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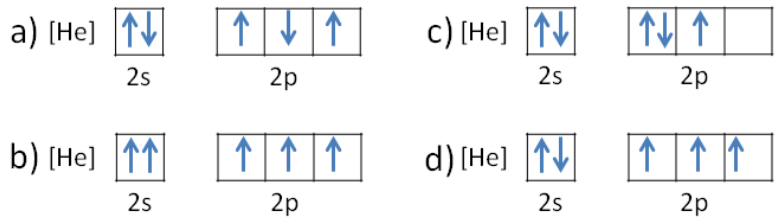
# Exercises Topic 1: Atoms

**1.** Consider the equation for an electronic transition from a certain level $n_i$ to a final state $n_f$. Calculate the first ionization energy for the hydrogen atom in its ground state in eV and joules.
Data: h = 6.626 × $10^{-34}$ J·s; $q_e$ = -1.609·$10^{-19}$ C
**Solution:** $n_f = \infty$, $n_i = 1$; I = 2.181·$10^{-18}$ J = 13.6 eV

**2.** $He^+$ ion suffers a transition between $n_i = 3$ to $n_f = 2$. Calculate the wavelength in nm of the emitted radiation. To which range of the electromagnetic spectrum belongs this radiation?
**Solution:** λ = 656.11 nm; visible

**3.** Consider the Heisenberg's Uncertainty Principle. Suppose that the precision with which mass and velocity can be determined is of 1 part in $10^{-12}$ parts. Which is the precision for the position of:
a) A meteorite with mass = $10^{15}$ tons, moving at 200 km·$s^{-1}$?
b) An electron that moves at 1/200 the speed of light
Data: h = 6.626 × $10^{-34}$ J·s; $m_e$ = 9.11·$10^{-28}$ g
**Solution**: a) Δx = 1.32·$10^{-40}$; b) Δx = 19.3 m

**4.** Which of the following is the correct orbital diagram for the ground-state electron configuration of nitrogen (Z = 7)? Explain what is wrong with each of the others.




**Solution**: The correct one is d); b) has two electrons with the same quantum numbers; a) and c) violate Hund's rule.

**5.** Write the electronic configurations for the following species in the ground state: Cl , $I^-$, Cu, $Ta^{3+}$, Xe. How many unpaired electrons have each of them?
**Solution**:[Cl]=[Ne]$3s^2p^5$, 1 unpaired $e^-$ ;[$I^-$]=[Kr]$4s^2p^6$, no unpaired $e^-$ ;[Cu]=[Ar]$4s^23d^9$, 1 unpaired $e^-$;[$Ta^{3+}$]=[Xe]$4f^96s^2$, no unpaired $e^-$; [Xe] =[Kr]$5s^24d^{10}5p^6$, no unpaired $e^-$.

**6.** Arrange the following species in order of increasing size: Ar, $Rb^+$, $Cl^-$, $S^{2-}$ and $Sr^{2+}$.
**Solution**: $Sr^{2+}$< $Rb^+$ <Ar < $F^-$ < $O^{2-}$

**7.** Given the following electron configurations: a) $2s^1$; b)$1s^22s^2p^63s^2p^64s^23d^3$; c) $1s^22s^2p^63s^2p^3$: d) $1s^22s^2p^63s^2p^64s^1$:
a) Indicate the corresponding chemical element for each one.
b) Arrange them in order of increasing first ionization energy and electronegativity.
**Solution**: a) Li, b) V, c) P, d) K; b) $I_1$ : Li < K < V < P; E: Li < K < V < P

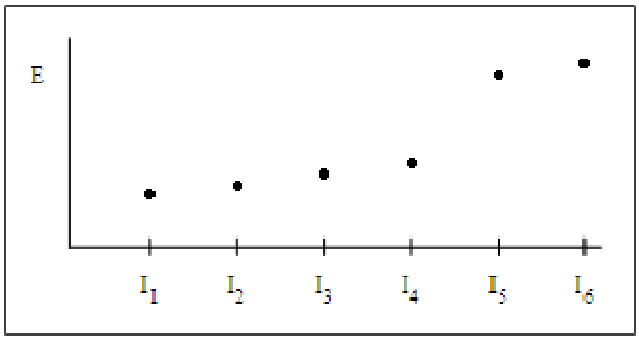
**8.** In the following table the n$^{th}$ successive ionization energies of several elements are collected. Look at them and answer the following questions:

| Element | Ionization Energy (kJ/mol) | | | | |
|---|---|---|---|---|---|
| | 1$^{st}$ | 2$^{nd}$ | 3$^{rd}$ | 4$^{th}$ | 5$^{th}$ |
| A | 630 | 1230 | 2390 | 7090 | 8840 |
| R | 590 | 1150 | 4900 | 6470 | 8140 |
| E | 550 | 1060 | 4210 | 5500 | 6910 |
| D | 500 | 4560 | 6900 | 9540 | 13300 |
| C | 650 | 1590 | 2980 | 4740 | 6690 |

Which two elements of the following pairs belong to the same group? Why?
1) A and R 2) C and D 3) D and E 4) R and E 5) C and E

What of the following chloride derivatives are correct? Why?
1) $DCl_2$ 2) $ECl_2$ 3) $RCl_3$ 4) $DCl_4$ 5) DCl
**Solution**: a) L and R belong to the same group; Correct 2) and 5)

**9.** Indicate which of the following elements will present the following pattern in the ionization energy: $^{11}$Na; $^{14}$Si; $^{13}$Al; $^{35}$Br; $^{7}$N; $^{8}$O. Explain your reasoning.




**Solution**: Oxygen because has four electrons in p and then experiences a jump.

**10.** In the spectrum of atomic hydrogen, a blue line is observed at 486 nm. Determine the beginning and ending energy levels of the electron during the emission of energy that leads to this spectral line
**Solution**: The initial level is 2 (visible: Balmer series) and the end is 4.

**11.** The velocity of an electron that is emitted from a metallic surface by a photon is 150 km·s$^{-1}$. (a) What is the wavelength of the ejected electron? (b) No electrons are emitted from the surface of the metal until the frequency of the radiation reaches $2 \cdot 10^{17}$ Hz. How much energy is required to remove the electron from the surface? (c) What is the wavelength of the radiation that caused the ejection of the electron? (d) What kind of radiation was used?
**Solution**: (a) 4.8nm; (b) $1.325 \cdot 10^{-16}$ J ; (c) 1.5 nm; (d) X-Ray

**12.** What are the principal and orbital angular momentum quantum numbers for each of the following orbitals: (a) 1s; (b) 5f; (c) 3d; (d) 2p

**Solution**: (a) n=1 and l=0; (b) n=5 and l=3; (c) n=3 and l=2; (d) n=2 and l=1

**13.** How many electrons can have the following quantum numbers in an atom: (a) n=2; (b) n=1, l=0; (c) n=3, l=2, $m_l$=-1; (e) n=3, l=2, $m_l$=1, $m_s$=1/2
**Solution**: (a) 8; (b) 2; (c) 2; (d) 1

**14.** Among the following sets of quantum numbers {n, l, $m_l$, $m_s$} identify the ones that are forbidden for an electron in an atom and explain why they are invalid: (a) {2,2,-1,+1/2}; (b) {5,0,-1,+1/2}; (c) {4,3,-1,0}
**Solution**: (a)Wrong, *l* must be smaller than *n* ; (b) Right ;(c) Wrong, $m_s$ can only be +1/2 or -1/2.

**15.** Predict the number of valence electrons present in each of the following atoms (include the outermost d-electrons): (a) O; (b) Zr; (c) S; (d) Br
**Solution**: (a) $6e^-$ ; (b) $4e^-$ ;(c) $6e^-$ ; (d) $7e^-$

**16.** Which member of each pair has the smallest first ionization energy and smallest second ionization energy: (a) Sr or Ca; (b) K or Ca; (c) Al or Na
**Solution**: Smallest 1$^{st}$ IE: (a) Sr; (b) K; (c) Na; Smallest 2$^{nd}$ IE: (a) Sr; (b) Ca; (c) Al

**17.** Identify the following elements as metals, nonmetals or metalloids: (a) lead; (b) phosphorus; (c) cadmium; (d) silicon; (e) antimony; (f) lithium; (g) aluminum; (h) carbon; (i) germanium; (j) arsenic; (k) tin; (l) astatine.
**Solution**: (a) metal; (b) non-metal; (c) metal; (d) metalloid; (e) metalloid; (f) metal; (g) metalloid; (h) non-metal; (i) metalloid; (j) metalloid; (k) metal; (l) non-metal.