Chemistry
for Teacher I

Faculty of Education,
Suan Sunandha Rajabhat University

Course Outline

Course Title: Basic Chemistry (Wk1-17/2025)

Email: Jadsadassru@gmail.com

Office: 1145

Website: http://www.eledu.ssru.ac.th/jadsada_ra/

Course description

Atomic structures, Elements and periodic table, Chemical bonding, Stoichiometry and solutions, Properties of gases, solids, and liquids; Applying knowledge to explain natural phenomena using empirical evidence; Using science laboratory according to international standards; Applying knowledge for science learning management in the basic education level appropriated with local conditions and contexts

Course Outline

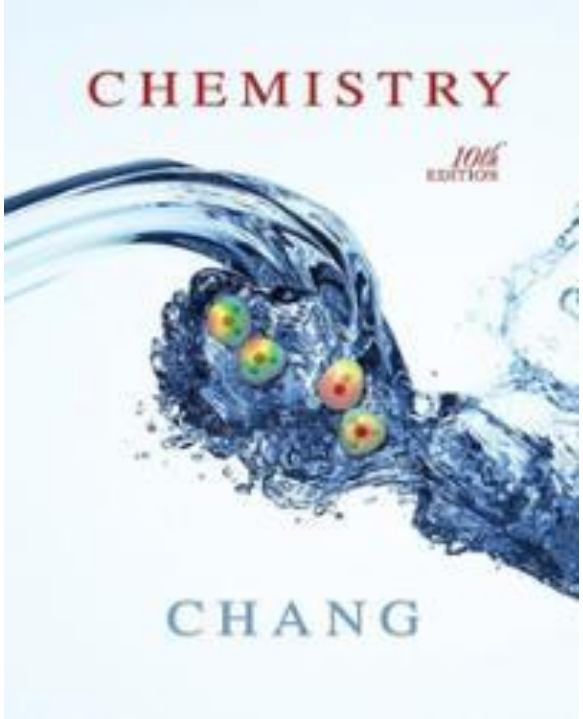
EVALUATION:

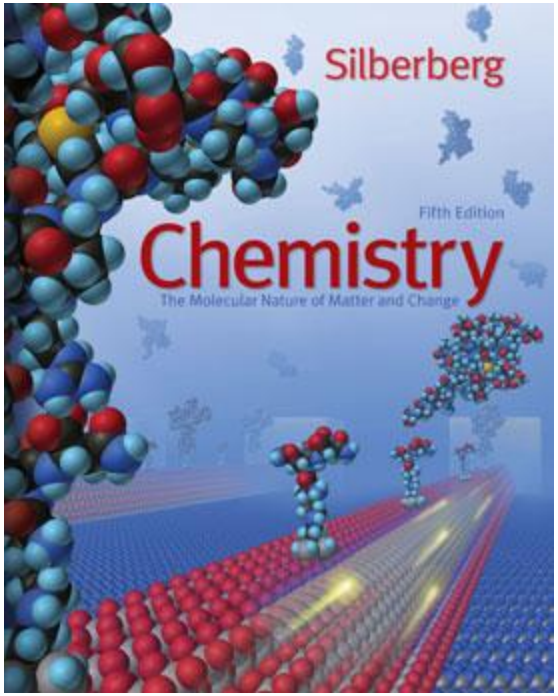
The final Grade for the course will be computed as:

Classroom attendance	10%
Problem Sets	10%
Lab report	20%
Midterm exam =	30%
Final exam =	30%

Recommended textbooks: Chemistry for Teachers

1. Chang, R. (2020). *Chemistry:* McGraw-Hill.
2. Silberberg, M., & Amateis, P. (2023). *Chemistry The Molecular Nature of Matter and Change 7th edition:* McGraw-Hill Science.





LAB SAFETY

1. Always wear lab coat
2. Wear gloves and safety goggles
3. Do not wear open-toed shoes
4. Do not eat at your workspace
5. Clean up your workspace
6. Do not obstruct eyewash station and emergency shower

labsafety.sabanciuniv.edu

LECTURE

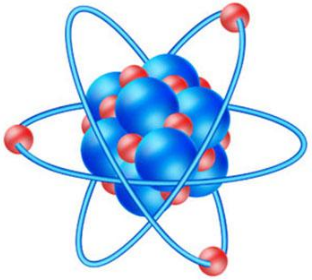
1

2nd semester

Academic Year 2025

Faculty of Education

Suansunandha Rajabhat University



ATOMIC

STRUCTURE

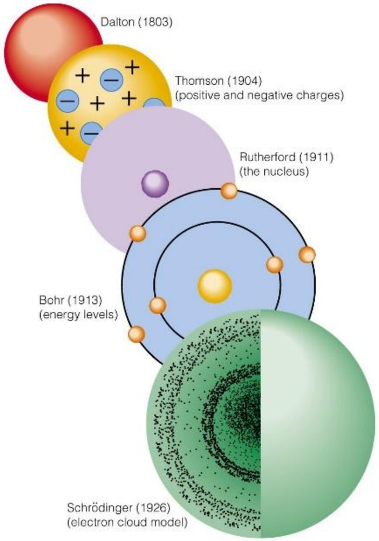
CHEMISTRY

This presentation was modified and used for academic purpose only. Picture and material were taken from references shown on the bottom in each pages

OUTLINE

1.1 Atomic structure

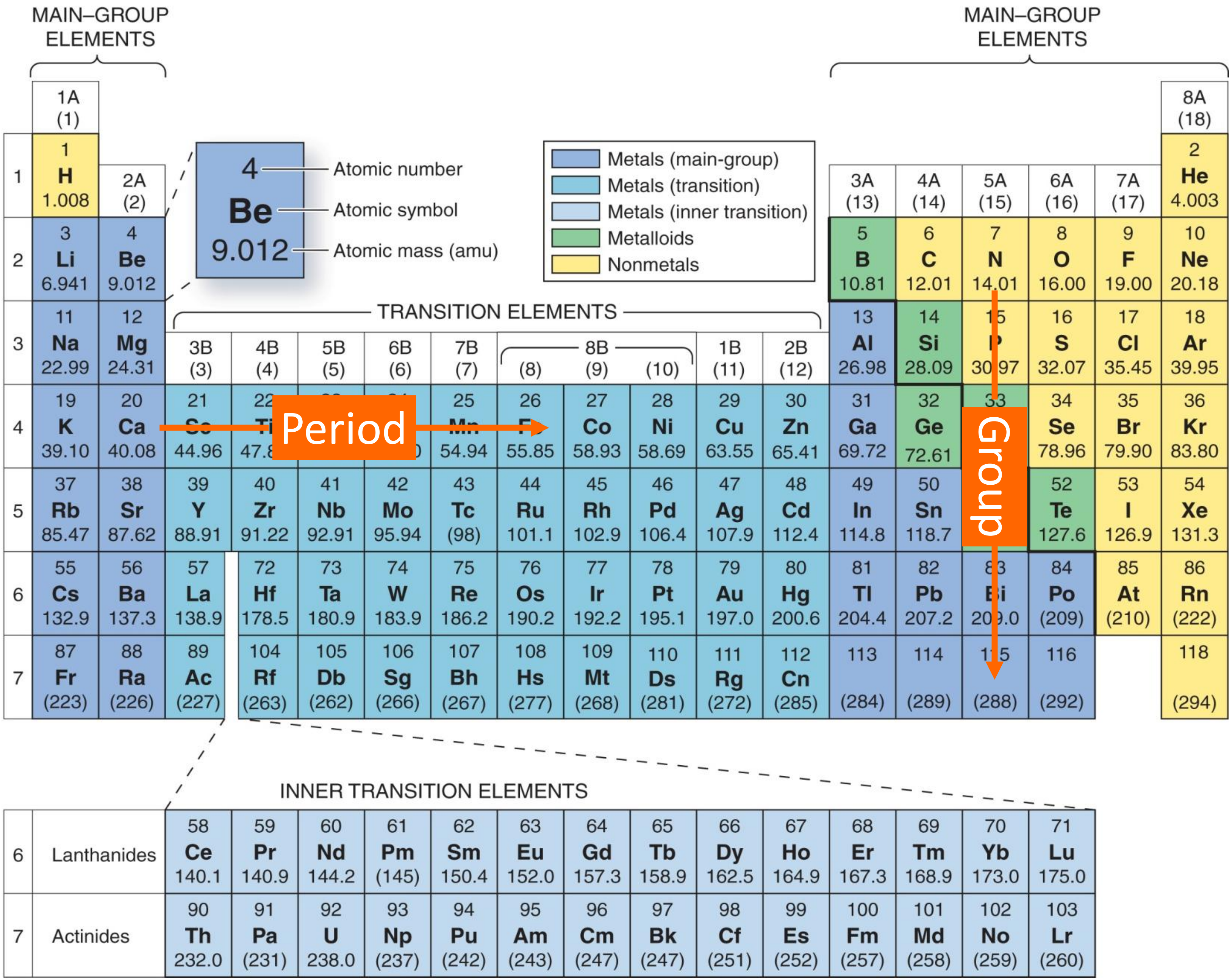
- ☐ Early atomic structure
- ☐ Bohr Model
- ☐ Schrödinger atom
- ☐ Atomic orbital
- ☐ Electron configurations



1.2 Periodic Table Trend and Atomic Properties

- ➢ Introduction to Periodic Table
- ➢ Atomic Size
- ➢ Ionization Energies
- ➢ Metals and Nonmetals

The modern periodic table.



🟦 Metals (main-group)
🟦 Metals (transition)
🟦 Metals (inner transition)
🟩 Metalloids
🟨 Nonmetals

	1A (1)	2A (2)	3B (3)	4B (4)	5B (5)	6B (6)	7B (7)	8B (8)	(9)	(10)	1B (11)	2B (12)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1	1 **H** 1.008																	2 **He** 4.003
2	3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.8			25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.41	31 **Ga** 69.72	32 **Ge** 72.61	33	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7		52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (263)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (267)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 (284)	114 (289)	115 (288)	116 (292)		118 (294)

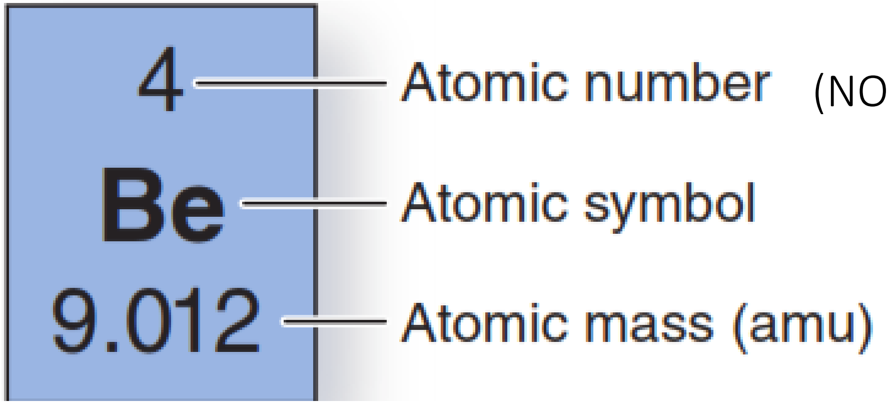
INNER TRANSITION ELEMENTS

6	Lanthanides	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
7	Actinides	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change:* McGraw-Hill Science.

Organization of the Periodic Table

- ☐ Each element has a box that contains its atomic number, atomic symbol, and atomic mass

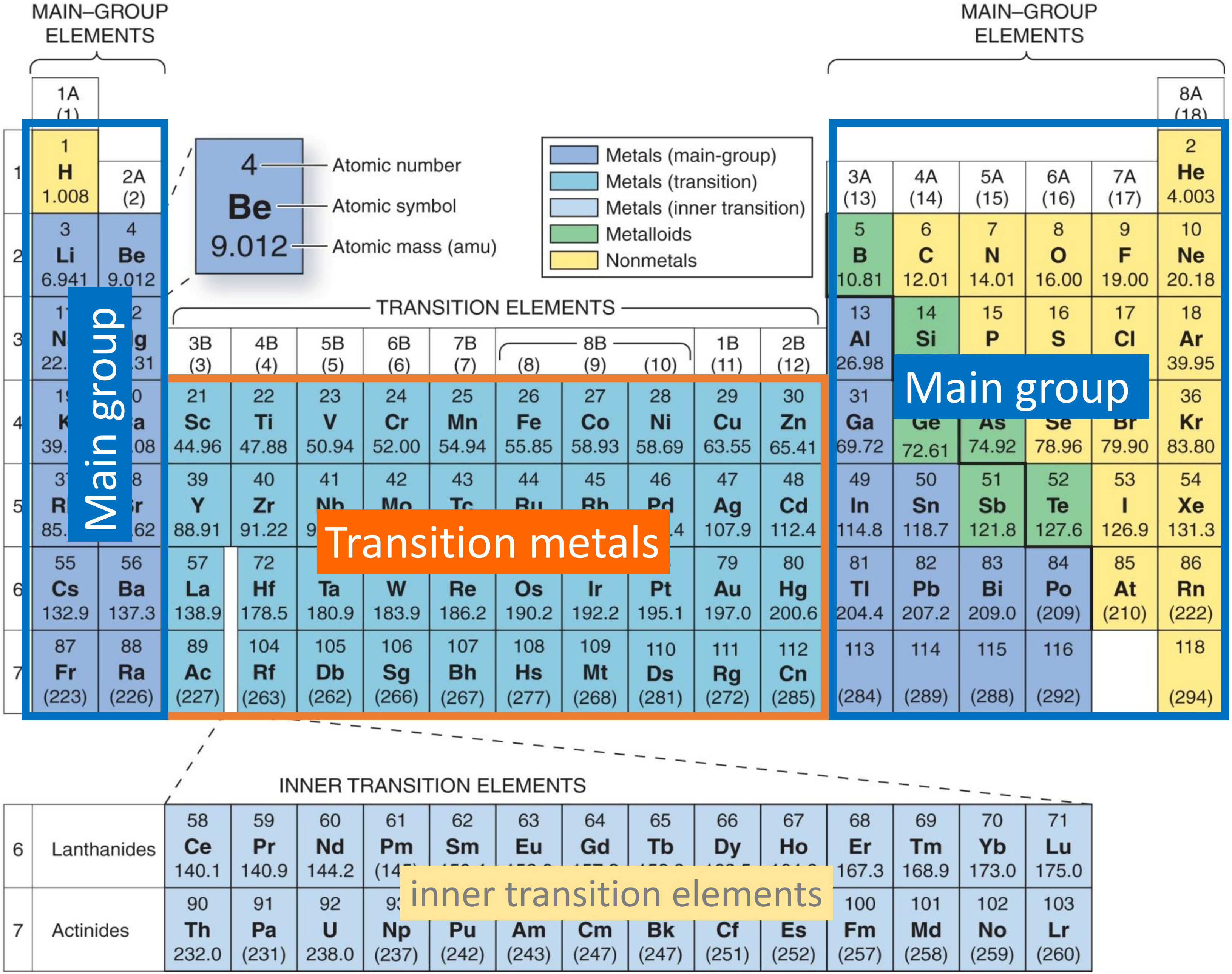


(NO. of proton)

- ☐ The boxes lie, from left to right, in order of ***increasing atomic number*** (number of protons in the nucleus).

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change:* McGraw-Hill Science.

The modern periodic table.



MAIN–GROUP ELEMENTS

TRANSITION ELEMENTS

MAIN–GROUP ELEMENTS

4 — Atomic number
Be — Atomic symbol
9.012 — Atomic mass (amu)

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🟩 Metalloids
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4	19 K 39.	0 a .08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	Ge 72.61	As 74.92	Se 78.96	Br 79.90	36 Kr 83.80
5	37 R 85.	8 r .62	39 Y 88.91	40 Zr 91.22	41 Nb 9	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd .4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	Ta 180.9	W 183.9	Re 186.2	Os 190.2	Ir 192.2	Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
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INNER TRANSITION ELEMENTS

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Main group

Transition metals

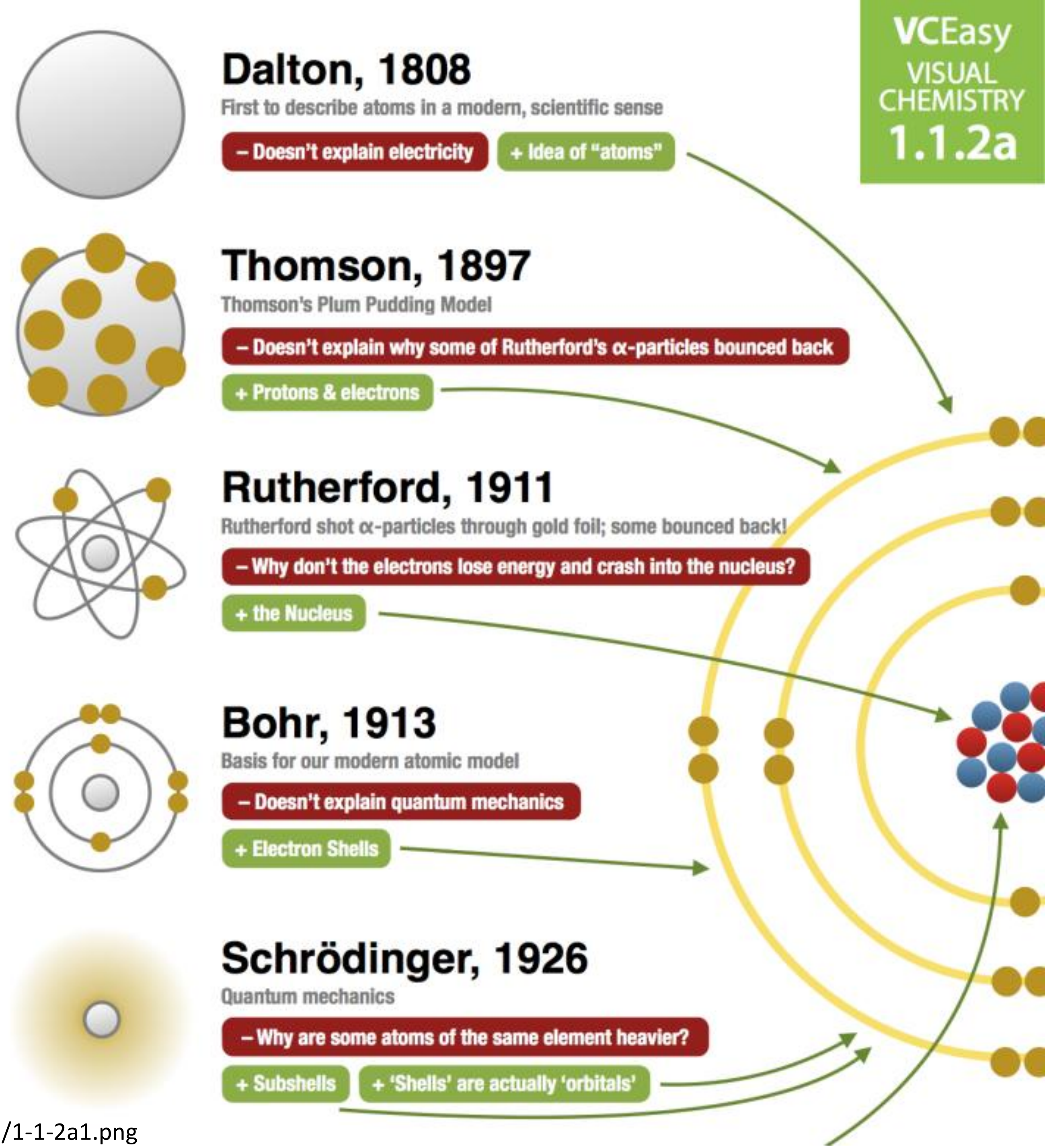
Main group

inner transition elements

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change:* McGraw-Hill Science.

Timeline

Atomic Structure



Dalton, 1808

First to describe atoms in a modern, scientific sense

– Doesn't explain electricity

+ Idea of "atoms"

Thomson, 1897

Thomson's Plum Pudding Model

– Doesn't explain why some of Rutherford's α-particles bounced back

+ Protons & electrons

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Rutherford shot α-particles through gold foil; some bounced back!

– Why don't the electrons lose energy and crash into the nucleus?

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Basis for our modern atomic model

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Schrödinger, 1926

Quantum mechanics

– Why are some atoms of the same element heavier?

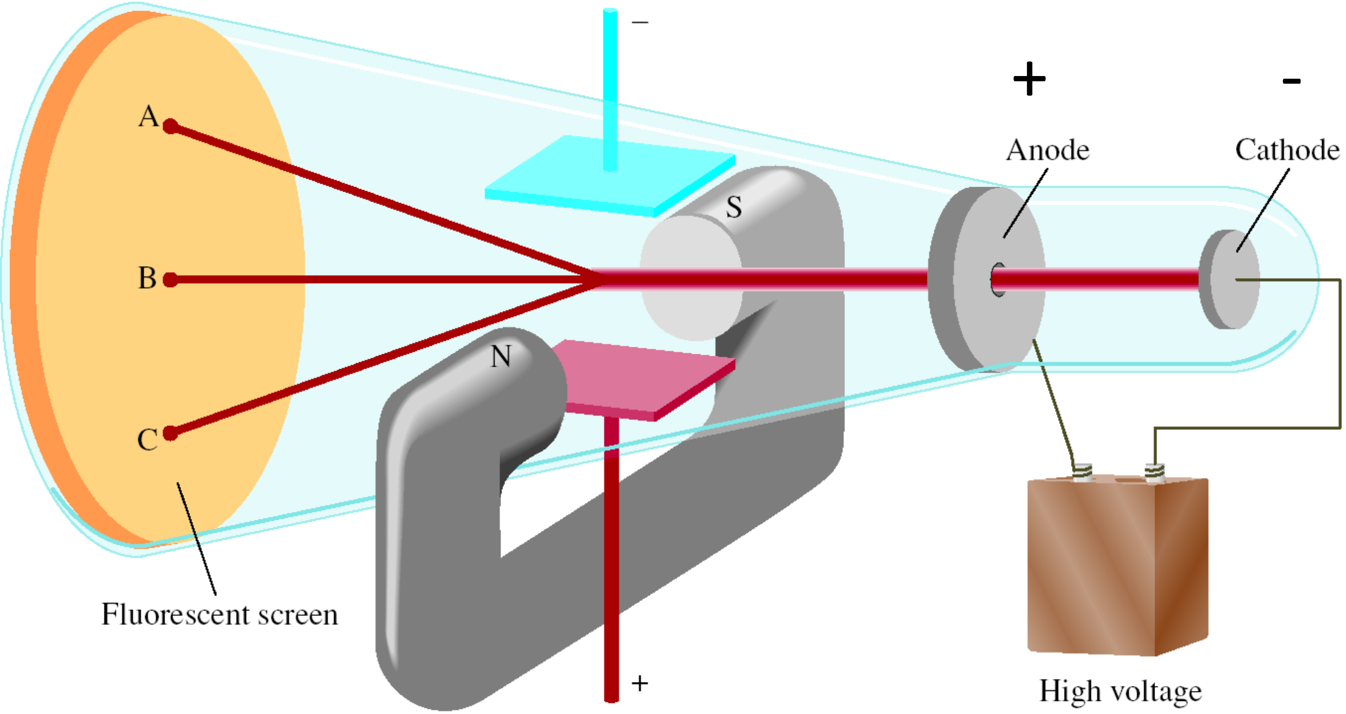
+ Subshells

+ 'Shells' are actually 'orbitals'

https://vceasy.files.wordpress.com/2014/02/1-1-2a1.png

Thomson's Experiment (1890)

- ☐ **A cathode ray tube**
  - eject particles from plates
  - cathode ray found to be negative



A → the presence of a magnetic field

B → the effects of the electric field and magnetic field cancel each other.

C → the presence of an electric field

Chang, R. (2010). Chemistry: McGraw-Hill.

Thomson's Experiment (1890)

Sir J.J. Thomson

(British physicist)

https://global.britannica.com/biography/J-J-Thomson

☐ He used a cathode ray tube to show that the atoms of any element can be made to emit tiny negative particles.

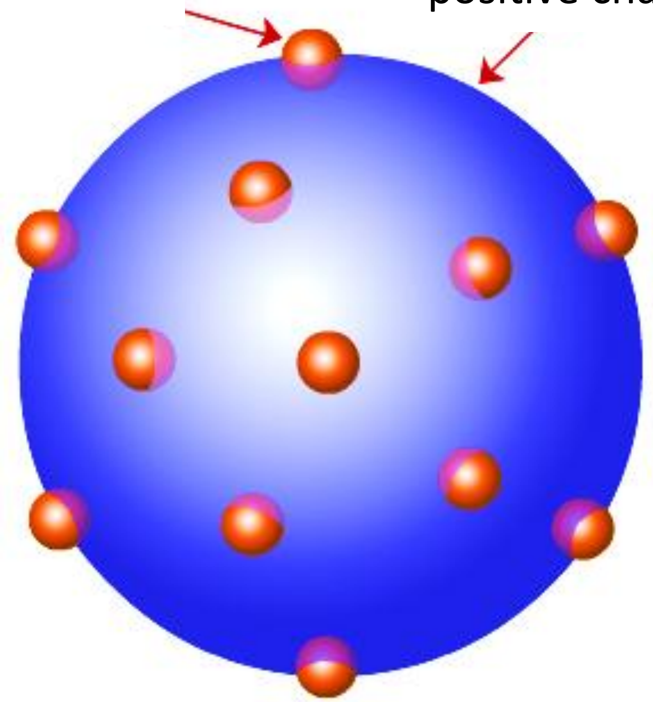
☐ all types of atoms must contain these negative particles, which are now called ***electrons***.

☐ Charge/mass of e = 1.76×10^8 coulombs/gram

☐ atom must also contain positive particles that balance exactly the negative charge carried by the electrons, giving the atom a zero overall charge.

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Thomson’s Atomic model



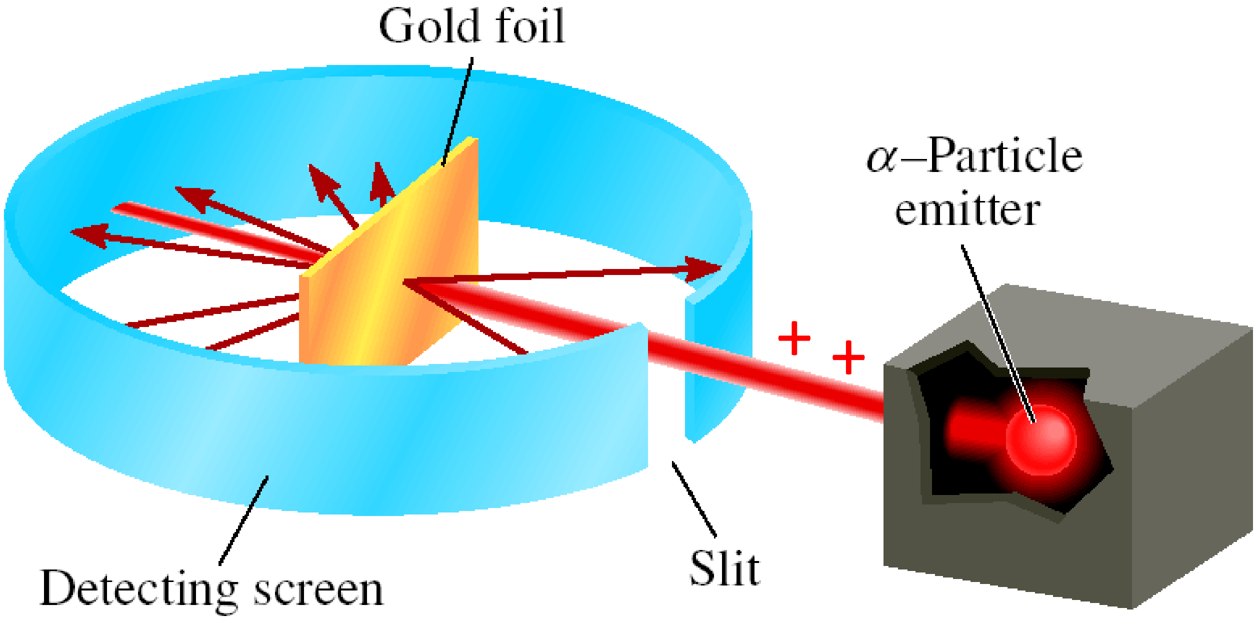
plum-pudding” model

- Thomson proposed that an atom could be thought of as a uniform, positive sphere of matter in which electrons are embedded like raisins in a cake

Chang, R. (2010). *Chemistry:* McGraw-Hill.

Rutherford’s Experiment

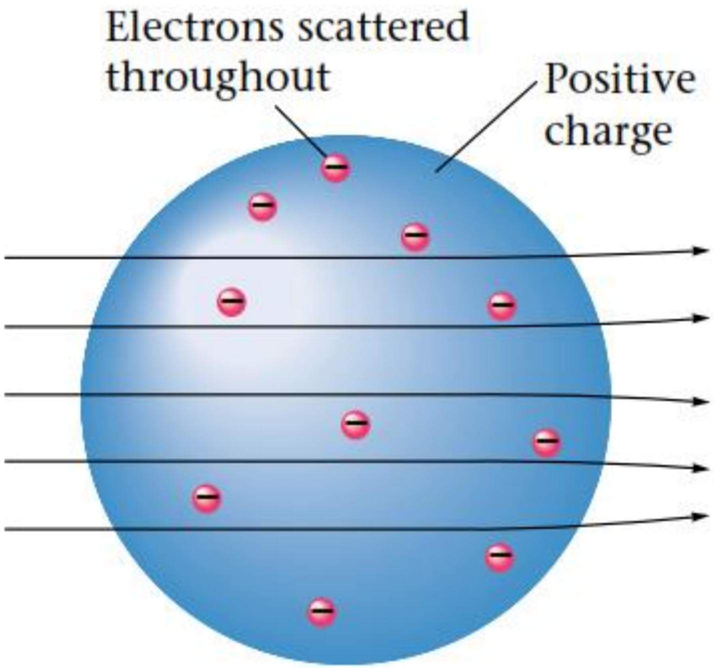
- ☐ In 1910, New Zealand physic, Erbest Rutherford, tested this **plum-pudding” model** and obtained a very unexpected result
- ☐ Rutherford knew that if the plum pudding model of the atom were correct, the massive alpha particles would crash through the thin foil like cannonballs through paper

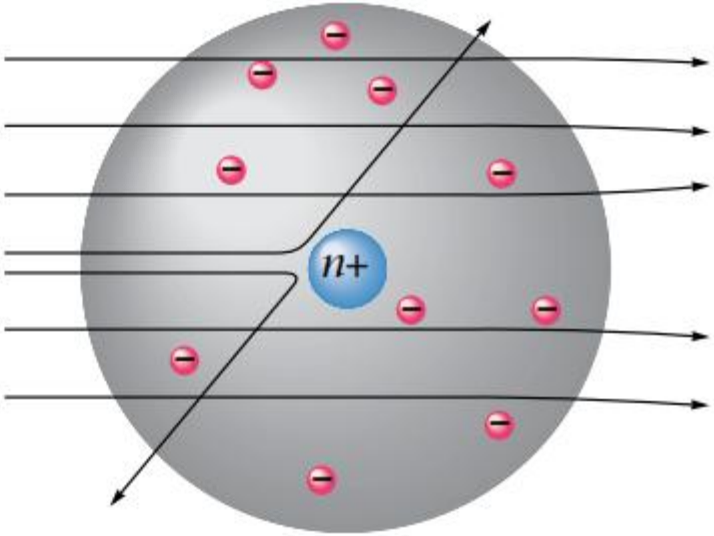


Chang, R. (2010). *Chemistry:* McGraw-Hill.

Rutherford's Experiment

plum-pudding" model



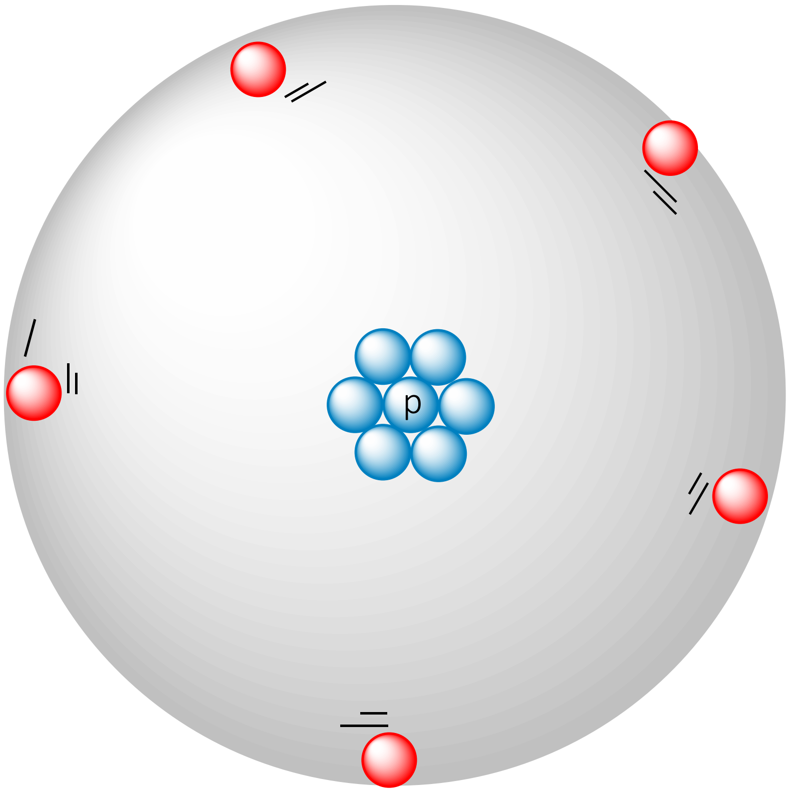


The results that the metal foil experiment would have yielded if the plum pudding model had been correct

Actual results

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Rutherford’s atomic model



❑ Rutherford concluded that atom mostly empty space

❑ Nucleus contains all the positive charge and essentially all the mass of the atom.

❑ positive particles lay within the nucleus and called them **protons**

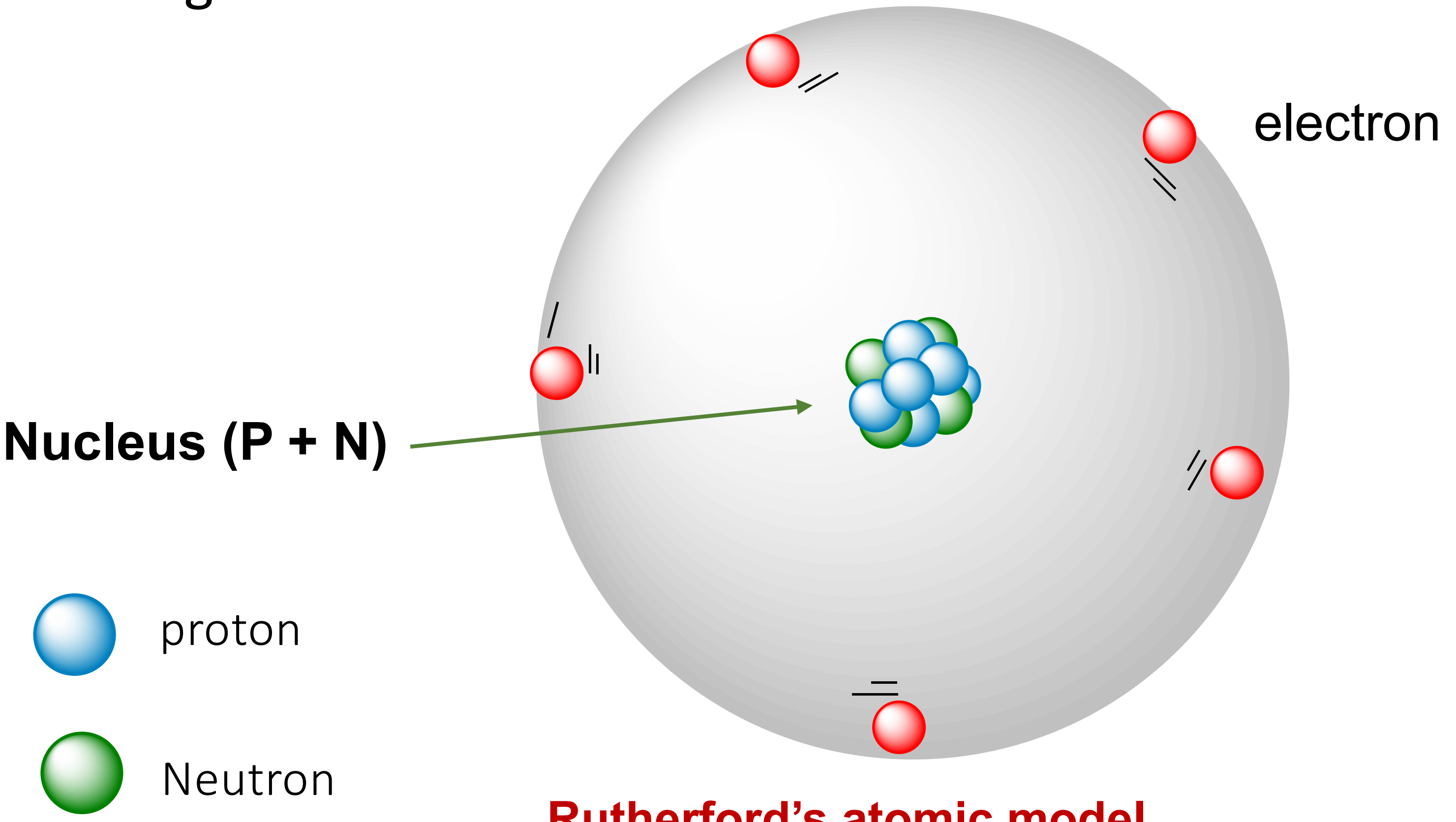
❑ A proton has the same magnitude (size) of charge as the electron

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Rutherford’s atomic model

- In 1932, **James Chadwick** (1891–1974) discovered the neutron, that also resides in the nucleus.
- A neutron is slightly more massive than a proton but has no charge.

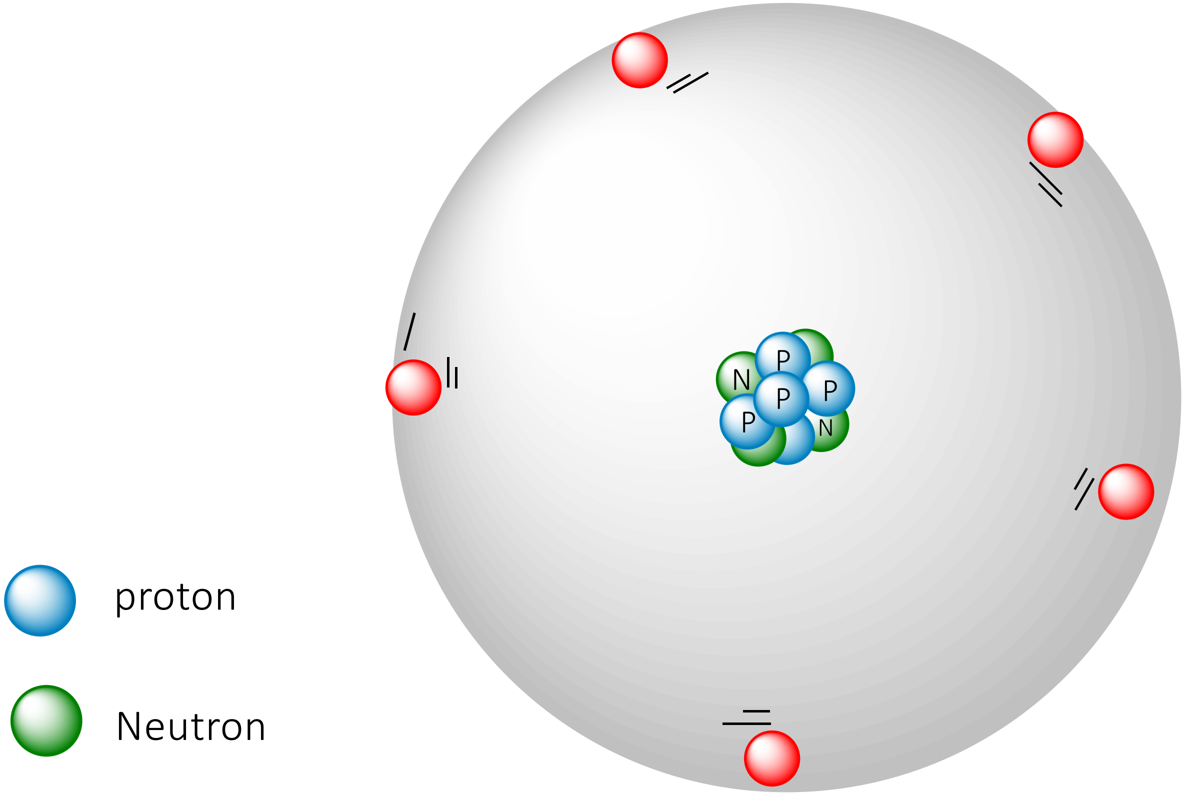


Rutherford’s atomic model

SUMMARY | General features of the atom today.

❑ An atom is neutral because the **number of protons in the nucleus equals the number of electrons** surrounding the nucleus.

❑ The atomic nucleus consists of protons and neutrons.



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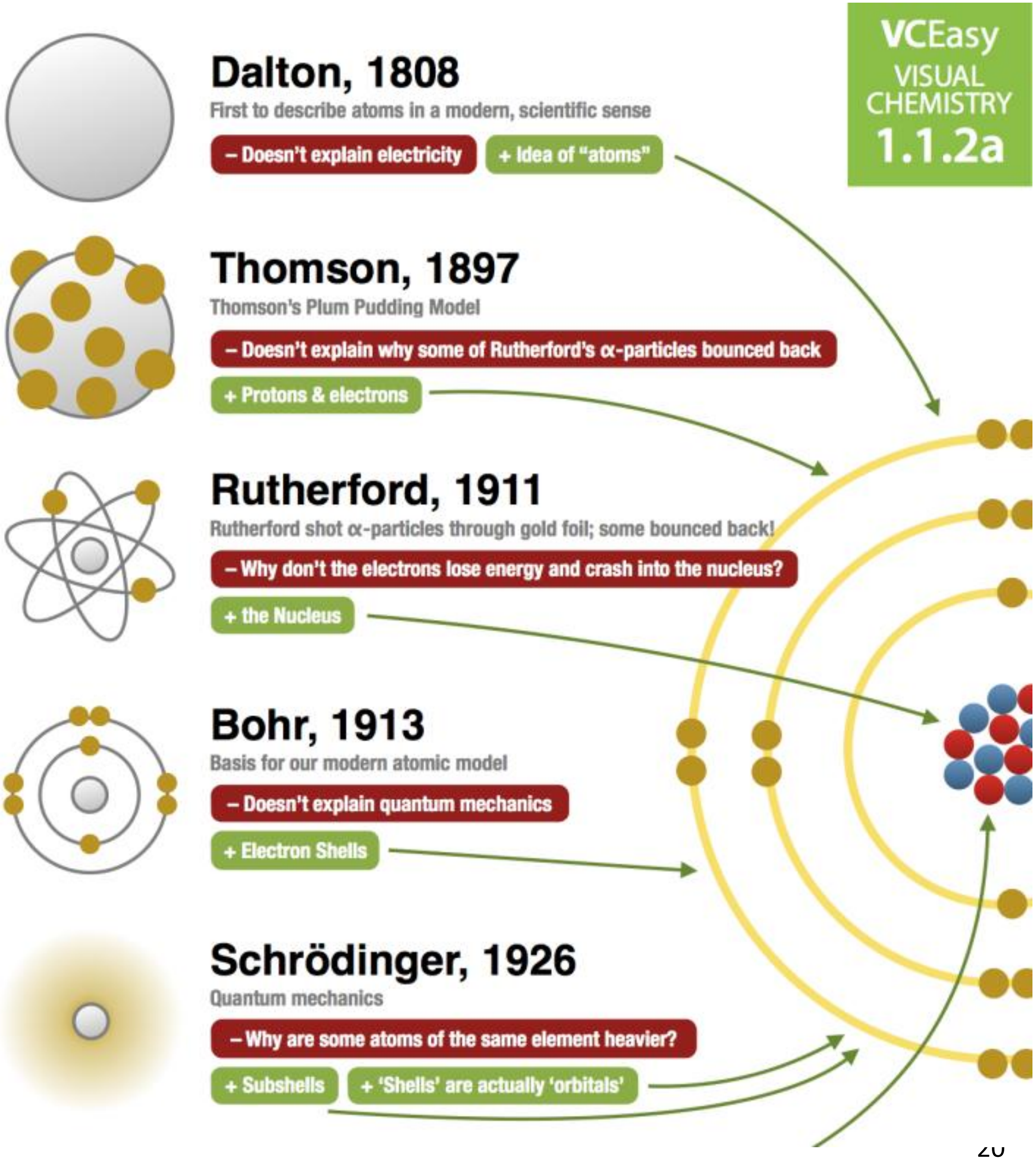

VCEasy
VISUAL CHEMISTRY
1.1.2a

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– Doesn't explain electricity
+ Idea of "atoms"

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Schrödinger, 1926
Quantum mechanics
– Why are some atoms of the same element heavier?
+ Subshells
+ 'Shells' are actually 'orbitals'

Table 2.2 Properties of the Three Key Subatomic Particles

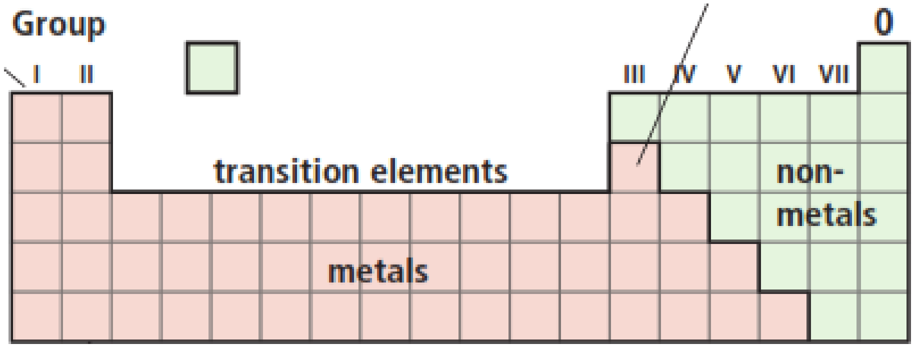
	Charge		Mass		
Name(Symbol)	**Relative**	**Absolute(C)***	**Relative(amu)†**	**Absolute(g)**	**Location in the Atom**
Proton (p^+)	**1+**	**$+1.60218\text{x}10^{-19}$**	**1.00727**	**$1.67262\text{x}10^{-24}$**	**Nucleus**
Neutron (n^0)	**0**	**0**	**1.00866**	**$1.67493\text{x}10^{-24}$**	**Nucleus**
Electron (e^-)	**1-**	**$-1.60218\text{x}10^{-19}$**	**0.00054858**	**$9.10939\text{x}10^{-28}$**	**Outside Nucleus**

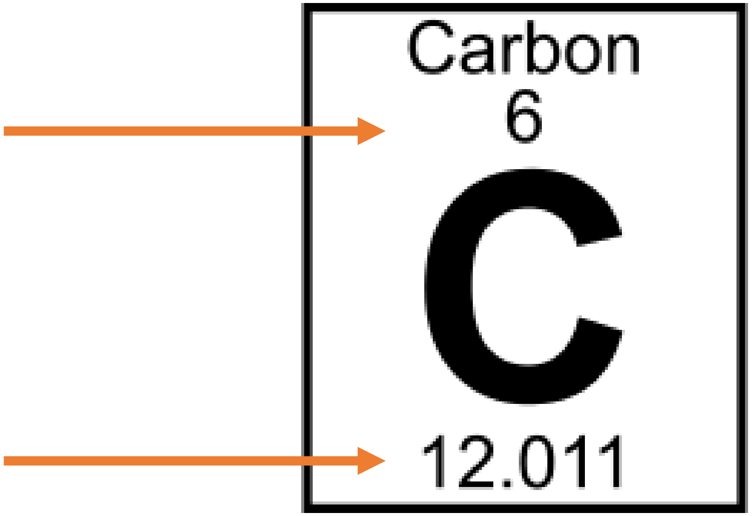
* The coulomb (C) is the SI unit of charge.

† The atomic mass unit (amu) equals $1.66054\text{x}10^{-24}$ g.

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

Atomic SYMBOLS, Atomic Mass, Atomic number





Atomic **NUMBER**

Atomic **MASS**

Atomic Symbols (element symbol)

$p^+ + n \rightarrow A$

$p^+ \rightarrow Z$

$${}^{A}_{Z}X$$ — The Symbol of the Atom

X = Atomic symbol of the element

A = mass number; A = Z + n

Z = atomic number (the number of protons in the nucleus)

N = number of neutrons in the nucleus

$${}^{1}_{1}H \qquad {}^{4}_{2}He \qquad {}^{235}_{92}U$$

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

Sample Problem 2.2B

Determining the Number of Subatomic Particles in the Isotopes of an Element

PROBLEM: จงหาจำนวนโปรตอน นิวตอน อิเล็กตรอน จากสัญลักษณ์นิวเคลียร์ที่กำหนดให้ หากข้อใด ไม่ได้กำหนดสัญลักษณ์นิวเคลียร์มา จะต้องเขียนสัญลักษณ์นิวเคลียร์ก่อน

(a) $^{11}_{5}X$

(b)
15
P
Phosphorus
30.973

(c) $^{28}_{14}X$

(d)
53
I
Iodine
126.904

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

Sample Problem 2.2C

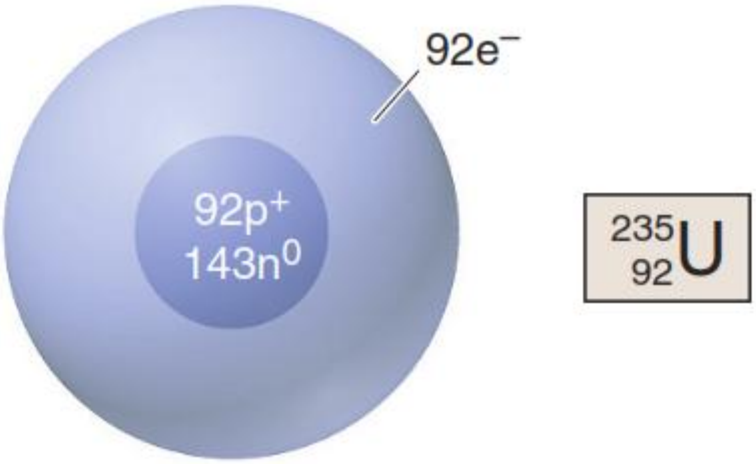
Determining the Number of Subatomic Particles in the Isotopes of an Element

PROBLEM: Complete the table below

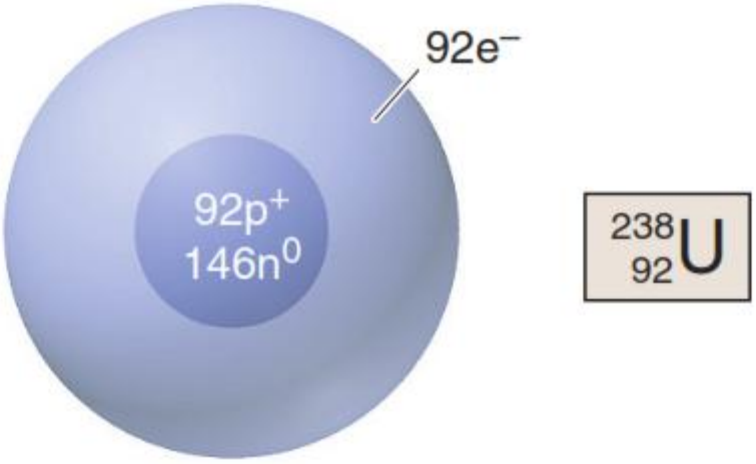
Elements	Element symbols	Number of particles			Atomic number	Mass number
		proton	neutron	electron		
	$^{27}_{13}Al$					
	$^{40}_{20}Ca$					
		15				

Isotope

- **Isotope =** atoms of an element with the same number of protons, but a different number of neutrons.
- all isotopes of an element have nearly identical chemical behavior, even though they have different masses.



An atom of uranium-235



An atom of uranium-238

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

Sample Problem 2.2

Determining the Number of Subatomic Particles in the Isotopes of an Element

PROBLEM: Silicon(Si) is essential to the computer industry as a major component of semiconductor chips. It has three naturally occurring isoltopes: ^{28}Si, ^{29}Si, and ^{30}Si.

Determine the number of protons, neutrons, and electrons in each silicon isotope.

PLAN: We have to use the atomic number and atomic masses.

Sample Problem 2.2A

Determining the Number of Subatomic Particles in the Isotopes of an Element

PROBLEM: Titanium (Ti) is is used structurally in many objects, such as electric turbines, aircraft bodies, and bicycle frames. It has three naturally occurring isoltopes: ^{47}Ti, ^{48}Ti, and ^{50}Ti.

Determine the number of protons, neutrons, and electrons in each Titanium isotope.

PLAN: We have to use the atomic number and atomic masses.

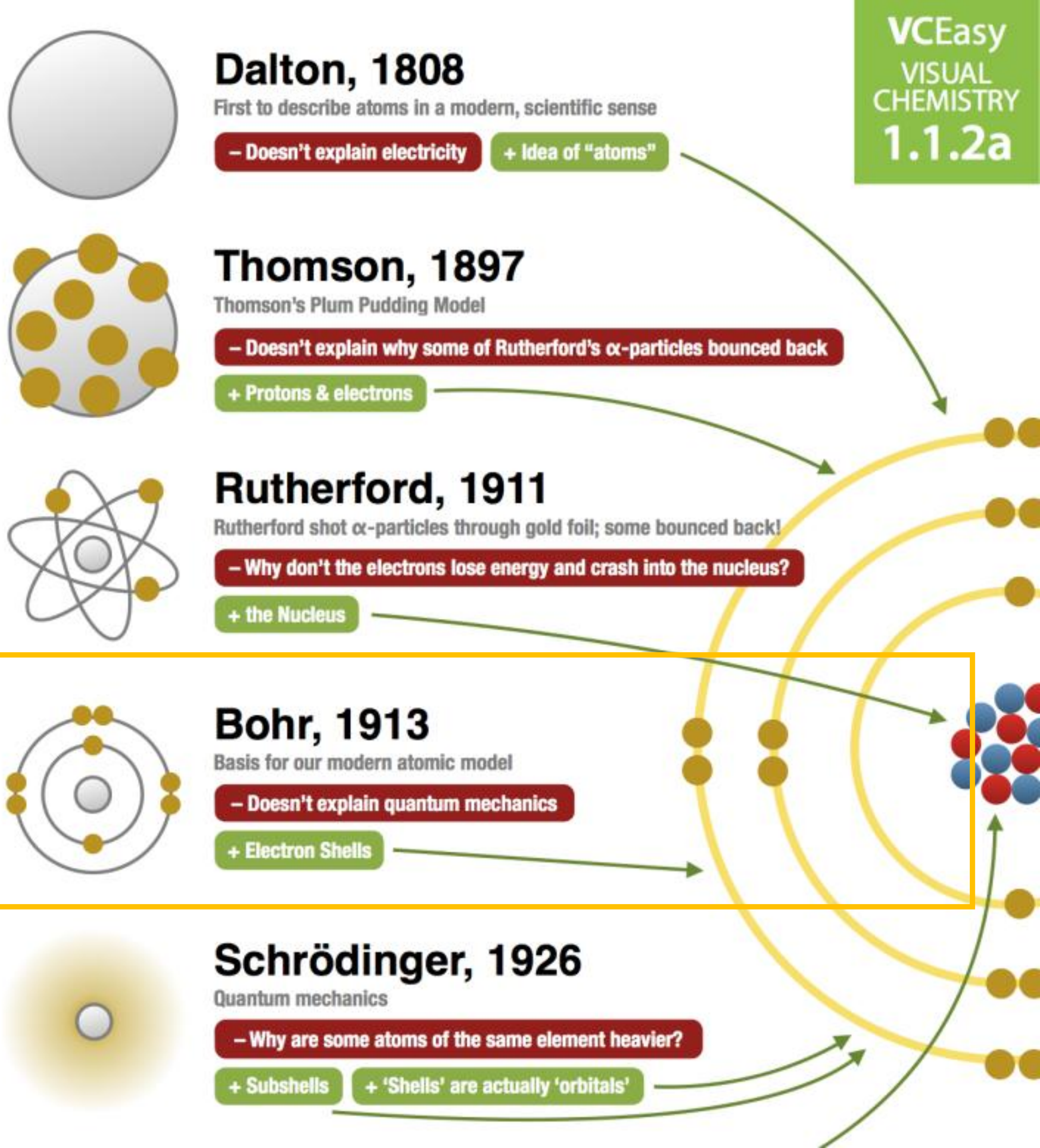
SOLUTION: The atomic number of **Titanium** is ____. Therefore

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

THE **MODERN CONCEPT**
of ATOMIC STRUCTURE

- Bohr’s atomic Model
- The Wave Mechanical Model of the Atom

Bohr’s atomic Model



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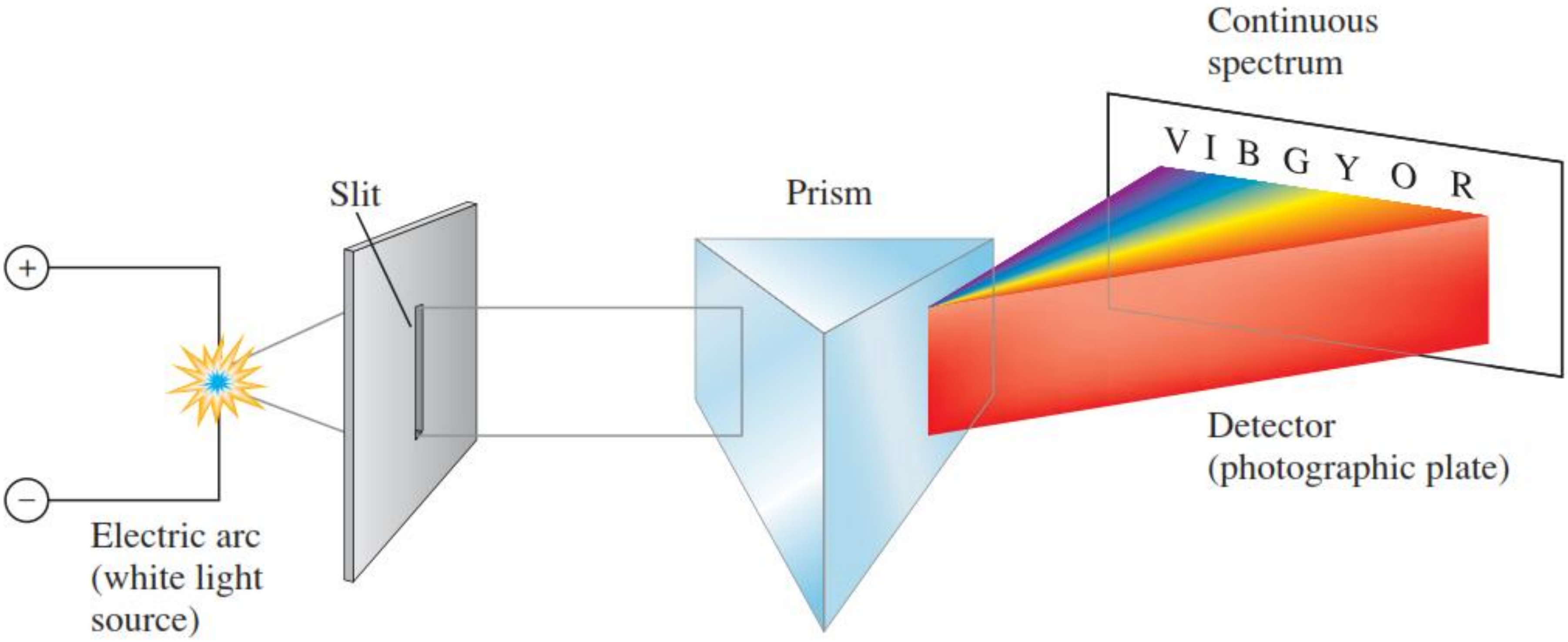
Atomic spectrum of Hydrogen

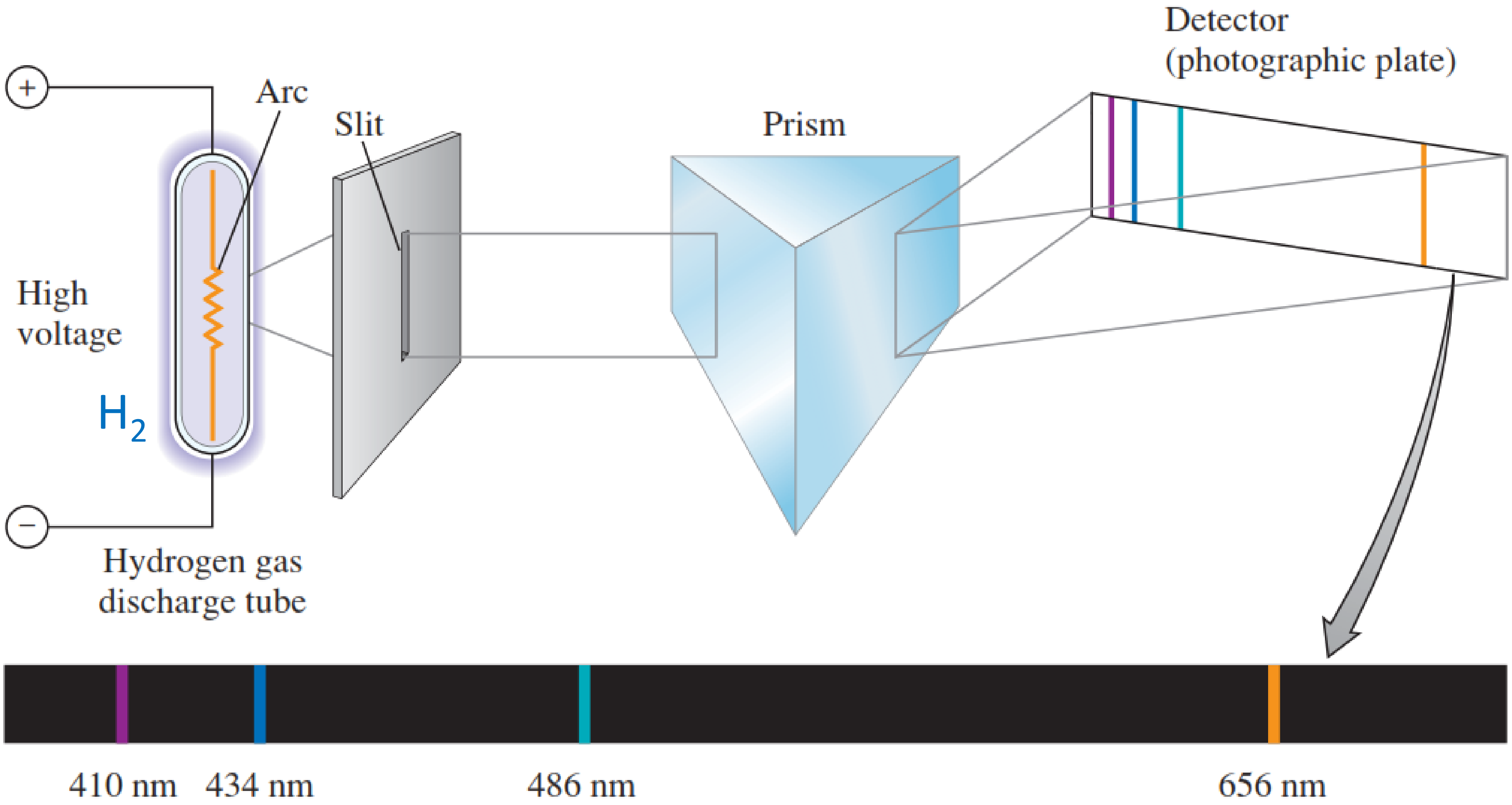
the continuous spectrum (like the rainbow) results when white light is passed through a prism



Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

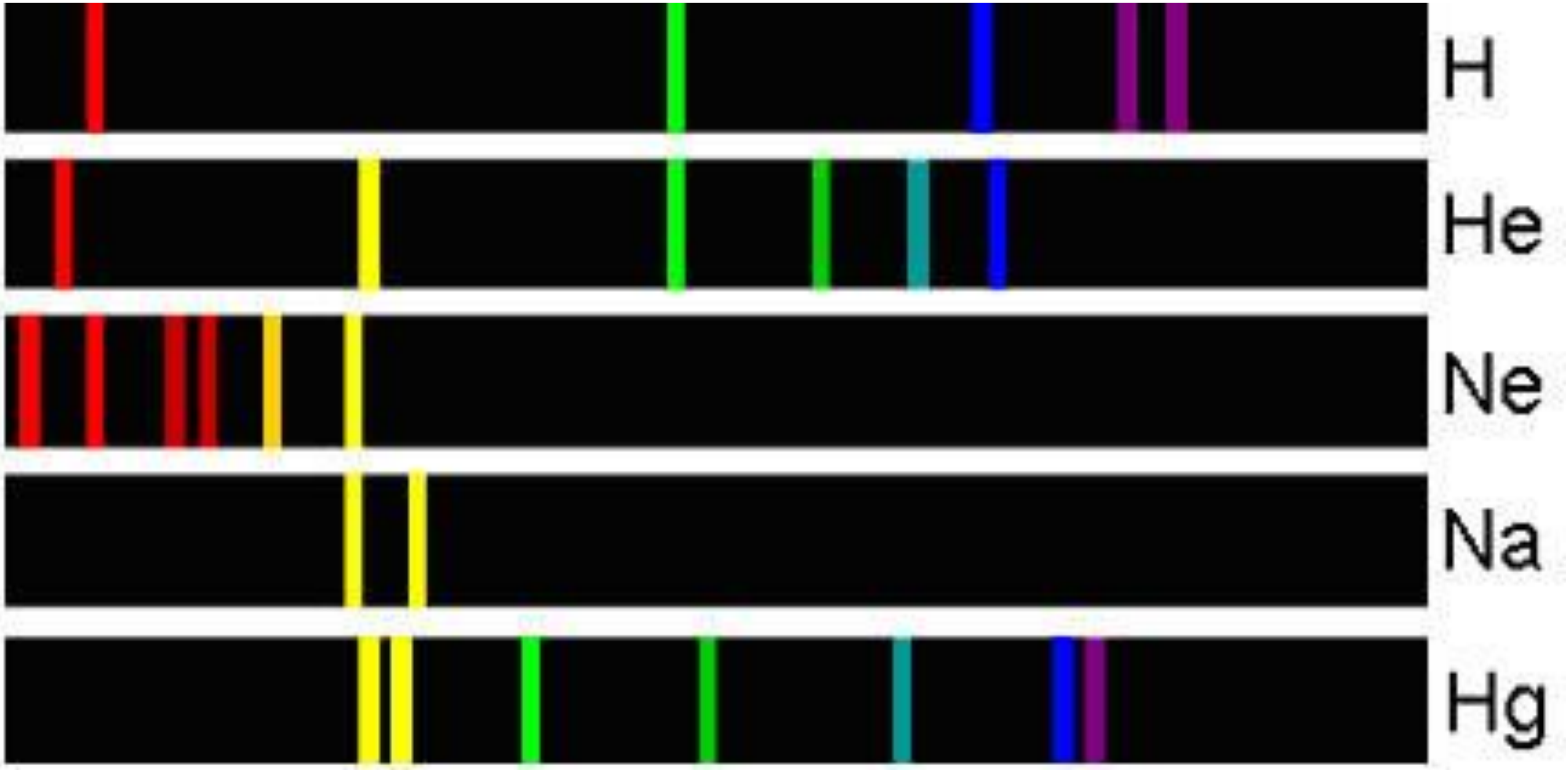
Atomic spectrum of Hydrogen

The hydrogen line spectrum contains only a few discrete wavelengths.



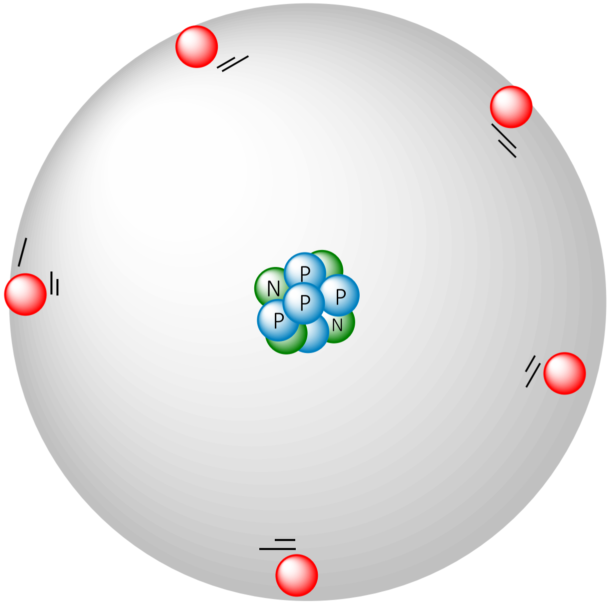
Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

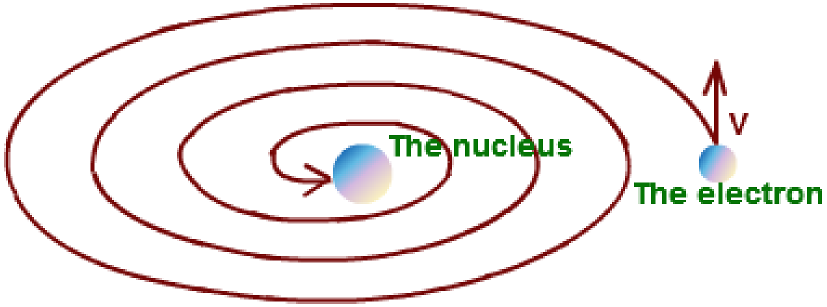
Atomic spectrum of Various elements



Problems with Rutherford’s Nuclear Model

a negative particle moving in a curved path around a positive particle must emit radiation and thus lose energy. If the orbiting electrons behaved in that way, they would spiral into the nucleus, and all atoms would collapse!



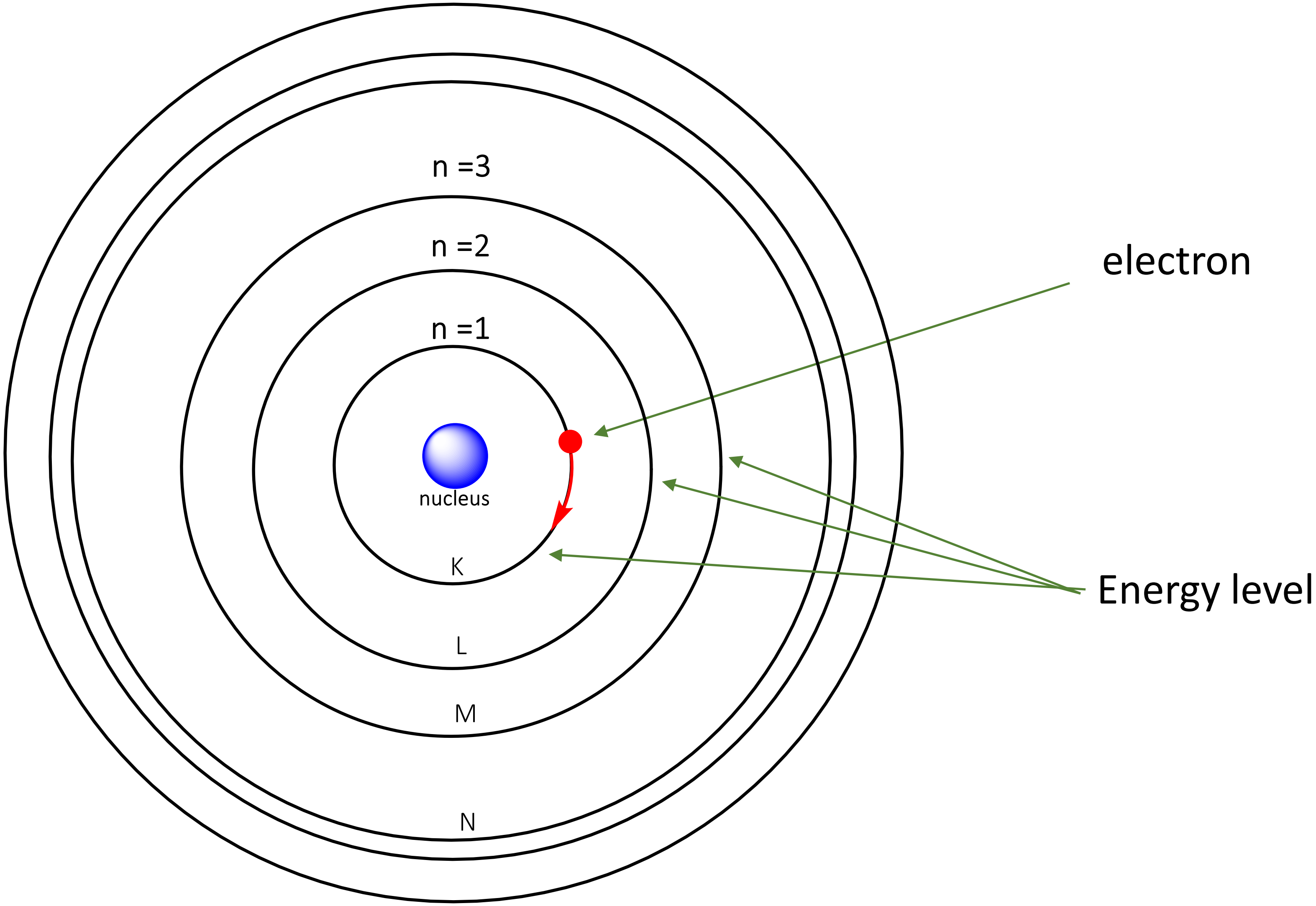


In the planetary model of atom, the electron should emit energy and spirally fall on the nucleus.

Chang, R. (2010). *Chemistry*: McGraw-Hill.

Bohr’s atomic Model

Niels Bohr (1885-1962) suggested a model for the H atom that did predict the existence of line spectra.



Postulates of Bohr’s atomic Model

Bohr proposed postulates:

1) อิเล็กตรอนจะเคลื่อนที่รอบนิวเคลียสเป็นวงกลม ในวงโคจรที่มีระยะห่างแน่นอน (เรียกว่า Orbit)

2) Electrons in allowed orbits **do not** radiate energy (ทำให้มีค่าพลังงานที่แน่นอน ตามระดับชั้นพลังงานนั้นๆ)

3) The higher the energy level, the farther the orbit is from the nucleus.

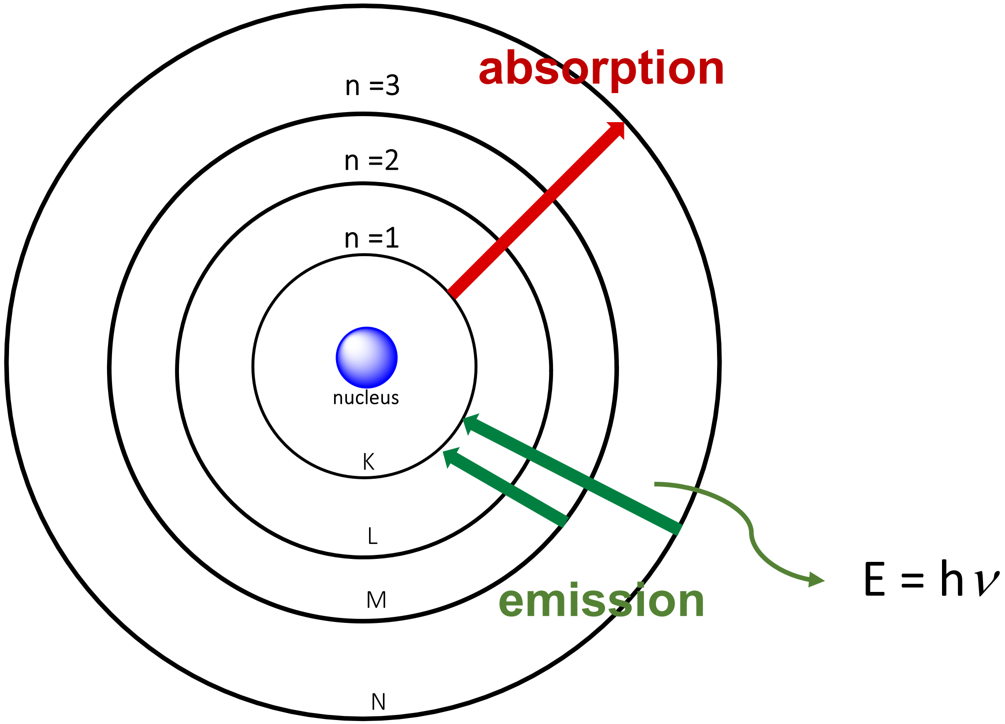
4) เมื่ออิเล็กตรอน (ของไฮโดรเจน) อยู่ในวงโคจรชั้นในสุด (ชั้นที่ 1) อะตอมจะมีพลังงานต่ำที่สุด เราเรียกสภาวะนี้ว่า "สถานะพื้น" (***Ground State***)

5) When the electron is in any orbit higher than n = 1, the atom is in an ***excited state***.

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

Postulates of Bohr's atomic Model

6) The atom changes to another stationary state only by **absorbing** or **emitting** a photon.

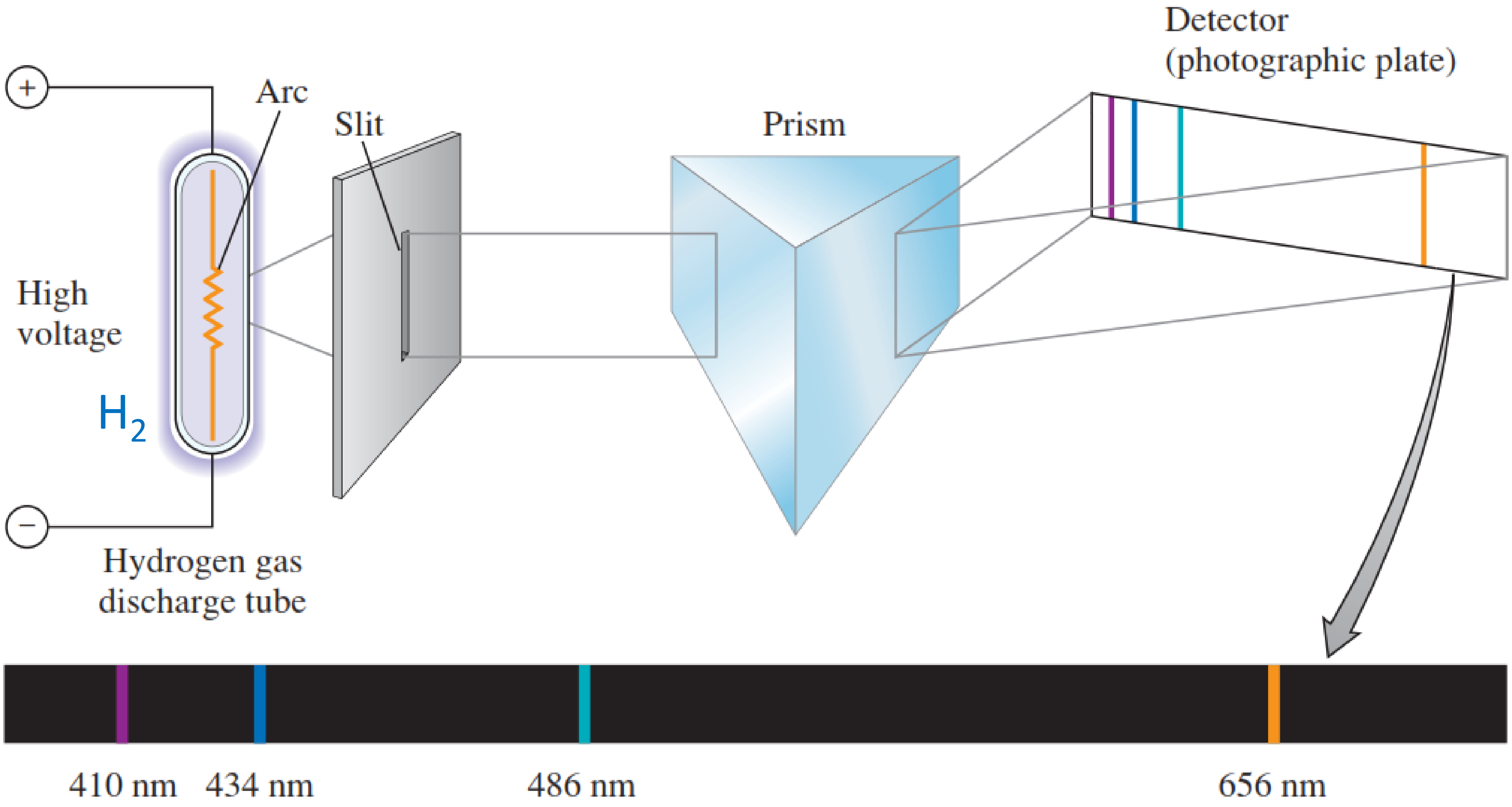


Electrons gain energy by "jumping" to a higher energy (further) orbit

–lose energy by falling to a lower energy

Atomic spectrum of Hydrogen

The hydrogen line spectrum contains only a few discrete wavelengths.



Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

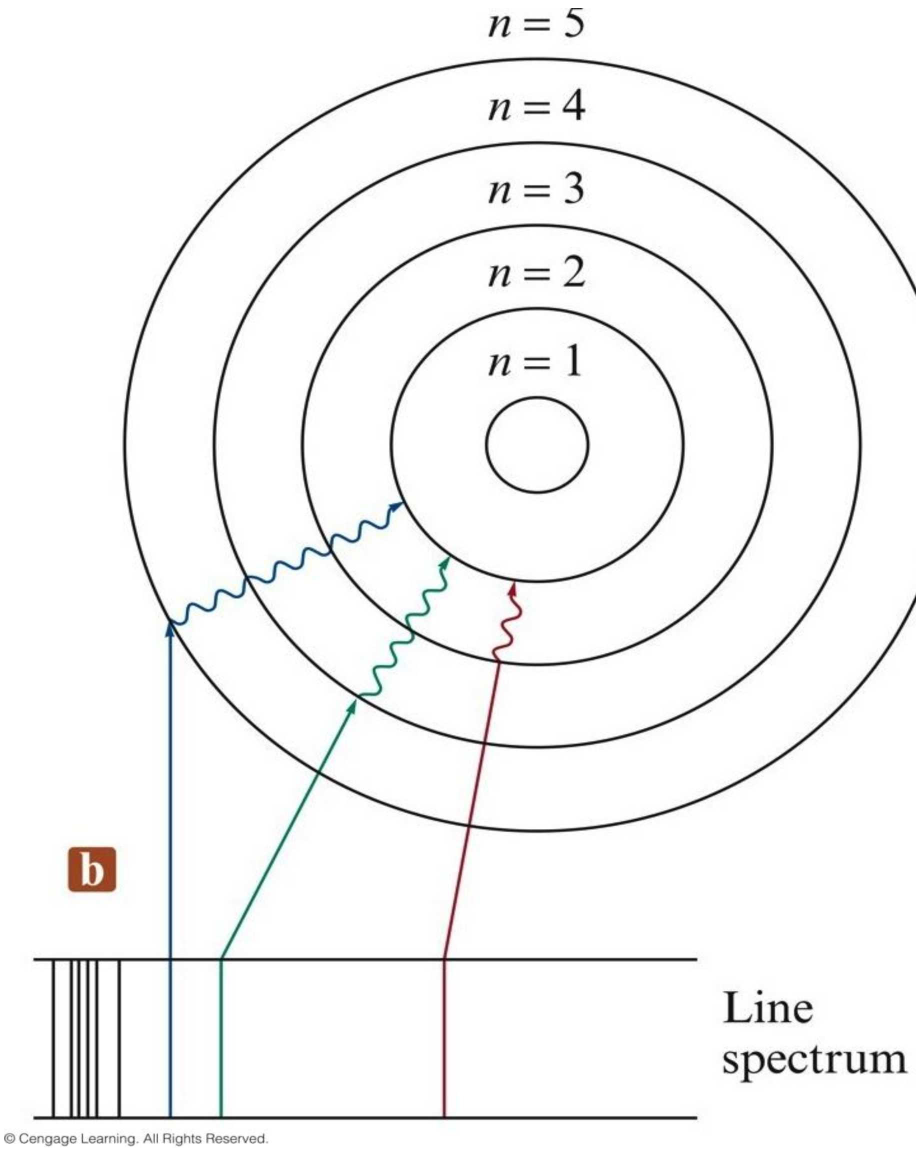
Atomic spectrum of Hydrogen

- เมื่อเราปล่อยกระแสไฟฟ้าพลังงานสูง (High-energy spark) เข้าไปในหลอดบรรจุก๊าซไฮโดรเจน (H_2) โมเลกุลของก๊าซจะดูดซับพลังงานนี้เข้าไป พลังงานที่สูงมากนี้จะไปทำลายพันธะเคมีระหว่าง H-H ทำให้โมเลกุลแตกตัวออกกลายเป็น "อะตอมของไฮโดรเจน" (H atoms)

- H atom ที่ได้รับพลังงานนี้ จะอยู่ในสถานะ Excited state ซึ่งไม่เสถียร จึงคายพลังงานออกมาในรูปของ สเปกตรัมแบบเส้น (Emission line spectrum) ให้เราเห็น

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Electronic transitions in the Bohr model for the H atom.



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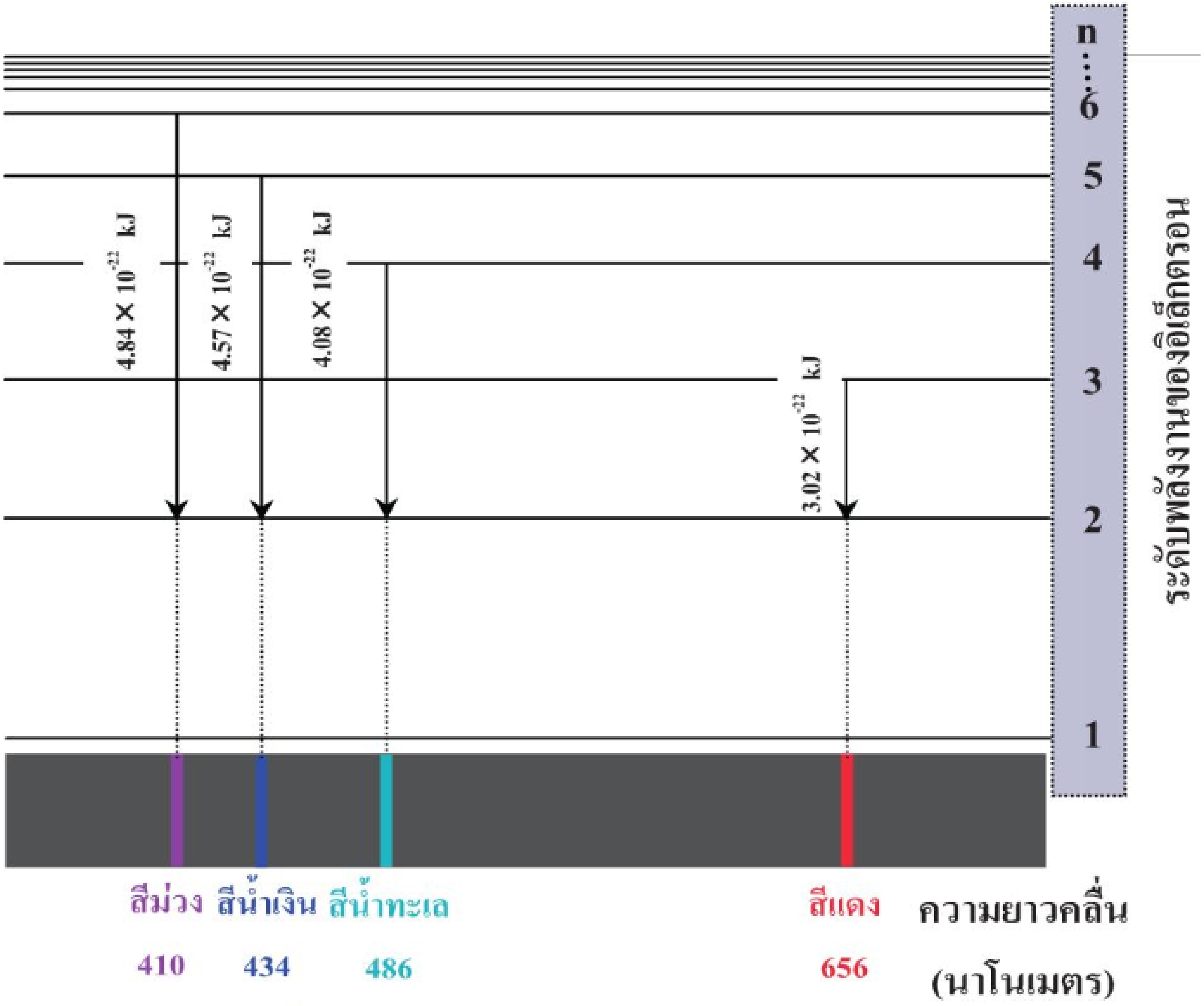
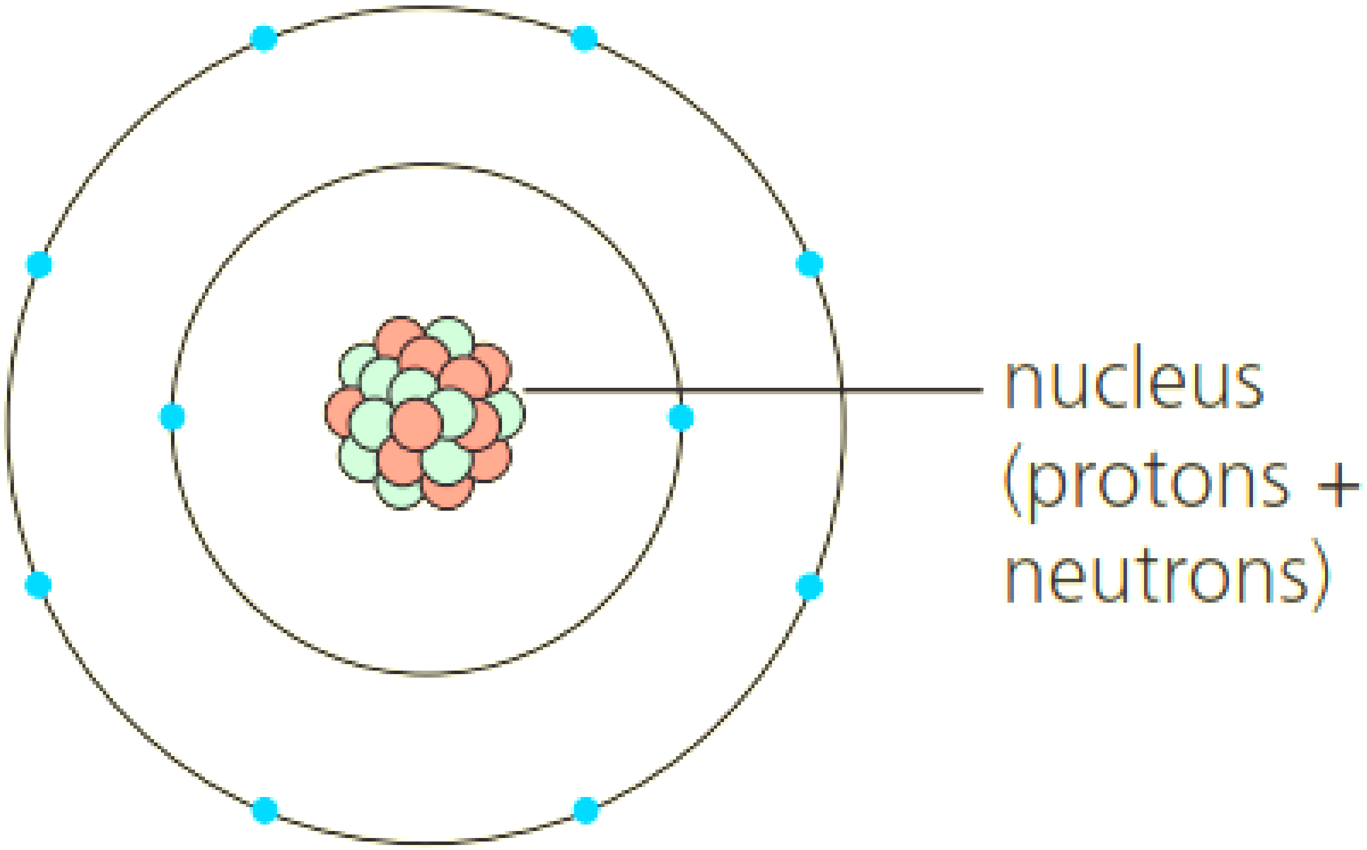
Bohr’s model gave hydrogen atom energy levels consistent with the hydrogen emission spectrum.

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Electronic transitions in the Bohr model for the H atom.



Bohr’s atomic Model



Sample Problem 2.3

Bohr atomic model

PROBLEM: ทำเครื่องหมายถูก หน้าข้อความที่กล่าวถูกต้องเกี่ยวกับแบบจำลองอะตอมของโบว์

☐ อิเล็กตรอนเคลื่อนที่รอบนิวเคลียสเป็นวงโคจร โดยมีค่าพลังงานที่แน่นอน ตามระดับชั้นพลังงานนั้นๆ

☐ ที่ระดับชั้นพลังงานต่ำ จะอยู่ใกล้กับนิวเคลียส

☐ อิเล็กตรอนไม่สามารถเปลี่ยนระดับชั้นพลังงานได้ แม้เกิดการดูดพลังงานขึ้น

☐ เมื่ออิเล็กตรอนได้รับพลังงาน จะข้ามขึ้นไปยังระดับพลังงานที่สูงขึ้นได้

☐ เส้นสเปกตรัมของ H atom เกิดจากการเปลี่ยนระดับชั้นพลังงานของอิเล็กตรอน จากระดับชั้นพลังงานสูง ลงมาระดับที่ต่ำกว่า

Bohr's atomic model

1. Bohr's model explains the stability of the atom.
2. Bohr's theory successfully explains the atomic spectrum of H-atom.

Limitations of Bohr's atomic model

Bohr's theory fails to explains the spectra of multi-electron atoms.

- ☐ it is important to realize that the current theory of atomic structure is not the same as the Bohr model.

  Electrons do not move around the nucleus in circular orbits like planets orbiting the sun

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

The Wave Mechanical Model of the Atom

The Wave Mechanical Model of the Atom

By the mid-1920s it had become apparent that the Bohr model was ***incorrect***.

Erwin Schrödinger
(1887-1961)

Wave Mechanical Model of atom was proposed by Erwin Schrödinger.

Bohr model

the electron was assumed to move in circular orbits

Wave Mechanical Model

$$\hat{\mathscr{H}}\psi = E\psi$$

solve

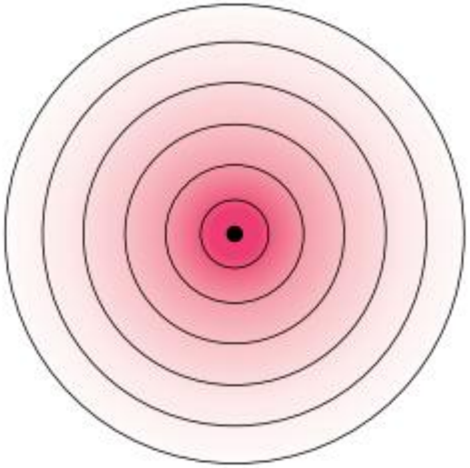
the electron states are described by **orbitals**.

Orbitals are nothing like orbits

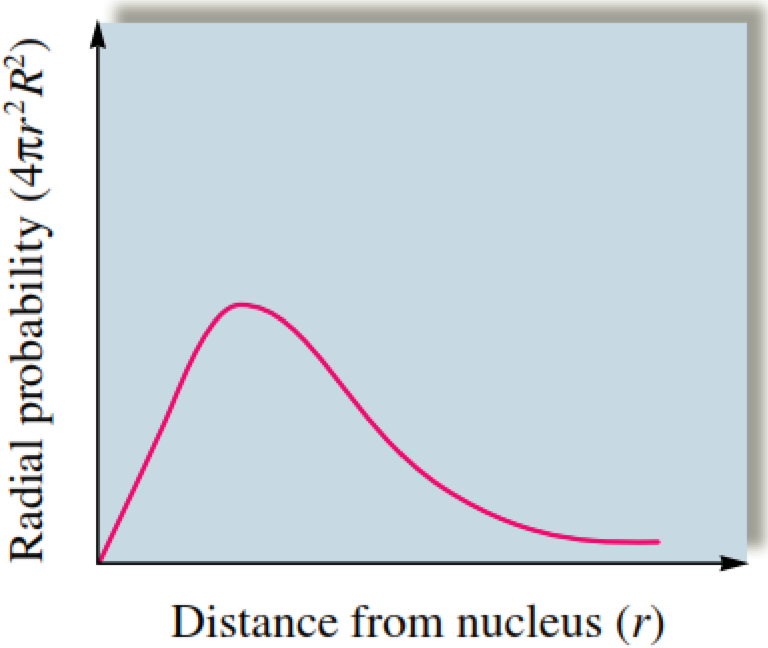
Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Orbital

Orbital was defined as ***“the three dimensional region of space around the nucleus where there is maximum probability of finding the electron”***



Cross section of the 1s hydrogen atomic orbital



Electron Configurations of Elements

How electrons are arranged?

Arrangement of electrons in atoms

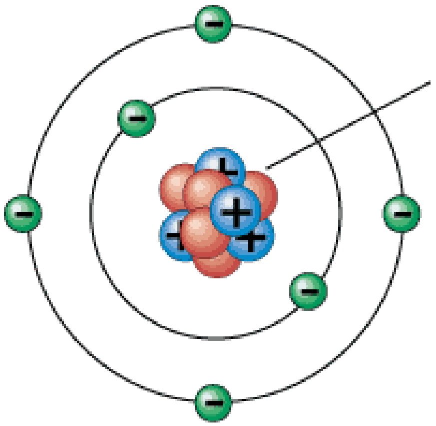
(electron configuration)

Electron configuration

Electrons are arrange in ….

Shell

Subshell

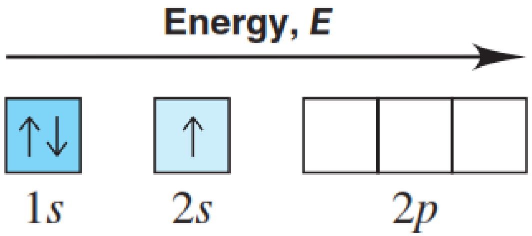


2, 8, 8, 1

☐ **Short hand notation**

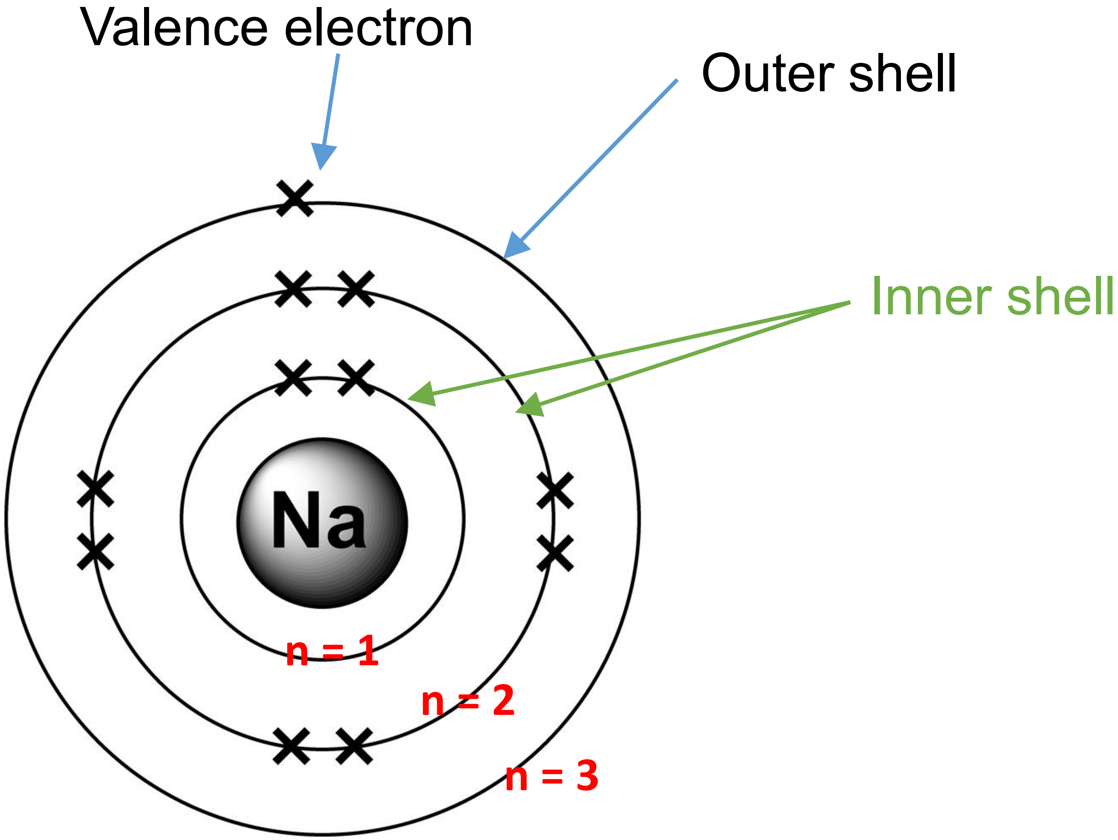
$1s^2, 2s^2 , 2p^6$

☐ **Orbital diagram**



Electrons are arrange in Shell

Lower level



Electron configuration (shell) of Na : 2, 8, 1

Ingram, P., & Gallagher, R. (2011). *Complete Chemistry for Cambridge IGCSE® (Second Edition)*: OUP Oxford.

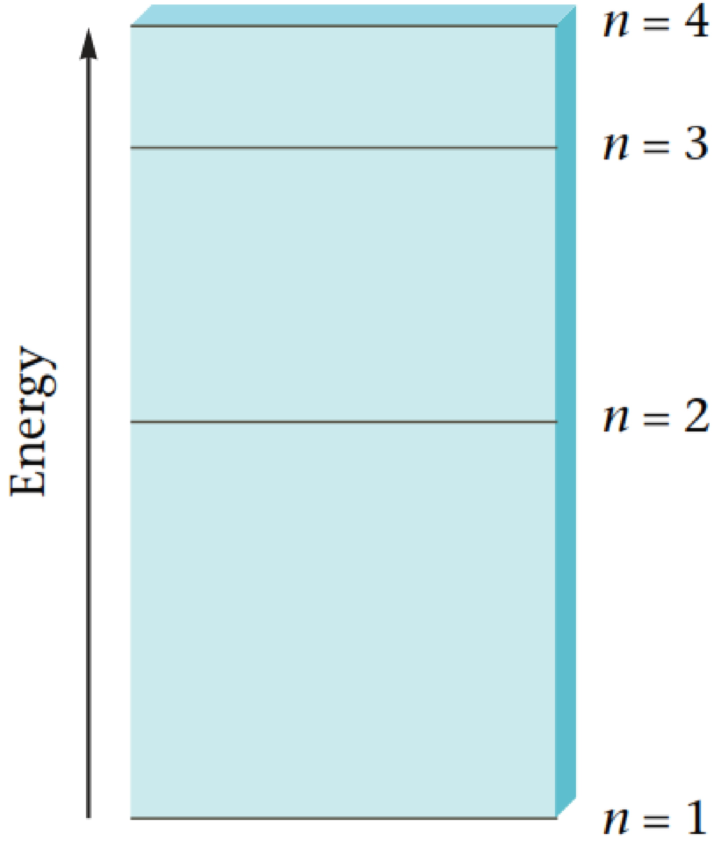
Lower level

คำถาม: ช่วยแสดงการจัดอิเล็กตรอนในระดับพลังงานหลักของ Ca ให้หน่อย

Hydrogen Energy Levels and its atomic orbital

principal energy levels

sublevels.



Principal level 4 consists of 4 sublevel (**s** , **p** , **d**, and **f** orbitals)

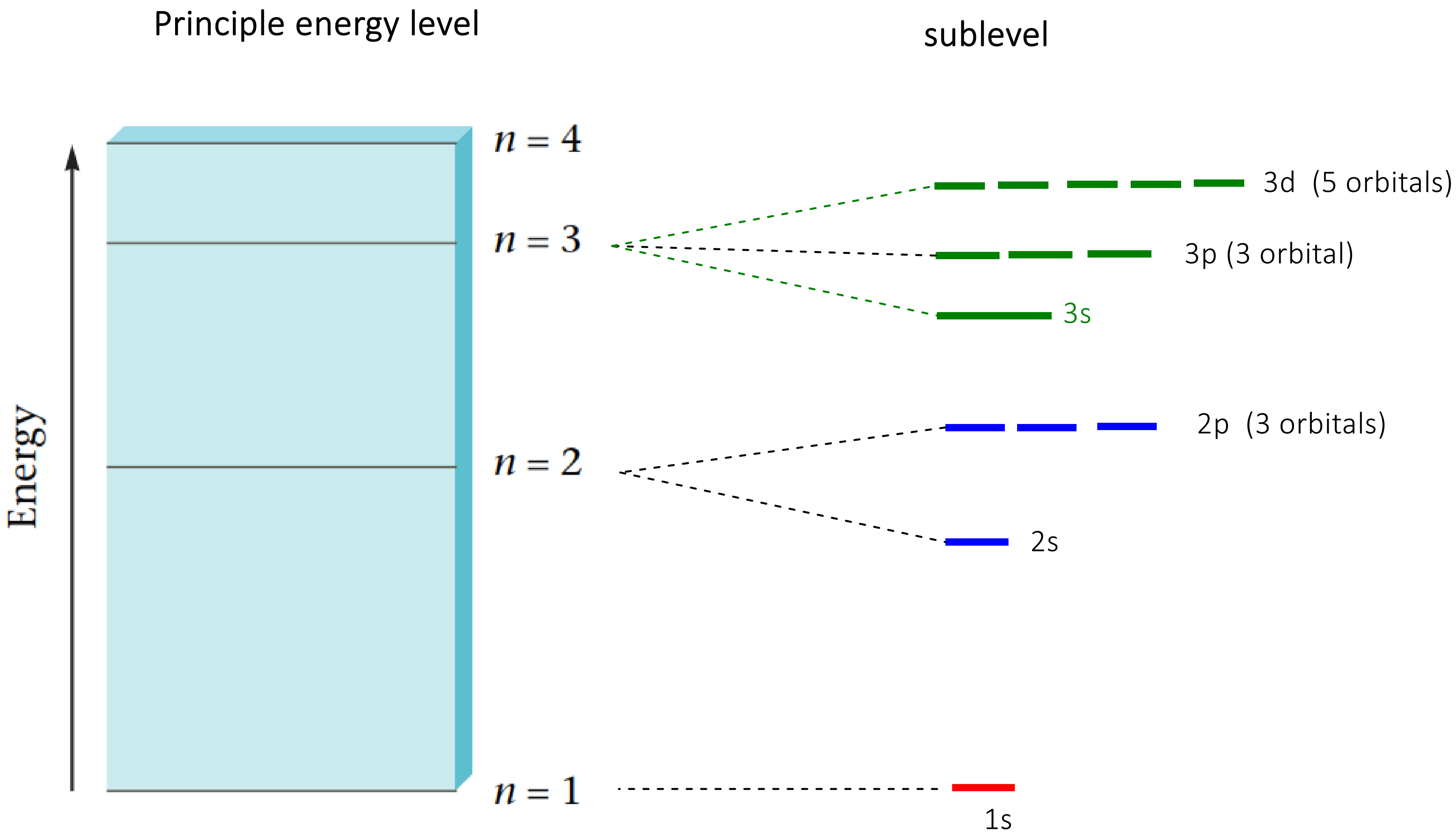
Principal level 3 consists of three sublevel (**s** , **p** , and **d** orbitals)

Principal level 2 consists of two sublevel (**s** and **p** orbitals)

Principal level 1 consists of one sublevel (**s**)

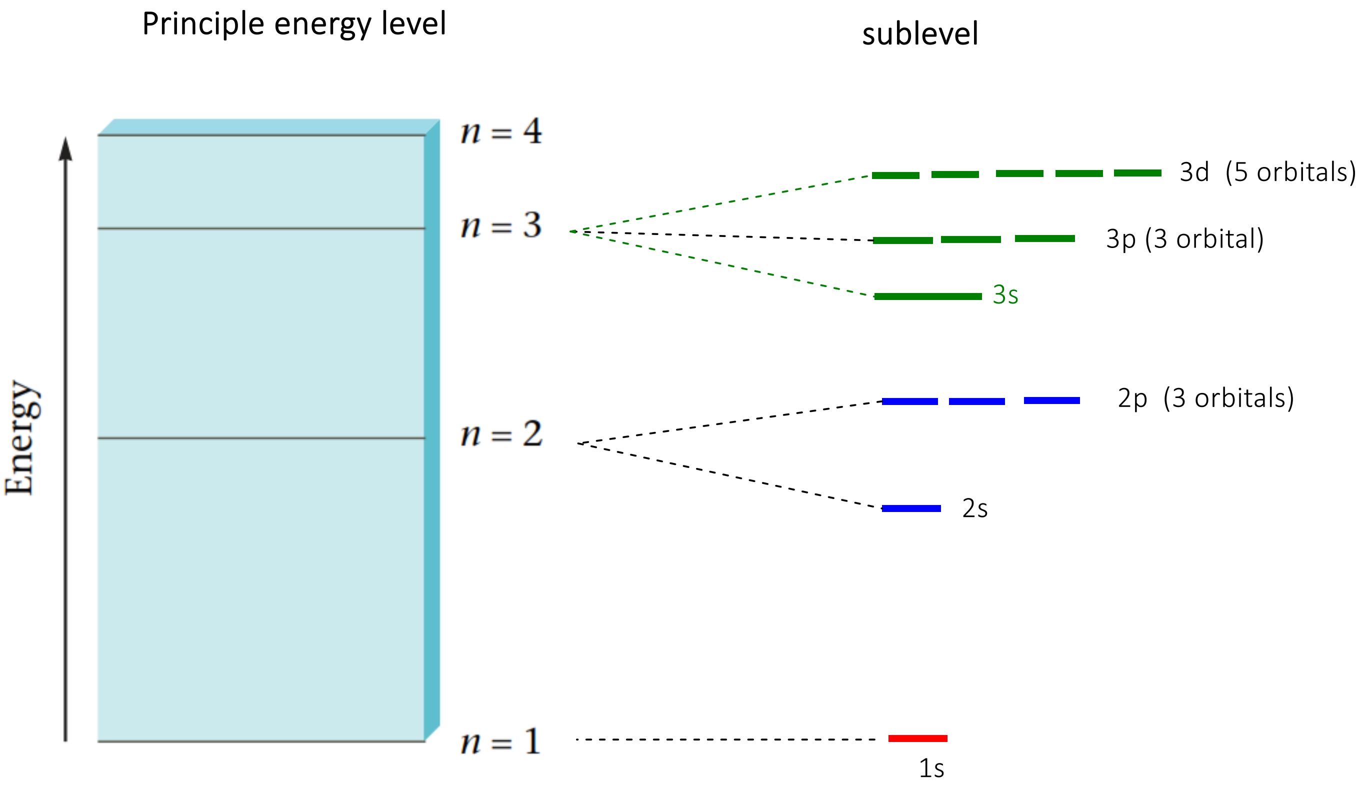
these sublevels contain spaces for the electron that we call orbitals

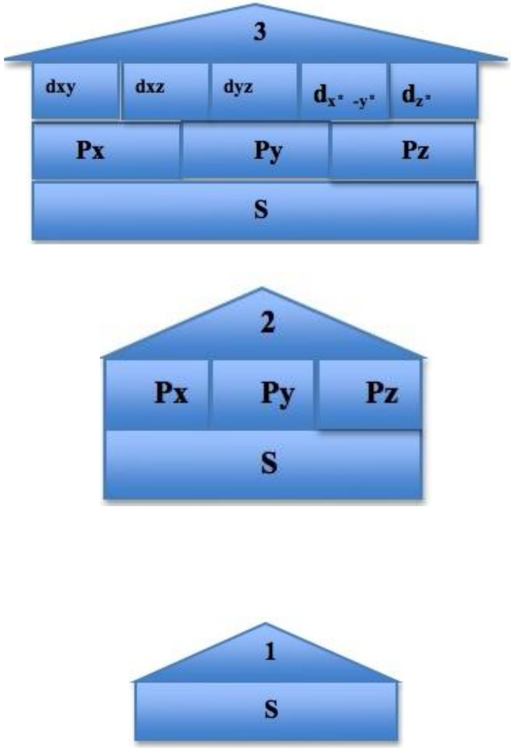
It should be noted that…



- ❑ An orbital can be empty or it can contain one or two electrons, but never more than two.

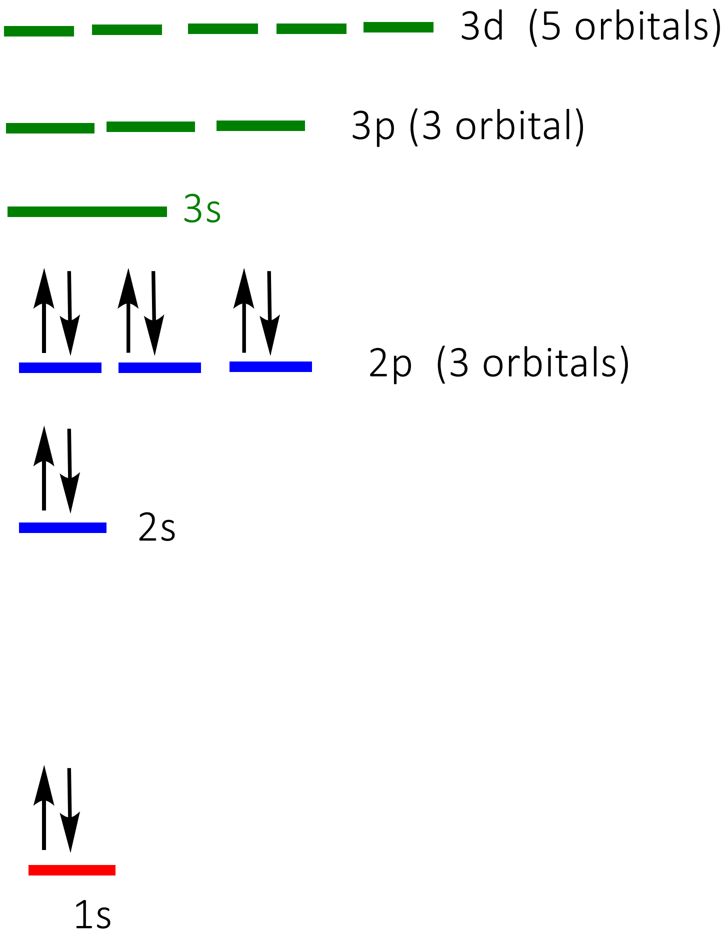
Electrons are arrange in Subshell





Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Electrons are arrange in Subshell



- We add electron to the *lowest energy sublevel available.*

s-sublevel can hold 2 electrons

p- sublevel can hold 6 electrons

d- sublevel can hold____ electrons

f-sublevel can hold____ electrons

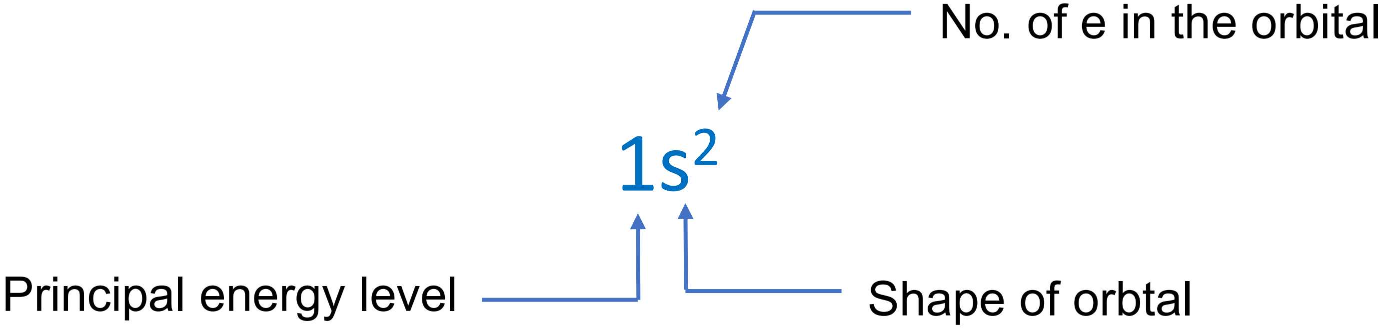
Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Electron Configurations of Elements

There are two common ways to indicate the distribution of electrons:

1) The electron configuration. (shorthand notation)

$^{7}_{3}Li$ $1s^2$, $2s^1$



No. of e in the orbital

$1s^2$

Principal energy level

Shape of orbtal

Silberberg, M.; Amateis, P. Chemistry The Molecular Nature of Matter and Change 7th edition; McGraw-Hill Science, 2014.

Sample Problem 1.4

electron configuration (subshell)

PROBLEM: write the full electron configuration (shorthand configuration) for the following elements.

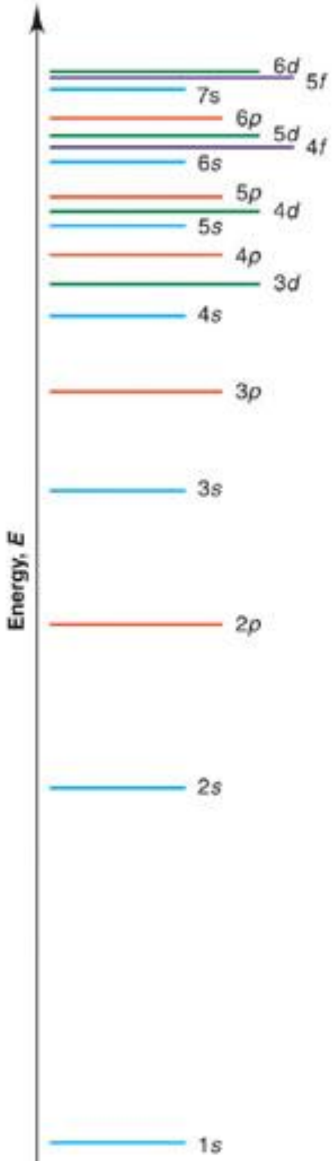
$^{9}_{4}Be$

$^{12}_{6}\mathrm{C}$

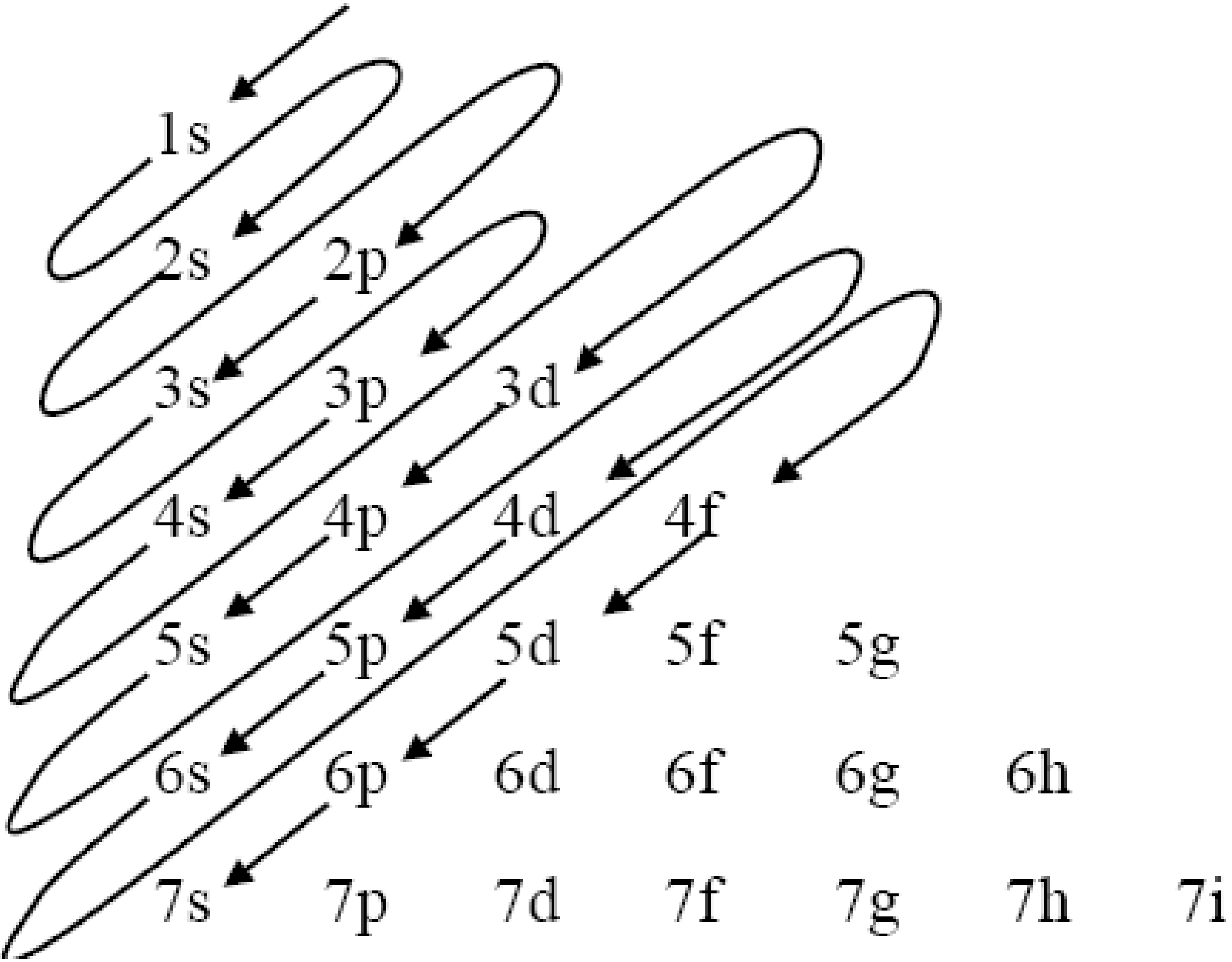
$^{23}_{11}Na$

$^{27}_{13}Al$

Order for filling energy sublevels with electrons.



Aid to Memorizing Sublevel Filling Order



1s						
2s	2p					
3s	3p	3d				
4s	4p	4d	4f			
5s	5p	5d	5f	5g		
6s	6p	6d	6f	6g	6h	
7s	7p	7d	7f	7g	7h	7i

Sample Problem 1.5

electron configuration (subshell)

PROBLEM: write the full electron configuration (shorthand configuration) for the following elements.

$_{18}Ar$

$^{40}_{20}Ca$

$^{48}_{22}Ti$

$_{28}Ni$

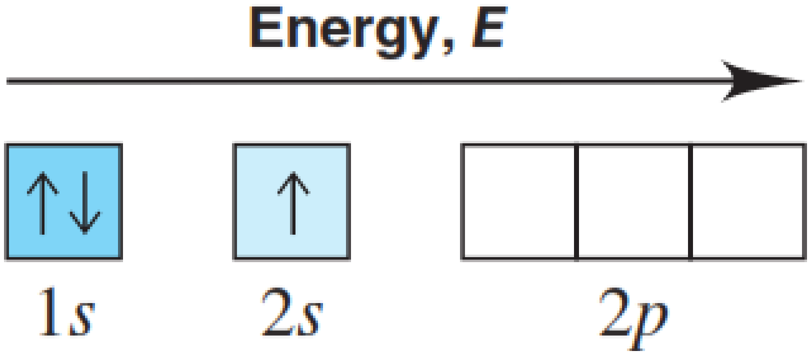
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change:* McGraw-Hill Science.

Electron Configurations of Elements

There are two common ways to indicate the distribution of electrons:

2) The orbital diagram.

$^{7}_{3}Li$



$1s^2$ $2s^1$

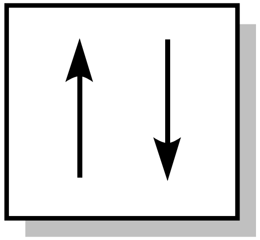
Silberberg, M.; Amateis, P. Chemistry The Molecular Nature of Matter and Change 7th edition; McGraw-Hill Science, 2014.

Pauli exclusion principle

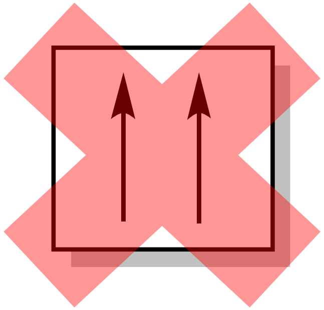
all atoms beyond hydrogen have more than one electron

Pauli exclusion principle

An atomic orbital can hold a maximum of two electrons, and those two electrons must have opposite spins.



2s

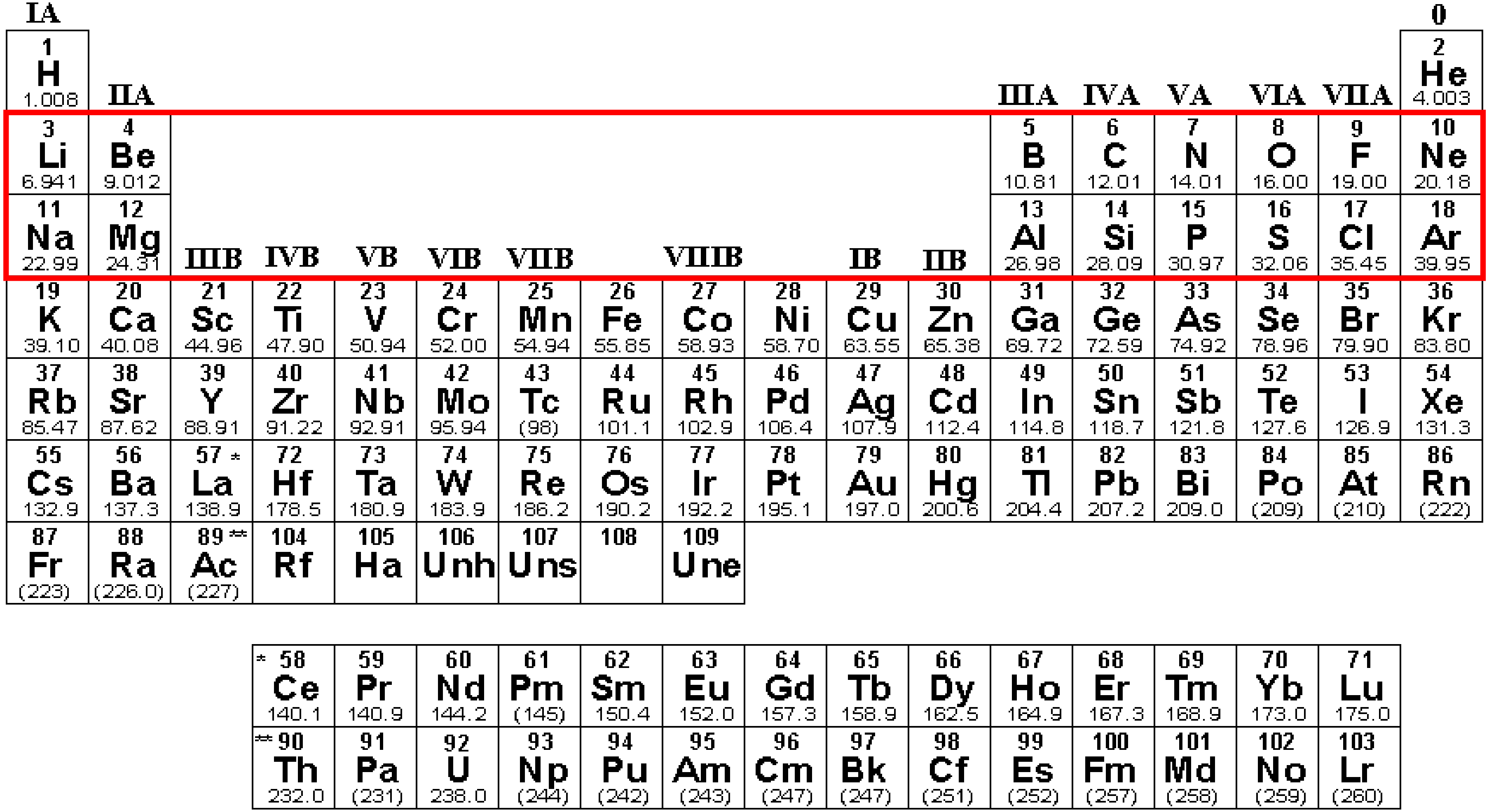


2s

☐ two electrons must have opposite spins to occupy the same orbital

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Orbital Diagrams and Electron Configurations* for the Elements in Period 2 and 3



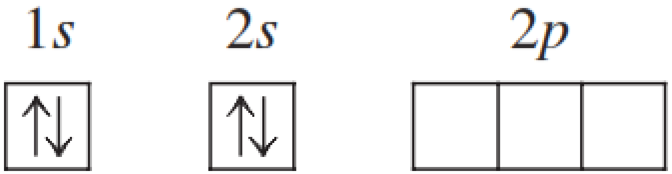
IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 * La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226.0)	89 ** Ac (227)	104 Rf	105 Ha	106 Unh	107 Uns	108	109 Une									

* 58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
** 90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (244)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

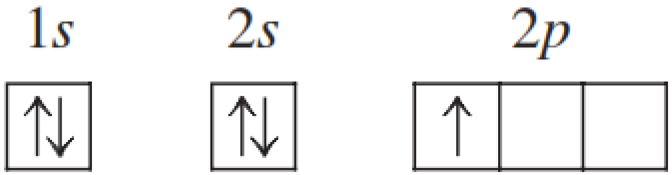
http://www.keyword-suggestions.com/bm9ubWV0YWxzIGF0IGhvbWU/ (accessed April 2017)

Orbital Diagrams and Electron Configurations* for the Elements in Period 2

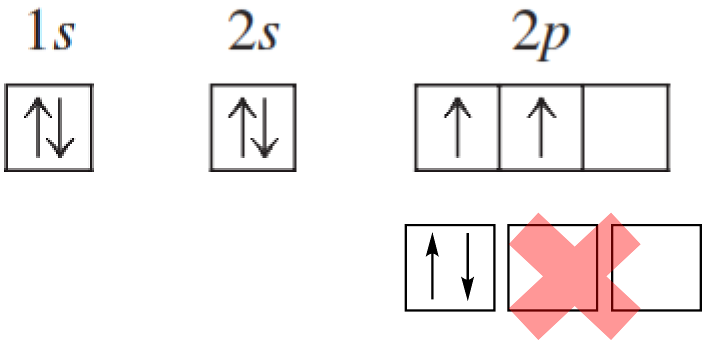
Be: $1s^22s^2$



B: $1s^22s^22p^1$



C: $1s^22s^22p^2$

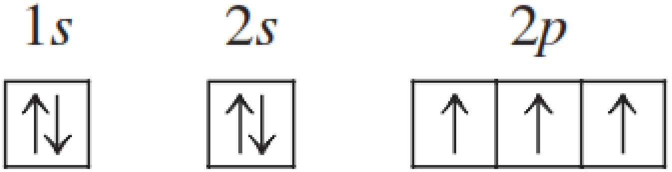


Silberberg, M.; Amateis, P. Chemistry The Molecular Nature of Matter and Change 7th edition; McGraw-Hill Science, 2014.

Orbital Diagrams and Electron Configurations* for the Elements in Period 2

N (Z = 7)

N: $1s^22s^22p^3$



O (Z = 8)

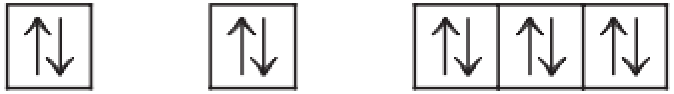
F (Z =9)

$_{10}$Ne

Silberberg, M.; Amateis, P. Chemistry The Molecular Nature of Matter and Change 7th edition; McGraw-Hill Science, 2014.

Information

Ne: $1s^22s^22p^6$



[Ne] is shorthand for $1s^2$, $2s^2$, $2p^6$

Mg (Z=12) : **$1s^2$, $2s^2$, $2p^6$, $3s^2$**

[Ne] $3s^2$

Ar (Z=18) : $[1s^22s^22p^6]\ 3s^23p^6$ → **[Ar]**

K (Z=19) : $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $4s^1$

[Ar] $4s^1$

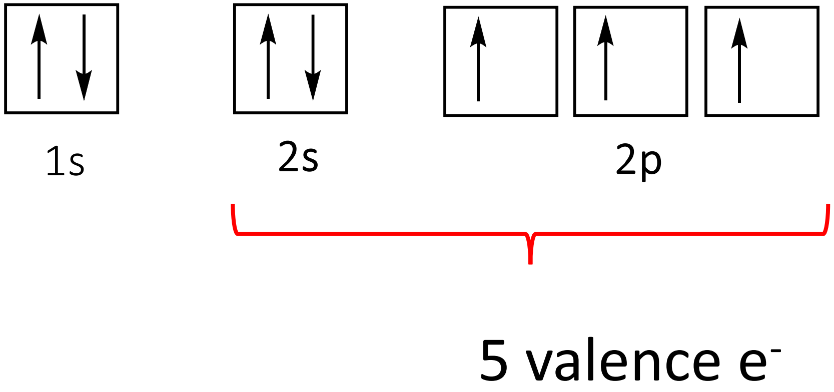
Silberberg, M.; Amateis, P. Chemistry The Molecular Nature of Matter and Change 7th edition; McGraw-Hill Science, 2014.

Concept of valence electrons

Valence electron is the electrons in the outermost principal energy level of an atom.

- The valence electrons are the most important electrons to chemists because they are the ones involved when atoms attach to each other (form bonds)

$$1s^2,\ \underbrace{2s^2,\ 2p^3}_{\text{5 valence } e^-}$$

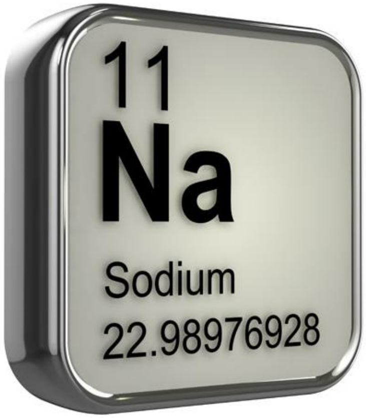


Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Core electrons

- **Core electron** is an inner electron; an electron not in the outermost principal energy level of an atom

- all nonvalence electrons → ***core electron***



valence e^-

$$\underbrace{1s^2,\ 2s^2,\ 2p^6}_{\textbf{core electron}},\ 3s^1$$

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Sample Problem 8.1

Electron configuration for the Elements in Period 3

PROBLEM: (a) Write the full electron configuration (shorthand configuration) and orbital diagram for the following elements.

(b) Determine the number of valence electrons

$_{11}Na$

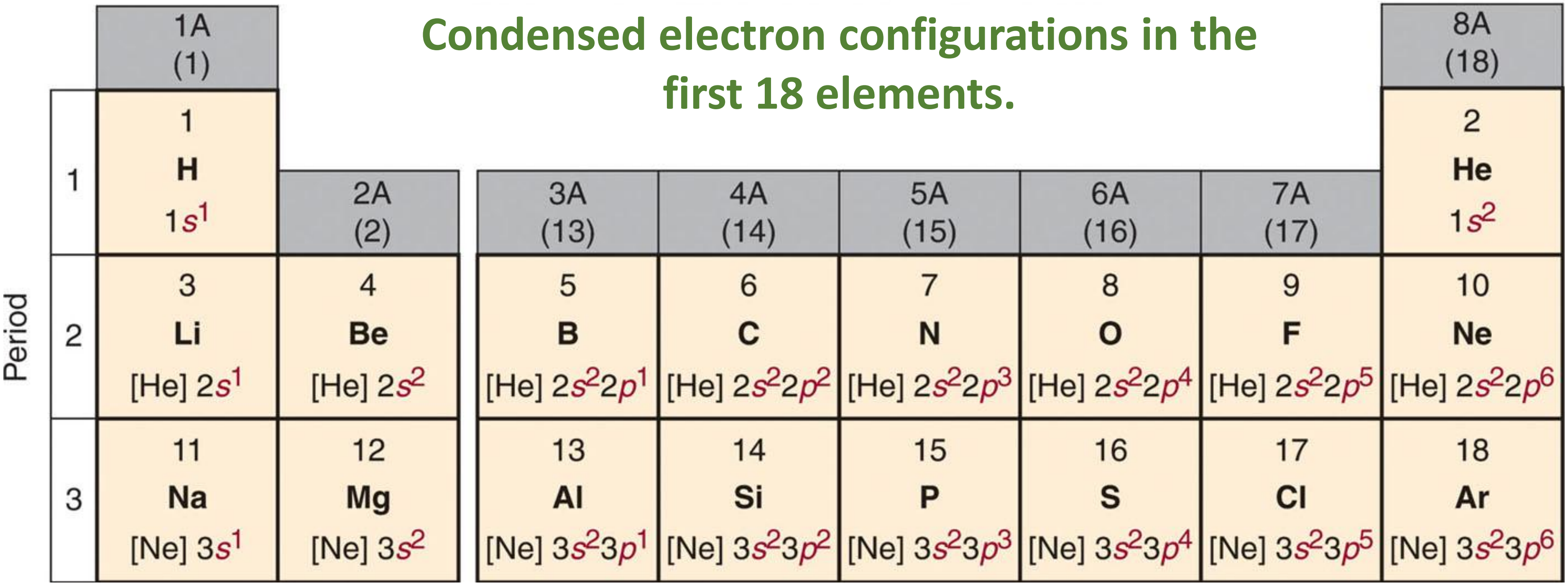
$_{13}Al$

$_{16}S$

Silberberg, M.; Amateis, P. Chemistry The Molecular Nature of Matter and Change 7th edition; McGraw-Hill Science, 2014.

Electron Configurations and the Periodic Table

Condensed electron configurations in the first 18 elements.



Period	1A (1)	2A (2)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
1	1 **H** $1s^1$							2 **He** $1s^2$
2	3 **Li** $[He]\ 2s^1$	4 **Be** $[He]\ 2s^2$	5 **B** $[He]\ 2s^22p^1$	6 **C** $[He]\ 2s^22p^2$	7 **N** $[He]\ 2s^22p^3$	8 **O** $[He]\ 2s^22p^4$	9 **F** $[He]\ 2s^22p^5$	10 **Ne** $[He]\ 2s^22p^6$
3	11 **Na** $[Ne]\ 3s^1$	12 **Mg** $[Ne]\ 3s^2$	13 **Al** $[Ne]\ 3s^23p^1$	14 **Si** $[Ne]\ 3s^23p^2$	15 **P** $[Ne]\ 3s^23p^3$	16 **S** $[Ne]\ 3s^23p^4$	17 **Cl** $[Ne]\ 3s^23p^5$	18 **Ar** $[Ne]\ 3s^23p^6$

- ☐ Elements in the **same group** have the same **valence elec**tron configurations.
- ☐ The period number is the ***n*** value of the **highest Principle energy level.**

For main group elements only

Silberberg, M.; Amateis, P. Chemistry The Molecular Nature of Matter and Change 7th edition; McGraw-Hill Science, 2014.

Building Up Period 4: The First Transition Series

- ☐ The 3d sublevel is filled in Period 4, but the **4s sublevel is filled first.**
  - ✓ the 4s orbital is slightly lower in energy than the 3d

K: $1s^22s^22p^63s^23p^64s^1$, or $[Ar]4s^1$

Ca: $1s^22s^22p^63s^23p^64s^2$, or $[Ar]4s^2$

- ☐ After calcium the next electrons go into the 3d orbitals to complete principal energy level 3.

Silberberg, M.; Amateis, P. Chemistry The Molecular Nature of Matter and Change 7th edition; McGraw-Hill Science, 2014.

Sample Problem 8.3

Electron configuration for the Elements in Period 4

PROBLEM: write the full electron configuration (shorthand configuration) and determine the number of **valence electrons** for the following elements.

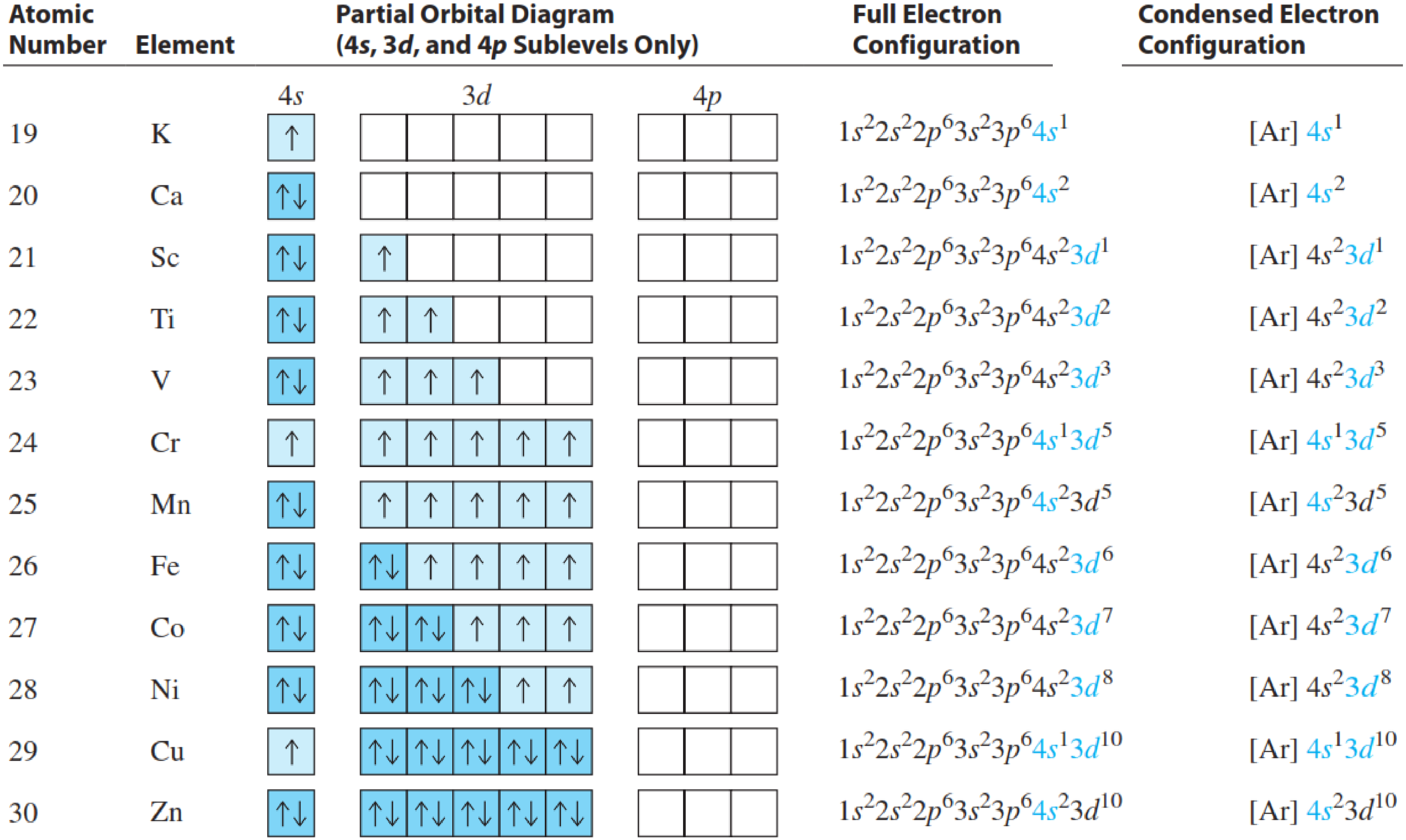
Sc (Z = 21)

Ti (Z = 22)

V (Z = 23)

Ni (Z = 28)

Orbital Diagrams and Electron Configurations* for the Elements in Period 4

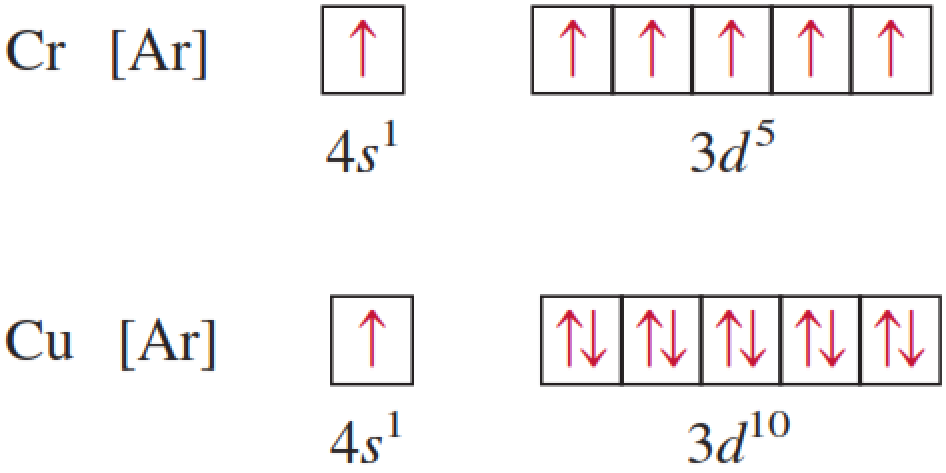


Atomic Number	Element	Partial Orbital Diagram (4s, 3d, and 4p Sublevels Only)									Full Electron Configuration	Condensed Electron Configuration
		4s	3d					4p				
19	K	↑									$1s^22s^22p^63s^23p^64s^1$	$[Ar]\ 4s^1$
20	Ca	↑↓									$1s^22s^22p^63s^23p^64s^2$	$[Ar]\ 4s^2$
21	Sc	↑↓	↑								$1s^22s^22p^63s^23p^64s^23d^1$	$[Ar]\ 4s^23d^1$
22	Ti	↑↓	↑	↑							$1s^22s^22p^63s^23p^64s^23d^2$	$[Ar]\ 4s^23d^2$
23	V	↑↓	↑	↑	↑						$1s^22s^22p^63s^23p^64s^23d^3$	$[Ar]\ 4s^23d^3$
24	Cr	↑	↑	↑	↑	↑	↑				$1s^22s^22p^63s^23p^64s^13d^5$	$[Ar]\ 4s^13d^5$
25	Mn	↑↓	↑	↑	↑	↑	↑				$1s^22s^22p^63s^23p^64s^23d^5$	$[Ar]\ 4s^23d^5$
26	Fe	↑↓	↑↓	↑	↑	↑	↑				$1s^22s^22p^63s^23p^64s^23d^6$	$[Ar]\ 4s^23d^6$
27	Co	↑↓	↑↓	↑↓	↑	↑	↑				$1s^22s^22p^63s^23p^64s^23d^7$	$[Ar]\ 4s^23d^7$
28	Ni	↑↓	↑↓	↑↓	↑↓	↑	↑				$1s^22s^22p^63s^23p^64s^23d^8$	$[Ar]\ 4s^23d^8$
29	Cu	↑	↑↓	↑↓	↑↓	↑↓	↑↓				$1s^22s^22p^63s^23p^64s^13d^{10}$	$[Ar]\ 4s^13d^{10}$
30	Zn	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓				$1s^22s^22p^63s^23p^64s^23d^{10}$	$[Ar]\ 4s^23d^{10}$

Silberberg, M.; Amateis, P. *Chemistry: The Molecular Nature of Matter and Change 7th edition;* McGraw-Hill Science, 2014.

Irregularities

The electron configuration of chromium ($Z = 24$) not [Ar], $4s^2$, $3d^4$, as we might expect

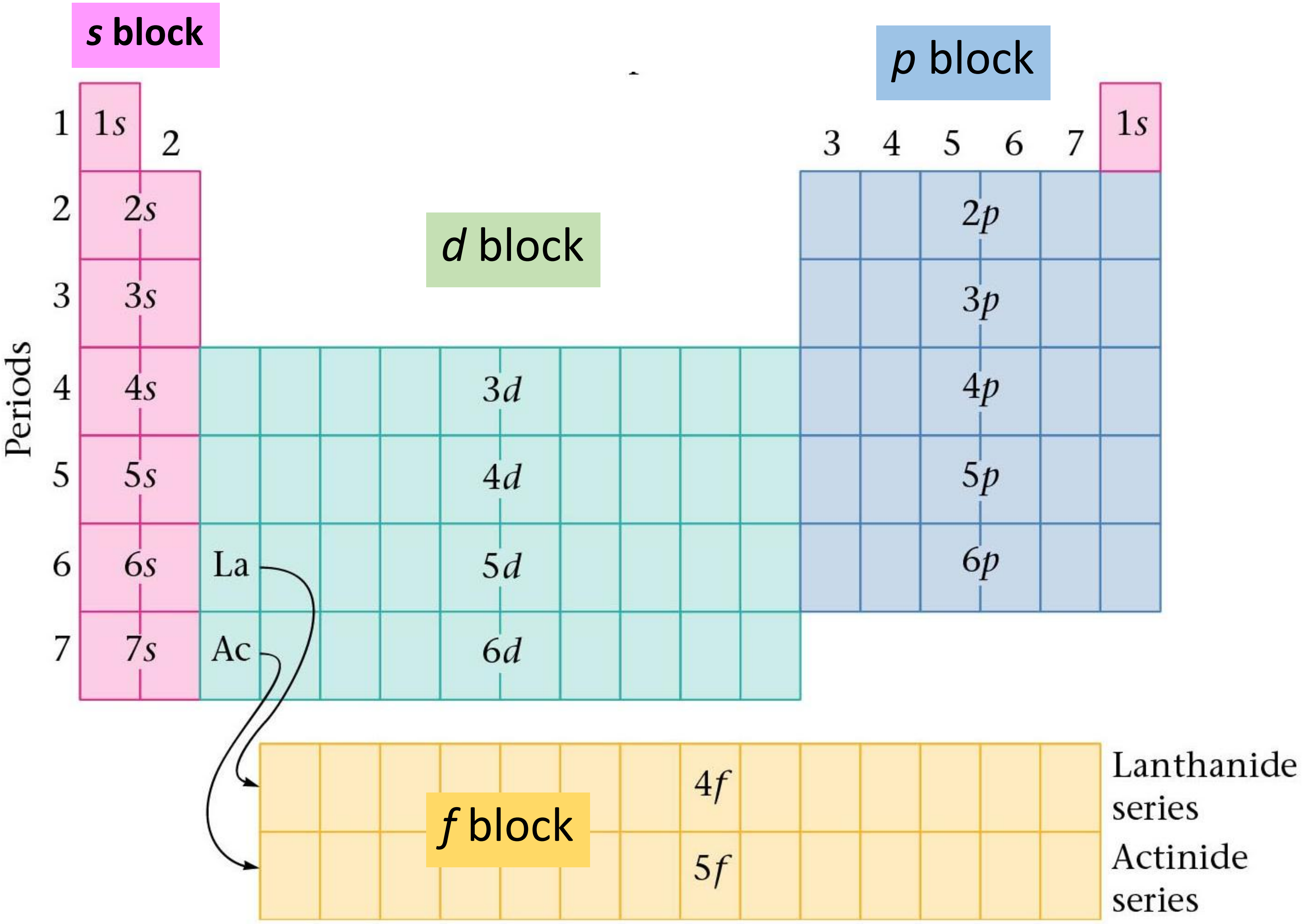


The reason for these irregularities is that;

- a slightly greater stability is associated with the half-filled ($3d^5$) and completely filled ($3d^{10}$) subshells.
- their shielding of one another is relatively small, and the electrons are more strongly attracted by the nucleus when they have the $3d^5$ configuration

Chang, R. *Chemistry*; McGraw-Hill, 2010.

Relationship between the periodic table and orbital filling



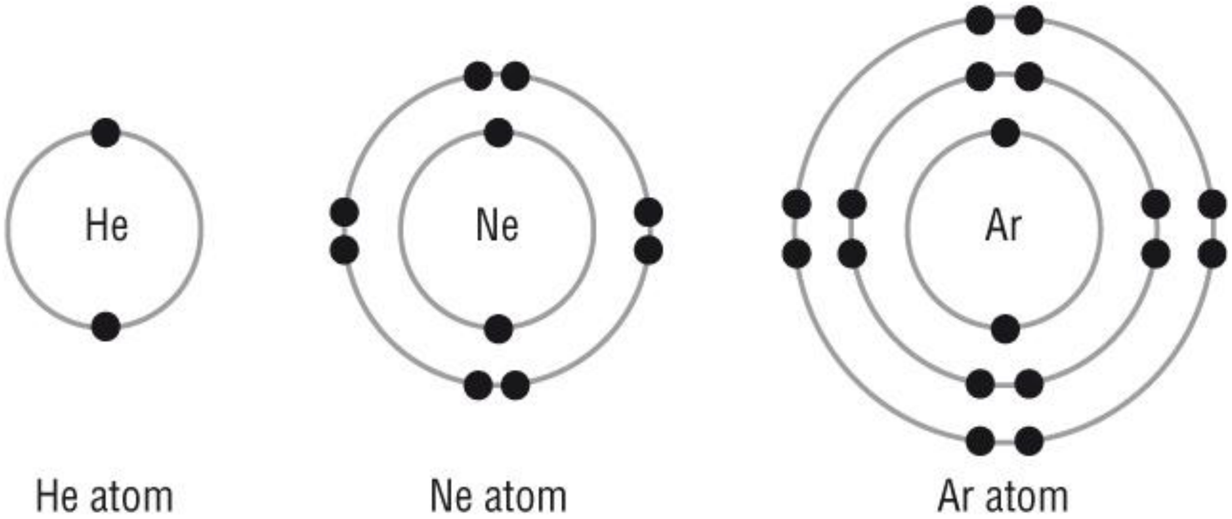
Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

THE **FORMATION**

OF IONS

Octet rule

An atom is stable if it has a octet configuration. An octet configuration is also known as a noble gas configuration

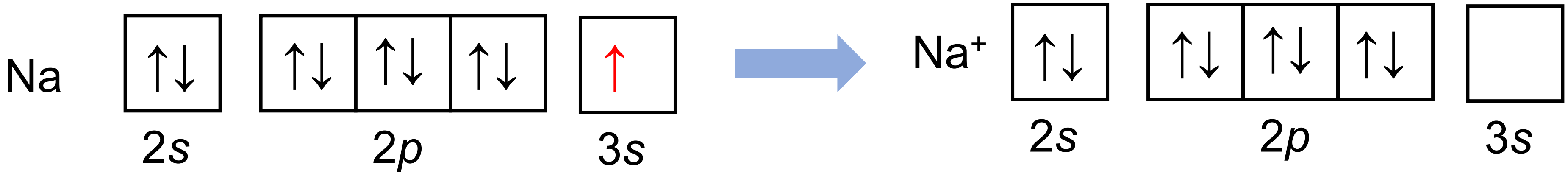


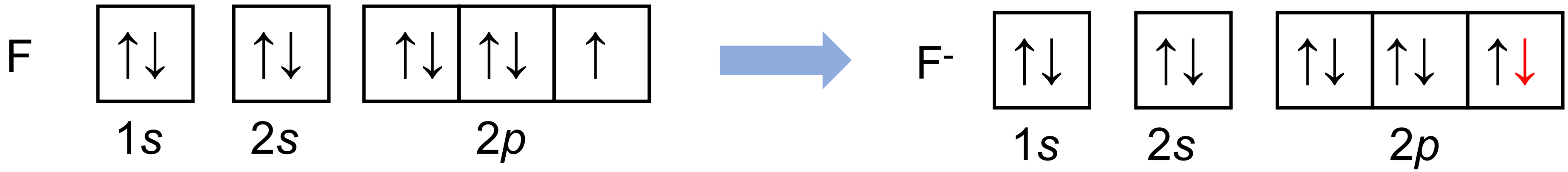
[He] $=1s^2$ [Ne] $= 1s^2\ 2s^2\ 2p^6$ [Ar] $= 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

- Atoms bond with each other in order to have the octet configuration (Octet rule)

Ingram, P., & Gallagher, R. (2011). *Complete Chemistry for Cambridge IGCSE*: OUP Oxford.

Formation of Ions by Metals and Nonmetals





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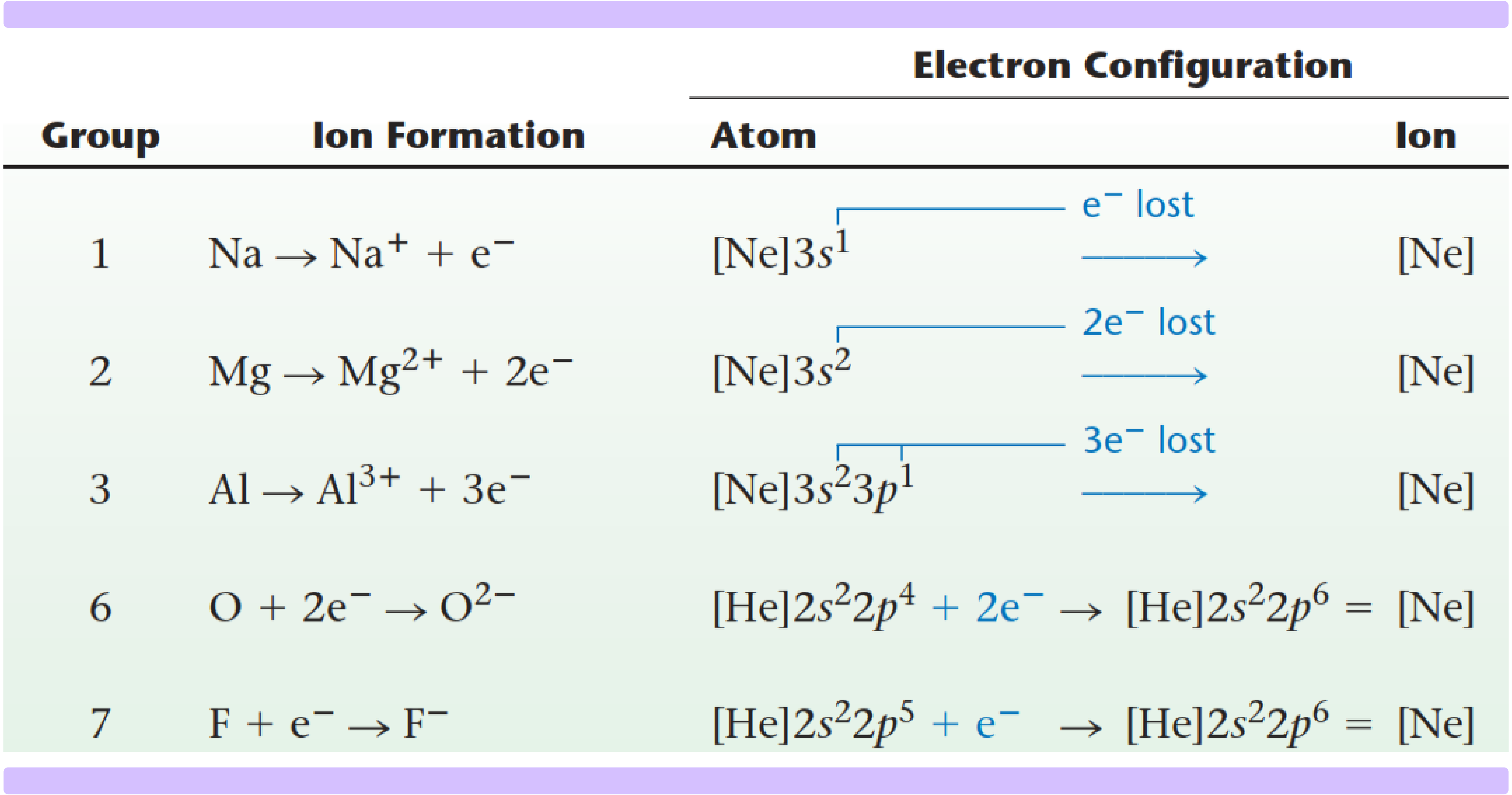
Formation of Ions by Metals and Nonmetals

$[Ne] = 1s^2\ 2s^2\ 2p^6$



		Electron Configuration		
Group	**Ion Formation**	**Atom**		**Ion**
1	$Na \rightarrow Na^+ + e^-$	$[Ne]3s^1$	$\xrightarrow{e^-\ \text{lost}}$	[Ne]
2	$Mg \rightarrow Mg^{2+} + 2e^-$	$[Ne]3s^2$	$\xrightarrow{2e^-\ \text{lost}}$	[Ne]
3	$Al \rightarrow Al^{3+} + 3e^-$	$[Ne]3s^23p^1$	$\xrightarrow{3e^-\ \text{lost}}$	[Ne]
6	$O + 2e^- \rightarrow O^{2-}$	$[He]2s^22p^4$	$+ 2e^- \rightarrow [He]2s^22p^6 =$	[Ne]
7	$F + e^- \rightarrow F^-$	$[He]2s^22p^5$	$+ e^- \rightarrow [He]2s^22p^6 =$	[Ne]

Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

SAMPLE PROBLEM 8.6 Writing Electron Configurations of Main-Group Ions

PROBLEM: Write full electron configuration for the common ions of the following elements:

(a) Potassium (Z = 19) **(b)** Phosphorus (Z = 15) **(c)** Br (Z = 35)

SOLUTION:

(a) Potassium (Z = 19) is in Group 1A(1) and will lose one electron to be isoelectronic with Ar: K : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$ K^+ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ or [Ar]

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Predicting the Number of Electrons lost or Gained

Metals lose electrons

Group 1A → + 1 cation Li^+ Na^+

Group 2A → + 2 cation Mg^{2+}

Group 3A → + 3 cation Al^{3+}

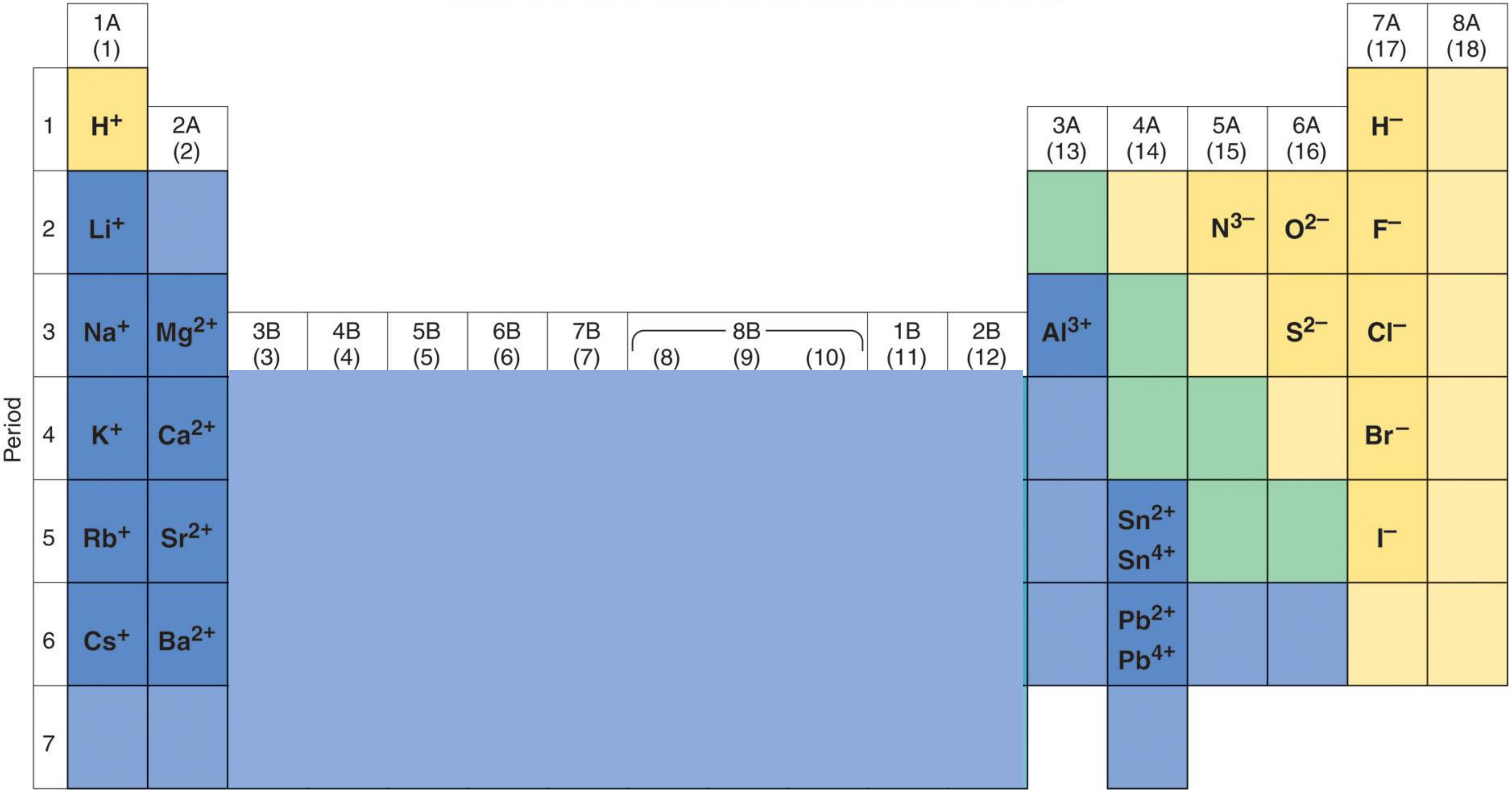
Nonmetals gain electrons

Group 5A → −3 anion (8-5) N^{3-}

Group 6A → −2 anion (8-6) O^{2-}

Group 7A → −1 anion F^-, Cl^-, Br^-,

Some common monatomic ions of the elements



Period	1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
1	H^+																H^-	
2	Li^+														N^{3-}	O^{2-}	F^-	
3	Na^+	Mg^{2+}											Al^{3+}			S^{2-}	Cl^-	
4	K^+	Ca^{2+}															Br^-	
5	Rb^+	Sr^{2+}												Sn^{2+} Sn^{4+}			I^-	
6	Cs^+	Ba^{2+}												Pb^{2+} Pb^{4+}				
7																		

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

SAMPLE PROBLEM 8.7

Writing Electron Configurations and Predicting Magnetic Behavior of Transition Metal Ions

PROBLEM: Write the condensed/full electron configuration of each transition metal ion

(a) Mn^{2+} **(b)** Cr^{3+} **(c)** Ni^{2+}

SOLUTION:

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Section 1.2

Periodic Table Trend

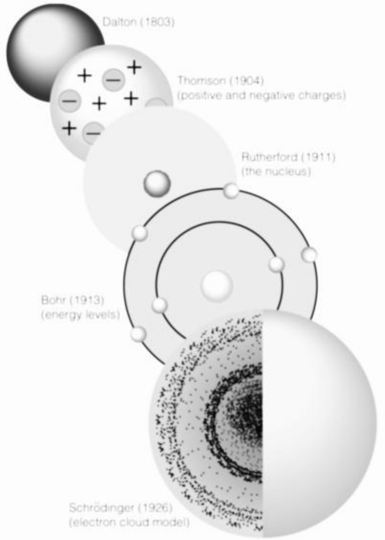
and

Atomic Properties

OUTLINE

1.1 Atomic structure

- ☐ Early atomic structure
- ☐ Bohr Model
- ☐ Schrödinger atom
- ☐ Atomic orbital
- ☐ Electron configurations



1.2 Periodic Table Trend and Atomic Properties

1.2A) Introduction to Periodic Table

1.2B) Atomic Size

1.2C) Ionization Energies

1.2D Metals and Nonmetals

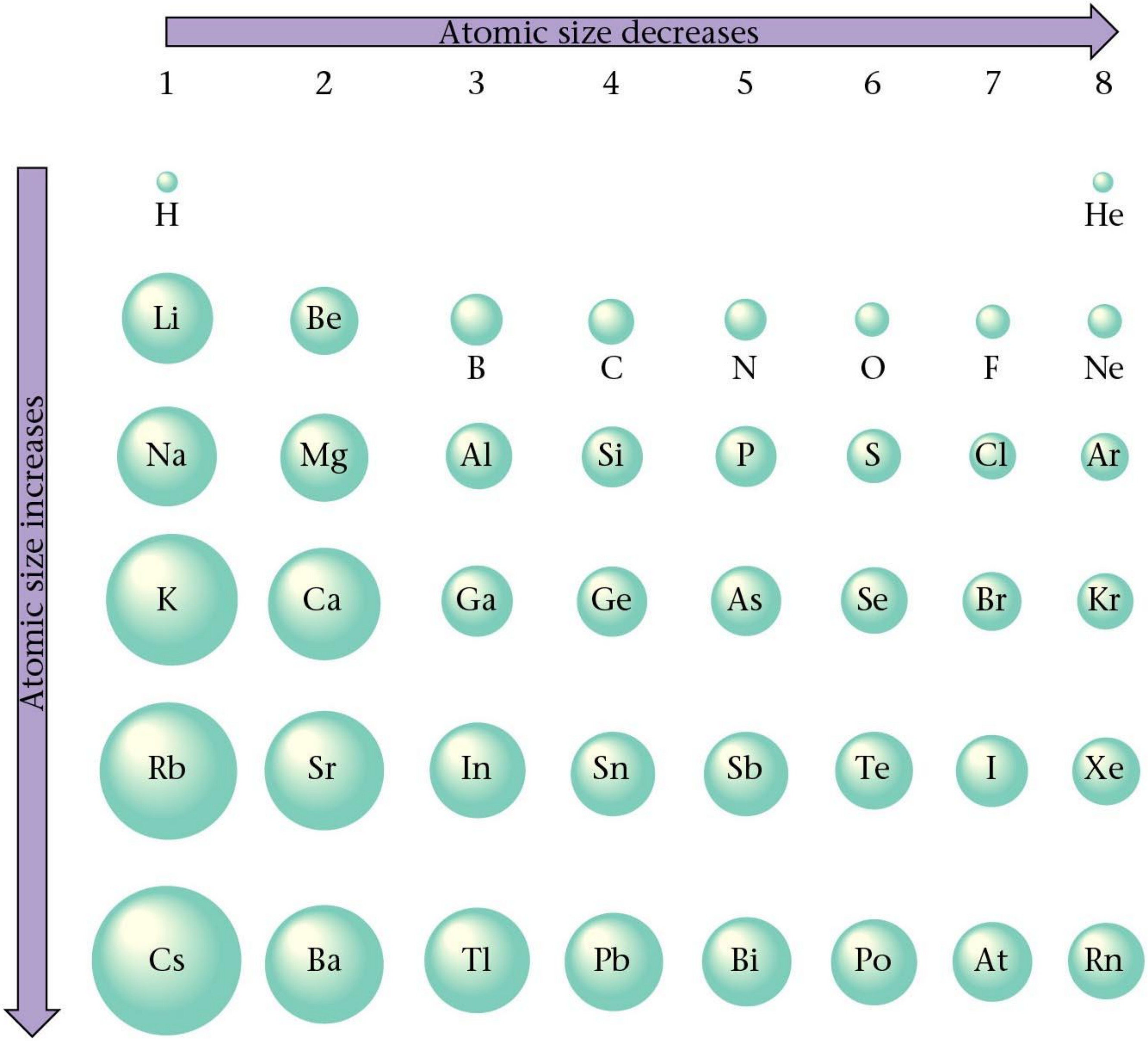
- ➢ Metallic behavier

Section

1.2B

Atomic Size

Atomic Size

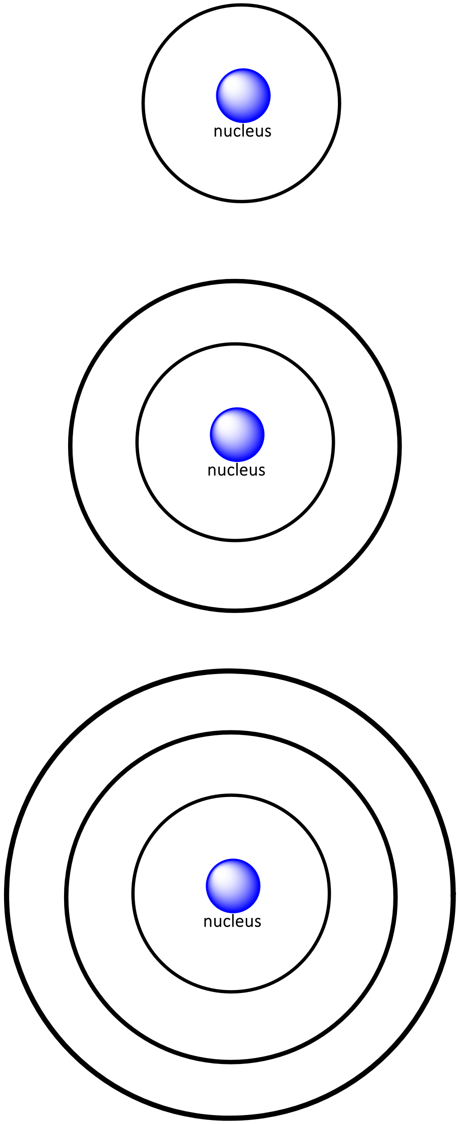


Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Atomic Size

DOWN a Group

principal energy level increases, The average distance of the electrons from the nucleus also increases.



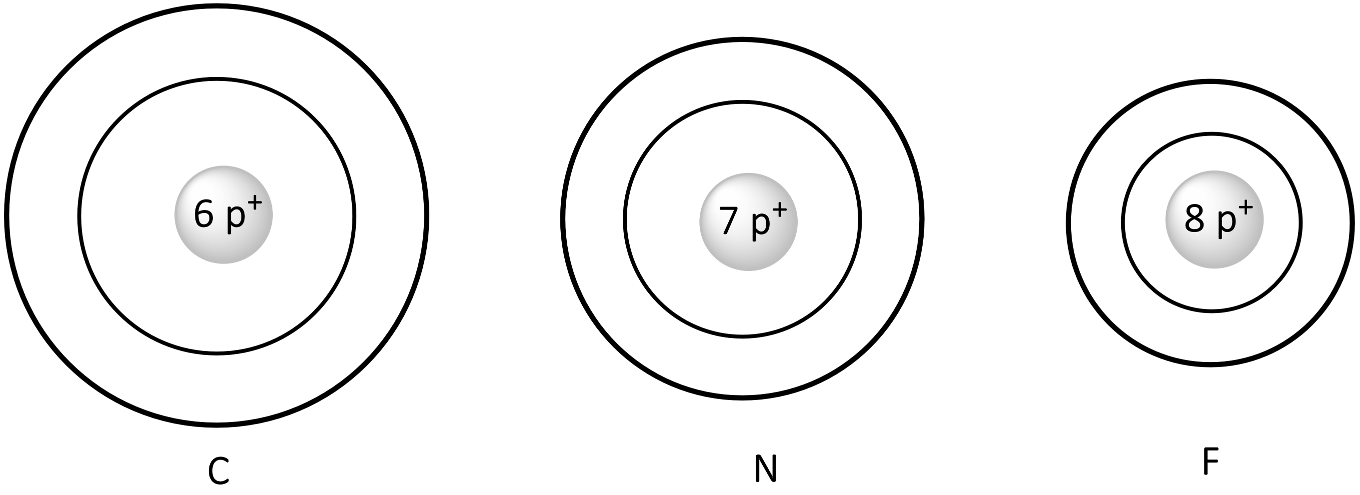
Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Atomic Size

Across a Period

The number of protons in the nucleus increases as we move from atom to atom in the period.

The resulting increase in positive charge on the nucleus tends to pull the electrons closer to the nucleus.



Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

SAMPLE PROBLEM 8.3

Ranking Elements by Atomic Size

PROBLEM: Using only the periodic table rank each set of main group elements in order of *decreasing* atomic size:

(a) Ca, Mg, Sr **(b)** K, Ga, Ca **(c)** Br, Rb, Kr **(d)** Sr, Ca, Rb

PLAN: Elements in the same group increase in size and you go down; elements decrease in size as you go across a period.

SOLUTION:

(a) Sr > Ca > Mg These elements are in Group 2A(2).

Section

1.2C

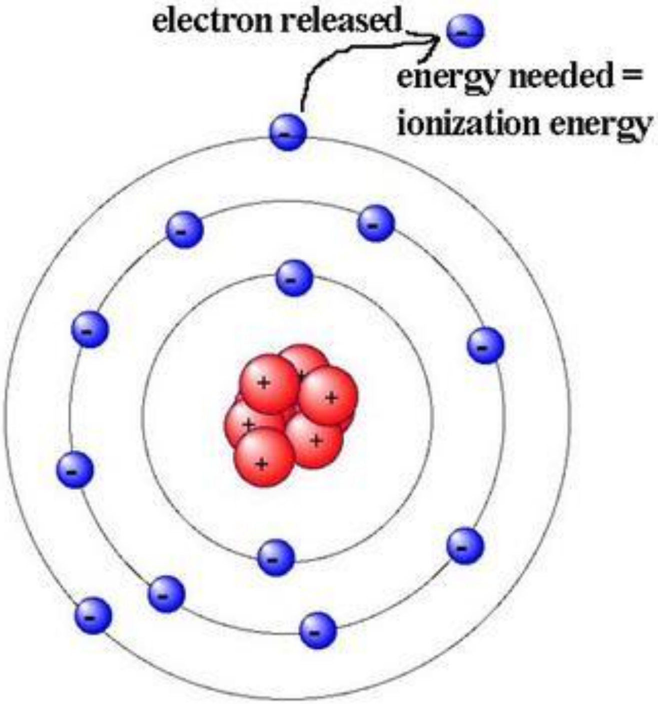
Ionization Energy

Ionization Energies (IE)

Ionization Energy

The amount of energy required to remove an electron from a gaseous atom or ion.

$$M(g) \xrightarrow[\text{Ionization energy}]{} M^{+}(g) + e^{-}$$



Zumdahl, S. S., Zumdahl, S. L., & DeCoste, D. J. (2012). *World of Chemistry*: CENGAGE Learning Custom Publishing.

Ionization Energies (IE)

$IE_1 + Al_{(g)} \longrightarrow Al^{+}_{(g)} + e^{-}$

IE_1 first ionization energy

$IE_2 + Al^{+}_{(g)} \longrightarrow Al^{2+}_{(g)} + e^{-}$

IE_2 second ionization energy

$IE_3 + Al^{2+}_{(g)} \longrightarrow Al^{3+}_{(g)} + e^{-}$

IE_3 third ionization energy

$$\boxed{IE_1 < IE_2 < IE_3}$$

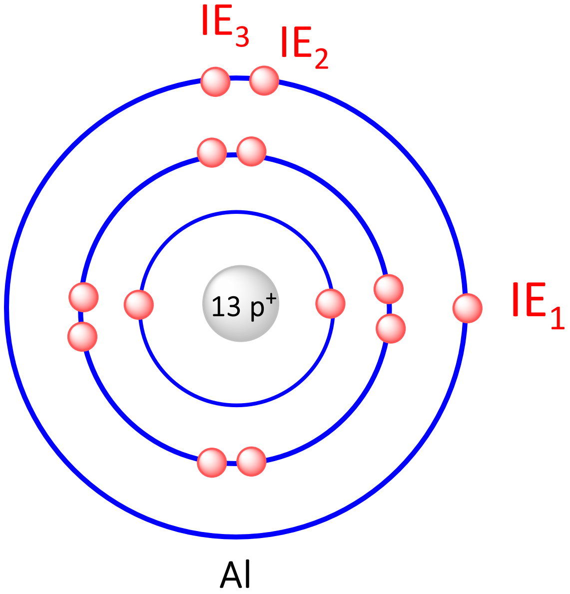
❑ The increase in positive charge binds the electrons more firmly, and the ionization energy increases.

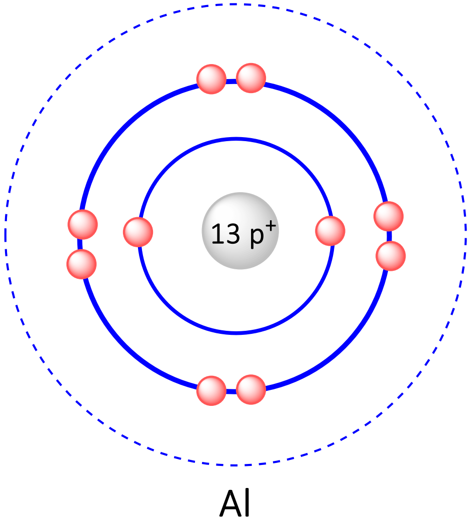
Zumdahl, S. S., & Zumdahl, S. A. (2006). *Chemistry*: Cengage Learning.

Table 7.5 Successive Ionization Energies (kJ/mol) for the Elements in Period 3

Element	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Na	495	4560					
Mg	735	1445	7730	Core electrons*			
Al	580	1815	2740	11,600			
Si	780	1575	3220	4350	16,100		
P	1060	1890	2905	4950	6270	21,200	
S	1005	2260	3375	4565	6950	8490	27,000
Cl	1255	2295	3850	5160	6560	9360	11,000
Ar	1527	2665	3945	5770	7230	8780	12,000

Note! the large jump in energy in each case in going from removal of valence electrons to removal of core electrons.





SAMPLE PROBLEM 8.5

Identifying an Element from Successive Ionization Energies

PROBLEM: Name the Period 3 element with the following ionization energies (in kJ/mol) and write its electron configuration:

IE_1	IE_2	IE_3	IE_4	IE_5	IE_6
1012	1903	2910	4956	6278	22,230

PLAN: Look for a large increase in energy which indicates that all of the valence electrons have been removed.

SOLUTION:

- ✓ The largest increase occurs after IE_5, that is, after the 5th valence electron has been removed.
- ✓ Five electrons would mean that the valence configuration is $3s^23p^3$ and the element must be in the Group 5 → phosphorous, P (Z = 15).
- ✓ The complete electron configuration is $1s^22s^22p^63s^23p^3$.

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

SAMPLE PROBLEM 8.5A

Identifying an Element from Successive Ionization Energies

PROBLEM: Name the Period 2 element with the following ionization energies (in kJ/mol) and write its electron configuration:

IE_1	IE_2	IE_3	IE_4	IE_5	IE_6
1090	2350	4620	6220	37,830	47,280

SOLUTION:

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

SAMPLE PROBLEM 8.5B

Identifying an Element from Successive Ionization Energies

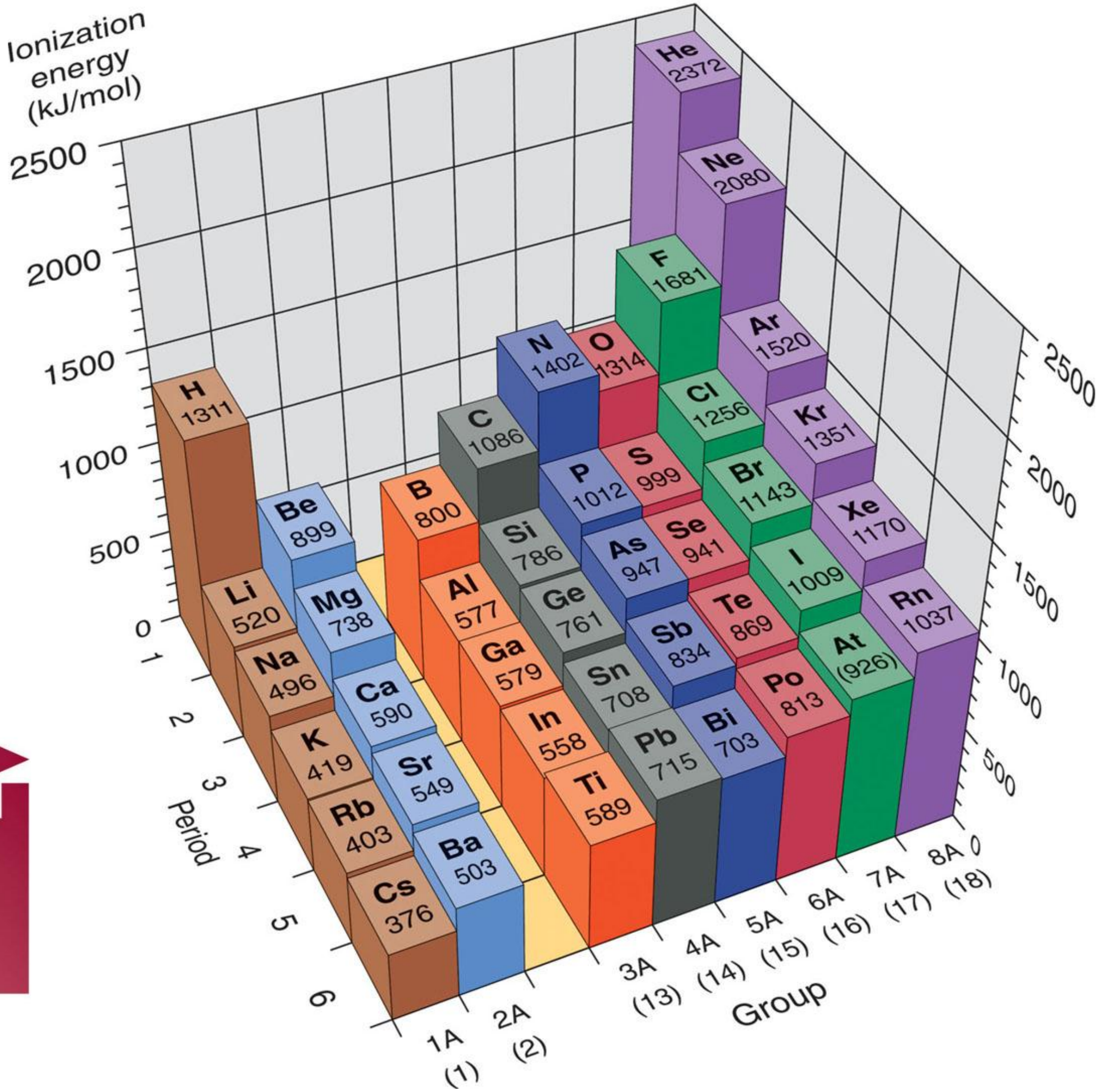
PROBLEM: Name the Period 3 element with the following ionization energies (in kJ/mol) and write its electron configuration:

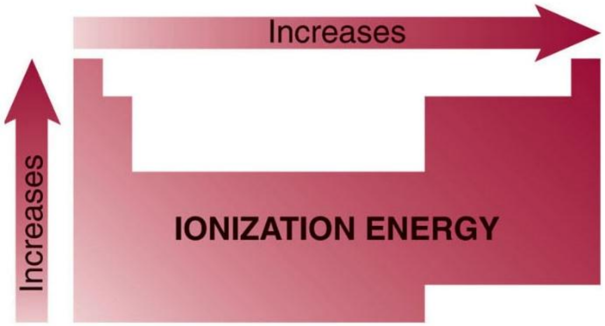
IE_1	IE_2	IE_3	IE_4	IE_5	IE_6	IE_7
501	4560	6910	13,350	16,610	20,110	25,490

SOLUTION:

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

First Ionization Energy





Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

First Ionization Energy

❑ Ionization energy generally **decreases down a group**. **Why?**

n value

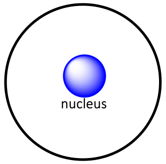
increase

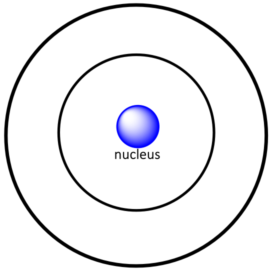
Atomic size **increase**

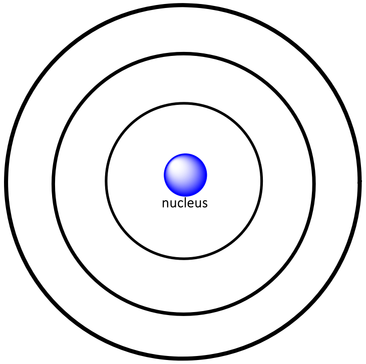
the distance from nucleus to outer electron increases

attraction between nucleus and outer electron **decrease**

Electron is easier to remove







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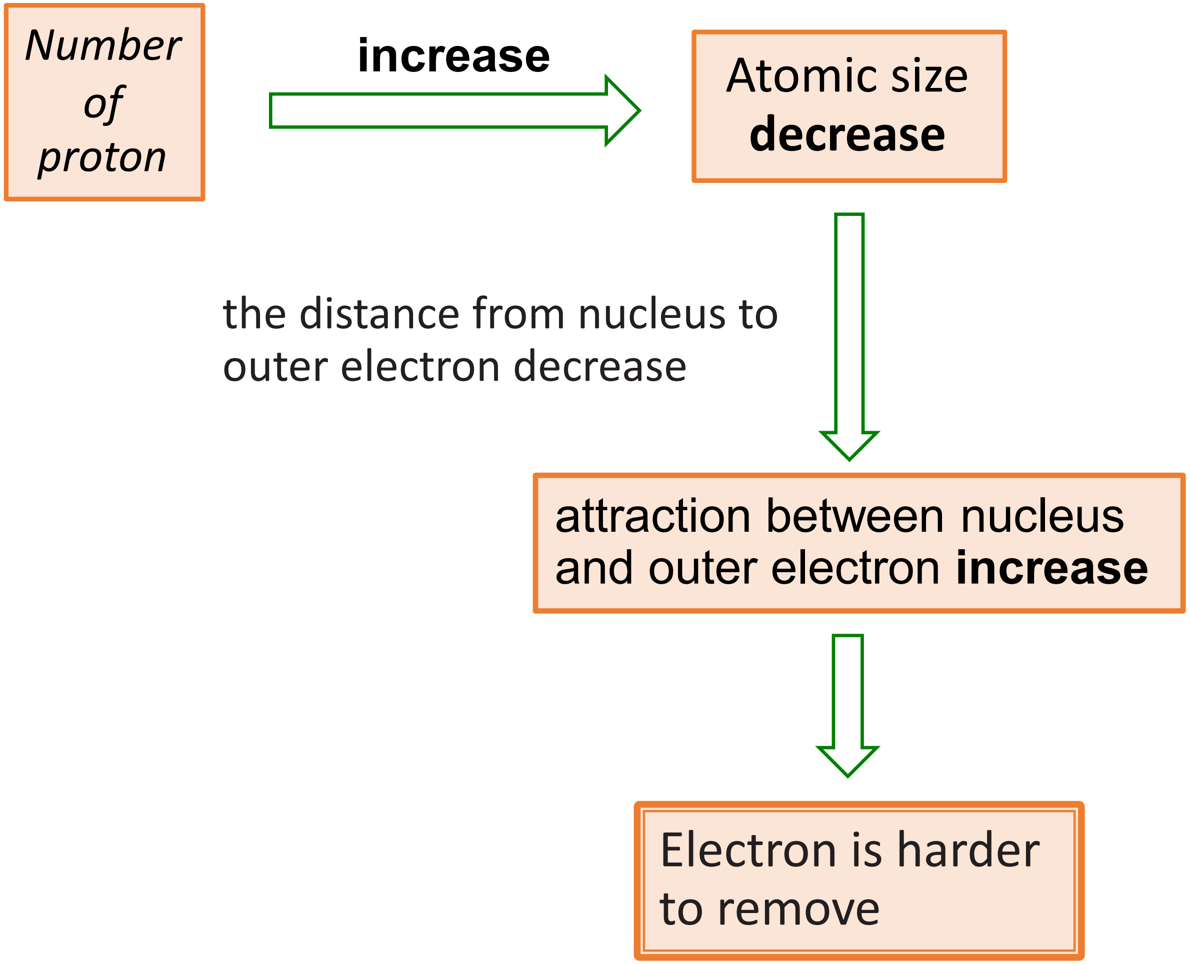
First Ionization Energy

❑ Ionization energy generally **increase across a group.** **Why?**



Number of proton

increase

Atomic size **decrease**

the distance from nucleus to outer electron decrease

attraction between nucleus and outer electron **increase**

Electron is harder to remove

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change 7th edition*: McGraw-Hill Science.

SAMPLE PROBLEM 8.4 Ranking Elements by First Ionization Energy

PROBLEM: Using the periodic table only, rank the elements in each of the following sets in order of *decreasing* IE_1:

(a) Kr, He, Ar **(b)** Sb, Te, Sn **(c)** K, Ca, Rb **(d)** I, Xe, Cs

PLAN: IE decreases as you proceed down in a group; IE increases as you go across a period.

SOLUTION:

(a) He > Ar > Kr Group 8A(18) - IE decreases down a group.

SAMPLE PROBLEM 8.4

Ranking Elements by First Ionization Energy

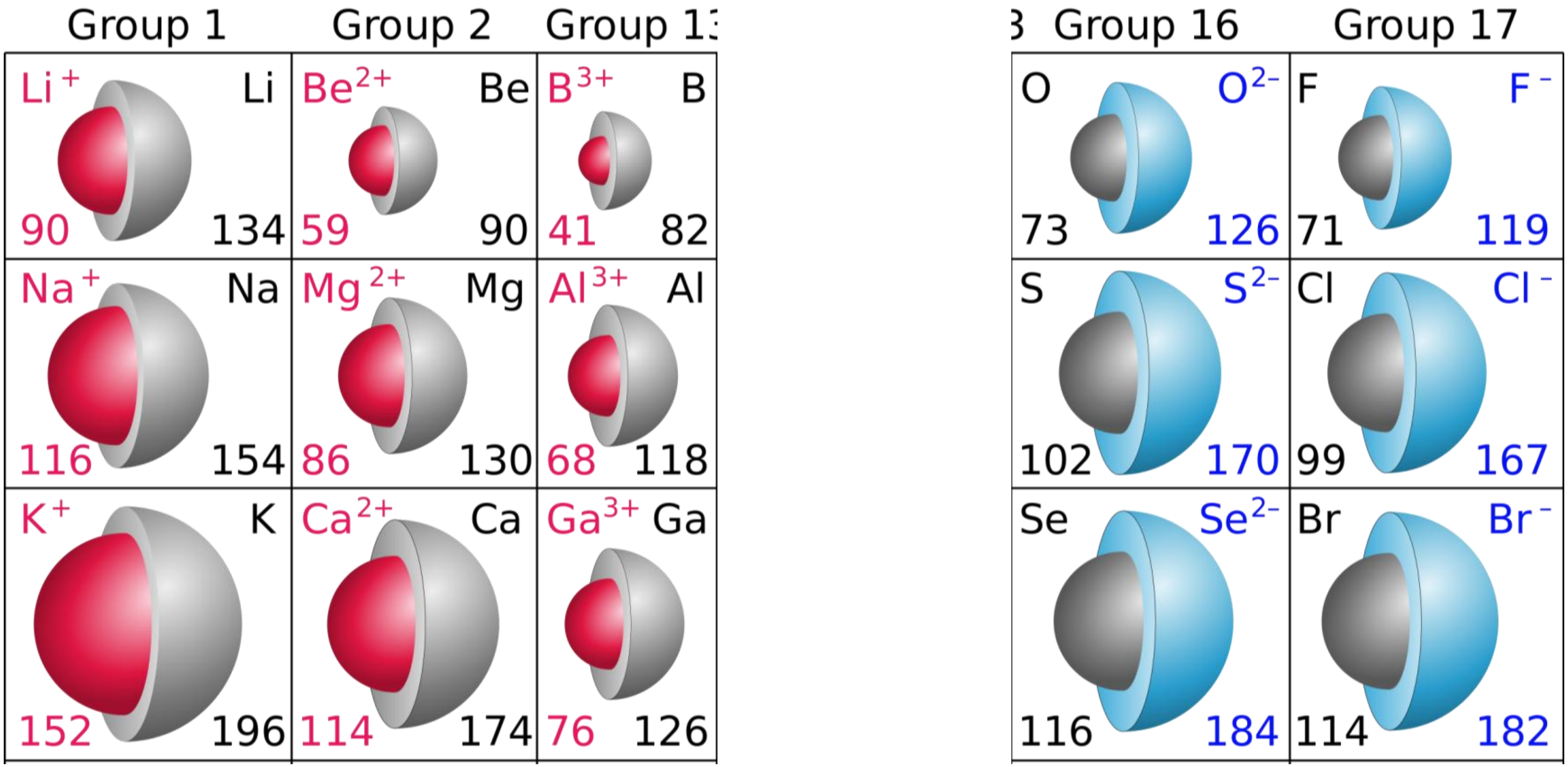
PROBLEM: Which atom would require more ionization energy to remove an electron?

1) Na *Vs* Cl

2) Li *Vs* Cs

Ionic Size

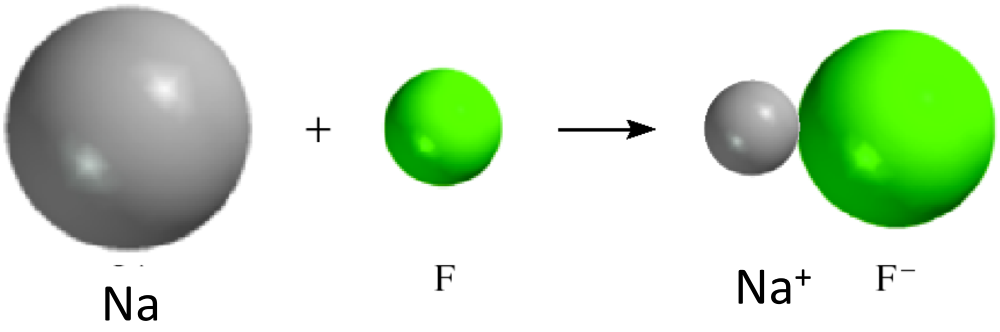
Ionic Size vs. Atomic Size



- **Cation** is always **smaller** than **atom** from which it is formed.

- **Anion** is always **larger** than **atom** from which it is formed.

Periodic Trends in Ionic Radii



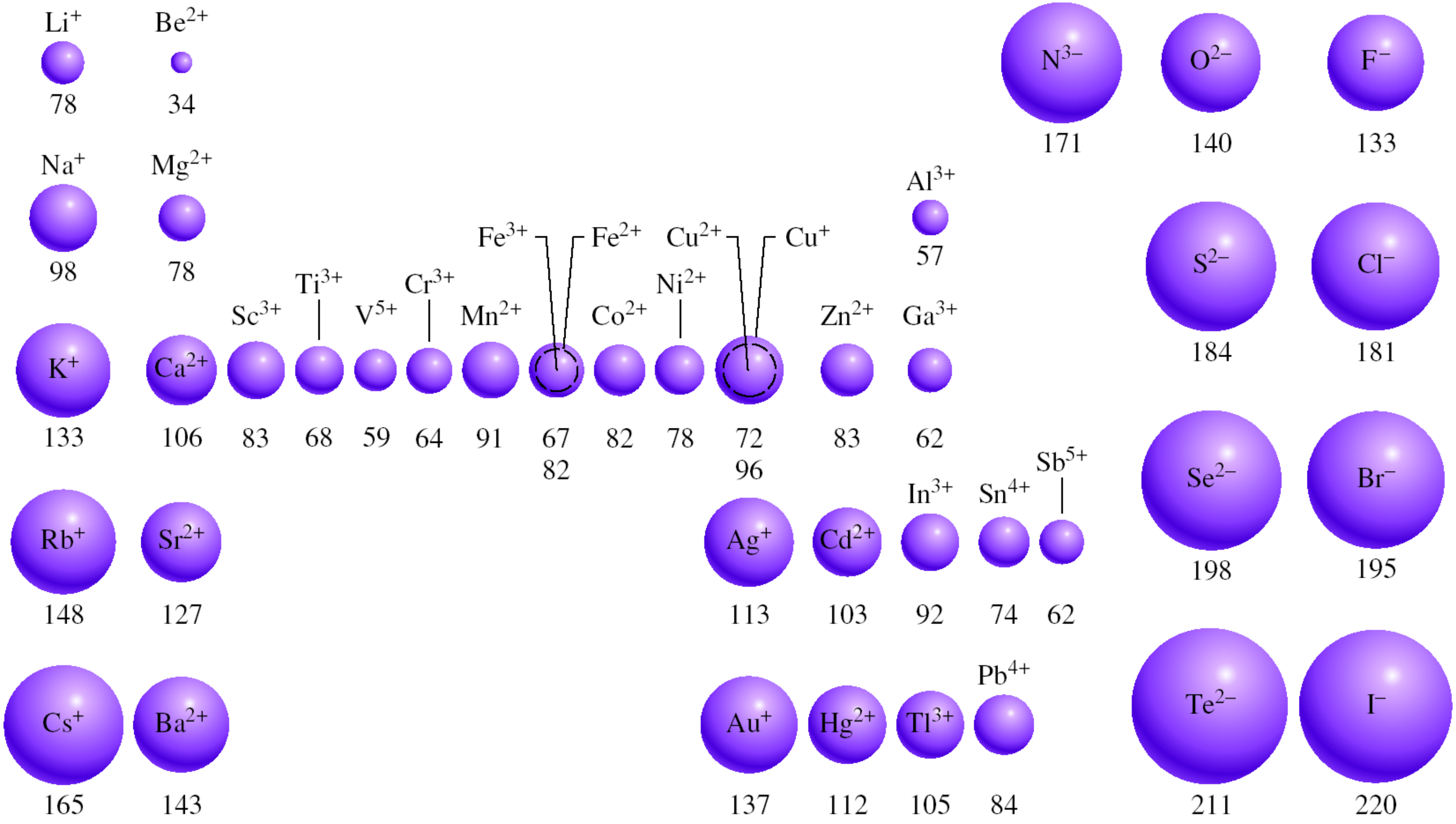
1s² 2s² 2p⁶

Both ions have the same number of electrons, but Na (Z = 11) has more protons than F (Z = 9) . The larger effective nuclear charge of Na results in a smaller radius.

- ☐ Anions are almost always larger than cations

Chang, R. *Chemistry*; McGraw-Hill, 2010.

Periodic Trends in Ionic Radii



Chang, R. *Chemistry*; McGraw-Hill, 2010.

Periodic Trends in Ionic Radii

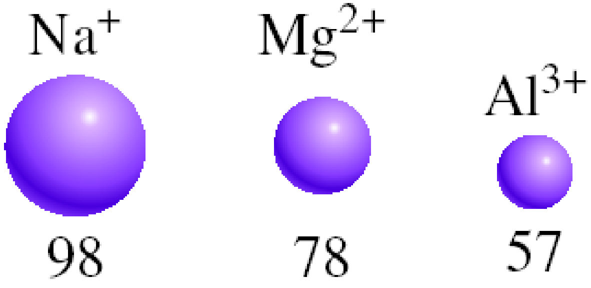
Down a group

ionic size increases because ***n*** increases.

Across a group

cation size

Number of proton increase from left to right makes Na^+ larger than Mg^{2+} and Al^{3+}



Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Periodic Trends in Ionic Radii

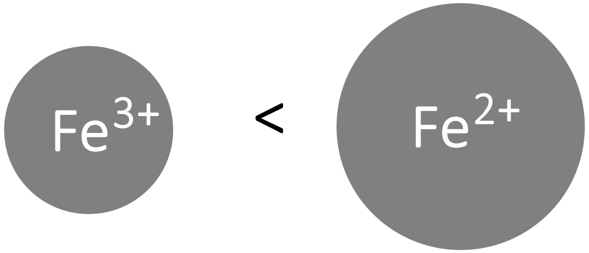
Down a group

ionic size increases because ***n*** increases.

Across a group

cation size decreases with charge

When a metal forms more than one cation, the greater the ionic charge, the smaller the ionic radius



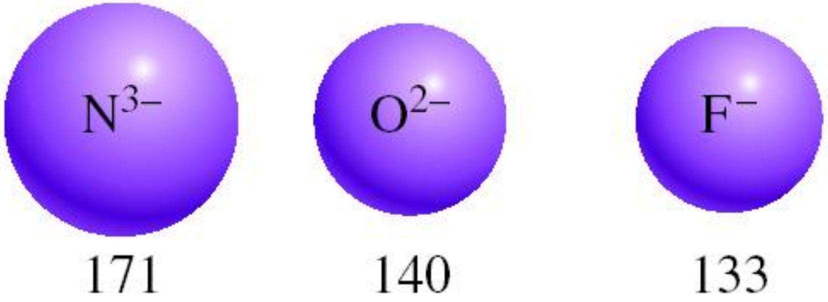
Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

Periodic Trends in Ionic Radii

Across a group

anion size decreases from left to right

Among anions, the increase in number of proton from left to right makes N^{3-} larger than O^{2-} which is larger than F^{-}.



Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

SAMPLE PROBLEM 8.8 Ranking Ions by Size

PROBLEM: Rank each set of ions in order of *decreasing* size, and explain your ranking:

(a) Ca^{2+}, Sr^{2+}, Mg^{2+} **(b)** K^+, S^{2-}, Cl^- **(c)** Au^+, Au^{3+}

PLAN: Compare positions in the periodic table, formation of positive and negative ions and changes in size due to gain or loss of electrons.

SOLUTION:

Silberberg, M., & Amateis, P. (2014). *Chemistry The Molecular Nature of Matter and Change* : McGraw-Hill Science.

References

1) Chang, R.; Overby, J. S. *General Chemistry: The Essential Concepts; McGraw-Hill, 2011.*

2) Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

3) Zumdahl, S. S. *World of Chemistry; McDougal Littell, 2001.*

4) Zumdahl, S. S.; Zumdahl, S. A. *Chemistry*; Cengage Learning, 2006.