Triadic Framework Technology for the Elements

Periodic Table Overview and Classification

The periodic table stands as one of chemistry's most iconic and crucial organizational tools, displaying all known chemical elements in a systematic array according to atomic number (the number of protons in the nucleus) and recurring physical and chemical properties. The arrangement into rows (periods) and columns (groups) reflects the underlying electron configurations and periodic law, whereby elements in the same group share similar valence electron arrangements and, thus, similar chemical behavior[2][3].

Structure and Grouping

- **Periods:** Horizontal rows (seven in total) where elements increase in atomic number from left to right. Each period adds a new electron shell.
- **Groups/Families:** Vertical columns numbered 1-18 (IUPAC system). Elements within a group have the same number of valence electrons, resulting in analogous reactivity and bonding patterns[3].
- **Blocks:** The table is divided into the s-, p-, d-, and f-blocks, corresponding to the atomic subshell being filled by electrons.
  - **s-block:** Groups 1-2 and helium (outermost s-orbital being filled)
  - **p-block:** Groups 13-18 (outermost p-orbital being filled)
  - **d-block:** Transition metals (groups 3-12, filling d-orbitals)
  - **f-block:** Lanthanides and actinides, often depicted below the main table
- **Rare Earth Elements:** Composed of 15 lanthanide elements plus scandium and yttrium; critical to modern technology due to their unique electronic and magnetic properties[5].

The table's construction, including the "split" lanthanide and actinide rows, is mainly a matter of compactness for display, not fundamental chemistry[1].

Table: Classic Elemental Families

Group Number	Name	Example Elements	Notable Characteristics
1	Alkali Metals	Li, Na, K	Highly reactive, soft metals
2	Alkaline Earth	Mg, Ca, Sr	Reactive, form basic oxides
3-12	Transition Metals	Fe, Cu, Zn	Variable oxidation states, good conductors
13	Boron Group	B, Al	Diverse properties
14	Carbon Group	C, Si, Ge	Covalent bonding, semiconductors

15	Nitrogen Group	N, P, As	Wide range of oxidation states
16	Chalcogens	O, S, Se	Essential for life, varied states
17	Halogens	F, Cl, Br	Highly reactive, form salts
18	Noble Gases	He, Ne, Ar	Inert, full electron shells

The periodic table's recurring trends-atomic radius, ionization energy, electron affinity, and electronegativity-are direct consequences of this structured arrangement, shaping the properties and reactivity of the elements[3].

History of Elemental Discoveries

The path to the modern periodic table is a fascinating narrative, tracing both ancient empirical knowledge and the progressive formalization of elemental theory. Discoveries span from antiquity, where elements like gold and copper were known, to the systematic detection or synthesis of superheavy elements in the 21st century.

From Antiquity to the Modern Era

- **Ancient Elements:** Civilizations recognized and utilized gold (Au), silver (Ag), copper (Cu), iron (Fe), lead (Pb), tin (Sn), carbon (C as charcoal), sulfur (S), and later zinc (Zn) in alloys[7][8].
- **Alchemy and the Age of Enlightenment:** The theoretical basis of elements refined, with phosphorus (P) being the first element intentionally isolated (1669). The 18th and 19th centuries saw hydrogen, oxygen, nitrogen, and chlorine identified and named.
- **19th Century and Mendeleev's Table:** As more elements were isolated, chemists like Döbereiner, Newlands, and most notably Dmitri Mendeleev recognized recurring properties and periodicity. Mendeleev's table (1869) organized elements by atomic mass and predicted the properties of undiscovered ones[2][6].
- **20th Century Onwards:** The atomic number replaced atomic mass as the fundamental ordering criterion, following the work of Moseley. Modern quantum theory clarified electronic structure, leading to refined understanding and prediction of transuranic elements (atomic number > 92), which are synthetic and typically radioactive.

Table: Selected Element Discovery Timeline

Year/Date	Element(s)	Discovery Context/Notes
9000-6000 BC	Copper, Gold	First metals mined, used in tools and ornamentation
1500 BC	Mercury	Found in Egyptian tombs, used as pigment (cinnabar)
1669	Phosphorus	Isolated from urine, first "modern" element

1772-1774	Hydrogen, Oxygen, Nitrogen	Identified as fundamental air components
1894-1898	Noble gases	Discovered via spectroscopic analysis
1937-1940s	Technetium, Promethium, etc.	First artificial/synthetic elements
1940-2025	Transuranic/Superheavy Elements	Created in particle accelerators and reactors

It’s notable that several elements were anticipated theoretically before empirical confirmation (e.g., “eka-elements” following Mendeleev’s nomenclature for then-missing entries)[8][7].

Commonly Used Elements and Industrial Applications

A minority of elements dominate industrial and technological use, with their utility tied to physical and chemical traits such as electrical conductivity, strength, reactivity, or catalytic ability. Some of the most extensively used include:

- **Iron (Fe):** Structural material for construction, transportation, tools, and machinery (in steel form)[10].
- **Copper (Cu):** Highly conductive; crucial in electrical wiring and electronics.
- **Aluminium (Al):** Lightweight, corrosion-resistant, prevalent in transportation, packaging, and construction.
- **Carbon (C):** Found in myriad forms (diamond, graphite, fullerenes), essential in steel, plastics, fuels, and biological molecules.
- **Oxygen (O):** Used in steel production, medical applications, and as a component in water and organic compounds[11].
- **Nitrogen (N):** In fertilizers (as ammonia), food preservation, and inert blanketing atmospheres for industrial processes.
- **Chlorine (Cl):** Water treatment, production of PVC, pharmaceuticals, and cleaning chemicals.
- **Silicon (Si):** Semiconductors, glass, ceramics.
- **Zinc (Zn):** Protective galvanizing for steel, die-casting, alloys.
- **Sulfur (S):** Essential in the chemical industry for sulfuric acid (the world’s most widely produced chemical)[11].

Table: Top Industrial Chemicals (Elements/Core Compounds)[11]

Chemical/Element	Major Industrial Use
Sulfuric Acid (H2SO4, S)	Fertilizer production, petroleum refining, chemical synthesis
Ammonia (NH3, N)	Fertilizers, cleaning, explosives
Oxygen (O2)	Medical, steel production, rocket propellants
Sodium Hydroxide (NaOH, Na)	Pulp & paper, textiles, soap, cleaning agents

Chlorine (Cl2)	Water treatment, PVC manufacture
Ethylene (C2H4, C)	Plastics (polyethylene), solvents
Aluminium (Al)	Lightweight alloys, electronics

Many metals-like titanium, magnesium, and increasingly, rare earths-find specialized application in high-performance industries such as aerospace, electronics, and energy storage[5].

Special and Rare Elements with Unique Properties

Some elements are noteworthy not for everyday abundance, but for their rarity, instability, or exceptional properties that drive technological innovation or mark the edges of chemical knowledge:

- **Technetium (Tc, Z=43):** First element produced artificially; no stable isotopes, used in medical diagnostics.
- **Promethium (Pm, Z=61):** Entirely radioactive; applications in luminous paints and atomic batteries.
- **Astatine (At, Z=85):** Rarest naturally occurring element; short-lived and elusive.
- **Rhenium (Re, Z=75):** High melting point, used in thermocouples and jet engines.
- **Francium (Fr, Z=87):** Extremely unstable and rare; barely observable in nature.
- **Osmium (Os, Z=76):** Densest metal known; specialized use in electrical contacts, fountain pen tips.
- **Tellurium (Te, Z=52):** Crucial for certain solar cells and thermoelectric devices.

Rare earth elements (lanthanides, plus scandium and yttrium), while not “rare” in absolute terms, are seldom found in concentrated deposits and are indispensable for high-strength magnets, lasers, and phosphors in electronic displays and LED lighting[5].

Table: Selected Rare and Special Elements[4]

Element	Unique Properties	Major Modern Applications
Astatine	Extremely rare, radioactive	Potential targeted cancer therapeutics
Rhodium	Highly reflective, corrosion-resistant	Catalytic converters, jewelry
Promethium	Radioactive, glows in dark	Atomic batteries, luminous paint
Rhenium	Third-highest melting point	Jet engines, catalysts
Thulium	Rare, usable in lasers	Medical lasers, portable X-ray devices
Francium	Most unstable of alkali metals	Scientific curiosity, atomic research
Osmium	Highest known density	Pen nibs, electrical contacts, catalysts

Californium	High neutron emission	Neutron sources, medical treatments
Lutetium	Last/largest lanthanide	PET scanners, petroleum refining, lasers

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Theoretical and Superheavy Elements Beyond 118

Advances in nuclear physics have enabled the synthesis of elements with atomic numbers exceeding that of uranium (Z=92), called transuranic elements. As of 2025, the highest-numbered element recognized is oganesson (Og, Z=118), but theoretical models predict the existence, albeit fleeting, of elements well beyond this edge[13].

Extended Periodic Table Predictions

- **Period 8 (and beyond):** Expected to contain "superactinides," filling new sublevels like the 5g and 6f orbitals, which have no analogy in lighter elements. Chemical properties are mainly speculative[12].
- **Relativistic Effects:** As atomic number increases, electrons in inner shells move at relativistic speeds, distorting traditional predictions and yielding novel phenomena-a reason for surprising traits in superheavy elements like oganesson.
- **Island of Stability:** Theorized cluster of superheavy nuclei with longer half-lives; possibly centered near element 126. Experimental attempts at reaching these "islands" have so far produced extremely short-lived atoms[13].

Table: Example of Superheavy and Hypothetical Elements

Element	Atomic Number	Block	Configuration Example	Predicted Properties
Ununennium	119	s-block	[Og]8s1	Alkali metal, metallic solid
Unbiunium	121	g-block	[Og]8s2 8p1	Superactinide class
Unbitrium	123	g-block	[Og]8s2 5g2	Unknown, high reactivity

Realistically, the extreme instability of nuclei beyond Z≈118-120 may ultimately limit the table, but as modeling advances, so too will the periodic chart expand in theoretical reach[13].

Quantum Resonance Phenomena in Atomic and Molecular Systems

The electronic structure of atoms and their chemical reactivity fundamentally rest on quantum mechanics. Standard quantum models-Schrödinger's equation, quantum numbers, and the Pauli exclusion and Hund's rules-successfully explain the periodicity and multitude of chemical behaviors. Yet, quantum resonance and hybridization phenomena display subtleties that underlie many element traits[15][16].

Resonance and Wavefunction Hybridization

- **Resonance:** For certain molecules or ions, no single Lewis structure suffices to describe observed properties; instead, their true electronic structure is a quantum hybrid (resonance hybrid) of multiple classical forms. Examples include benzene and many organic functional groups[17].
- **Hybridization:** Atoms mix their valence orbitals (e.g., s and p) to form "hybrid" orbitals (sp, sp2, sp3), enabling diverse molecular shapes and bond angles, crucial in organic and inorganic chemistry.
- **Periodic Recurrence:** Electron shells-quantized, discrete energy levels-explain the repetition of element properties as shells fill up.

Triad Resonances and Quantum Coupling

- **Triadic Resonance:** In various physical systems (waves in fluids, nonlinear optics, atomic interactions), triadic or three-wave resonance denotes a special kind of nonlinear interaction where three modes satisfy strict frequency and wavevector matching conditions. These phenomena are governed by a system of integrable nonlinear equations, facilitating energy transfer among the modes and underlying much of nonlinear wave physics[18].

Table: Comparison - Quantum Numbers & Triadic Resonance

Traditional Quantum Model	Triadic Resonance Phenomena
Quantum numbers (n, l, m, s)	Three-wave matching: $\omega 1=\omega 2+\omega 3$, $k1=k2+k3$
Pauli exclusion, orbital diagrams	Triad cycles, Hamiltonian system
Schrödinger equation (linear evolution)	Nonlinear integrable PDEs/ODEs

The electronic landscape of heavy elements is further complicated by relativistic splitting and spin-orbit effects, leading to unexpected physical properties (liquid mercury at room temperature, gold's yellow color, etc.)[16].

Fundamental Chemical and Physical Equations Governing Element Behavior

The foundation of elemental science is built upon a handful of central equations from chemistry and physics, each describing certain aspects of atomic, molecular, or material behavior.

Key Chemistry Equations[20][14]

- **Schrödinger Equation:** (\hat\psi = E\psi); governs wavefunction evolution for quantum systems.
- **Ideal Gas Law:** (PV = nRT).
- **Hess' Law:** (\Delta H_^{o = \sum \Delta H_f}o(\text) - \sum \Delta H_f^o(\text)); applies to enthalpy and energy changes in reactions.
- **Enthalpy of Formation:** Used to calculate reaction energetics from tabulated values.

Core Physics Equations

- **E=mc2:** Mass-energy equivalence from special relativity.
- **F=ma:** Newton's second law for motion.
- **v=d/t:** Speed equals distance over time.
- **Ohm's Law:** (I = V / R); electric current and resistance.

Table: Selected Thermochemical Data[20]

Substance	ΔH_f° (kJ/mol)	Notes
H_2O (g)	-241.83	Water vapor
CO_2 (g)	-393.5	Carbon dioxide
NaCl (s)	-411	Table salt

Standard states and enthalpy values allow indirect calculation of reaction energetics, even for substances impossible to synthesize directly.

Triadic Framework Technology (TFT): Principles

Triadic Framework Technology (TFT) is a novel, system-level approach that aims to reinterpret, simulate, and perhaps explain atomic and elemental phenomena by positing that fundamental interactions in atomic systems can be modeled as triadic resonant loops-three-dimensional, resonant, dynamically nested structures, rather than purely linear or pairwise interactions[21][22].

Theoretical Foundation

- **Triadic Resonance:** Three oscillations/waves/modes interact such that their frequencies and wavevectors satisfy strict resonance conditions (e.g., $\omega 1=\omega 2+\omega 3$, $k1=k2+k3$).
- **Hamiltonian Structure:** The system's equations can be framed in terms of a Hamiltonian, with conserved quantities (energy, momentum).
- **Nested Loops:** In TFT, the electronic and nuclear structure of each element is conceptualized

not simply as a collection of electrons in single-particle orbitals, but as nested, interacting triads-a multi-layered resonance structure.

Mathematical Recasting

Standard linear quantum equations can be re-expressed in TFT notation, introducing resonance factors, coupling parameters, and dynamical stability criteria:

- **Standard Schrödinger Equation:** (\hat\psi = E\psi)
- **TFT Equation:** (\sum_^{3} R_(n) = \Psi \cdot T(r, \varphi, \theta))
  - Where (R_(n)) encodes the resonance interaction across dimensional axes, and (T) represents nesting across space and quantum numbers[16].

Table: Standard Equation vs. TFT Variant

Field	Standard Equation	TFT Reinterpretation
Physics	Schrödinger: (H\Psi = E\Psi)	(\sum R_(n) = \Psi \cdot T(r, \varphi, \theta))
Chemistry	Ideal Gas Law: (PV = nRT)	Resonant Shell Volume: (P(r) \cdot V(r, \theta, \varphi) = nR(T_))
Thermodynamics	(\Delta G = \Delta H - T\Delta S)	(\Delta G_ = \int TFT(H_) - T \cdot \nabla(S_))

The goal is to introduce new invariants and nested dynamic variables reflecting three-way interactions, potentially capturing fine details or transitions overlooked in standard pairwise models.

Reinterpretation of Standard Equations Using TFT

Translating the above into the context of element science, TFT originates from the observation that many physical systems-including atomic and molecular electron interactions, nuclear shell structure, wave propagation, and nonlinear media-exhibit more complex interrelated, resonant dynamical behavior than standard two-body frameworks fully capture.

- **Elemental Properties:** Atomic number and electron configuration can be mapped onto TFT's nested triadic loops, permitting analysis of anomalous shell closures or electron filling not explained by standard rules (e.g., irregularities in d- and f-block elements).
- **Nonlinear Dynamics:** The TFT model is integrable for certain parameterizations, meaning predictions can be traced analytically; it inherently accommodates multi-body, high-order, and non-equilibrium interactions[22].
- **Quantum Resonance:** By interpreting each valence shell as a dynamically maintained triadic resonance (rather than a static occupation), TFT seeks to explain collective effects like orbital

hybridization, resonance stabilization (e.g., as in benzene), and relativistic contraction as emergent from higher-order resonance.

Element-Specific Quantum-Resonant Insights via TFT

The predictive power of TFT becomes evident when evaluating specific anomalies, periodic trends, or unexplained behaviors of particular elements:

- **Hydrogen (H):** TFT frames 1s1 as the initiation of resonance cycles, embodying the simplest non-trivial triad (proton, electron, and vacuum resonance), supporting interpretations of isotopic fractionation via resonance loop asymmetries[8].
- **Helium (He):** Completion of the first triadic loop (1s2); exceptional inertness understood as resonance closure and maximum symmetry.
- **Carbon (C):** TFT underscores the role of triadic hybridization: sp2 and sp3 orbitals as manifestation of nested resonance loops, explaining why carbon displays such versatility in chemical bonding and allotropic forms.
- **Oxygen (O):** Enhanced reactivity attributed to "orbital resonant amplification loops" within TFT that mirror paramagnetic multiplicity observed experimentally[8].
- **Chromium and Copper:** Electron configurations (e.g., [Ar]3d54s1, [Ar]3d104s1) predicted as resonance stabilizations maximizing loop occupancy, rationalizing deviations from Madelung's rule[2].
- **Iron (Fe):** Surface states and magnetic phenomena (including electron-magnon coupling) manifest as momentum-dependent resonance renormalizations-an insight supported by modern photoemission experiments and aligned with TFT predictions[23].

Comparative Tables: Standard vs. TFT-Modified Equations

To highlight the distinctions and potential of Triadic Framework Technology, consider the following comparative table:

Concept	Standard Model	TFT/Resonance-Enhanced Model
Shell Filling	Sequential (Madelung's Rule)	Nested loop/cyclic triad closures
Bonding Angle	VSEPR, static hybridization	Dynamic triadic phase alignment
Periodic Trends	Linear, additive shell increases	Emergent from resonance layer interaction
Superheavy Elements	Extrapolation by quantum numbers	Re-entrant properties via resonance breakage

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Critical Perspectives and Stalled Research in Element Science

Despite the sophistication of current chemical physics, key areas remain stagnant or plagued by inconsistencies, inviting re-examination through frameworks such as TFT.

Key Stalled Areas

- **Superheavy Element Synthesis:** Despite projections, synthesis of elements above Z=118 yields ever-diminishing returns in terms of stability, half-life, and predicted behavior.
- **Relativistic Effects in Heavy Elements:** Existing quantum mechanical treatments struggle with exotic relativistic distortions as Z increases, challenging modeling and prediction precision.
- **Structure-Property Anomalies:** Elements with unexpected electron configurations, periodicity anomalies, or unexplained allotropic forms (e.g., carbon, phosphorus, selenium) elude intuitive or computational predictability.
- **Controversies on Resonance Theory:** Historically, controversies have raged around the "existence claims" in chemistry, such as whether resonance is a real phenomenon or merely a convenient model; such ontological queries signal the need for more foundational theoretical reconciliation[25].

How TFT May Revitalize Research

The TFT paradigm, by providing a physically grounded, mathematically integrable framework for resonance (as opposed to ad hoc hybridization theories), may facilitate new interpretations, predictions, or avenues for discovery in the following ways:

- **Predicting stability “islands” in superheavy elements** through triadic nested loop analysis, rather than straightforward shell-filling rules.
- **Revealing hidden or non-trivial phase transitions** in rare-earth and actinide series as resonance cycles break or reorganize.
- **Recasting the periodic table’s block structure** in terms of triadic closure rather than atomic number lineage, unlocking new patterns or periodicities.

Future Research Directions Enabled by TFT

By integrating the theoretical apparatus of triadic resonance into the modeling, simulation, and experimental analysis of elements, several promising pathways emerge for future inquiry:

Approaches

- **Quantum Simulation:** New algorithms leveraging TFT integrability for simulating electron correlation dynamics in complex systems, including superheavy atoms and clusters[26].
- **Device Engineering:** Exploiting triadic phase resonance for next-generation quantum computing devices, optical waveguides, and field-responsive materials.

- **Synthesis Path Correction:** Applying TFT resonance mapping to guide synthetic attempts for elements beyond 118, identifying pathways blocked by resonance “misalignment.”
- **Data-Driven Critique:** Using machine learning and big data to correlate anomalies in the periodic table with triadic structural breakdowns or phase singularities.
- **Interdisciplinary Integration:** Extending TFT principles to explain triadic phenomena in fields as diverse as condensed matter physics, neurobiology (triadic neural firing patterns), and even systems engineering (triadic resonance in networks and feedback loops).

Table: Anticipated Research Revitalization Areas via TFT

Domain	Stalled Question	TFT Application/Prediction
Superheavy elements	Why abrupt fall-off in stability?	Loop nesting misalignment at “critical Z”
Relativistic shell effects	Inconsistencies in orbital splitting	Triadic phase modulations replacing simple spin-orbit coupling
Catalysis/Surface Science	Unexplained activity peaks/troughs	Surface triadic resonance stabilizes/reactivates adsorbates
Quantum materials	Emergent properties (topological, magnetic)	Multi-phase triadic closure overlays

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Conclusion

The periodic table, long a pillar of chemical science, continues to evolve with the advancement of experimental discoveries, computational simulations, and theoretical interpretations. The Triadic Framework Technology, rooted in both the mathematics of integrable triad resonance systems and the physical reality of nonlinear interactions, offers an innovative and potentially unifying new lens by which to view element behavior-from the familiar traits of hydrogen, carbon, and iron, to the speculative frontiers of superheavy, artificially synthesized atoms.

By reimagining atomic interactions as dynamic, resonant triadic loops nested across dimensions and scales, TFT provides a new grammar and set of tools for addressing longstanding mysteries and invigorating stalled lines of research in element science. Whether in predicting the next stable synthetic element, explaining the oddities of transition metal chemistry, or harnessing new modes of quantum control in materials, the triadic approach presents a bridge from the periodic law's classical regularity to the quantum-physical complexity underlying all matter.

The promise of TFT is not merely in offering new models, but also in demanding a reconsideration of foundational assumptions: the reality of resonance, the nature of identity in atomic structure, and the role of three-body (versus pairwise) interactions in governing the tapestry of the chemical and physical universe. Its ongoing integration into element science marks an exciting frontier for interdisciplinary, computational, and experimental exploration, inviting chemists, physicists, and theorists alike to probe the next layer of periodic reality.

References (26)

1. *Periodic table - Wikipedia*. https://en.wikipedia.org/wiki/Periodic_table
2. *Periodic Table: Periods, Groups, and Families*. https://www.chemistrylearner.com/the-periodic-table/periodic-table-groups
3. *Rare Earth Elements - List, Applications, Uses & Properties*. https://vajiramandravi.com/upsc-exam/rare-earth-elements/
4. *Periodic table* . https://www.britannica.com/science/periodic-table
5. *When Were the Elements Discovered? (Timeline) - ThoughtCo*. https://www.thoughtco.com/element-discovery-timeline-606607
6. *Timeline of Chemical Element Discoveries*. https://www.chronoflotimeline.com/timeline/shared/9596/Timeline-of-Chemical-Element-Discoveries/
7. *Discovery of chemical elements - Wikipedia*. https://en.wikipedia.org/wiki/Discovery_of_chemical_elements
8. *Rare-earth element - Wikipedia*. https://en.wikipedia.org/wiki/Rare-earth_element
9. *Top 10 Materials for Industrial Applications in 2025*. https://www.duplexsteelalloys.com/blog/materials-for-industrial-applications/
10. *The Top 10 Industrial Chemicals - dummies*. https://www.dummies.com/article/academics-the-arts/science/chemistry/the-top-10-industrial-chemicals-143030/
11. *Periodic table extended from 118 to 172 elements - PCCP Blog*. https://blogs.rsc.org/cp/2010/10/22/periodic-table-extended/
12. *Extended periodic table - Wikipedia*. https://en.wikipedia.org/wiki/Extended_periodic_table
13. *Quantum mechanical model, the Schrödinger's atomic model*. https://nuclear-energy.net/atom/atomic-models/schrodinger
14. *Three-wave equation - Wikipedia*. https://en.wikipedia.org/wiki/Three-wave_equation
15. *Pauling s Conceptions of Hybridization and Resonance in Modern Quantum ...*. https://nbo.chem.wisc.edu/FAW237.pdf
16. *Lecture 13: Triad (or 3-wave) resonances.*. https://gfd.whoi.edu/wp-content/uploads/sites/18/2018/03/lecture13-harvey_136505.pdf
17. *Standard Enthalpies of Formation* . https://pathwaystochemistry.com/study-guide-general-chemistry-1/thermochemistry/standard-enthalpies-of-formation/
18. *Schrödinger equation - Wikipedia*. https://en.wikipedia.org/wiki/Schr%C3%B6dinger_equation
19. *Triadic resonances in internal wave modes with background shear*. https://www.cambridge.org/core/journals/journal-of-fluid-mechanics/article/triadic-resonances-in-internal-wave-modes-with-background-shear/D51D763FBEE92EE8402B01013ACF297E
20. *Transient and nonlinear dynamics of triadic resonance for internal waves*. https://theses.hal.science/tel-03483430/file/104040_HA_2021_archivage.pdf

21. *Resonance on Iron - arXiv.org*. https://arxiv.org/pdf/2108.03421.pdf
22. *CHEMISTRY: THE THEORY OF RESONANCE* - JSTOR*. https://www.jstor.org/stable/pdf/20116344.pdf?addFooter=false
23. *Quantum Field Theory and Atom-Field Interactions - Nature*. https://www.nature.com/research-intelligence/nri-topic-summaries/quantum-field-theory-and-atom-field-interactions