Periodic Table and Atomic Structure: Secret Agent
Teacher Version

This lab explores the structure of atoms and elements as well as simple ionic bonds. Students use colored beads and the periodic table to model and identify different elements. Students also assemble a periodic table of secret agents, and try to identify the missing agent, based on trends and patterns.

California Science Content Standards:

- **1. Atomic and Molecular Structure: The periodic table displays the elements in increasing atomic number and shows how periodicity of the physical and chemical properties of the elements relates to atomic structure.**
- 1a. Students know how to relate the position of an element in the periodic table to its atomic number and atomic mass.
- 1c. Students know how to use the periodic table to identify alkali metals, alkaline earth metals and transition metals, trends in ionization energy, electronegativity, and the relative sizes of ions and atoms.
- 1d. Students know how to use the periodic table to determine the number of electrons available for bonding.
- 1e. Students know the nucleus of the atom is much smaller than the atom yet contains most of its mass.
- **2. Chemical Bonds: Biological, chemical, and physical properties of matter result from the ability of atoms to form bonds from electrostatic forces between electrons and protons and between atoms molecules.**
- 2a. Students know atoms combine to form molecules by sharing electrons to form covalent or metallic bonds or by exchanging electrons to form ionic bonds.
- **2g. Students know how electro-negativity and ionization energy relate to bond formation.

Prerequisites:

- Students should be able to do basic arithmetic (addition and subtraction).
- Previous exposure to the periodic table would be beneficial, but is not required.

Key Concepts:

- An **atom** is the smallest particle any given molecule can be broken down to.
- A **proton** is a positively charged particle in an atom.
- An **electron** is a negatively charged particle in an atom.
- A **neutron** is a neutral (neither negative nor positive) particle in an atom.
- The **atomic number** is the number of protons in an atom.
- **Primary energy levels,** also called **electron shells**, are regions that electrons move in within the atom. The innermost of the energy levels surrounds the nucleus of the atom and has a maximum electron-holding capacity of two.
- Each energy level after the first one fills up with 8 electrons.
- **Ions** are charged atoms formed by losing or gaining electrons.

Materials:

Parts 1 & 2: Atoms & Elements / Introducing Ions & Ionic Bonding

- 50 red beads (to represent electrons)
- 50 green beads (to represent protons)
- 50 yellow beads (to represent neutrons)
- Atom template (separate document)
- Periodic table
- 3 different colored pens (the colors of the beads)

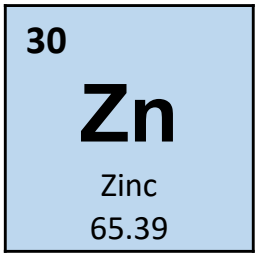
Part 3: Introducing Ions & Ionic Bonding

- Computers with Internet access (optional) – Teachers may prefer to scaffold this portion of the lab further by showing students an Internet video on the background/history of the Periodic Table of Elements which normally covers patterns/trends. Searching for "Periodic Table of Elements" on YouTube or Google Videos will produce several useful examples.
- Secret Agent Photographs (2 separate documents)
- Scissors
- Presentation or poster paper
- Glue sticks or Scotch tape
- Periodic table (optional)

Information on the Periodic Table of Elements: An Example

The elements are ordered in consecutive order according to their **atomic number**. In most periodic tables, this number is found at the top (30). It represents the number of protons, which equals the number of electrons, so the positive and negative charges cancel, and give the

23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.93	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39
41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41
73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59
105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]



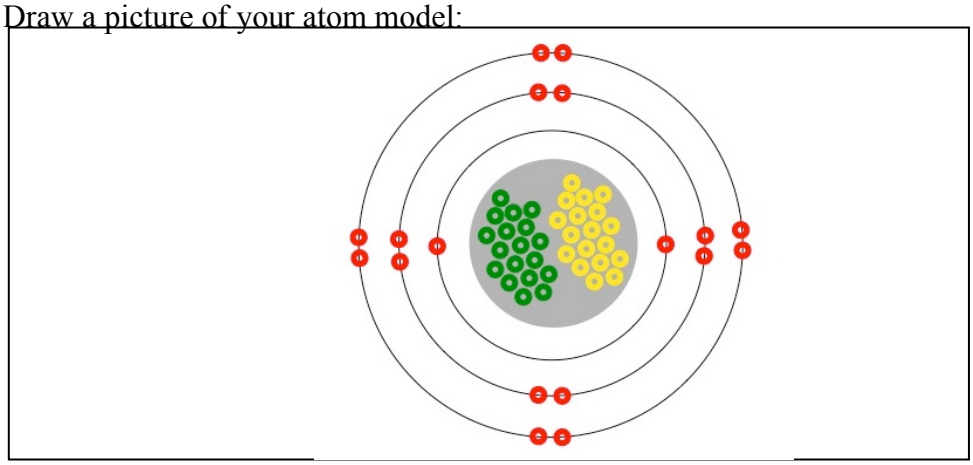
element's atom as a whole a neutral charge. An abbreviated form of referring to the element is through its **atomic symbol** (Zn), though the actual name of the element is always given (Zinc). The only other number besides the atomic number in an element box is the **atomic mass**. It can be a rounded number, or a decimal (65.39). The atomic mass is approximately the weight of protons + neutrons (in this case, there are 35 neutrons).

Part 1 – Atoms & Elements

Procedure:

Use the Atom Template to model the following atoms and elements.

1. Place 22 yellow beads in the central grey area marked with 0 (neutral) charge. *What part of the atom are you now modeling?*___*Neutrons*_____
2. Place 18 green beads in the central grey area marked with + (positive) charge. *What part of the atom are you now modeling?*_____*Protons*_____
3. *What part of the atom do the three concentric ovals represent?* ____*Electron shells*_____
4. Place 2 red beads, one in each of the boxes in the first (inner) circle, then 8 red beads in the boxes the second, and finally 8 red beads in the third circle boxes. *What do red beads represent?* _____*Electrons*_____
5. Draw a picture of your atom model:

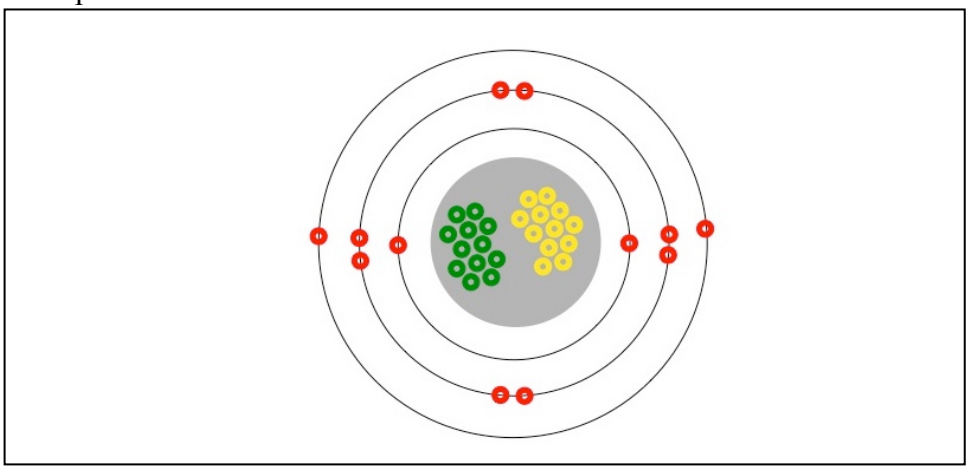


Q1. Using a Periodic Table of the Elements, fill in the following for your atom:

Atomic Number = 18 *Atomic Mass = 39.948* *Chemical Symbol = Ar*

Chemical Name = Argon *Overall Charge = Neutral (protons and electrons cancel out charges)*

1. Place 12 yellow beads in the neutral oval and 12 green beads in the positive oval.
2. On the first circle place 2 red beads. Continue placing red beads (total number of electrons is equal to the number of protons) onto the next energy levels until you run out of beads (make sure they don't exceed 8 beads per orbit!).
3. Draw a picture of this new model.

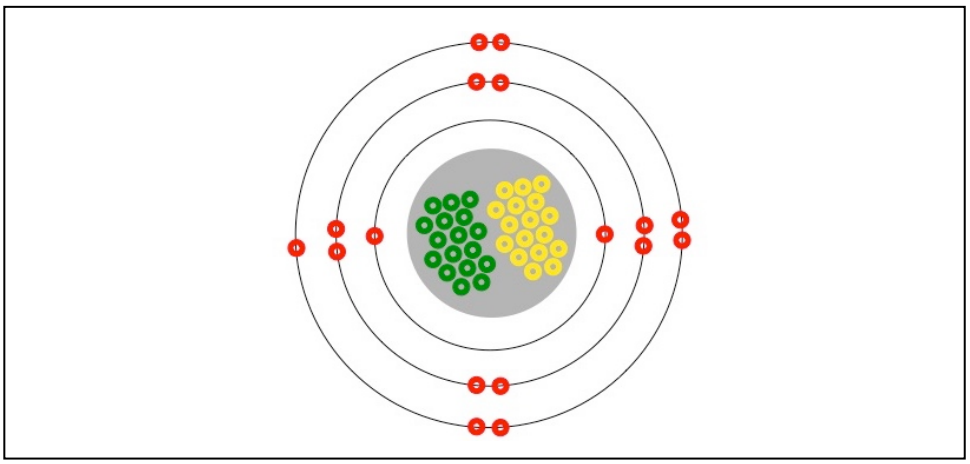


QS2. What are this atom's number of protons, electrons, and neutrons?
12 protons, 12 electrons, 12 neutrons.

QS3, QSA2. What is your atom's Atomic number: 12 Atomic Mass: 24.305 Chemical Symbol: Mg

Chemical Name: Magnesium Charge: Neutral (protons and electrons cancel out charges)

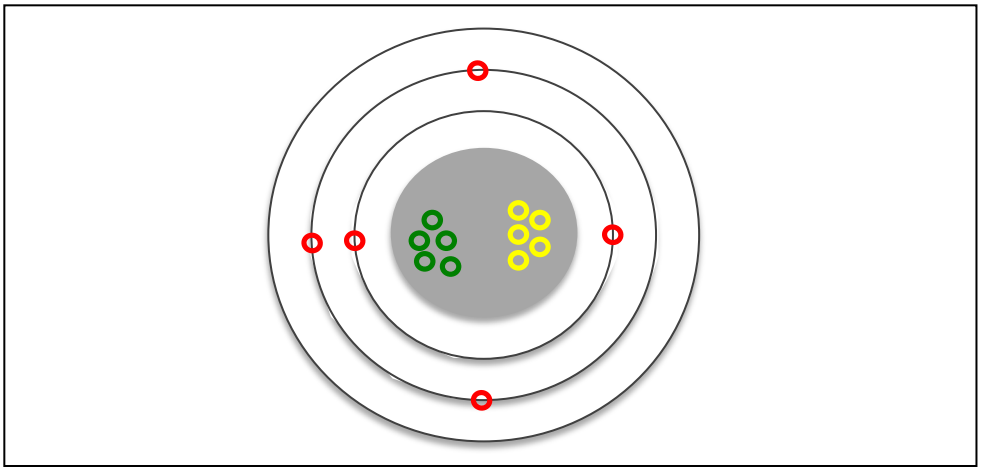
1. Look at the Periodic Table of the Elements and locate Chlorine.
2. Create a model of the chlorine atom on your template, then draw it here:



QS4, QSA3. What is chlorine's Atomic number: 17 Atomic mass: 35.452 Chemical symbol: Cl

Number of neutrons:18 Overall charge: Neutral (protons and electrons cancel out charges)

1. Look at the Periodic Table of the Elements and locate Boron.
2. Using your three different color beads, create a model of the boron atom:



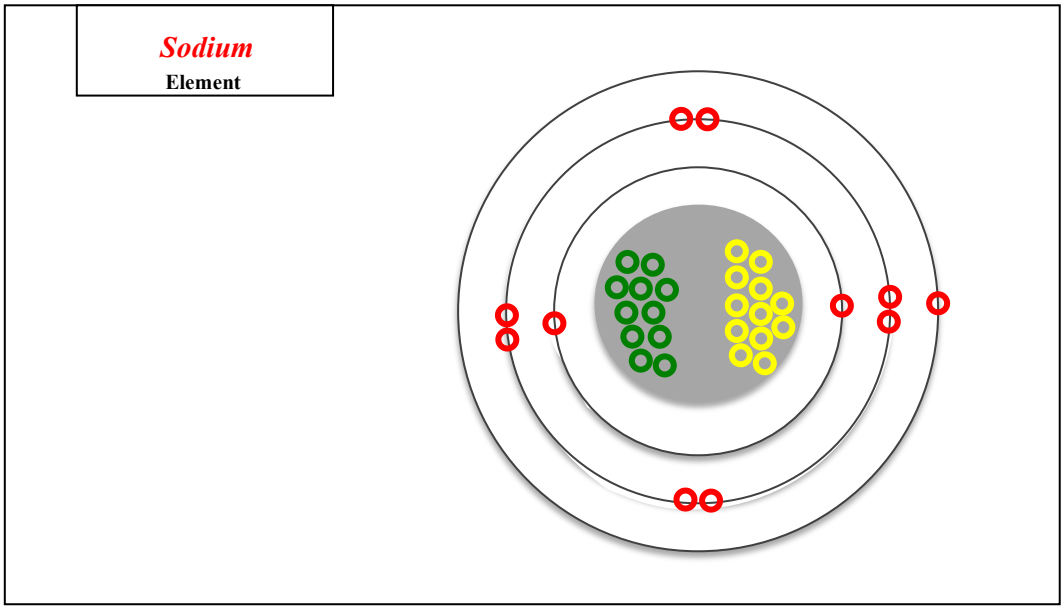
QS5, QSA4. What is boron's Atomic number: 5 Atomic mass: 10.811 Chemical symbol: B

Number of neutrons: 6 Overall charge: Neutral

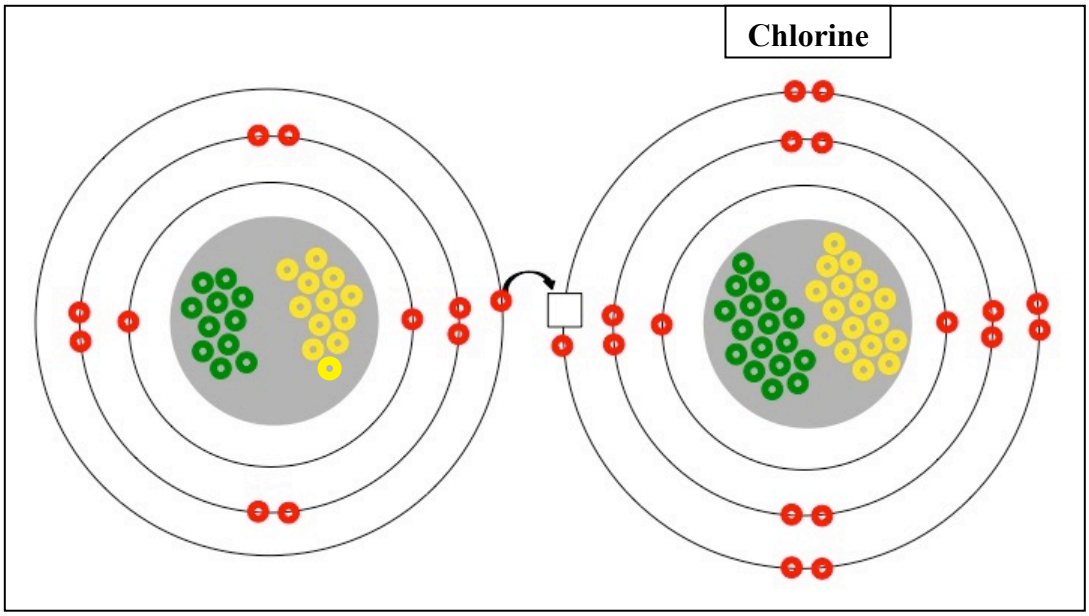
Part 2 – Introducing Ions & Ionic Bonding

Procedure:

1. Draw a model of an atom that has 11 protons, 12 neutrons, and 11 electrons. (Use the Atom Template first if necessary) What element is this?



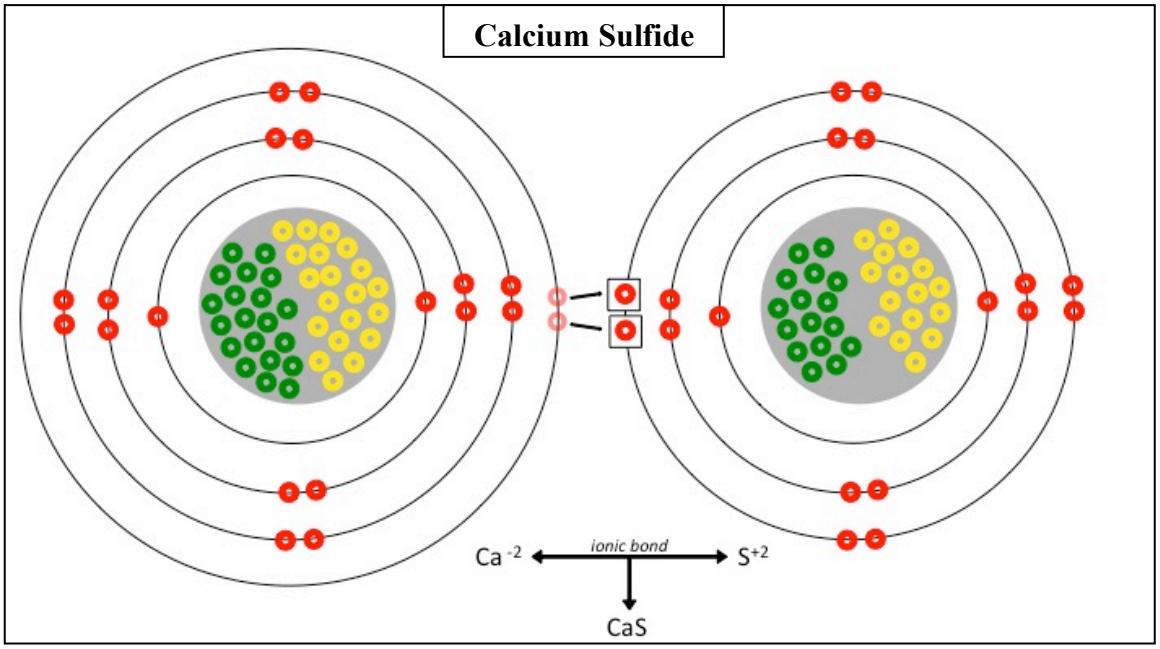
2. Draw your atom with a chlorine atom. Show how 1 electron in the third shell leaves the atom, but joins the outermost shell of a chlorine atom (which has 7 electrons):



QS6, QSA5. After the electron transfer, what is sodium's atomic number, atomic mass, chemical symbol, chemical name, and new overall charge?
Atomic Number = 11; Atomic Mass = 22.99; Chemical symbol = Na
Charge = +1 (there is one more positive protons [11] than negative electrons [10]

----------*ADVANCED STUDENT ONLY* ----------

1. Draw a model showing the ionic bonding of Calcium and Sulfur. What does the electron transfer look like if these two atoms come together?



QSA6. After the electron transfer occurs between calcium and sulfur, what are the sulfur atom's atomic number, atomic mass, chemical symbol, and overall charge?

Atomic Number = 16; Atomic Mass = 32.065; Chemical Symbol = S; Charge = -2 (there are more negative electrons [18] than positive protons [16]

Note: Calcium needs 6 more electrons to fill its outermost shell, but sulfur only needs 2, so the 2 extra electrons from calcium is transferred to sulfur forming an ionic bond and creating a neutral compound, calcium sulfide. The electrons in the outermost shell can now travel in between the two atoms. The overall charge on CaS is neutral as the positive charge on the calcium ion cancels out the negative charge on the sulfur ion.

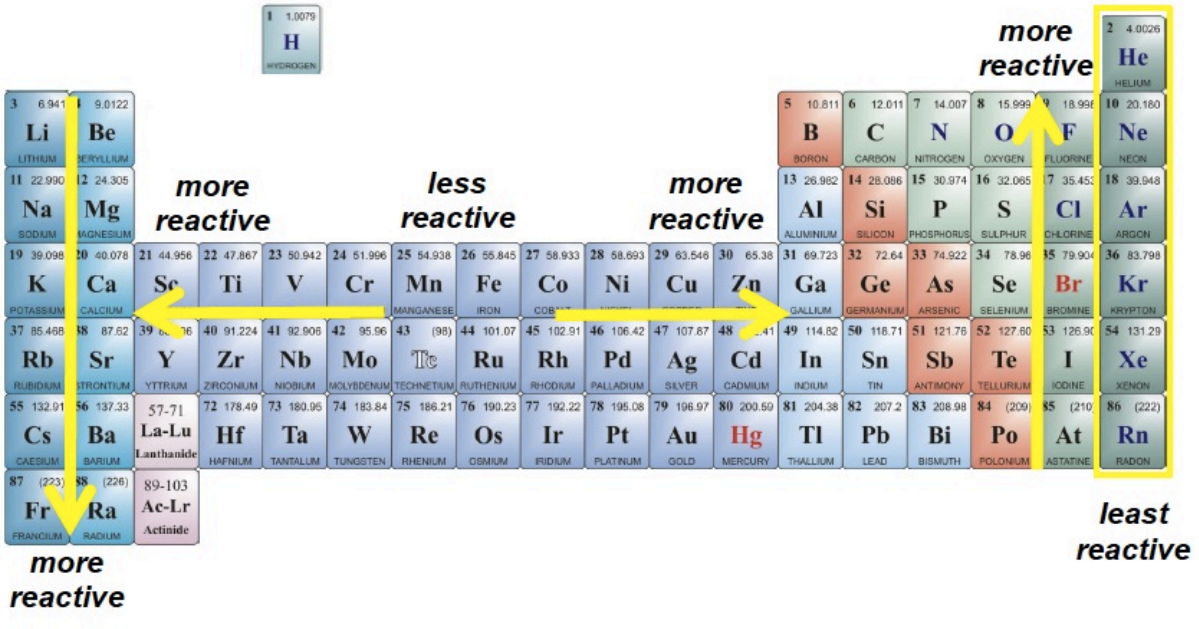
Part 3 – Secret Agent Activity

Mini-lecture

For this hands-on portion of the Atomic Structure Lab, students will be deciphering common **trends** or **patterns** found within the Periodic Table of Elements. The elements found within the Periodic Table are arranged in a very particular pattern, based on several common traits or characteristics. In 1869, Dmitri Mendeleev produced a table of elements based on their atomic weights. Properties of elements vary "periodically" depending on their atomic weight. Today, the elements of the Periodic Table are arranged by atomic number, which also indicates the number of **protons** in an atom (see Periodic Table Tutorial above). **Neutrons** are uncharged particles in the atom's nucleus that only affect the overall weight of the atom, not the charge. The Periodic Table of Elements is arranged in horizontal rows, called **periods** and vertical columns, called **groups**.

The trends or patterns of the Periodic Table of Elements demonstrated in this activity include:

- The group number—usually depicted by a Roman numeral above the group—refers to the number of **valence** electrons in the outermost electron shell. Ex: Group IA elements (Alkali Metals) have one valence electron in their outermost shells.
- The period number refers to the number of electron shells or primary energy levels an atom of each element has. Ex: Period 3 elements—Na, Mg, Al, Si, P, S, Cl, and Ar—have three primary electron energy levels.
- Atomic mass (i.e. an approximation of the number of protons + number of neutrons) increases as you move left-to-right and top-to-bottom on the Periodic Table.
- Element **Reactivity/Stability** – Atoms are generally most stable and least reactive when their outermost energy level is either completely filled with or empty of electrons. Reactivity refers to an atoms likelihood or desire to bond with another atom. See below for a chart of reactivity in the Periodic Table. As you can see, the pattern or trend moves more or less in an inside-out fashion. The least reactive elements, or most stable, on the Periodic Table are the Noble Gases (Group 8A) because they have octets (or 8 electrons) in their outermost electron shells. The Alkali Metals (Group 1A) are highly unstable (except for hydrogen which is moderately reactive), thus highly reactive, because they only have one electron in their outermost electron shells. These elements are likely to bond with other elements on the Periodic Table of Elements.



Create

Introduction ("The Mission"):

Based on your expertise in problem solving, your mission, should you accept it, is to work with the "photographs" of the suspicious characters on the attached Secret Agent sheet. They are part of a family of Secret Agents, but the deadliest agent of all has never been photographed, thus his "true" identity remains a mystery. Ultimately, your job is to arrange the photographs in a specific pattern that provides enough information enabling you to sketch the identity of the missing secret agent. Then you will create a "family portrait" of all the characters on poster paper as well as answering a few post-activity questions.

The beginning part of the below procedure can be done as a guided group activity. Ask the group to identify all the different characteristics of the agent pictures (body size, fingers, hair, arms, facial expression and body filling). Then start sorting by a single characteristic (ex. all the agents who have same body filling, same numbers of arms, or from one finger to 18 fingers). From this point the student could break into smaller groups or individuals for grouping into additional characteristics

Procedure:

1. You should begin by cutting out all 17 photographs of the Secret Agents as well as the three blank squares.
2. **Note: You only need *one* blank to sketch the identity of the missing agent, but three blank squares are provided in case you make mistakes and need to start over.**
3. Arrange the photographs of the known Secret Agents by what they share in common, perhaps by choosing one or two shared characteristics at first to separate the Secret Agents into smaller piles.
4. Once you have several distinct piles focusing on one or two shared characteristics, now try looking at the big picture and combine the agents into one large family portrait.
5. If you have compiled the Secret Agents into the correct arrangement, there will be one empty spot in the family portrait.
6. **This missing spot is where the missing Secret Agent belongs in the family portrait.**
7. You should be able to sketch his exact identity by looking at the characteristic of those agents closest to him in the family portrait.
8. Once you have determined the identity of the missing Secret Agent *and* have the correct arrangement for the family portrait, look closely! Describe what you see:
   Students may recognize either from prior knowledge or from the copies distributed during the activity that the family portrait resembles a rudimentary periodic table in shape. The number of fingers is the Atomic Number, thus the Secret Agent with only one finger is Hydrogen and the Secret Agent with two fingers is Helium and so forth. A correct family portrait arrangement with a total of 3 rows and 8 columns can be compiled in this manner of using the fingers as models for the element Atomic Number.
9. Obtain one piece of large construction or presentation paper and a glue stick or tape.
10. Paste or tape all 18 Secret Agents onto the piece of construction paper in the correct arrangement.
11. Give the family portrait a creative family name of your choosing.
12. Give your missing Secret Agent a creative name (other than what it's really called).
13. If time is available, decorate your family portrait in a creative and artistic fashion.

Concept Questions:

Q7. List all relationships observed in the characters as you look down a column.
Answers will vary, but should include: (1) the number of hairs is the same—except for the last group where the first character only has 2 hairs, but the other two characters in the column have 8 hairs, (2) facial expression is the same, (3) the number of arms continually increase by one, and (4) body symbol/design is the same.

Q8. List all relationships observed in the characters as you look across a row
Answers will vary, but should include: (1) the number of hairs continually increases by one, (2) the number of fingers continually increases by one, (3) character's bodies continue to get larger in size, (4) the number of arms stays the same for the entire row, and (5) the character's facial expressions go from frowns, to indifferent/smirk, to smiles.

Q9. What is the actual identity of the missing secret agent
The identity of the missing Secret Agent is the element Phosphorus (Atomic Number 15).

Q10. What information from the Periodic Table of Elements does the character fingers represent?
The fingers represent the Atomic Number. The Atomic Number is analogous to an element's social security number; it never changes. The Atomic Number is defined as the number of protons in an atom.

Q11. What information from the Periodic Table of Elements does the character arms represent?
The character arms represent the period (row) number on the Periodic Table of Elements as well as the number of electron shells or energy levels.

Q12. What information from the Periodic Table of Elements does the character hair represent?
The hair represents the group (column) number on the Periodic Table as well as the number of (valence) electrons found in the outermost shell/energy level of the elements in this group.

Q13. What information from the Periodic Table of Elements does an increase in character body size represent?
An increase in character body size models the increase in atomic mass (proton number plus neutron number). As you move from left-to-right or top-to-bottom on the Periodic Table, atomic mass increases, thus the characters get "rounder" as you move across rows or down columns.

Q14. What information from the Periodic Table of Elements does the character facial expression represent?
The character facial expression models atomic reactivity/stability. Secret Agents on the left side of the Period Table of Elements (Columns I and II) have frowns on their faces because they are generally very reactive and unstable since they have a small number of valence electrons in their outermost energy levels. Column I Secret Agents—except for hydrogen—have more dramatic frowns than Column II Secret Agents to represent the trend on the Periodic Table of Column I elements being more reactive/less stable than Column II elements. As you move from left-to-right on the Secret Agent Periodic Table beginning with Column III and ending with Column VII, Secret Agents will become increasingly unhappy demonstrated by more pronounced frowns since reactivity/instability increases as you move horizontally along rows II and III toward the Noble Gases. The Secret Agents on the far right of the Periodic Table of Elements (Noble Gases) have smiles on their faces because they are nonreactive and very stable since they have octets (or 8 electrons) in their outmost energy levels.