

Ionization- Energy Evaluation Information Page

Search Terms:

- Periodic trends, Ionization energy
- Successive ionization energy
- Second ionization energy
- Third ionization energy
- Ionization energy
- Ionization energy, Coulomb's law
- Why does ionization energy decrease going down a family?
- Why does ionization energy increase going across a period in the periodic table?

Broad definition of what we are considering

- We are considering primarily the conceptual understanding related to ionization energy, both trends in first ionization energy and trends in successive ionization energies.

Johnstone's Triangle Elements

Element	Examples
Macroscopic	<i>General Definition for Macro: things we can see (observations) OR specific measurements.</i> Ionization energy values explicitly provided (or interpretable). Visual examples of relative reactivity of alkali metals.
Symbolic	<i>General Definition for Symbolic: standardized, discipline-specific short-form representations that efficiently communicate significant information. It is a universal shorthand that bridges the macroscopic and particulate levels.</i> Periodic table is a symbolic representation. Chemical equations showing neutral atom losing an electron to form an ion. Chemical equations for successive removal of electrons. Graph that shows trends in IE.
Particulate	<i>General Definition for Particulate: visual model that helps "visualize" arrangement, movement, interaction, or composition of matter as it relates to the concept of interest.</i> Particle depictions showing position of electrons, valence electrons, electron shielding.
Connection between levels	Videos should make explicit connections between two or more levels for this to be coded as present. For example, connecting graph of first IEs to the periodic table (macro to symbolic) - must explicitly connect to table; connect Bohr models of atoms to IE values (e.g., why Li has a lower IE than Ne).

Core Ideas

Core Idea Elements	
Atomic/Molecular Structure & Properties	Energy
The macroscopic physical and chemical properties of a substance are determined by the three-dimensional structure, the distribution of electron density, and the nature and extent of noncovalent interactions between the particles. Video needs to include: A description of how the ionization energy is connected to things like the reactivity of substances (e.g. relative reactivity of alkali metals) or to the common ions formed by different elements. E.g., why do metals form positive ions but nonmetals form negative ions.	Energy changes are either the cause or the consequence of change in chemical systems, which can be considered on different scales and can be accounted for by the conservation of the total energy of the system of interest and the surroundings. Video needs to include: Trend in 1st ionization energies needs to include: valence electrons are attracted to the nucleus of the atom and strength of the attraction depends on number of protons in the nucleus and/or distance from the nucleus. The stronger the force of attraction, the higher the IE. OR Successive ionization energies will always increase in value due to the greater attraction to the nucleus. AND A very large jump will occur when you move from one shell to a more interior shell.

Scientific Practices

Note: A trend is a phenomena/observation so as these videos are focused on trends, all should have phenomena/observations - so what we need to focus on is whether a complete explanation is given.

If videos have CMR, they will then by default also have SP of at least Constructing Explanations.

Scientific Practices Criteria (must satisfy all criteria)
SP 1: Asking Questions ☐ Instruction presents an event, observation, phenomenon, data, scenario, or model. ☐ Instruction has instructor/students <i>generate</i> an empirically testable question about the given event, observation, phenomenon, data, scenario, or model. (Question cannot be rhetorical or simply a part of instruction; rather it must be a <i>process of generating</i> a testable question.)
SP 2: Developing and Using Models ☐ Instruction presents an event, observation, or phenomenon for instructor/students to explain or make a prediction about. ☐ Instruction presents a representation or asks instructor/students to construct a representation. ☐ Instruction has instructor/students explain or make a prediction about the event, observation, or phenomenon. ☐ Instruction has instructor/students provide the reasoning that links the representation to their explanation or prediction.
SP 3: Planning Investigations

☐ Instruction poses a scientific question, claim, or hypothesis to be investigated. ☐ Instruction has instructor/students describe or design an investigation, or identify the observations required to answer the question or test the claim or hypothesis. ☐ Instruction has instructor/students justify how their description, design, or observations can be used to answer the question or test the claim or hypothesis.
SP 4: Analyzing and Interpreting Data ☐ Instruction presents a scientific question, claim, or hypothesis to be investigated. ☐ Instruction provides a representation of data (table, graph, or list of observations) used to answer the question or test the claim or hypothesis. ☐ Instruction provides an analysis of the data or asks instructor/students to analyze the data. ☐ Instruction has instructor/students interpret the results or assess the validity of the conclusions in the context of the scientific question, claim, or hypothesis.
SP 5: Using Mathematics and Computational Thinking ☐ Instruction presents an event, observation, or phenomenon. ☐ Instruction has instructor/students perform a calculation or statistical test, generate a mathematical representation, or demonstrate a relationship between parameters. ☐ Instruction has instructor/students give a consequence or an interpretation in words, diagrams, symbols, or graphs of their mathematical results while demonstrating reasoning in the context of the given event, observation, or phenomenon.
SP 6: Constructing Explanations and Engaging in Argument from Evidence ☐ Instruction presents an event, observation, or phenomenon. ☐ Instruction presents or asks instructor/students to make a claim based on the given event, observation, or phenomenon. ☐ Instruction has instructor/students provide scientific principles or evidence (data or observations) to support the claim. ☐ Instruction has instructor/students provide reasoning about why the scientific principles or evidence support the claim.
SP 7: Evaluating Information ☐ Instruction provides an excerpt from a conversation, article, student solution, or other communication that makes one or more assertions. ☐ Instruction presents a conclusion about the validity of the assertion(s) made or asks instructor/students to make a conclusion about the validity of the assertion(s), or reconcile multiple assertions with each other. ☐ Instruction has instructor/students provide reasoning to support their conclusion(s) about the validity of the assertion(s) or reconciliation with data, observations, or scientific principles.

Causal Mechanistic Reasoning - Must have Both How and Why!

Option 1: What causes ionization energies to get larger going across the periodic table?

- **How:** As we go across the periodic table, atoms gain an additional proton in the nucleus and *electrons to the same electron shell (must address this explicitly)*. This will increase the attractive force (Z or Z_{eff}) between the valence electrons and the nucleus.
- **Why:** Increased attractive forces between the outermost electron and the nucleus will mean that the force of attraction will be stronger and so will require more energy to be removed from the atom. The answer should address the concept of Coulomb's Law, though specifically naming it is not required.

OR

- **How:** As we go across the periodic table, atoms will get successively smaller. This will increase the attractive force (Z or Z_{eff}) between the electrons and the protons.
- **Why:** The decreased distance between the outermost electron and the nucleus means that the force of attraction is stronger and thus will require more energy to be removed from the atom. The answer should address the concept of Coulomb's Law, though specifically naming it is not required.

Option 2: What causes ionization energies to get smaller going down a family in the periodic table?

- **How:** As we go down a family in the periodic table, atoms gain an additional electron shells which are further from the nucleus.
- **Why:** As the size of the atom increases through additional shells (and protons), and because (Z_{eff} remains constant OR explicitly addressing the inverse squared relationship between attractive force and distance (**one of these MUST be explicitly addressed**)), the force of attraction between the outermost electron and the nucleus will decrease, meaning that less energy will be needed to remove the electron from the atom. The answer should address the concept of Coulomb's Law, though specifically naming it is not required.

Option 3: What causes successive ionization energies to increase?

- **How:** Removing successive electrons requires removing electrons from ions that are already positive and in some cases electrons from a different electrons shell.
- **Why:** The outermost electrons will experience an increased force of attraction as the positive charge on the ion increases, thus requiring more energy to remove electrons from a lower shell as these electrons are closer to the nucleus and experience a notably greater force of attraction.

Option 4: What causes exceptions to the general trend of ionization energies (specifically group 2 vs 3 and 15 vs 16)? (often linked with analyzing and interpreting data)

- **How:** The electrons being removed from group 13 vs. 2 are in different subshells and in 15 vs. 16 the electrons have been paired.
- **Why:** p orbitals are higher in energy than the s orbitals in the same subshell, so less energy is required to remove that electron than might otherwise have been anticipated. This difference results in group 13 having a lower first ionization energy than the group 2 elements in the same period. For group 15 vs. 16, in the case of group 16, the last electron is paired up with another electron in an orbital. The energy cost of pairing this electron (or extra electron repulsion) means that it is easier to remove than might otherwise have been expected resulting in group 16 being lower in IE than group 15 despite the increase in Z_{eff} and decrease in size.

Must address both aspects of the why.

Multimedia Principles

Multimedia learning as knowledge construction: The goal of multimedia presentations is not only to present information but also to provide guidance for how to process the presented information – that is, for determining what to pay attention to, how to mentally organize it, and how to relate it to prior knowledge. We will categorize the videos along each of the following criteria (High and Low should be mutually exclusive.)

High	Low
• Video almost exclusively involves <u>meaningful and relevant</u> images and verbal components <u>AND images are explained for a novice learner</u> • Text on screen is minimal (ex. Only brief bullet points or keywords if text is used) • Content is all relevant to the topic and learning (no music, unhelpful animations, graphics, etc.) • Contains elements that meaningfully support student organizing content or identify key ideas (introductory organizer, section heading, summary, guiding questions/topic (for short, focused video only) Key Question: Could a novice learner clearly understand what they should take away from the video? Yes=high.	• Large segments of video are presented just verbally and not pictorially (ex. just the instructor talking, or just written words) OR images presented are not relevant to learning or explained • Contains full sentences of written text that are also narrated (<i>e.g., several bullet points or sentences on one screen OR full sentences of text on many screens includes forced closed captioning</i>) • Contains extraneous content, music, graphics, animations, background changes, sounds, or just too much stuff on the screen at one time - anything that detracts attention from core content • Does not contain any elements that meaningfully help learners organize content or identify key ideas (e.g., no introductory organizer, section headings, video segments, summary, guiding question/topic (for short focused videos only)

Misleading vs. Inaccuracies

- Several minor spelling issues is misleading, not inaccurate

Topics:

- Coulomb's Law specifically addressed
- Zeff specifically addressed
- Gave specific data for 1st ionization energies (graph or table)
- Addressed multiple ionization energies for one or more elements

Captions

- Videos with full on-screen captions (that can not be removed) are considered “low” for multimedia when considering text usage.

Self-Assessment

- Self-assessment needs to be relevant to the general conceptual idea, and there needs to be enough pause or verbal suggestion to imply to a watcher they should take time to answer the question.