

# CHEMISTRY



## Periodic Table of Elements

|              |             |              |              |              |              |              |              |              |             |              |              |              |              |              |             |            |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |
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| 1            |             |              |              |              |              |              |              |              |             |              |              |              |              |              |             |            | 2            |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |
| H<br>1.008   |             |              |              |              |              |              |              |              |             |              |              |              |              |              |             |            | He<br>4.002  |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |              |
| 3            | 4           |              |              |              |              |              |              |              |             |              |              |              |              |              |             | 5          | 6            | 7            | 8            | 9            | 10           |              |              |              |              |              |              |              |              |              |              |              |              |              |
| Li<br>6.941  | Be<br>9.012 |              |              |              |              |              |              |              |             |              |              |              |              |              |             | B<br>10.81 | C<br>12.01   | N<br>14.01   | O<br>16.00   | F<br>18.998  | Ne<br>20.18  |              |              |              |              |              |              |              |              |              |              |              |              |              |
| 11           | 12          |              |              |              |              |              |              |              |             |              |              |              |              |              |             | 19         | 20           | 21           | 22           | 23           | 24           | 25           | 26           | 27           | 28           | 29           | 30           |              |              |              |              |              |              |              |
| Na<br>22.99  | Mg<br>24.31 |              |              |              |              |              |              |              |             |              |              |              |              |              |             | K<br>39.10 | Ca<br>40.08  | Sc<br>44.96  | Ti<br>47.88  | V<br>50.94   | Cr<br>52.00  | Mn<br>54.94  | Fe<br>55.85  | Co<br>58.93  | Ni<br>58.69  | Cu<br>63.55  | Zn<br>65.38  |              |              |              |              |              |              |              |
| 37           | 38          | 39           | 40           | 41           | 42           | 43           | 44           | 45           | 46          | 47           | 48           | 49           | 50           | 51           | 52          | 53         | 54           | 55           | 56           | 57           | 58           | 59           | 60           | 61           | 62           | 63           | 64           | 65           | 66           | 67           | 68           | 69           | 70           | 71           |
| Rb<br>85.47  | Sr<br>87.62 | Y<br>88.91   | Zr<br>91.22  | Nb<br>92.91  | Mo<br>95.94  | Tc<br>98.91  | Ru<br>101.07 | Rh<br>101.07 | Pd<br>106.3 | Ag<br>107.87 | Cd<br>112.41 | In<br>114.82 | Sn<br>118.71 | Sb<br>121.76 | Te<br>127.6 | I<br>126.9 | Xe<br>131.3  | Cs<br>132.91 | Ba<br>137.33 | La<br>138.91 | Ce<br>140.12 | Pr<br>140.91 | Nd<br>144.24 | Pm<br>144.91 | Sm<br>150.36 | Eu<br>151.96 | Gd<br>157.25 | Tb<br>158.93 | Dy<br>162.50 | Ho<br>164.93 | Er<br>167.26 | Tm<br>168.93 | Yb<br>173.05 | Lu<br>174.97 |
| 73           | 74          | 75           | 76           | 77           | 78           | 79           | 80           | 81           | 82          | 83           | 84           | 85           | 86           | 87           | 88          | 89         | 90           | 91           | 92           | 93           | 94           | 95           | 96           | 97           | 98           | 99           | 100          | 101          | 102          | 103          | 104          | 105          | 106          | 107          |
| Ta<br>180.95 | W<br>183.84 | Re<br>186.21 | Os<br>190.23 | Ir<br>192.22 | Pt<br>195.08 | Au<br>196.97 | Hg<br>200.59 | Tl<br>204.38 | Pb<br>207.2 | Bi<br>208.98 | Po<br>209    | At<br>210    | Rn<br>222    | Fr<br>223    | Ra<br>226   | Ac<br>227  | Th<br>232.04 | Pa<br>231.04 | U<br>238.03  | Np<br>237.05 | Pu<br>244.06 | Am<br>243.06 | Cm<br>247.07 | Bk<br>247.07 | Cf<br>251.08 | Es<br>252.08 | Fm<br>257.10 | Md<br>258.10 | No<br>259.10 | Lr<br>262.11 |              |              |              |              |

1

H

1.008

ATOMIC  
NUMBER

SYMBOL

ATOMIC  
WEIGHT

|       |               |
|-------|---------------|
| 1     | ATOMIC NUMBER |
| H     | SYMBOL        |
| 1.008 | ATOMIC WEIGHT |

- Elemental forms:**
  - Monoatomic:** Noble gases: helium, neon, argon, krypton, xenon, and radon; nonreactive
  - Diatomics:** Gases: fluorine, chlorine, hydrogen, oxygen, and nitrogen; Liquid: bromine; Solid: iodine
  - Molecular solids:** Sulfur
  - Covalent solids:** Carbon (diamond, graphite)
  - Metals:** Most common type of element; high coordination numbers; very dense
- Types of compounds:** Large variety due to ionic, covalent, and metallic bonding options
  - Ionic:** Electron exchange
  - Covalent:** Shared electrons
    - Polar covalent: Unequal sharing
  - Ion complex:** Central ion + Solvent
  - Transition metal compounds:**
    - Coordination compounds: Non-bonding ligands
    - Organometallics: Metal-C bond
  - Complex minerals:** Metal oxides and silicates
- Periodicity:** The chemical properties of an element depend on valence electrons
  - Family of elements:** Column in periodic table
  - The addition of d-orbitals produces an expanded octet

### Periodic Trends

- Chemistry determined by the behavior of valence electrons
- Atoms or ions get larger as you go down the column; electron shells are added
- Cation and anions (same charge) decrease in size as the atomic number ( $Z$ ) increases

- Ionization energies:** Noble gases are the most stable; alkali metals are the easiest to ionize; electron screening lessens  $Z$ -effect on orbital energy
- Atomic and ionic radii:** Not real properties; derive from structural data; divide bond into radii using a consistent scheme
  - Ionic radius:** Depends on charge, counter ion, and coordination (crystal type)
  - Atomic radius:** Based on diatomic gas data or metallic solid structural data

### Development of the Periodic Table

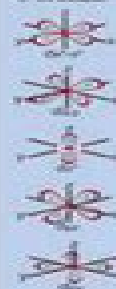
- Missing elements were predicted using periodicity
- Column 1: Alkali metals
- Column 2: Alkaline earth metals
- First transition series: Titanium-Copper
- Column 17: Halogens: fluorine, chlorine, bromine, iodine, and astatine
- Column 18: Rare gases: helium, neon, argon, krypton, xenon, and radon
- Artificial:  $Z = 90$  or above; radioactive
- Lanthanides: f-subshell elements; starts with  $Z = 58$



### Practical Application

- The colors of fireworks depend on the elements in the explosive

d-subshell 5 orbitals



p-subshell 3 orbitals



s-subshell 1 orbital



## Atomic Structure

- Atomic number ( $Z$ ):** The number of protons in the nucleus; for a neutral atom,  $Z$  = number of electrons; for an anion of charge  $-q$ ,  $Z = +q$  electrons; for a cation of charge  $+q$ ,  $Z = -q$  electrons
- Mass number ( $A$ ):**  $A = Z + N$ , where  $N$  = the number of neutrons in the nucleus
- Isotopes:** Atoms with the same  $Z$ , different  $A$ ; an element can have one or more isotopes; any sample contains a number of isotopes; in practical work, use the average mass number or atomic weight (weighted average of natural isotopes for a given element)



## Atomic Quantum Numbers & Orbitals

- $n$ : principle**
  - angular momentum (orbital shape)
  - magnetic (orbital direction)
  - electron spin
- For each  $n$ , the possible  $l$  values are  $0, 1, \dots, n-1$
- For each  $l$ , the possible  $m_l$  values are  $-l, \dots, 0, \dots, +l$
- $m_s$  has two possible values:  $+\frac{1}{2}$  and  $-\frac{1}{2}$  (spin up, spin down)
- Each value of  $n$  denotes a "shell" in the atomic structure; each  $l$  denotes a subshell
  - s-orbital:  $l = 0$ , 1 type
  - d-orbital:  $l = 2$ , 5 types
  - p-orbital:  $l = 1$ , 3 types
  - f-orbital:  $l = 3$ , 7 types

### Many-Electron Atoms

Orbitals and quantum numbers derived for the hydrogen atom are used to describe all many-electron atoms and ions; a more rigorous treatment determines exact energy levels and orbital properties; the main result is that subshells have different energies; the filling of levels is guided by the Aufbau principle:

### Aufbau Order for Filling Subshells



| $n$ | $l$ | $m_l$ | $m_s$          | element |
|-----|-----|-------|----------------|---------|
| 1   | 0   | 0     | $+\frac{1}{2}$ | H       |
| 1   | 0   | 0     | $-\frac{1}{2}$ | He      |
| 2   | 0   | 0     | $+\frac{1}{2}$ | Li      |
| 2   | 0   | 0     | $-\frac{1}{2}$ | Be      |
| 2   | 1   | -1    | $+\frac{1}{2}$ | B       |
| 2   | 1   | 0     | $+\frac{1}{2}$ | C       |
| 2   | 1   | 0     | $-\frac{1}{2}$ | N       |
| 2   | 1   | +1    | $+\frac{1}{2}$ | O       |
| 2   | 1   | +1    | $-\frac{1}{2}$ | F       |
| 2   | 1   | +1    | $-\frac{1}{2}$ | Ne      |

- Electron configuration:** Atomic orbital occupancy for an atom
- Pauli exclusion principle:** Each electron has a unique set of quantum numbers; an orbital may hold up to two electrons: one with spin up,  $m_s = +\frac{1}{2}$ , and one with spin down,  $m_s = -\frac{1}{2}$
- Hund's rule:** Electrons fill p, d, and f subshells in a manner to maximize the number of unpaired electrons (half-filled orbitals); spin is maximized
- Ionization potential (IP):** Energy required to remove electron from an atom or ion
  - First IP:** Removal of first valence electron
- Electronegativity:** Tendency of an atom to attract electrons in a chemical bond; 0-4 scale, 0 for rare gas

# Lavc Chemistry Study Guide

**JE Gale**



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## **Table of Contents Lavc Chemistry Study Guide**

1. Understanding the eBook Lavc Chemistry Study Guide
  - The Rise of Digital Reading Lavc Chemistry Study Guide
  - Advantages of eBooks Over Traditional Books
2. Identifying Lavc Chemistry Study Guide
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Lavc Chemistry Study Guide
  - User-Friendly Interface
4. Exploring eBook Recommendations from Lavc Chemistry Study Guide
  - Personalized Recommendations

- Lavc Chemistry Study Guide User Reviews and Ratings
- Lavc Chemistry Study Guide and Bestseller Lists
- 5. Accessing Lavc Chemistry Study Guide Free and Paid eBooks
  - Lavc Chemistry Study Guide Public Domain eBooks
  - Lavc Chemistry Study Guide eBook Subscription Services
  - Lavc Chemistry Study Guide Budget-Friendly Options
- 6. Navigating Lavc Chemistry Study Guide eBook Formats
  - ePub, PDF, MOBI, and More
  - Lavc Chemistry Study Guide Compatibility with Devices
  - Lavc Chemistry Study Guide Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Lavc Chemistry Study Guide
  - Highlighting and Note-Taking Lavc Chemistry Study Guide
  - Interactive Elements Lavc Chemistry Study Guide
- 8. Staying Engaged with Lavc Chemistry Study Guide
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Lavc Chemistry Study Guide
- 9. Balancing eBooks and Physical Books Lavc Chemistry Study Guide
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Lavc Chemistry Study Guide
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine Lavc Chemistry Study Guide
  - Setting Reading Goals Lavc Chemistry Study Guide
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Lavc Chemistry Study Guide
  - Fact-Checking eBook Content of Lavc Chemistry Study Guide

- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
  - Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
- 14. Embracing eBook Trends
  - Integration of Multimedia Elements
  - Interactive and Gamified eBooks

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