Topic 2.4
How are properties of atoms used to organize elements into the periodic table?

Overview

In this topic, students will explore how the periodic table is organized according to atomic number and the properties of the elements. They will also learn how to draw atoms based on their subatomic particles and relate an element's atomic structure to its placement in the periodic table.

Common Misconceptions

- **Students may think that subatomic particles can exist anywhere within an atom, or may not remember where each particle is located.** Tell students a simple story about the particles' locations to clarify and reinforce atomic structure. For example, the protons and neutrons are sheep and the electrons are the dogs who circle the sheep to guard them. Another memory aid could be that *proton* and *neutron* both start with a consonant (like *centre*) while *electron* starts with a vowel (like *edge*).
- **Since atomic number determines the number of protons, many students will assume it also determines the number of neutrons and electrons.** If there is confusion about this, remind students that the atomic number refers only to protons, but the mass of an atom is determined by its protons and neutrons. Each atom has a different atomic mass. The number of neutrons in an atom is found by subtracting the number of protons from the atomic mass.
- **Students might find Bohr-Rutherford diagrams too confusing to be helpful.** Students do not need to examine atomic structure in much detail in this topic. You can substitute simpler Bohr diagrams that show electron placement for the more complex diagrams.
- **Students have difficulty understanding the relative masses of subatomic particles.** Compare the mass of a toenail clipping (an electron) to the mass of a hand (a proton or neutron) to the mass of an atom (a person) to clarify this concept. These kinds of images are very helpful for English language learners.

Background Knowledge

Dmitri Mendeleev developed the first periodic table by listing the properties of known elements on index cards and sorting them until he saw a pattern. His original periodic table was based on atomic mass. Each new period began because he saw a change in the properties from those of the halogens to those of the alkali metals.

The modern periodic table is organized by increasing atomic number. It is important to use atomic number as it represents the number of protons and the number of electrons in a neutral atom. The number of electrons in the outer shell of each element increases from left to right along each period, ending with an element whose outer shell is full (a noble gas). This signals the beginning of a new period. Students may be curious about why the first period has only two elements, the second and third periods have eight elements, and the remaining periods have 18 elements. This is due to the number of electrons each shell can hold. For example, shell 1 can hold two electrons, so period 1 has two elements. The family names of the four most studied groups of elements are alkali metals (group 1), alkali earth metals (group 2), halogens (group 17), and noble gases (group 18).

Specific Expectations

- **C2.5** investigate and compare the chemical properties of representative elements within groups in the periodic table families of elements
- **C3.1** identify the characteristics of neutrons, protons, and electrons, including charge, location, and relative mass
- **C3.3** identify general features of the periodic table
- **C3.4** explain the relationships between the properties of elements and their position in the periodic table

Skills

- select, organize, and record relevant information from various sources
- make predictions or hypotheses based on research
- communicate using appropriate language and a variety of formats
- use appropriate modes of representation and units of measurement

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see page TR-40 for a summary of the materials required in this topic.

The development of atomic theory began with John Dalton, who stated that matter was made of small particles. J. J. Thompson determined that those particles had positive and negative aspects and thought that the negatives were sprinkled like blueberries inside the positive stuff, which he described as being like dough. Ernest Rutherford completed experiments that showed the atom was not solid but was mostly empty space and had a small central positive area he called the nucleus. Niels Bohr completed experiments that involved burning different metals and concluded that electrons orbited the nucleus in different energy shells.

You can demonstrate Bohr's experiment by dipping wooden splints into solutions like sodium chloride, copper nitrate, and strontium chloride (separately) and then burning the splints in a Bunsen burner flame. Each solution will burn a different colour, which represents the different amounts of energy each substance has. You could also have students use spectroscopes to view different elements in gas tubes. The spectra that students see will represent the electrons present in different energy levels.

Literacy Strategies

Before Reading

- Review what students already know about elements. Provide small objects for them to use to demonstrate concepts, such as the similarity of all particles in an element, and the difference from one element to another.
- Have students preview the visuals in the topic and predict what they will learn about elements in this topic.

During Reading

- Students can use the text to complete **BLM 2-20 Subatomic Particles**.
- Ask students to look at Figure 2.10 and describe any patterns they see. Encourage them to focus on the numbers of electrons and the atomic numbers.

After Reading

- Challenge students to use the periodic table to find the number of protons in various elements.
- Students can add "periodic table," "group," and "period" to their pictorial glossaries.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Starting Point Activity, page 121	Students recognize that atoms of the same element are identical.	• ELL Supply English language learners with **BLM 2-19 Colouring Sheet** to reinforce the concept.
Learning Check, page 123 Activity 2.7, page 123	Students explain atomic structure and create two- and three-dimensional models of atoms.	• Draw the nucleus and rings of an atom on the board, and use magnets to represent protons, neutrons, and elecrons. Students can move the magnets to represent different atoms. • DI Assign atoms for students to model based on the atom's complexity and the students' spatial reasoning skills.
Activity 2.8, page 125 Learning Check, page 125 Activity 2.9, page 128	Students explain the patterns they see in the periodic table by referring to the properties and atomic structure of the elements and recognize that elements in the same family share similar physical and chemical properties.	• DI Provide bodily-kinesthetic and spatial learners with **BLM 2-21 Activity 2.8** and have them model the electrons in the outer shell of each atom with pennies or buttons. • For Learning Check question 2, students could use a diagram to show the patterns. • DI Bodily-kinesthetic learners will benefit from manipulating the models in Activity 2.9. • If students find the Bohr-Rutherford diagrams in Figure 2.10 difficult to understand, have them cover the protons and neutrons, and focus on the electrons.

Topic 2.4 (Student textbook pages 120–129)

Using the Topic Opener

- ELL Gold is used as the basis of the world's economy. Some students will be familiar with the importance and cost of gold; however, some English language learners may not be. Using the images shown in the student textbook, introduce the terms *jewellery*, *sculpture*, and *masks*.
- You can use **BLM 2-18 Topic 2.4 Anticipation Guide** to assess students' understanding of the topic.
- Students who have difficulty understanding how particles of any one element are the same may benefit from a review of the properties of elements. Supply students with diagrams of elements or manipulatives—such as the paper clips they may have used earlier in the unit—which represent particles of elements as molecules and atoms to further reinforce this concept.

Starting Point Activity (Student textbook page 121)

Pedagogical Purpose

This activity is designed to review students' prior knowledge of the composition of elements. Students practise comparing objects.

Planning	
Materials	**BLM 2-19 Colouring Sheet** (optional) photographs of gold objects (optional) models of gold and silver atoms (optional)
Time	10 min

Activity Notes and Troubleshooting

- This activity is a good diagnostic of students' prior knowledge.
- Students should work in pairs and then discuss their answers as a class.

Additional Support

- ELL Prior to the activity, review the questions with English language learners. Explain key verbs like *compare* and *describe*.
- ELL Some students, including English language learners, may require **BLM 2-19 Colouring Sheet** to reinforce the idea of particles being the same for the same element.
- DI Spatial learners and others may benefit from more examples of elements. Bring in aluminum foil and copper wire, and ask about the atoms in one part of each as compared to the atoms in another part.
- DI Ask bodily-kinesthetic learners to demonstrate their understanding by acting out the atoms in two elements. They could use labels, the same colour clothes, or same gender in a group to represent being identical atoms, and differences in these characteristics to represent different atoms.

Answers

1. Atoms of one element are different from the atoms of another element.
2. Gold atoms in the raven's mouth are identical to gold atoms in the middle of the statue.
3. Gold atoms in the raven's mouth are identical to gold atoms in the mouth of Agamemnon.

4. An atom is a particle. Atoms are very small. The atoms of an element are always the same, but different from atoms of another element.

Instructional Strategies for Topic 2.4

Elements are made up of atoms, which are made up of subatomic particles. (Student textbook pages 122–123)

- Before reading, hand out **BLM 2-20 Subatomic Particles** and have students work with a partner to label what they can in pencil. Read the text together as a class and display the answers to the blackline master for students to complete as they read.
- ELL To help English language learners, discuss the relationship between the features on these two pages. For example, point out the bold vocabulary terms and how they relate to the diagram, table, and definitions found in the margin.
- DI Spatial learners may want to use colours that will remind them of each subatomic particle.
- ELL Discuss the prefixes in the words *proton*, *neutron*, and *electron* with English language learners. Together, build a web for each Key Term, including other words that use the same prefix.
- After reading, have students count the number of each subatomic particle and ask them if another atom of carbon would have the same or a different number of each subatomic particle. This will reinforce the idea from the topic opener that all atoms of the same element are the same. Stress the point that the number of protons "defines" an atom and is the same as the atomic number of the atom found on the periodic table in Figure 2.11. Ask students to use the periodic table to find the number of protons in hydrogen (1), gold (79), and silver (47).
- Students may have difficulty drawing the atom of beryllium for Learning Check question 3. Direct them to the table in Activity 2.7 on the same page to help them.

Elements are arranged in the periodic table according to their atomic structure and properties. (Student textbook page 124)

- Before reading, have students examine Figure 2.10 and look for a pattern in each column and each row. Then ask them to make a rule about where to place an element if they know how many electrons are in its outer shell. Quiz them by asking where they would put a mystery element that has two outer shell electrons. Ask, "Which column would it go in?"
- After reading, have students add "group" and "period" to their pictorial glossaries and put the words on the word wall.

Elements in the same family (group) share similar physical and chemical properties. (Student textbook pages 125–127)

- DI For Learning Check question 2, spatial learners could use a diagram to show the patterns. Have them list the general properties of each element in its box in a blank periodic table and then colour the metals one colour, colour the non-metals another colour, circle the gases, and place a diamond shape around the liquids.
- Demonstrate the similar properties of elements in the same column by showing how lithium, sodium, and potassium react with water. You will need a sample the size of a grain of rice for each element and a beaker with an asbestos pad on top, or do the experiment behind a splash guard. Use about 100 mL of water with 1 or 2 drops of phenolphthalein added for each experiment. Caution: potassium can be explosive. Explain to students that the three elements are in the same column of the periodic table. As you place each sample in the water, ask students to predict the properties and then record their observations. Students should notice three things: the reaction causes bubbles, the water turns pink, and the elements are increasingly reactive.

Topic 2.4 Review (Student textbook page 129)

- Instead of completing a concept map for question 2, students could make a simple table or draw and label a diagram of an atom. Creative learners might enjoy writing a story that gives protons, electrons, and neutrons positive, negative, and neutral personalities and show where they live in relation to one another.

Learning Check Answers (Student textbook page 123)

1. The atomic number represents the number of protons.
2. *Similarities*: Both atoms have electrons and protons; the electrons are found outside the nucleus and the protons are found inside the nucleus.
   Differences: Hydrogen has no neutron and has only one electron and one proton. Oxygen has eight neutrons, eight protons, and eight electrons.
3. Diagrams may vary. Atom should have four protons, five neutrons, and four electrons (in two shells).

Activity 2.7 Building Atoms (Student textbook page 123)

Pedagogical Purpose

In this activity, students build models of atoms to help visualize and communicate their structure.

Planning	
Materials	Per student/group: Option 1: paper shapes in three colours Option 2: modelling clay in three colours Option 3: beads in three colours (two colours of large beads and one colour of small beads) scissors tape or glue string or thread and needle skewers or stir sticks sheets of paper
Time	30 min
Safety	Students should be careful when handling sharp scissors and needles.

Skills Focus

- design a model
- use a model to communicate

Activity Notes and Troubleshooting

- You have many options for materials in this activity. The simplest option is to use coloured paper, tape or glue, and string to represent the electron shells. Students could use clay and skewers to build three-dimensional models. Beads are more expensive but can make pleasing models. Students might find it easier to glue the beads to paper instead of stringing them. Pom-poms or plastic foam pieces are also good modelling materials.
- If you give students small plastic bags of materials, they will need up to 22 pieces of each item that represents an atomic particle. If you do not have enough materials, group students around materials stations. Students should work independently to build their models.
- Students will need some parameters set for their models. Suggest that the largest size for their models be a sheet of paper and that the models do not have to be three-dimensional. Remind students they can use only the materials provided.

- Tell students that it is useful to make a plan before building a model so they can remember what each type of material represents. Have students write a step-by-step plan or draw a labelled diagram and show you their plans before they start building. Remind students that they can revise their plans if their models do not work.
- Remind students to label and keep their models. Provide a place to store the models. They will need the models for Activity 2.9.

Additional Support

- You might suggest that students having difficulties with modelling atomic structure choose simpler atoms. They might need some hints to get started. You could give them a simple construction plan instead of having them make their own, or display some samples to keep the focus of the activity on applying knowledge to construct models.
- Students who have dexterity challenges will find beads frustrating to work with. They could glue the beads to paper or use different materials.

Activity 2.7 Answers

What To Do

1. Answers will vary. Models should resemble Bohr-Rutherford diagrams. If you have introduced students to other types of models of the atom, their own models may resemble them.

Activity 2.8 Patterns in the Periodic Table (Student textbook page 125)

Pedagogical Purpose

The purpose of this activity is to have students look for patterns in the arrangement of elements in the periodic table and to connect the position of an element in the table to its atomic structure and properties.

Planning	
Materials	index cards from Activity 2.6 (not Activity 2.7) **BLM 2-21 Activity 2.8** (optional)
Time	10 min

Skills Focus

- recognize patterns
- make connections

Activity Notes and Troubleshooting

- Students could work in pairs or small groups and discuss their answers as a class.
- Ask students to focus on one column at a time and look for similarities within that column. Then ask them to look at the adjacent column and look for similarities within that column. Once they have looked at each column, they should see a pattern and should move on to looking at each row.
- Students will find it helpful to see a model of how electrons are added to the outer shell as you move across a period. Use an overhead projector and buttons to represent electrons. Start with lithium and move across that period, adding an electron to the model to represent each new element. Alternatively, draw a Bohr-Rutherford model on the chalkboard and use magnets to represent the electrons.
- You could give each group a template to colour that represents each Bohr diagram, such as **BLM 2-21 Activity 2.8**.
- If you do not have the index cards from Activity 2.6, have students refer to the periodic table on pages 126 and 127 for some of the properties of the elements.

Additional Support

- DI Bodily-kinesthetic learners would benefit from using concrete materials to model each atom. Provide them with **BLM 2-21 Activity 2.8** and have them model the electrons in the outer shell of each atom with pennies or buttons.
- DI Linguistic learners could explain the rule to a classmate or write a rhyme to help them remember how columns and periods are similar and different.
- Enrichment—Ask students to predict the properties of a new element that has been discovered and is found in group 17. Or have students create a poster or cartoon that shows the properties of each family of elements.
- Enrichment—After completing Activity 2.8, ask students to work in pairs to test each other by making up a new element and placing it in the correct spot on the periodic table. Then have pairs share their solutions as a class.

Activity 2.8 Answers

1. In each column, the number of electrons in the outer shell is the same. In each row, the number of electrons in the outer shell increases by one as you move left to right. The properties of elements in the same column are very similar. Elements that are next to each other are not as similar.
2. Elements with a similar atomic structure will be close together in the periodic table. Elements with the same number of electron shells will be in the same row. Elements with the same number of electrons in the outer shell will be in the same column.

Learning Check Answers (Student textbook page 125)

1. An element's physical and chemical properties are mostly determined by the number of electrons in the outer shell and also by the number of electron shells it has.
2. Families of elements have similar properties. The properties of metals are stronger the farther down you are in the family. The properties of non-metals are stronger the higher up you are in the family.
3. Magnesium is the most reactive metal in group 2 in Figure 2.10. (Figure 2.9 shows more of the periodic table. Barium is the most reactive metal in Group 2 in Figure 2.9.) Oxygen is the most reactive non-metal in group 16.

Activity 2.9 Build a Periodic Table (Student textbook page 128)

Pedagogical Purpose

In this activity, students apply their prior knowledge to help them place elements in the periodic table and begin to investigate the collaborative nature of science.

Planning	
Materials	models from Activity 2.7 **BLM 2-22 Activity 2.9 Template** (optional) **BLM 2-23 Activity 2.9 Models** (optional) **BLM 2-24 Element Bingo** (optional)
Time	15 min

Skills Focus

- work cooperatively
- apply pattern rules
- classify elements based on known properties.

Activity Notes and Troubleshooting

- Periodic tables will be quite large. Ensure students have enough space to spread out.
- Some students might have missed making a model in Activity 2.7. Provide them with cutouts of Bohr-Rutherford models from **BLM 2-23 Activity 2.9 Models**. They should choose an element that is not represented in their group.
- Students can draw the template or you can supply them with **BLM 2-22 Activity 2.9 Template**. They can arrange the models and labels on the floor as a large table.
- Students should focus only on the number of electron shells and the number of electrons in the outer shell of their model. The number of protons and neutrons in their model is not important for this activity.
- Ask students to examine each model and then point to where it should be placed. After students agree on the placement of their models, they can use Figure 2.9 on page 124 to check their work and reposition their elements if necessary.
- Suggest that students refer to the group and period numbers to identify the address or location of an element in the periodic table. For example, hydrogen has an address of group 1, period 1.

Additional Support

- DI Spatial learners will benefit from seeing a teacher-led demonstration. Display **BLM 2-22 Activity 2.9 Template** and cutouts of the Bohr-Rutherford diagrams in **BLM 2-23 Activity 2.9 Models** on an overhead projector or an interactive whiteboard. Ask students where each model should be placed. Bodily-kinesthetic learners would benefit from physically moving the model onto the correct spot on the overhead.
- DI ELL Spatial, bodily-kinesthetic, and English language learners will benefit from playing a game to reinforce the idea of the element address. Give students **BLM 2-24 Element Bingo** and have them write the first 20 elements randomly in the blank spaces. Call out an element's address, such as group 2, period 2, and have students locate the element on a periodic table, such as Figure 2.9 or on page 434 of the student textbook, and mark their cards (either with pencil or a marker like a button). Students call out "elemento" when they have completed a column, a row, or the right diagonal. English language learners may never have played Bingo and may need a demonstration of the game.
- If students find the Bohr-Rutherford diagrams difficult to understand, have them cover the protons and neutrons so they can focus on the number of electron shells and the number of electrons in the outer shell. Tell students that the atomic number tells them the number of electrons.

Activity 2.9 Answers

What Did You Find Out?

1. The rows on the periodic table show the number of electron shells each element has.
2. The columns on the periodic table show how many electrons are in the outer shell of each element.

Inquire Further

1. **a)** Answers will vary. Some chemists were very critical of Mendeleev's ideas, even when his predictions about where new elements should be placed in his periodic table were proven to be true.

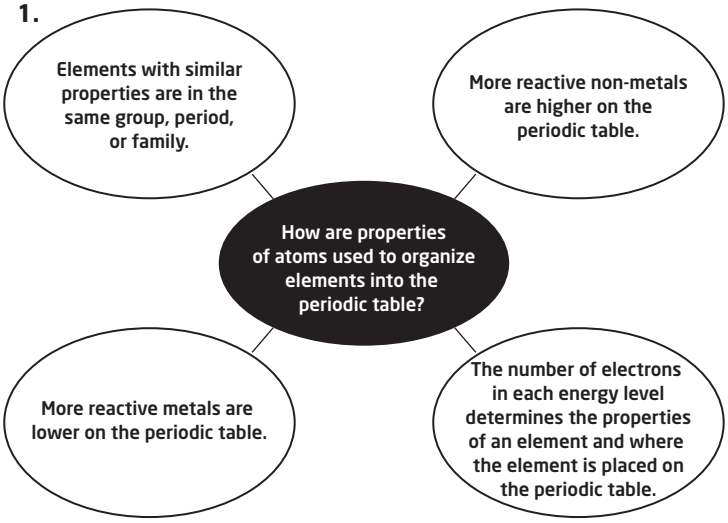
   b) Opinions will vary. Some students may feel scientists of some nationalities might not be willing to believe the results of scientists of other nationalities. Others may believe that today's scientists are more interested in the good of humanity as a whole and will not let prejudices influence their work.

Topic 2.4 Review (Student textbook page 129)

Please also see **BLM 2-25 Topic 2.4 Review (Alternative Format)**.

Answers

1.



2. Students' concept maps should include the following information.
Proton: positive charge, mass of 1, found in nucleus.
Neutron: no charge, mass of 1, found in nucleus.
Electron: negative charge, mass of $\frac{1}{2000}$, orbits nucleus in shells, first shell holds two electrons, second and third shells hold eight electrons.

3. Sulfur has 16 protons, 16 electrons, and 16 neutrons. Magnesium has 12 protons, 12 electrons, and 12 neutrons.

4. Answers may vary. The periodic table is very organized. It contains information about the properties of an element. If you know which column an element is in, you should be able to predict some of its properties.

5. Answers could include lithium, beryllium, and carbon.

6. Answers could include fluorine and chlorine.

7. a) Nitrogen has seven protons and seven electrons.

b) Diagrams may vary. Atom should have seven protons, seven neutrons, and seven electrons (two in the innermost shell and five in the next).

8. Potassium is soft and can be cut with a knife. It will react more violently than sodium will when placed in water.