

Chem 10 Chapter 9

Electrons in Atoms and the Periodic Table

Practice and End of Chapter Questions

Worked solutions at the end

Use your course periodic table and a calculator as needed. Show the setup, include units, and round at the end. Question numbers match the numbers in the solutions. Use heading navigation to move between sections.

In orbital diagrams, each bracketed group represents one orbital. Up and down arrows represent opposite spins. Use ground-state configurations unless stated otherwise.

Useful constants (standard rounded values):

$$c = 2.998 \times 10^8 \text{ m/s}; \quad h = 6.626 \times 10^{-34} \text{ J s}$$

Practice Questions

Question 1

Which statement about light is false, or are all four statements true?

- A) Light travels through space at $3.00 \times 10^8 \text{ m/s}$.
- B) A packet of light energy is called a photon.
- C) A characteristic of light that determines its color is its wavelength.
- D) Light travels much faster than sound.
- E) All of the above statements are true.

Question 2

The distance between adjacent wave crests is called:

- A) frequency
- B) trough
- C) ν
- D) wavelength
- E) none of the above

Question 3

The number of cycles of a wave that pass a stationary point in one second is its:

- A) frequency
- B) crest
- C) trough
- D) wavelength
- E) none of the above

Question 4

Which statement is true?

- A) The wavelength of light is inversely related to its photon energy.
- B) As wavelength increases, frequency also increases.
- C) Red light has a shorter wavelength than violet light.
- D) As photon energy increases, frequency decreases.
- E) none of the above

Question 5

How are wavelength and frequency of light related?

- A) Wavelength increases as frequency decreases.
- B) Wavelength is independent of frequency.
- C) Wavelength is double the frequency.
- D) Wavelength is one-half of the frequency.
- E) Wavelength increases as frequency increases.

Question 6

Which visible color has the shortest wavelength, about 400 nm?

- A) violet
- B) green
- C) red
- D) orange
- E) yellow

Question 7

Which order runs from shortest to longest wavelength?

- A) Gamma rays → X-rays → visible → ultraviolet → infrared → microwaves → radio waves
- B) Gamma rays → X-rays → ultraviolet → visible → infrared → microwaves → radio waves
- C) Visible → infrared → microwaves → radio waves → gamma rays → X-rays → ultraviolet
- D) Gamma rays → X-rays → infrared → visible → ultraviolet → microwaves → radio waves
- E) Radio waves → X-rays → ultraviolet → visible → infrared → microwaves → gamma rays

Question 8

Which statement about the quantum-mechanical model is false?

- A) Orbitals are specific paths that electrons follow.
- B) Electrons exhibit both particle and wave properties.
- C) Orbitals describe the probability of finding electrons in space.
- D) Electron paths cannot be described exactly.
- E) none of the above

Question 9

The subshell letter:

- A) specifies the actual number of electrons occupying that subshell
- B) specifies the principal quantum number of the orbital
- C) specifies the principal shell of the orbital
- D) specifies the three-dimensional shape of the orbital
- E) none of the above

Question 10

How many subshells are in the $n = 2$ principal shell?

- A) 1
- B) 2
- C) 3
- D) 4
- E) not enough information

Question 11

What is the lowest principal shell that can contain a d subshell?

- A) $n = 1$
- B) $n = 2$
- C) $n = 3$
- D) $n = 4$
- E) not enough information

Question 12

What is the maximum number of electrons in a d subshell?

- A) 10
- B) 5
- C) 6
- D) 2
- E) none of the above

Question 13

How many unpaired electrons are in the orbitals of a ground-state carbon atom?

- A) 2
- B) 4
- C) 12
- D) 6
- E) none of the above

Question 14

In a noble-gas abbreviation for the electron configuration of bromine, which element goes inside the brackets?

- A) Xe
- B) Ne
- C) Ar
- D) He
- E) Kr

Question 15

What is the electron configuration of a ground-state krypton atom?

- A) $1s^2 2s^2 2p^6 3s^2 3p^4 3d^{10} 4s^2 4p^6$
 B) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$
 C) $1s^2 2s^2 2p^6 3s^2 3p^2 4s^2 3d^{10} 4p^6$
 D) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2 4p^6$
 E) none of the above

Question 16

Which option gives the correct ground-state orbital diagram for nitrogen? Each table cell represents one orbital; “up” and “down” name the directions of the electron arrows. Option E is “none of the above.”

Option	1s	2s	2p orbital 1	2p orbital 2	2p orbital 3
A	up, down	down, down	down	up	up
B	up, down	up, down	down	down	up
C	up, down	up, down	up	up	up
D	up, down	down, down	up	up	up

Question 17

How many core electrons are in a chlorine atom?

- A) 10
 B) 7
 C) 1
 D) 17
 E) none of the above

Question 18

How many valence electrons are in a chlorine atom?

- A) 1
 B) 7
 C) 17
 D) 10
 E) none of the above

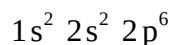
Question 19

Why do chlorine and bromine have very similar chemical properties?

- A) They have equal numbers of protons and electrons.
- B) They are both in period 3.
- C) They have the same number of valence electrons.
- D) They are both gases.
- E) none of the above

Question 20

Which species have the configuration shown?



- 1. Na^+
 - 2. O^{2-}
 - 3. F^-
- A) 1 and 3 only
 - B) 1 and 2 only
 - C) 2 and 3 only
 - D) all of 1, 2, and 3
 - E) none of 1, 2, or 3

Question 21

Atomic size generally increases:

- A) down a group and from right to left across a period
- B) up a group and diagonally across the table
- C) up a group and from left to right across a period
- D) up a group and from right to left across a period
- E) down a group and from left to right across a period

Question 22

Which element has the lowest first ionization energy?

- A) F
- B) He
- C) Rb
- D) C
- E) Na

Question 23

Which atom has the greatest metallic character?

- A) Ti
- B) Au
- C) Cs
- D) Be
- E) Cu

End of Chapter Questions

Question 24

What is light? How fast does it travel?

Question 25

What is white light? What is colored light?

Question 26

Explain, in terms of absorbed and reflected light, why a blue object appears blue.

Question 27

How is the wavelength of light related to the energy carried by each photon? How are wavelength and frequency related?

Question 28

What is an emission spectrum? Use the Bohr model to explain why the hydrogen emission spectrum has distinct lines at specific wavelengths.

Question 29

Explain the difference between a Bohr orbit and a quantum-mechanical orbital.

Question 30

What is the difference between the ground state and an excited state of an atom?

Question 31

Explain the difference between valence electrons and core electrons.

Question 32

Identify the s, p, d, and f blocks in the blank periodic table. Use positions as well as colors to identify each region: the left two columns plus helium, the right six columns excluding helium, the central ten columns, and the two detached rows.

[illegible]

Figure description: A blank periodic-table grid. A pale-blue region occupies the left two columns and the isolated upper-right helium cell. An orange region occupies the central ten columns beginning in period 4. A pink region occupies the six right-hand columns except the helium cell. A pale-green region comprises two detached rows, each fourteen cells long, below the main table.

Question 33

Which listed type of electromagnetic radiation has the longest wavelength?

- (a) visible
(b) ultraviolet
(c) infrared
(d) X-ray

Question 34

Put infrared, X-rays, and radio waves in order of:

- (a) increasing energy per photon
(b) increasing frequency
(c) increasing wavelength

Question 35

Hydrogen has emission lines at 410 nm and 434 nm. One comes from $n = 6$ to $n = 2$ and the other from $n = 5$ to $n = 2$. Match each wavelength to its transition.

Question 36

Which electron is, on average, closer to the nucleus: one in a 2s orbital or one in a 3s orbital?

Question 37

Write the full ground-state electron configuration of each atom.

- (a) Sr
- (b) Ge
- (c) Li
- (d) Kr

Question 38

Write each ground-state electron configuration using the preceding noble gas in brackets for the core.

- (a) Ga
- (b) As
- (c) Rb
- (d) Sn

Question 39

Write the ground-state electron configuration of each atom. Noble-gas abbreviations may be used.

- (a) Zn
- (b) Cu
- (c) Zr
- (d) Fe

Question 40

Write the full ground-state electron configuration, and identify the valence and core electrons, for each atom.

- (a) Kr
- (b) Ge
- (c) Cl
- (d) Sr

Question 41

Draw the orbital diagrams for the valence electrons and give the number of unpaired electrons in each ground-state atom.

- (a) Br
- (b) Kr
- (c) Na
- (d) In

Question 42

How many valence electrons are in each main-group atom?

- (a) O
- (b) S
- (c) Br
- (d) Rb

Question 43

Give the general outer electron configuration for each main-group column. Use n for the period number.

- (a) 1A (Group 1)
- (b) 2A (Group 2)
- (c) 5A (Group 15)
- (d) 7A (Group 17)

Question 44

Use the periodic table to write each ground-state electron configuration. Noble-gas abbreviations may be used.

- (a) Sr
- (b) Y
- (c) Ti
- (d) Te

Question 45

How many 2p electrons are in a ground-state atom of each element?

- (a) C
- (b) N
- (c) F
- (d) P

Question 46

Name the period 3 element with each description.

- (a) Three valence electrons
- (b) Four 3p electrons
- (c) Six 3p electrons
- (d) Two 3s electrons and no 3p electrons

Question 47

Identify the atom with each ground-state electron configuration.

- (a) $[\text{Ne}] 3s^2 3p^3$
- (b) $[\text{Ar}] 4s^2 3d^{10} 4p^1$
- (c) $[\text{Ar}] 4s^2 3d^6$
- (d) $[\text{Kr}] 5s^1$

Question 48

Choose the atom with the higher first ionization energy in each pair. Use general periodic trends; for the close comparison in part (c), use the supplied measured values: S, 10.360 eV; I, 10.451 eV.

- (a) As or Bi
- (b) As or Br
- (c) S or I
- (d) S or Sb

Question 49

Arrange Te, Pb, Cl, S, and Sn in order of increasing first ionization energy. Use general trends, together with these reference values for the close Sn/Pb comparison: Sn, 7.344 eV; Pb, 7.417 eV.

Question 50

Choose the atom with the larger size in each pair.

- (a) Al or In
- (b) Si or N
- (c) P or Pb
- (d) C or F

Question 51

Arrange Ca, Rb, S, Si, Ge, and F in order of increasing atomic size.

Question 52

Choose the more metallic element in each pair. For part (c), use the course criterion of greater tendency to lose an electron (lower first ionization energy): Cl, 12.968 eV; O, 13.618 eV.

- (a) Sr or Sb
- (b) As or Bi
- (c) Cl or O
- (d) S or As

Question 53

What is the maximum number of electrons that can occupy the $n = 3$ shell?

Question 54

Write the ground-state electron configuration of each ion. What do the configurations have in common?

- (a) Ca^{2+}
- (b) K^{+}
- (c) S^{2-}
- (d) Br^{-}

Question 55

Identify what is wrong with each configuration and write the correct ground-state configuration for the same total number of electrons.

- (a) $1s^3 2s^3 2p^9$
- (b) $1s^2 2s^2 2p^6 2d^4$
- (c) $1s^2 1p^5$
- (d) $1s^2 2s^2 2p^8 3s^2 3p^1$

Question 56

When a hydrogen electron moves from $n = 3$ to $n = 2$, an energy difference of $3.0 \times 10^{-19} \text{ J}$ is emitted as a photon. Calculate the wavelength of this light. Use $E = hc/\lambda$, $h = 6.626 \times 10^{-34} \text{ J s}$, and $c = 3.00 \times 10^8 \text{ m/s}$.

Solutions

Find the solution with the same question number.

Question 1 Solution

E. All four statements are true. Light in vacuum travels at approximately 3.00×10^8 m/s; its energy comes in packets called photons; visible color is associated with wavelength; and light travels much faster than sound.

Question 2 Solution

D. Wavelength is the distance between two consecutive crests, two consecutive troughs, or any two equivalent points on a wave.

Question 3 Solution

A. Frequency counts cycles per unit time. Its unit is s^{-1} , also called hertz (Hz).

Question 4 Solution

A. Photon energy is proportional to frequency and inversely proportional to wavelength.

$$E = h\nu = \frac{hc}{\lambda}$$

A longer wavelength therefore means lower frequency and lower energy per photon. Red light has a longer wavelength than violet light.

Question 5 Solution

A. For light traveling in vacuum, its speed is c . Wavelength and frequency must therefore vary inversely.

$$c = \lambda\nu$$

$$\lambda = \frac{c}{\nu}$$

If frequency decreases, wavelength increases.

Question 6 Solution

A. Violet is at the short-wavelength end of the visible spectrum; red is at the long-wavelength end. Violet photons therefore have higher energies than red photons.

Question 7 Solution

B. The order is gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves, and radio waves. Frequency and photon energy decrease in that same order.

Question 8 Solution

A. An orbital is not a fixed path followed by an electron. It describes the spatial probability distribution for an electron. Electrons have both wave and particle properties, but the model does not specify an exact classical trajectory.

Question 9 Solution

D. The subshell letter describes the characteristic shape of its orbitals: s orbitals are spherical and p orbitals have two lobes. The preceding number gives the principal shell. A subshell letter also determines capacity, but it does not tell us the actual electron occupancy.

Question 10 Solution

B. The number of subshells in a shell equals n. The n = 2 shell contains 2s and 2p, so it contains two subshells.

Question 11 Solution

C. The first shell contains s; the second contains s and p; and the third contains s, p, and d. Therefore a d subshell first occurs at n = 3.

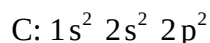
Question 12 Solution

A. A d subshell has five orbitals. Each orbital can hold two electrons with opposite spins.

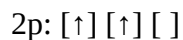
$$5 \text{ orbitals} \times \frac{2 \text{ electrons}}{1 \text{ orbital}} = 10 \text{ electrons}$$

Question 13 Solution

A. Carbon has six electrons.



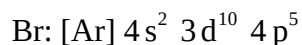
The 1s and 2s electrons are paired. By Hund's rule, the two 2p electrons occupy different orbitals with parallel spins.



There are two unpaired electrons.

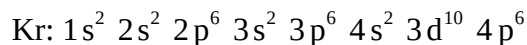
Question 14 Solution

C. Use the noble gas immediately preceding bromine, not the noble gas at the end of bromine's period. Bromine has 35 electrons and argon accounts for the first 18.



Question 15 Solution

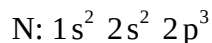
B. Krypton has 36 electrons. Fill the subshells in the usual order; 4s fills before 3d, followed by 4p.



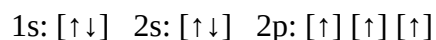
The occupancies add to 36. Each occupied subshell is filled.

Question 16 Solution

C. Nitrogen has seven electrons.



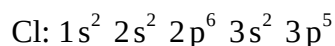
The 1s and 2s orbitals each contain opposite-spin pairs. The three 2p orbitals each contain one electron, with all three spins parallel.



Options A and D put equal-spin electrons in 2s, violating the Pauli principle. Option B has nonparallel spins in the singly occupied 2p orbitals, so it is not the ground-state arrangement.

Question 17 Solution

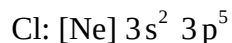
A. Chlorine has 17 electrons. Its seven outer-shell electrons are valence electrons; the other ten are core electrons.



$$\text{Core electrons} = 2 + 2 + 6 = 10$$

Question 18 Solution

B. For this main-group atom, valence electrons occupy the highest principal shell. Chlorine's highest shell is $n = 3$.



$$\text{Valence electrons} = 2 + 5 = 7$$

Question 19 Solution

C. Both are halogens in Group 17 ($7A$), with seven valence electrons and an outer configuration of $ns^2 np^5$. Similar valence configurations lead to similar chemical behavior.

Question 20 Solution

D. The configuration contains ten electrons. Count electrons by subtracting a positive charge or adding a negative charge to the atomic number.

$$\text{Na}^+ : 11 - 1 = 10 \text{ electrons}$$

$$\text{O}^{2-} : 8 + 2 = 10 \text{ electrons}$$

$$\text{F}^- : 9 + 1 = 10 \text{ electrons}$$

All three are isoelectronic with neon.

Question 21 Solution

A. Moving down a group adds occupied principal shells, increasing size. Moving from right to left across a period generally reduces the nuclear attraction experienced by the outer electrons, so size increases.

Question 22 Solution

C. Rb and Na are alkali metals, whose outer electron is relatively easy to remove. Rb lies below Na; its valence electron is farther from the nucleus and more shielded. Rb therefore has the lowest first ionization energy among these choices.

Question 23 Solution

C. Metallic character generally increases downward and toward the left of the periodic table. Cesium is a low-lying alkali metal whose outer electron is readily lost.

Question 24 Solution

Light is electromagnetic radiation. It has wave properties and transfers energy in discrete packets called photons. Its speed in vacuum is approximately 3.00×10^8 m/s. It travels more slowly in materials such as water or glass.

Question 25 Solution

White light is a mixture of visible wavelengths that appears white to the eye. Colored light contains a narrower selection of visible wavelengths; a single-wavelength example has a color associated with that wavelength. A colored light need not contain only one wavelength.

Question 26 Solution

When illuminated with white light, an opaque blue object reflects blue wavelengths more strongly than most other visible wavelengths and absorbs much of the other light. The reflected blue light reaches the eye. Its appearance depends on the illuminating light; light containing no blue wavelengths will not make it appear the same blue.

Question 27 Solution

Both photon energy and frequency are inversely proportional to wavelength.

$$\nu = \frac{c}{\lambda}$$

$$E = h\nu = \frac{hc}{\lambda}$$

Shorter wavelength means higher frequency and greater energy per photon. Longer wavelength means lower frequency and less energy per photon.

Question 28 Solution

An emission spectrum is the set of wavelengths of light emitted by a substance. In the Bohr model, the electron in hydrogen can occupy only certain allowed energy levels. An excited electron can fall to a lower level and emit a photon.

$$E(\text{photon}) = E(\text{initial}) - E(\text{final})$$

Only specific energy differences are possible, so only specific photon energies and wavelengths are emitted. Those wavelengths appear as discrete spectral lines.

Question 29 Solution

A Bohr orbit is a definite circular path with an assigned energy. A quantum-mechanical orbital is a wavefunction describing an electron's spatial probability distribution. It gives the likelihood of finding the electron in different regions, rather than specifying a path.

Question 30 Solution

The ground state is the atom's lowest-energy electron arrangement. An excited state has higher energy because one or more electrons occupy higher-energy states than in the ground state. The atom can return to a lower energy state by releasing energy, often as a photon.

Question 31 Solution

For the main-group atoms used here, valence electrons occupy the highest occupied principal shell. They are the outer electrons most directly involved in bonding and chemical reactions. Core electrons occupy the inner filled shells. For example, chlorine has seven valence electrons in 3s and 3p and ten core electrons in its neon-like inner configuration.

Question 32 Solution

The block tells us the type of subshell being filled.

- (a) s block: the left two columns, plus helium. Helium has $1s^2$ even though its chemical properties place it in Group 18.
- (b) p block: the six columns at the right, excluding helium.
- (c) d block: the central ten columns.
- (d) f block: the two detached rows below the main body of the table.

Question 33 Solution

(c) Infrared. The listed types run from shortest to longest wavelength as X-ray < ultraviolet < visible < infrared.

Question 34 Solution

Energy per photon and frequency increase together, whereas wavelength varies inversely with both.

- (a) Radio waves < infrared < X-rays.
- (b) Radio waves < infrared < X-rays.
- (c) X-rays < infrared < radio waves.

Question 35 Solution

Both transitions end at the same lower level. The $n = 6$ starting level is higher in energy than $n = 5$, so the 6-to-2 transition emits the more energetic photon. Higher photon energy means shorter wavelength.

$n = 6 \rightarrow n = 2$: 410 nm

$n = 5 \rightarrow n = 2$: 434 nm

Question 36 Solution

The electron in 2s is, on average, closer. For comparable s orbitals in the same atom, increasing the principal shell number increases their characteristic size and average distance from the nucleus. This is an average statement, not a fixed path or fixed distance.

Question 37 Solution

A neutral atom has an electron count equal to its atomic number. Fill the subshells in order, respecting their capacities. Here 4s is listed before 3d and 5s after 4p.

(a) Sr, 38 electrons: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2$

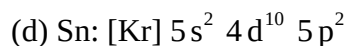
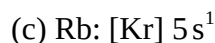
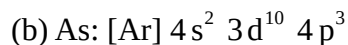
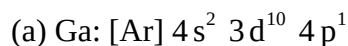
(b) Ge, 32 electrons: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$

(c) Li, 3 electrons: $1s^2 2s^1$

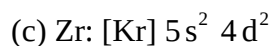
(d) Kr, 36 electrons: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$

Question 38 Solution

Start with the preceding noble gas, then place the remaining electrons in the subshells that follow it. Check that the noble-gas core plus the written occupancies totals the atomic number.

**Question 39 Solution**

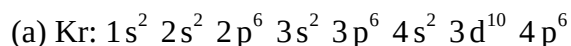
The d subshell being filled is one principal shell below the outer s subshell. Copper is an exception to the simplest filling pattern.



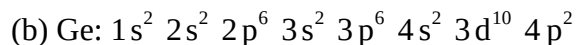
Cu has a filled 3d subshell and one 4s electron, rather than the simple prediction $4s^2 3d^9$.

Question 40 Solution

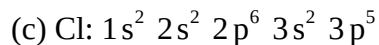
For these main-group atoms, the highest occupied principal shell contains the valence electrons. Lower-shell electrons are core electrons.



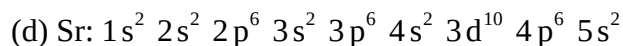
Valence: $4s^2 4p^6$, eight electrons. Core: all remaining subshells, 28 electrons.



Valence: $4s^2 4p^2$, four electrons. Core: all remaining subshells, including $3d^{10}$, 28 electrons.



Valence: $3s^2 3p^5$, seven electrons. Core: $1s^2 2s^2 2p^6$, ten electrons.



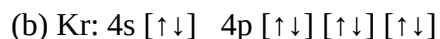
Valence: $5s^2$, two electrons. Core: the krypton configuration, 36 electrons.

Question 41 Solution

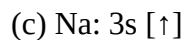
Each pair of brackets below represents one orbital. Up and down arrows represent opposite spin orientations. Fill degenerate p orbitals singly with parallel spins before pairing.



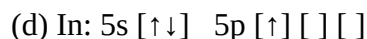
One unpaired electron.



Zero unpaired electrons.



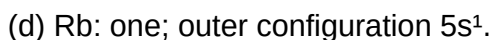
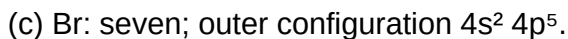
One unpaired electron.



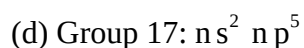
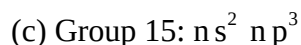
One unpaired electron.

Question 42 Solution

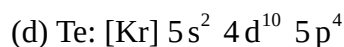
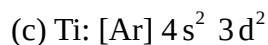
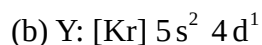
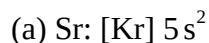
Use the main-group column or count the electrons in the highest occupied principal shell.

**Question 43 Solution**

The main-group column fixes the number of outer-shell s and p electrons.

**Question 44 Solution**

Read the subshell filling order from the s, d, and p blocks. In a d block, the principal number of the d subshell is one less than the period number.



Question 45 Solution

The superscript on 2p gives the answer. A heavier atom can have a filled 2p core even when its valence electrons are in a higher shell.

- (a) C: two, from $1s^2 2s^2 2p^2$.
- (b) N: three, from $1s^2 2s^2 2p^3$.
- (c) F: five, from $1s^2 2s^2 2p^5$.
- (d) P: six, from $1s^2 2s^2 2p^6 3s^2 3p^3$.

Question 46 Solution

Start with the neon core, then fill 3s and 3p across period 3.

- (a) Al: $[\text{Ne}] 3s^2 3p^1$; three valence electrons.
- (b) S: $[\text{Ne}] 3s^2 3p^4$.
- (c) Ar: $[\text{Ne}] 3s^2 3p^6$.
- (d) Mg: $[\text{Ne}] 3s^2$.

Question 47 Solution

Count all electrons, including those represented by the noble-gas core. A neutral atom's electron count equals its atomic number.

- (a) $10 + 2 + 3 = 15$: phosphorus, P.
- (b) $18 + 2 + 10 + 1 = 31$: gallium, Ga.
- (c) $18 + 2 + 6 = 26$: iron, Fe.
- (d) $36 + 1 = 37$: rubidium, Rb.

Question 48 Solution

Ionization energy generally increases upward and to the right. For diagonal comparisons, the two directions can compete, so a trend alone need not settle the answer.

- (a) As. It is above Bi in the same group.
- (b) Br. It is to the right of As in the same period.
- (c) I. Its measured first ionization energy, 10.451 eV, is slightly larger than S's 10.360 eV. The supplied values determine this close comparison.
- (d) S. It is above and to the right of Sb.

Question 49 Solution

The order of measured first ionization energies is:



Sn and Pb are an exception to the simple down-group decrease: Pb's supplied value is slightly greater than Sn's. Te is below S in Group 16, so Te is lower than S; Cl is to the right of S in period 3, so Cl is higher.

Question 50 Solution

Atomic size generally increases downward and to the left.

- (a) In, below Al in the same group.
- (b) Si, below and to the left of N.
- (c) Pb, below and to the left of P.
- (d) C, to the left of F in the same period.

Question 51 Solution

Atomic size generally increases downward and to the left.

$F < S < Si < Ge < Ca < Rb$

S is smaller than Si in period 3; Ge is below Si; Ca is left of Ge in period 4; and Rb is below and left of Ca. F, high on the right, is the smallest.

Question 52 Solution

Metallic character describes the tendency to lose electrons and generally increases downward and to the left.

- (a) Sr. It is farther to the left; Sr is a metal whereas Sb is a metalloid.
- (b) Bi. It is below As in the same group.
- (c) Cl. Both are nonmetals; Cl is less tightly bound in the first-ionization comparison and is more metallic in that relative sense. The diagonal positions alone are not a decisive shortcut.
- (d) As. It is below and to the left of S.

Question 53 Solution

The $n = 3$ shell contains 3s, 3p, and 3d. Their capacities are 2, 6, and 10 electrons.

Maximum = $2 + 6 + 10 = 18$ electrons

Equivalently, the shell capacity is $2n^2 = 2(3^2) = 18$. Capacity is different from the order in which subshells fill in a ground-state atom.

Question 54 Solution

Subtract electrons for a positive charge and add electrons for a negative charge.

(a) Ca^{2+} , $20 - 2 = 18$ electrons: $1s^2 2s^2 2p^6 3s^2 3p^6 = [\text{Ar}]$

(b) K^+ , $19 - 1 = 18$ electrons: $1s^2 2s^2 2p^6 3s^2 3p^6 = [\text{Ar}]$

(c) S^{2-} , $16 + 2 = 18$ electrons: $1s^2 2s^2 2p^6 3s^2 3p^6 = [\text{Ar}]$

(d) Br^- , $35 + 1 = 36$ electrons:

$$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 = [\text{Kr}]$$

All four have closed-shell noble-gas configurations. The first three are isoelectronic with argon; Br^- is isoelectronic with krypton.

Question 55 Solution

First count the electrons without changing the total. Then check which subshells exist and their capacities: s holds at most 2, p at most 6, and d at most 10.

(a) The s occupancies exceed 2 and 2p exceeds 6. There are $3 + 3 + 9 = 15$ electrons, identifying P.

Correct: $1s^2 2s^2 2p^6 3s^2 3p^3$

(b) A 2d subshell does not exist. There are $2 + 2 + 6 + 4 = 14$ electrons, identifying Si.

Correct: $1s^2 2s^2 2p^6 3s^2 3p^2$

(c) A 1p subshell does not exist. There are $2 + 5 = 7$ electrons, identifying N.

Correct: $1s^2 2s^2 2p^3$

(d) The 2p occupancy exceeds 6. There are $2 + 2 + 8 + 2 + 1 = 15$ electrons, identifying P.

Correct: $1s^2 2s^2 2p^6 3s^2 3p^3$

Question 56 Solution

The photon energy is positive even though the atom's energy decreases. Rearrange the photon-energy equation to solve for wavelength.

$$\lambda = \frac{hc}{E}$$

$$\lambda = \frac{(6.626 \times 10^{-34} \text{ J s})(3.00 \times 10^8 \text{ m/s})}{3.0 \times 10^{-19} \text{ J}} = 6.626 \times 10^{-7} \text{ m}$$

To the two significant figures in the supplied energy:

$$\lambda = 6.6 \times 10^{-7} \text{ m} = 6.6 \times 10^2 \text{ nm}$$

This is visible red light. The rounded energy in the question limits the precision of the calculated wavelength.