. Catalysts: Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. Design for Degradation: Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. Real-Time Analysis for Pollution Prevention: Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. Inherently Safer Chemistry for Accident Prevention: Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions and fires. [Source]

2. Matter and Change

2.14. Chemical Change

Chemical Change in Islamic Law

In Islamic Law, the term *istihala* refers to the transformation of an object so that it no longer has its original nature but takes on a new nature. This process of *istihala* becomes relevant for ritually impure substances such as wine, pork, and flowing blood, because these substances are not legal to use for any purpose. However, transform wine into vinegar, for example, and the vinegar is now ritually pure and permissible to use. Other

example of *istihala* include grape juice to alcohol, wood with urine to ash, manure to ash, blood to musk, and oil to soap.

So what constitutes *istiḥāla*? The scholars of law said that its indicators include 1) a change in the nature or essence of the thing, 2) irreversibility. One cannot conclude that *istihala* has occurred from simply

- mixing substances (*ikhtilat*). For example, dissolving salt in water is simply mixing and not transforming. Similarly, mixing wine in dough does not transform the substance and instead the mixture in its entirety is impure.
- a difference in appearance. For example, iron, when used for different purposes, looks different, but is not transformed.
- heating & cooking. For example, heating and cooking pork does not change it being impure.
- cooling & freezing. For example, fats and oils solidify at lower temperatures but do not transform.
- fragmentation of the original substance. For example, grinding, cutting, or crushing sugar does not transform its nature as sugar.

If we map documented cases of *istihala* onto their chemical structure, we find that in all instances, *istihala* involves significant molecular transformation.

- Grape juice is glucose and fructose ($C_6H_{12}O_6$) --> ethanol (C_2H_5OH) and carbon dioxide (CO_2). The sugars are converted to ethanol and carbon dioxide through yeast fermentation.
- Wine contains ethanol (C_2H_5OH) --> Acetic Acid (CH_3COOH). Ethanol is oxidized to acetic acid.
- Wood (($C_6H_{10}O_5$)n) with urine: urea ($CO(NH_2)_2$), water, creatinine, salt --> to ash composed of inorganic materials and oxides such as calcium oxide (CaO), potassium oxide (K2O), and magnesium oxide (MgO). If urine-soaked wood is burned, the nitrogen compounds enhance the formation of potassium nitrate.
- Manure --> ash. When manure is burned, organic matter is decomposed through pyrolysis and oxidation.
- Oils to soap. Fats and oil begin as one glycerol ($C_3H_8O_3$) and become soap made of sodium or potassium salts such as $C_{17}H_{35}COONa$ and glycerol.

As such, contemporary scholar Mufti Faraz Adam recommends that *istihala* in a post-industrial world be examined on the basis on significant transformation in the molecular structure of a substance and a change in its distinguishing properties and characteristics. (Faraz Adam, *A Framework for Istihala in the Contemporary World*)

3. Measurements

4. Atomic Structure

4.1. The History of the Atom

Muslim Atomism

Many Muslim theologians also offered a theory of atomism inspired by the Qur'an. They were inspired by God's words, "We tore them apart completely," (Qur'an, Saba 34:19) arguing that there must exist a smallest piece after a substance is torn apart that cannot be torn apart more. They explained that the world is made of grains of sand, like scattered dust in the wind, as God describes the Day of Judgment, "And the mountains will crumble. And become dust scattered," (Qur'an, al-Waqi'a 56:5-6). Because of this, the physical makeup of the world matches its spiritual meaning: the world is scattered dust, holding no significance to the life of the believer because the life of this world is illusory. It only seems substantial.

The theory of the atom proposed by Muslims differed from Indian and Greek theories in significant ways.

- The first major characteristic is that they had no size: no length, no width, and no depth. They were like geometric points.
- They were all homogenous, being of the same kind.
- They were finite in number.
- They were perishable by nature and capable of being destroyed. They only persisted by God re-creating them in every moment.

(Osman Bakar, The History and Philosophy of Islamic Science, 87-91).

4.7. Atom

Nanotechnology and Contemporary Muslim Scholars

Nanotechnology, also called molecular manufacturing, is “a branch of engineering that deals with the design and manufacture of extremely small electronic circuits and mechanical devices built at the molecular level of matter.” The goal of nanotechnology is to manipulate materials at the atomic level to build the smallest possible electromechanical devices, given the physical limitations of matter. Many of the

mechanical systems that we know how to build will be transferred to the molecular level as some atomic analogy.

Some of the more prominent benefits of nanotechnology include:

- Medicine. Medical applications are pharmaceutical creation, disease treatment, and nanomachine-assisted surgery. Nanomedicine deals with the comprehensive monitoring, control, construction, repair, defense, and improvement of all human biological systems by working at the molecular level with engineered nanodevices and nanostructures; the science and technology of diagnosing, treating, and preventing disease and traumatic injury, as well as relieving pain and preserving and improving human health.
- Water Purification. Nanotechnology is being developed to remove waste from water, to remove salt and metals from water to make it drinkable, and to filter out viruses and microorganisms.
- Energy. Nanotechnology is being used to reduce the cost and improve the efficiency of fuel cells and solar cells.

However, there significant associated risks and concerns regarding its development and use:

- Weapons. It is possible for assemblers and disassemblers to create weapons, to be used as weapons themselves. Armies could develop disassemblers to attack physical structures or biological organisms at the molecular level. A similar hazard would be if general-purpose disassemblers escaped into the environment and started disassembling every molecule they encountered.
- Transhumanism. This form of human “enhancement” recklessly envisions that progress should advance towards liberating the human race from its biological constraints. This fever dream disregards the untold destruction that may be wrought from this pursuit to make human beings stronger, smarter, and immortal.
- Electronic surveillance. The implications of unleashing molecular data collection on civil liberties are grave. Information collection may also be abused for profiling individuals and spying.
- Toxicity and exposure to humans or upsetting the balance of natural environments.

Muslim scholars trained in Islamic Law have begun treating the topic of nanotechnology. At large, since the Qur'an and sunna do not directly address nanotechnology and because scholars already approve of physics, chemistry, biology, and genetics, it follows at nanotechnology in general as a field is also acceptable. However, when we turn our attention to particular applications, the legal principle at work must be to preempt harm (*sadd al-dhara'i*): where nanotechnology where inextricably lead to the unlawful or harmful, the means that lead to it are forbidden in Islamic Law. Indeed, this takes priority over any potential benefits to nanotech applications because of the legal principle that "preventing harm is prior to obtaining benefit." This is all the more the case when the degree of potential harm is great, such as with fundamentally altering the environment or human activities. Unfortunately, because there is no conclusive data on what these harms actually are or may be, scholars need to assess to what degree "preempting harm" should be applied. [Source 1, 2]

5. Electrons in Atoms

6. The Periodic Table

6.5. Metals

[Gold] Since gold is very valuable and easily malleable, it and silver are recognized forms of currency in Islamic Law as goods that intrinsically hold value as opposed to other commodities. Yet, because gold and silk are often used to show off wealth as jewelry, God forbids men from wearing them in this life. Instead, he says that they are for righteous in Paradise: "Gardens of Eden, which they will enter. They will be adorned there with bracelets of gold and pearls, and their garments there are silk," (Qur'an, Fatir 35:33). In the meanwhile, in the present life, gold is only an illusory good not worth pursuing. God says, "Made attractive to people is love of what they covet: women, children, heaps of gold and silver, well-bred steeds, cattle, and land. These are the enjoyments of the lowly life. But with God lies the best of aims!" (Qur'an, Al-'Imran 3:14).

[Copper] This metal is non-corrosive and prevents other metal from oxidizing and rusting. This property was known to Dhul Qarnayn in the Qur'an. God says, "'Bring me sheets of iron!' Then, when he had levelled them between the two mountain sides, he said, 'Blow!' then, when it became a fire [burning], he said, 'Bring me molten copper to pour over it'" (Qur'an al-Kahf 18:96).

Iron (Fe) is one of the cheapest and most-used metals on Earth. It is an essential element for life, with the average human being containing 4 grams of iron. Iron makes up 5% of the earth's crust and much of it likely comes from meteorites impacting the Earth. God refers to this as "sending down", declaring, "We sent down iron in which there is tremendous harm as well as uses for people so that God sees who will support Him and His messengers unseen," (Qur'an, al-Hadid 57:25). Iron is a tool by which God tests His slaves: will they use iron to wage unjust war and bring 'tremendous harm' or to aid the helpless among other beneficial 'uses for people'?

Copper (Cu): “And to Sulayman [We subjected] the wind. It’s morning was a month’s journey and it’s evening a month. We made flow for him a river of copper.” (Qur’an, Saba 34:12)

Gold (Au): “For those who disbelieved and died as disbelievers, nothing will be accepted from them as ransom, not even the earth’s fill of gold!” (Qur’an, Al ‘Imran 3:91)

6.16. Ion

Ions Make You Happy?!

After a storm, the air feels clean and fresh. People often report feelings of pleasantness and well-being following an electric storm. In the Qur'an, God says, "And among his signs is that He shows you lightning while you fear it and hope for it and that He sends down rain from the sky reviving the earth after it dies. In this there are signs for those who reflect," (Qur'an, al-Rum 30:24). For most people, lightning and thunder are terrible, frightening phenomena. Thunder deafens and lightning can kill and destroy infrastructure. And so it is clear what God refers to by fearing lightning. But what about hoping for it?

In normal circumstances, the molecules in air have an equal number of protons and electrons, and so their charges cancel out. In nature, abundant ions are generated whenever energy is transferred into the air by the friction in wind, rain, and water. Lightning discharges specifically cause electrons to be torn loose from a molecule which are then adopted by nearby molecules, transforming them into negative ions. Negative ions carry the air's electrical energy.

Scientists have demonstrated that small air ions are biologically active. An abundance of negative ions in the air boost the production of serotonin, the happiness hormone, and reduce migraines. In contrast, positive ions are associated with irritation, tension, and

exhaustion. The pleasant feeling you find after lightning? Thank God for the negative ions He has placed in the air! [Source]

7. Chemical Nomenclature

8. Ionic and Metallic Bonding

8.12. Alloys

Brass, a copper (Cu) and zinc (Zn) alloy. God describes the Last Day as "a day when the sky will be like molten brass," (Qur'an, al-Ma'arij 70:8).

9. Covalent Bonding

10. The Mole

11. Chemical Reactions

12. Stoichiometry

12.1. Everyday Stoichiometry

Man and Clay

In 2002, American limnologists Robert Sterner and James Elser defined the human body in terms of the chemical composition of the human body. Taking the stoichiometric approach of considering whole organisms as a single abstract molecule, they defined the human body in terms of this 22-element molecule:

$H_{375,000,000}O_{132,000,000}C_{85,700,000}N_{6,430,000}Ca_{1,500,000}P_{1,020,000}S_{206,000}Na_{183,000}K_{177,000}Cl_{127,000}Mg_{40,000}Si_{38,600}Fe_{2,680}Zn_{2,110}Cu_{76}I_{14}Mn_{13}F_{13}Cr_{7}Se_{4}Mo_{3}Co_{1}$

This distribution of elements more or less mirrors the chemical composition of clays and soils. God says about the creation of the human being, "Verily did We create man from an extract of clay," (Qur'an al-Mu'minun 23:12). And regarding soil, God says, "From it did We create you and to it We shall return you and from it We shall bring you out once more," (Qur'an, TaHa 20:55). [Source 1, Source 2]

13. States of Matter

13.16. Amorphous Solid

The History of Glassmaking

Throughout Muslim civilizations, glassware was produced in vast amounts from the 8th century either by blowing liquid glass into holds or by cutting it from crystal. Glassmakers in Syria and Egypt inherited the Roman glass industry, improving on it by

perfecting glass decoration and coloring and expanding the range of possible glass products. Glass from Syria was highly prized the world over. Glass objects such as Syrian enameled glass were discovered in medieval European sites in Sweden, and Southern Russia.

In the early 14th century, Maragha astronomer-mathematician Kamal al-Din al-Farsi (1267-1319) experimented with a glass sphere filled with water to analyze the way sunlight breaks into the spectrum colors of a rainbow. The rays that produced the colors of the rainbow, he observed: were refracted upon entering his glass sphere, underwent a total internal reflection at the back surface of the glass sphere (which sent them back toward the observer), and experienced a second refraction as they exited the sphere. This occurred in each droplet within a mist to produce a rainbow."

The technique of cutting crystal was said to have been introduced by 'Abbas ibn Firnas (d. 887), scholar and inventor in the courts of 'Abd al-Raḥman II and Muḥammad I. al-Firnas contributed to the early experiments with lenses and magnifying script with their use. He also lent his skills to the glassmaking furnaces of Cordoba, and made a representation of the sky in glass, parts of it clear and parts cloudy with lightning and thunder.

Stained glass windows first originated in Syria in about 750 CE on the outside wall of the Umayyad palace. "The first painters of glass in the Islamic world applied a brownish or yellowish metallic pigment on bowls, dishes, and other objects. The decoration usually consists of animal or vegetal motifs, sometimes accompanied by inscriptions. By applying pigments to both sides of these objects, glassmakers could highlight details or exploit the transparency of the glass to produce subtle shading effects," said historian Muneneh Michael. Some of the most sophisticated Egyptian glass vessels were decorated with luster. This shiny, sometimes metallic effect was achieved by painting copper or silver oxide on the surface of the object, which was then fired at a temperature of about 600°C (1112°F) in reducing conditions. [Source]

14. The Behavior of Gases

15.5. Dissolving Process

Purifying Water: Removing Solutes

Medieval Muslim scientists spoke at length about the process of purifying water, not only to be safe for drinking, but also because of its special ritual significance. In Islamic Law,

water only remains valid to use in ritual ablutions (*wudu'*) if it's color, taste, and smell do not change. And so scientists aimed at purifying water to be colorless, tasteless, and without smell.

Water purification had three stages: 1) sedimentation (*tarwiq*), 2) filtration, and 3) sterilization. Sedimentation removed any suspended elements in water. However, because leaving water sitting to naturally let the heavier elements drop to the bottom was long and tedious, medical practitioners like Ibn Rubn al-Tatari would advise adding coagulants such as cores of peach and apricot to cause the suspended elements to form into larger particles and drop quicker.

For filtration, he would instruct that dirty water be passed through layers of soil and sand to filter, clarify, and extract any contaminants. Abu Bakr al-Razi and Avicenna introduced another method of filtration involving two pots, one of them containing the dirty water and the other empty. Then a roll of spun wool should be placed between the pots, one tip in the dirty water and the other tip in the empty pot. When the water was heated, it would be collected as steam on the wool, travel along the wool, and condense into liquid again at the empty pot. The hadith scholar Ibn Qayyim al-Jawziyya would speak about the natural filtration of fresh water from seawater by digging a series of holes in sand and passing water from one to another until it becomes "pure and sweet".

For sterilization, Abu Bakr al-Razi would describe how long one should boil water to remove the "corruption" in it, and Jabir ibn Hayyan would invent a method of boiling water, collecting the steam in a series of canes, passing it through cotton which lowers it temperature, and collecting the condensed steam as pure water. He would emphasize the need to distill water several times to remove all soft and dissolved impurities in water. [Source]

15. WATER

16. SOLUTIONS

17. THERMOCHEMISTRY

18. KINETICS

19. EQUILIBRIUM

20. ENTROPY AND FREE ENERGY

21. ACIDS AND BASES

Clay, a seemingly infertile blend of minerals, might have been the birthplace of life on Earth. Or at least the place where complex biochemicals such as DNA, amino acids, and enzymes necessary for life were nurtured! [Source]

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