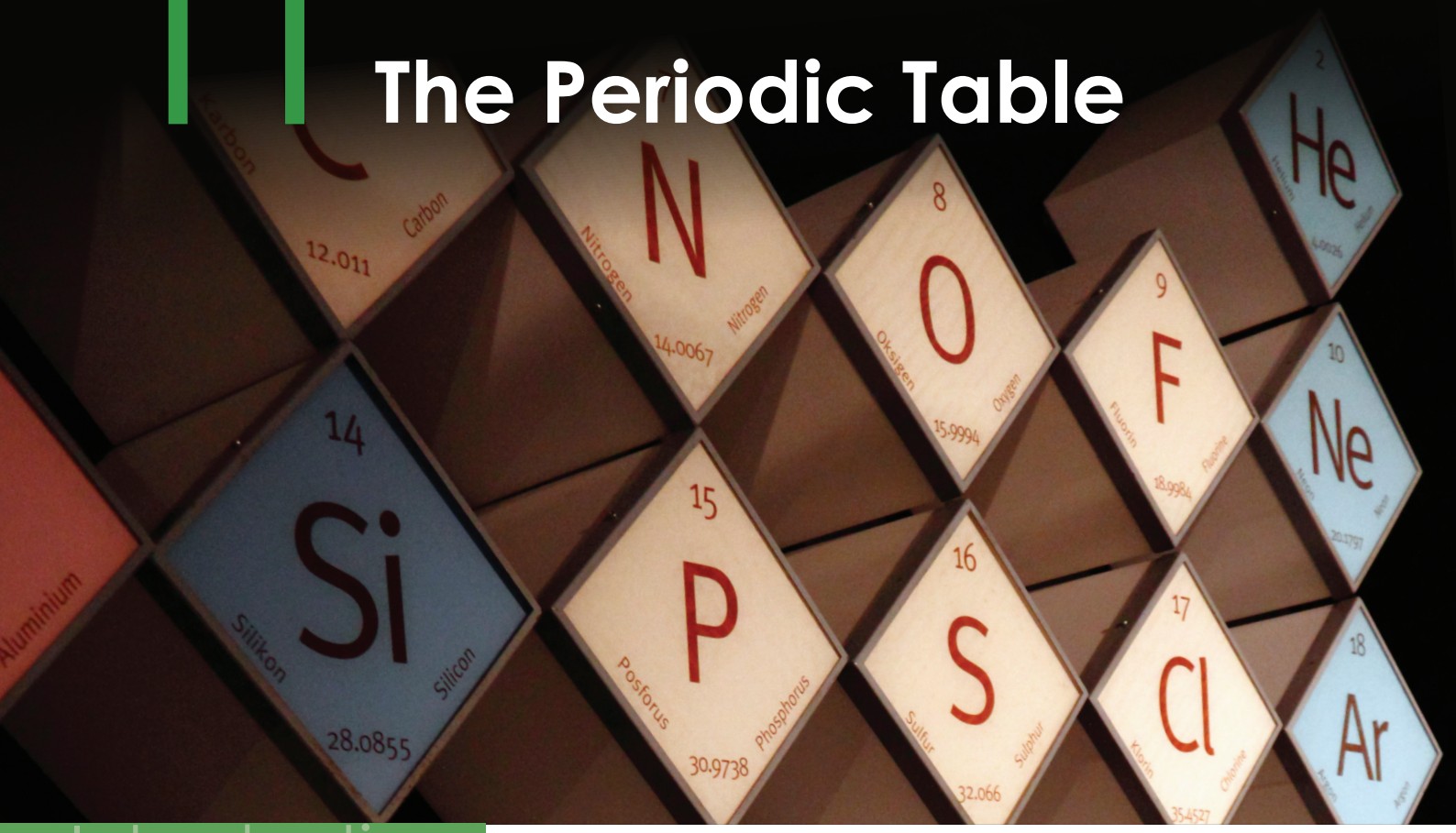
11 The Periodic Table



Introduction

Through the study of this section, students will be come to appreciate the origins of the Periodic Table, its connection with atomic structure, some of the basic patterns in the table, and that the table can be used to predict properties of elements and compounds. In addition, through links to the development of the Periodic Table, students will further appreciate how scientific knowledge changes and accumulates over time.

Chapter Opener (page 164)

1. To open the chapter, teachers can get students to brainstorm what they already know about the Periodic Table. This could include classification of elements which was introduced in Chapter 4. Precise answers are not needed at this stage.

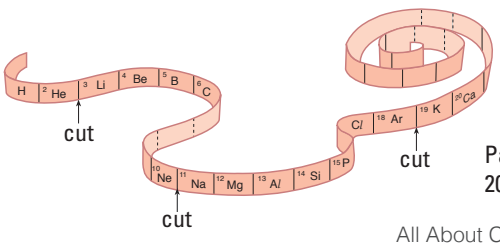
2. Carry out an 'Inquiry Preview.'

Stimulation

Here are two ways to introduce this chapter:

1. Before introducing the Periodic Table, it may be useful to discuss the idea of periodicity. First, point out or ask for the meaning of periodic (adj) as 'occurring or appearing at regular intervals.' Show a calendar and discuss how the days start off at Sunday and move to Monday, etc, and return to Sunday of the next week. Get students to think of examples in everyday life. Examples are months in a year, seasons in a year, day and night cycle.

2. Then introduce the idea of the periodic arrangement of elements by writing out the symbols for the first 20 elements in order of proton number along a 'ticker tape' about 1 cm wide as below:



Paper strip showing the first 20 elements

Then cut the paper strip into a number of horizontal rows. The divisions are made so that each row starts with one of the very reactive metals (Li, Na and K) and ends with unreactive elements (He, Ne and Ar). Then place the rows together so that the Li, Na and K are arranged under each other. A result such as the one shown on the right is obtained. The arrangement of the elements in the table is not unlike the arrangements of the days and dates in the calendar. Although students have arranged the elements as in the Periodic Table, they will not yet know why periodicity among the properties of the elements exists.

H	He	Li	Be	B	C	N	O	F	Ne
		Na	Mg	Al	Si	P	S	Cl	Ar
		K	Ca						

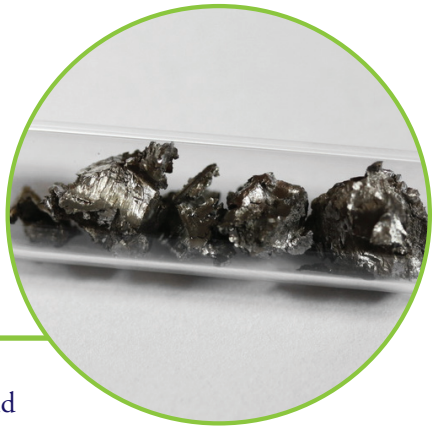
Learning Outcomes

After completing this chapter, students should be able to:

- describe the Periodic Table as an arrangement of the elements in the order of increasing proton (atomic) number
- describe how the position of an element in the Periodic Table is related to proton number and electronic structure
- describe the relationship between group number and the ionic charge of an element
- explain the similarities between the elements in the same group of the Periodic Table in terms of their electronic structure
- describe the change from metallic to non-metallic characteristics from left to right of the Periodic Table across a period
- describe the relationship between group number, number of valency electrons and metallic/non-metallic character
- predict the properties of elements in Group I and Group VII using the Periodic Table

Teaching Notes for

ChemMystery (page 165)



What place does praseodymium have in our world?

Students will be familiar with the importance of common metals such as iron, aluminium and copper. But they are probably unaware of the rare earth metals, a group of elements in a section of the Periodic Table once ignored by chemistry teachers. But now rare earths are everywhere and of increasing importance in daily life and industry. This 'mystery' will give students an introduction to this increasingly important group of elements.

Initial Investigation

- Refer to the Textbook Chapter 4, pages 51–52.
- The most common elements by mass in the Earth's crust are: oxygen, silicon, aluminium, iron and calcium. The rarest elements include gold, and the six 'platinum group' elements (platinum Pt and Ru, Rh, Pd, Os, Ir). Note: The 'rare' earth elements is a historical misnomer; the term reflects unfamiliarity rather than true rarity.
- It organises the elements in an efficient way (e.g. by placing elements with similar properties in the same groups) to see how they related to each other. It allows predictions to be made about the chemical and physical properties of elements based on their position in the table (e.g. metal or non-metal).

Teaching pointers

11.1 What is the Idea Behind the Periodic Table? (page 166)

1. The Periodic Table shows that there is a connection between properties of elements and their relative atomic mass. However, to many chemists in the 19th Century, this idea seemed ridiculous. If chemists at that time found it difficult to appreciate this connection, students may find it difficult to understand too. To facilitate their learning process, the similarities in the properties of lithium, sodium and potassium can be shown using demonstrations of their reactions with water from a CD-ROM (e.g. Science and Nature: Elements, Chemistry Set 2000).
2. Following the introduction, students could carry out Activity 11.1 in the Theory Workbook on the development of the Periodic Table. This is a major activity and students should be given sufficient time to search for information and to present it. Refer to the Lesson Plan for Chapter 11 for suggestions on how to carry out this activity.

Skills Practice (page 166)

(a) The days start on a Sunday, go on from Monday to Saturday, and then return to Sunday again in the next week.

(b) Other everyday examples of periodicity are months in a year, seasons in a year and the day and night cycle.

Notes for Teachers

Historical Development of the Periodic Table

Guiding questions for students

1. What did the development of the Periodic Table depend on?

2. (a) By the year 1800, approximately how many elements had been discovered?
   (b) Name some of these elements.

3. (a) Who first proposed the idea that elements consist of atoms and that atoms of different elements have different masses?
   (b) In which country did this scientist live and work?
   (c) In which year did he publish his atomic theory?

4. A chemist named Dobereiner made a discovery about the chemical properties of some elements.(a) In which year was this discovery made?
   (a) Which country did Dobereiner come from?
   (b) What did Dobereiner discover?
   (c) Name two groups of three elements that Dobereiner found had similar properties.
   (d) Take one of these groups. State the two similar properties that the three elements in the group have.

5. What other interesting facts can you find about the early development of the Periodic Table?

The first Periodic Tables (1860–1869)

By the 1860s, many elements had been discovered and their atomic masses determined.
Approximately how many elements had been discovered by 1860?

2. Several chemists arranged the elements in order of increasing atomic mass. What did they notice?

3. One of the first Periodic Tables was produced by John Newlands.
   (a) Which country did Newlands come from?
   (b) In which year did he produce his periodic table?
   (c) Draw part of his table.
   (d) Were other chemists excited about his ideas? Give the reason.

4. A few years later, the first good Periodic Table was produced.
   (a) Who produced this table?
   (b) Which country did he come from?
   (c) In which year did he produce this Periodic Table?
   (d) State two ways in which this Periodic Table was improved on Newland's Table.

5. Mendeleev's Periodic Table had gaps in it.
   (a) Why?
   (b) Where can such a gap be found? Give an example.
   (c) Mendeleev predicted properties for missing elements. What happened later when these elements were discovered?

6. What other interesting facts can you find about the first Periodic Tables?

The modern Periodic Table

1. How many elements are there in
   (a) Mendeleev's Periodic Table, and
   (b) the modern Periodic Table?

2. The modern Periodic Table has a group of elements that was not present in Mendeleev's table.
   (a) Which group of elements is this?
   (b) Why did Mendeleev not include this group of elements?

3. Mendeleev arranged the elements in order of atomic mass.
   (a) Why was this, a problem with his table?
   (b) This problem was solved when the elements are arranged in another way. How? And in which year was this done?
   (c) Who first arranged them in this way and from which country did he come from?
   (d) Name two elements in the modern Periodic Table which are not in order of atomic mass.

4. One element in the modern table is named after Mendeleev.
   (a) What is its name and symbol?
   (b) What is its atomic number?

5. What other interesting facts can you find about the modern Periodic Table?

Answers to guiding questions

The early development of the Periodic Table (1800–1860)

1. The development of the Periodic Table depended on:
   – the discovery of elements,
   – knowledge of the atomic masses of elements, and
   – knowledge of the properties of elements.

2. (a) About 23 elements had been discovered by the year 1800.
   (b) E.g. Gold, silver, oxygen.

3. (a) John Dalton
   (b) England
   (c) In 1803

4. (a) 1829
   (b) Germany
   (c) The elements occurred in groups of three.
   (d) One group consists of lithium, sodium and potassium. Another group is made up of chlorine, bromine and iodine.
   (e) Lithium, sodium and potassium are all soft, silvery-grey metals. They react with water to produce hydrogen gas.

5. –

The first Periodic Tables (1860–1869)

1. About 60 elements had been discovered by 1860.

2. The properties of later elements were similar to the properties of earlier elements.

3. (a) England
   (b) 1864
   (c) Part of his arrangement of elements is shown below.

H	Li	Be	B	C	N	O
F	Na	Mg	*Al*	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe

   (d) No. Some elements had different properties from other elements in the same column of the table, e.g. iron has very different properties from that of oxygen and sulfur.

4. (a) Dimitri Mendeleev
   (b) Russia
   (c) 1869
   (d) All the elements in a group had similar properties. He left gaps for elements that had not been discovered.

5. (a) Not all the elements had been discovered.
   (b) Between aluminium (Al) and Indium (In).
   (c) The properties of the elements were the same as Mendeleev has predicted.

6. –

The modern Periodic Table

1. (a) 69 elements
   (b) 115 elements (refer to the Periodic Table on page 504 of the Textbook.)

2. (a) Group 0 – the noble gases
   (b) The elements were not discovered until the late 1890s (1894–1898).

3. (a) To get elements with the similar properties in the same groups, sometimes the atomic masses of the elements were out of order.
   (b) By arranging them in order of proton (atomic) number. This was done in 1914.
   (c) Henry Moseley first arranged them in this way. He came from England.
   (d) Argon – Ar = 18; Mr = 40 Potassium – Ar = 19; Mr = 39

4. (a) Mendelevium, Md
   (b) Ar = 101

5. –

Teaching pointers

11.2 How Did the Modern Periodic Table Come About? (page 166)

1. Briefly discuss Mendeleev's Periodic Table. Place emphasis on
   (a) how he discovered the periodic relationship (see 'Notes for Teachers' on the next page), and
   (b) his predictions for the properties of missing elements, such as Germanium, and how these turned out to be accurate (refer to Chemistry in Society: 'Mendeleev and the Periodic Table' on page 168 of the Textbook).
2. Compare Mendeleev's Periodic Table with the modern table. The modern table has three main differences:
   (a) the addition of the group of noble gases,
   (b) the arrangement of elements in order of proton number, and
   (c) the inclusion of synthetic elements.
3. Focus on the different parts of the Periodic Table such as the various groups and the block of transition elements.
4. Point out that hydrogen does not belong to any group in the Periodic Table. It can resemble Group I elements (as it forms H^+ ions) or Group VII elements (as it forms H^- ions).
5. To complete this section an Additional Exercise 1 "Grouping Elements in the Periodic Table" is provided at the end of this chapter. In the exercise, students place elements in a periodic table based on the properties of the elements, in much the same way that Mendeleev did. (See 'Notes for Teachers' below on this exercise.)

(page 167)

Mystery Clue

Praseodymium has the symbol Pr and a proton number of 59. It is the second element is a special block of elements known as the 'Lanthanum (or lanthanide) series', the set of chemically related elements with properties similar to those of lanthanum, with atomic numbers from 57 to 71; they are also called the rare-earth elements as they were originally thought to be rare.

Skills Practice (page 168)

1. Using Table 11.1 on page 166 of the Textbook, the elements that are not in Mendeleev's Periodic Table are:
   - the noble gases such as helium (He), neon (Ne), argon (Ar), krypton (Kr) and xenon (Xe),
   - gallium (Ga),
   - germanium (Ge),
   - scandium (Sc), and
   - technetium (Tc)
2. (a) (i) E.g. K (potassium)
   (ii) E.g. P (phosphorus)
   (b) 18 elements
   (c) The elements on the left of the Periodic Table are metals. Across a period from left to right, the elements become less metallic.
3. E.g. A soft silvery metal similar to sodium. It reacts with water. Has a higher relative atomic mass than sodium. (Students learn more about this in Exercise 11.2 in the Theory Workbook and in Chapter 12. Teachers could then refer back to the tentative answers students give here.)
4. The carbon atom has 6 protons and the nitrogen atom has 7 protons. As the number of protons for an element is a whole number, no element could fit between carbon and nitrogen.

Chemistry in Society (page 168)

Mendeleev and the Periodic Table

Exercise

1. The periodic table allowed scientists to order elements (and predict the existence of elements not yet discovered) and predict the properties of newly discovered (or even undiscovered) elements.
2. No. Mendeleev displayed attributes such as critical and creative thinking. He realised that there were still elements that were undiscovered, and the organisation chart (which would become the periodic table) had to leave blanks for them. Mendeleev also took several years to come up with a properly organised table, and this took resilience and a strong spirit of mind.
3. As above.

Notes for Teachers

More on how Mendeleev devised his Periodic Table

- Mendeleev wrote the names and summarised the known Chemistry of each of the 69 elements known at that time on cards.
- He then arranged the cards in horizontal order of relative atomic mass. This arrangement is almost the same as that obtained when arrange in order of proton number (which was unknown to Mendeleev).
- He realised that the properties of sodium resembled those of lithium, so he broke the horizontal row into two rows – starting the second row with sodium and placing it under lithium.
- He then repeated this, starting a third row with potassium under sodium. He knew he was correct because other similar elements were then automatically put together (e.g. fluorine and chlorine are in the same group).
- The noble gases had not been discovered in 1869 and thus were not in Mendeleev's table. Fortunately, this did not affect his procedure.
- Mendeleev left gaps in his table for undiscovered elements so that he could put similar elements together. For example, two gaps were left for gallium and germanium. He predicted that they would eventually be found. The two elements were later discovered which finally convinced doubting chemists that Mendeleev's table was fundamentally correct.

More on Mendeleev's dream

Mendeleev had a dream regarding the Periodic Table. On the night of February 17th, 1869, Mendeleev went to bed frustrated by a puzzle he had been playing with for years: how to group the relative atomic masses of the elements in such a way that would reveal the hidden structure of nature. He dreamed of "a table where all the elements fell into place as required". His intuition was that when the elements were listed in order of relative atomic mass, their properties repeated at regular intervals, giving rise to the Periodic Table of elements which underlies modern Chemistry.

Special names for groups in the Periodic Table

- The Group I elements are called the alkali metals as they react with water to form alkalis. For example, sodium forms sodium hydroxide.
- The Group II elements (sometimes with the exception of beryllium) are loosely termed alkaline earth metals; the oxides of these metals react with water to form alkalis. For example, magnesium reacts (slowly) with water to form magnesium hydroxide.
- The Group VII elements are called the halogens, which mean 'salt producing', because the elements react readily with many metals to form salts.

Alternative forms of the Periodic Table

Apart from Mendeleev, there are other scientists who have come out with alternative forms of the Periodic Table. They include Stowe, Benfrey and Zmaczynski. For more information on these other forms, visit the following websites:

http://www.wou.edu/las/physci/ch412/alttable.htm
http://en.wikipedia.org/wiki/Alternative_periodic_tables

Periodic Tables on the Internet
Here are four websites on the Periodic Table that are available on the Internet:
http://periodic.lanl.gov/
http://www.chemicalelements.com/
http://www.rsc.org/periodic-table/
http://www.webelements.com/

The first three websites show Periodic Tables of 'O' Level standard. The Periodic Table shown on the fourth website is more advanced and is of 'A' Level and higher standard but it can be used selectively by students. These websites provide information on each element such as the date of its discovery, its uses, electronic structure and properties, and also show graphs of the properties of the elements across a period.

Cards for Additional Exercise 1

- A set of cards is included at the end of this chapter. They can be photocopied, pasted onto cardboard and cut out to form sets of cards.
- Some of the cards include the names of the elements. These are needed to enable students to place all the cards in the correct places as in the Periodic Table.
- You may withhold several cards to create gaps in the table. Get students to predict the properties of these missing elements and check their predictions against the data on the cards. This illustrates the process first used by Mendeleev with his Periodic Table.
- Key for the elements on the cards:

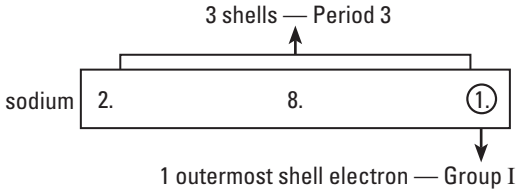
Y – Lithium	R – Beryllium	T – Oxygen	D – Fluorine	L - Calcium
Q – Neon	G – Sodium	A – Magnesium	M – Aluminium	
E – Silicon	J – Phosphorus	Z – Argon	X – Potassium	

Note: Letters have been chosen that do not correspond to symbols for any common elements.

Teaching pointers

11.3 What Patterns can be found in Periodic Table? (page 169)

1. The diagram below could be used to show the relationship between the electronic structure, periodic number and group number. The example shown below is for sodium:



2. To make the change from metal to non-metal more concrete, arrange samples of the elements in Period 2. As neon is colourless, a gas jar of air labelled 'neon' can be used.

3. Changes in the chemical properties of Group I and Group VII elements down a group will be investigated in detail in Chapter 12.

Skills Practice (page 170)

1. A charge of –1, like the chloride ion.
2. **(a)** 2.3
   (b) **(i)** Period 2
   (ii) Group III
   (c) Metalloid
   (d) B_2O_3
3. **(a)** E.g. Both have 2 outer shell electrons. Both are metals. Both form ions with a charge of +2.
   (b) E.g. Different proton numbers, relative atomic masses and numbers of electron shells.

(page 170)

Mystery Clue

A metal as it is located to the left and the bottom of the Periodic Table, both areas where metals are located.

Teaching pointers

11.4 What is the Periodic Table Used for? (page 170)

1. Emphasise the importance of the Periodic Table in being able to make accurate predictions of the properties of elements. This idea is used again in Chapter 12 for predicting both the physical and chemical properties of elements.
2. In Exercise 11.2, students predict physical properties of a Group I element based on trends in the properties of the Group I elements. They also get practice in using a spreadsheet to draw a graph.

Chemistry Inquiry (page 171–172)

What is the Melting Point of Astatine?

Group Discussion

1. Good theories and models not only explain observations but must also be able to make predictions. If experiments show these predictions to be correct, this gives scientists greater confidence in the correctness and power of the theories and models. Such is the case with the Periodic Table.
2. Based on the other elements in Group VII, the formula for astatine would be At; and its molecules would have single covalent bond At–At. At room temperature it will be a solid.
3. Yes. It gives us less confidence in the correctness of the predictions we make based on the properties of the other elements in the group.

Skills Practice (page 51)

1. The formula of the compound of sulfur and hydrogen is H_2S (hydrogen sulfide), just like H_2O is the formula of the compound of oxygen and hydrogen. Both sulfur and oxygen have 6 outer shell electrons each. They share 2 electrons with the two hydrogen atoms to form two covalent bonds, forming H_2S and H_2O respectively.
2. **(a)** Radium is expected to conduct electricity. Radium is in Group II and so is a metal.
   (b) The formula of radium chloride is $RaCl_2$, just like magnesium and calcium (which are in the same groups as radium) forms $MgCl_2$ and $CaCl_2$ respectively.
3. **(a)** 230 °C
   (b) Solid at room conditions, since its melting point is above room temperature.

Notes for Teachers

Periodic Table card game and file

There are a number of free Periodic Table games that students can play online or which can be downloaded and used. Here are some of them:
http://education.jlab.org/elementflashcards/index.html
http://www.can-do.com/uci/lessons99/periodictablecards.html
http://www.bingocardcreator.com/bingo-cards/chemistry/periodic-table-of-elements
http://www.bigbadbrain.com/chemcards/gameideas.htm
http://www.ellenjmchenry.com/homeschool-freedownloads/chemistry-games/quicksix.php

11 Chapter Review

Self-Management

Misconception Analysis (page 173)

1. **False** In Mendeleev's original table, the elements were arranged in order of relative atomic mass. In the modern table, they are in order of proton (atomic) number.

2. **True** The period number corresponds to the number of shells. For example, in Period 2, the elements have 2 shells.

3. **False** Elements in the same group have similar chemical properties. For example, the Group I metals sodium and potassium both react with water but potassium reacts more vigorously than sodium.

4. **False** Metals are found in most parts of the Periodic Table except in the upper right-hand section where non-metals are located.

5. **True** This is one of the reasons why the Periodic Table is so important in Chemistry.

Practice

Structured Questions (pages 173 – 174)

1. (a) **A** (b) **E** (c) **B**
   (d) **C** (e) **D** (f) **E**

2. (a) magnesium, sodium, tin, caesium, aluminium, beryllium
   (b) magnesium, argon, chlorine, sodium, aluminium
   (c) sodium, caesium
   (d) magnesium, beryllium
   (e) tin, carbon

3. (a) Elements **A**, **D** and **E** (any two)
   (b) Element **C**
   (c) Elements **A** and **E**
   (d) Elements **A**, **B** and **C** (any two)

4. (a) **X** is in Group VI, as the group number is the same as the number of outer shell electrons.
   (b) **X** is sulfur, S.
   (c) **X** has three electron shells. (Its electronic structure is 2.8.6.)
   (d) Non-metal

5. (a) strontium carbonate, $SrCO_3$
   (b) (i) It has two outer shell electrons. All elements in Group II have two outer shell electrons.
   (ii) Sr^{2+}

6. (a) 118 (difference of 32 between each element down the group)
   (b) 300 (should increase across the period)

7. (a) proton number; total number of electrons; number of outer shell electrons
   (b) proton number; the number of electron shells; total number of electrons
   (c) proton number; total number of electrons

Free Response Questions (page 174)

1. The two other very valuable metals are silver and gold. Copper, silver and gold are in the same group of the Periodic Table and so they all have similar properties. As copper is found free in the Earth, so too are silver and gold.

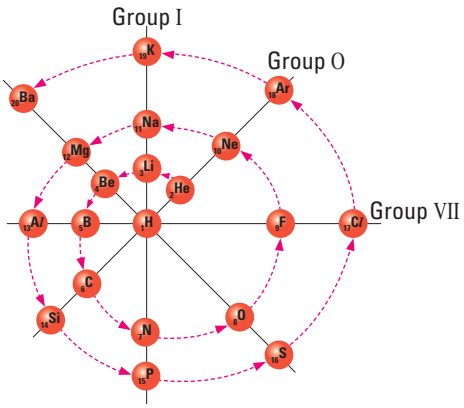
2. Students' responses would include the following:
   Elements in the same group
   – have the same number of outer shell electrons,
   – form ions with same charge,
   – form compounds with similar formulae, and
   – have similar properties.

   Across a period from left to right
   – proton number increases, and
   – elements become less metallic.

   The properties of elements change gradually down a group.

Extension (page 174)

(a) (b)



(c) Advantages:
- It is more compact.
- It is continuous without a break at the end of every period.

Disadvantages:
- It is not easy to see the members of a group.
- It is difficult to add extra information such as names and relative atomic masses.
- It does not include transition metals.
- As the number of elements increases, it becomes increasingly difficult to follow the spiral.

For more information on the Periodic Table visit the following website.

http://www.nytimes.com/imagepages/2006/10/23/science/20061024_ILLO_GRAPHIC.html

Additional Teaching Material

Additional Exercise 1: Grouping Elements in the Periodic Table

Objective

- To analyse data and classify elements in the Periodic Table

Strategy

- Using thinking skills: Analysing, organising, classifying
- Learning through games

Your teacher will give you some data cards for the first 20 elements in the Periodic Table. Each card has some properties of the element. Some cards include the name of the element. Other cards have a letter instead of the name.

1. In small groups, study each card in turn. Place the elements that have similar properties in separate piles.
2. Arrange the cards where you think they should go in the Periodic Table. Then complete the table below with the name or the letter for the element.

			Hydrogen				Helium
Y	R	boron	carbon	nitrogen	T	D	Q
G	A	M	E	J	sulfur	chlorine	Z
X	L						

Give some reasons for placing elements in the following groups.

Group I: All are metals, silvery in colour (under the surface), soft, react with water.

Group VII: All are non-metals, have low melting points, coloured, very reactive.

Group 0: All are non-metals, colourless gases, very unreactive.

Compare your classification with that of other groups. Then check with your teacher to see if your table is correct.

Additional Teaching Material

All cards should be of the same size with 4 lines of text under the name.

Hydrogen
colourless, odourless gas
lightest element
explodes when mixed
with air and ignited

Helium
colourless, odourless gas
non-metal
very unreactive
density = 0.000 17 g/cm^3

Y
silvery white solid
soft metal
reacts slowly with water
reacts vigorously with chlorine

R
silvery metal (grey surface)
does not react with water
does not react with steam
reacts very slowly with dilute acids

Boron
black solid
some metallic properties
does not react with water or steam
does not react with most acids

Carbon
solid
very high melting point
burns in air
does not react with chlorine

Nitrogen
colourless gas
non-metal
insoluble in water
does not react with air

T
colourless gas
non-metal
reacts with most metals
does not react with water

D
pale yellow gas
low melting point (–220 °C)
most reactive of all elements
reacts vigorously with metals

Q
colourless, odourless gas
non-metal
very unreactive element
density = 0.000 84 g/cm^3

G
silvery white solid
soft metal
reacts vigorously with water
reacts vigorously with chlorine

A
silvery white metal
little reaction with water
reacts vigorously with steam
reacts slowly with dilute acids

M
silvery solid
metal
reacts with steam but not water
reacts slowly with acids

E
dark grey solid
high melting point
little reaction with air
reacts vigorously with chlorine

J
dull red solid
non-metal
insoluble in water
reacts with air

Sulfur
pale yellow solid
non-metal
reacts with most metals
does not react with water

Chlorine
greenish-yellow gas
low melting point (–101 °C)
reactive element
reacts with most metals

Z
colourless, odourless gas
non-metal
very unreactive element
density = 0.0166 g/cm^3

X
silvery white solid
very soft metal
reacts very rapidly with water
reacts vigorously with chlorine

L
silvery white metal (grey surface)
reacts with water
reacts vigorously with steam
reacts vigorously with dilute acids