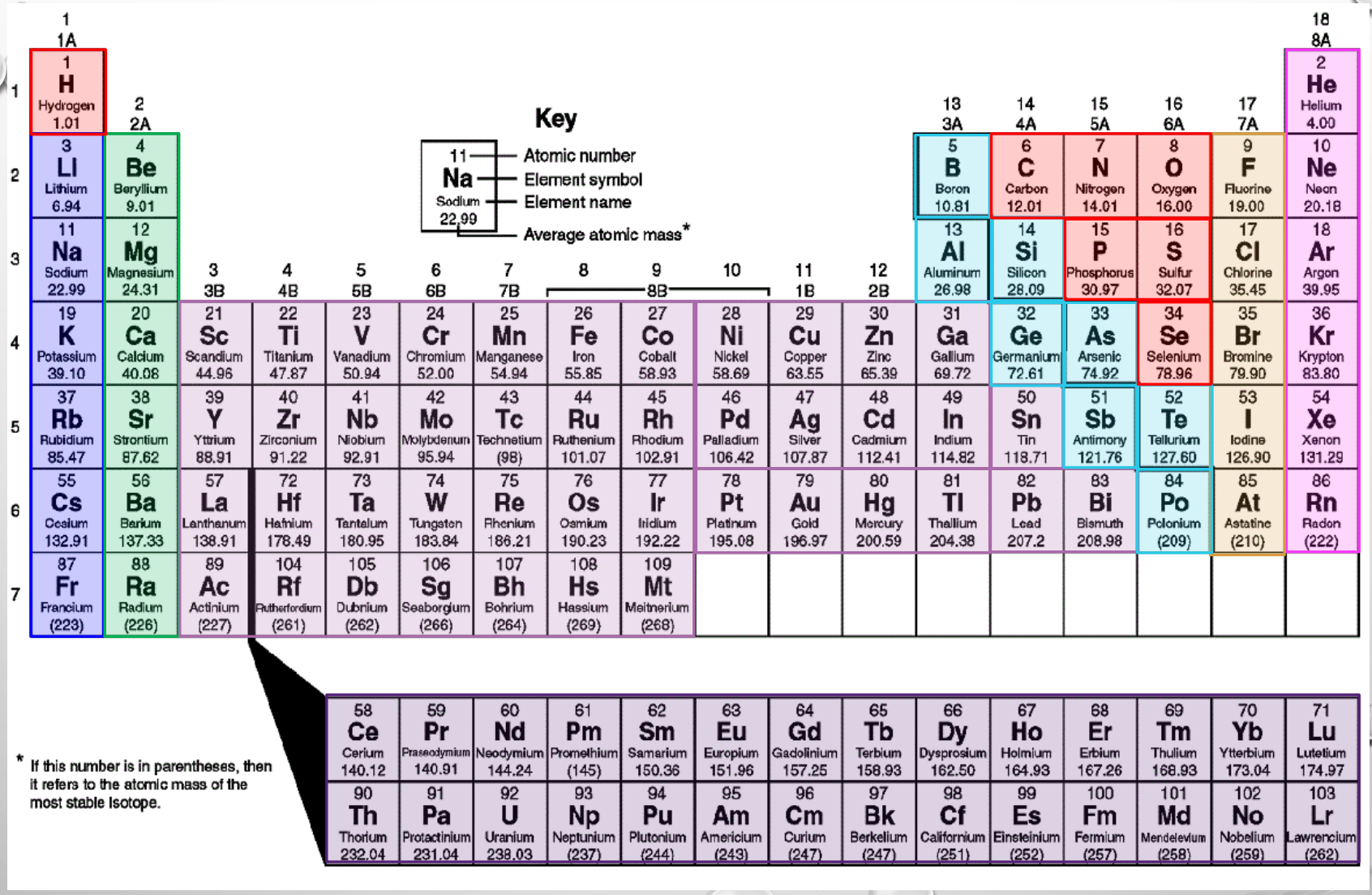
MODULE 3-ELEMENTS
ELECTRONIC STRUCTURE AND CHEMICAL PERIODICITY

REF: TEXTBOOK, CHAPTER 4, SUBSECTIONS 4.4 - 4.7

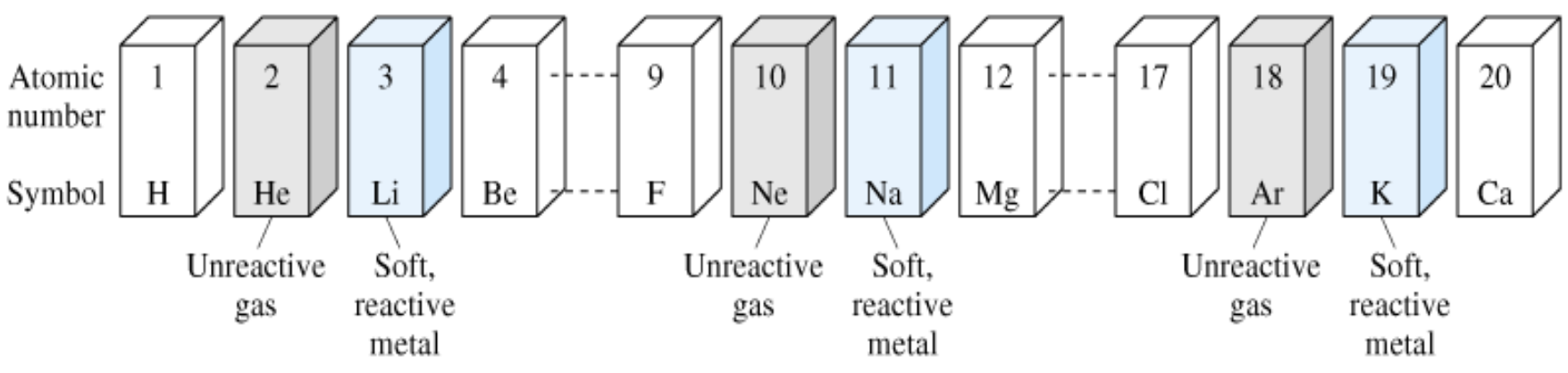

Key
11
Na
Sodium
22.99
Atomic number
Element symbol
Element name
Average atomic mass*
* If this number is in parentheses, then it refers to the atomic mass of the most stable isotope.

ELECTRONIC STRUCTURE & CHEMICAL PERIODICITY

- THE PERIODIC LAW
- THE PERIODIC TABLE
- PERIODIC TABLE TREND
- ELECTRON SHELLS, SUBSHELLS & ORBITALS
- ELECTRON CONFIGURATION
- CONDENSED ELECTRON CONFIGURATION
- PARAMAGNETIC & DIAMAGNETIC SUBSTANCES

PERIODIC TABLE

- **PERIODIC LAW**
  - WHEN ELEMENTS ARE ARRANGED IN ORDER OF INCREASING ATOMIC NUMBER, ELEMENTS WITH SIMILAR CHEMICAL BEHAVIOR OCCUR AT REGULARLY RECURRING (PERIODIC) INTERVALS.



PERIODIC TABLE

- SYMBOLS IN THE PERIODIC TABLE ARE NOT USED IN THE NUCLEAR NOTATION FORM AS DISCUSSED PREVIOUSLY. THEY USE THE ATOMIC NUMBER AND THE ATOMIC MASS:

27	28	29
Co	**Ni**	**Cu**
58.93	58.69	63.55

PERIODIC TABLE

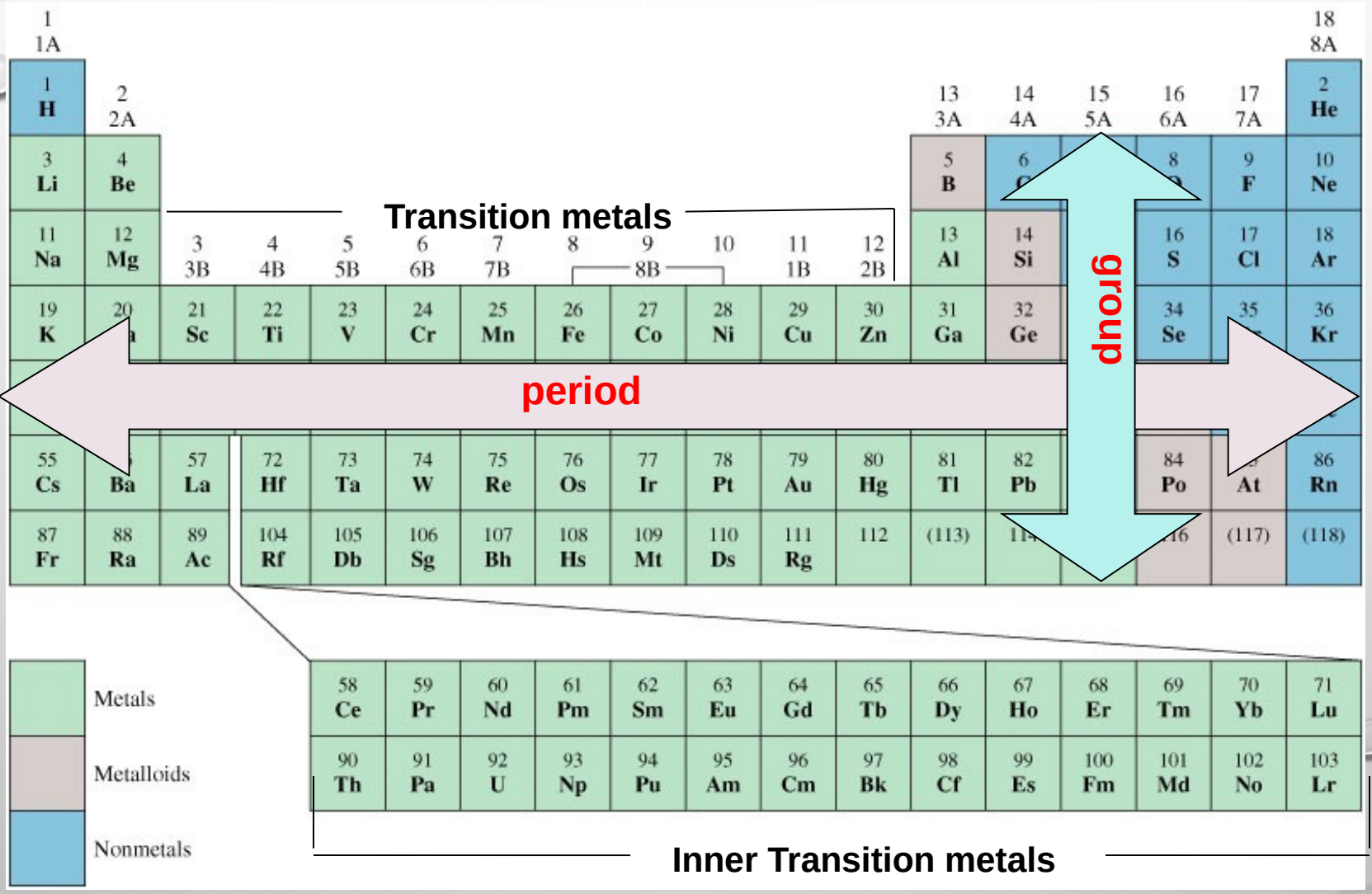
- PERIODIC TABLE:
  - A TABULAR ARRANGEMENT OF THE ELEMENTS IN ORDER OF INCREASING ATOMIC NUMBER SUCH THAT ELEMENTS HAVING SIMILAR CHEMICAL BEHAVIOR ARE GROUPED IN VERTICAL COLUMNS.
  - TO CREATE THE PERIODIC TABLE, ELEMENTS ARE ARRANGED BY ELECTRON LEVELS.

PERIODIC TABLE

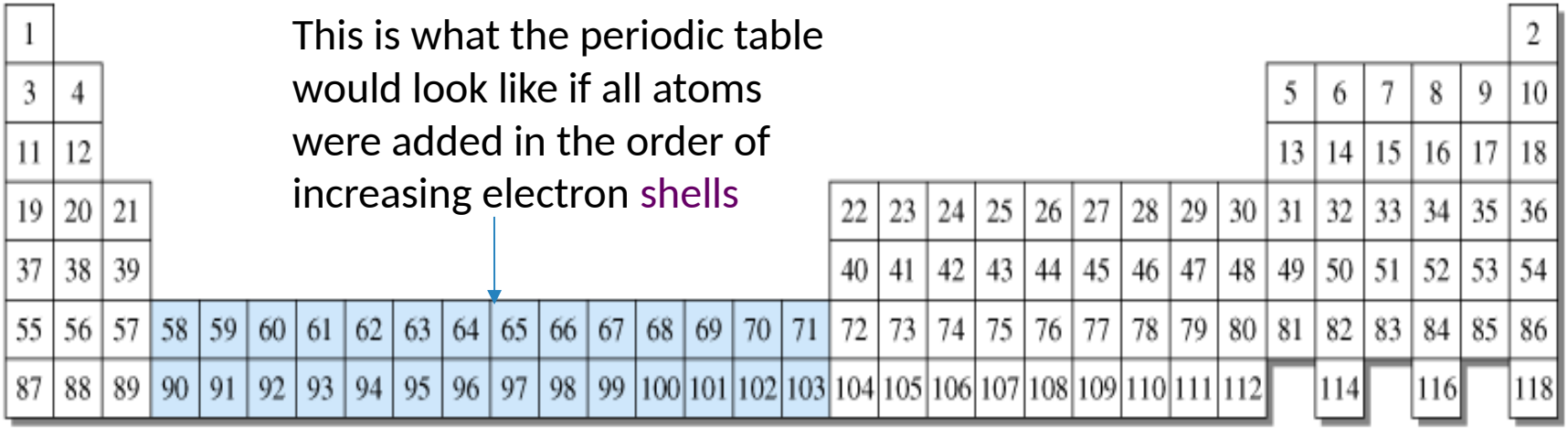
- PERIOD - HORIZONTAL ROW OF ELEMENTS IN THE PERIODIC TABLE.

- GROUP - VERTICAL COLUMN OF ELEMENTS IN THE PERIODIC TABLE.
  - 3 WAYS TO NAME COLUMNS, US, EU, IUPAC
  - 4 GROUPS WITH NON-NUMERICAL NAMES: ALKALI METAL, ALKALINE EARTH METAL, HALOGEN, NOBLE GAS

The Periodic Table of the Elements

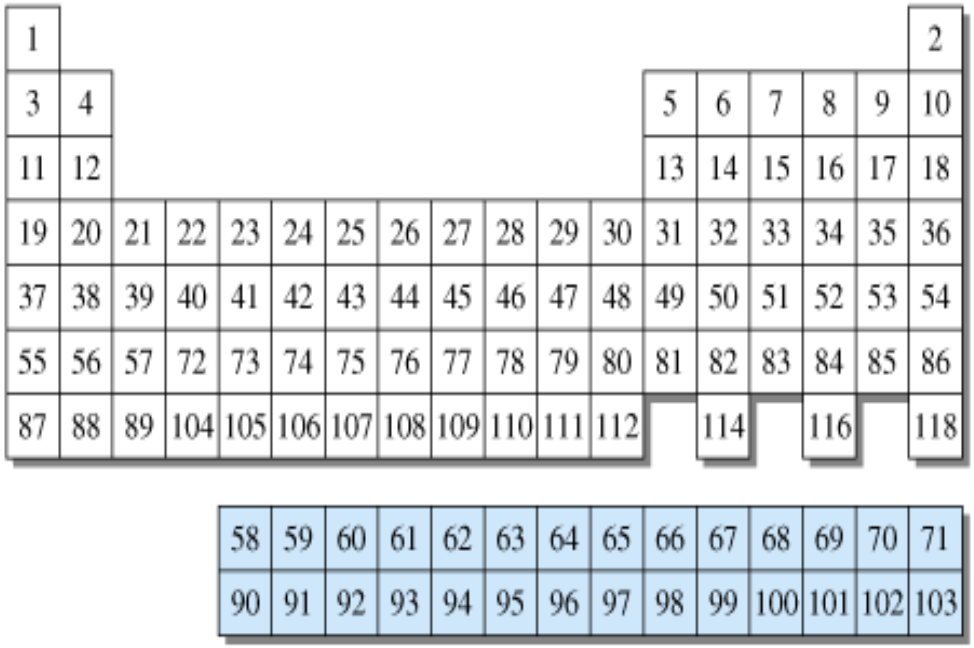


This is what the periodic table would look like if all atoms were added in the order of increasing electron shells



(a)

This is a compressed version of the periodic table with the rare earth elements separated out.

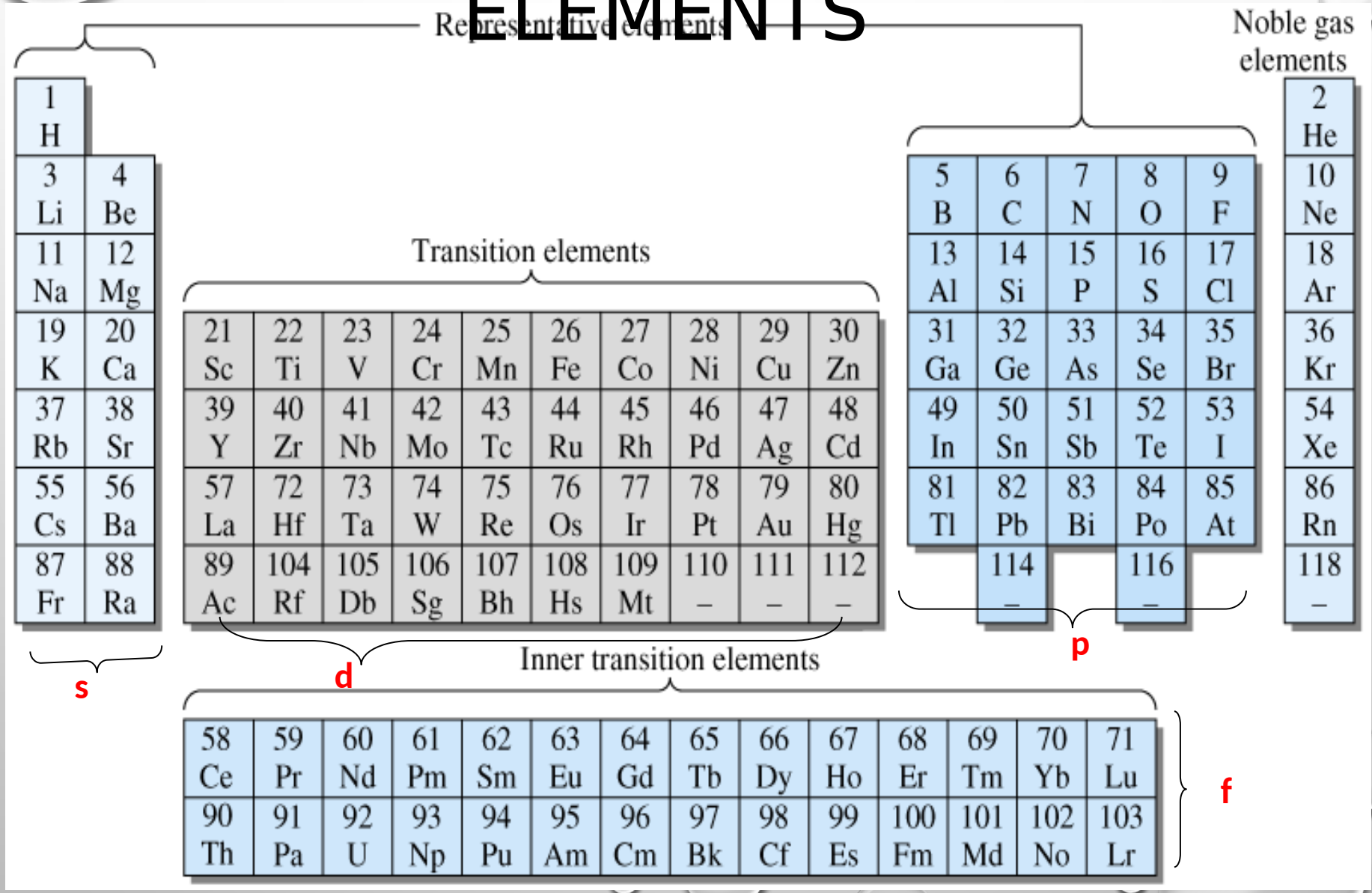


(b)

PERIODIC TABLE

- CLASSIFICATION BASED ON ELECTRON CONFIGURATIONS OF ELEMENTS
  - NOBEL GAS
  - REPRESENTATIVE
  - TRANSITION
  - INNER TRANSITION OR RARE EARTH ELEMENTS
- CLASSIFICATION BASED ON PHYSICAL PROPERTIES
  - METALS
  - NON-METALS

CLASSIFICATION SYSTEMS FOR ELEMENTS



PERIODIC TABLE

REPRESENTATIVE ELEMENT

- AN ELEMENT LOCATED IN THE '*s*' AREA OR THE FIRST FIVE COLUMNS OF THE '*p*' AREA OF THE PERIODIC TABLE.
- HAVE PARTIALLY OR COMPLETELY FULL '*s*' ELECTRON LEVEL.
- HAVE EMPTY OR PARTIALLY FULL '*p*' ELECTRON LEVEL.
- INCLUDES MOST COMMON ELEMENTS

PERIODIC TABLE

- ALKALI METALS – GROUP IA
  - Li, Na, K, Rb, Cs
  - ALL HAVE ONE VALENCE ELECTRON
  - THESE ARE ALL SOFT SHINY METALS.
  - ALL ARE VERY REACTIVE WITH WATER.

PERIODIC TABLE

- ALKALINE EARTH METALS – GROUP IIA
  - Be, Mg, Ca, Sr, Ba
  - ALL HAVE TWO VALENCE ELECTRONS.
  - SOFT, SHINY METALS.
  - ONLY MODERATELY REACTIVE WITH WATER.

PERIODIC TABLE

- HALOGEN – GROUP VIIA
  - F, Cl, Br, I, At (ASTATINE)
  - ALL HAVE 7 VALENCE ELECTRONS
  - EXIST AS DIATOMIC MOLECULES.
  - ARE VERY REACTIVE COLORED SUBSTANCES
  - GASES AT ROOM TEMPERATURE OR SLIGHTLY ABOVE ROOM TEMPERATURE.
  - Br IS LIQUID AT ROOM TEMPERATURE

PERIODIC TABLE

- NOBEL GASES – GROUP VIIIA
  - He, Ne, Ar, Kr, Xe, Rn
  - HAVE A FULL VALENCE SHELL OF ELECTRONS.
  - UNREACTIVE
  - ALL GASES AT ROOM TEMPERATURE

PERIODIC TABLE

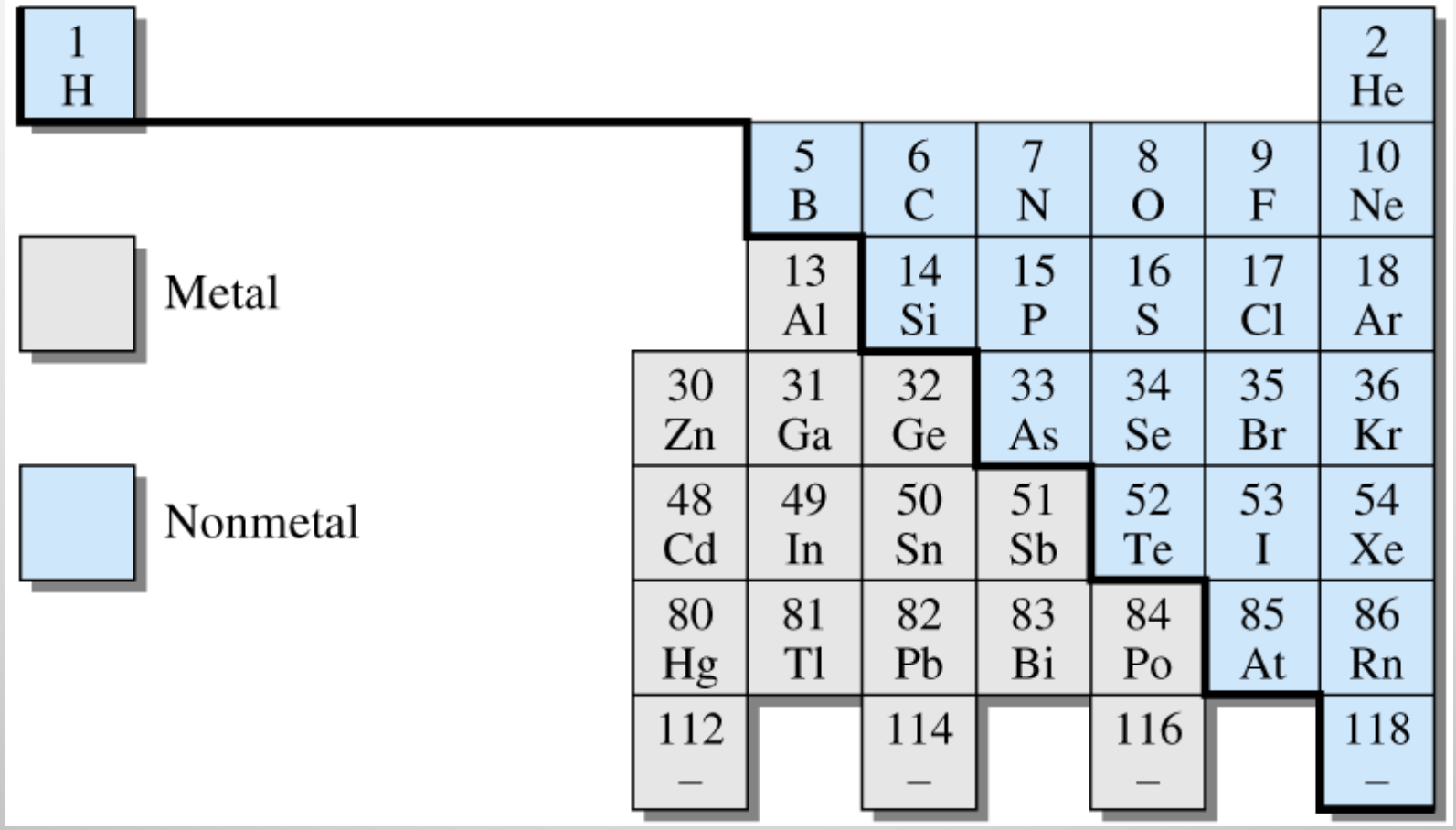
TRANSITION ELEMENT

- LOCATED IN THE '*d*' AREA OF THE PERIODIC TABLE
- ELECTRONS FILL THE '*D*' ENERGY LEVEL.

INNER TRANSITION ELEMENT

- LOCATED IN THE '*f*' AREA OF THE PERIODIC TABLE
- ELECTRONS FILL THE '*f*' ENERGY LEVEL
- SERIES ARE CALLED LANTHANIDES AND ACTINIDES – ALSO KNOW AS RARE EARTH ELEMENTS

ANOTHER COMMONLY USED SYSTEM DIVIDES THE PERIODIC TABLE INTO



PERIODIC TABLE – PHYSICAL PROPERTIES

METALS

- HAS THE CHARACTERISTIC PROPERTIES OF
  - LUSTER (SHINE)
  - THERMAL CONDUCTIVITY
  - ELECTRICAL CONDUCTIVITY
  - MALLEABILITY – CAN BE ROLLED INTO SHEETS
  - DUCTILE – CAN BE DRAWN INTO WIRES
  - SOLIDS (EXCEPT MERCURY)
  - HIGH DENSITY
  - HIGH MELTING POINT
  - 94 METALS

PERIODIC TABLE – PHYSICAL PROPERTIES

NON-METALS

- CHARACTERIZED BY THE ABSENCE OF THE PROPERTIES OF LUSTER, THERMAL CONDUCTIVITY, ELECTRICAL CONDUCTIVITY, AND MALLEABILITY
  - CAN BE SOLID, LIQUID OR GASES AT ROOM TEMPERATURE
  - GENERALLY HAVE LOWER DENSITY AND LOWER MELTING POINTS THAN METALS.
  - ONLY 22 NON-METALS
  - 11 NONMETALS OCCUR NATURALLY IN THE GASEOUS STATE.
    - N, O, H, Cl, F, He, Ne, Ar, Kr, Xe, Rn
    - Br IS A LIQUID
    - C, P, S, Se, I, At, Te ETC. EXISTS AS SOLID

LEARNING CHECK

1) IDENTIFY THE ELEMENT, BY GIVING ITS CHEMICAL SYMBOL

- PERIOD 4 AND GROUP IIIA Ga
- PERIOD 2 AND GROUP IIA Be
- GROUP IV A AND PERIOD 5 Sn
- GROUP IA AND PERIOD 4 K

2) IDENTIFY EACH OF THE FOLLOWING ELEMENTS BY NAME

Na

- PERIOD 3 ALKALI META Kr
- PERIOD 4 NOBLE GAS Sr
- PERIOD 5 ALKALINE EA F TAL
- PERIOD 2 HALOGEN

PERIODIC TABLE

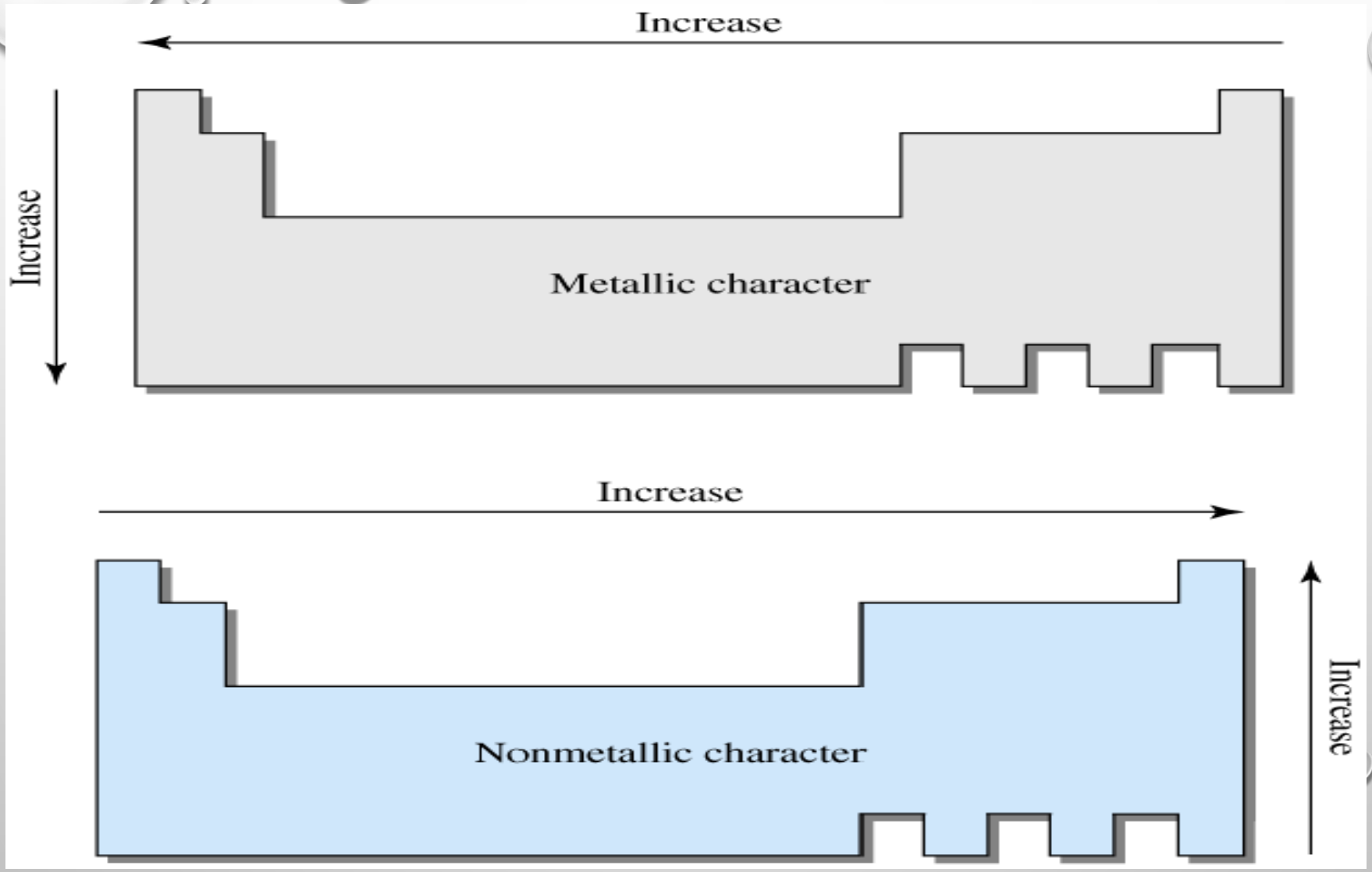
- CHEMICAL PERIODICITY – THE VARIATION IN PROPERTIES OF ELEMENTS AS A FUNCTION OF THEIR POSITION IN THE PERIODIC TABLE.
  - BASICALLY HOW ATOMS CHANGE AS ONE TRAVELS ACROSS ROWS OR UP/DOWN COLUMNS
- WE WILL CONSIDER THREE PROPERTIES OF ELEMENTS THAT EXHIBIT CHEMICAL PERIODICITY
  - METALLIC AND NON-METALLIC CHARACTER
  - ATOMIC SIZE (ATOMIC RADIUS)
  - ELECTRONEGATIVITY

PERIODIC TABLE TRENDS
METALLIC CHARACTER

- METALLIC CHARACTER INCREASES FROM RIGHT TO LEFT WITHIN A GIVEN PERIOD (ROW) OF THE PERIODIC TABLE
- METALLIC CHARACTER INCREASES FROM TOP TO BOTTOM WITH A GROUP (COLUMN) IN THE PERIODIC TABLE.
  - E.G. Na IS MORE METALLIC THAN Mg BUT LESS METALLIC THAN K

PERIODIC TABLE TRENDS NONMETALLIC CHARACTER

- NONMETALLIC CHARACTER INCREASES FROM LEFT TO RIGHT WITHIN A GIVEN PERIOD (ROW) OF THE PERIODIC TABLE.
- NONMETALLIC CHARACTER INCREASES FROM BOTTOM TO TOP WITHIN A GROUP (COLUMN) IN THE PERIODIC TABLE.
  - E.G. CHLORINE IS MORE NON-METALLIC THAN PHOSPHORUS BUT LESS NON-METALLIC THAN FLUORINE.


Increase
Increase
Metallic character
Increase
Nonmetallic character
Increase

Learning Check

1) USING THE PERIODIC TABLE, INDICATE WHICH MEMBER OF EACH OF THE FOLLOWING PAIRS OF ELEMENTS HAS LARGER METALLIC CHARACTER.

$_{3}Li$ OR $_{19}K$ — K

$_{15}P$ OR $_{12}Mg$ — Mg

2) USING THE PERIODIC TABLE, INDICATE WHICH MEMBER OF EACH OF THE FOLLOWING PAIRS OF ELEMENTS HAS LARGER NON-METALLIC CHARACTER

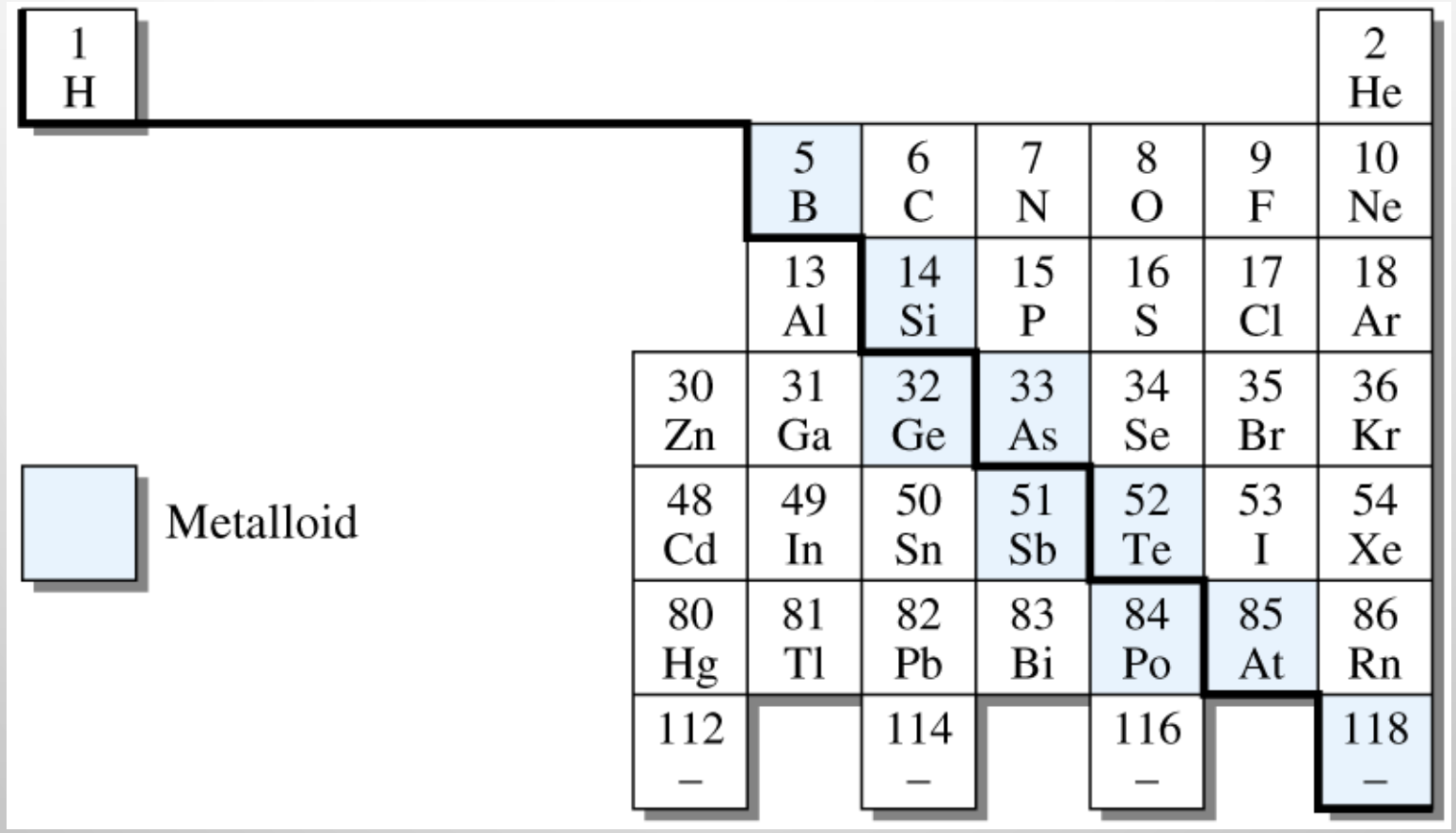
$_{5}B$ OR $_{8}O$ — O

$_{9}F$ OR $_{53}I$ — F

PERIODIC TABLE TRENDS

- METALLOID – AN ELEMENT WITH PROPERTIES INTERMEDIATE BETWEEN THOSE OF METALS AND NONMETALS.
  - EIGHT METALLOIDS: B, Si, Ge, As, Sb, Te, Po AND At
- SEMICONDUCTOR – A METALLOID ELEMENT THAT DOES NOT CONDUCT ELECTRICAL CURRENT AT ROOM TEMPERATURE BUT DOES AT HIGHER TEMPERATURES [Si, Ge, Sb (ANTIMONY)]
  - VERY IMPORTANT IN THE ELECTRONICS INDUSTRY.

Metalloids reside along the stepped line which divides the metals and non-metals.

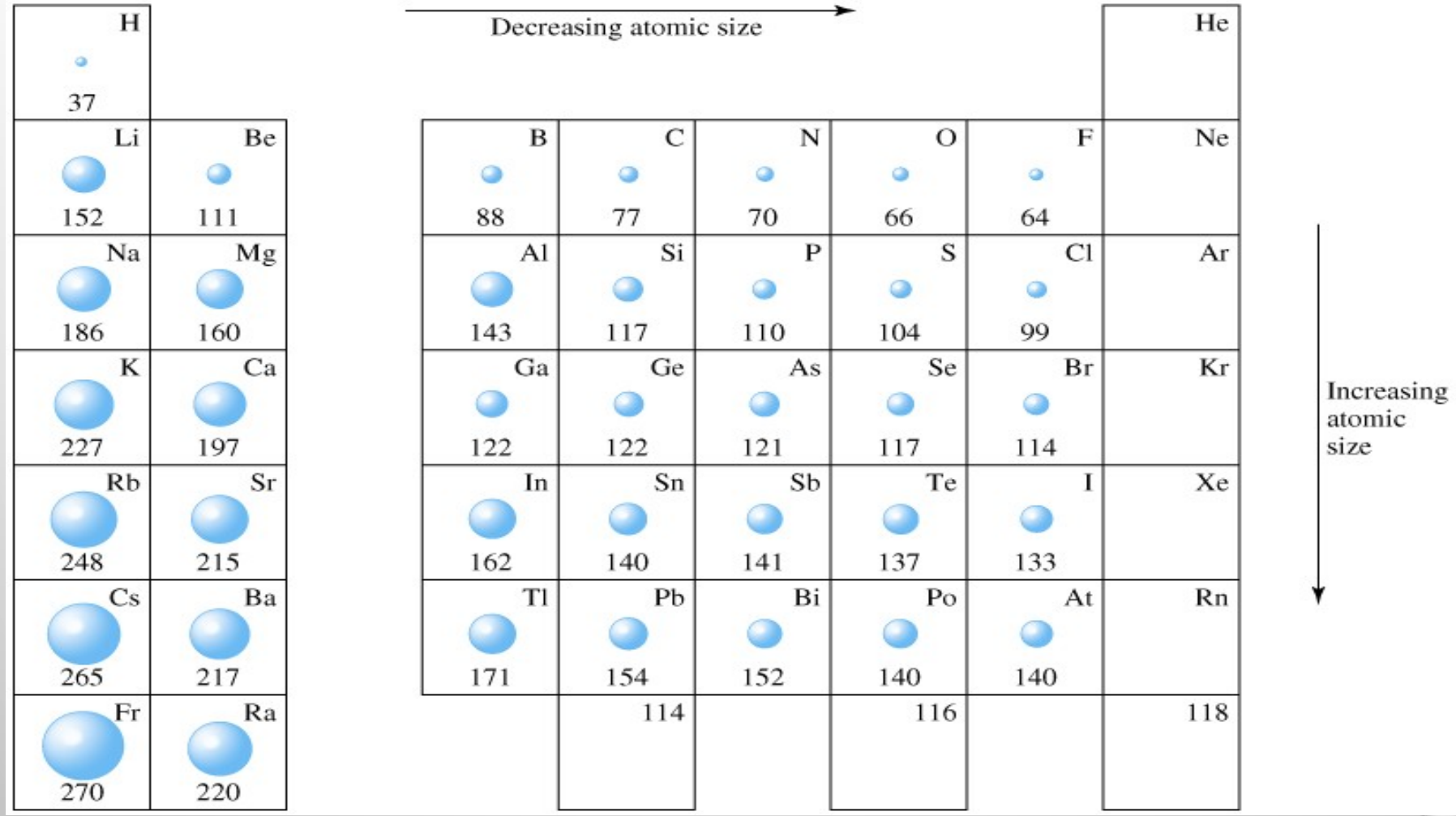


PERIODIC TABLE TRENDS

- NOTE:
  - INCREASING ATOMIC NUMBER DOES NOT ALWAYS EQUAL INCREASING ATOMIC MASS
    - Ar (39.95 AMU), K (39.1 AMU), Ca (40.08 AMU)
    - Co (58.93 AMU), Ni (58.69 AMU), Cu (63.55 AMU)

PERIODIC TABLE TRENDS

- ATOMIC SIZE
  - ATOMIC RADII TEND TO DECREASE FROM LEFT TO RIGHT WITHIN A PERIOD (ROW) OF THE PERIODIC TABLE.
  - ATOMIC RADII TEND TO INCREASE IN SIZE FROM TOP TO BOTTOM WITHIN A PERIODIC TABLE GROUP.


Decreasing atomic size
Increasing atomic size
H
37
He
Li
152
Be
111
B
88
C
77
N
70
O
66
F
64
Ne
Na
186
Mg
160
Al
143
Si
117
P
110
S
104
Cl
99
Ar
K
227
Ca
197
Ga
122
Ge
122
As
121
Se
117
Br
114
Kr
Rb
248
Sr
215
In
162
Sn
140
Sb
141
Te
137
I
133
Xe
Cs
265
Ba
217
Tl
171
Pb
154
Bi
152
Po
140
At
140
Rn
Fr
270
Ra
220
114
116
118

PERIODIC TABLE TRENDS

- ELECTRONEGATIVITY – A MEASURE OF THE RELATIVE ATTRACTION THAT AN ATOM HAS FOR THE SHARED ELECTRONS IN A BOND.
  - THE HIGHER THE ELECTRONEGATIVITY OF AN ELEMENT, THE GREATER THE ELECTRON-ATTRACTING ABILITY OF ATOMS OF THAT ELEMENT.
    - ELECTRONEGATIVITY GENERALLY INCREASES FROM LEFT TO RIGHT WITHIN A PERIOD (ROW) OF PERIODIC TABLE.
    - FACTORS: SIZE, NUCLEAR CHARGE, NUMBER OF NON-VALENCE ELECTRONS

Increasing electronegativity

H 2.1																	He –
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne –
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar –
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.8	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr –
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe –
Cs 0.7	Ba 0.9	57–71 1.1–1.2	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2	Rn –
Fr 0.7	Ra 0.9																

LEARNING CHECK

1) USING THE PERIODIC TABLE, INDICATE WHICH MEMBER OF EACH OF THE FOLLOWING PAIRS OF ELEMENTS HAS LARGER ATOMIC RADIUS.

$_{13}Al$ OR $_{16}S$

$_{37}Rb$ OR $_{3}Li$

$_{13}Al$

$_{37}Rb$

2) USING THE PERIODIC TABLE, INDICATE WHICH MEMBER OF EACH OF THE FOLLOWING PAIRS OF ELEMENTS HAS HIGHEST ELECTRONEGATIVITY CHARACTER.

$_{7}N$ OR $_{9}F$

$_{53}I$ OR $_{17}Cl$

F

Cl

ELECTRONS

- REMEMBER:
  - ELECTRONS ARE THE SMALLEST OF THE THREE SUBATOMIC PARTICLES WE WILL DEAL WITH.
  - THEY HAVE VERY LITTLE MASS.
  - THEY RESIDE IN THE ELECTRON CLOUD THAT SURROUNDS THE NUCLEUS.
  - THEIR MOVEMENT RAPIDLY ABOUT THE NUCLEUS DEFINES THE SIZE OF THE ATOM
  - THE INFORMATION ABOUT THE BEHAVIOUR AND ARRANGEMENTS OF ELECTRONS WITHIN THE EXTRANUCLEAR REGION IS DERIVED FROM COMPLEX MATHEMATICAL MODEL FOR ELECTRON BEHAVIOUR CALLED ***QUANTUM MECHANICS.***

ELECTRONS

- ELECTRONS ARE THE HIGH ENERGY PART OF THE ATOM.
- THE FASTER THE ELECTRON MOVES THE MORE ENERGY IT HAS AND THE FARTHER FROM THE NUCLEUS IT TENDS TO TRAVEL.
- ELECTRONS HAVE SPIN.
- QUANTUM THEORY IS USED TO EXPLAIN THEIR ENERGY AND MOVEMENT. WHAT YOU NEED TO REMEMBER IS THAT THE ENERGY IN AN ELECTRON IS DEFINED. IT IS RESTRICTED. IT DOESN'T JUST GO EVERYWHERE.
- AN ENERGY OF ELECTRONS IS ***QUANTIZED.*** A QUANTIZED PROPERTY IS A PROPERTY THAT CAN HAVE ONLY CERTAIN VALUES AND NOT ALL VALUES ARE ALLOWED.

ELECTRONS

- **ELECTRON SHELL** – A DEFINED REGION OF SPACE ABOUT A NUCLEUS THAT CONTAINS ELECTRONS WITH APPROXIMATELY THE SAME ENERGY.

- **SHELL NUMBER** – '**n**' USED TO IDENTIFY THE ELECTRON SHELL.
  - THESE ARE NUMBERED 1-7
  - ELECTRONS IN HIGHER NUMBER SHELLS HAVE MORE ENERGY.

ELECTRONS

HOW MANY ELECTRONS IN AN ELECTRON SHELL?

- DEPENDS –
  - NOT ALL SHELLS ARE EQUAL.
  - LOWER SHELLS HAVE LESS ELECTRONS, LESS ENERGY.
  - NUMBER OF ELECTRONS IN A SHELL FOLLOWS THE RULE $2n^2$ WHERE ‘n’ IS THE ELECTRON SHELL LEVEL.
  - LOWER LEVEL SHELLS FILL BEFORE HIGHER ONES.
- SO HOW MANY ELECTRONS ARE IN SHELL 3 ?

ELECTRONS – SUBSHELLS AND ORBITALS

- WITHIN A **SHELL** THERE ARE **SUBSHELLS** AND **ORBITALS**.
  - A SUBSHELL IS DEFINED REGION OF SPACE WITHIN AN ELECTRON SHELL THAT CONTAIN ELECTRONS OF THE SAME ENERGY. Ex. *s*, *p*, *d* OR *f*
  - NUMBER OF SUBSHELLS IN A SHELL = ‘n’, WHERE ‘n’ IS THE SHELL NUMBER.
  - SUBSHELLS ARE WRITTEN WITH A NUMBER, ‘n’, AND A LETTER.
  - THE SUPERSCRIPT REPRESENTS THE NUMBER OF ELECTRONS IN THE SUBSHELL. EX: $\mathbf{1}s^2$

ELECTRONS – SUBSHELLS AND ORBITALS

- **SUBSHELLS**
  - SUBSHELLS ARE WRITTEN WITH A NUMBER, ‘n’, AND A LETTER, *s, p, d, f* (ALWAYS IN LOWER CASE).
  - NUMBER OF ELECTRONS PER SUBSHELL IS DEFINED AND INDEPENDENT OF SHELL NUMBER.

SUBSHELLS	ELECTRONS
s	2
p	6
d	10
f	14

ELECTRONS – SUBSHELLS AND ORBITALS

- **ELECTRON ORBITAL** – A REGION OF SPACE WITHIN AN ELECTRON SUBSHELL WHERE AN ELECTRON WITH A SPECIFIC ENERGY IS MOST LIKELY TO BE FOUND.
  - HOW MANY ORBITALS ARE IN EACH SUBSHELL?

$$s = 1$$

$$p = 3$$

$$d = 5$$

$$f = 7$$

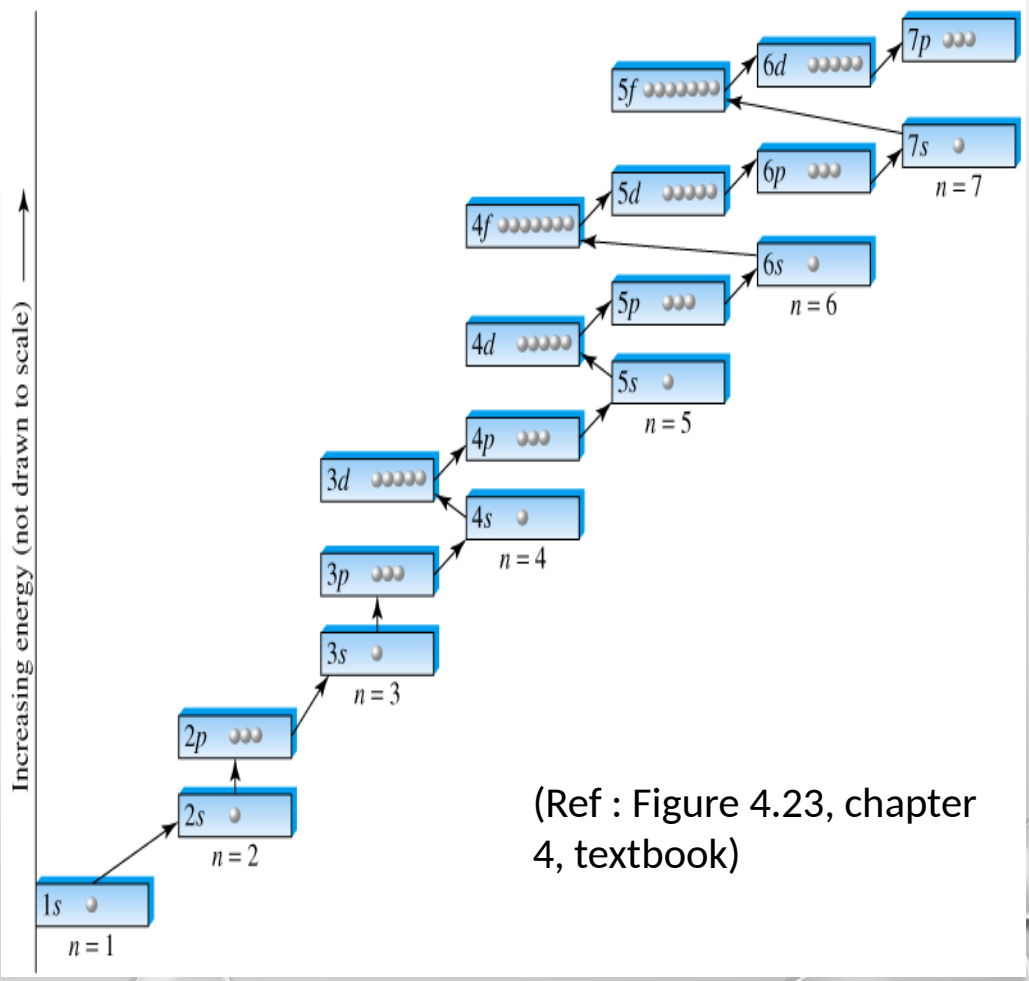
- EACH ✯✻✢☆✶✡★ CAN HOLD TWO ELECTRONS.

AUFBAU PRINCIPLE -FILLING ELECTRON SHELLS

- Electron shells fill according to the ***Aufbau Principle.***

Electrons normally occupy electron subshells in an atom in order of increasing subshell energy.

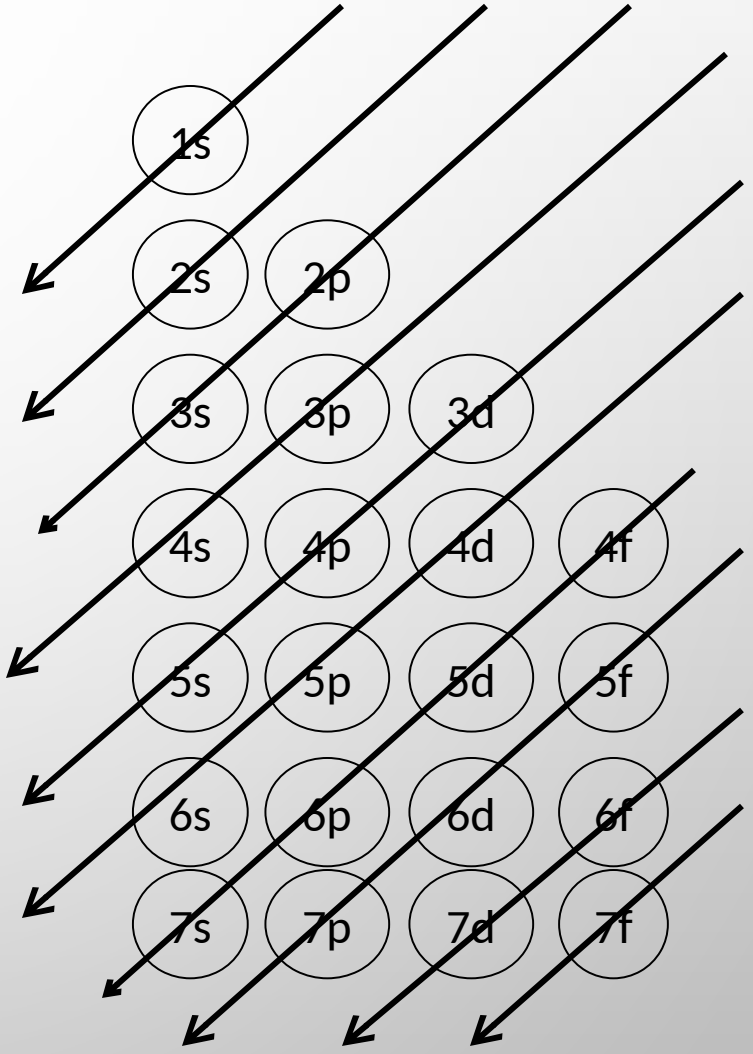
Energy of subshells can overlap



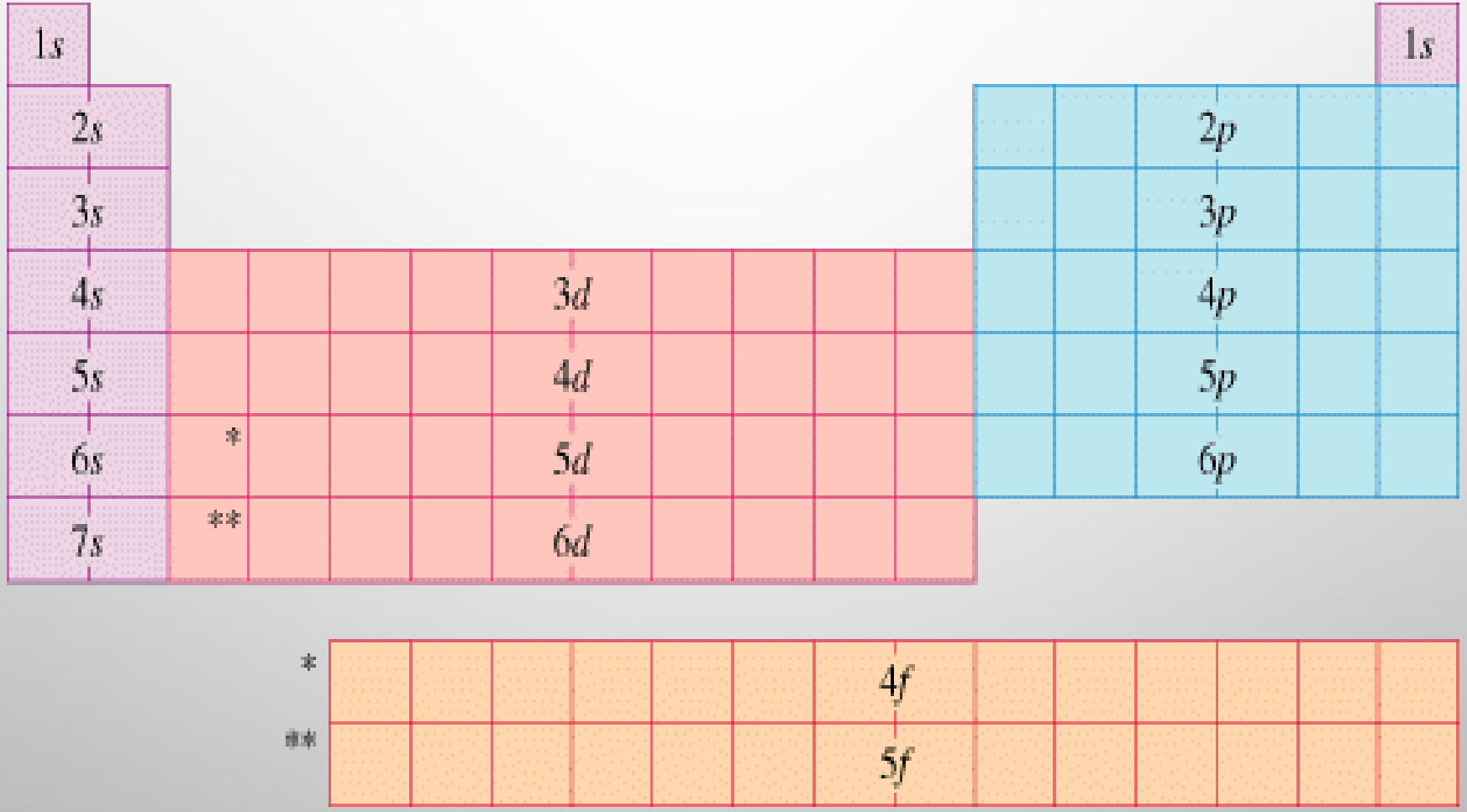
(Ref : Figure 4.23, chapter 4, textbook)

FILLING ELECTRON SHELLS

THIS IS THE AUFBAU DIAGRAM WHICH DETAILS HOW TO FILL THE ELECTRON ENERGY LEVELS.



OUTERMOST SHELLS AND SUBSHELLS



WRITING ELECTRON CONFIGURATION

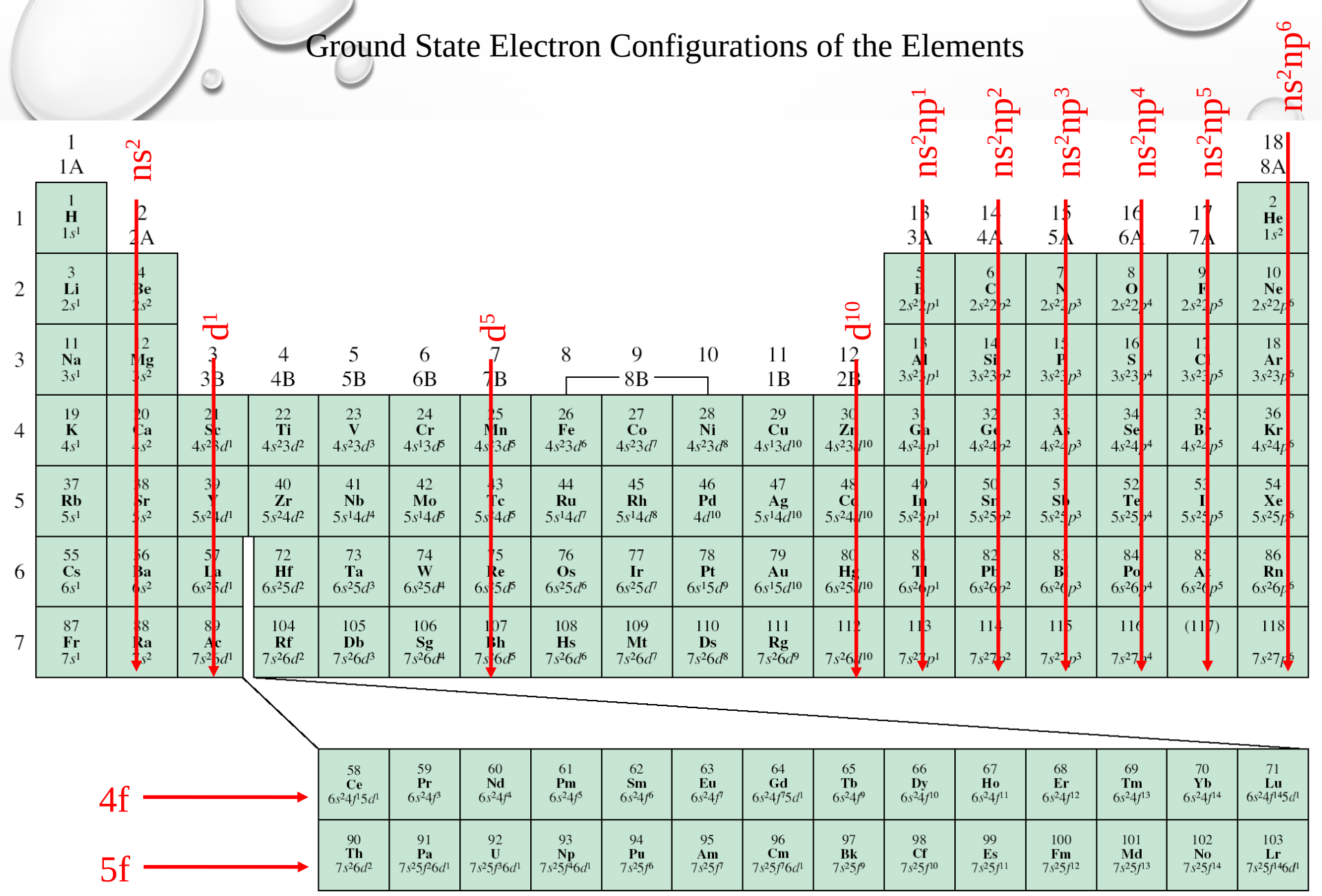
- WHILE THIS MAY SEEM TEDIOUS, YOU CAN LEARN A LOT FROM THE WRITTEN ELECTRON CONFIGURATION.
- THIS IS A SHORTHAND NOTATION DESIGNATING THE SUBSHELLS IN AN ATOM THAT ARE OCCUPIED BY ELECTRONS.
- START AT THE BEGINNING AND KEEP FILLING SUBSHELLS UNTIL THE CORRECT NUMBER OF ELECTRON IS REPRESENTED:

- REMEMBER THE NUCLEAR NOTATION AND ‘*Z*’ IS THE NUMBER OF PROTONS WHICH EQUALS THE NUMBER OF ELECTRONS IN A NEUTRAL ATOM:

Element	Z	Electron Configuration
Hydrogen	1	$1s^1$
Helium	2	$1s^2$
Carbon	6	$1s^2 2s^2 2p^2$
Neon	10	$1s^2 2s^2 2p^6$
Sodium	11	$1s^2 2s^2 2p^6 3s^1$

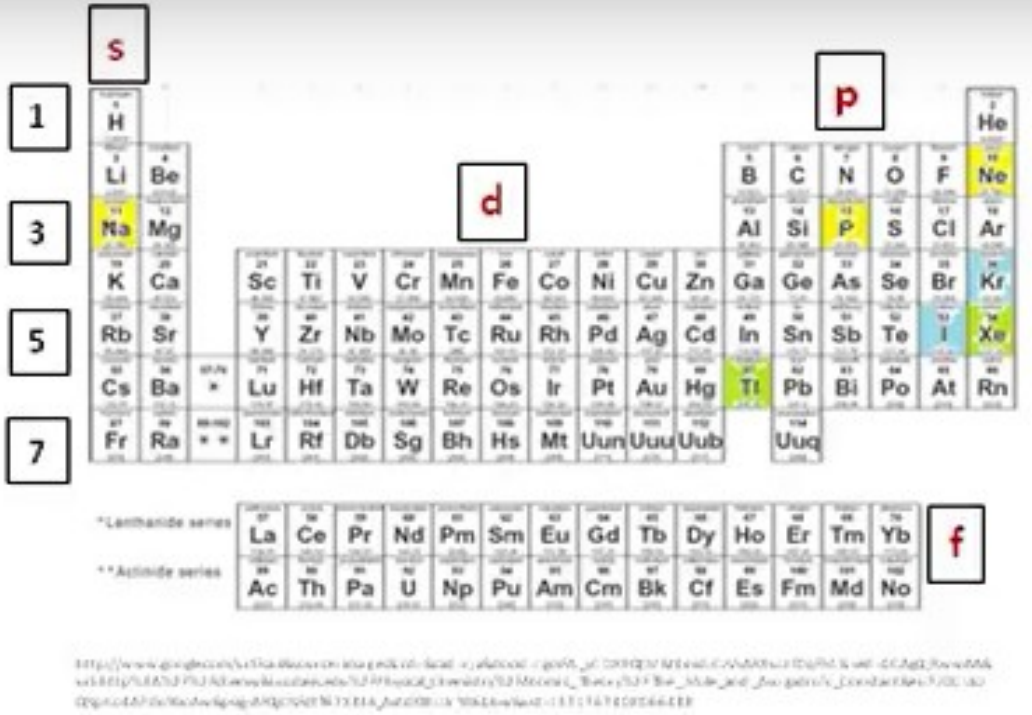
Element	*z*	Electron Configuration
Hydrogen	1	$1s^1$
Sodium	11	$1s^2 2s^2 2p^6 3s^1$
Potassium	19	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
Rubidium	37	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6\ 5s^1$
Cesium	55	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2$ $4d^{10} 5p^6\ 6s^1$

Ground State Electron Configurations of the Elements



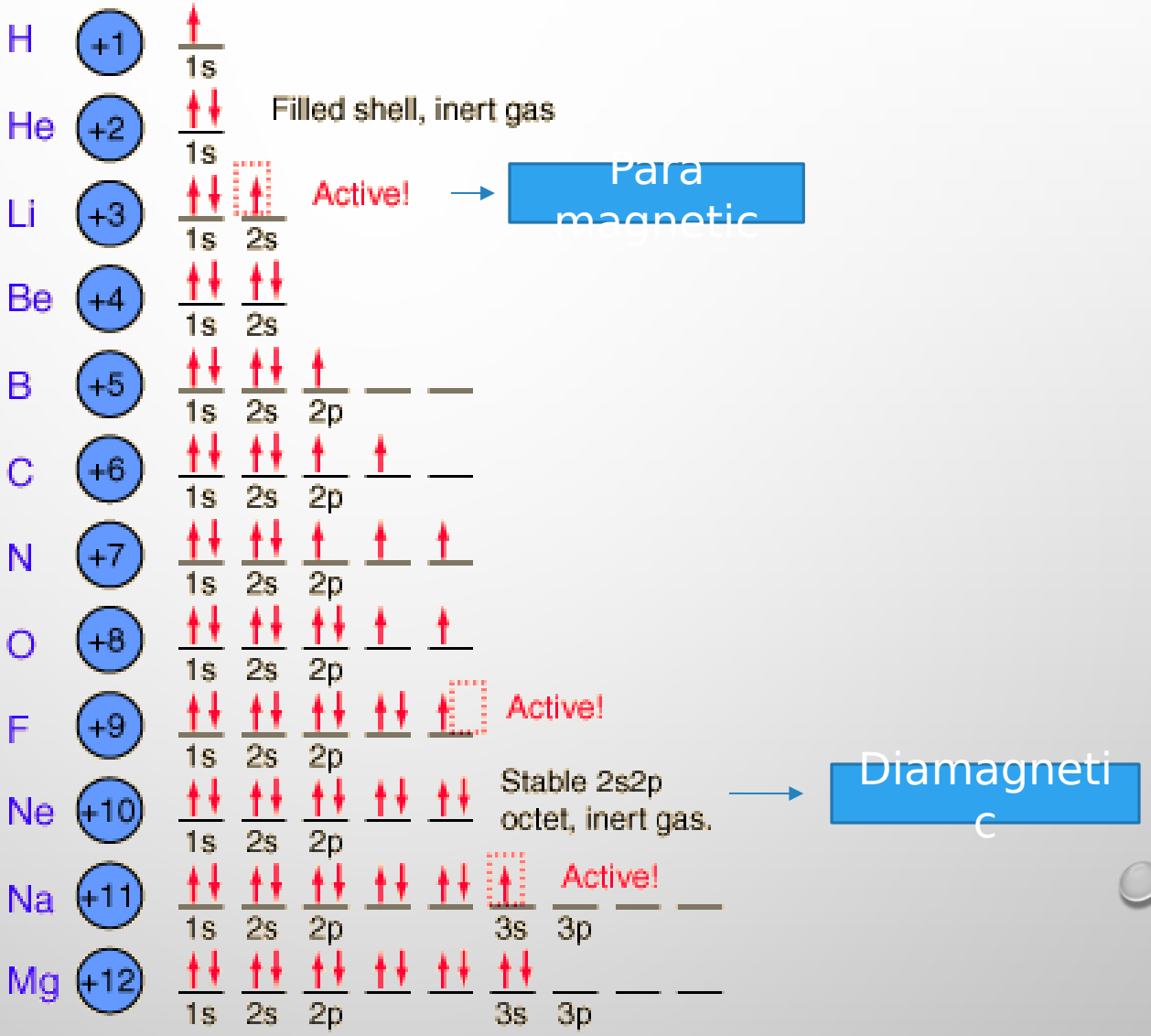
CONDENSED ELECTRON CONFIGURATION

$_{11}Na$	$1s^2, 2s^2, 2p^6, 3s^1$
$_{10}Ne$	$1s^2, 2s^2, 2p^6$
$_{11}Na$	$[Ne]\ 3s^1$
$_{15}P$	$1s^2, 2s^2, 2p^6, 3s^2, 3p^3$
$_{15}P$	$[Ne]\ 3s^2, 3p^3$
$_{53}I$	$[Kr]\ 5s^2, 4d^{10}, 5p^5$
$_{81}Tl$	$[Xe]\ 6s^2, 4f^{14}, 5d^{10}, 6p^1$



For “d” use one less than the period

For “f” use two less than the period



http://hyperphysics.phy-astr.gsu.edu/hbase/chemical/eleorb.html

- ATOMS WHERE ALL ELECTRON ORBITALS ARE OCCUPIED BY PAIRS OF ELECTRONS ARE CALLED **DIAMAGNETIC ATOMS**.
- ATOMS WHERE ALL ELECTRON ORBITALS ARE NOT OCCUPIED BY PAIRS OF ELECTRONS ARE CALLED **PARAMAGNETIC ATOMS**.
- INTRODUCTION TO ELECTRON CONFIGURATION http://www.chem.latech.edu/~deddy/lectnote/chap7b.html