Periodic Properties of the elements

Introduction

The periodic table is fundamentally organized in order of increasing atomic number. Additionally, the rows and columns of the periodic table are selected to highlight important trends and relationships between the elements. In studying these trends, we obtain a better understanding of other areas of Chemistry, such as molecular structure and chemical reactions.

The 3D printed periodic tables each have a name on the base plate depicting the property represented by the height of the cuboid. A larger cuboid indicates a larger property. The different colors indicate the different *blocks* of the periodic table: pink is the s-block, blue is the p-block and green is the d-block.

Question What property of an atom is related to the atomic number?

When describing the periodic table, the columns are referred to as *groups* and the rows are referred to as *periods*.

Question How many periods and groups are there in the 3D printed periodic tables?

Note that the 3D prints do not display all of the periods in the actual table, but they do display all of the groups. Scientists do not yet have a comprehensive set of atomic properties for most elements above atomic number 87, so for the sake of simplicity, period 7 and the f-block elements are not included in the 3D printed tables.

Atomic Size

The probabilistic nature of the electron makes it difficult to define *size* for atoms. The electron is not at a set distance from the nucleus; instead, pictures display electron *clouds* that represent where an electron is most likely (95%) found.

Look at the table labeled atomic radius and focus on the right-hand most group of atoms (the noble gases).

Question What is the *smallest* noble gas? What is the *largest* noble gas?

Smallest:_____ Largest:_____

Question How does the size of atoms change within the noble gases? Write your answer using a complete sentence and be sure to incorporate the word *group* properly.

Follow-up Does the trend you observe apply to some, most or all of the other groups?

Going deeper Does the period *increase* or *decrease* down the group?

Write a sentence describing the relationship between atomic size and period.

In the previous questions, you explored the atomic size trend *within a group*; now, you will explore trends *within a period*.

Question What is the first period (remember, Chemists refer to the rows of the periodic table as periods) that contains 18 elements?

Question What is the trend in atomic size across this period?

Follow up question Does the trend you observe apply to all, most or some of the other periods?

Going deeper Thinking about what atoms are made of, what constituents change systematically within a period? (There are a couple of answers.)

Do this Fill in the table below with the *largest element* found in the each of the blocks of the periodic table. Include a brief description (center, top, lower right) of where the element is found in the block:

Block	Symbol	Location in block
s:		
p:		
d:		

Thinking critically The 3D printed table does not contain the 7th period elements nihonium (Nh), radium (Ra) and bohrium (Bh). Given that Nihonium is in the p-block, radium is in the s-block and bohrium is in the d-block, predict the relative sizes (smallest to largest) of these three elements.

Thikcing critically Ytterbium (Yb) is in the upper right corner of the f-block. Can you predict whether it will be the smallest or largest f-block element? Be sure to explain your reasoning.

Putting it together

Explain why the following statements are false. In your answer, provide two elements that supporty your argument.

- As period increases, so does atomic size.
- As atomic number increases, so does atomic size.

Wrapping up

In this exercise, you have explored the relationships between atomic size, atomic number and period. At this point, you should appreciate that *we need to consider both atomic number and period* to obtain a solid description of the periodic trends in atomic size.

Fill in the blanks

For elements with the same period, the atomic size _____ with _____ atomic number. For elements within the same group, atomic size _____ with increasing _____.

Summary sheet

Use the 3D printed atomic radius periodic table to answer the following questions.

1. Which is larger, K or Cl?
2. Why is Br smaller than I?
3. Which is larger, Ca or Mg?
4. Which is larger, Zn or Pb?
5. Why is question 4 harder than questions 2 or 3?
6. Arrange the following elements in order of *decreasing* atomic size: Al, Si, Ge, Ga.
7. Arrange the following elements in order of *increasing* atomic size: Li, Na, Be, Mg.
8. Based upon your answers to questions 6 and 7, which property, atomic number or period, has a bigger effect on atomic size. Provide an explanation for your answer.

Ionization energy

Ionization energy is the amount of energy required to remove an electron from gaseous atom. It can be described using the following chemical equation:

$$\mathrm{Li(g)} \longrightarrow \mathrm{Li^{+}(g)} + \mathrm{e^{-}}$$

Refresher question What are the names that Chemists use to refer to columns and rows of the periodic table?

Do this Using the 3D printed periodic table labeled Ionization Energy, fill in the table below. Ionization Energy has been abbreviated as IE.

block	lowest IE element	highest IE element
s	symbol:___ location:_____	symbol:_____ location:_____
d	symbol:___ location:_____	symbol:_____ location:_____
p	symbol:___ location:_____	symbol:_____ location:_____

Refresher question What two properties were used to describe trends in the atomic size of elements?

Question Focusing on the second group of elements (the alkaline earth metals), and the elements of the third row, describe trends in ionization energy based upon the two properties mentioned above.

Follow up question Are the trends you described in the previous question applicable to all, most or some of the remaining parts of the periodic table? Provide details in your explanation.

Going deeper Discuss with your group regions of the ionization energy periodic table that seem to go against the general trends. Identify the three most significant, keeping in mind they may be trends within a group or within a period.

Question Nitrogen has an ionization energy that is higher than would be expected by the periodic trend. Is this true for *all* group 15 (the pnictogens) elements?

Follow up Question The d-block has a number of elements that appear to disobey the periodic trend in ionization energies. Of the three d-block periods shown, which period agrees most with the general trend in ionization energy?

Thinking critically Based upon your observations in the previous two questions, write a sentence describing where the trend in ionization energy is most likely to be followed *and why this might be the case*.

Putting it together

Focusing on groups, compare the trend in ionization energy to the trend in atomic size.

Now focusing on periods, compare the ionization energy and atomic size trends.

Fill in the blank: Within a group, ionization energy _____ with _____ principal quantum number.

Fill in the blank: Within a period, ionization energy generally _____ with increasing atomic number.

Summary sheet

Use the 3D printed periodic tables to answer the following questions:

1. Circle the element with the larger ionization energy and briefly state your reasoning.
    - Na or Mg
    - Mg or Al
    - B or Al
    - F or Cl
2. Which elements are more likely to produce cations: alkali metals (group 1) or halogens (group 17)? Explain your reasoning and include ionization energy in your answer.
3. Order the following elements in terms of *increasing* ionization energy: Mn, Co, V, Sc, Zn. Explain your reasoning.
4. Order the following elements in terms of *decreasing* ionization energy: Ba, Cs, Hf, W, Ta. Explain your reasoning.
5. In this activity, the term Ionization Energy should actually be called the *First* Ionization Energy, because it is possible to remove more than one electron from an atom. Write a balanced chemical equation that describes the *Second* Ionization Energy of Mg. (Hint: the second ionization energy is the energy required to remove an electron from an atom with a +1 charge.)