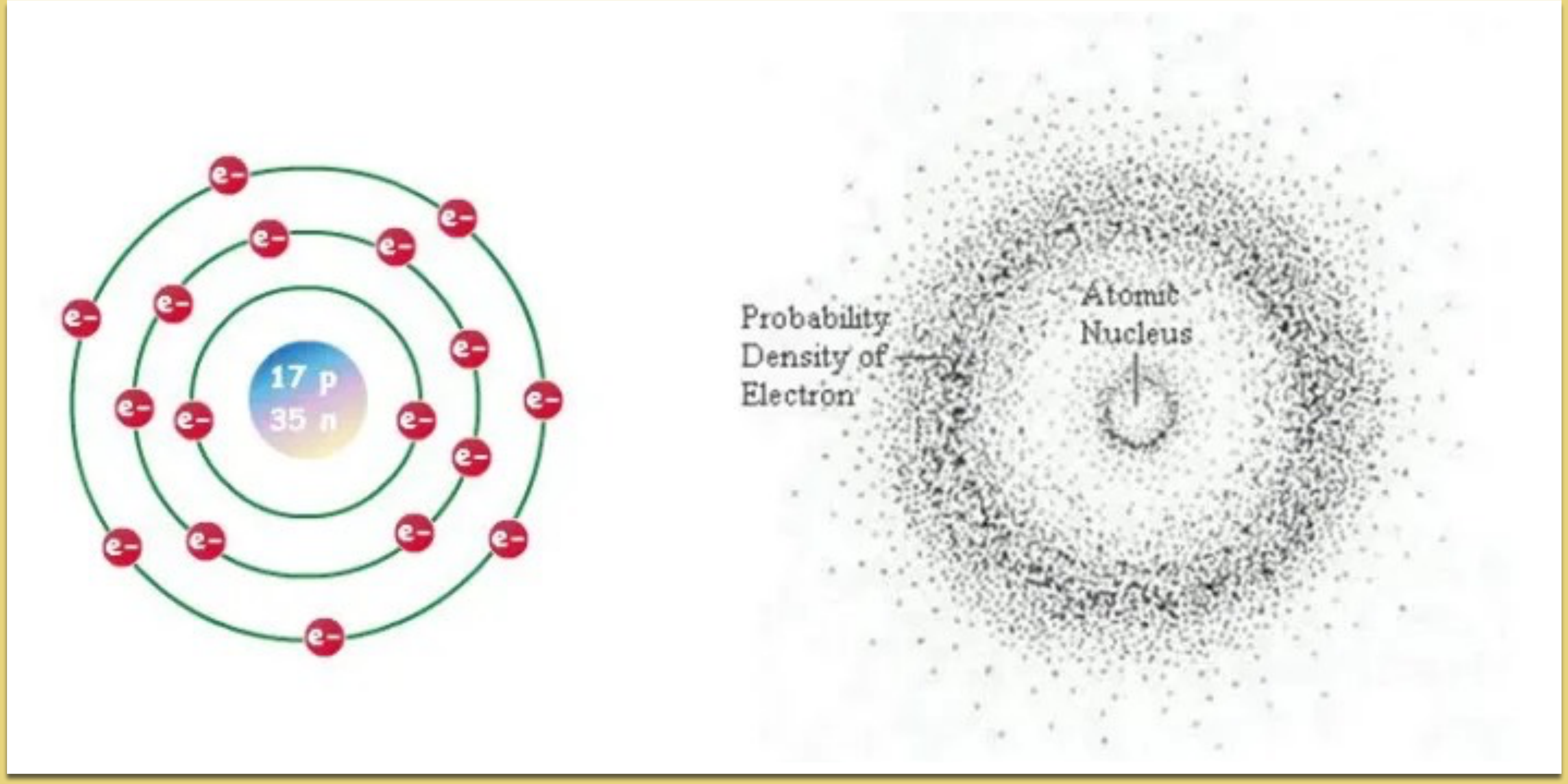
Unit 7

Atomic Structure & Periodic Table

Atomic Models

Topic 1



- Orbitals are sometimes called **electron clouds** because they do not have sharp boundaries. Orbitals show where electrons are most likely to be.

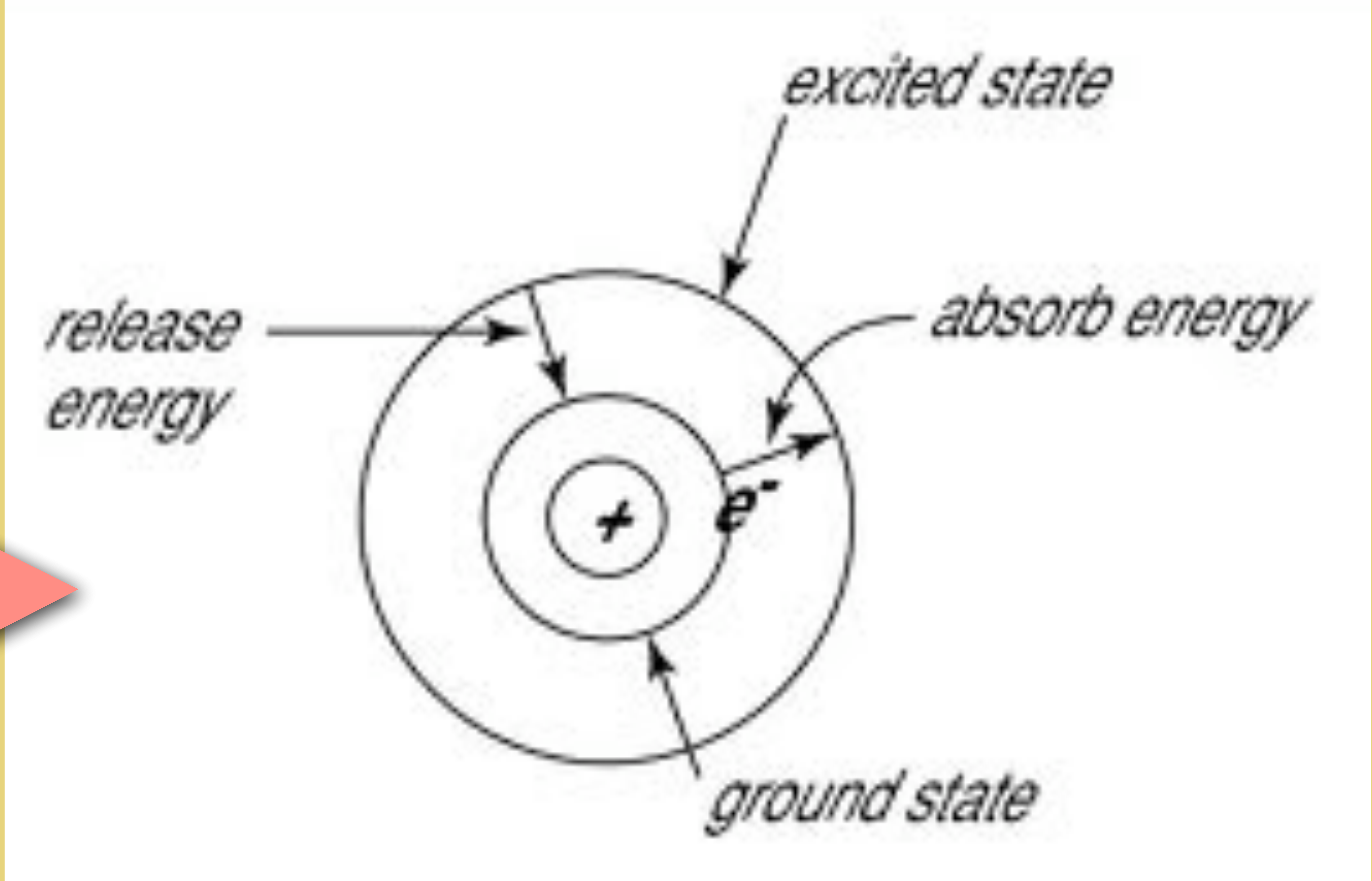
Ground vs. Excited State

Topic 2

- Ground State: most probable electron location (lowest energy level possible).
- Excited State: place an electron goes after gaining a specific amount of energy.

When writing an excited state, keep it simple!

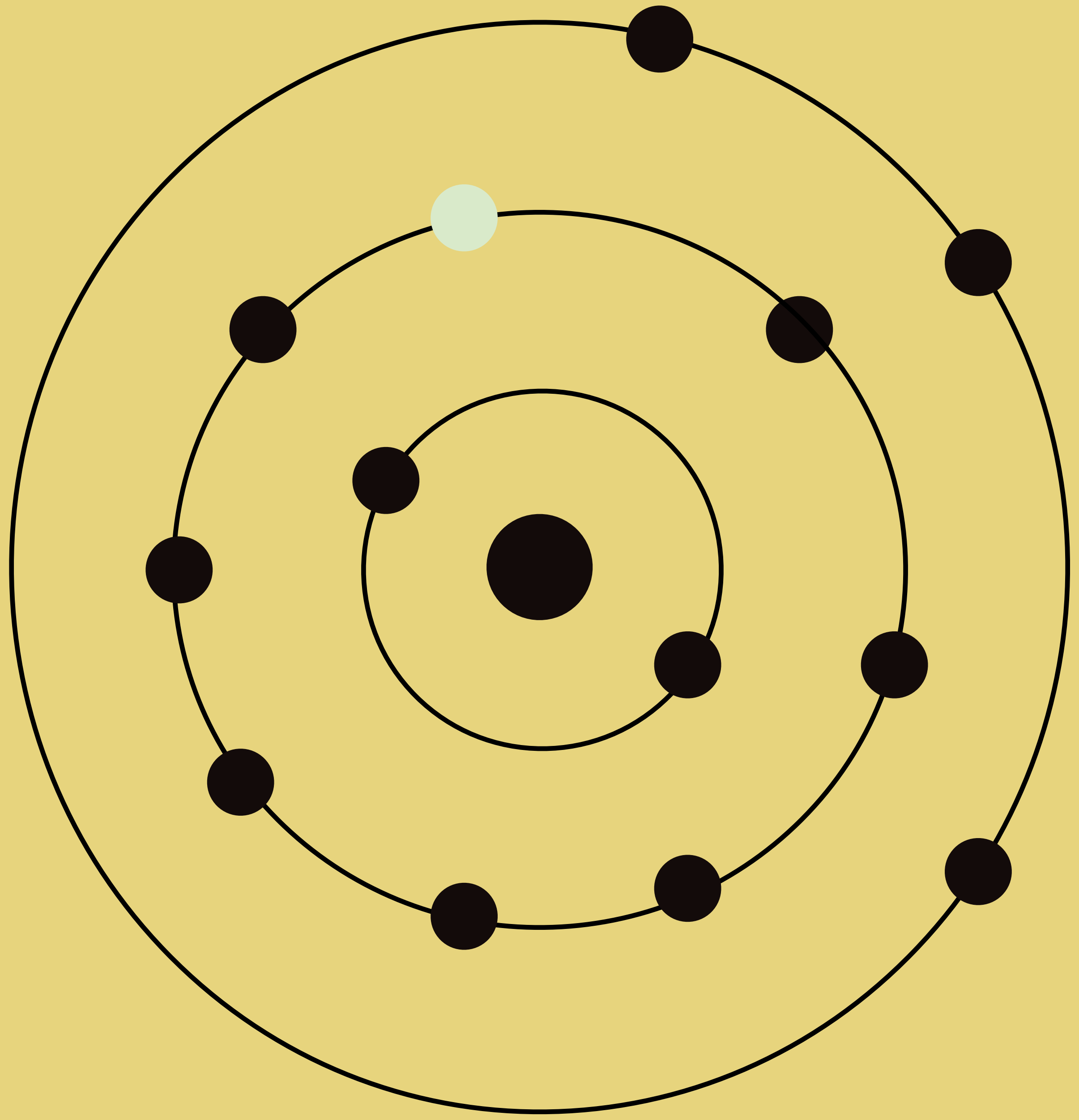
Only ONE possible ground state, but MANY possible excited states!



Examples of Excited States!

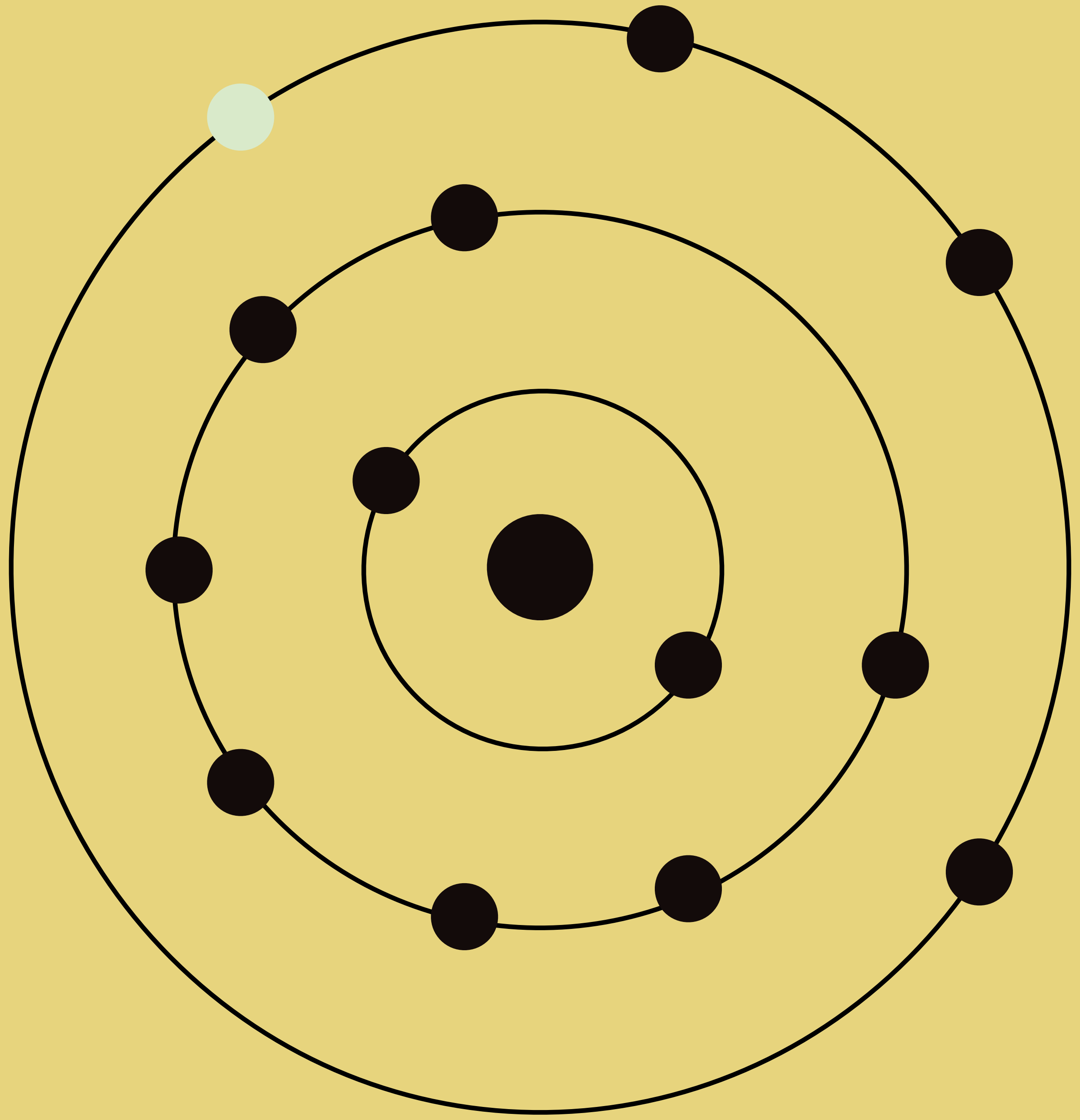
- What happens to the electron configuration of Aluminum if an electron from the second energy level jumps to the 3rd energy level?
- Ground State:

2-8-3



- Excited State:

2-7-4



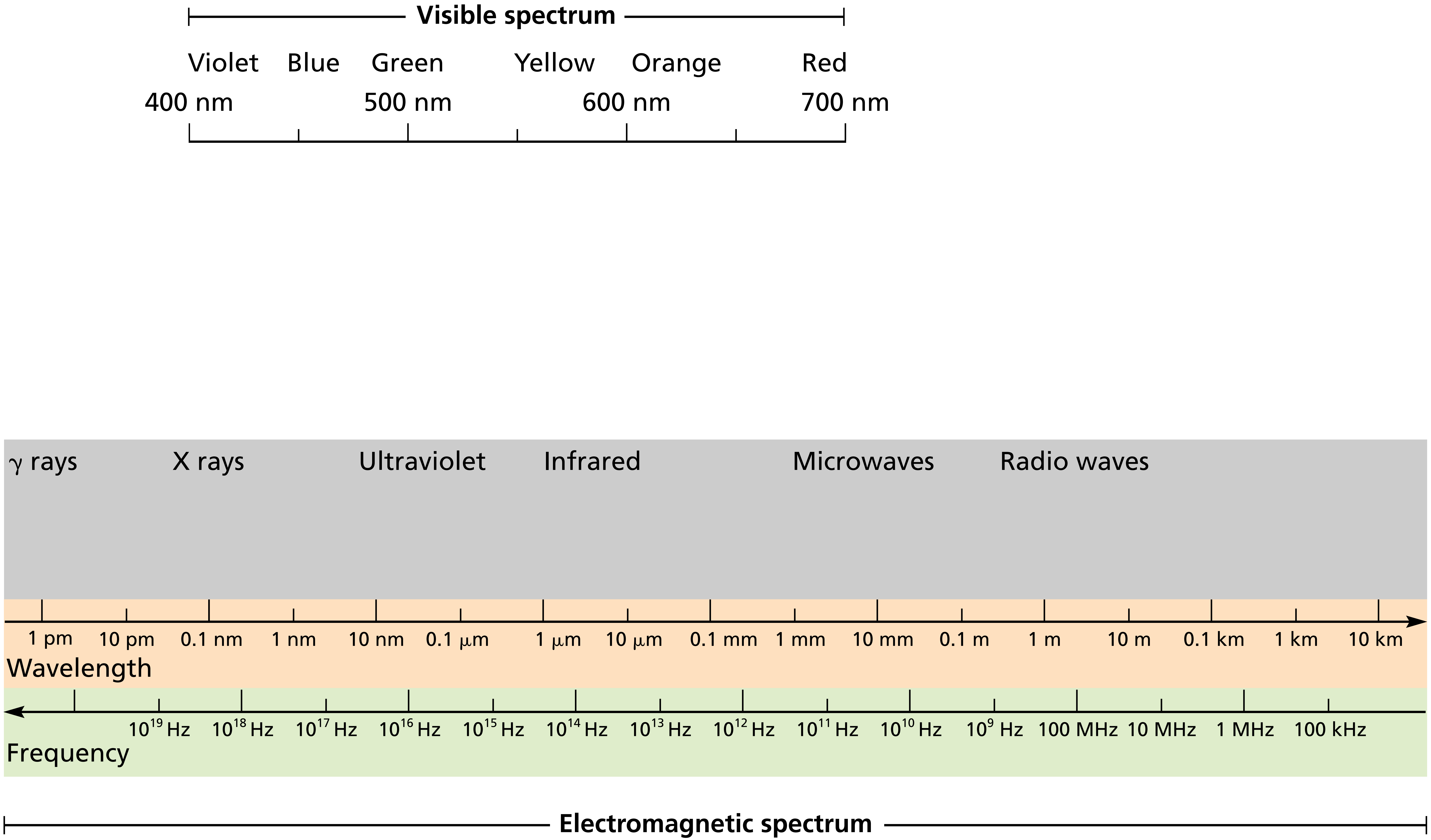
Pick out the Excited State Configurations

2-8-1	Ground
2-8-1-1	Excited
2-7-6	Excited
2-5	Ground

- Is energy released when the electron jumps from the ground state to the excited state, OR when the electron falls back down from the excited state to the ground state?

FALLS BACK DOWN!

Electromagnetic Spectrum



Visible spectrum

Violet Blue Green Yellow Orange Red

400 nm 500 nm 600 nm 700 nm

γ rays X rays Ultraviolet Infrared Microwaves Radio waves

1 pm 10 pm 0.1 nm 1 nm 10 nm 0.1 µm 1 µm 10 µm 0.1 mm 1 mm 10 mm 0.1 m 1 m 10 m 0.1 km 1 km 10 km

Wavelength

10^{19} Hz 10^{18} Hz 10^{17} Hz 10^{16} Hz 10^{15} Hz 10^{14} Hz 10^{13} Hz 10^{12} Hz 10^{11} Hz 10^{10} Hz 10^{9} Hz 100 MHz 10 MHz 1 MHz 100 kHz

Frequency

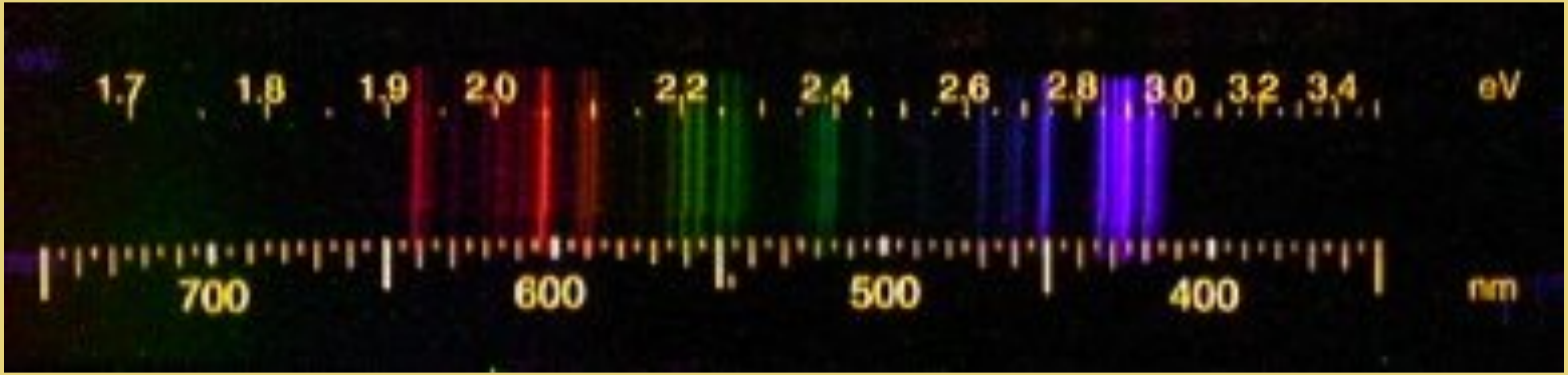
Electromagnetic spectrum

Light Provides Information about Electrons

- Normally, if an electron is in a state of lowest possible energy, it is in a ground state. If an electron gains energy, it moves to an excited state.
- An electron in an excited state will release a specific quantity of energy as it quickly “falls” back to its ground state.
- This energy is emitted as certain wavelengths of light, which give each element a unique line-emission spectrum.

Bright-Line Spectra

- The specific set of frequencies of energy emitted by atoms as they return to the ground state produces a unique light, which can be separated into a bright-line spectrum. This can be either an emission spectrum (pictured below) or an absorption spectrum, depending if the gas is hot or cold.



Like a prism

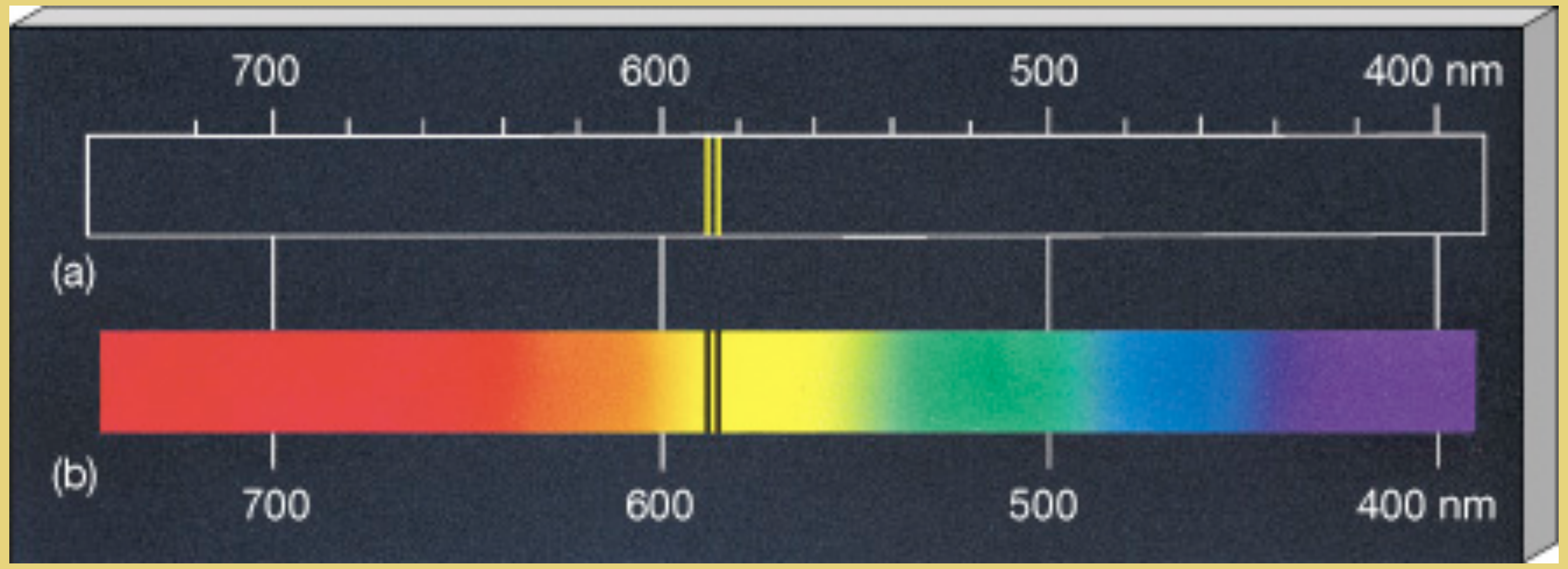

high density
hot matter
diffraction
grating
Continuous spectrum
hot gas
Emission spectrum
cold gas
Absorption spectrum

Other Bright-Line Spectra

- Every element has its own unique spectrum, and could be thought of as the “fingerprint” of that element. A spectrum of samples of unknown composition can be observed in order to identify the elements present.

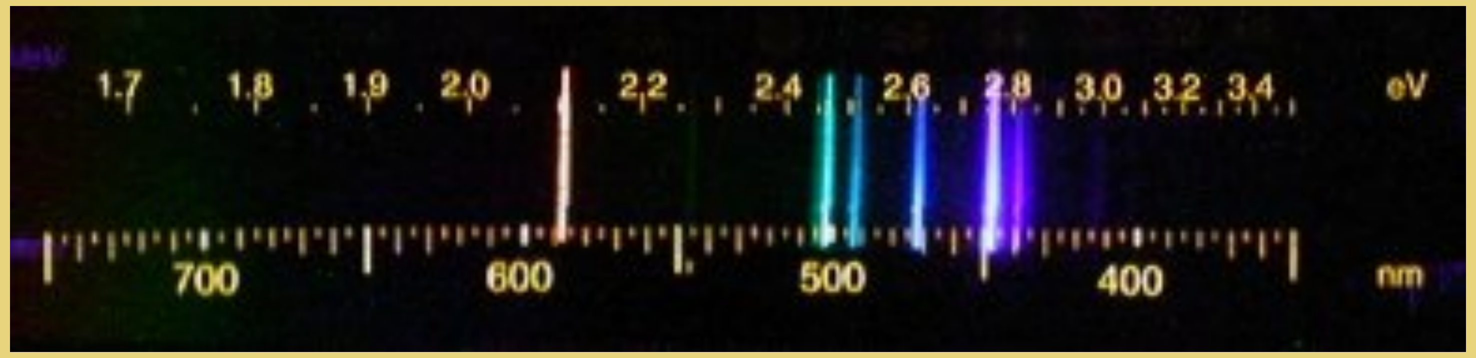
Mercury

Sodium



Hydrogen

Helium



Neon

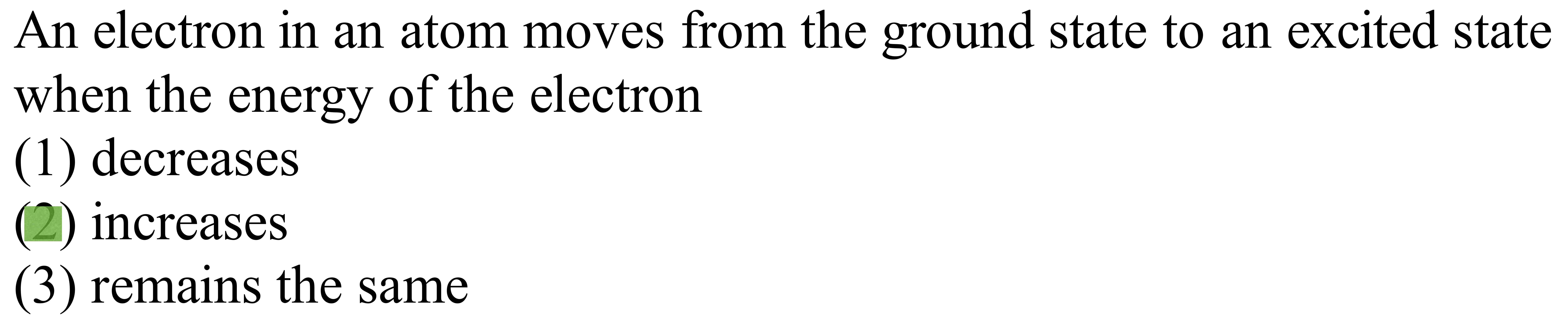
So what???

Much of what we know about the structure and history of the universe has been figured out by observing the spectra of stars. We know what gases are present in distant stars and galaxies by splitting the light they produce into spectra, and using the elements' fingerprints to identify them.

Check for Understanding - How all this Works!!

- As electrons go from ground state to excited state, they must ____ Absorb ____ (absorb or release) energy.
- This process is ____ Endothermic ____ (endo- or exothermic). The opposite is true as electrons "de-excite" or relax back to the ground state. They must give up or ____ Emit ____ (emit or absorb) energy.
- Since this results in the electron (atom) giving up energy, it is ____ Exothermic ____ (endo- or exothermic). The energy is observed as some color of ____ Light ____.
- If examined through a spectroscope, the element's characteristic ____ Bright ____-line spectrum will be observed, and may serve to identify the element.

Regents Practice #1

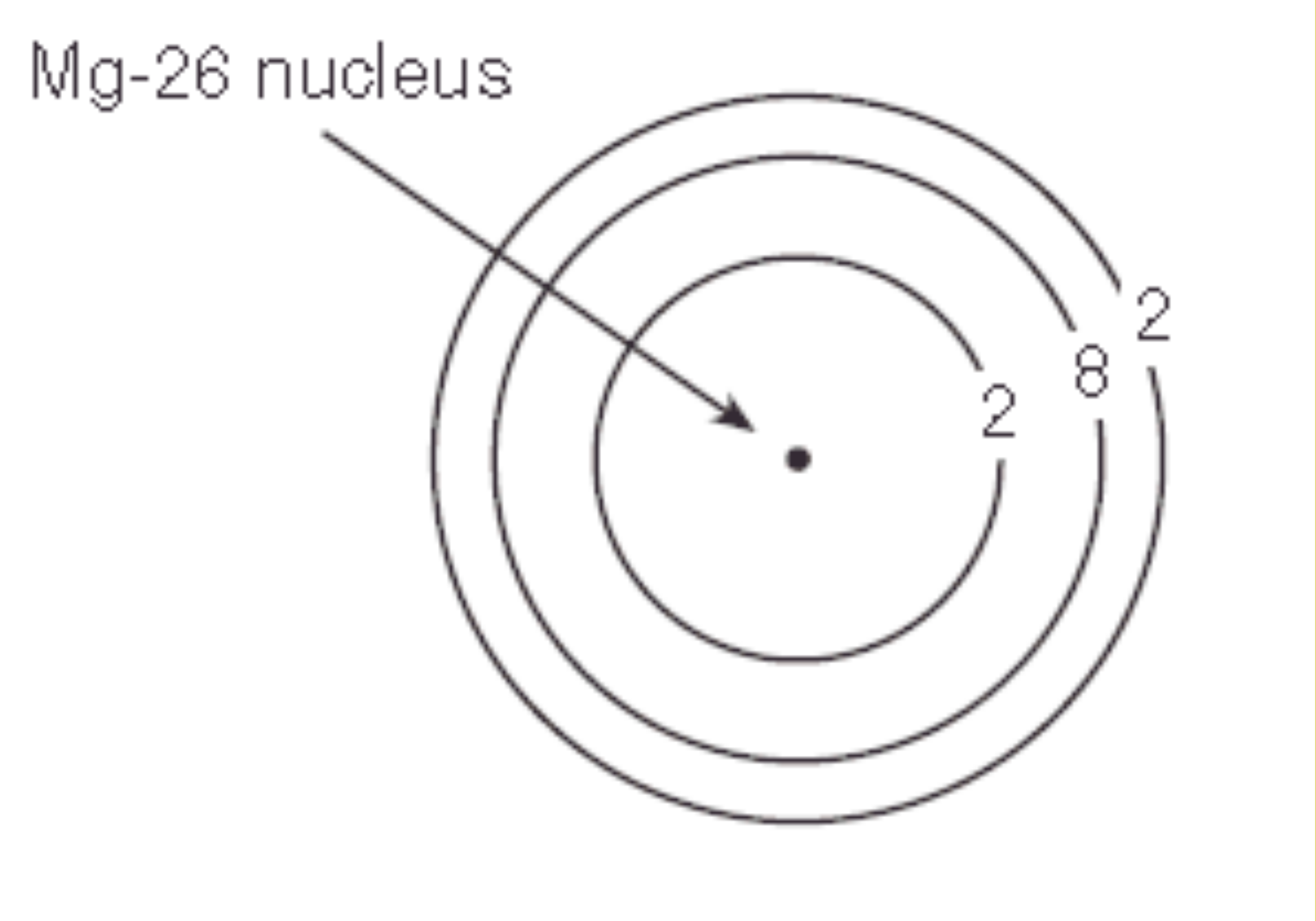


An electron in an atom moves from the ground state to an excited state when the energy of the electron

(1) decreases
[✓ (2) increases]
(3) remains the same

Regents Practice #2

- Base your answers to these questions on the diagram to the right, which represents an atom of magnesium-26 in the ground state.



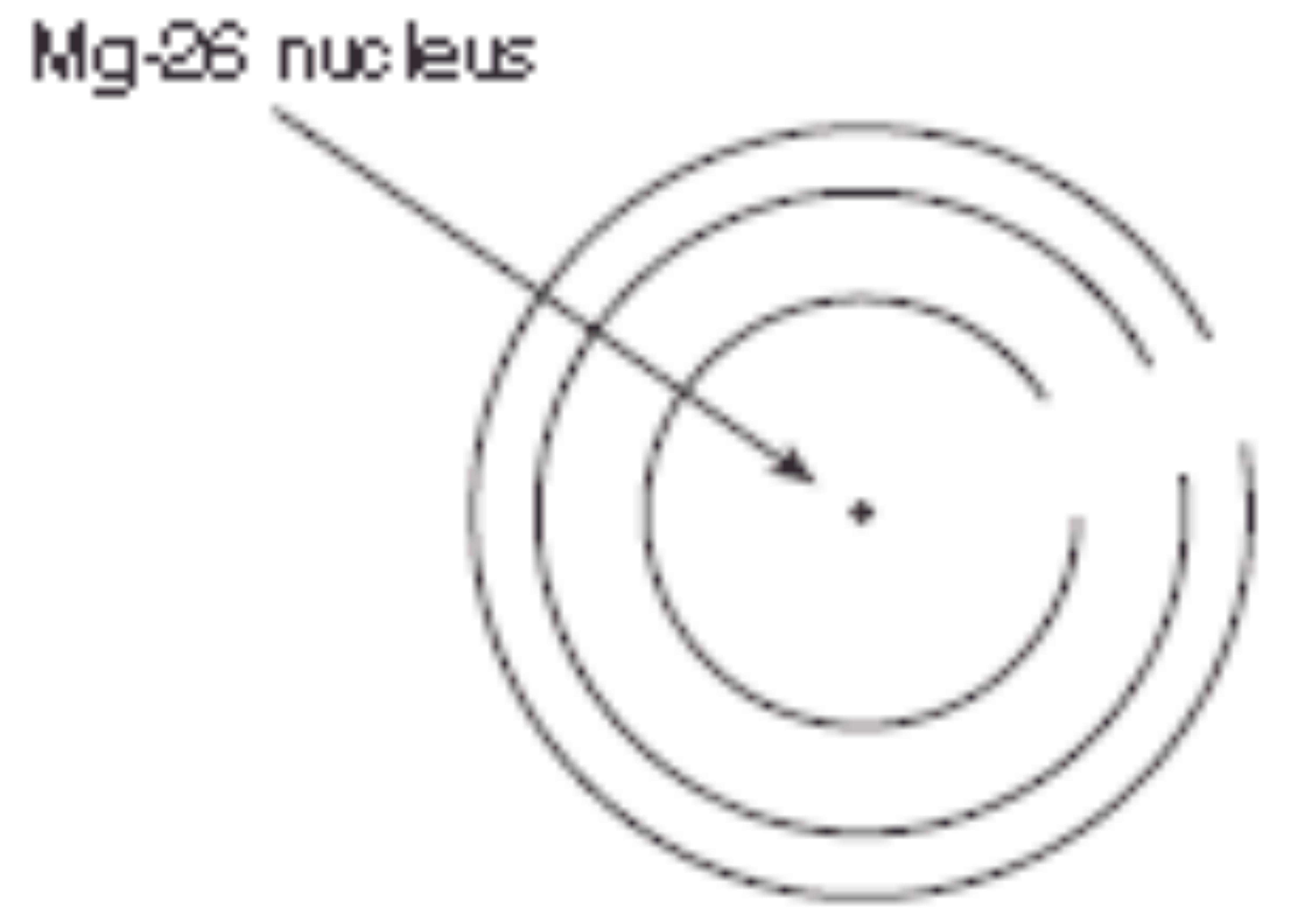
- What is the total number of valence electrons in an atom of Mg-26 in the ground state?

2

There are (2-8-2) = 12 TOTAL electrons

Regents Practice #3

- On the diagram below, write an appropriate number of electrons in each shell to represent a Mg-26 atom in an excited state. Your answer may include additional shells. (Many possible answers.)



Weighted Atomic Mass & Allotropes

Topic 3

Weighted Atomic Mass

- # Protons: determine which element an atoms is = ATOMIC NUMBER
- # electrons: determine the charge on an atom
  - Protons = electrons: atoms are neutral
  - Protons > electrons: ION (cation), positively charged (lost electrons)
  - Protons < electrons: ION (anion), negatively charged (gained electrons)
- # neutrons: determines the mass number of an atom (protons + neutrons).

Weighted Atomic Mass

- **Mass Number** = protons + neutrons for an individual atom. It's a WHOLE number.
- **Atomic mass** = weighted average of mass of all naturally occurring isotopes of an element. This is the DECIMAL on the periodic table.
- **Isotopes** = 2 atoms of the same element having the different number of neutrons.
- *NOTE: All atoms of an element are isotopes of that element.*

Weighted Atomic Mass

- Look at your periodic tables … carbon's atomic mass is 12.011 u (mass units). SO, what is the mass of carbon's most abundant isotope? (Yes, we did learn this earlier this year!)
    - Closest to 12, so C-12 is the most abundant
    - Abundant means LOTS
- Most elements have 1, 2, or 3 naturally occurring isotopes. This means that in any sample of the element, these naturally occurring isotopes are all present typically always in the same % ratio.

Isotope Example

- C-12: 6 protons, 6 neutrons (90% abundance)
- C-13: 6 protons, 7 neutrons (9% abundance)
- C-14: 6 protons, 8 neutrons (1% abundance)
- *% abundance of naturally occurring isotopes* means that in a sample of carbon (like a lump of coal or a diamond) 90% of the carbon atoms will be carbon-12, 9% will be carbon-13, and 1% will be carbon-14.
- Since not all the atoms in a sample of an element have the same mass, we have to calculate an average atomic mass for the element. The average atomic mass is calculated taking into account the different percents of each isotope present.

Average Atomic Mass Example

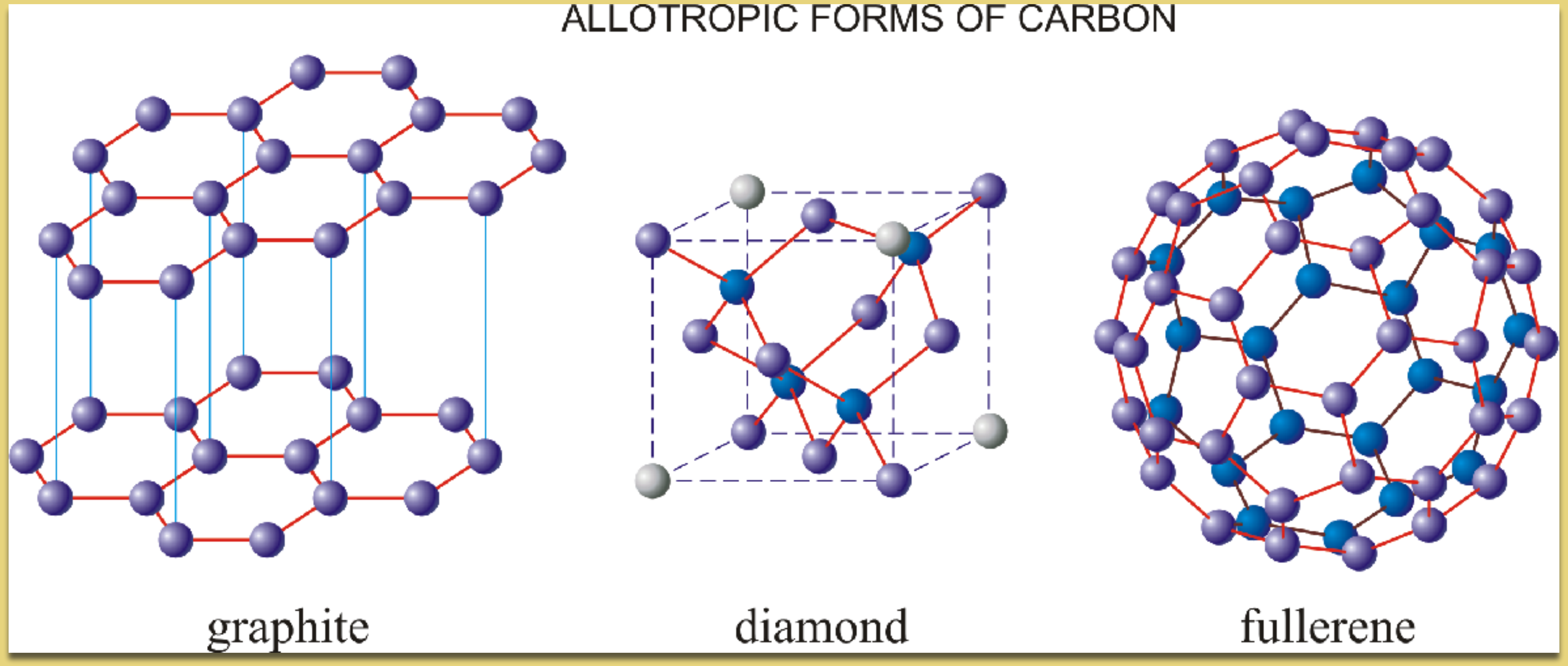
- Here's the equation (it's NOT in Table T!!)

$$\text{Atomic mass} = \frac{(\%\text{ isotope 1 x mass isotope 1}) + (\%\text{ isotope 2 x mass Isotope 2}) + (\%\text{ isotope 3 x mass Isotope 3})}{100}$$

- Let's calculate the atomic mass of carbon!

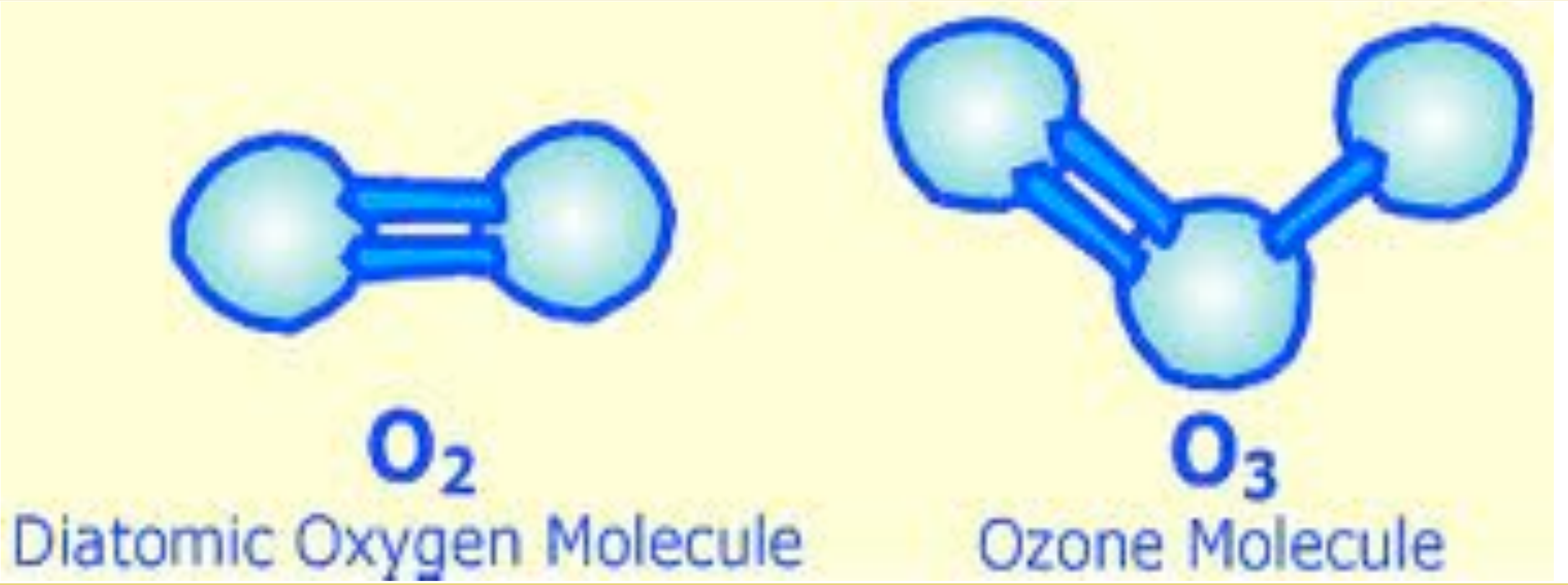
Allotropes

- What does this word sound like? Why do you think many people get this confused?
- **Allotropes: When elements exist in 2 or more different forms. Same atoms, same element, different structure, different formula.**
- **Only a few elements exist like this.**
  - **Carbon**
  - **Oxygen**
  - **Sulfur**
  - **Phosphorus**

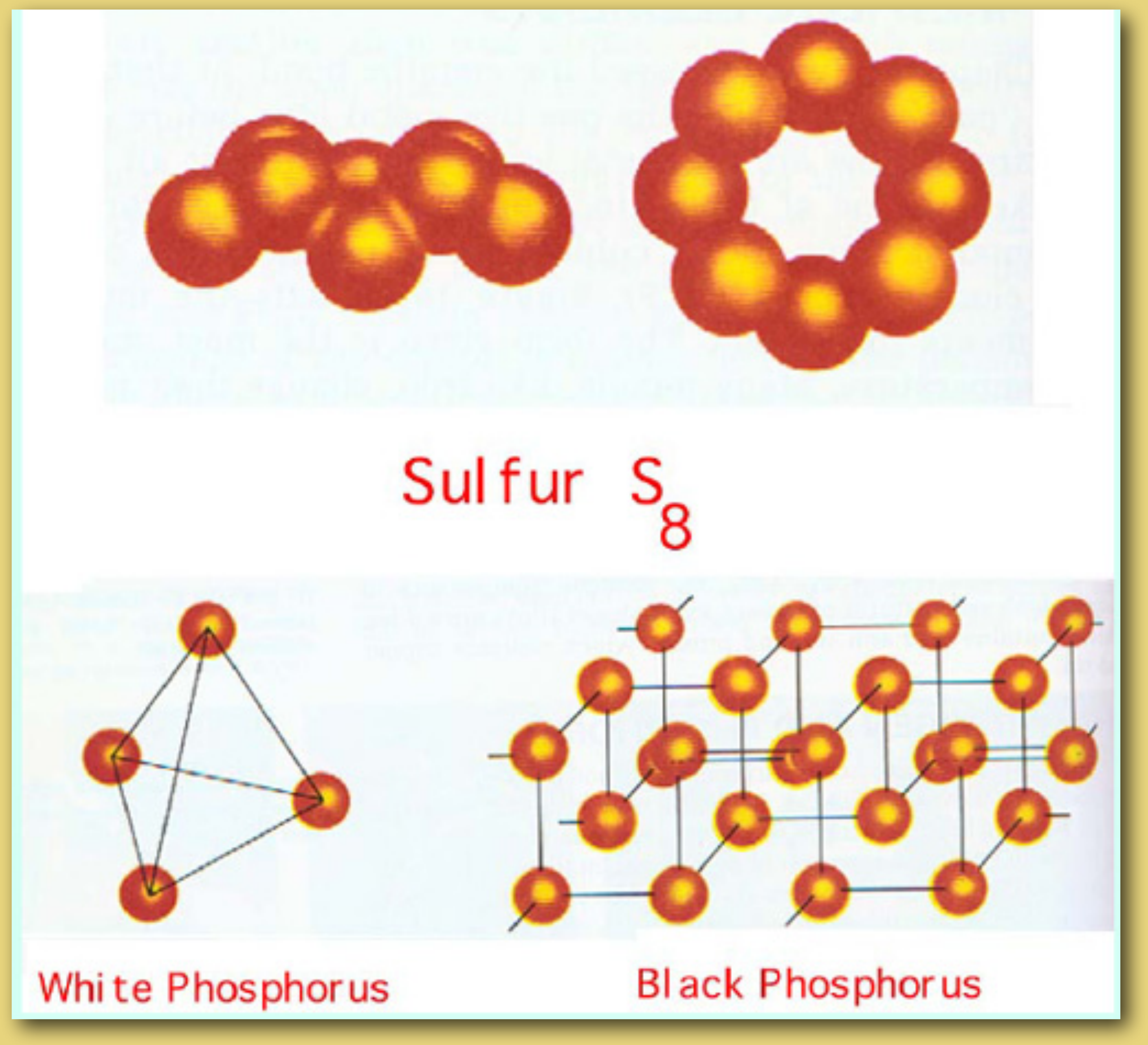


Allotrope Examples

Oxygen



Sulfur & Phosphorus



Regents Practice

The weighted atomic mass of a substance is

1. the most abundant isotope
[✓ 2.] The average of all naturally occuring isotopes
3. The atomic number of an element
4. Always the same as the number of protons plus neutrons

Trends of the Periodic Table

Topic 4

- **Take out your Periodic Table … What happens to:**
- # of valence electrons as you go left to right across a period?
- # of valence electrons as you go down a group?
- # of energy levels as you go left to right across a period?
- # of energy levels as you go down a group?
- Atomic radius (size) as you go left to right across a period? (Table S)
- Atomic radius (size) as you down a group? (Table S)
- Metallic character as you go left to right across a period?
- Metallic character as you go down a group?

Periodic Table of the Elements

KEY

Atomic Mass → 12.011 –4 ← Selected Oxidation States
+2
+4
Symbol → **C**
Atomic Number → **6**
Electron Configuration → 2-4

Relative atomic masses are based on $^{12}C = 12$ (exact)

Note: Numbers in parentheses are mass numbers of the most stable or common isotope.

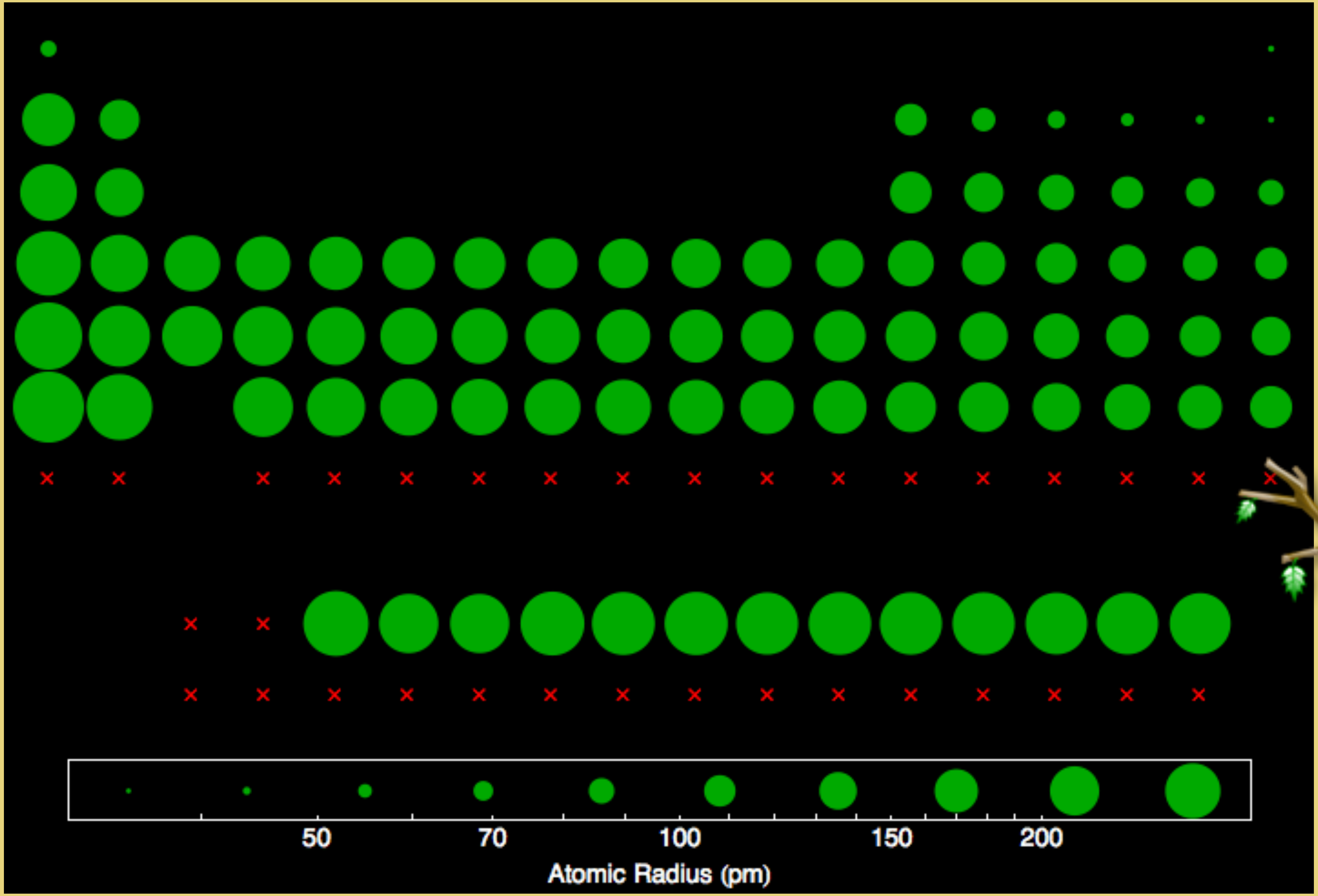
Period	Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1.00794 +1 –1 **H** 1 1																	4.00260 0 **He** 2 2
2	6.941 +1 **Li** 3 2-1	9.01218 +2 **Be** 4 2-2											10.81 +3 **B** 5 2-3	12.011 –4 +2 +4 **C** 6 2-4	14.0067 –3 –2 –1 +1 +2 +3 +4 +5 **N** 7 2-5	15.9994 –2 **O** 8 2-6	18.9984 –1 **F** 9 2-7	20.180 0 **Ne** 10 2-8
3	22.98977 +1 **Na** 11 2-8-1	24.305 +2 **Mg** 12 2-8-2											26.98154 +3 **Al** 13 2-8-3	28.0855 –4 +2 +4 **Si** 14 2-8-4	30.97376 –3 +3 +5 **P** 15 2-8-5	32.065 –2 +4 +6 **S** 16 2-8-6	35.453 –1 +1 +5 +7 **Cl** 17 2-8-7	39.948 0 **Ar** 18 2-8-8
4	39.0983 +1 **K** 19 2-8-8-1	40.08 +2 **Ca** 20 2-8-8-2	44.9559 +3 **Sc** 21 2-8-9-2	47.867 +2 +3 +4 **Ti** 22 2-8-10-2	50.9415 +2 +3 +4 +5 **V** 23 2-8-11-2	51.996 +2 +3 +6 **Cr** 24 2-8-13-1	54.9380 +2 +3 +4 +7 **Mn** 25 2-8-13-2	55.845 +2 +3 **Fe** 26 2-8-14-2	58.9332 +2 +3 **Co** 27 2-8-15-2	58.693 +2 +3 **Ni** 28 2-8-16-2	63.546 +1 +2 **Cu** 29 2-8-18-1	65.409 +2 **Zn** 30 2-8-18-2	69.723 +3 **Ga** 31 2-8-18-3	72.64 +2 +4 **Ge** 32 2-8-18-4	74.9216 –3 +3 +5 **As** 33 2-8-18-5	78.96 –2 +4 +6 **Se** 34 2-8-18-6	79.904 –1 +1 +5 **Br** 35 2-8-18-7	83.798 0 +2 **Kr** 36 2-8-18-8
5	85.4678 +1 **Rb** 37 2-8-18-8-1	87.62 +2 **Sr** 38 2-8-18-8-2	88.9059 +3 **Y** 39 2-8-18-9-2	91.224 +4 **Zr** 40 2-8-18-10-2	92.9064 +3 +5 **Nb** 41 2-8-18-12-1	95.94 +6 **Mo** 42 2-8-18-13-1	(98) +4 +6 +7 **Tc** 43 2-8-18-13-2	101.07 +3 **Ru** 44 2-8-18-15-1	102.906 +3 **Rh** 45 2-8-18-16-1	106.42 +2 +4 **Pd** 46 2-8-18-18	107.868 +1 **Ag** 47 2-8-18-18-1	112.41 +2 **Cd** 48 2-8-18-18-2	114.818 +3 **In** 49 2-8-18-18-3	118.71 +2 +4 **Sn** 50 2-8-18-18-4	121.760 –3 +3 +5 **Sb** 51 2-8-18-18-5	127.60 –2 +4 +6 **Te** 52 2-8-18-18-6	126.904 –1 +1 +5 +7 **I** 53 2-8-18-18-7	131.29 0 +2 +4 +6 **Xe** 54 2-8-18-18-8
6	132.905 +1 **Cs** 55 2-8-18-18-8-1	137.33 +2 **Ba** 56 2-8-18-18-8-2	138.9055 +3 **La** 57 2-8-18-18-9-2	178.49 +4 **Hf** 72 *18-32-10-2	180.948 +5 **Ta** 73 -18-32-11-2	183.84 +6 **W** 74 -18-32-12-2	186.207 +4 +6 +7 **Re** 75 -18-32-13-2	190.23 +3 +4 **Os** 76 -18-32-14-2	192.217 +3 +4 **Ir** 77 -18-32-15-2	195.08 +2 +4 **Pt** 78 -18-32-17-1	196.967 +1 +3 **Au** 79 -18-32-18-1	200.59 +1 +2 **Hg** 80 -18-32-18-2	204.383 +1 +3 **Tl** 81 -18-32-18-3	207.2 +2 +4 **Pb** 82 -18-32-18-4	208.980 +3 +5 **Bi** 83 -18-32-18-5	(209) +2 +4 **Po** 84 -18-32-18-6	(210) **At** 85 -18-32-18-7	(222) 0 **Rn** 86 -18-32-18-8
7	(223) +1 **Fr** 87 -18-32-18-8-1	(226) +2 **Ra** 88 -18-32-18-8-2	(227) +3 **Ac** 89 -18-32-18-9-2	(261) +4 **Rf** 104	(262) **Db** 105	(266) **Sg** 106	(272) **Bh** 107	(277) **Hs** 108	(276) **Mt** 109	(281) **Ds** 110	(280) **Rg** 111	(285) **Cn** 112	(284) **Uut** 113**	(289) **Uuq** 114	(288) **Uup** 115	(292) **Uuh** 116	(?) **Uus** 117	(294) **Uuo** 118

140.116 +3 +4 **Ce**	140.908 +3 **Pr**	144.24 +3 **Nd**	(145) +3 **Pm**	150.36 +2 +3 **Sm**	151.964 +2 +3 **Eu**	157.25 +3 **Gd**	158.925 +3 **Tb**	162.500 +3 **Dy**	164.930 +3 **Ho**	167.259 +3 **Er**	168.934 +3 **Tm**	173.04 +2 +3 **Yb**	174.9668 +3 **Lu**

Atomic Number	Symbol	Name	First Ionization Energy (kJ/mol)	Electronegativity	Melting Point (K)	Boiling* Point (K)	Density** (g/cm^3)	Atomic Radius (pm)
1	H	hydrogen	1312	2.2	14	20.	0.000082	32
2	He	helium	2372	—	—	4	0.000164	37
3	Li	lithium	520.	1.0	454	1615	0.534	130.
4	Be	beryllium	900.	1.6	1560.	2744	1.85	99
5	B	boron	801	2.0	2348	4273	2.34	84
6	C	carbon	1086	2.6	—	—	—	75
7	N	nitrogen	1402	3.0	63	77	0.001145	71
8	O	oxygen	1314	3.4	54	90.	0.001308	64
9	F	fluorine	1681	4.0	53	85	0.001553	60.
10	Ne	neon	2081	—	24	27	0.000825	62
11	Na	sodium	496	0.9	371	1156	0.97	160.
12	Mg	magnesium	738	1.3	923	1363	1.74	140.
13	Al	aluminum	578	1.6	933	2792	2.70	124
14	Si	silicon	787	1.9	1687	3538	2.3296	114
15	P	phosphorus (white)	1012	2.2	317	554	1.823	109
16	S	sulfur (monoclinic)	1000.	2.6	388	718	2.00	104
17	Cl	chlorine	1251	3.2	172	239	0.002898	100.
18	Ar	argon	1521	—	84	87	0.001633	101
19	K	potassium	419	0.8	337	1032	0.89	200.
20	Ca	calcium	590.	1.0	1115	1757	1.54	174

Atomic Radius: the "Falling Snowman"

Atomic size increases



Atomic size decreases

ELECTRONEGATIVITY

- *Force of attraction the atom has for an electron. "Desire" for electrons.*
- Which do you think would have greater electronegativity; metals or nonmetals? __Nonmetals__ Why??
- Look at Table S. Which element has the highest electronegativity?
- Why?

Fluorine only wants 1 e-, so strong desire, and small so valence shell close to pull of electrons

Ionization Energy

- the amount of energy needed to remove an electron from the atom. (The more energy, the harder to remove.)
- Which do you think would have higher ionization energy; metals or nonmetals? Nonmetals Why??
- Which element has the highest ionization energy? He
- Why??

Full shell, small size, so e- close to nucleus & held tightly.
VERY STABLE

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh	Uus	Uuo
	*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
	**	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

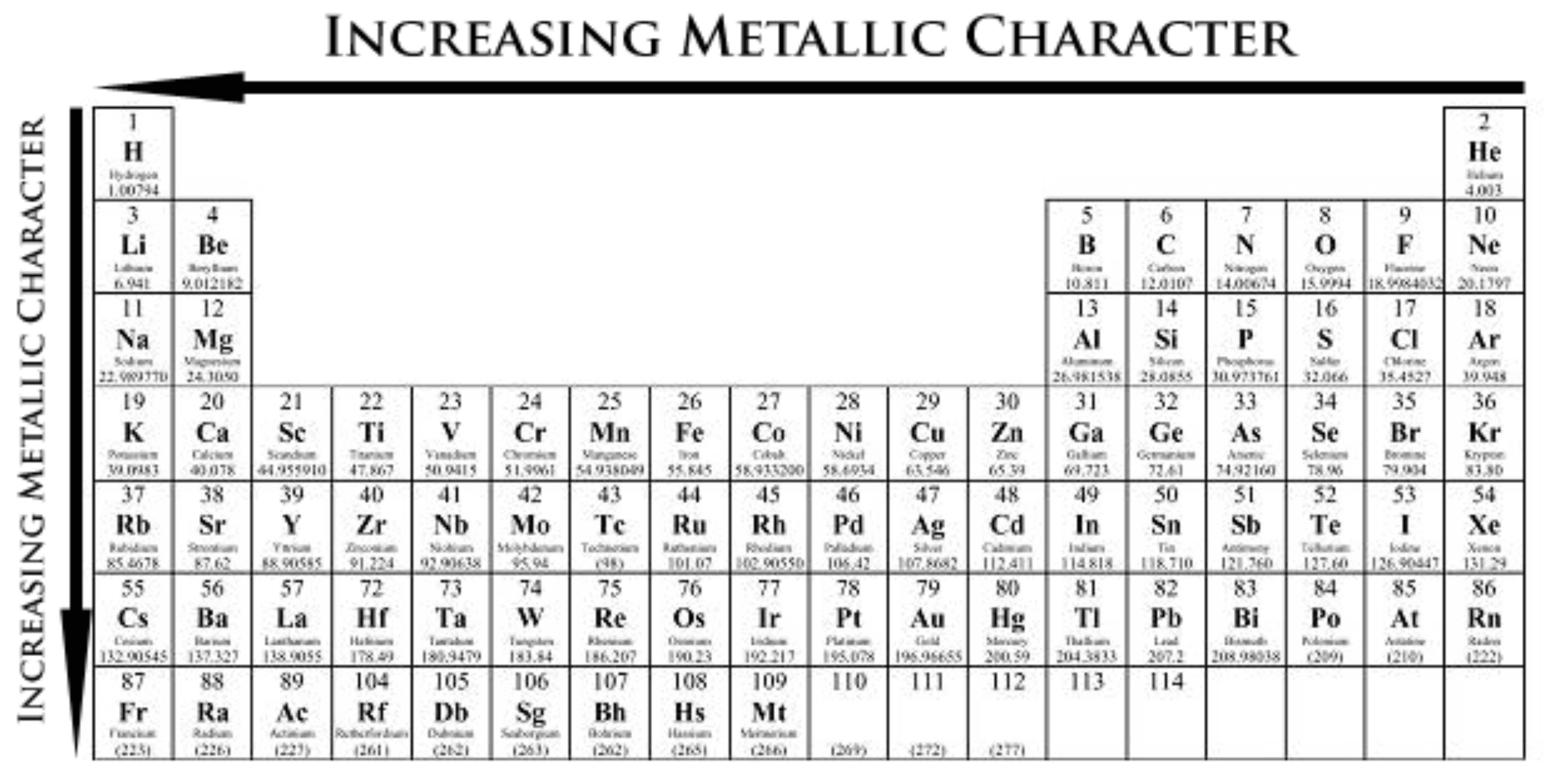
Metallic Character

- Describes how readily an atom will ___lose___ electrons to become an ion.
- Let's refresh our memory about the properties of metals vs. nonmetals…

Metals	Nonmetals
• conduct electricity	• do not conduct
• shiny, reflective luster	• dull or pearly / no luster
• malleable	• brittle
• want to lose electrons	• want to gain electrons

Metallic Character Trends

- Based on what you already know about the periodic table, identify the trend in metallic character as you go down a group and from left to right across a period.



1 H 1.00794																	2 He 4.003
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)	113	114				

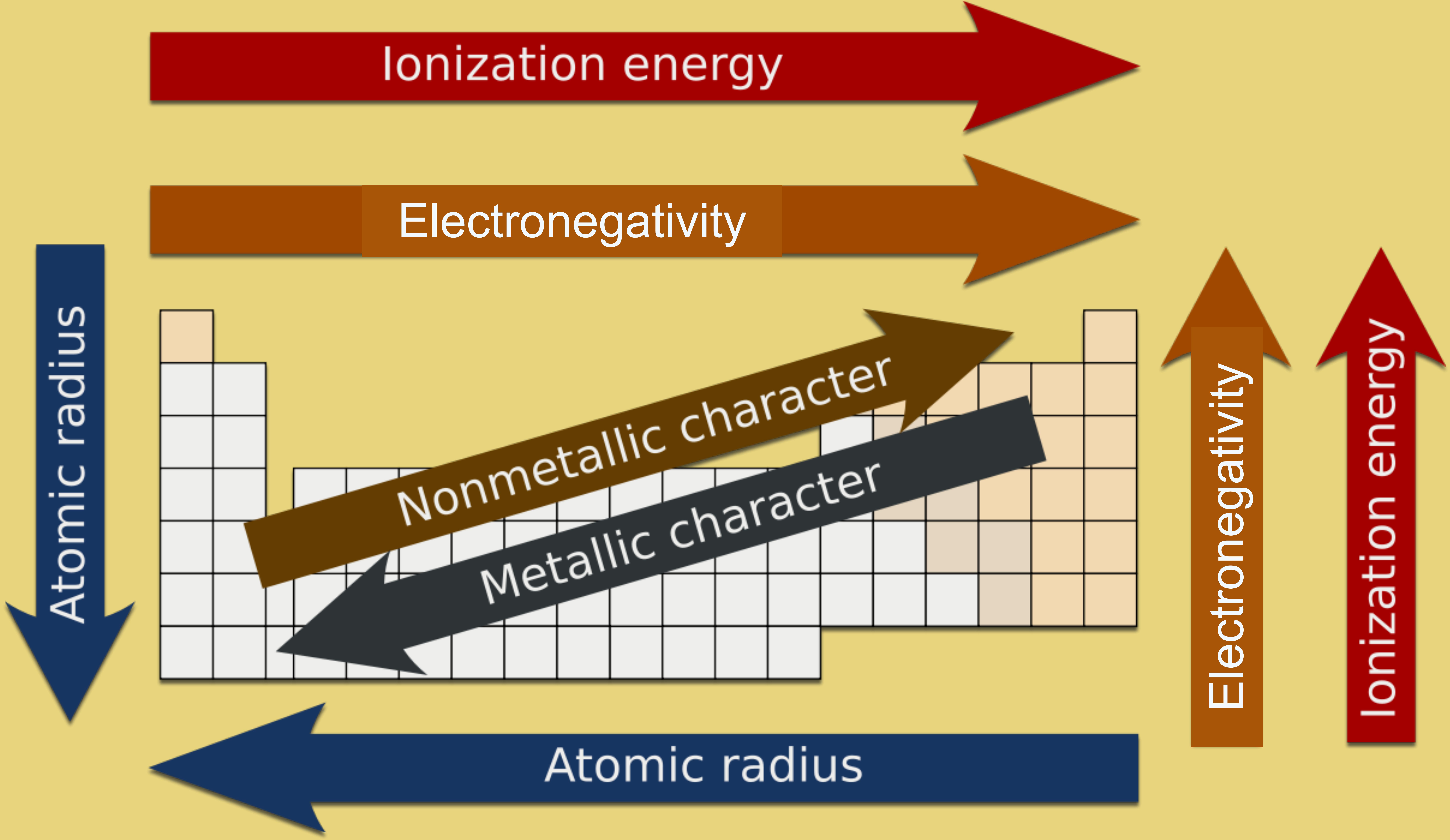
Reactivity - Metals

- For METALS, they are more reactive if they ___lose___ electrons easily.

- So, which element is the MOST reactive METAL? ___Fr___ Why?
    - Group 1: only wants to lose 1 e- to become stable. REALLY wants to lose it.
    - Largest group 1, so e- to lose is farthest away from pull of the nucleus.

Reactivity - Nonmetals

- For NONMETALS, they are more reactive if they **gain** electrons easily.
- So, which element is the MOST reactive NONMETAL? **F** Why?
  - Halogen, only needs 1 e- to become stable so it REALLY wants one.
  - Smallest halogen, so e- to gain is closest to the pull of the positively charged nucleus.



Ionization energy
Electronegativity
Atomic radius
Nonmetallic character
Metallic character
Electronegativity
Ionization energy
Atomic radius

Regents Practice

Atoms of which element have the greatest tendency to gain electrons

A) Bromine

[✓ B)] Fluorine

C) Chlorine

D) Iodine

Which element in Group 15 has the strongest metallic character?

A) As

B) P

C) N

[✓ D)] Bi

Compared to atoms of metals, atoms of nonmetals generally

A) Have lower first ionization energies

B) Conduct electricity more readily

[✓ C)] Have higher electronegativities

D) Lose electrons more readily