حل تجميعة أسئلة وفق الهيكل الوزاري الجديد منهج انسباير

Chemistry Grade 11 General EoT1 2025-2026 revision

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1	CHM.5.1.01.001.07 Differentiate between the ground and excited states of an atom	Textbook + figure 10	13

Bohr's Model of the Atom

The dual wave-particle model of light accounted for several previously unexplainable phenomena, but scientists still did not understand the relationships among atomic structure, electrons, and atomic emission spectra. Recall that hydrogen's atomic emission spectrum is discontinuous; that is, it is made up of only certain frequencies of light. Why are the atomic emission spectra of elements discontinuous rather than continuous? Niels Bohr, a Danish physicist working in Rutherford's laboratory in 1913, proposed a quantum model for the hydrogen atom that seemed to answer this question. Bohr's model also correctly predicted the frequencies of the lines in hydrogen's atomic emission spectrum.

Energy states of hydrogen

Building on Planck's and Einstein's concepts of quantized energy, Bohr proposed that the hydrogen atom has only certain allowable energy states, as illustrated in **Figure 10**. The lowest allowable energy state of an atom is called its **ground state.** When an atom gains energy, it is said to be in an excited state.

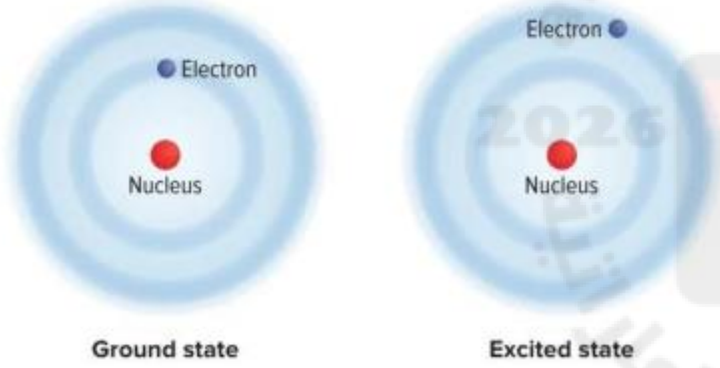


Figure 10 The figure shows an atom that has one electron. Note that the illustration is not to scale. In its ground state, the electron is associated with the lowest energy level. When the atom is in an excited state, the electron is associated with a higher energy level.

Bohr suggested that the electron in a hydrogen atom moves around the nucleus in only certain allowed circular orbits. The smaller the electron's orbit, the lower the atom's energy state, or energy level. Conversely, the larger the electron's orbit, the higher the atom's energy state, or energy level. Bohr assigned a number, n, called a **quantum number,** to each orbit. He also calculated the radius of each orbit. **Table 1** shows data for the first seven energy levels of a hydrogen atom according to Bohr's model.

1	CHM.5.1.01.001.07 Differentiate between the ground and excited states of an atom	Textbook + figure 10	13

What is called the state of the atom when it gains energy according to Bohr's model?	ماذا تسمى الحالة التي تكون الذرة فيها عندما تكتسب طاقة وفق نموذج بور؟
A. Ground state	A. الحالة الأرضية
B. Excited state	B. الحالة المستثارة
C. Inert state	C. الحالة الخاملة
D. Radiation-emitting state	D. حالة انبعاث الاشعاع

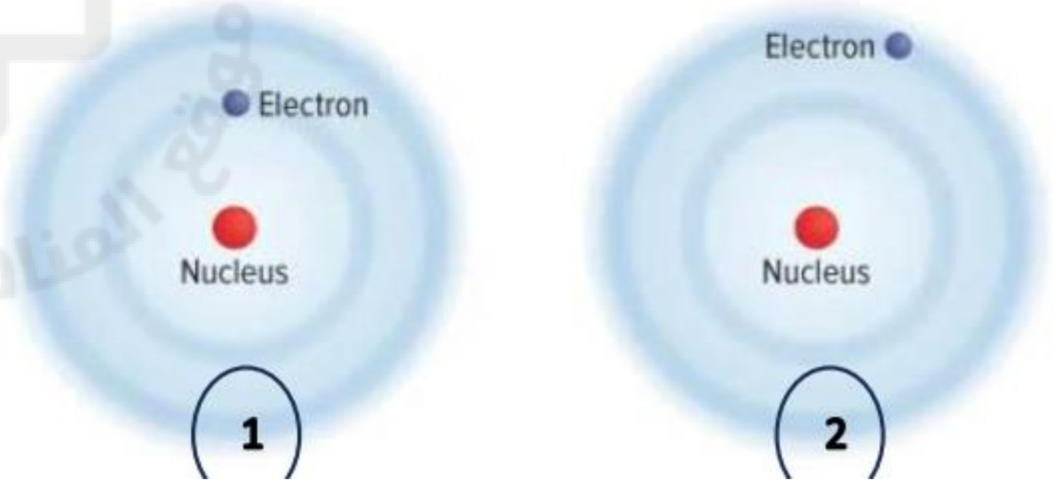
4- Regarding the atom structure on the right

a) Figure 2 represents lowest allowable energy state

b) Figure 2 represents excited energy state

c) The atoms gain energy to reach figure 1

d) The atoms lose energy to reach figure 2



2	CHM.5.1.01.002.03 Relate the principal quantum number to the total number of orbitals of the principal energy levels and the number of orbitals in sub-energy levels	Textbook + figure 16		20

Principal quantum number

Recall that the Bohr atomic model assigns quantum numbers to electron orbits. Similarly, the quantum mechanical model assigns four quantum numbers to atomic orbitals. The first one is the **principal quantum number** (n) and indicates the relative size and energy of atomic orbitals. As n increases, the orbital becomes larger, the electron spends more time farther from the nucleus, and the atom's energy increases. Therefore, n specifies the atom's major energy levels. Each major energy level is called a **principal energy level.** An atom's lowest principal energy level is assigned a principal quantum number of 1. When the hydrogen atom's single electron occupies an orbital with $n = 1$, the atom is in its ground state. Up to 7 energy levels have been detected for the hydrogen atom, giving n values ranging from 1 to 7.

Energy sublevels

Principal energy levels contain **energy sublevels.** Principal energy level 1 consists of a single sublevel, principal energy level 2 consists of two sublevels, principal energy level 3 consists of three sublevels, and so on. To better understand the relationship between the atom's energy levels and sublevels, picture the seats in a wedge-shaped section of a theater, as shown in **Figure 16**. As you move away from the stage, the rows become higher and contain more seats. Similarly, the number of energy sublevels in a principal energy level increases as n increases.

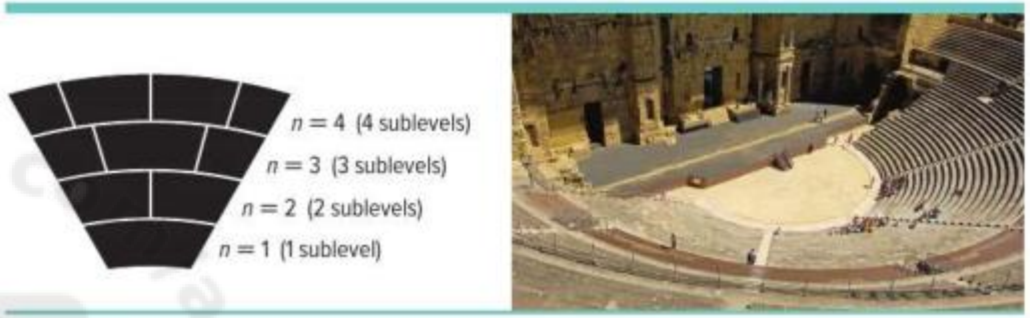


Figure 16 Energy levels can be thought of as rows of seats in a theater. The rows that are higher up and farther from the stage contain more seats. Similarly, energy levels related to orbitals farther from the nucleus contain more sublevels.

Table 2 Hydrogen's First Four Principal Energy Levels

Principal Quantum Number (n)	Sublevels (Types of Orbitals) Present	Number of Orbitals Related to Sublevel	Total Number of Orbitals Related to Principal Energy Level (n^2)
1	s	1	1
2	s p	1 3	4
3	s p d	1 3 5	9
4	s p d f	1 3 5 7	16

Hydrogen's first four principal energy levels, sublevels, and related atomic orbitals are summarized in **Table 2**. Note that the number of orbitals related to each sublevel is always an odd number, and that the maximum number of orbitals related to each principal energy level equals n^2.

2	CHM.5.1.01.002.03 Relate the principal quantum number to the total number of orbitals of the principal energy levels and the number of orbitals in sub-energy levels	Textbook + figure 16	20

Which of the following statements is correct?

أي العبارات التالية صحيحة؟

Principal energy level 3 consists of three sublevels, they are 3s, 3p and 3f

يتكون مستوى الطاقة الرئيس 3 من ثلاث مستويات فرعية هي 3s و 3p و 3f

Principal energy level 3 consists of three sublevels, they are 3s, 3p and 3d

يتكون مستوى الطاقة الرئيس 3 من ثلاث مستويات فرعية هي 3s و 3p و 3d

Principal energy level 2 consists of two sublevels, they are 2s, 2d

يتكون مستوى الطاقة الرئيس 2 من مستويين فرعيين هما 2s و 2d

Principal energy level 2 consists of two sublevels, they are 2s, 2f

يتكون مستوى الطاقة الرئيس 2 من مستويين فرعيين هما 2s و 2f

3	CHM.5.1.01.003.02 Explain the Aufbau principle, the Pauli exclusion principle, and Hund's rule	Textbook + figure 18 + table 3	23 ,24
6	CHM.5.1.01.003.02 Explain the Aufbau principle, the Pauli exclusion principle, and Hund's rule	Textbook	24

Ground-State Electron Configuration

The arrangement of electrons in an atom is called the atom's **electron configuration.** Because low-energy systems are more stable than high-energy systems, electrons in an atom tend to assume the arrangement that gives the atom the lowest energy possible. The most stable, lowest-energy arrangement of the electrons is called the element's ground-state electron configuration.

Three rules, or principles—the aufbau principle, the Pauli exclusion principle, and Hund's rule—define how electrons can be arranged in an atom's orbitals.

The aufbau principle

The **aufbau principle** states that each electron occupies the lowest energy orbital available. Therefore, your first step in determining an element's ground-state electron configuration is learning the sequence of atomic orbitals from lowest energy to highest energy. This sequence, known as an aufbau diagram, is shown in **Figure 18.** In the diagram, each box represents an atomic orbital.

Figure 18 The aufbau diagram shows the energy of each sublevel relative to the energy of other sublevels.

Determine *Which sublevel has the greater energy, 4d or 5p?*

The Pauli exclusion principle

Every electron has an associated spin, similar to the way a top spins on its point. Like a top, an electron is able to spin in only one of two directions. The **Pauli exclusion principle,** proposed by Austrian physicist Wolfgang Pauli (1900–1958), states that a maximum of two electrons can occupy a single atomic orbital, but only if the electrons have opposite spins.

Electrons in orbitals can be represented by arrows in boxes. An arrow pointing up [↑] represents the electron spinning in one direction, and an arrow pointing down [↓] represents the electron spinning in the opposite direction. An empty box [ ] represents an unoccupied orbital, a box containing a single up arrow [↑] represents an orbital with one electron, and a box containing both up and down arrows [↑↓] represents a filled orbital containing a pair of electrons with opposite spins.

Hund's rule

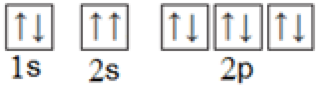
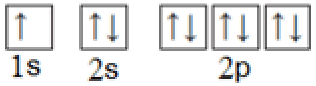
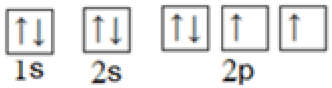
The fact that negatively charged electrons repel each other affects the distribution of electrons in equal-energy orbitals. **Hund's rule** states that single electrons with the same spin must occupy each equal-energy orbital before additional electrons with opposite spins can occupy the same orbitals. For example, the boxes below show the sequence in which six electrons occupy the three 2p orbitals. One electron enters each of the orbitals before a second electron enters any of the orbitals.

1. [↑][ ][ ] **2.** [↑][↑][ ] **3.** [↑][↑][↑]

4. [↑↓][↑][↑] **5.** [↑↓][↑↓][↑] **6.** [↑↓][↑↓][↑↓]

3	CHM.5.1.01.003.02 Explain the Aufbau principle, the Pauli exclusion principle, and Hund's rule	Textbook + figure 18 + table 3	23 ,24
6	CHM.5.1.01.003.02 Explain the Aufbau principle, the Pauli exclusion principle, and Hund's rule	Textbook	24

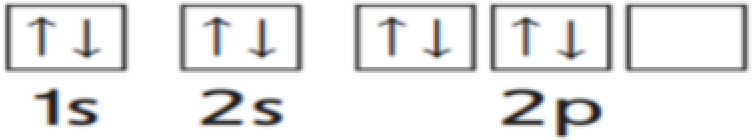
Which of the following is **correct**? أي مما يأتي **صحيح**؟

	يتفق مع قاعدة هوند It agrees with Hund's rule	A
	يتفق مع مبدأ باولي للاستبعاد It agrees with the Pauli exclusion principle	B
	يتفق مع مبدأ أوفباو It agrees with the Aufbau principle	C
	يتفق مع كل قواعد ومبادئ الترتيب الإلكتروني It agrees with all electron configuration rules and principles	D

Which of the following orbital diagrams violates Hund's rule?	أي من أشكال مخططات الأفلاك التالية تخالف قاعدة هوند؟

2- What rule does the electron notation on the right violate?

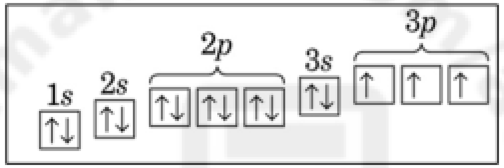
a) Aufbau b) Pauli c) Hund



3	CHM.5.1.01.003.02 Explain the Aufbau principle, the Pauli exclusion principle, and Hund's rule	Textbook + figure 18 + table 3	23 ,24
6	CHM.5.1.01.003.02 Explain the Aufbau principle, the Pauli exclusion principle, and Hund's rule	Textbook	24

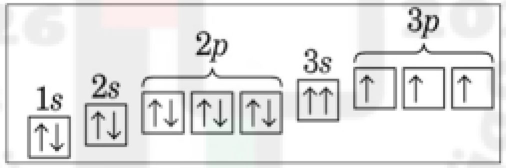
Which of the following is true related to the orbital diagrams below? أي مما يأتي صحيح فيما يتعلق بمخططات الأفلاك أدناه؟

Matches all electron configuration principles



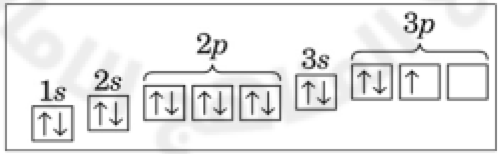
يتطابق مع كل قواعد الترتيب الإلكتروني

Matches Pauli exclusion principle



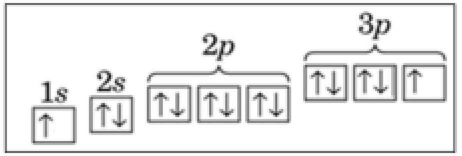
يتطابق مع مبدأ باولي للاستبعاد

Matches Hund's rule



يتطابق مع قاعدة هوند

Matches aufbau principle



يتطابق مع مبدأ أوفباو

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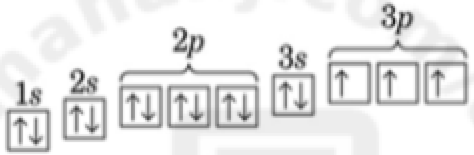
Which of the following is true related to the orbital diagrams below? أي مما يأتي صحيح فيما يتعلق بمخططات الأفلاك أدناه؟

Matches Hund's rule

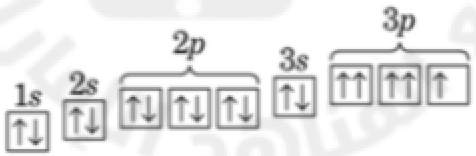


يتطابق مع قاعدة هوند

Matches Aufbau principle

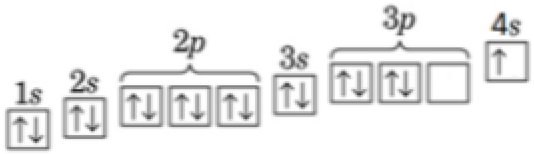
يتطابق مع مبدأ أوفباو

Matches Pauli exclusion principle



يتطابق مع مبدأ باولي للاستبعاد

Matches all electron configuration principles



يتطابق مع كل قواعد الترتيب الإلكتروني

3	CHM.5.1.01.003.02 Explain the Aufbau principle, the Pauli exclusion principle, and Hund's rule	Textbook + figure 18 + table 3	23 ,24
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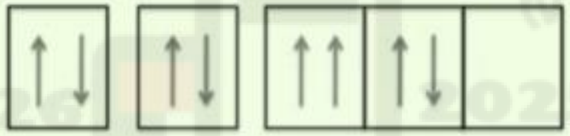
Regarding the electron arrangement with orbital diagram method below, which of the following is **correct**?

فيما يتعلق بالترتيب الإلكتروني بطريقة مخطط الأفلاك أدناه، أي مما يأتي **صحيح**؟



1. This electronic arrangement violates only to the Pauli exclusion– principle
يتعارض هذا الترتيب الإلكتروني مع مبدأ باولي للاستبعاد فقط

2. This electronic arrangement violates only the aufbau principle
يتعارض هذا الترتيب الإلكتروني مع مبدأ أوفباو فقط

3. This electronic arrangement violates Hund's rule and aufbau principle
يتعارض هذا الترتيب الإلكتروني مع قاعدة هوند و مبدأ أوفباو

4. This electronic arrangement violates Hund's rule and Pauli's exclusion principle
يتعارض هذا الترتيب الإلكتروني مع قاعدة هوند و مبدأ باولي للاستبعاد

4	CHM.5.1.01.003.05 Write the electron configuration, orbital diagram, and noble gas notation of different elements	Textbook + tables 4 , 5	25 , 26
5	CHM.5.1.01.003.05 Write the electron configuration, orbital diagram, and noble gas notation of different elements	Textbook + table 6+ example problem 3 + practice problems + check your progress	28 , 29

Electron Arrangement

You can represent an atom's electron configuration using one of two convenient methods: orbital diagrams or electron configuration notation.

Orbital diagrams

As mentioned earlier, electrons in orbitals can be represented by arrows in boxes. Each box is labeled with the principal quantum number and sublevel associated with the orbital. For example, the orbital diagram for a ground-state carbon atom, shown below, contains two electrons in the 1s orbital, two electrons in the 2s orbital, and one electron in two of three separate 2p orbitals. The third 2p orbital remains unoccupied.

1s	2s	2p		
↑↓	↑↓	↑	↑	

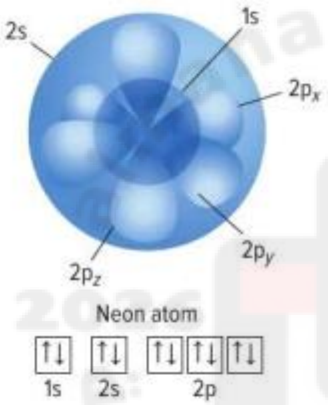


Figure 19 The 1s, 2s, and 2p orbitals of a neon atom overlap.
Determine *how many electrons a neon atom has.*

Electron configuration notation

The electron configuration notation designates the principal energy level and energy sublevel associated with each of the atom's orbitals and includes a superscript representing the number of electrons in the orbital. For example, the electron configuration notation of a ground-state carbon atom is written $1s^2 2s^2 2p^2$.

Orbital diagrams and electron configuration notations for the elements in periods one and two of the periodic table are shown in **Table 4. Figure 19** illustrates how the 1s, 2s, 2p$_x$, 2p$_y$, and 2p$_z$ orbitals illustrated earlier in **Figure 17** overlap in the neon atom.

Table 4 Electron Configurations and Orbital Diagrams for Elements 1–10

Element	Atomic Number	Orbital Diagram 1s	2s	2p$_x$	2p$_y$	2p$_z$	Electron Configuration Notation
Hydrogen	1	↑					$1s^1$
Helium	2	↑↓					$1s^2$
Lithium	3	↑↓	↑				$1s^2 2s^1$
Beryllium	4	↑↓	↑↓				$1s^2 2s^2$
Boron	5	↑↓	↑↓	↑			$1s^2 2s^2 2p^1$
Carbon	6	↑↓	↑↓	↑	↑		$1s^2 2s^2 2p^2$
Nitrogen	7	↑↓	↑↓	↑	↑	↑	$1s^2 2s^2 2p^3$
Oxygen	8	↑↓	↑↓	↑↓	↑	↑	$1s^2 2s^2 2p^4$
Fluorine	9	↑↓	↑↓	↑↓	↑↓	↑	$1s^2 2s^2 2p^5$
Neon	10	↑↓	↑↓	↑↓	↑↓	↑↓	$1s^2 2s^2 2p^6$

4	CHM.5.1.01.003.05 Write the electron configuration, orbital diagram, and noble gas notation of different elements	Textbook + tables 4 , 5	25 , 26
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Noble-gas notation Noble gases are the elements in the last column of the periodic table. Their outermost energy levels are full, and they are unusually stable. Noble-gas notation uses bracketed symbols to represent the electron configurations of noble gases. For example, [He] represents the electron configuration for helium, $1s^2$, and [Ne] represents the electron configuration for neon, $1s^22s^22p^6$.

Compare the electron configuration for neon with sodium's configuration above. Note that the inner-level configuration for sodium is identical to the electron configuration for neon. Using noble-gas notation, sodium's electron configuration can be shortened to the form $[Ne]3s^1$. The electron configuration for an element can be represented using the noble-gas notation for the noble gas in the previous period and the electron configuration for the additional orbitals being filled. The complete and abbreviated (using noble-gas notation) electron configurations of the period 3 elements are shown in **Table 5**.

Table 5 Electron Configurations for Elements 11–18

Element	Atomic Number	Complete Electron Configuration	Electron Configuration Using Noble Gas
Sodium	11	$1s^22s^22p^63s^1$	$[Ne]3s^1$
Magnesium	12	$1s^22s^22p^63s^2$	$[Ne]3s^2$
Aluminum	13	$1s^22s^22p^63s^23p^1$	$[Ne]3s^23p^1$
Silicon	14	$1s^22s^22p^63s^23p^2$	$[Ne]3s^23p^2$
Phosphorus	15	$1s^22s^22p^63s^23p^3$	$[Ne]3s^23p^3$
Sulfur	16	$1s^22s^22p^63s^23p^4$	$[Ne]3s^23p^4$
Chlorine	17	$1s^22s^22p^63s^23p^5$	$[Ne]3s^23p^5$
Argon	18	$1s^22s^22p^63s^23p^6$	$[Ne]3s^23p^6$ or [Ar]

The atomic number of the element copper (Cu) is 29. What is the correct electronic configuration of copper using the noble-gas notation?

العدد الذري لعنصر النحاس (Cu) يساوي 29. ما الترتيب الإلكتروني الصحيح للنحاس باستخدام ترميز الغاز النبيل؟

$[Ar]\ 4s^23d^9$

$[Ar]\ 4s^13d^{10}$ Exception

$[Kr]\ 5s^23d^9$

$[Kr]\ 5s^13d^{10}$

$_{24}Cr: [Ar]\ 4s^1 3d^5$

$_{29}Cu\ [Ar]\ 4s^1 3d^{10}$

7- What is the correct electron configuration for Phosphorus $_{15}P$?

a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ b) $1s^2\ 2s^2\ 2p^6\ 3s^2$ c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3d^3$ d) $1s^2\ 2s^2\ 2p^6\ 4s^2\ 4p^3$

4	CHM.5.1.01.003.05 Write the electron configuration, orbital diagram, and noble gas notation of different elements	Textbook + tables 4 , 5	25 , 26
5	CHM.5.1.01.003.05 Write the electron configuration, orbital diagram, and noble gas notation of different elements	Textbook + table 6+ example problem 3 + practice problems + check your progress	28 , 29

Valence Electrons

Only certain electrons, called valence electrons, determine the chemical properties of an element. **Valence electrons** are defined as electrons in the atom's outermost orbitals—generally those orbitals associated with the atom's highest principal energy level. For example, a sulfur atom contains 16 electrons, only six of which occupy the outermost 3s and 3p orbitals, as shown by sulfur's electron configuration, $[Ne]3s^2 3p^4$. Sulfur has six valence electrons. Similarly, although a cesium atom has 55 electrons, it has just one valence electron, the 6s electron shown in cesium's electron configuration, $[Xe]6s^1$.

Electron-dot structures

Because valence electrons are involved in forming chemical bonds, chemists often represent them visually using a simple shorthand method, called electron-dot structure. An atom's **electron-dot structure** consists of the element's symbol, which represents the atomic nucleus and inner-level electrons, surrounded by dots representing all of the atom's valence electrons. In writing an atom's electron-dot structure, dots representing valence electrons are placed one at a time on the four sides of the symbol (they may be placed in any sequence) and then paired up until all are shown. **Table 6** shows examples for the second period.

Table 6 Electron Configurations and Dot Structures

Element	Atomic Number	Electron Configuration	Electron-Dot Structure
Lithium	3	$1s^2 2s^1$	Li·
Beryllium	4	$1s^2 2s^2$	·Be·
Boron	5	$1s^2 2s^2 2p^1$	·Ḃ·
Carbon	6	$1s^2 2s^2 2p^2$	·Ċ·
Nitrogen	7	$1s^2 2s^2 2p^3$	·N̈·
Oxygen	8	$1s^2 2s^2 2p^4$	:Ö·
Fluorine	9	$1s^2 2s^2 2p^5$	:F̈·
Neon	10	$1s^2 2s^2 2p^6$	:N̈e:

EXAMPLE Problem 3

ELECTRON-DOT STRUCTURES Some toothpastes contain stannous fluoride, a compound of tin and fluorine. What is tin's electron-dot structure?

1 ANALYZE THE PROBLEM

Consult the periodic table to determine the total number of electrons in a tin atom. Write out tin's electron configuration, and determine its number of valence electrons. Then use the rules for electron-dot structures to draw the electron-dot structure for tin.

2 SOLVE FOR THE UNKNOWN

Tin has an atomic number of 50. Thus, a tin atom has 50 electrons.

$[Kr]5s^2 4d^{10} 5p^2$ — Write out tin's electron configuration using noble-gas notation. The closest noble gas is Kr.

The two 5s and the two 5p electrons (the electrons in the orbitals related to the atom's highest principal energy level) represent tin's four valence electrons. Draw the four valence electrons around tin's chemical symbol (Sn) to show tin's electron-dot structure.

·Ṡn·

EXAMPLE Problem 3 (continued)

3 EVALUATE THE ANSWER

The correct symbol for tin (Sn) has been used, and the rules for drawing electron-dot structures have been correctly applied.

Mg· ·Tl· :Xe: ·Al

PRACTICE Problems — ADDITIONAL PRACTICE

24. Draw electron-dot structures for atoms of the following elements.
a. magnesium **b.** thallium **c.** xenon

25. An atom of an element has a total of 13 electrons. What is the element, and how many electrons are shown in its electron-dot structure? Al

26. CHALLENGE This element exists in the solid state at room temperature and at normal atmospheric pressure and is found in emerald gemstones. It is known to be one of the following elements: carbon, germanium, sulfur, cesium, beryllium, or argon. Identify the element based on the electron-dot structure at right.

·X·

4	CHM.5.1.01.003.05 Write the electron configuration, orbital diagram, and noble gas notation of different elements	Textbook + tables 4 , 5	25 , 26
5	CHM.5.1.01.003.05 Write the electron configuration, orbital diagram, and noble gas notation of different elements	Textbook + table 6+ example problem 3 + practice problems + check your progress	28 , 29

Check Your Progress

Summary

- The arrangement of electrons in an atom is called the atom's electron configuration.
- Electron configurations are defined by the aufbau principle, the Pauli exclusion principle, and Hund's rule.
- An element's valence electrons determine the chemical properties of the element.
- Electron configurations can be represented using orbital diagrams, electron configuration notation, and electron-dot structures.

Demonstrate Understanding

27. **Apply** the Pauli exclusion principle, the aufbau principle, and Hund's rule to write the electron configuration and draw the orbital diagram for each of the following elements.
    a. silicon b. fluorine c. calcium d. krypton
28. **Define** *valence electron*.
29. **Illustrate** and describe the sequence in which ten electrons occupy the five orbitals related to an atom's d sublevel.
30. **Extend** the aufbau sequence through an element that has not yet been identified, but whose atoms would completely fill 7p orbitals. How many electrons would such an atom have? Write its electron configuration using noble-gas notation for the previous noble gas, radon.
31. **Interpret Scientific Illustrations** Which is the correct electron-dot structure for an atom of selenium? Explain.
    a. ·Se: b. ·Se· c. ·Se· d. ·S·

electrons in the outermost level.

Silicon: Si 14 $1s^2 2s^2 2p^6 3s^2 3p^2$ or $[Ne]3s^2 3p^2$

1s ↑↓ 2s ↑↓ 2p ↑↓ ↑↓ ↑↓ 3s ↑↓ 3p ↑ ↑

fluorine: $1s^2 2s^2 2p^5$

1s ↑↓ 2s ↑↓ 2p ↑↓ ↑↓ ↑

Calcium $[Ar]\ 4s^2$

1s ↑↓ 2s ↑↓ 2p ↑↓ ↑↓ ↑↓ 3s ↑↓ 3p ↑↓ ↑↓ ↑↓ 4s ↑↓

group 16

Krypton $[Ar]\ 4s^2 3d^{10} 4p^6$

1s ↑↓ 2s ↑↓ 2p ↑↓ ↑↓ ↑↓ 3s ↑↓ 3p ↑↓ ↑↓ ↑↓ 4s ↑↓ 3d ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ 4p ↑↓ ↑↓ ↑↓

7	CHM.5.1.01.004.05 Distinguish between a goup and a period in the periodic table	Textbook	38
10	CHM.5.1.01.004.04 Identify the information that can be displayed in the periodic table	Textbook + figures 3 , 4	38 , 39

The Modern Periodic Table

The modern periodic table consists of boxes, each containing an element name, symbol, atomic number, and atomic mass. A typical box from the table is shown in **Figure 3**.

The table orders elements horizontally by the number of protons in an atom's nucleus, and places those with similar chemical properties in columns. The columns are called **groups** or families. The rows are called **periods.**

The periodic table is shown in **Figure 4** on the next page and on the inside back cover of your textbook. Becoming familiar with the periodic table will help you understand how the properties of different elements relate to one another.

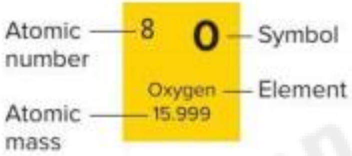


Figure 3 A typical box from the periodic table contains the element's name, its chemical symbol, its atomic number, and its atomic mass.

8- There are …….. periods and …….. groups in the periodic table

a) 7,18 b) 7,20 c) 6,18 d) 6,20

8	CHM.5.1.01.010.01 Describe the general properties of metals, non-metals and metalloids and their uses	Textbook + figures 6	41
9	CHM.5.1.01.010.02 Describe the general properties of alkali metals and their uses	Textbook	40
11	CHM.5.1.01.007.02 Describe some properties and uses of lanthanides - CHM.5.1.01.007.03 Describe some properties and uses of actinides	Textbook	41
12	CHM.5.1.01.010.01 Describe the general properties of metals, non-metals and metalloids and their uses	Textbook	42

Groups and periods

Beginning with hydrogen in period 1, there are a total of seven periods. Each group is numbered 1 through 18. For example, period 4 contains potassium and calcium. Oxygen is in group 16. The elements in groups 1, 2, and 13 to 18 possess a wide range of chemical and physical properties. For this reason, they are often referred to as the main group, or **representative elements.** The elements in groups 3 to 12 are referred to as the **transition elements.** Elements are also classified as metals, nonmetals, and metalloids.

Metals

Elements that are generally shiny when smooth and clean, solid at room temperature, and good conductors of heat and electricity are called **metals.** Most metals are also malleable and ductile, meaning that they can be pounded into thin sheets and drawn into wires, respectively, as shown in **Figure 5**.

Most representative elements and all transition elements are metals. If you look at boron (B) in column 13, you will see a heavy stairstep line that zigzags down to astatine (At) at the bottom of group 17. This stairstep line is a visual divider between the metals and the nonmetals on the table. In the periodic table shown in **Figure 4** metals are represented by the blue boxes.

Alkali Metals Except for hydrogen, all of the elements on the left side of the table are metals. The group 1 elements (except for hydrogen) are known as the **alkali metals.** Because they are so reactive, alkali metals usually exist as compounds with other elements. Two familiar alkali metals are sodium (Na), one of the components of salt, and lithium (Li), often used in batteries.

Alkaline Earth Metals The **alkaline earth metals** are in group 2. They are also highly reactive. Calcium (Ca) and magnesium (Mg), two minerals important for your health, are examples of alkaline earth metals. Because magnesium is strong and relatively light, it is used in applications in which strength and low mass are important, as shown in **Figure 6**.

Figure 6 Because magnesium is light and strong, it is often used in the production of safety devices such as these caribiners used by climbers.

8	CHM.5.1.01.010.01 Describe the general properties of metals, non-metals and metalloids and their uses	Textbook + figures 6	41
9	CHM.5.1.01.010.02 Describe the general properties of alkali metals and their uses	Textbook	40
11	CHM.5.1.01.007.02 Describe some properties and uses of lanthanides - CHM.5.1.01.007.03 Describe some properties and uses of actinides	Textbook	41
12	CHM.5.1.01.010.01 Describe the general properties of metals, non-metals and metalloids and their uses	Textbook	42

Transition and Inner Transition Metals The transition elements are divided into **transition metals** and **inner transition metals.** The two sets of inner transition metals, known as the **lanthanide series** and **actinide series,** are located along the bottom of the periodic table. The rest of the elements in groups 3 to 12 make up the transition metals. Elements from the lanthanide series are used extensively as phosphors, substances that emit light when struck by electrons. Because it is strong and light, the transition metal titanium is used to make frames for bicycles and eyeglasses.

Nonmetals

BIOLOGY Connection Nonmetals occupy the upper-right side of the periodic table. They are represented by the yellow boxes in **Figure 4**. **Nonmetals** are elements that are generally gases or brittle, dull-looking solids. They are poor conductors of heat and electricity. The only nonmetal that is a liquid at room temperature is bromine (Br). The most abundant element in the human body is the nonmetal oxygen, which constitutes 65% of the body mass.

Group 17 comprises highly reactive elements that are known as **halogens.** Like the group 1 and group 2 elements, the halogens are often part of compounds. Compounds made with the halogen fluorine (F) are commonly added to toothpaste and drinking water to prevent tooth decay. The extremely unreactive group 18 elements are commonly called the **noble gases.** They are used in applications where their unreactivity is an advantage, such as in lasers, a variety of light bulbs, and neon signs.

Metalloids

The elements in the green boxes bordering the stairstep line in **Figure 4** are called metalloids, or semimetals.

Metalloids have physical and chemical properties of both metals and nonmetals. Silicon (Si) and germanium (Ge) are two important metalloids used extensively in computer chips and solar cells. Silicon is also used to make prosthetics or in lifelike applications, as shown in **Figure 7**.

This introduction to the periodic table touches only the surface of its durable explanatory power. You can refer to the Elements Handbook at the end of your textbook to learn more about the elements and their various groups.

8	CHM.5.1.01.010.01 Describe the general properties of metals, non-metals and metalloids and their uses	Textbook + figures 6	41
9	CHM.5.1.01.010.02 Describe the general properties of alkali metals and their uses	Textbook	40
11	CHM.5.1.01.007.02 Describe some properties and uses of lanthanides - CHM.5.1.01.007.03 Describe some properties and uses of actinides	Textbook	41
12	CHM.5.1.01.010.01 Describe the general properties of metals, non-metals and metalloids and their uses	Textbook	42

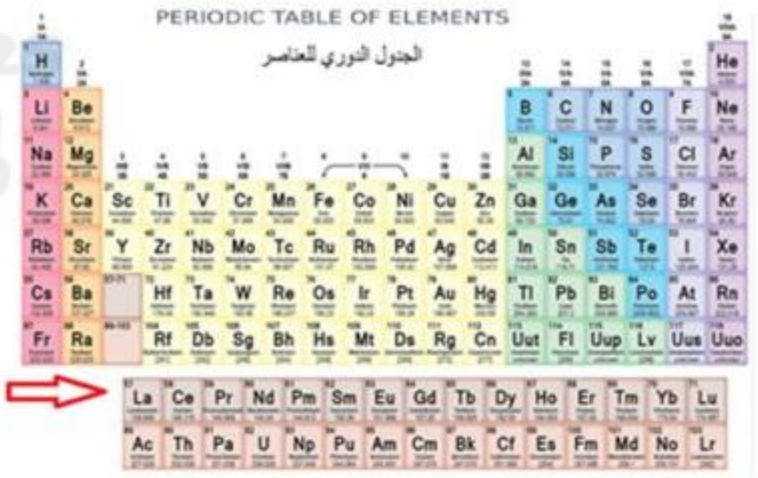
2) What is the name of the series indicated by the red arrow

a) Actinide series

b) Alkali metals

c) Lanthanide series

d) halogens



8	CHM.5.1.01.010.01 Describe the general properties of metals, non-metals and metalloids and their uses	Textbook + figures 6	41
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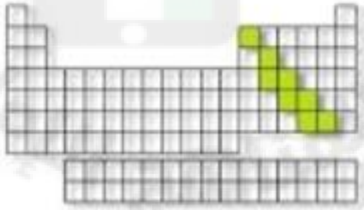
12	CHM.5.1.01.010.01 Describe the general properties of metals, non-metals and metalloids and their uses	Textbook	42

Q.19: الخط المتعرج في الجدول الدوري للعناصر

What does the green boxes bordering the stairstep line in below figure represent?

ماذا تُمثل المربعات الخضراء على جانب الخط المتعرج في الشكل أدناه؟



1. Metals — الفلزات
2. Nonmetals — اللافلزات
3. Metalloids — أشباه الفلزات
4. Lanthanides — اللانثينيدات

13	CHM.5.1.01.004.07 Explain why the properties of the elements in the same group are similar	Textbook	43
15	CHM.5.1.01.004.07 Explain why the properties of the elements in the same group are similar	Textbook	44

Valence electrons

Recall that electrons in the highest principal energy level of an atom are called valence electrons. Each of the group 1 elements has one valence electron. The group 1 elements have similar chemical properties because they have the same number of valence electrons. This is one of the most important relationships in chemistry: atoms in the same group have similar chemical properties because they have the same number of valence electrons. Each group 1 element has a valence electron configuration of s^1. Each group 2 element has a valence electron configuration of s^2. Groups 1, 2, and 13 to 18 all have their own valence electron configurations.

Table 3 **Electron Configuration for the Group 1 Elements**

Period 1	hydrogen	$1s^1$	$1s^1$
Period 2	lithium	$1s^22s^1$	$[He]2s^1$
Period 3	sodium	$1s^22s^22p^63s^1$	$[Ne]3s^1$
Period 4	potassium	$1s^22s^22p^63s^23p^64s^1$	$[Ar]4s^1$

Valence electrons and period

The energy level of an element's valence electrons indicates the period on the periodic table in which it is found. For example, lithium's valence electron is in the second energy level and lithium is found in period 2. Now look at gallium, with its electron configuration of $[Ar]4s^23d^{10}4p^1$. Gallium's valence electrons are in the fourth energy level, and gallium is found in the fourth period.

Valence electrons of the representative elements

Elements in group 1 have one valence electron; group 2 elements have two valence electrons. Group 13 elements have three valence electrons, group 14 elements have four, and so on. The noble gases in group 18 each have eight valence electrons, with the exception of helium, which has only two valence electrons. **Figure 8** shows how the electron-dot structures you studied previously illustrate the connection between group number and number of valence electrons. Notice that the number of valence electrons for the elements in groups 13 to 18 is ten less than their group number.

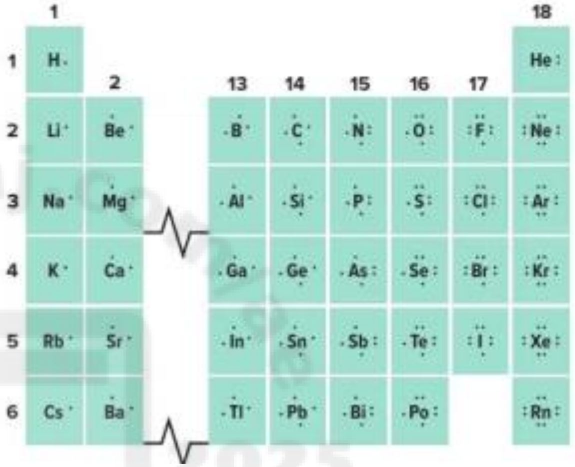
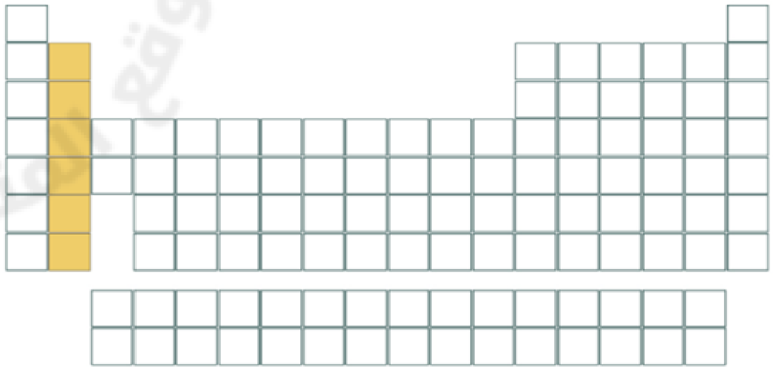


Figure 8 The figure shows the electron-dot structure of most representative elements.
Observe *How does the number of valence electrons vary within a group?*

Group II elements in the periodic table have similar chemical properties. **What explains this**?

تمتلك عناصر المجموعة الثانية في الجدول الدوري خصائص كيميائية متشابهة. **ما الذي يفسر ذلك**؟



Because they have the same atomic numbers — لأن لها نفس الأعداد الذرية

Because they contain the same energy levels — لأنها تحتوي على نفس مستويات الطاقة

Because they have the same number of valence electrons — لأن لها نفس العدد من إلكترونات التكافؤ

Because they are located in the same block — لأنها توجد في نفس المجمع

The s-, p-, d-, and f-Block Elements

The periodic table has columns and rows of varying sizes. The reason behind the table's odd shape becomes clear if it is divided into sections, or blocks, representing the atom's energy sublevel being filled with valence electrons. Because there are four different energy sublevels (s, p, d, and f), the periodic table is divided into four distinct blocks, as shown in **Figure 9** on the next page.

s-Block elements

The s-block consists of groups 1 and 2, and the element helium. Group 1 elements have partially filled s orbitals containing one valence electron and electron configurations ending in s^1. Group 2 elements have completely filled s orbitals containing two valence electrons and electron configurations ending in s^2. Because s orbitals hold two electrons at most, the s-block spans two groups.

d-Block elements

The d-block contains the transition metals and is the largest of the blocks. With some exceptions, d-block elements are characterized by a filled outermost s orbital of energy level n, and filled or partially filled d orbitals of energy level $n - 1$.

Table 4 **Noble Gas Electron Configuration**

Period	Principal Energy Level	Element	Electron Configuration
1	$n = 1$	helium	$1s^2$
2	$n = 2$	neon	$[He]2s^22p^6$
3	$n = 3$	argon	$[Ne]3s^23p^6$
4	$n = 4$	krypton	$[Ar]4s^23d^{10}4p^6$

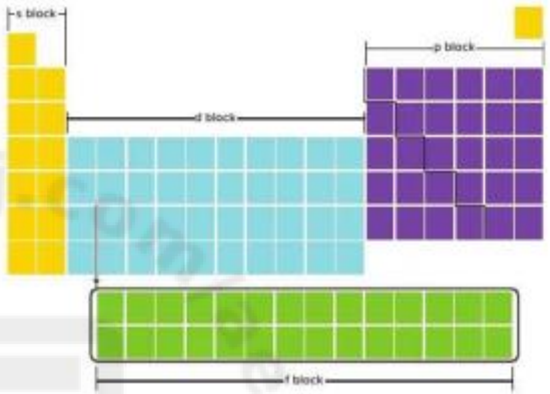


Figure 9 The periodic table is divided into four blocks—s, p, d, and f.

Analyze *What is the relationship between the maximum number of electrons an energy sublevel can hold and the number of columns in that block on the diagram?*

p-Block elements

After the s sublevel is filled, the valence electrons next occupy the p sublevel. The p-block is comprised of groups 13 through 18 and contains elements with filled or partially filled p orbitals. There are no p-block elements in period 1 because the p sublevel does not exist for the first principal energy level (n = 1). The first p-block element is boron (B), which is in the second period. The p-block spans six groups because the three p orbitals can hold a maximum of six electrons.

The group 18 elements, which are called the noble gases, are unique members of the p-block. The atoms of these elements are so stable that they undergo virtually no chemical reactions. The electron configurations of the first four noble gas elements are shown in **Table 4**. Here, both the s and p orbitals corresponding to the period's principal energy level are completely filled. This arrangement of electrons results in an unusually stable atomic structure. Together, the s- and p-blocks comprise the representative elements.

14	CHM.5.1.01.008.02 Use the electron configuration notation, orbital notation, and noble gas notation of an element (Z 1 - 36) to identify the location of an element in the periodic table (period, group and block)	Textbook + example problem 1	46

As you move across a period, electrons fill the d orbitals. For example, scandium (Sc), the first d-block element, has an electron configuration of $[Ar]4s^2 3d^1$. Titanium (Ti), the next element on the table, has an electron configuration of $[Ar]4s^2 3d^2$. Note that titanium's filled outermost s orbital has an energy level of $n = 4$, while the d orbital, which is partially filled, has an energy level of $n = 3$.

As you learned previously, the aufbau principle states that the 4s orbital has a lower energy level than the 3d orbital. Therefore, the 4s orbital is filled before the 3d orbital. The five d orbitals can hold a total of 10 electrons; thus, the d-block spans 10 groups on the periodic table.

f-Block elements

The f-block contains the inner transition metals. Its elements are characterized by a filled, or partially filled outermost s orbital, and filled or partially filled 4f and 5f orbitals.

The electrons of the f sublevel do not fill their orbitals in a predictable manner. Because there are seven f orbitals holding up to a maximum of 14 electrons, the f-block spans 14 columns of the periodic table.

EXAMPLE Problem 1

ELECTRON CONFIGURATION AND THE PERIODIC TABLE Strontium, which is used to produce red fireworks, has an electron configuration of $[Kr]5s^2$. Without using the periodic table, determine the group, period, and block of strontium.

1 ANALYZE THE PROBLEM

You are given the electron configuration of strontium.

Known	Unknown
Electron configuration = $[Kr]5s^2$	Group = ?
	Period = ?
	Block = ?

2 SOLVE FOR THE UNKNOWN

The s^2 indicates that strontium's valence electrons fill the s sublevel. Thus, strontium is in **group 2** of the **s-block**.

For representative elements, the number of valence electrons can indicate the group number.

The 5 in $5s^2$ indicates that strontium is in **period 5**.

The number of the highest energy level indicates the period number.

3 EVALUATE THE ANSWER

The relationships between electron configuration and position on the periodic table have been correctly applied.

14	CHM.5.1.01.008.02 Use the electron configuration notation, orbital notation, and noble gas notation of an element (Z 1 - 36) to identify the location of an element in the periodic table (period, group and block)	Textbook + example problem 1	46

The atomic number of the element copper (Cu) is 29. What is the correct electronic configuration of copper using the noble-gas notation?

العدد الذري لعنصر النحاس (Cu) يساوي 29. ما الترتيب الإلكتروني الصحيح للنحاس باستخدام ترميز الغاز النبيل؟

$[Ar]\ 4s^2 3d^9$

$[Ar]\ 4s^1 3d^{10}$

$[Kr]\ 5s^2 3d^9$

$[Kr]\ 5s^1 3d^{10}$

Determine the period, group and block of an element has an electron configuration shown below.

حدد الدورة والمجموعة والمجمع لعنصر له الترتيب الإلكتروني أدناه.

Period

$$[Kr]5s^2 4d^{10} 5p^5$$

الدورة Period 5

المجموعة Group 17

المجمع Block p

Question 3: Use the following electron notations to locate period, group, block and valence electrons of each element (4 points)

A) 1s2 2s2 2p1 +10=13 -10

Period: ...2....

Group: 13.......

Block: ...P.......

valence: ..3...

B) [Ne] 3s2

Period: ...3....

Group: ...2....

Block: .....s....

valence: 2......

C) [Ar] 4s2 3d7 2+7

Period: ....4..

Group: .....9....

Block: ......d....

valence: ..2.. ......

D) [Ne] 3s2 3p5 +10 2+5

Period: ....3....

Group: ..17.....

Block: ...P......

valence: .....7....

Ahmed Elgharpawy

14	CHM.5.1.01.008.02 Use the electron configuration notation, orbital notation, and noble gas notation of an element (Z 1 - 36) to identify the location of an element in the periodic table (period, group and block)	Textbook + example problem 1	46

Q.17: *** BONUS ***** المجمع**

Using the following electron configuration,

مُستخدمًا الترتيب الإلكتروني التالي ،

$[Ar]\ 4s^2\ 3d^5$

In which block in the periodic table the elements is most likely found?

ما المجمع في الجدول الدوري الذي يقع فيه العنصر ؟

Block = last filled orbital

1. Block s — المجمع s
2. Block p — المجمع p
3. Block d — المجمع d
4. Block f — المجمع f

What is the period, group, and block for an element with the following electron configuration?

ما الدورة والمجموعة والمجمع التي ينتمي إليها العنصر ذو الترتيب الإلكتروني التالي؟

$[Ne]\ 3s^2\ 3p^5$

Group المجموعة	Period الدورة	Block المجمع
2	2	s

Group المجموعة	Period الدورة	Block المجمع
17	6	p

Group المجموعة	Period الدورة	Block المجمع
15	3	p

Group المجموعة	Period الدورة	Block المجمع
17	3	p

s + p electrons = valence electrons

s+p electrons + 10 = group numbers

S and p must be the same level

Q.10: المجموعة والدورة

Which of the following is the correct electron configuration of an element in group 2, and the fourth period?

أي مما يلي هو الترتيب الإلكتروني الصحيح لعنصر في المجموعة 2 ، وفي الدورة الرابعة؟

1. $[He]2s^2\ 2p^2$
2. $[Ne]3s^2\ 3p^2$
3. $[Ar]4s^2$
4. $[Ar]4s^2\ 3d^2$

14	CHM.5.1.01.008.02 Use the electron configuration notation, orbital notation, and noble gas notation of an element (Z 1 - 36) to identify the location of an element in the periodic table (period, group and block)	Textbook + example problem 1	46

Which of the following arrangement represents an element in group 4, period 4 and block d?

أي الترتيبات التالية تُمثل عنصر يقع في المجموعة 4 والدورة 4 والمجمع d؟

$[Ar]\ 4s^2\ 3d^2$

$[Ne]\ 3s^2\ 3p^2$

$[Ar]\ 4s^2\ 3d^{10}\ 4p^4$

$[Ar]\ 4s^2\ 3d^{10}\ 4p^2$

s + d = group number

s only = valence electrons

s is higher level than d

4s 3d

Which of the following table represents an atom with the following electron configuration: $[Ne]\ 3s^2\ 3p^1$

أي من الجداول التالية يُعبر عن ذرة لها التوزيع الإلكتروني التالي: $[Ne]\ 3s^2\ 3p^1$

المجمع block	المجموعة group	الدورة period
s	3	1

المجمع block	المجموعة group	الدورة period
p	3	3

s + p + 10 = group number

s + p = valence

المجمع block	المجموعة group	الدورة period
s	3	3

المجمع block	المجموعة group	الدورة period
p	13	3

14	CHM.5.1.01.008.02 Use the electron configuration notation, orbital notation, and noble gas notation of an element (Z 1 - 36) to identify the location of an element in the periodic table (period, group and block)	Textbook + example problem 1	46

s + p + 10 = group number = 14

s + p = Valence = 4

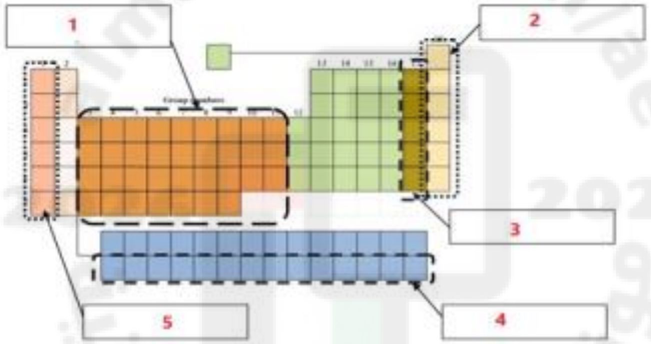
Where is located the element with the electron configuration $[Kr]\ 5s^2\ 4d^{10}\ 5p^2$ in the periodic table?	أين يقع العنصر ذو الترتيب الإلكتروني $[Kr]\ 5s^2\ 4d^{10}\ 5p^2$ في الجدول الدوري؟
A – Period 5 and group 2	A – في الدورة 5 والمجموعة 2
B – Period 5 and group 12	B – في الدورة 5 والمجموعة 12
c – Period 5 and group 14	c – في الدورة 5 والمجموعة 14
D – Period 5 and group 4	D – في الدورة 5 والمجموعة 4

14	CHM.5.1.01.008.02 Use the electron configuration notation, orbital notation, and noble gas notation of an element (Z 1 - 36) to identify the location of an element in the periodic table (period, group and block)	Textbook + example problem 1	46

Q.3: مواقع العناصر

What elements are represented by the region labeled by the number 1 in the figure below?

ما هي العناصر التي تُمثّلها المنطقة المُشار إليها بالرقم 1 في الشكل أدناه ؟



1. Transition elements — العناصر الانتقالية
2. Representative elements — العناصر الرئيسة
3. Actinides — الأكتنيدات
4. Alkali metals — الفلزات القلوية

Atomic Radius

Many properties of the elements tend to change in a predictable way, known as a trend, as you move across a period or down a group. Atomic size is one such periodic trend. The sizes of atoms are influenced by electron configuration.

Recall that the electron cloud surrounding a nucleus does not have a clearly defined edge. The outer limit of an electron cloud is defined as the spherical surface within which there is a 90% probability of finding an electron. However, this surface does not exist in a physical way, as the outer surface of a golf ball does. Atomic size is defined by how closely an atom lies to a neighboring atom. Because the nature of the neighboring atom can vary from one substance to another, the size of the atom itself also tends to vary somewhat from substance to substance.

For metals such as sodium, the atomic radius is defined as half the distance between adjacent nuclei in a crystal of the element, as shown in **Figure 11**. For elements that commonly occur as molecules, such as many nonmetals, the atomic radius is defined as half the distance between nuclei of identical atoms that are chemically bonded together. The atomic radius of a nonmetal diatomic hydrogen molecule (H_2) is shown in **Figure 11**.

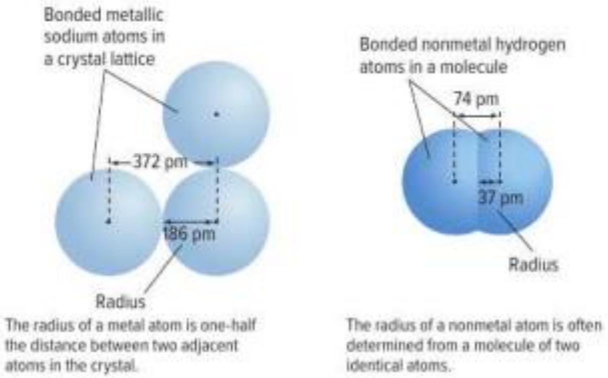


Figure 11 Atomic radii depend on the type of bonds that atoms form.

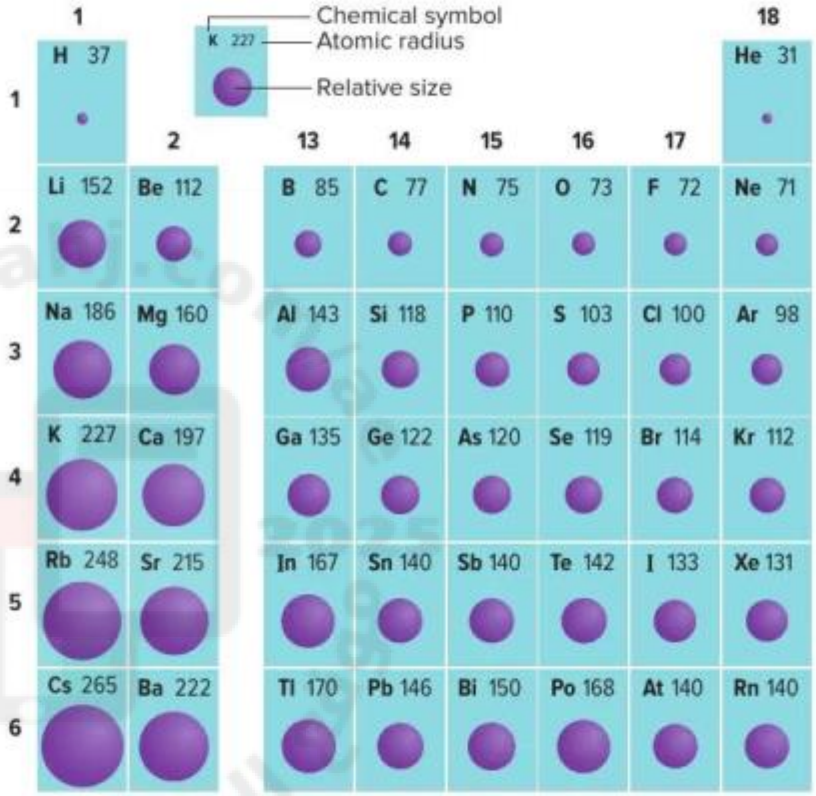


Figure 12 The atomic radii of the representative elements, given in picometers (10^{-12} m), vary as you move from left to right within a period and down a group.

Infer *why the atomic radii increase as you move down a group.*

Trends within periods

In general, there is a decrease in atomic radii as you move from left to right across a period. This trend is illustrated in **Figure 12**. It is caused by the increasing positive charge in the nucleus and the fact that the principal energy level within a period remains the same. Each successive element has one additional proton and electron, and each additional electron is added to orbitals corresponding to the same principal energy level. Moving across a period, no additional electrons come between the valence electrons and the nucleus. Thus, the valence electrons are not shielded from the increased nuclear charge, which pulls the outermost electrons closer to the nucleus.

16	CHM.5.1.01.009.06 Explain the periodic trend of atomic radii across a period and down a group	Textbook + figures 11 , 12 , 13 + example problem 2 + practice problems	49 , 50 , 51

Trends within groups

Atomic radii generally increase as you move down a group on the periodic table. The nuclear charge increases, and electrons are added to orbitals corresponding to successively higher principal energy levels. However, the increased nuclear charge does not pull the outer electrons toward the nucleus to make the atom smaller as you might expect. Why does the increased nuclear charge not make the atom smaller?

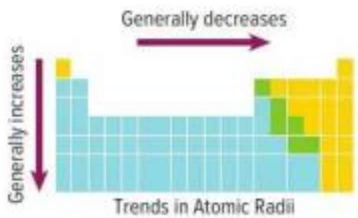


Figure 13 Atomic radii generally decrease from left to right in a period and generally increase as you move down a group.

Moving down a group, the outermost orbital increases in size along with the increasing principal energy level; thus, the atom becomes larger. The larger orbital means that the outer electrons are farther from the nucleus. This increased distance offsets the pull of the increased nuclear charge. Also, as additional orbitals between the nucleus and the outer electrons are occupied, these electrons shield the outer electrons from the nucleus. **Figure 13** summarizes the group and period trends.

EXAMPLE Problem 2

ELECTRON CONFIGURATION AND THE PERIODIC TABLE Which has the largest atomic radius: carbon (C), fluorine (F), beryllium (Be), or lithium (Li)? Answer without referring to **Figure 12**. Explain your answer in terms of trends in atomic radii.

1 ANALYZE THE PROBLEM

You are given four elements. First, determine the groups and periods the elements occupy. Then apply the general trends in atomic radii to determine which has the largest atomic radius.

2 SOLVE FOR THE UNKNOWN

From the periodic table, all the elements are found to be in period 2. — Determine the periods.

Ordering the elements from left-to-right across the period yields: Li, Be, C, and F.

The first element in period 2, lithium, has the largest radius. — Apply the trend of decreasing radii across a period.

3 EVALUATE THE ANSWER

The period trend in atomic radii has been correctly applied. Checking radii values in **Figure 12** verifies the answer.

PRACTICE Problems ADDITIONAL PRACTICE

Answer the following questions using your knowledge of group and period trends in atomic radii. Do not use the atomic radii values in Figure 12 to answer the questions.

16. Which has the largest atomic radius: magnesium (Mg), silicon (Si), sulfur (S), or sodium (Na)? The smallest?

smallest

biggest

17. The figure on the right shows helium, krypton, and radon. Which one is krypton? How can you tell?

He
Kr
Rn

18. Can you determine which of two unknown elements has the larger radius if the only known information is that the atomic number of one of the elements is 20 greater than the other? Explain.

the element with higher electrons, likely in the next level

19. CHALLENGE Determine which element in each pair has the largest atomic radius:

a. the element in period 2, group 1; or the element in period 3, group 18

b. the element in period 5, group 2; or the element in period 3, group 16

c. the element in period 3, group 14; or the element in period 6, group 15

d. the element in period 4, group 18; or the element in period 2, group 16

16	CHM.5.1.01.009.06 Explain the periodic trend of atomic radii across a period and down a group	Textbook + figures 11 , 12 , 13 + example problem 2 + practice problems	49 , 50 , 51

Which is the correct ascending order of the atomic radius for the period 4 elements shown in the table below?	ما الترتيب التصاعدي الصحيح حسب نصف القطر الذري لكل من عناصر الدورة الرابعة المبيّنة في الجدول أدناه؟

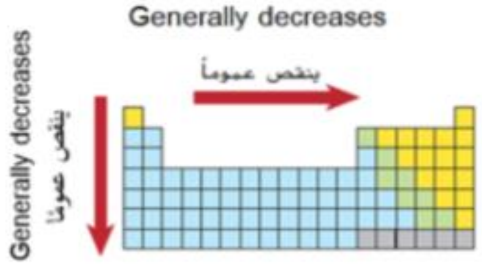
same period

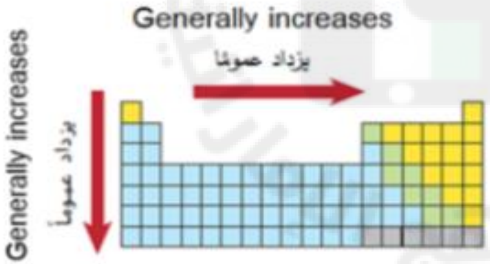
Element symbol رمز العنصر	K	Ga	Ge	Ca
Atomic number العدد الذري	19	31	32	20

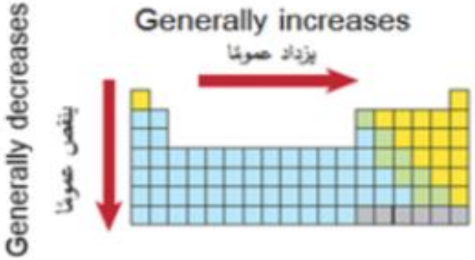
A. (lowest) Ga → Ge → Ca → K (highest)	A. (الأقل) Ga ← Ge ← Ca ← K (الأكبر)
B. (lowest) Ge → Ga → Ca → K (highest)	B. (الأقل) Ge ← Ga ← Ca ← K (الأكبر)
C. (lowest) K → Ca → Ga → Ge (highest)	C. (الأقل) K ← Ca ← Ga ← Ge (الأكبر)
D. (lowest) Ca → Ga → Ge → K (highest)	D. (الأقل) Ca ← Ga ← Ge ← K (الأكبر)

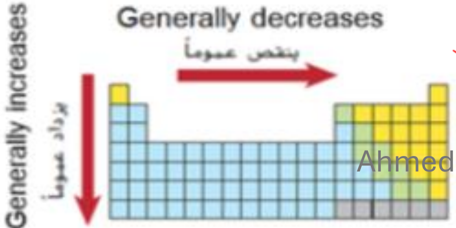
Which of the following figures shows the trends of the atomic radius through both a period and a group?

أي الأشكال التالية يُوضح تدرج نصف القطر الذري خلال كل من الدورة والمجموعة؟







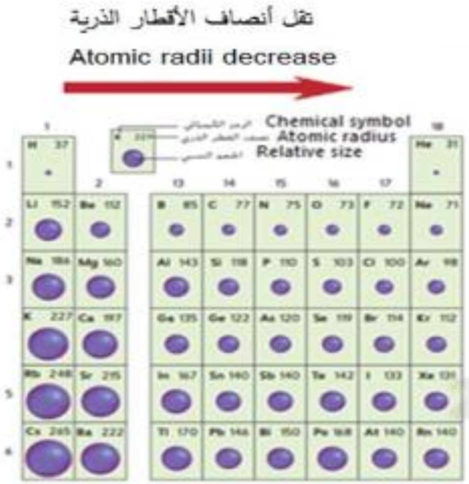


16	CHM.5.1.01.009.06 Explain the periodic trend of atomic radii across a period and down a group	Textbook + figures 11 , 12 , 13 + example problem 2 + practice problems	49 , 50 , 51

Q.1: أنصاف الأقطار الذرية

Why atomic radii generally decrease as moving from left to right across a period?

لماذا تقل أنصاف الأقطار الذرية عند الانتقال من اليسار إلى اليمين عبر الدورة بوجه عام؟



1. Because the number of principle energy levels decrease — بسبب نقصان عدد مستويات الطاقة الرئيسية
2. Because the positive charge in the nucleus decrease — بسبب نقصان الشحنة الموجبة في النواة
3. Because the positive charge in the nucleus increase — بسبب زيادة الشحنة الموجبة في النواة
4. Because the number of principle energy levels increase — بسبب زيادة عدد مستويات الطاقة الرئيسية

1- Which of the following elements has the largest atomic radius?

a) Na b) K c) Br d) Cs

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17	CHM.5.1.01.009.07 Define ionization energy (first ionization energy)	Textbook	52
18	CHM.5.1.01.009.10 Explain the trend of first ionization energy across a period (Exceptions between Groups 2 & 3 and 5 & 6 are included), and down a group of the periodic table	Textbook + figure 17	54

Ionization Energy

To form a positive ion, an electron must be removed from a neutral atom. This requires energy. The energy is needed to overcome the attraction between the positive charge of the nucleus and the negative charge of the electron.

Ionization energy is defined as the energy required to remove an electron from a gaseous atom. For example, 8.64×10^{-19} J is required to remove an electron from a gaseous lithium atom. The energy required to remove the first outermost electron from an atom is called the first ionization energy. The first ionization energy of lithium equals 8.64×10^{-19} J. The loss of the electron results in the formation of a Li^+ ion. The first ionization energies of the elements in periods 1 through 5 are plotted on the graph in **Figure 17**.

Removing more than one electron

After removing the first electron from an atom, it is possible to remove additional electrons. The amount of energy required to remove a second electron from a 1+ ion is called the second ionization energy, the amount of energy required to remove a third electron from a 2+ ion is called the third ionization energy, and so on. **Table 5** lists the first through ninth ionization energies for elements in period 2.

Reading across **Table 5** from left to right, you will see that the energy required for each successive ionization always increases. However, the increase in energy does not occur smoothly. Note that for each element there is an ionization for which the required energy increases dramatically. For example, the second ionization energy of lithium (7300 kJ/mol) is much greater than its first ionization energy (520 kJ/mol). This means that a lithium atom is likely to lose its first valence electron but extremely unlikely to lose its second.

Think of ionization energy as an indication of how strongly an atom's nucleus holds onto its valence electrons. A high ionization energy value indicates the atom has a strong hold on its electrons. Atoms with large ionization energy values are less likely to form positive ions. Likewise, a low ionization energy value indicates an atom loses an outer electron easily. Such atoms are likely to form positive ions. Lithium's low ionization energy, for example, is important for its use in lithium-ion computer backup batteries, where the ability to lose electrons easily makes a battery that can quickly provide a large amount of electrical power.

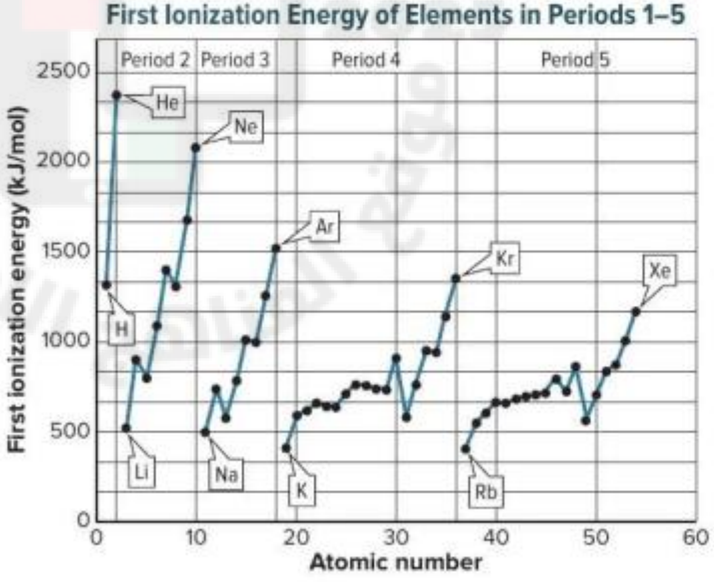

Figure 17 The first ionization energies for elements in periods 1 through 5

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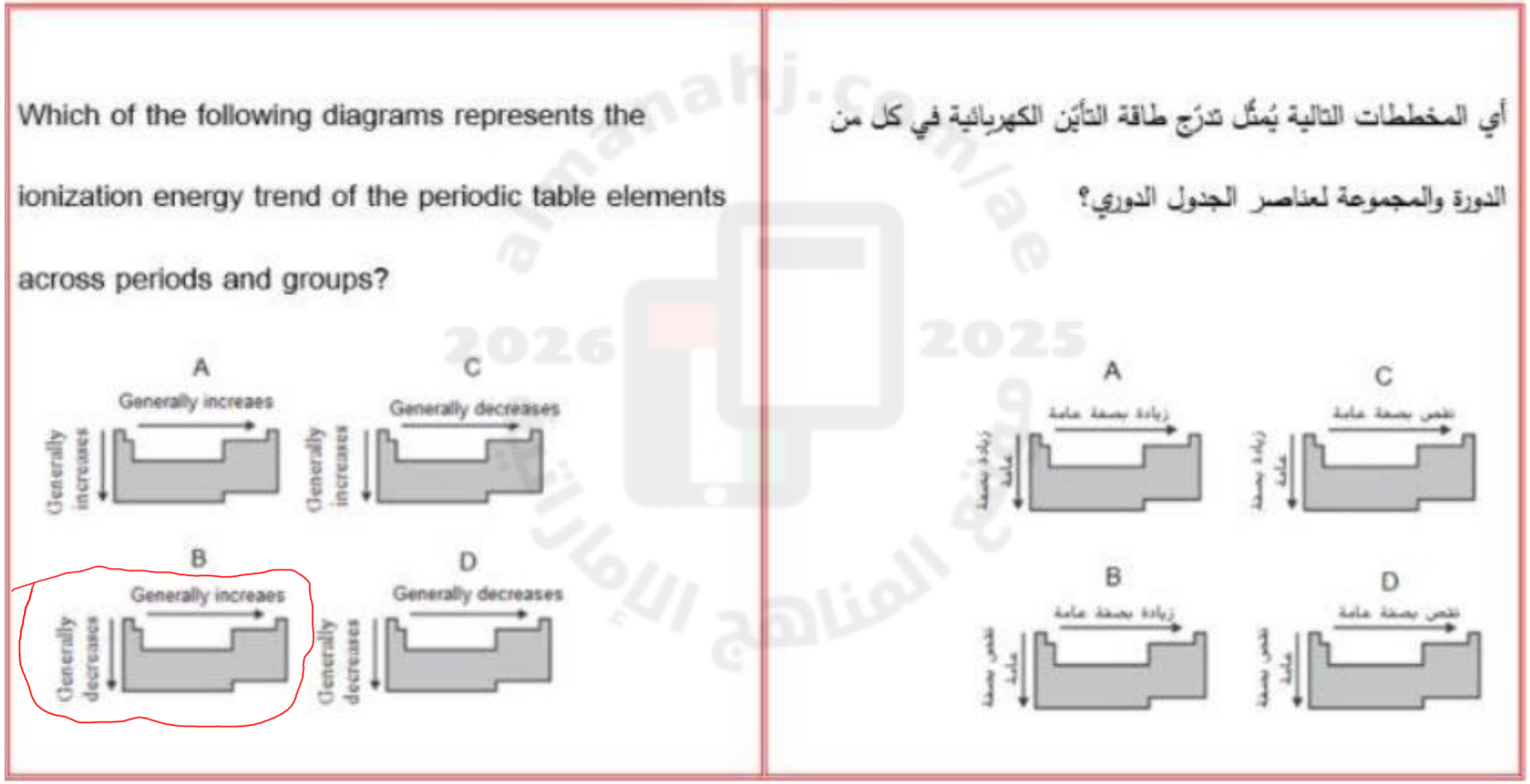
17	CHM.5.1.01.009.07 Define ionization energy (first ionization energy)	Textbook	52
18	CHM.5.1.01.009.10 Explain the trend of first ionization energy across a period (Exceptions between Groups 2 & 3 and 5 & 6 are included), and down a group of the periodic table	Textbook + figure 17	54



Which of the following diagrams represents the ionization energy trend of the periodic table elements across periods and groups?

أي المخططات التالية يُمثّل تدرّج طاقة التأيّن الكهربائية في كل من الدورة والمجموعة لعناصر الجدول الدوري؟

2- Which element has the lowest first ionization energy?

a) Cl b) F c) Br d) I

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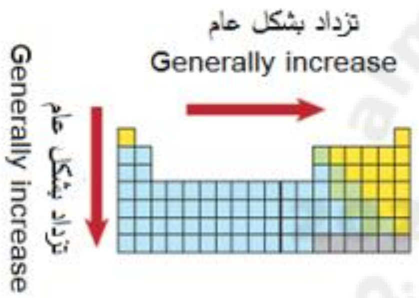
17	CHM.5.1.01.009.07 Define ionization energy (first ionization energy)	Textbook	52
18	CHM.5.1.01.009.10 Explain the trend of first ionization energy across a period (Exceptions between Groups 2 & 3 and 5 & 6 are included), and down a group of the periodic table	Textbook + figure 17	54

Q.5: طاقة التأين الأولى

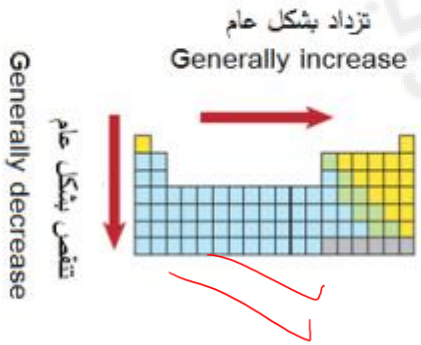
Which diagram correctly shows the trends for the first ionization energy?

أي مخطط مما يلي يصف تدرج طاقة التأين الأولى بشكل صحيح؟

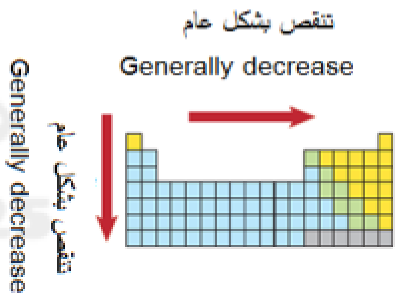
1.

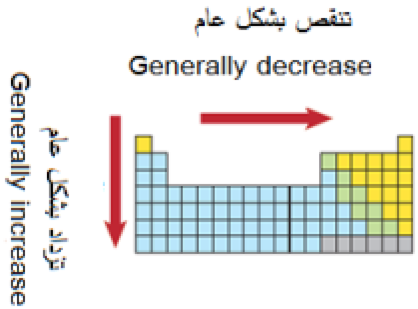


2.



3.

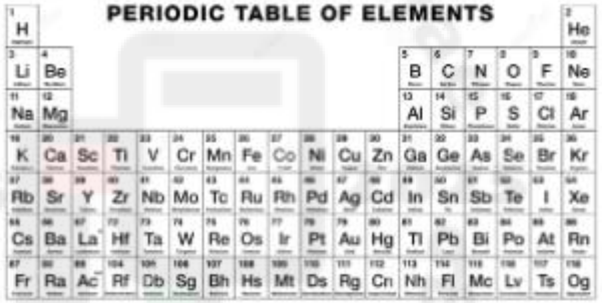




17	CHM.5.1.01.009.07 Define ionization energy (first ionization energy)	Textbook	52
18	CHM.5.1.01.009.10 Explain the trend of first ionization energy across a period (Exceptions between Groups 2 & 3 and 5 & 6 are included), and down a group of the periodic table	Textbook + figure 17	54

Which of the following is true regarding 1st Ionization energy in the periodic table?

أي مما يأتي صحيح فيما يتعلق طاقة التأين الأولى في الجدول الدوري؟



Alkali metals have the highest ionization energy	الفلزات القلوية لها أعلى طاقة تأين
Ionization energy of noble gases equal zero	طاقة التأين للغازات النبيلة تساوي صفر
Ionization energy increases as we move from left to right across a period	تزداد طاقة التأين عند الانتقال في الدورة من اليسار إلى اليمين
Ionization energy increases as we move down a group	تزداد طاقة التأين عند الانتقال في المجموعة من أعلى إلى أسفل

17	CHM.5.1.01.009.07 Define ionization energy (first ionization energy)		Textbook	52
18	CHM.5.1.01.009.10 Explain the trend of first ionization energy across a period (Exceptions between Groups 2 & 3 and 5 & 6 are included), and down a group of the periodic table		Textbook + figure 17	54

Why the difference between 1^{st} and 2^{nd} Ionization Energy for lithium is the highest in period 2 elements?

لماذا يكون الفرق بين طاقة التأين الأولى والثانية لعنصر الليثيوم هو الأعلى بين عناصر الدورة الثانية؟

Element العنصر	1^{st} ionization Energy (KJ/mol) طاقة التأين الأولى (KJ/mol)	2^{nd} ionization Energy (KJ/mol) طاقة التأين الثانية (KJ/mol)	Difference between 1^{st} and 2^{nd} I.E. الفرق بين طاقة التأين الأولى والثانية
Li	520	7300	6780
Be	900	1760	860
B	800	2430	1630
C	1090	2350	1260
N	1400	2860	1460
O	1310	3390	2080
F	1680	3370	1690
Ne	2080	3950	1870

First ionization removes valence electrons ⇒ easy

2^{nd} ionization removes inner electrons ⇒ hard

- Because the effect of lithium nucleus on electrons is the weakest among period 2 elements — لأن تأثير شحنة نواة الليثيوم على الإلكترونات يكون هو الأضعف بين عناصر الدورة الثانية
- Because the energy required for each successive ionization always increases — لأن الطاقة اللازمة لكل عملية تأين تالية تزيد دوماً
- Because lithium easily forms the common lithium 2+ ion but is unlikely to form a lithium 1+ ion. — لأن الليثيوم يُشكل أيون الليثيوم +2 الشائع بسهولة لكن لا يحتمل أن يُشكل أيون الليثيوم +1.
- Because the atom holds onto their inner core electrons much more strongly than they hold onto their valence electrons. — لأن الذرة تتمسك بإلكتروناتها الأساسية الداخلية بقوة شديدة تفوق تمسكها بإلكترونات التكافؤ

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19	CHM.5.1.01.009.14 Describe the trend of ionic radii across a period and down a group of the periodic table	Textbook + fiqures 14 , 15 + , 16	52 , 53

Ionic Radius

Atoms can gain or lose one or more electrons to form ions. Because electrons are negatively charged, atoms that gain or lose electrons acquire a net charge. Thus, an **ion** is an atom or a bonded group of atoms that has a positive or negative charge.

You will learn more about ions later, but for now, consider how the formation of an ion affects the size of an atom.

Losing electrons

When atoms lose electrons and form positively charged ions, they always become smaller. The reason is twofold. The electron lost from the atom will almost always be a valence electron. The loss of a valence electron can leave a completely empty outer orbital, which results in a smaller radius. Furthermore, the electrostatic repulsion between the now-fewer number of remaining electrons decreases. As a result, they experience a greater nuclear charge allowing these remaining electrons to be pulled closer to the positively charged nucleus.

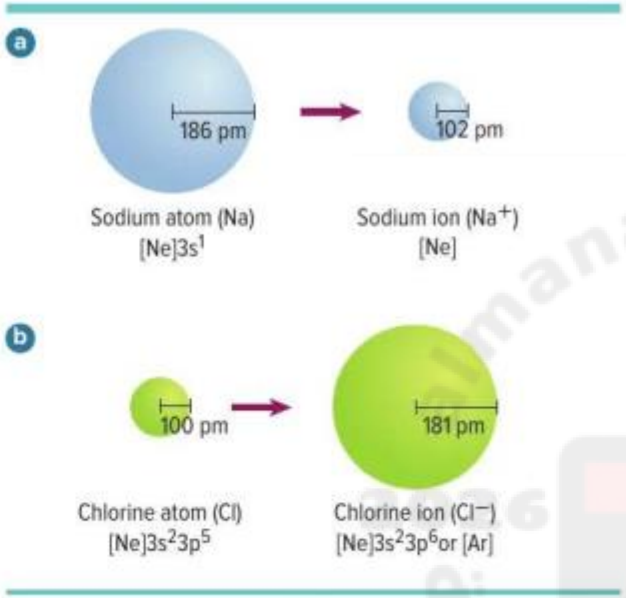

Figure 14 The size of atoms varies greatly when they form ions.

a. Positive ions are smaller than the neutral atoms from which they form.

b. Negative ions are larger than the neutral atoms from which they form.

Gaining electrons

When atoms gain electrons and form negatively charged ions, they become larger. The addition of an electron to an atom increases the electrostatic repulsion between the atom's outer electrons, forcing them to move farther apart. The increased distance between the outer electrons results in a larger radius.

Figure 14b shows how the radius of chlorine increases when chlorine atoms form negative ions. Adding an electron to a chlorine atom increases the electrostatic repulsion among its valence electrons. The increased repulsion causes the electrons to move farther apart and results in the radius of a chloride ion being almost twice as large as that of a chlorine atom.

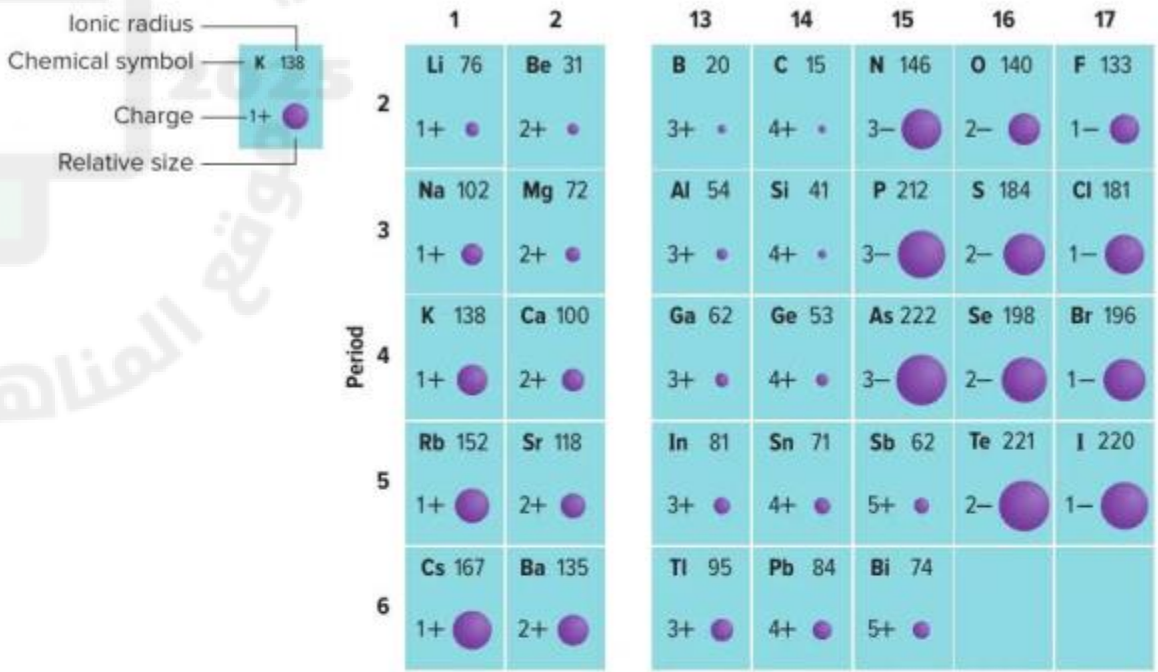

Figure 15 The ionic radii of most of the representative elements are shown in picometers (10^{-12} m).
Explain why the ionic radii increase for both positive and negative ions as you move down a group.

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19	CHM.5.1.01.009.14 Describe the trend of ionic radii across a period and down a group of the periodic table	Textbook + fiqures 14 , 15 + , 16		52 , 53

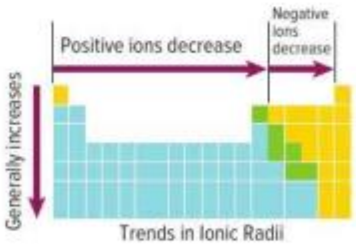
Trends within periods

The ionic radii of most of the representative elements are shown in **Figure 15**. Note that elements on the left side of the table form smaller positive ions, and elements on the right side of the table form larger negative ions.

In general, as you move from left to right across a period, the size of the positive ions gradually decreases. Then, beginning in group 15 or 16, the size of the much-larger negative ions also gradually decreases.

Trends within groups

As you move down a group, an ion's outer electrons are in orbitals corresponding to higher principal energy levels, resulting in a gradual increase in ionic size. Thus, the ionic radii of both positive and negative ions increase as you move down a group. The group and period trends in ionic radii are summarized in **Figure 16**.



Get It?
Explain why calcium has a greater atomic radius than magnesium.

Figure 16 The diagram summarizes the general trends in ionic radii.

Which of the following ions has the **largest** ionic radius?

A – O^{2-}

B – N^{3-}

C – Li^{+}

D – F^{-}

the more negative the ion, the bigger the radius

smallest because Li^{+}

Ion symbol	Li^{+}	N^{3-}	O^{2-}	F^{-}
Element group number	1	15	16	17

أي من الأيونات التالية له **أكبر** نصف قطر أيوني؟

A – O^{2-}

B – N^{3-}

C – Li^{+}

D – F^{-}

رمز الأيون	Li^{+}	N^{3-}	O^{2-}	F^{-}
رقم مجموعة العنصر	1	15	16	17

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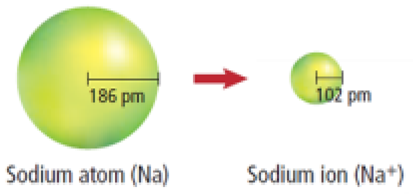
19	CHM.5.1.01.009.14 Describe the trend of ionic radii across a period and down a group of the periodic table	Textbook + fiqures 14 , 15 + , 16	52 , 53

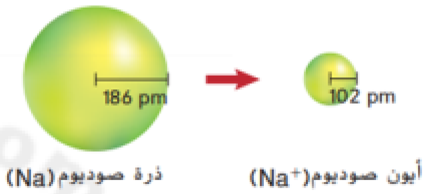
Using the figure below, if A represents an atom and B represents an ion of the same element Which of the following statements is TRUE?	مستخدمًا الشكل أدناه، إذا كان A يرمز لذرة و B يرمز لأيون لنفس العنصر أي العبارات التالية صحيحة ؟
→ bigger ⇒ negative 	
A. The ion is positive as the ionic diameter becomes larger when an electron is lost	A. الأيون موجب حيث أصبح القطر الأيوني أكبر عند فقدان الإلكترون
B. The ion is negative as the ionic diameter becomes larger when an electron is gain	B. الأيون سالب حيث أصبح القطر الأيوني أكبر عند اكتساب الإلكترون
C. The ion is negative as the ionic diameter becomes smaller due the decrease in the electrostatic repulsion	C. الأيون سالب حيث أصبح القطر الأيوني أصغر بسبب انخفاض قوى التنافر الإلكترو ستاتيكي
D.The ion is positive as the ionic diameter becomes larger due the increase in the electrostatic repulsion	D. الأيون موجب حيث أصبح القطر الأيوني أكبر بسبب زيادة قوى التنافر الإلكترو ستاتيكي

19	CHM.5.1.01.009.14 Describe the trend of ionic radii across a period and down a group of the periodic table	Textbook + fiqures 14 , 15 + , 16	52 , 53

Why sodium ion Na^+ is smaller than its atom Na?

لماذا يكون حجم الأيون Na^+ أصغر من حجم ذرته Na ؟





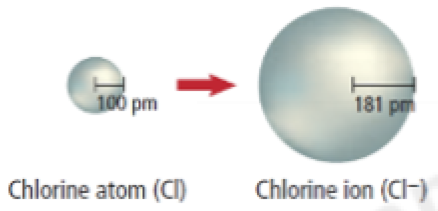
I	Outer orbital is left completely empty.	ترك مستوى الطاقة الأخير خالياً تماماً	I
II	The effective nuclear charge increases for the remaining electrons	زيادة تأثير شحنة النواة في الإلكترونات المتبقية	II
III	Increase in number of energy levels	زيادة عدد مستويات الطاقة	III

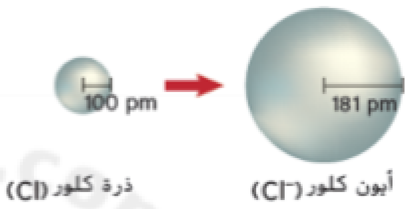
II only	فقط II
I and II	I و II
I only	فقط I
II and III	II و III

19	CHM.5.1.01.009.14 Describe the trend of ionic radii across a period and down a group of the periodic table	Textbook + fiqures 14 , 15 + , 16	52 , 53

Why Cl^- ion is bigger than its atom Cl?

لماذا يكون حجم الأيون Cl^- أكبر من حجم ذرته Cl ؟





I.	The electrostatic repulsion between the atom's outer electrons **increases**	زيادة التنافر الألكتروستاتيكي بين الإلكترونات الخارجية للذرة	I.
II.	The electronic cloud is **stretched outward**	**تمدد** السحابة الإلكترونية للخارج	II.
III.	The electrostatic repulsion between the atom's outer electrons **decreases**	**انخفاض** التنافر الألكتروستاتيكي بين الإلكترونات الخارجية للذرة	III.

II only	II فقط
I only	I فقط
I and II	I و II
II and III	II و III

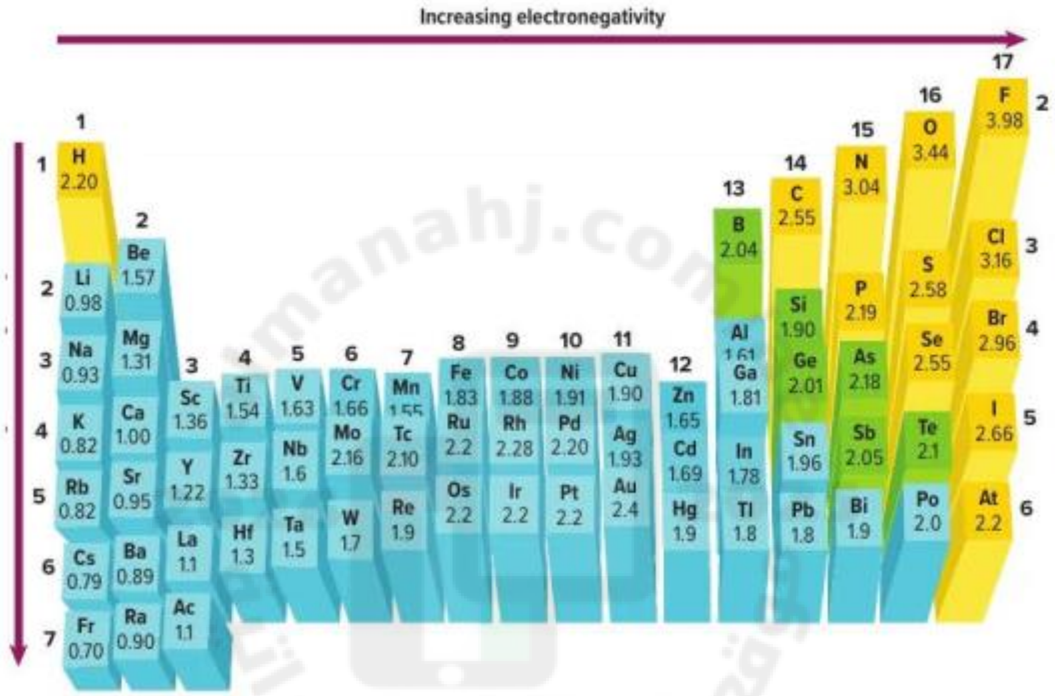
3- Which of the following ions has the largest radius?

a) Si^{2+} b) Mg^{2+} c) Al^{3+} d) Si^{4+}

20	CHM.5.1.01.011.02 Explain the periodic trend of electronegativity across a period and down a group of the periodic table	Textbook + figure 19	56 , 57

Electronegativity

The **electronegativity** of an element indicates the relative ability of its atoms to attract electrons in a chemical bond. As shown in **Figure 19**, on the next page, electronegativity generally decreases as you move down a group. **Figure 19** also indicates that electronegativity generally increases as you move from left to right across a period. Fluorine is the most electronegative element, with a value of 3.98, meaning it attracts electrons more strongly than any other element in a chemical bond. Cesium and francium are the least electronegative elements, with values of 0.79 and 0.70, repectively. In a chemical bond, the atom with the greater electronegativity more strongly attracts the bond's electrons. Note that because the noble gases form very few compounds, they do not have electronegativity values.



Electronegativity Values in Paulings

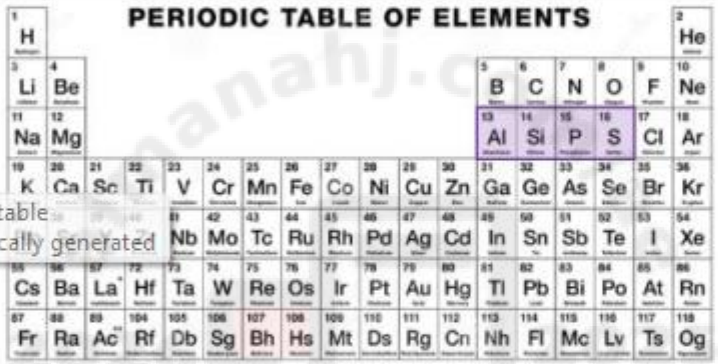
Figure 19 The electronegativity values for most of the elements are shown. The values are given in Paulings, a unit named after American scientist Linus Pauling (1901–1994).

Infer *why electronegativity values are not listed for the noble gases.*

20	CHM.5.1.01.011.02 Explain the periodic trend of electronegativity across a period and down a group of the periodic table	Textbook + figure 19	56 , 57

Which one of the following elements have the highest electronegativity?

أي من العناصر التالية لها أعلى سالبية كهربائية؟



A picture containing table
Description automatically generated

S

Si

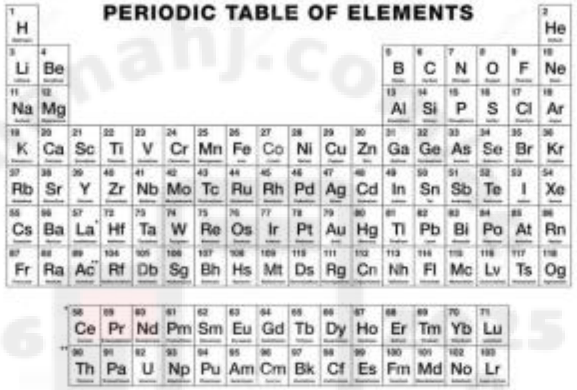
P

Al

20	CHM.5.1.01.011.02 Explain the periodic trend of electronegativity across a period and down a group of the periodic table	Textbook + figure 19	56 , 57

Which of the following is true regarding electronegativity in the periodic table?

أي مما يأتي صحيح فيما يتعلق بالسالبية الكهربائية في الجدول الدوري؟



Electronegativity increases as we move down a group

تزداد السالبية الكهربائية عند الانتقال في المجموعة من أعلى إلى أسفل

Fluorine (F) is the least electronegative element

الفلور (F) هو العنصر الأقل سالبية كهربائية

Cesium (Cs) is the most electronegative element

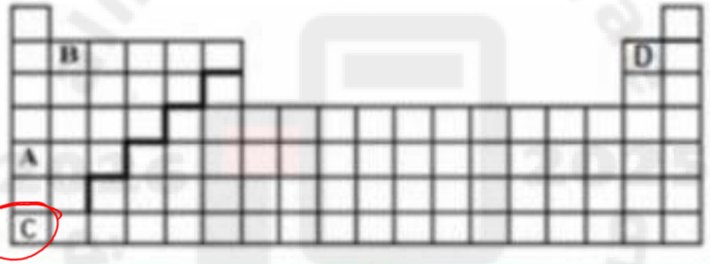
السيزيوم (Cs) هو العنصر الأعلى سالبية كهربائية

Electronegativity increases as we move from left to right across a period

تزداد السالبية الكهربائية عند الانتقال في أي دورة من اليسار إلى اليمين

20	CHM.5.1.01.011.02 Explain the periodic trend of electronegativity across a period and down a group of the periodic table	Textbook + figure 19	56 , 57

Which of the following symbols (Letters) refers to the element with the **lowest** electronegativity?	أي من الرموز (الحروف) التالية تُشير إلى العنصر ذو **أقل** سالبية كهربائية؟



C

20	CHM.5.1.01.011.02 Explain the periodic trend of electronegativity across a period and down a group of the periodic table	Textbook + figure 19	56 , 57

Q.16: السالبية الكهربائية

Which group does not have electronegativity values on the periodic table of elements?

أي مجموعة ليس لها قيم سالبية كهربائية في الجدول الدوري للعناصر؟

PERIODIC TABLE OF THE ELEMENTS

الجدول الدوري للعناصر

1. Group 1 — المجموعة 1
2. Group 17 — المجموعة 17
3. Group 2 — المجموعة 2
4. Group 18 — المجموعة 18

21	Force that bon atoms together		Text book	63

Valence Electrons and Chemical Bonds

Imagine going on a scuba dive, diving below the ocean's surface and observing the awe-inspiring world below. You might explore the colorful and exotic organisms teeming around a coral reef, such as the one shown in **Figure 1**. The reef is formed from a compound called calcium carbonate, which is just one of thousands of compounds found on Earth. How do so many compounds form from the relatively few elements known to exist? The answer to this question involves the electron structure of atoms and the nature of the forces between atoms.

In previous chapters, you learned that elements within a group on the periodic table have similar properties. Many of these properties depend on the number of valence electrons the atom has. These valence electrons are involved in the formation of chemical bonds between two atoms. A **chemical bond** is the force that holds two atoms together.

Chemical bonds can form by the attraction between the positive nucleus of one atom and the negative electrons of another atom, or by the attraction between positive ions and negative ions. This chapter discusses chemical bonds formed by ions, atoms that have acquired a positive or negative charge. You will learn about bonds that form from the sharing of electrons in a later chapter.

22	Reactivity of elements and factors affect it	Textbook	64
23	CHM.5.1.02.022.03 Describe how ions (cations and anions) form to fulfill the octet rule	Textbook	65
24	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations		

Valence electrons

Recall that an electron-dot structure is a type of diagram used to keep track of valence electrons. Electron-dot structures are especially helpful when used to illustrate the formation of chemical bonds. **Table 1** shows several examples of electron-dot structures. For example, carbon, with an electron configuration of $1s^2 2s^2 2p^2$, has four valence electrons in the second energy level. These valence electrons are represented by the four dots around the symbol C in the table.

Table 1 Electron-Dot Structures

Group	1	2	13	14	15	16	17	18
Diagram	Li·	·Be·	·Ḃ·	·Ċ·	·N̈·	:Ö·	:F̈·	:N̈e:

Recall that ionization energy refers to how easily an atom loses an electron. *Electron affinity* (EA) is a term used to describe how much attraction an atom has for electrons. Noble gases, which have high ionization energies and low electron affinities, show a general lack of chemical reactivity. Other elements on the periodic table react with each other, forming numerous compounds. The difference in reactivity is directly related to the valence electrons.

The difference in reactivity involves the octet—the stable arrangement of eight valence electrons in the outer energy level. Unreactive noble gases have electron configurations that have a full outermost energy level. This level is filled with two electrons for helium ($1s^2$) and eight electrons for the other noble gases (ns^2np^6). Elements tend to react to acquire the stable electron structure of a noble gas.

Positive Ion Formation

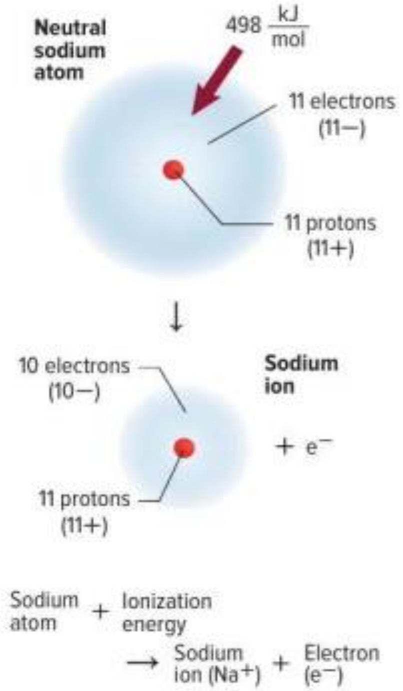
A positive ion forms when an atom loses one or more valence electrons in order to attain a noble gas configuration. A positively charged ion is called a **cation.** To understand the formation of a positive ion, compare the electron configurations of the noble gas neon (atomic number 10) and the alkali metal sodium (atomic number 11).

Neon atom (Ne) $1s^2 2s^2 2p^6$

Sodium atom (Na) $1s^2 2s^2 2p^6 3s^1$

Note that the sodium atom has one 3s valence electron; it differs from the noble gas neon by that single valence electron. When sodium loses this outer valence electron, the resulting electron configuration is identical to that of neon.

Figure 2 shows how a sodium atom loses its valence electron to become a sodium cation. By losing an electron, the sodium atom acquires the stable outer electron configuration of neon. It is important to understand that although sodium now has the electron configuration of neon, it is not neon. It is a sodium ion with a single positive charge. The 11 protons that establish the character of sodium still remain within its nucleus.



Get It?
Identify the number of electrons in the outermost energy level that are associated with maximum stability.

Metal ions

Metal atoms are reactive because they lose valence electrons easily. The group 1 and 2 metals are the most reactive metals on the periodic table. For example, potassium and magnesium, group 1 and 2 elements, respectively, form K^+ and Mg^{2+} ions. Some group 13 atoms also form ions. The ions formed by metal atoms in groups 1, 2, and 13 are summarized in **Table 2**.

Ahmed Elgharpawy

22	Reactivity of elements and factors affect it	Textbook	64
23	CHM.5.1.02.022.03 Describe how ions (cations and anions) form to fulfill the octet rule	Textbook	65

24	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations	25	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations

Transition metal ions

Recall that, in general, transition metals have an outer energy level of ns^2. Going from left to right across a period, atoms of each element fill an inner d sublevel. When forming positive ions, transition metals commonly lose their two valence electrons, forming 2+ ions. However, it is also possible for d electrons to be lost. Thus, transition metals also commonly form ions of 3+ or greater, depending on the number of d electrons in the electron structure. It is difficult to predict the number of electrons that will be lost. For example, iron (Fe) forms both Fe^{2+} and Fe^{3+} ions. A useful rule of thumb for these metals is that they form ions with a 2+ or a 3+ charge.

Get It?

Explain in your own words why transition metals can form ions with 2+ or 3+ charges.

Table 2 Group 1, 2, and 13 Ions

Group	Configuration	Charge of Ion Formed
1	[noble gas]ns^1	1+ when the s^1 electron is lost
2	[noble gas]ns^2	2+ when the s^2 electrons are lost
13	[noble gas]ns^2np^1	3+ when the s^2p^1 electrons are lost

Pseudo-noble gas configurations

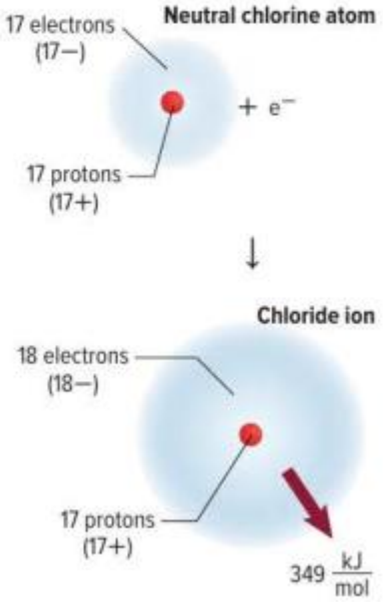
Although the formation of an octet is the most stable electron configuration, other electron configurations can also provide some stability. For example, elements in groups 11–14 lose electrons to form an outer energy level containing full s, p, and d sublevels. These relatively stable electron arrangements are referred to as pseudo-noble gas configurations. The zinc atom has the electron configuration of $1s^22s^22p^63s^23p^64s^23d^{10}$, in **Figure 3.** When forming an ion, the zinc atom loses the two 4s electrons in the outer energy level, and the stable configuration of $1s^22s^22p^63s^23p^63d^{10}$ results in a pseudo-noble gas configuration.

Negative Ion Formation

Nonmetals, which are located on the right side of the periodic table, easily gain electrons to attain a stable outer electron configuration. Examine **Figure 4**. To attain a noble-gas configuration, chlorine gains one electron, forming an ion with a 1– charge. After gaining the electron, the chloride ion has the electron configuration of an argon atom.

Chlorine atom (Cl)	$1s^22s^22p^63s^23p^5$
Argon atom (Ar)	$1s^22s^22p^63s^23p^6$
Chloride ion (Cl^-)	$1s^22s^22p^63s^23p^6$

An **anion** is a negatively charged ion. To designate an anion, the ending *-ide* is added to the root name of the element. Thus, a chlorine atom becomes a chloride anion.



Ahmed Elgharpawy

22	Reactivity of elements and factors affect it	23	CHM.5.1.02.022.03 Describe how ions (cations and anions) form to fulfill the octet rule	Textbook	64
24	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations			Textbook	65
25	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations				
26	CHM.5.1.02.022.04 Relate the charge of an ion to the group number of an element in the periodic table				

How the atoms of group **15** elements become stable?

A – By losing two electrons

B – By gaining two electrons

C – By losing 3 electrons

D – By gaining 3 electrons

كيف تستقر ذرات عناصر المجموعة **15**؟

A – بفقدان إلكترونين

B – باكتساب إلكترونين

C – بفقدان 3 إلكترونات

D – باكتساب 3 إلكترونات

Table 3 Group 15–17 Ions

Group	Configuration	Charge of Ion Formed
15	[noble gas]ns^2np^3	3– when three electrons are gained
16	[noble gas]ns^2np^4	2– when two electrons are gained
17	[noble gas]ns^2np^5	1– when one electron is gained

Nonmetal ions

As shown in **Table 3**, nonmetals gain the number of electrons that, when added to their valence electrons, equals 8. For example, consider phosphorus, with five valence electrons. To form a stable octet, the atom gains three electrons and forms a phosphide ion with a 3– charge. Likewise, oxygen, with six valence electrons, gains two electrons and forms an oxide ion with a 2– charge.

Some nonmetals can lose or gain other numbers of electrons to form an octet. For example, in addition to gaining three electrons, phosphorus can lose five. However, in general, group 15 elements gain three electrons, group 16 elements gain two, and group 17 elements gain one to achieve an octet.

The electronic configuration of sulfur atom (S) is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$.What is the electron configuration of the ion formed by this atom?

الترتيب الإلكتروني لذرة الكبريت (S) هو $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$. ما الترتيب الإلكتروني للأيون الذي تكوّنه هذه الذرة؟

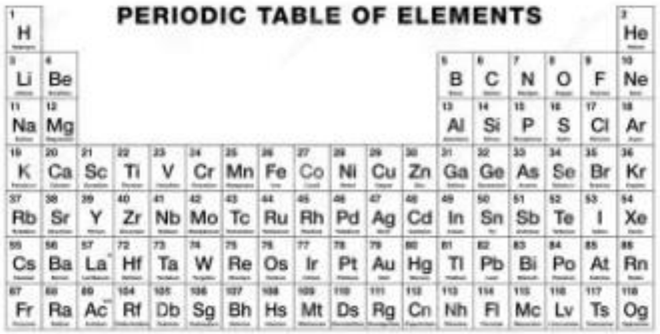
A	B	C	D
$1s^22s^22p^63s^23p^6$	$1s^22s^22p^63s^23p^5$	$1s^22s^22p^63s^23p^3$	$1s^22s^22p^63s^2$

22	Reactivity of elements and factors affect it	Textbook	64
23	CHM.5.1.02.022.03 Describe how ions (cations and anions) form to fulfill the octet rule	Textbook	65
24	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations		
25	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations		

Which of the ions below has the following electron configuration?

أي من الأيونات أدناه له الترتيب الإلكتروني التالي؟

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ = 18



Co^{2+} 27 - 2 = 25 ✗

Sc^{3+} 21 - 3 = 18 ✓

Cu^{1+} 29 - 1 = 28 ✗

Zn^{2+} 30 - 2 = 28 ✗

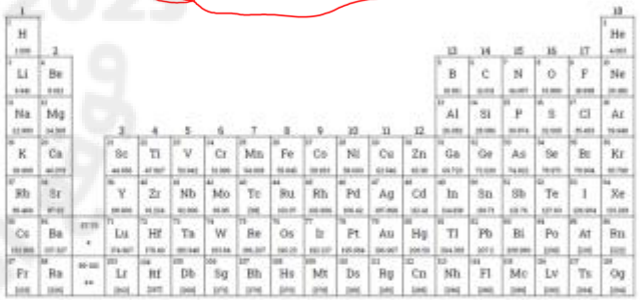
Describe how ions (cations and anions) form to fulfill the octet rule

يصف تكون الأيونات (كاتيون – أنيون) للوصول إلى الترتيب الإلكتروني المستقر

Which of the ions below has the following electron configuration?

أي من الأيونات أدناه له الترتيب الإلكتروني التالي؟

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$ = 28



Co^{2+} 25 ✗

Zn^{2+} 28 ✓

Cu^{2+} 27 ✗

Ni^{2+} 26 ✗

Ahmed Elgharpawy

22	Reactivity of elements and factors affect it	Textbook	64
23	CHM.5.1.02.022.03 Describe how ions (cations and anions) form to fulfill the octet rule	Textbook	65
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25	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations		
26	CHM.5.1.02.022.04 Relate the charge of an ion to the group number of an element in the periodic table		

What is the pseudo-noble gas configuration for Cd atom when it loses $2e^-$? (Cd: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}$)	ما الترتيب الإلكتروني للغاز شبه النبيل لذرة الكادميوم Cd عندما تفقد $2e^-$؟ (Cd: $1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10} 4p^6\ 5s^2\ 4d^{10}$)

remove electrons from the highest level

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 =$

$[Kr]\ 4d^{10}$

$[Ar]4s^2 3d^{10} 4p^6$

$[Kr]5s^2 4d^8$

$[Ar]4d^{10}$

The Group 13 elements of the periodic table tend to lose valence electrons to attain a stable outer electron configuration and form ions. What is the charge of the formed ions?	تميل عناصر المجموعة 13 من الجدول الدوري إلى فقدان إلكترونات التكافؤ للوصول الى الترتيب الإلكتروني الخارجي المستقر مكوّنةً أيونات. ما شحنة الأيونات المتكوّنة؟

+2

0

-3

+3

Ahmed Elgharpawy

22	Reactivity of elements and factors affect it	Textbook	64
23	CHM.5.1.02.022.03 Describe how ions (cations and anions) form to fulfill the octet rule	Textbook	65
24	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations		
25	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations		

The atomic number of zinc equals 30, and its electron configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$

Which of the following is the Pseudo-noble gas configurations for this element's ion?

العدد الذري للخارصين يساوي 30 وله الترتيب الإلكتروني التالي $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$

أي مما يأتي هو ترتيب الغاز شبه النبيل لأيون هذا العنصر؟

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^9$

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$

Which of the following is **correct** regarding **negative** ion?

أي مما يأتي **صحيح** فيما يتعلق بالأيون **السالب**؟

A A neutral atom loses one or more valence electrons, and this requires energy

تفقد الذرة المتعادلة إلكترونًا أو أكثر من إلكترونات التكافؤ ويتطلب ذلك طاقة

B A neutral atom gains one or more valence electrons, and this requires energy

تكتسب الذرة المتعادلة إلكترونًا أو أكثر من إلكترونات التكافؤ ويتطلب ذلك طاقة

C A neutral atom loses one or more valence electrons, and energy released

تفقد الذرة المتعادلة إلكترونًا أو أكثر من إلكترونات التكافؤ وتتحرر طاقة

D A neutral atom gains one or more valence electrons, and energy released

تكتسب الذرة المتعادلة إلكترونًا أو أكثر من إلكترونات التكافؤ وتتحرر طاقة

22	Reactivity of elements and factors affect it	Textbook	64
23	CHM.5.1.02.022.03 Describe how ions (cations and anions) form to fulfill the octet rule	Textbook	65
24	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different		

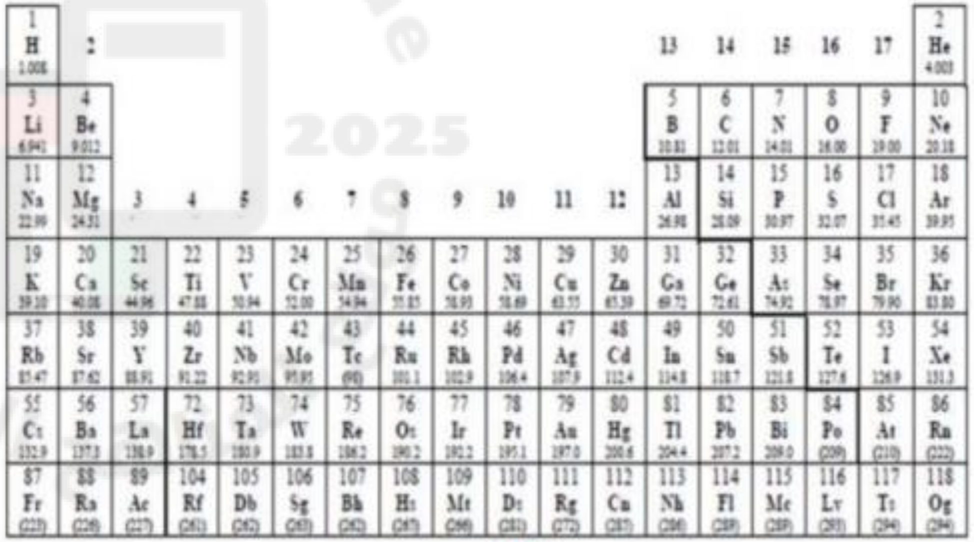
Which of the following groups, its elements gain two electrons and form ions with charge = −2?

أي المجموعات التالية تكتسب عناصرها إلكترونين وتكوّن أيونات شحنة كل منها تساوي 2− ؟

PERIODIC TABLE OF THE ELEMENTS

الجدول الدوري للعناصر

1 18



1. 17
2. 16
3. 15
4. 13

22	Reactivity of elements and factors affect it	Textbook	64
23	CHM.5.1.02.022.03 Describe how ions (cations and anions) form to fulfill the octet rule	Textbook	65
24	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations		
25	CHM.5.1.02.022.05 Write the electron configuration notation, noble gas notation and Lewis structure of different anions and cations		

What is the pseudo-noble gas configuration for Cd atom when it loses 2e⁻?
(Cd: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10}$)

- $[Kr]\,4d^{10}$
- $[Ar]4s^2 3d^{10} 4p^6$
- $[Kr]5s^2 4d^8$
- $[Ar]4d^{10}$

The element zinc (Zn) has an atomic number = 30 and its electron configuration is: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$. Which of the following is the pseudo-noble gas electronic configuration for this element's ion Zn^{2+}?

عنصر الخارصين (Zn) عدده الذري يساوي 30 وترتيبه الإلكتروني هو: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$. أي مما يأتي هو الترتيب الإلكتروني للغاز شبه النبيل لأيون هذا العنصر Zn^{2+}؟

1. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$
2. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
3. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$
4. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^9$

27	CHM.5.1.02.022.10 Explain how an ionic compound made up of charged particles can be electrically neutral	Textbook + table 4 + practice problems	68 , 69 , 70

Formation of an Ionic Bond

What do the reactions shown in **Figure 5** have in common? In both cases, elements react with each other to form a compound. **Figure 5a** shows the reaction between the elements sodium and chlorine. During this reaction, a sodium atom transfers its valence electron to a chlorine atom and becomes a positive ion. The chlorine atom accepts the electron into its outer energy level and becomes a negative ion. The oppositely charged ions attract each other, forming the compound sodium chloride. The electrostatic force that holds oppositely charged particles together in an ionic compound is referred to as an **ionic bond.** Compounds that contain ionic bonds are **ionic compounds.** If ionic bonds occur between metals and the nonmetal oxygen, oxides form. Most other ionic compounds are called salts.

Binary ionic compounds

Thousands of compounds contain ionic bonds. Many ionic compounds are binary, which means that they contain only two different elements. Binary ionic compounds contain a metallic cation and a nonmetallic anion. Sodium chloride (NaCl) is a binary compound because it contains two different elements, sodium and chlorine. Magnesium oxide (MgO), the reaction product shown in **Figure 5b** on the previous page, is also a binary ionic compound.

Table 4 summarizes several ways in which the formation of an ionic compound such as sodium chloride can be represented.

Table 4 Formation of Sodium Chloride

Chemical Equation

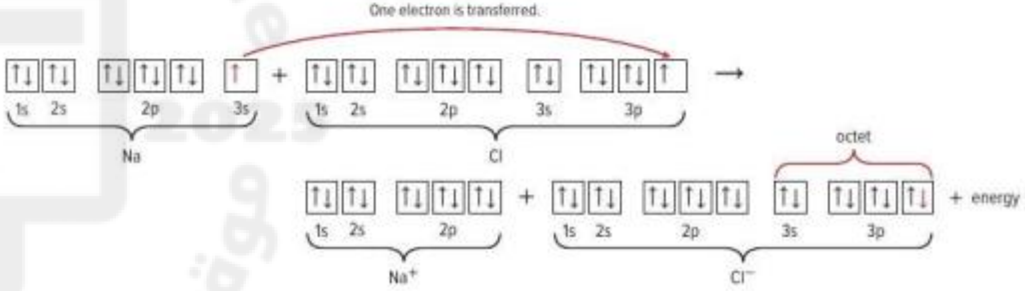
$Na + Cl \rightarrow Na^{+} + Cl^{-} + energy$

Electron Configurations

One electron is transferred.

$\underbrace{[Ne]3s^1}_{Na} + \underbrace{[Ne]3s^2 3p^5}_{Cl} \rightarrow \underbrace{[Ne]}_{Na^+} + \underbrace{[Ar]}_{Cl^-} + energy$

Orbital Notation

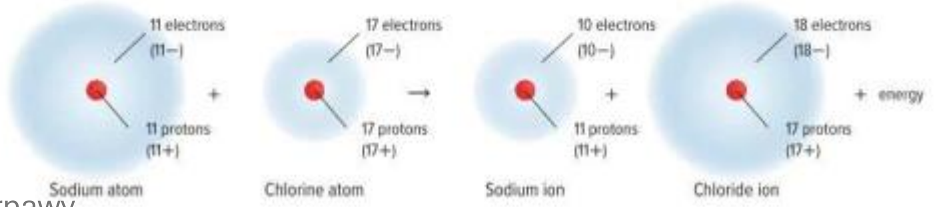


Electron-Dot Structures

One electron is transferred.

$Na\cdot + \cdot\ddot{\underset{..}{Cl}}: \rightarrow [Na]^{+} + [:\ddot{\underset{..}{Cl}}:]^{-} + energy$

Atomic Models



27	CHM.5.1.02.022.10 Explain how an ionic compound made up of charged particles can be electrically neutral	Textbook + table 4 + practice problems	68 , 69 , 70
30	CHM.5.1.02.022.06 Define ionic bond while identifying the type of elements involved and movement of electrons		

What role does ionic charge play in the formation of ionic compounds? To answer this question, consider how calcium fluoride forms. Calcium has the electron configuration [Ar]$4s^2$, and needs to lose two electrons to attain the stable configuration of argon. Fluorine has the configuration [He]$2s^2 2p^5$, and must gain one electron to attain the stable configuration of neon. Because the number of electrons lost and gained must be equal, two fluorine atoms are needed to accept the two electrons lost from the calcium atom. As you can see, the overall charge of one unit of calcium fluoride (CaF_2) is zero.

$$1\ \cancel{\text{Ca ion}}\left(\frac{2+}{\cancel{\text{Ca ion}}}\right) + 2\ \cancel{\text{F ions}}\left(\frac{1-}{\cancel{\text{F ion}}}\right) = (1)\ (2+) + (2)(1-) = 0$$

Next, consider aluminum oxide, the whitish coating that forms on aluminum chairs. To acquire a noble-gas configuration, each aluminum atom loses three electrons and each oxygen atom gains two electrons. Thus, three oxygen atoms are needed to accept the six electrons lost by two aluminum atoms. The neutral compound formed is aluminum oxide (Al_2O_3).

$$2\ \cancel{\text{Al ions}}\left(\frac{3+}{\cancel{\text{Al ion}}}\right) + 3\ \cancel{\text{O ions}}\left(\frac{2-}{\cancel{\text{O ion}}}\right) = 2(3+) + 3(2-) = 0$$

PRACTICE Problems ADDITIONAL PRACTICE

Explain how an ionic compound forms from these elements.

7. sodium and nitrogen
8. lithium and oxygen
9. strontium and fluorine
10. aluminum and sulfur
11. **CHALLENGE** Explain how elements in the two groups shown on the periodic table at the right combine to form an ionic compound.

Which of the following cations and anions complete the chemical equation below to form an ionic compound?

أي من الكاتيونات والأنيونات التالية يُكمل المعادلة الكيميائية أدناه لتكوين مركب أيوني؟

Na· + ·F: → ________ + ________

[Na]$^{+1}$ + [:F:]$^{-1}$

[Na:]$^{+6}$ + [·F·]$^{-6}$

[:Na:]$^{+1}$ + [·F]$^{-1}$

[·Na·]$^{+1}$ + [·F·]$^{-1}$

Ahmed Elgharpawy

27	CHM.5.1.02.022.10 Explain how an ionic compound made up of charged particles can be electrically neutral	Textbook + table 4 + practice problems	68 , 69 , 70
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Which of the following cations and anions complete the chemical equation below to form an ionic compound?

أي من الكاتيونات والأنيونات التالية يُكمل المعادلة الكيميائية أدناه لتكوين مركب أيوني؟

$[Ne]\ 3s^2 + [He]\ 2s^2\ 2p^4 \rightarrow$ ________ + ________

Cation كاتيون	Anion أنيون
[Ne]	[Ne]

Cation كاتيون	Anion أنيون
$[Ne]\ 3s^1$	$[He]\ 2s^2\ 2p^5$

Cation كاتيون	Anion أنيون
$[Ne]\ 3s^2\ 3p^6$	$[He]\ 2s^2\ 2p^6$

Cation كاتيون	Anion أنيون
[Ar]	[He]

What happens when aluminum reacts with nitrogen according to the equation below?

ماذا يحدث عندما يتفاعل الألمنيوم مع النيتروجين حسب المعادلة أدناه؟

A – The Aluminum atom gains 5 electrons and forms Al^{5-} ion

B – The Aluminum atom loses 3 electrons and forms Al^{3+} ion

C – The Nitrogen atom gains 5 electrons and forms N^{5-} ion

D – The Nitrogen atom loses 3 electrons and forms N^{3+} ion

- تكتسب ذرة الألمنيوم 5 إلكترونات وتكوّن أيون Al^{5-}
- تفقد ذرة الألمنيوم 3 إلكترونات وتكوّن أيون Al^{3+}
- تكتسب ذرة النيتروجين 5 إلكترونات وتكوّن أيون N^{5-}
- تفقد ذرة النيتروجين 3 إلكترونات وتكوّن أيون N^{3+}

$$\cdot\dot{\underset{\cdot}{Al}} + :\dot{N}: \rightarrow \ldots\ldots\ldots\ldots$$

Which of the following statements is correct according to the reaction below?	أي العبارات التالية صحيحة بالنسبة للتفاعل أدناه؟
$:Mg + :\dot{\underset{\cdot}{S}}: \rightarrow [Mg]^{2+} + [S]^{2-}$	
A. Mg is considered an atom which gained 2 electrons during the reaction	A. تُعتبر Mg ذرة اكتسبت إلكترونين خلال التفاعل
B. S is considered an atom which lose 2 electrons during the reaction	B. تُعتبر S ذرة فقدت إلكترونين خلال التفاعل
C. The formula of the formed compound is MgS	C. صيغة المركب المتكوّن هي MgS
D. The overall charge of the formed compound is -2	D. الشحنة الكلية للمركب المتكوّن هي -2

28	CHM.5.1.02.022.08 Explain the physical properties of ionic compounds as melting point and boiling point, conductivity when solid, molten or aqueous, and its solubility in water	Textbook	72 , 73
29	CHM.5.1.02.022.09 Explain the effect of applying an external force on the crystal	Textbook + figure 8	72

Properties of Ionic Compounds

The chemical bonds in a compound determine many of its properties and applications. For ionic compounds, electrical forces in the ionic bonds produce unique physical structures, unlike those of other compounds. The physical structures of ionic compounds also contribute to their bulk physical properties.

Physical structure

In an ionic compound, large numbers of positive ions and negative ions exist together in a ratio determined by the number of electrons transferred from the metal atom to the nonmetal atom. These ions are packed into a regular repeating pattern that balances the forces of attraction and repulsion between the ions.

Examine the pattern of the ions in the sodium chloride crystal shown in **Figure 6**. Note the highly organized nature of an ionic crystal—the consistent spacing of the ions and the uniform pattern formed by them. Although the ion sizes are not the same, each sodium ion in the crystal is surrounded by six chloride ions, and each chloride ion is surrounded by six sodium ions. What shape would you expect a large crystal of this compound to be? As shown in **Figure 6**, the one-to-one ratio of sodium and chloride ions produces a highly ordered cubic crystal. As in all ionic compounds, in NaCl, no single unit consisting of only one sodium ion and one chloride ion is formed. Instead, large numbers of sodium ions and chloride ions exist together. If you can, obtain a magnifying lens and use it to examine some crystals of table salt (NaCl). What is the shape of these small salt crystals?

The strong attractions among the positive ions and the negative ions in an ionic compound result in the formation of a **crystal lattice.** A crystal lattice is a three-dimensional geometric arrangement of particles. In a crystal lattice, each positive ion is surrounded by negative ions, and each negative ion is surrounded by positive ions. Ionic crystals vary in shape due to the sizes and relative numbers of the ions bonded, as shown by the minerals in **Figure 7**.

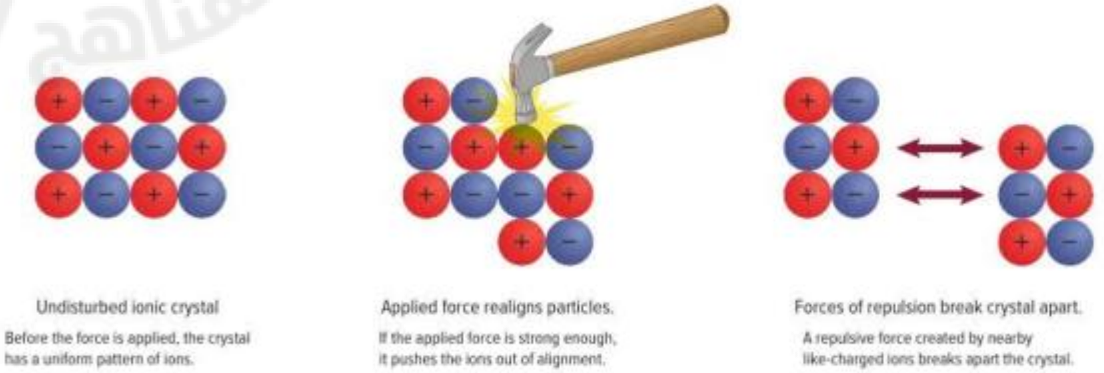
Physical properties

Melting point, boiling point, and hardness are bulk physical properties of matter that are determined by the strength of electrical forces between particles that make up the matter. Because ionic bonds are relatively strong, ionic crystals require a large amount of energy to be broken apart. Thus, ionic crystals have high melting points and high boiling points, as shown in **Table 5**. Many crystals, including gemstones, have brilliant colors. These colors are due to the presence of transition metals in the crystal lattices.

Table 5 Melting and Boiling Points of Some Ionic Compounds

Compound	Melting Point (°C)	Boiling Point (°C)
NaI	660	1304
KBr	734	1435
NaBr	747	1390
$CaCl_2$	782	>1600
NaCl	801	1413
MgO	2852	3600

Ionic crystals are also hard, rigid, brittle solids due to the strong attraction between electric charges that holds the ions in place. When an external force is applied to the crystal—a force strong enough to overcome the attractive forces holding the ions in position within the crystal—the crystal cracks or breaks apart, as shown in **Figure 8**. The crystal breaks apart because the applied force repositions the like-charged ions next to each other; the resulting repulsion between electric forces breaks apart the crystal.



Ahmed Elgharpawy

Figure 8 Strong attractive forces hold the ions in place until a force strong enough to overcome the attraction is applied.

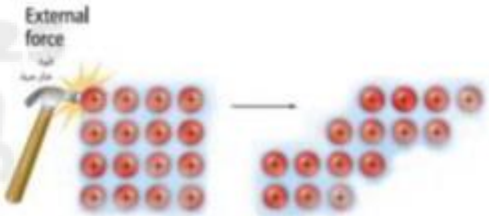
28	CHM.5.1.02.022.08 Explain the physical properties of ionic compounds as melting point and boiling point, conductivity when solid, molten or aqueous, and its solubility in water	Textbook	72 , 73
29	CHM.5.1.02.022.09 Explain the effect of applying an external force on the crystal	Textbook + figure 8	72
30	CHM.5.1.02.022.06 Define ionic bond while identifying the type of elements involved and movement of electrons		

Another property—the ability of a material to conduct electricity—depends on the availability of freely moving charged particles. Ions are charged particles, so whether they are free to move determines whether an ionic compound conducts electricity. In the solid state, the ions in an ionic compound are locked into fixed positions by strong attractive forces. As a result, ionic solids do not conduct electricity.

The situation changes dramatically, however, when an ionic solid melts to become a liquid or is dissolved in solution. The ions—previously locked in position—are now free to move and conduct an electric current. Both ionic compounds in solution and in the liquid state are excellent conductors of electricity. An ionic compound whose aqueous solution conducts an electric current is called an **electrolyte.**

What is the property of metals shown in the figure below?

ما خاصية الفلزات التي تتضح في الشكل أدناه؟



Thermal and electrical conductivity — توصيل الحرارة والكهرباء

Hardness and strength — الصلابة والقوة

Malleability, ductility, and durability — قابلية الطرق والسحب والمتانة

Melting and boiling points — درجات الغليان و الانصهار

28	CHM.5.1.02.022.08 Explain the physical properties of ionic compounds as melting point and boiling point, conductivity when solid, molten or aqueous, and its solubility in water	Textbook	72 , 73
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30	CHM.5.1.02.022.06 Define ionic bond while identifying the type of elements involved and movement of electrons		

Regarding the properties of ionic compounds, which of the following is **incorrect**?

فيما يتعلق بخصائص المركبات الأيونية، أي مما يأتي **غير صحيح**؟

المركب الأيوني في الحالة الصلبة، تكون الأيونات ثابتة في أماكنها بفعل قوى التجاذب الفعالة ولا يُوصل الكهرباء An ionic compound in the solid state, the ions are locked into fixed positions by strong attractive forces, as a result, ionic solids do not conduct electricity	1
المركب الأيوني في الحالة السائلة أو حالة المحلول، تكون الأيونات ثابتة في أماكنها بفعل قوى التجاذب الفعالة ولا يُوصل الكهرباء An ionic compound in the liquid state, or is dissolved in solution ,the ions are locked into fixed positions by strong attractive forces and does not conduct electricity	2
المركب الأيوني في الحالة السائلة أو حالة المحلول، تكون الأيونات حرة الحركة ويُوصل التيار الكهربائي An ionic compound in the liquid state, or is dissolved in solution, the ions are free to move and conduct an electric current	3

1 only — 1 فقط

2 only — 2 فقط

1 and 3 — 1 و 3

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3 only — 3 فقط