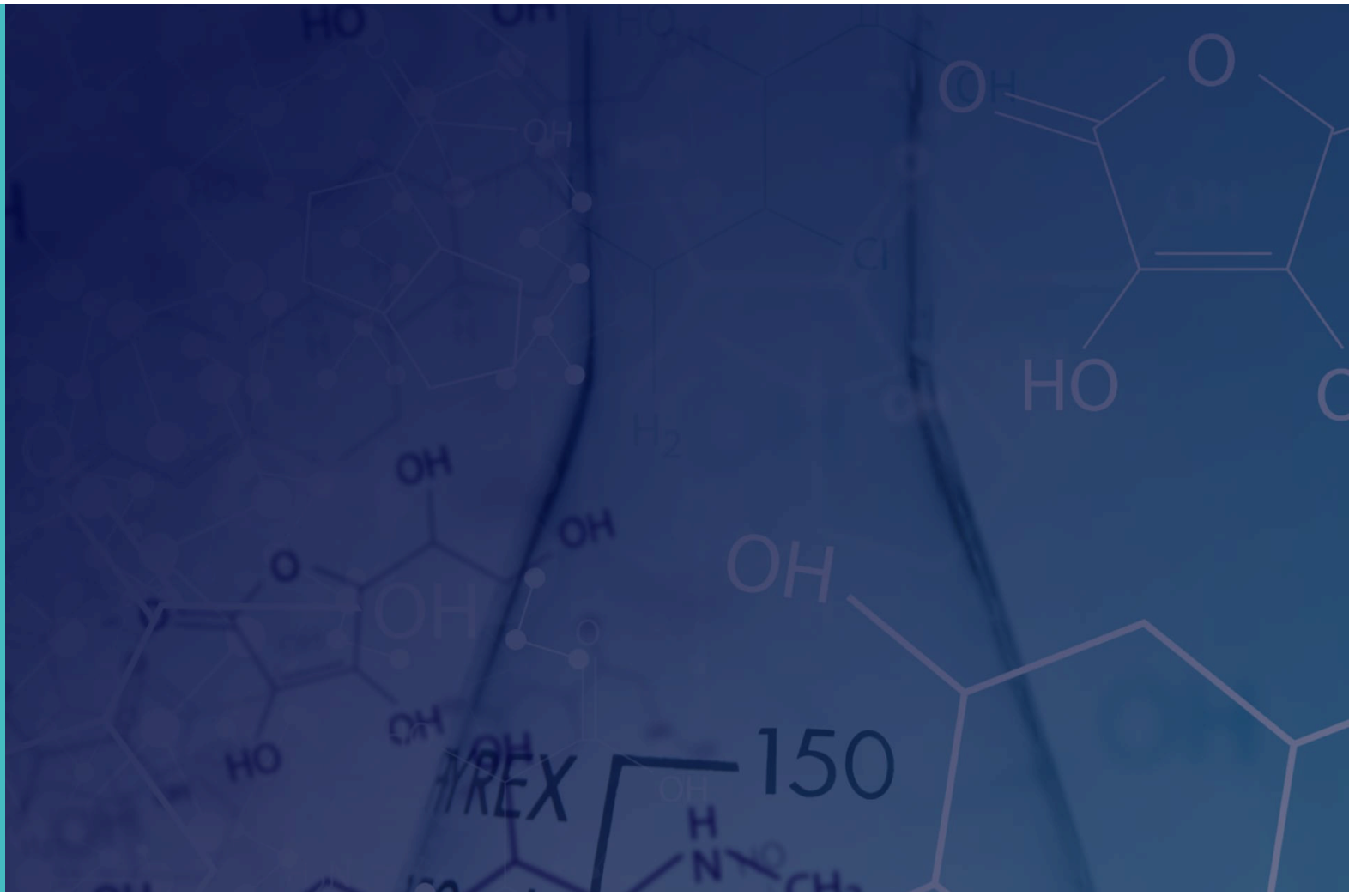


Ontario High School

Grade 11 Chemistry

Summer 2024, Chapter 2 Notes

Table of Contents

2. Atomic Structure and Periodic Trends

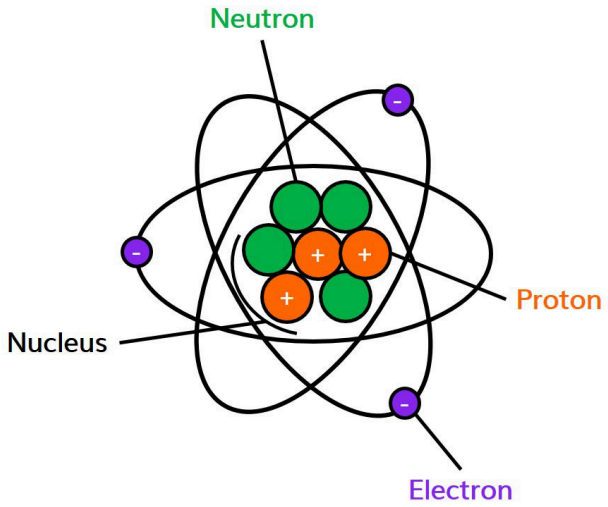
2.1 Atoms

2.1.1 Atoms: Composition and Structure

Atoms: Composition and Structure

Subatomic Particles

- All matter is made out of **atoms.**
- **Atoms** are made of even smaller particles, known as **subatomic particles**.



Properties of Subatomic Particles

Subatomic Particle	Symbol	Charge	Location	Approximate Mass
Protons	p^+	+1	Inside the nucleus	1 a.m.u.
Neutrons	n^0	0	Inside the nucleus	1 a.m.u.
Electrons	e^-	-1	Outside the nucleus	0 a.m.u.

- A **neutral atom** will have **equal** numbers of **protons** and **electrons.**
  Example: Oxygen has eight protons inside the nucleus, so for the atom to be neutral it has to have _____ electrons orbiting the nucleus

- An atom that has lost or gained electrons is known as an **ion.**
  Example: Oxygen can gain two electrons to form an oxide ion. Lithium can lose an electron to form a lithium ion.

- Atoms that have the same number of protons, but different number of neutrons are known as **isotopes**.
  Example: There are three stable isotopes of oxygen: oxygen-16, oxygen -17 and oxygen-18.

2.1.2

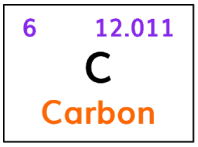
Atomic Number and Mass Number

- The number of protons in a given atoms is known as the **atomic number**, represented by the symbol **Z**.
- The **mass number** for an atom is the sum of all particles in the nucleus.

$$\boxed{\text{mass number} = \text{number of neutrons} + \text{number of protons}}$$

- We use atomic mass units to measure the mass of an atom (a.m.u.). An a.m.u. is equal to 1/12th the mass of a carbon-12 atom.
- The **chemical notation** of an atom in the periodic table helps us determine the number of protons and neutrons inside the nucleus

  Example: Carbon has a mass number of 12 and an atomic number of 6, meaning it has _____ neutrons inside the nucleus

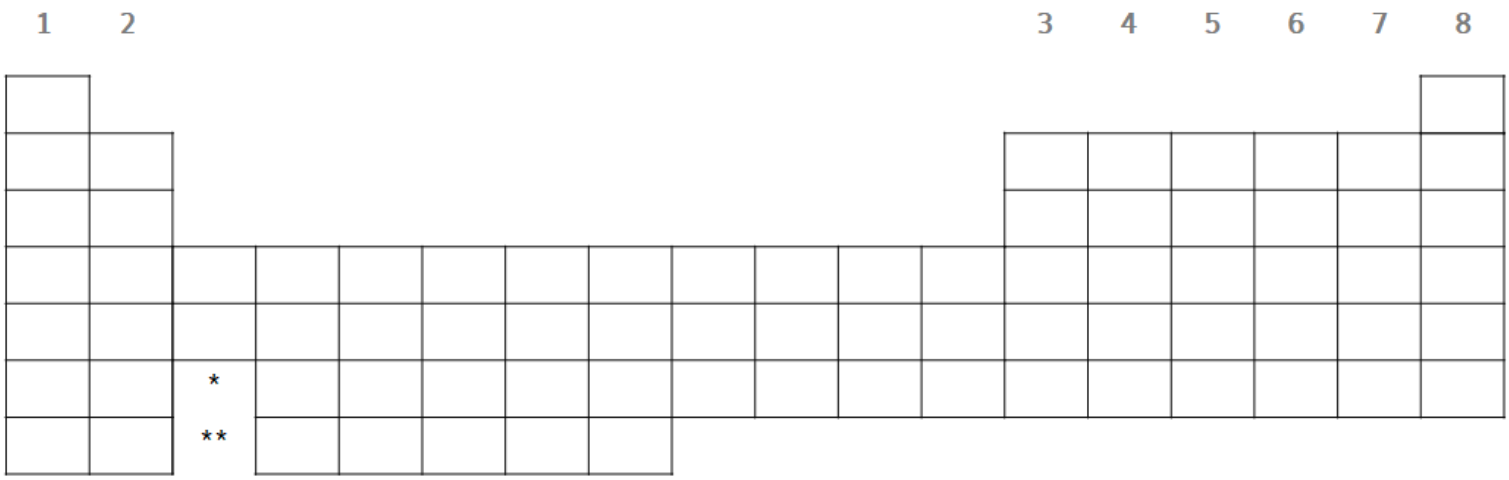


$${}^{12}_{6}\mathrm{C}$$

2.1.3

Valance Electrons and Ions

- **Valence electrons** are the electrons found in the outermost shell of an atom. These are the electrons that participate in **bonding**
- The simplest way of determining the number of valence electrons an atom has is by looking at which group an atom is in



- Atoms will form ions by losing or gaining electrons, such that they obtain a full valence shell (full octet).
    - Metals will **lose electrons** to form **cations**
    - Non-metals will **gain electrons** to form **anions**
- **Multivalent** atoms are atoms that can form more than one stable ion. Most transition metals are multivalent
- **Polyatomic ions** are ions containing more than one atom

2.1.4

Example: Counting Subatomic Particles

How many electrons, protons and neutrons are in a ^{52}Cr isotope?

2.1.5

Practice: Atoms Definitions

Connect the term with the definition

A. Positively charged subatomic particle

B. Subatomic particle that weighs significantly less than the others

C. The total number of protons and neutrons in the atom

D. The total number of protons in the atom

E. The charge-neutral subatomic particle

Proton

Electron

Mass Number

Atomic Number

Neutron

2.1.6

Practice: Atomic Number and Mass Number

How many electrons, protons, and neutrons are in $[^{38}_{17}C\ell]^{1-}$?

- 17 electrons, 17 protons and 21 neutrons
- 18 electrons, 18 protons and 20 neutrons
- 18 electrons, 17 protons and 21 neutrons
- 16 electrons, 17 protons and 21 neutrons

2.1.7

Practice: Counting Protons and Neutrons

Fill in the blanks in the following table. Assume each atom is uncharged.

a) $^{45}_{21}Sc$

b) $^{33}_{16}S$

c) $^{23}_{11}Na$

d) $^{39}_{18}Ar$

Element	Number of Protons	Number of Neutrons
a)		
b)		
c)		
d)		

2.2 Isotopes

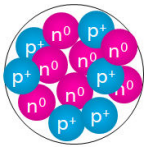
2.2.1

Isotopes and Atomic Mass

Isotopes and Radioisotopes

- When two atoms have the **same atomic number**, but a **different number of neutrons**, we call these **isotopes**.
- Since they have a different number of neutrons, isotopes will have **different mass numbers**

^{12}C
$C-12$
$\text{carbon}-12$
98.9%



^{13}C
$C-13$
$\text{carbon}-13$
1.1%

- Isotopes can be **stable**, meaning that they do not decay.
- **Radioisotopes** are radioactive isotopes of an element. The nucleus of these isotopes is unstable and will decay with time, emitting radiation.

Calculating the Atomic Mass

- The **atomic mass number** is a **weighted average** based on the **relative abundance of isotopes** Isotopes have similar reactivity to one another, that's why we can form C bonds with either C-12 or C-13
- To determine the average mass of an element, use this equation:

$$\text{atomic mass} = (\text{mass of isotope 1})(\text{abundance of isotope 1}) + (\text{mass of isotope 2})(\text{abundan}$$

- Plug in the **mass of each isotope in a.m.u.** and plug in the **relative abundance of each isotope as a decimal**
  Example: we are told the relative abundance of C-12 is 98%. You would want to plug in _____ for this isotope's relative abundance.

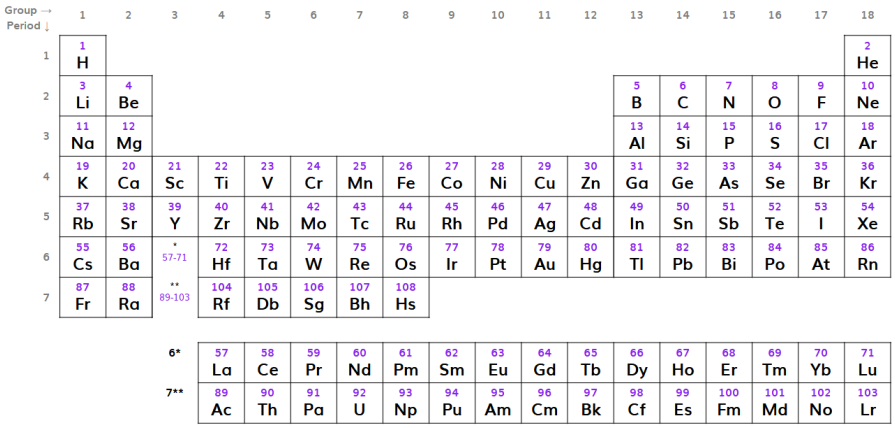
2.2.2

Example: Solving for the Atomic Mass

Chlorine can be found in nature as ^{35}Cl (mass 34.969a.m.u, 75.78% abundance) and ^{37}Cl (mass 36.966a.m.u, 24.22% abundance). What is the average atomic mass of Cl?

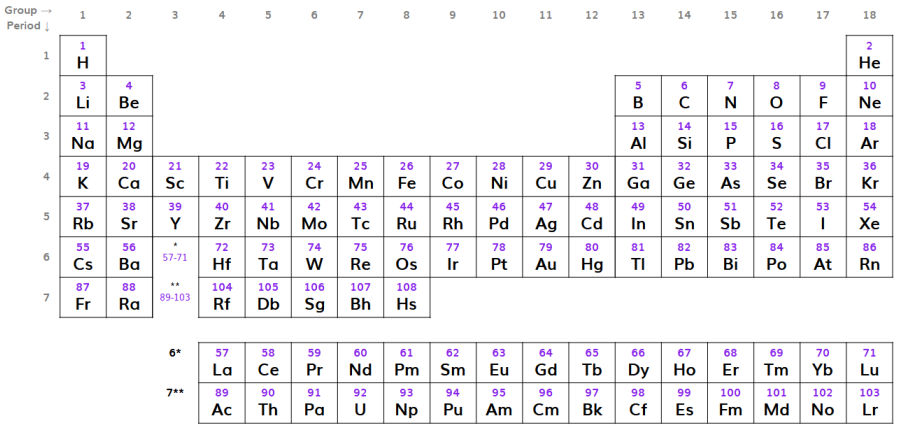
2.2.3

Example: Finding the Number of Subatomic Particles in a Nucleus

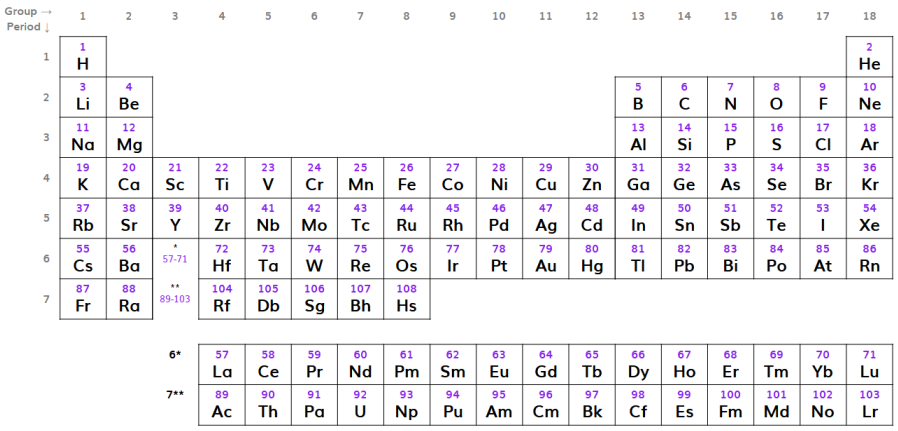


Group → / Period ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	* 57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	** 89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs										
6*				57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
7**				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

a) How many protons are in an ^{53}Cr nuclei?



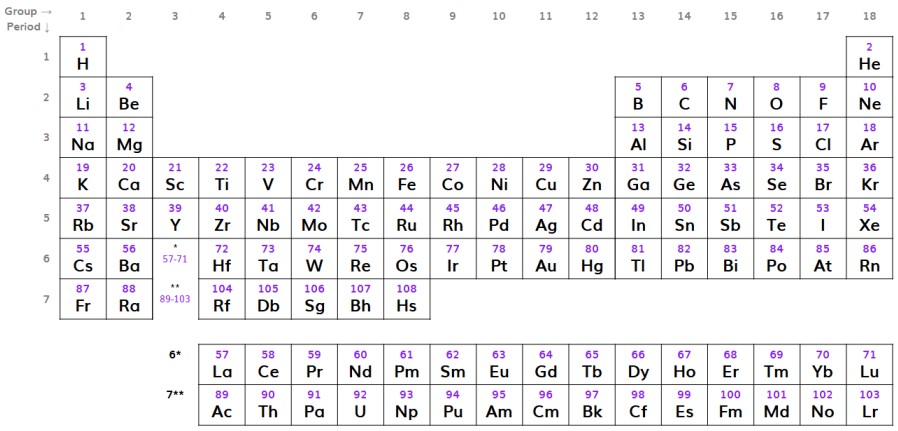
b) How many protons are in a ^{232}Th nuclei?



Group → / Period ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	* 57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	** 89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs										

6*				57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
7**				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

c) How many neutrons are in a ^{18}O nuclei?

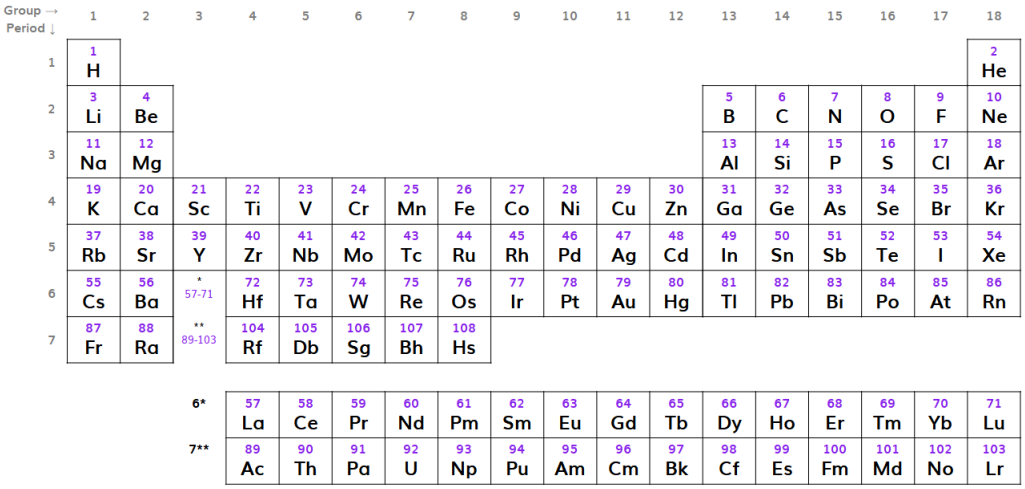


d) How many neutrons are in a ^{64}Cu nuclei?

2.2.4

Practice: Identifying Isotopes of Elements

An atom with 6 neutrons and a mass number of 13 is an isotope of which element?



- carbon
- oxygen
- nitrogen
- boron

2.2.5

Practice: Solving for the Weight of an Isotope

Naturally occurring potassium contains two stable isotopes. The lighter isotope, ^{39}K (38.9637 amu) is the more abundant isotope, accounting for 93.26% of the nuclei. What is the weight of the heavier isotope, ^{41}K?

- 41.00 a.m.u.
- 40.96 a.m.u.
- 39.09 a.m.u.
- 41.08 a.m.u.

2.2.6

Practice: Finding Abundance

The two stable isotopes of Boron are as follows:

Isotope 1: $^{10}_{5}B$ (10.013a.m.u)
Isotope 2: $^{11}_{5}B$ (11.009a.m.u.).

Calculate the percentage abundance of each isotope based on boron's average atomic mass. Express your answer in a percentage value, rounded to the nearest whole integer. Do not include any symbols.

Isotope 1

Isotope 2

2.3 The Periodic Table

2.3.1

The Periodic Table of Elements

Periodic Law

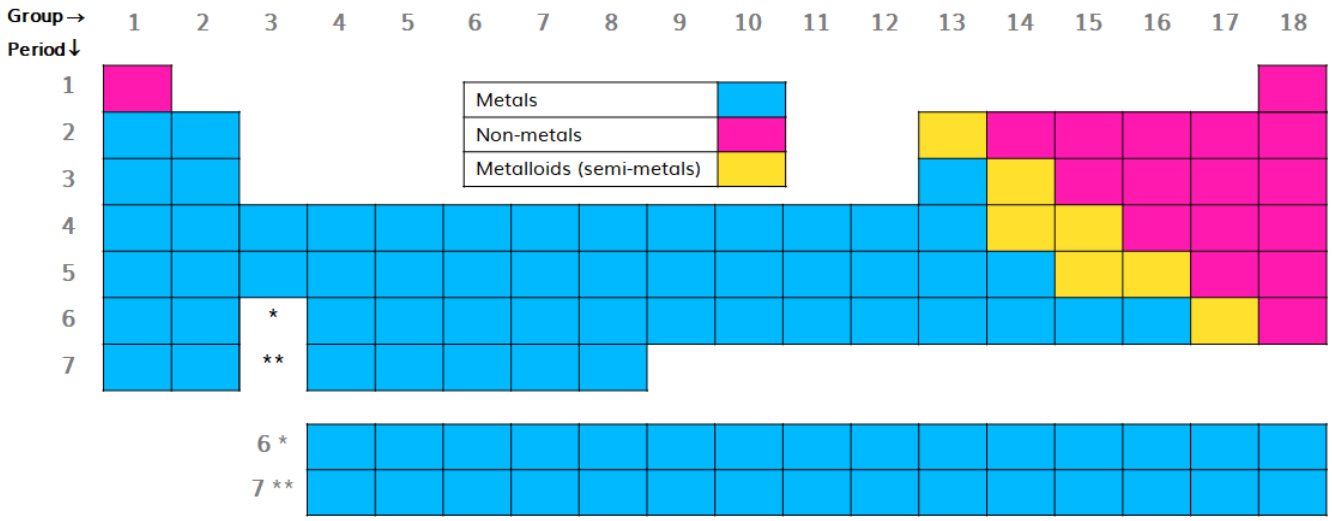
- The **periodic table** organizes the elements by their **atomic number (Z)** and is organized into **groups (columns)** and **periods (rows)**.
- Elements in the **same group have very similar reactivity**

Group → / Period ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	* 57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	** 89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs										

6*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
7**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

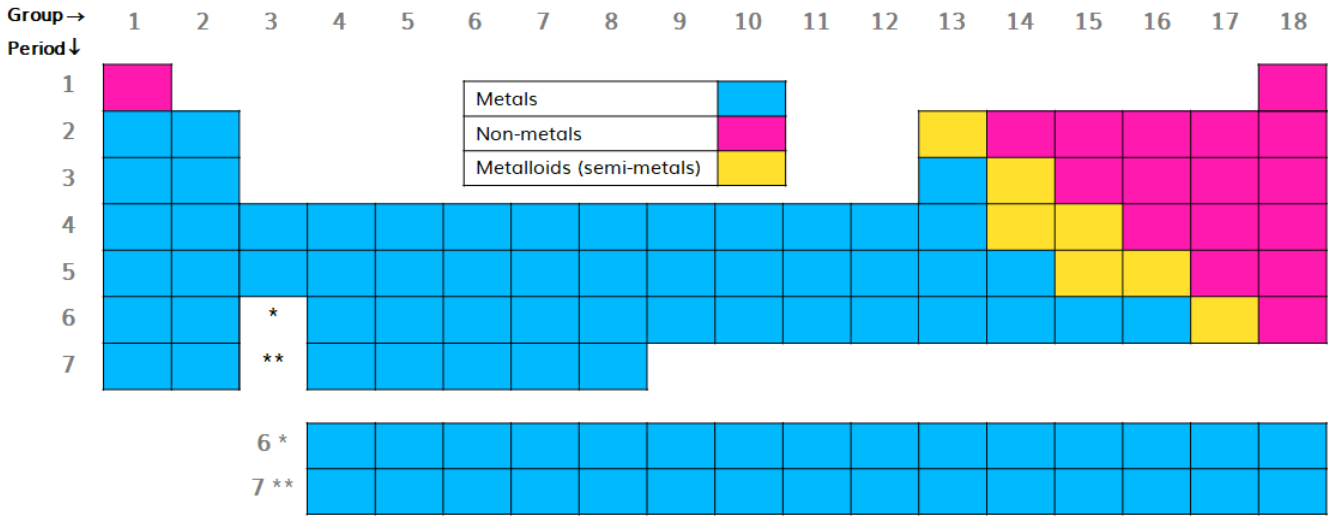
Metals

- Metals are found on the left hand side of the periodic table
- They are solid at room temperature, with the exception of mercury which is a liquid
- They are generally shiny and flexible
- Most metals are good conductors of heat and electricity



Non-metals

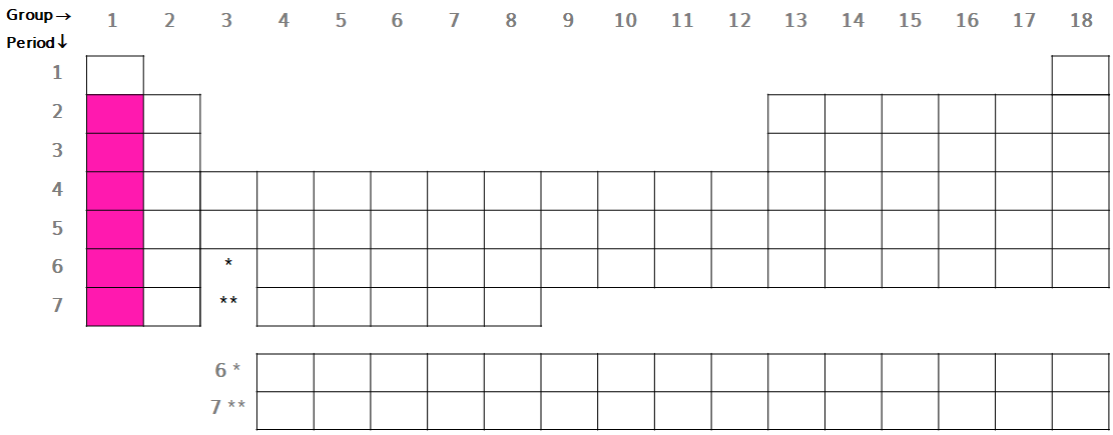
- Non-metals are found on the right hand side of the periodic table
- Most are gas or solid at room temperature, with bromine being the only liquid element
- They are dull and non-malleable
- They are poor conductors of heat and electricity



2.3.2

Families and Series of Elements

Alkali Metals

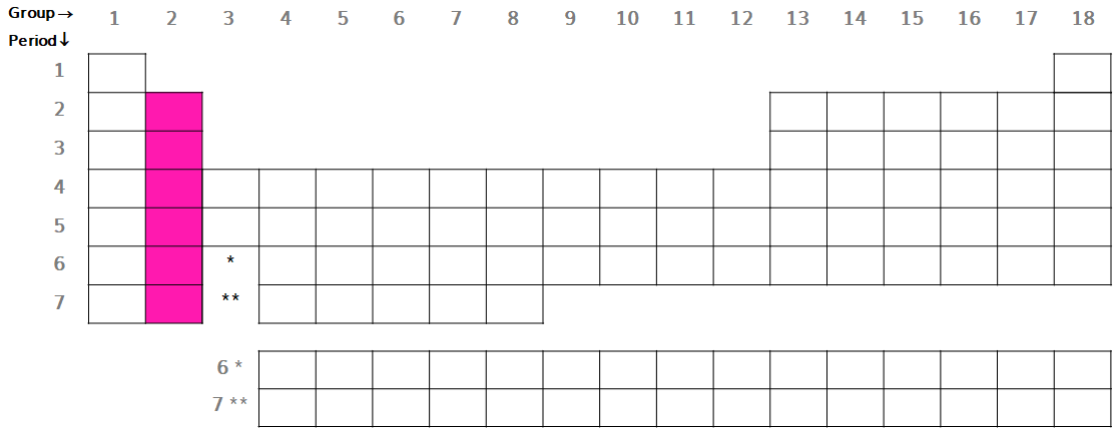


- **Chemical properties:**
  - react with water to form strong bases and release hydrogen
    Example:

  - react with oxygen to form oxides
    Example:

  - react with halogens to form metal halides
    Example:

Alkaline Earth Metals



- **Chemical properties:**
  - react with water to form strong bases and release hydrogen (with the exception of Be)
    Example:

$$Ba\,(s) + 2H_2O\,(\ell) \rightarrow Ba\,(OH)_2\,(aq) + H_2\,(g)$$

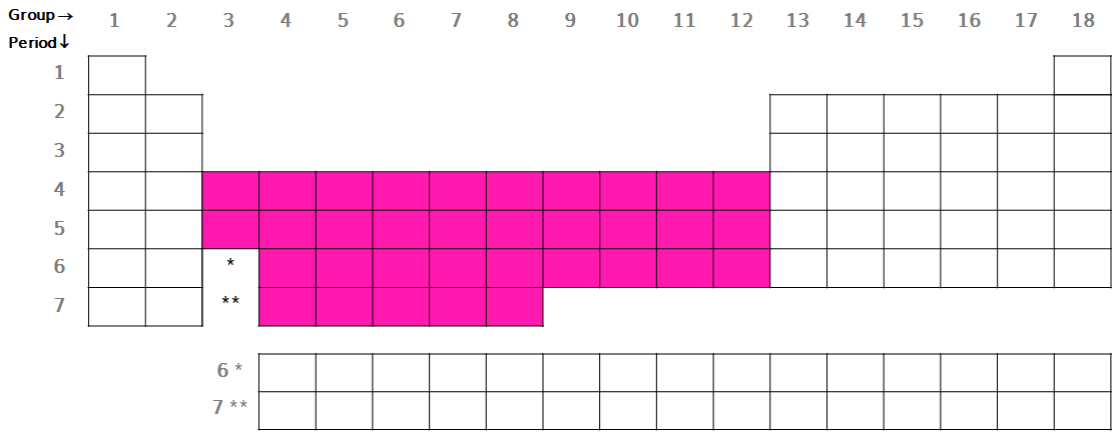
  - react with halogens to form metal halides
    Example:

$$Mg\,(s) + I_2\,(g) \rightarrow MgI_2\,(s)$$

  - react with oxygen to form metal oxides
    Example:

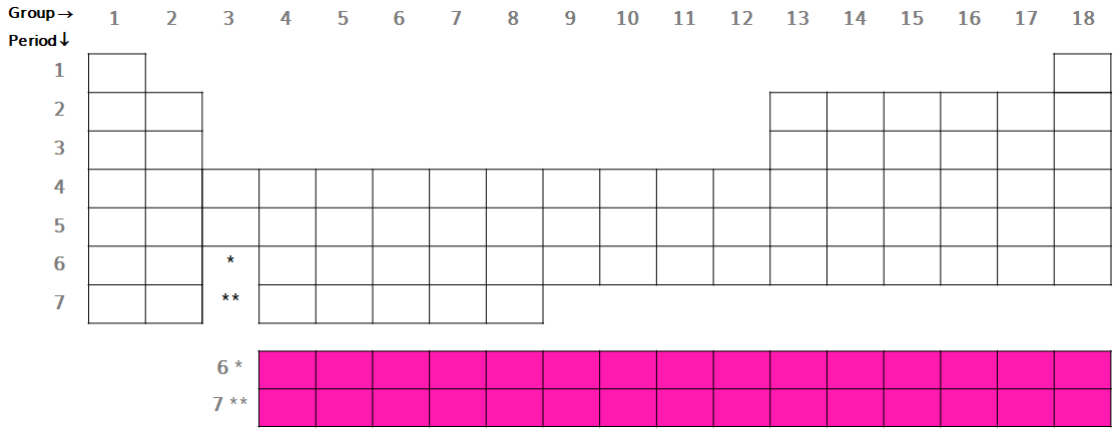
$$2Ca\,(s) + O_2\,(g) \rightarrow 2CaO\,(s)$$

Transition Metals



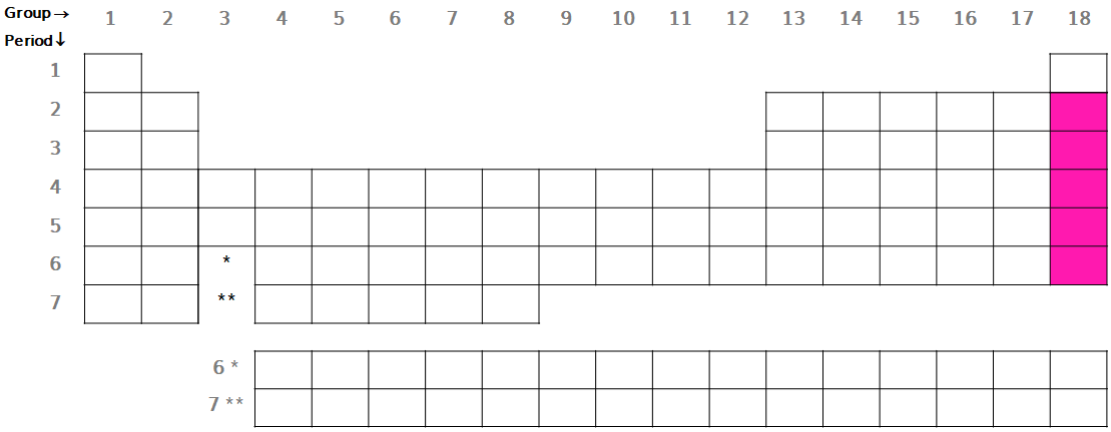
- **Chemical properties:**
  - form colored ions with different charges
  - overall, less reactive then alkali and alkaline metals
  - Ag and Au are unreactive

Rare Earth Metals



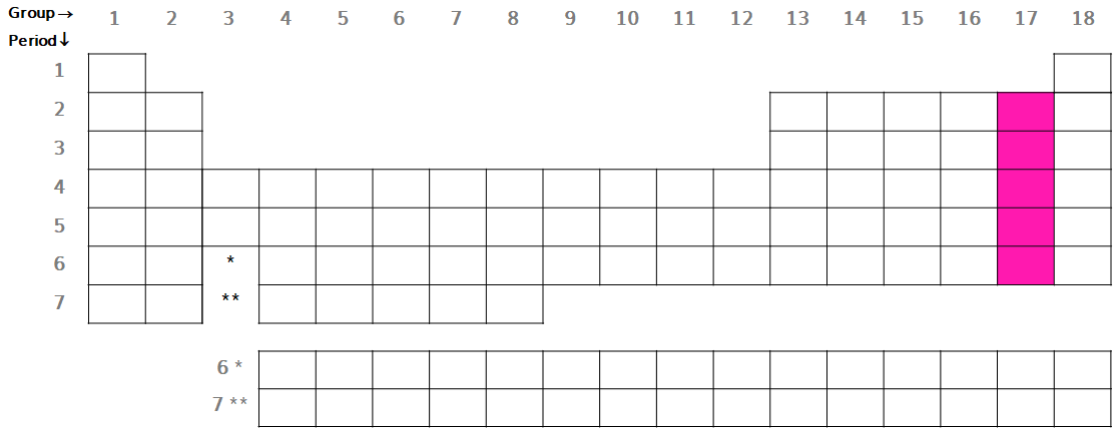
- The rare earth metals are the lanthanides and actinides
- Rare earth metals tend to share many of their properties; that means that sometimes it is hard to distinguish them from one another

Noble Gases



- **Chemical properties:**
  - inert; they are unreactive

Halogens



- **Chemical properties:**
  - all exist as **diatomic molecules**
  - react with water to produce acids

    Example:

$$Cl_2\,(aq) + H_2O\,(\ell) \rightarrow HC\ell\,(aq) + HOC\ell\,(aq)$$

  - react with metals to produce metal halides

    Example:

$$2Na\,(s) + C\ell_2\,(g) \rightarrow 2NaC\ell\,(s)$$

  - react with hydrogen to produce hydrogen halides

    Example:

$$H_2\,(g) + I\,(g) \rightarrow 2HI\,(g)$$

2.3.3

Example: The Periodic Table

Using the periodic table, give an example of each of the following:

a. a gas
b. an element that is a solid at room temperature
c. a noble gas
d. an alkaline earth metal
e. an element that is a liquid at room temperature

2.3.4

Practice: Periodic Law

Select all that apply. In the modern periodic table elements are arranged in order of increasing:

- [ ] atomic number
- [ ] mass number
- [ ] number of isotopes
- [ ] melting point

2.3.5

Practice: Families of Elements and Their Properties

Match each term with the correct definition below.

A. Reactive elements of group 17 that are poor conductors

B. Group 2 elements that have two valence electrons

C. Highly reactive elements that belong to group 1

D. Elements that belong to groups 3 - 12 and are somewhat reactive

E. Very stable due to the fact that they have a full outermost energy level

halogens

alkaline - earth metals

alkali metals

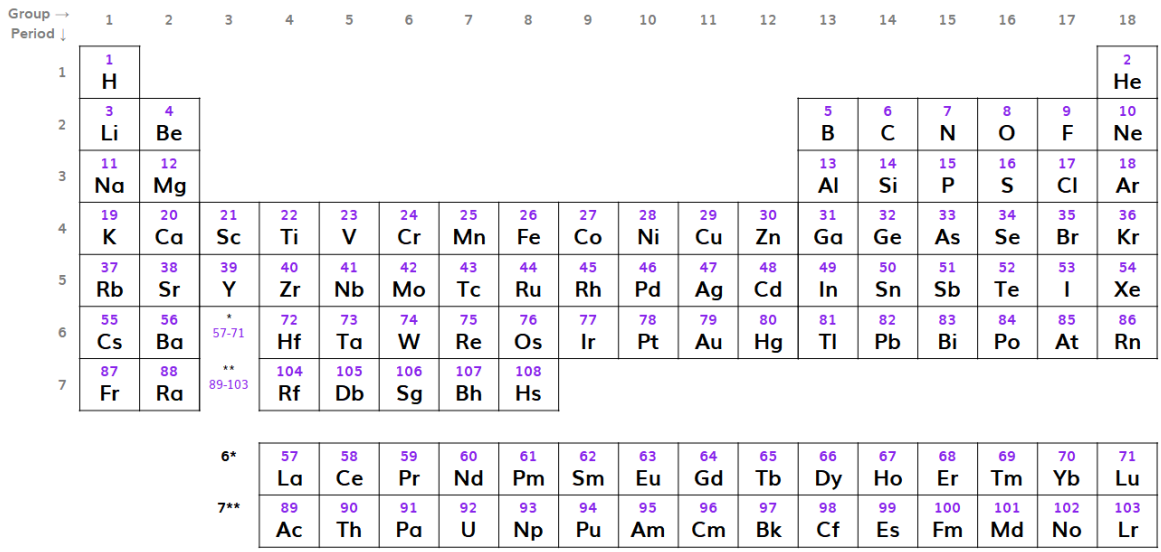
transition metals

noble (inert) gases

2.3.6

Practice: Families and Series of Elements

The greatest similarity in chemical properties is expected for elements with the atomic numbers:



- 3 and 4
- 6 and 12
- 17 and 25
- 19 and 37

2.4 Periodic Trends

2.4.1

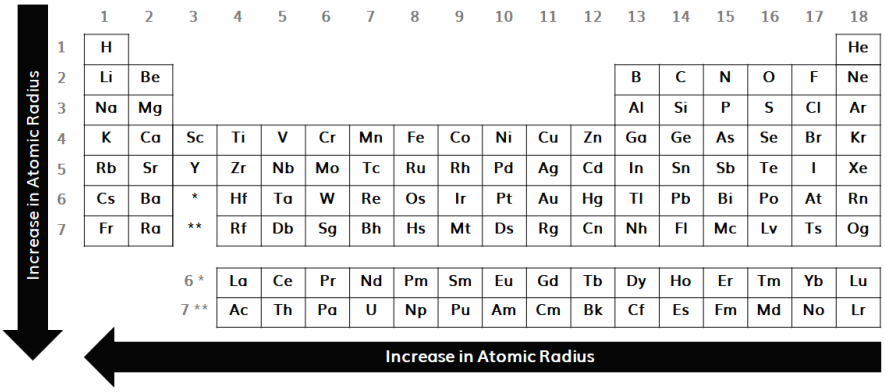
Atomic and Ionic Radii

- **Atomic radius** is the radius of the atom, which includes the nucleus and all the way to the valence electrons.

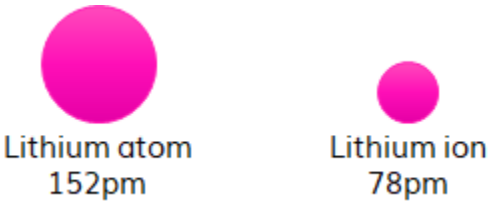
Periodic Trend

- In a **period** the atomic radius **increases from right to left**;
  The nuclear “pull” on valence electrons decreases, which means these valence electrons can wander farther away from the nucleus.

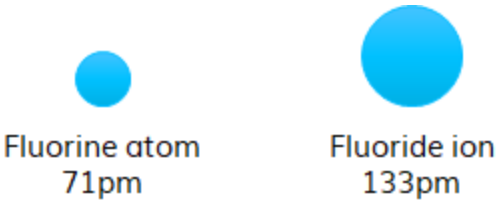
- In a **group** the atomic radius **increases from top to bottom**;
  The number of electron shells increases and makes the atom larger.



- The **ionic radius** of an ion is the distance from the center of the atom to the outermost electrons
- For a **cation**, when you remove an electron the **ionic radius is smaller** than the atomic radius
  The remaining electrons in the ion feel a stronger pull by the nucleus



- For an **anion**, when you add an electron, the **ionic radius is greater** than the atomic radius.
  The added electron is not strongly attracted by the nucleus



2.4.2

Ionization Energy

- **Ionization energy** is the energy required to remove a single electron from an atom in a gaseous state.

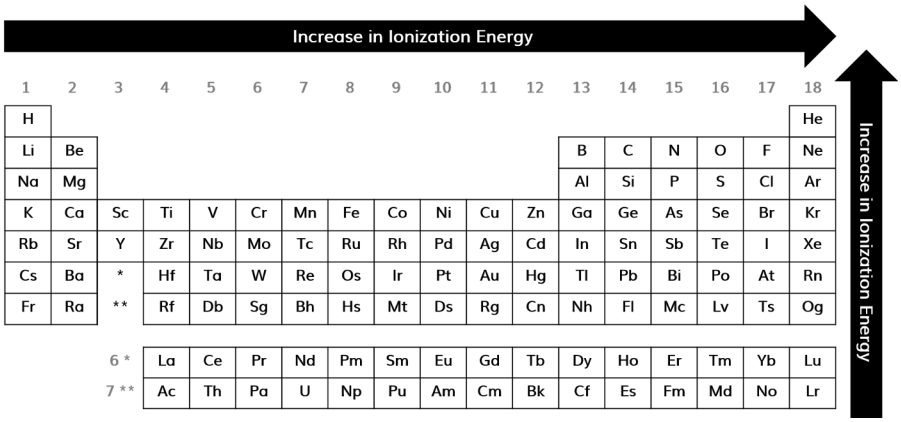
$$A\left(g\right) \rightarrow A^{+}\left(g\right) + e^{-}$$

- More positive value means more energy is required to remove electrons. The atom or the ion really wants to hang onto its electrons!

Periodic Trend

- In a **period**, ionization energy **increases from left to right**;
  This can be explained by the smaller atom size, hence electrons feel a stronger pull by the nucleus

- In **a group**, ionization energy **increases from the bottom to the top.**
  It is easier to remove electrons that are further away from the nucleus.



2.4.3

Electron Affinity

- **Electron affinity** is the energy associated with the addition of an electron to an atom

$$A(g) + e^- \rightarrow A^-(g)$$

- Depending on element, reaction can be endothermic (require energy) or exothermic (releasing energy). More negative value means more stability in gaining electrons (the atom really wants extra electron)

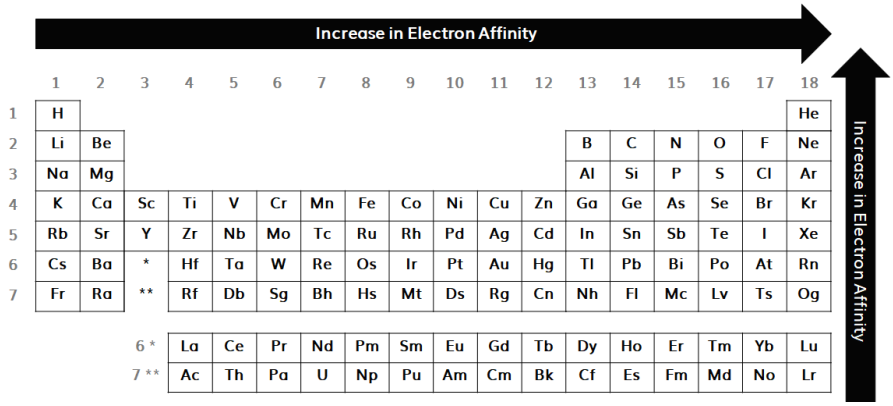
Periodic Trend

- In **a period** electron affinity **increases from left to right**
  The attraction between the nucleus and electrons increases as you go across a period, hence easier to add an electron

- In **a group** electron affinity **increases from bottom to top**
  It is easier to add electrons to smaller atoms, the extra electron will be easily attracted to the nucleus

WATCH OUT!

This trend excludes noble gases. Noble gases have stable, completely filled shells. Adding electrons to noble gases will break the noble gas configuration.



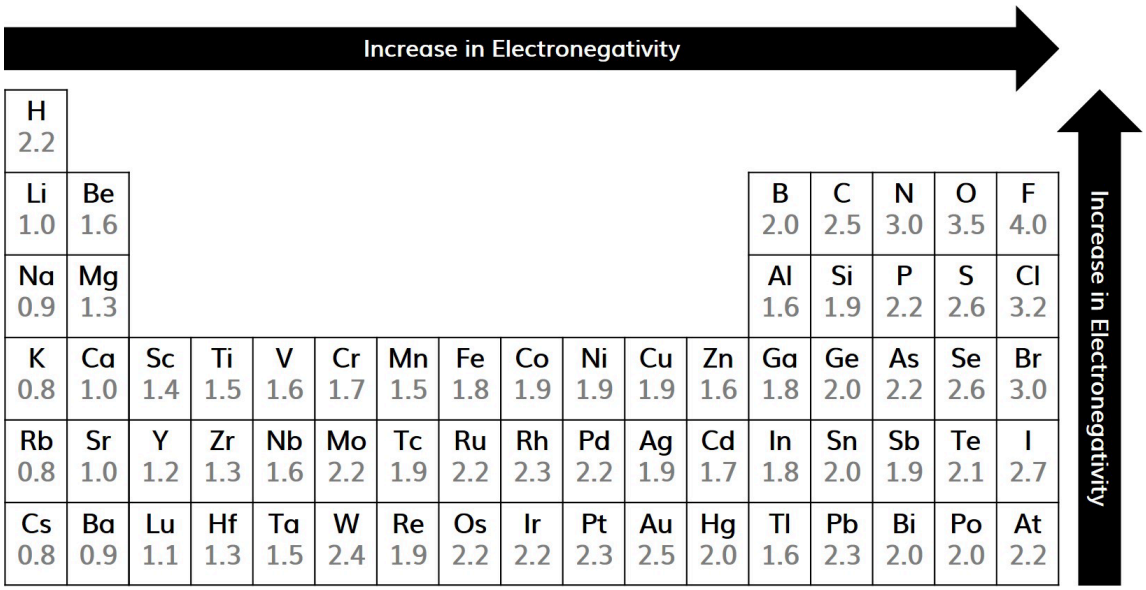
2.4.4 Electronegativity

Electronegativity

- **Valence electrons** are involved in chemical bonding.
- The type of bond depends on the **difference in electronegativity (ΔEN)** between bonding species.
- **Electronegativity** is the tendency for an atom to draw bonding electrons to itself.

WATCH OUT!

This is similar to electron affinity but not the same! Electron affinity involves a single atom/ion, whereas electronegativity involves two bonded atoms.



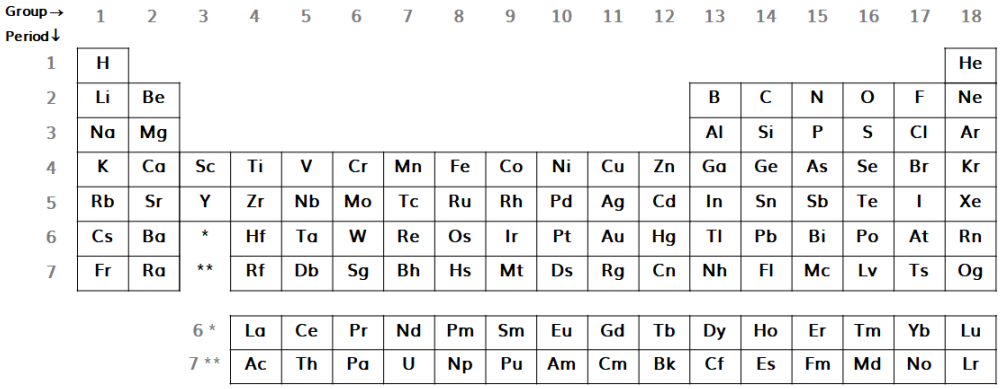
H 2.2																
Li 1.0	Be 1.6											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.3											Al 1.6	Si 1.9	P 2.2	S 2.6	Cl 3.2
K 0.8	Ca 1.0	Sc 1.4	Ti 1.5	V 1.6	Cr 1.7	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.8	Ge 2.0	As 2.2	Se 2.6	Br 3.0
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.3	Nb 1.6	Mo 2.2	Tc 1.9	Ru 2.2	Rh 2.3	Pd 2.2	Ag 1.9	Cd 1.7	In 1.8	Sn 2.0	Sb 1.9	Te 2.1	I 2.7
Cs 0.8	Ba 0.9	Lu 1.1	Hf 1.3	Ta 1.5	W 2.4	Re 1.9	Os 2.2	Ir 2.2	Pt 2.3	Au 2.5	Hg 2.0	Tl 1.6	Pb 2.3	Bi 2.0	Po 2.0	At 2.2

2.4.5

Example: Periodic Trends

Label the following statements as either TRUE or FALSE

1. Ionization energy decreases when the atomic size decreases
2. As atomic size increases it gets easier to add an additional electron



Group → / Period ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

6 *	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
7 **	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

2.4.6

Practice: Atomic and Ionic Size

Group → / Period ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	* 57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	** 89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs										

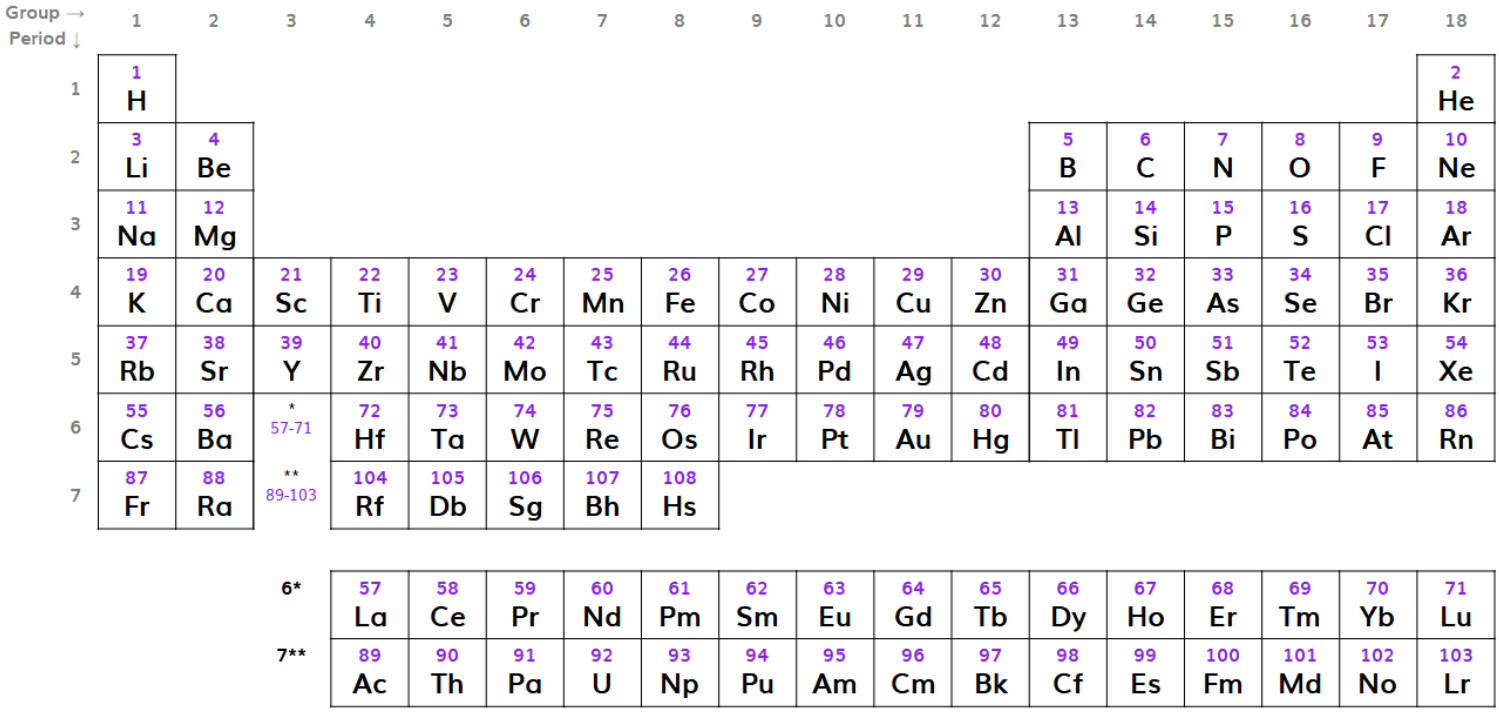
6*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
7**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Part 1

Use the periodic table to choose the largest atom in the following set

- Rb
- Sr
- Sn
- Te

Practice: Atomic and Ionic Size



Part 2

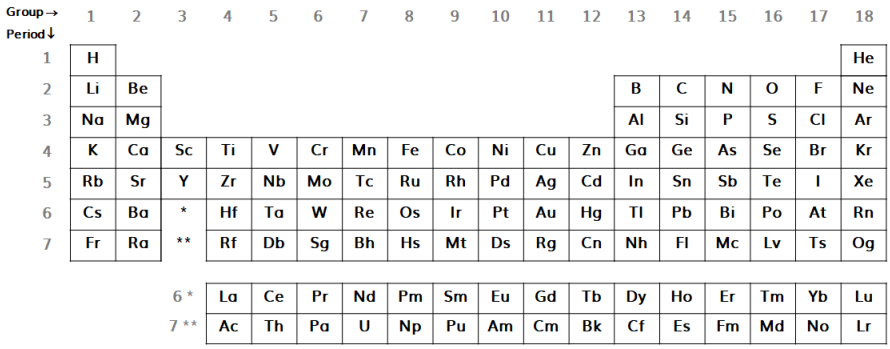
Use the periodic table to determine the smallest ion or atom in the series

- Fe
- Fe^{2+}
- Fe^{3+}

2.4.7

Practice: Ionization Energy

Rank the following atoms in order of increasing ionization energy: C, Ca, Al, K, Si, Ne (1 = smallest ionization energy, 6 = largest ionization energy).



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1	H																	He
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4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

6 *	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
7 **	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

A. 5

B. 2

C. 3

D. 1

E. 4

F. 6

C

Ca

Al

K

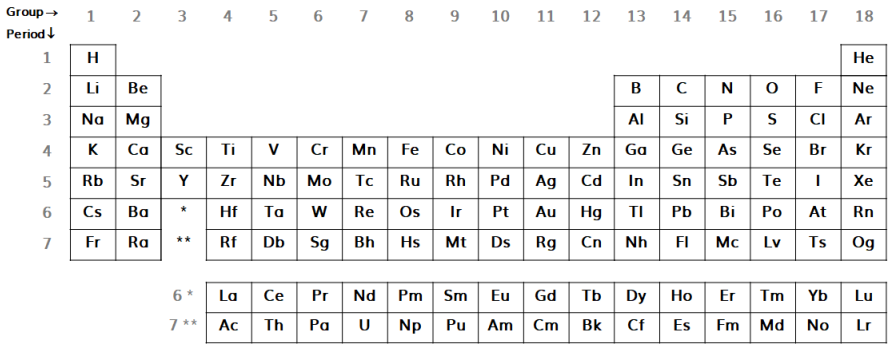
Si

Ne

2.4.8

Practice: Electron Affinity

Which of the following has the lowest electron affinity?



Group → / Period ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
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4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

6 *	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
7 **	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

- Si
- P
- Po
- I