1 FOCUS

Objectives

5.1.1 Describe how Mendeleev arranged the elements in his table.

5.1.2 Explain how the predictions Mendeleev made and the discovery of new elements demonstrated the usefulness of his periodic table.

Reading Focus

Build Vocabulary `L2`

Word Forms Use the word *periodical* to help students understand the meaning of *periodic.* Explain that a periodical is published at regular intervals (weekly, monthly, or quarterly).

Reading Strategy `L2`

a. Mendeleev arranged the elements in order of increasing mass so that elements with similar properties were in the same column. **b.** Mendeleev used the properties of existing elements to predict properties of undiscovered elements. **c.** The close match between Mendeleev's predictions and the actual properties of new elements showed how useful his periodic table could be.

2 INSTRUCT

The Search for Order

Build Reading Literacy `L1`

Sequence Refer to **page 290D** in **Chapter 10**, which provides the guidelines for a sequence.

Have students create a flowchart showing the sequence of events described in the last two paragraphs on page 126. Ask, **Based on your sequence, what happened after Lavoisier grouped the known elements into four categories?** *(Scientists looked for different ways to classify the elements.)*
Verbal, Portfolio

5.1 Organizing the Elements

Reading Focus

Key Concepts

- How did Mendeleev organize the elements in his periodic table?
- What evidence helped verify the usefulness of Mendeleev's table?

Vocabulary

- periodic table

Reading Strategy

Identifying Main Ideas Copy the table. As you read, write the main idea for each topic.

Topic	Main Idea
Mendeleev's proposal	a._____?
Mendeleev's prediction	b._____?
Evidence supporting Mendeleev's table	c._____?

In a video store, the latest movies are usually placed on the shelves in alphabetical order. Older movies are grouped into categories such as Action or Comedy. The manager has to choose a set of categories and then place each movie in the most appropriate location.

Scientists faced a similar challenge when they looked for a logical way to organize the elements. They had to decide what categories to use and where to place each element. An organized table of the elements is one of the most useful tools in chemistry. The placement of elements on the table reveals the link between the atomic structure of elements and their properties.

Figure 1 Older movies in video stores are placed into categories such as Drama or Comedy.

The Search for Order

Until 1750, scientists had identified only 17 elements. These were mainly metals, such as copper and iron. The rate of discovery increased rapidly as chemists began to investigate materials in a systematic way. As the number of known elements grew, so did the need to organize them into groups based on their properties.

In 1789, French chemist Antoine Lavoisier (la VWAH zee ay) grouped the known elements into categories he called metals, nonmetals, gases, and earths. For the next 80 years, scientists looked for different ways to classify the elements. But none of their systems provided an organizing principle that worked for all the known elements. A Russian chemist and teacher, Dmitri Mendeleev (Duh MEE tree Men duh LAY uff), would discover such a principle.

Section Resources

Print
- *Reading and Study Workbook With Math Support,* Section 5.1
- *Transparencies,* Chapter Pretest and Section 5.1

Technology
- *Interactive Textbook,* Section 5.1
- *Presentation Pro CD-ROM,* Chapter Pretest and Section 5.1
- *Go Online,* NSTA SciLinks, Periodic table

Mendeleev's Periodic Table

In the 1860s, Mendeleev was working on a text-book to use with his chemistry students. Because he needed to describe 63 elements, Mendeleev was looking for the best way to organize the information. He found a way to approach the problem while playing his favorite card game, a version of solitaire. In this game, the player sorts a deck of cards by suit and value. To finish the game, the player must end up with four columns, as shown in Figure 2. Each column contains cards of a single suit arranged in order by value.

Figure 2 A deck of cards can be divided into four suits—diamonds, spades, hearts, and clubs. In one version of solitaire, a player must produce an arrangement in which each suit is ordered from ace to king. This arrangement is a model for Mendeleev's periodic table.

Mendeleev's Proposal Mendeleev's strategy for organizing the elements was modeled on the card game. Mendeleev made a "deck of cards" of the elements. On each card, he listed an element's name, mass, and properties. He paid special attention to how each element behaved in reactions with oxygen and hydrogen. When Mendeleev lined up the cards in order of increasing mass, a pattern emerged. The key was to break the elements into rows, as shown in Figure 3.

🔑 **Mendeleev arranged the elements into rows in order of increasing mass so that elements with similar properties were in the same column.** The final arrangement was similar to a winning arrangement in solitaire, except that the columns were organized by properties instead of suits. Within a column, the masses increased from top to bottom. Mendeleev's chart was a periodic table. A **periodic table** is an arrangement of elements in columns, based on a set of properties that repeat from row to row.

Figure 3 This is a copy of a table that Mendeleev published in 1872. He placed the elements in groups based on the compounds they formed with oxygen or hydrogen. **Using Tables** How many elements did Mendeleev place in Group II?

Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
H = 1							
Li = 7	Be = 9.4	B = 11	C = 12	N = 14	O = 16	F = 19	
Na = 23	Mg = 24	Al = 27.3	Si = 28	P = 31	S = 32	Cl = 35.5	Fe = 56, Co = 59, Ni = 59, Cu = 63.
K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	
(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	Ru = 104, Rh = 104, Pd = 106, Ag = 108.
Rb = 85	Sr = 87	Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	
(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	I = 127	— — — —
Cs = 133	Ba = 137	Di = 138	Ce = 140	—	—	—	
(—)	—	—	—	—	—	—	Os = 195, Ir = 197, Pt = 198, Au = 199.
—	—	Er = 178	La = 180	Ta = 182	W = 184	—	
(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208			
—	—	—	Th = 231	—	U = 240		

The Periodic Table **127**

Quick Lab

Making a Model of a Periodic Table

L2

Objective
After completing this activity, students will be able to
• organize items in an array based on properties.
• predict where an additional item would fit in an incomplete array.

Skills Focus Classifying, Inferring, Observing

Prep Time 20 minutes

Materials resealable plastic sandwich bag, different colored paint chip strips

Advance Prep For each group, collect 4 strips with distinctly different colors. Make sure the color chips are about the same size after you cut off any printing number codes used to identify the shades. Remove one chip from each set. Place each set of chips in a bag.

Class Time 20 minutes

Expected Outcome Students are likely to organize chips of the same color in columns based on the intensity of the shades so that the pattern of colors repeats across the rows.

Analyze and Conclude
1. Students are likely to choose color and shade.
2. Color or intensity of shade repeats across each row.
3. Students should describe the color and approximate shade of the missing chip.
4. Both processes involve selecting properties to organize related items in a repeating pattern and predicting the properties of missing items. However, unlike the periodic table, the order of the columns in the color array can be arbitrary. **Visual, Logical**

Go Online

NSTA SCiLINKS

Download a worksheet on the periodic table for students to complete, and find additional teacher support from NSTA SciLinks.

Quick Lab

Making a Model of a Periodic Table

Materials
plastic bag containing color chips

Procedure

1. Remove the color chips from the bag and place them on a flat surface, color side up.
2. Identify a property that you can use to divide the chips into groups. Then, identify a second property that you can use to order the chips from top to bottom within a group.
3. Use the properties you chose to arrange the chips into a table with rows and columns. Your teacher deliberately left out a chip from each bag. Decide where to leave a gap in your table for the missing chip.

Analyze and Conclude

1. **Classifying** What property did you use to divide the color chips into groups? What property did you use to arrange the chips within a group from top to bottom?
2. **Making Generalizations** What pattern repeats across each row of your table?
3. **Predicting** Based on its location on your table, describe the missing chip.
4. **Comparing and Contrasting** Compare the process you used to construct your table to the process Mendeleev used to make his table. Describe similarities and differences.

Mendeleev's Prediction Mendeleev could not make a complete table of the elements because many elements had not yet been discovered. He had to leave spaces in his table for those elements. For example, Mendeleev placed bromine (Br) in Group VII because bromine and chlorine (Cl) have similar properties. This placement left four spaces in row 4 between zinc (Zn) and bromine. Mendeleev had only two elements, arsenic and selenium, to fill those spaces, based on their masses. He placed arsenic and selenium in the columns where they fit best and left gaps in the columns labeled Groups III and IV.

Mendeleev was not the first to arrange elements in a periodic table. He was not even the first to leave spaces in a periodic table for missing elements. But he was able to offer the best explanation for how the properties of an element were related to its location in his table.

An excellent test for the correctness of a scientific model, such as Mendeleev's table, is whether the model can be used to make accurate predictions. Mendeleev was confident that the gaps in his table would be filled by new elements. He used the properties of elements located near the blank spaces in his table to predict properties for undiscovered elements. Some scientists didn't accept these predictions. Others used the predictions to help in their search for undiscovered elements.

Go Online

NSTA SCiLINKS

For: Links to periodic table
Visit: www.SciLinks.org
Web Code: ccn-1051

Reading Checkpoint *Why did Mendeleev place bromine in Group VII of his periodic table?*

Facts and Figures

Recognizing a Pattern Actions Mendeleev took while developing his table show that he realized the table represented a fundamental pattern in nature. First, he left gaps in the table for undiscovered elements. Second, he sometimes ignored accepted knowledge. For example, Berzelius had reported a formula of Be_2O_3 for beryllium oxide, which (if true) would mean that beryllium belonged in the third column. But, Mendeleev used beryllium to fill a space in the second column. Third, Mendeleev did not place all elements in order by atomic mass. He placed tellurium before iodine even though tellurium has a larger atomic mass.

Evidence Supporting Mendeleev's Table

Mendeleev named missing elements after elements in the same group. He gave the name eka-aluminum to the element that belonged one space below aluminum on the table. (*Eka* is a Sanskrit word meaning "one.") Mendeleev predicted that eka-aluminum would be a soft metal with a low melting point and a density of 5.9 g/cm³.

In 1875, a French chemist discovered a new element. He named the element gallium (Ga) in honor of France. (The Latin name for France is *Gallia*.) Gallium is a soft metal with a melting point of 29.7°C and a density of 5.91 g/cm³. Figure 4 shows a sample of gallium and a traffic signal that uses gallium compounds.

The properties of gallium are remarkably similar to the predicted properties of eka-aluminum. Scientists concluded that gallium and eka-aluminum are the same element. 🔑 **The close match between Mendeleev's predictions and the actual properties of new elements showed how useful his periodic table could be.** The discovery of scandium (Sc) in 1879 and the discovery of germanium (Ge) in 1886 provided more evidence. With the periodic table, chemists could do more than predict the properties of new elements. They could explain the chemical behavior of different groups of elements.

Figure 4 Gallium was discovered in 1875. Heat from a person's hand can melt gallium. In some traffic signals, there are tiny light emitting diodes (LEDs) that contain a compound of gallium. **Comparing and Contrasting** *How does the melting point of gallium (29.7°C) compare to room temperature (about 25°C)?*

Section 5.1 Assessment

Reviewing Concepts
1. 🔑 Describe how Mendeleev organized the elements into rows and columns in his periodic table.
2. 🔑 How did the discovery of new elements such as gallium demonstrate the usefulness of Mendeleev's table?
3. Scientists before Mendeleev had proposed ways to organize the elements. Why were Mendeleev's efforts more successful?
4. What characteristic of solitaire did Mendeleev use as a model for his periodic table?
5. Why did Mendeleev leave spaces in his table?
6. In general, how can a scientist test the correctness of a scientific model?

Critical Thinking
7. **Inferring** Explain why it would not have been possible for a scientist in 1750 to develop a table like Mendeleev's.
8. **Predicting** How was Mendeleev able to predict the properties of elements that had not yet been discovered?

Writing in Science

Writing to Persuade Write a paragraph about Mendeleev's periodic table. Use the paragraph to convince a reader that the periodic table is extremely useful to scientists. (*Hint:* Use specific facts to support your argument.)

The Periodic Table **129**

Section 5.1 Assessment

1. Mendeleev arranged the elements in rows in order of increasing mass so that elements with similar properties were in the same column.
2. The close match between Mendeleev's predictions and the actual properties of new elements showed how useful his periodic table could be.
3. Mendeleev provided an organizing principle that worked for all of the known elements.
4. In solitaire, cards are arranged into categories called suits and ordered by value.
5. In order to place elements with similar properties in the same column, Mendeleev needed to leave spaces for undiscovered elements.
6. The scientist tests whether the model can be used to make accurate predictions.
7. With only 17 known elements to work with, the scientist would not have had enough data.
8. Mendeleev based his predictions on the properties of nearby elements and other elements in the same column.