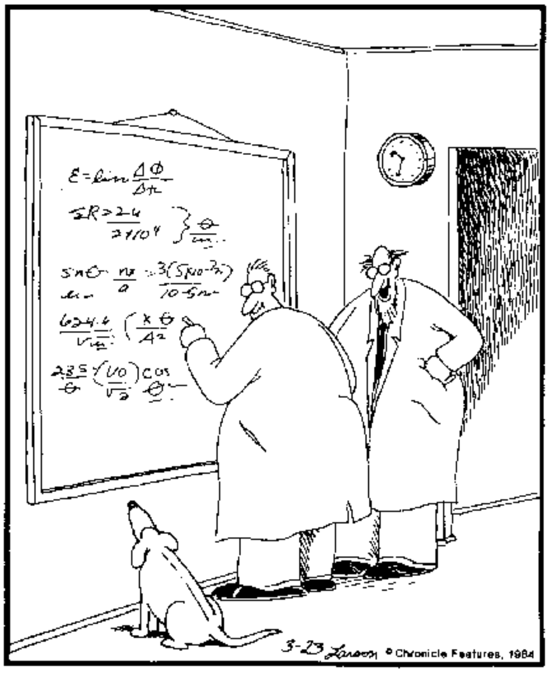
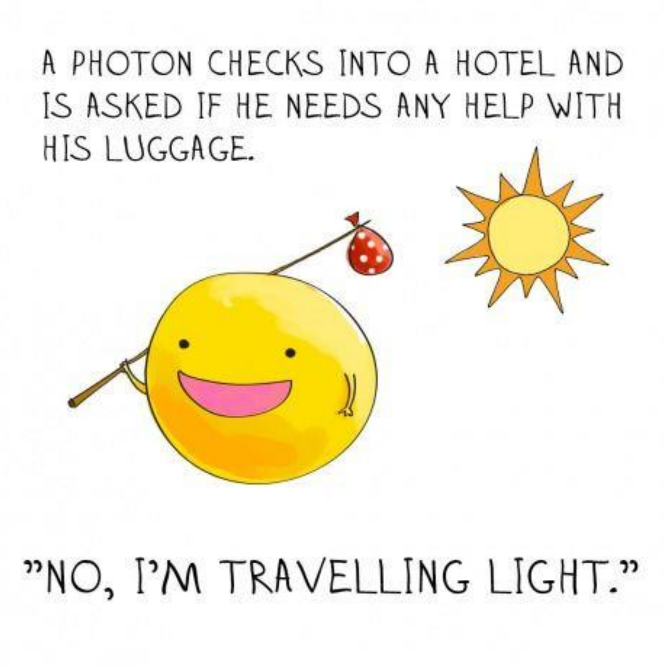
CHEMISTRY 40S

The Alchemist's Cookbook

UNIT 5 – ATOMIC STRUCTURE



"Ohhhhhhh . . . Look at that, Schuster . . . Dogs are so cute when they try to comprehend quantum mechanics."



NAME:______________________________________

It is expected that the activities in this book are completed as they are performed in class. This book will be collected at the end of the unit and a mark will be given.

LET’S GET STARTED!

By the end of this unit, you should be able to:

- ✓ Describe qualitatively and quantitatively, the electromagnetic spectrum of radiation in terms of frequency, wavelength, and energy.
- ✓ Recognize, through direct observation, that elements have unique line spectra.
- ✓ Outline the historical development of the quantum mechanical model of the atom.
- ✓ Write electron configurations for elements of the periodic table.
- ✓ Relate the electron configuration of an element to its valence electron(s) and its position on the periodic table.
- ✓ Identify and account for periodic trends among the properties of elements and relate the properties to electron configuration

This unit will take approximately 10 lessons to complete and will comprise 10% of your mark in this class.

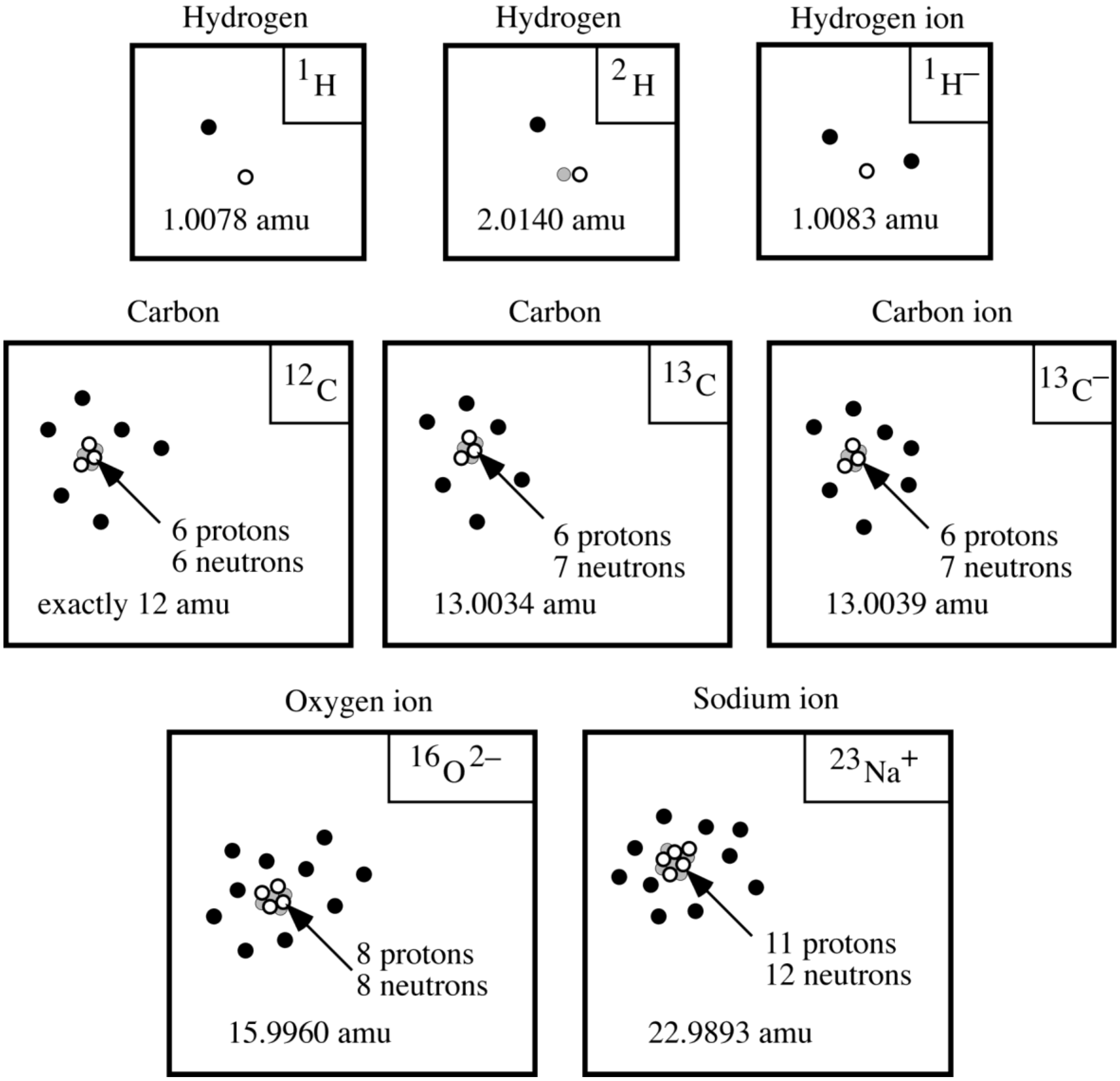
ACTIVITY #1 – DO YOU REMEMBER?

Model #1: Schematic Diagrams for Various Atoms.

● electron (–)
○ proton (+)
◍ neutron (no charge)

1 amu = 1.6606×10^{-24} g

The **nucleus** of an atom contains the protons and the neutrons.



^{1}H and ^{2}H are **isotopes** of hydrogen. ^{12}C and ^{13}C are **isotopes** of carbon.

Use Model 1 on the previous page to answer the following questions:

1. How many protons are found in ^{12}C? ^{13}C? $^{13}C^{-}$?

2. How many neutrons are found in ^{12}C? ^{13}C? $^{13}C^{-}$?

3. How many electrons are found in ^{12}C? ^{13}C? $^{13}C^{-}$?

4. What structural feature distinguishes a neutral atom from an ion?

5. How can you determine the quantity of charge on an ion of an element?

6. What structural feature is different in isotopes of a particular element?

7. How can you determine the number of neutrons in an atom or ion of an element?

8. What is the significance of the atomic number, Z, above each atomic symbol in the periodic table?

Summary:

Complete the following chart.

	^{24}**Mg**	^{23}**Na**$^{+}$	^{35}**Cl**	^{35}**Cl**$^{-}$	^{56}**Fe**$^{3+}$	^{15}**N**	^{16}**O**$^{2-}$	^{27}**Al**$^{3+}$
p^{+}								
n^{o}								
e^{-}								

ACTIVITY #2 – LET'S SHRED SOME WAVES BRO!

Formulas and Constants	
$c = \lambda \nu$	**$E = h \nu$**
λ = wavelength (m) ν = frequency (Hz or s^{-1}) c = speed of light = 3.0×10^8 m/s	E = energy of photon (Joules) h = 6.626×10^{-34} J·s ν = frequency (Hz or s^{-1})

Use the information above to answer the following questions

1. List all the forms of electromagnetic radiation from lowest to highest energy.

2. An FM radio station has a frequency of 88.9 MHz [1 MegaHertz (MHz) = 10^6 Hertz (Hz), or cycles per second (s^{-1})]. What is the wavelength of this radiation in meters?

3. The U.S. Navy has a system for communicating with submerged submarines. The system uses radio waves with a frequency of 76 s^{-1}. What is the wavelength of this radiation in meters? In km?

4. Violet light has a wavelength of about 410 nm (1 meter = 10^9 nanometers)
    a. What is its frequency?
    b. Calculate the energy of one photon of violet light.
    c. What is the energy of 1.0 mol of violet photons?

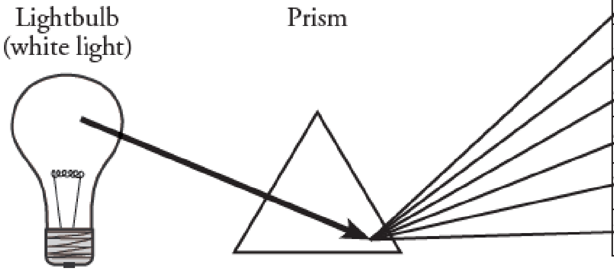
5. The energy of a mole of photons of red light from a laser is 175 kJ/mol.
    a. Calculate the energy of one quanta (photon) of red light.
    b. What is the wavelength of red light in meters? In nm?
    c. Compare the energy of quanta (photons) of violet light from #4 with those of red light. Which is more energetic?

ACTIVITY #3 – LET THERE BE LIGHT!

Why?

From fireworks to stars, the color of light is useful in finding out what's in matter. The emission of light by hydrogen and other atoms has played a key role in understanding the electronic structure of atoms. Trace materials, such as evidence from a crime scene, lead in paint or mercury in drinking water, can be identified by heating or burning the materials and examining the color(s) of light given off in the form of bright-line spectra.

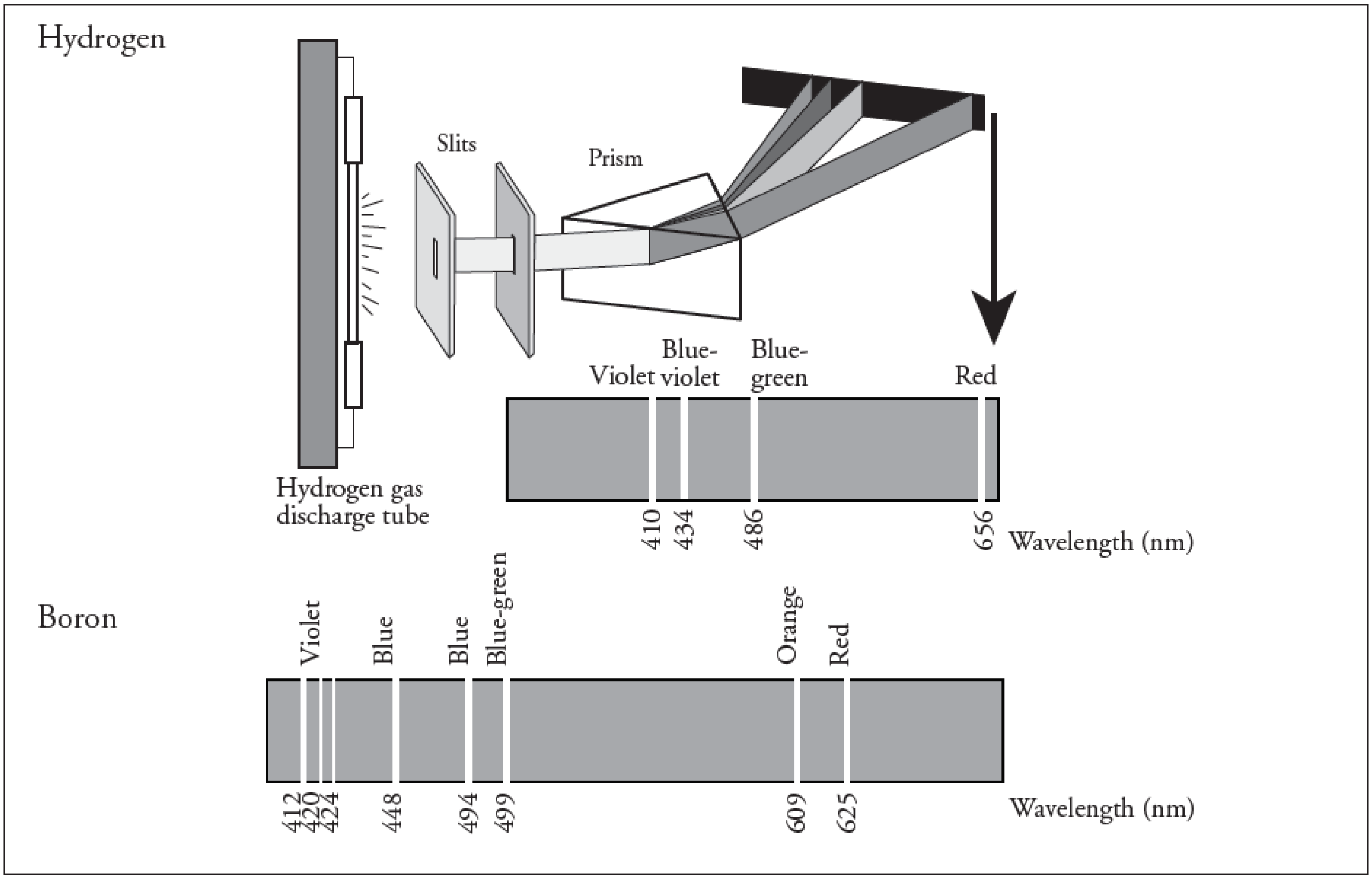
Model 1 – White Light



Color	Photon Energy $(\times 10^{-21})$ (J)	Wavelength Range (nm)	Speed (m/s)
Reds	269–318	625–740	3.00×10^8
Oranges	318–337	590–625	3.00×10^8
Yellows	337–352	565–590	3.00×10^8
Greens	352–382	520–565	3.00×10^8
Blues	382–452	440–520	3.00×10^8
Violets	452–523	380–440	3.00×10^8

1. Trace the arrows in Model 1 and shade in the table with colored pencils where appropriate.
2. What happens to white light when it passes through a prism?
3. Why are the color labels in the table in Model 1 plural (*i.e.,* "Reds" rather than "Red")?
4. Do all colors of light travel at the same speed?
5. Do all colors of light have the same energy? If no, which colors have the highest energy and the least energy, respectively?
6. Consider the light illustrated in Model 1.
    a. Which color corresponds to the longest wavelengths?
    b. Which color corresponds to the shortest wavelengths?
    c. Write a sentence that describes the relationship between wavelength and energy of light.

Model 2 – Emission Spectra for Hydrogen and Boron Atoms



7. Use colored pencils to color the hydrogen and boron spectral lines within their respective spectra in Model 2.
8. List the spectral lines for hydrogen gas by color and corresponding wavelength.
9. The spectral lines for boron were produced using the same method as hydrogen. List three of the colors and corresponding wavelengths for boron's spectral lines as its light passes through a prism.
10. Consider the hydrogen spectrum in Model 2.
    a. Which color of light corresponds to the shortest wavelength?
    b. Which color of light corresponds to the longest wavelength?

11. Consider the hydrogen spectrum in Model 2.
    a. Which color of light has the most energy?

    b. Which color of light has the least energy?

12. Does a gas discharge tube filled with boron emit the same wavelengths of light as a tube filled with hydrogen? Use evidence from Model 2 to support your answer.

13. "The spectral lines for atoms are like fingerprints for humans." How do the spectral lines for hydrogen and boron support this statement?

Circle the appropriate word to complete each statement in Questions 14–17.

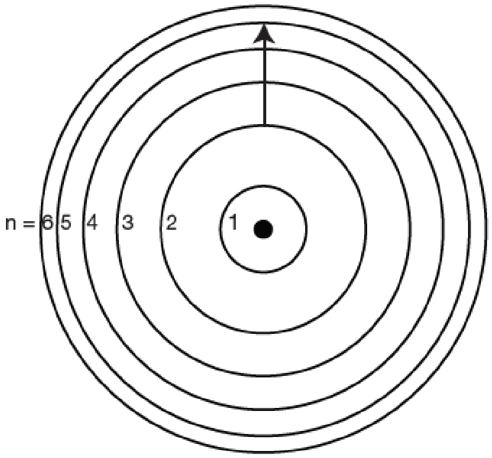
14. Electrons and protons (attract/repel) each other.
15. As an electron gets closer to the nucleus the (attraction/repulsion) to the nucleus gets (stronger/weaker).
16. For an electron to move from an energy level close to the nucleus to an energy level far from the nucleus it would need to (gain/lose) energy.
17. For an electron to move from an energy level far from the nucleus to an energy level close to the nucleus it would need to (gain/lose) energy.

STOP

Read This!

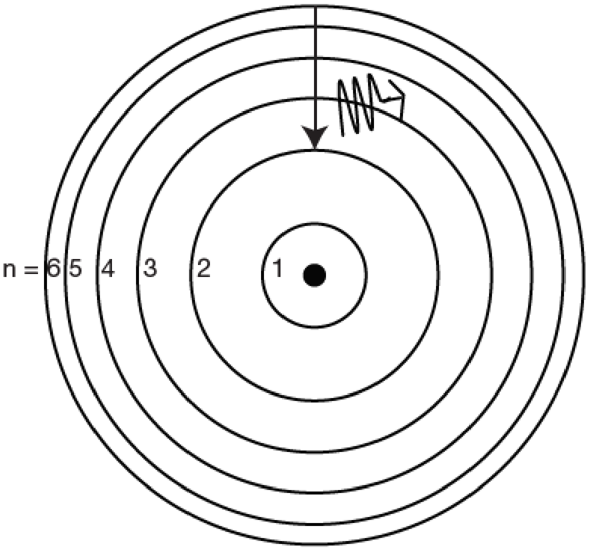
Niels Bohr modified Rutherford's Nuclear Atom model to explain how light interacted with the electrons in an atom to produce spectral lines. His model included electrons orbiting the nucleus at specific energy levels. Electrons absorb energy from various sources (electricity) when they move from lower energy levels (ground state) to higher energy levels (excited states). Energy is released as electrons return to their lower energy levels.

18. Is energy absorbed or released for the electron transition shown in the diagram to the right? Explain.

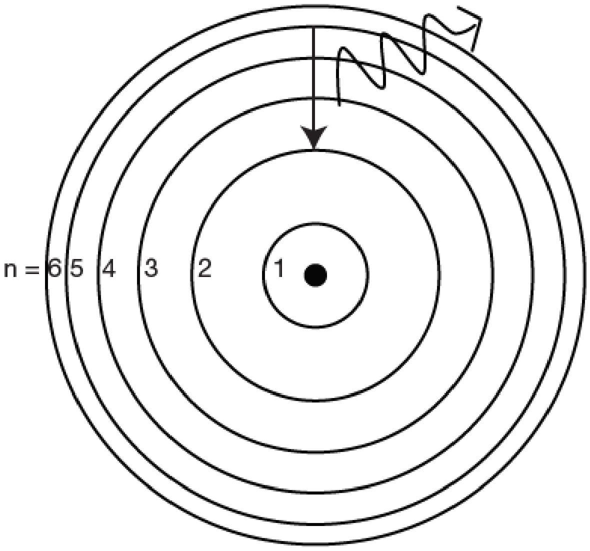


Model 3 – Bohr Model of a Hydrogen Atom

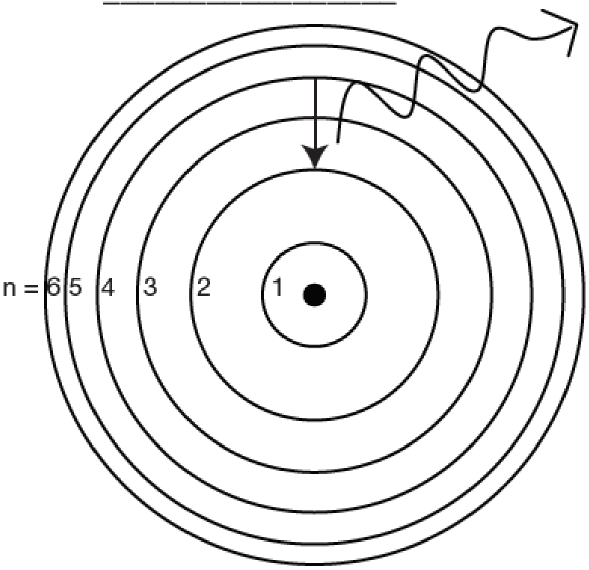
A. ________________



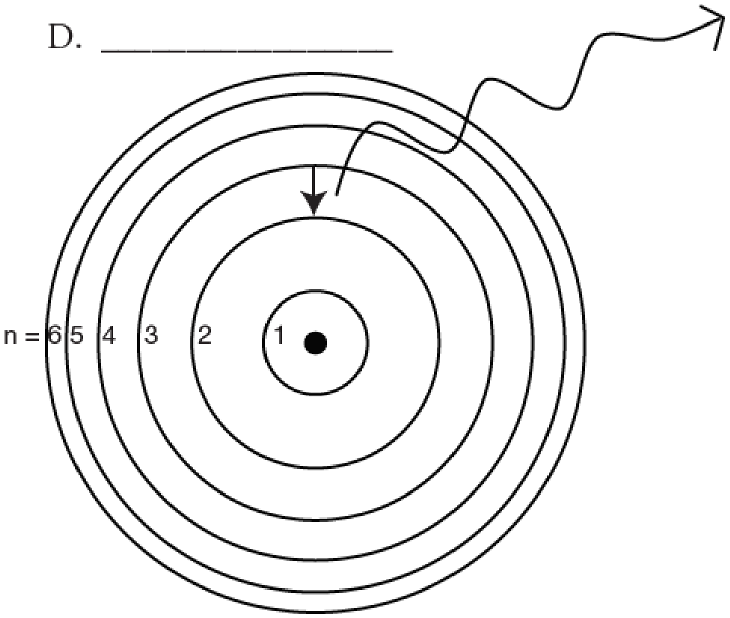
B. ________________



C. ________________



D. ________________



19. Identify the drawing in Model 3 that depicts a hydrogen atom with an electron moving from energy level 5 to energy level 2. Refer to Models 1 and 2 for the following questions.
    - *a.* Label the picture with "n=5 to n=2" and list the corresponding color of light emitted.
    - *b.* This electron transition (absorbs/releases) energy.
    - *c.* This electron moves from a (lower/higher) energy state to a (lower/higher) energy state.
    - *d.* Is light absorbed or released in the electron transition?

20. Label the remaining drawings in Model 3 with the electron transitions that are occurring (n=? to n=?), the wavelengths, and the corresponding colors as given in example A in Model 3. See Model 2 in order to identify the color of spectral lines produced in each of the hydrogen atom electron transitions shown in Model 3. Use colored pencils to trace the light wave in each of the four pictures with the appropriate color.

21. Consider the electron transitions in Model 3.

    a. Which of the electron transitions involves the most energy?

    b. Explain why this transition involves the most energy based on your understanding of the attractive forces between the electrons and protons in the atom.

22. Explain why a single atom of hydrogen cannot produce all four hydrogen spectral lines simultaneously.

23. If Question 22 is true, how can we see all four colors from a hydrogen gas discharge tube simultaneously?

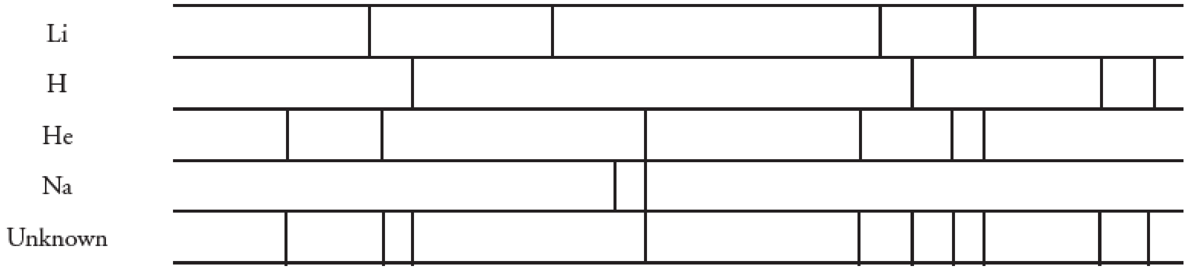
Extension Questions

24. The hydrogen spectral lines in Model 2 are only the wavelengths of light that are in the visible range and therefore "seen" by the naked eye. However, many other wavelengths can be detected with special equipment.

    a. Propose a hydrogen electron transition that involves light with a wavelength in the ultraviolet (UV) range (10–400 nm).

    b. Propose a hydrogen electron transition that involves light with a wavelength in the infrared (IR) range (1000–106 nm).

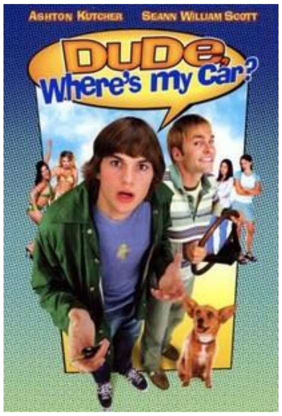
25. Below are diagrams for the bright line spectra of four elements and the spectrum of a mixture of unknown gases.



    a. Which element(s) are not present in the Unknown?

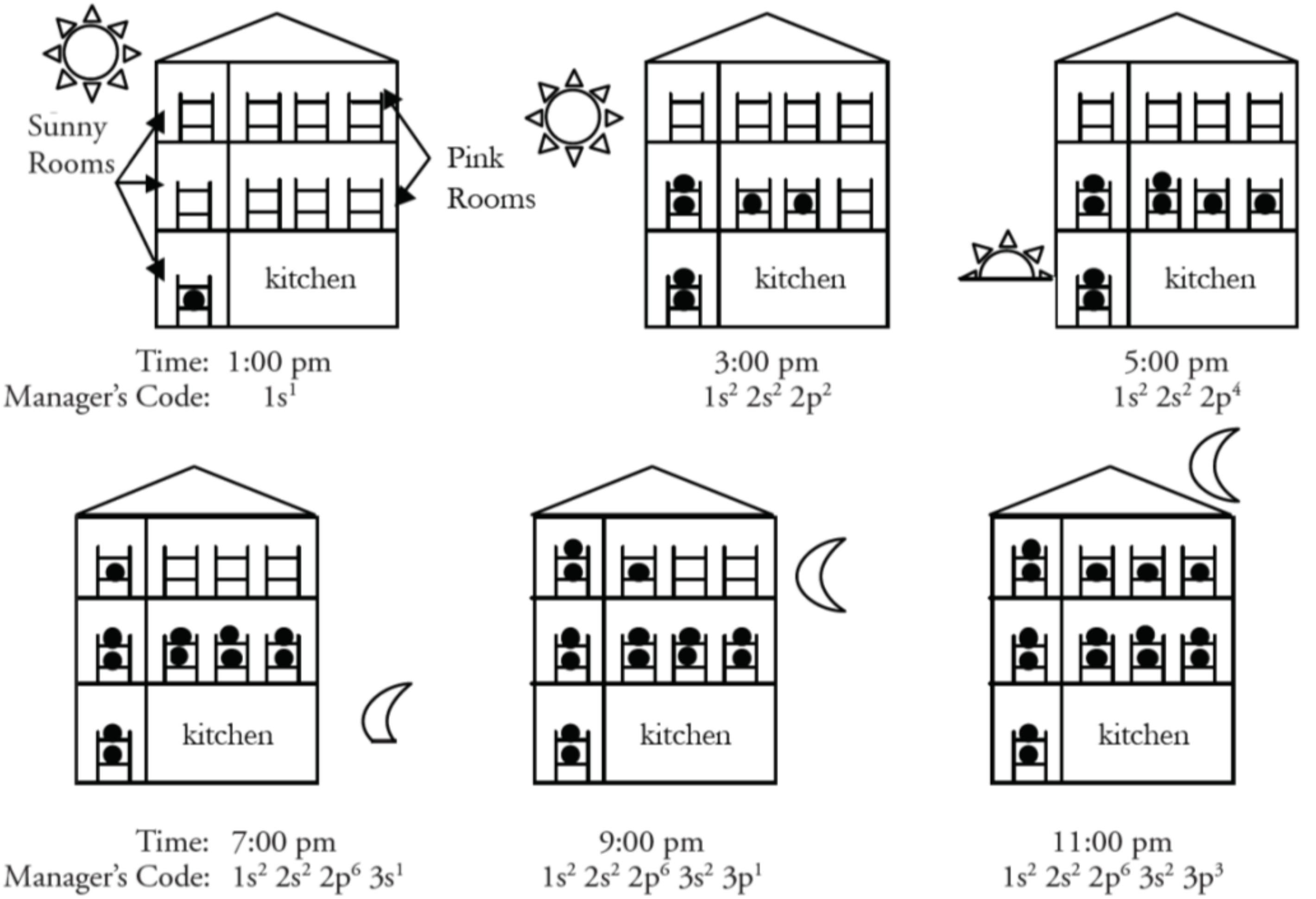
    b. Which element(s) are in the Unknown?

ACTIVITY #4 – DUDE…WHERE'S MY ELECTRON?



The electron structure of an atom is very important. Scientists use the electron structures of atoms to predict bonding in molecules, the charges the atom might have, and the physical properties of elements. For scientists to describe the electronic structure of atoms, they give the electrons "addresses" similar to your home address. In this activity, you will learn how to determine the probable location of electrons in an atom and how to communicate that information.

Model 1 – The Boarding House



Time: 1:00 pm
Manager's Code: $1s^1$

3:00 pm
$1s^2\ 2s^2\ 2p^2$

5:00 pm
$1s^2\ 2s^2\ 2p^4$

Time: 7:00 pm
Manager's Code: $1s^2\ 2s^2\ 2p^6\ 3s^1$

9:00 pm
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

11:00 pm
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

1. Examine the boarding house diagrams in Model 1. Match each symbol below with its most likely meaning.

_____*a.* ●

_____*b.* 

_____*c.* $1s^2\ 2s^2\ 2p^6\ 3s^1$

I. Bunk bed for boarders

II. Manager's code for the number of boarders in the house and their room assignments.

III. Boarder

2. Refer to Model 1.

   a. How many boarders were in the boarding house at 5:00 pm?

   b. Describe how you determined your answer to part *a*.

3. Examine each diagram in Model 1 and the corresponding manager's code. Using the following manager's code:

$$1s^2 \quad 2s^2 \quad 2p^4$$

   a. Underline the floor numbers.

   b. Circle the types of rooms.

   c. Draw a box around the numbers of boarders.

4. The manager of the boarding house has some very strict rules on how beds will be rented out for the night. Examine the diagrams in Model 1 and the statements below to determine the phrase that best describes the manager's set of rules. Circle the correct answer.

   a. The boarding house will rent out beds on the _______ floor first.

   1st 2nd 3rd

   b. Boarders are only allowed to double up in a bunk in a room when ____________________.

   there is an even number of boarders in the room all bottom bunks are occupied

   c. The next floor of rooms will be opened for boarders only when _____________________ on the floor below are occupied.

   half of the bunks at least one of the rooms all of the bunks

   d. The pink room on a floor will be opened for boarders only when ____________________.

   all of the lower bunks in the sunny room on that floor are occupied

   all of the bunks in the sunny room on that floor are occupied

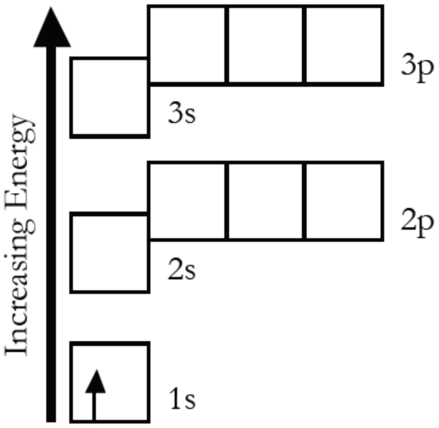
   the sunny room on that floor is open

5. Provide (a) the manager's code and (b) a boarding house diagram showing 12 boarders present.

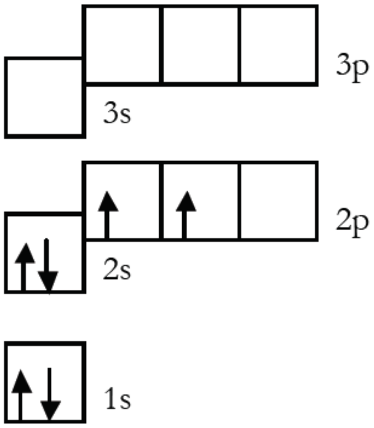
   a.

   b.

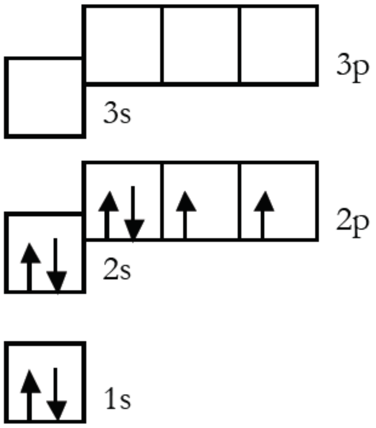
Model 2 – Ground State Orbital Diagrams and Electron Configurations



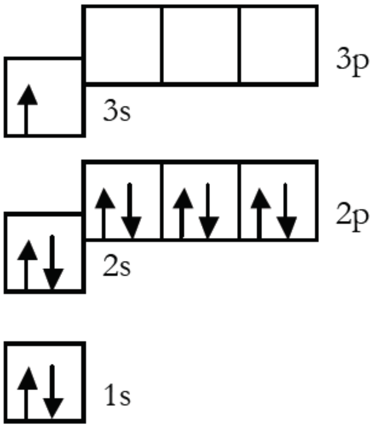
Hydrogen
$1s^1$



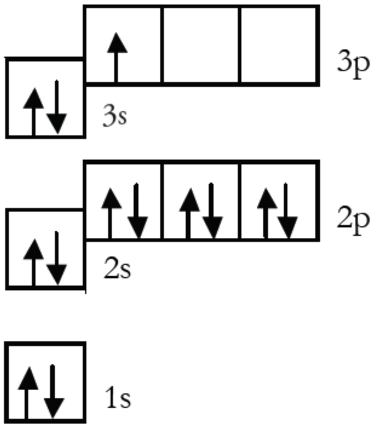
Carbon
$1s^2\ 2s^2\ 2p^2$



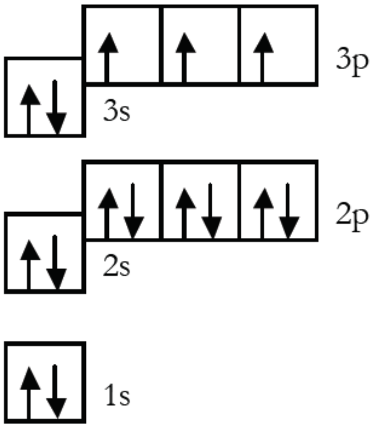
Oxygen
$1s^2\ 2s^2\ 2p^4$



Sodium
$1s^2\ 2s^2\ 2p^6\ 3s^1$



Aluminum
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$



Phosphorus
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

6. Examine the orbital diagrams and electron configurations in Model 2. Match each symbol below with its meaning.

_____*a.* ☐ I. Single electron
_____*b.* ↑ II. Pair of electrons with opposite spins
_____*c.* ↑↓ III. Atomic orbital (region of space where an electron is likely to be found)
_____*d.* ☐☐☐ IV. Sublevel (set of orbitals having equivalent energy)
_____*e.* $1s^2\ 2s^2\ 2p^4$ V. Electron configuration

7. Consider the orbital diagram for oxygen in Model 2.

   a. How many electrons are present in the orbital diagram?

   b. Based on its position in the periodic table, explain how you know that your answer to part *a* is the *correct* number of electrons for oxygen.

8. Examine the orbital diagrams and electron configurations in Model 2. Using the following electron configuration:

$$1s^2 \quad 2s^2 \quad 2p^4$$

   a. Underline the energy levels.

   b. Circle the sublevels.

   c. Draw a box around the numbers of electrons.

9. The 2s and 2p sublevels are very close in energy, as are the 3s and 3p sublevels. Explain how the orbital diagram for sodium confirms that the 3s sublevel is lower in energy than the 3p sublevel.

10. The lowest potential energy arrangement of electrons in an atom is called the **ground state**. Ground state electron configurations can be predicted by a strict set of rules known as the **Aufbau principle** ("aufbau"means filling up). Examine the diagrams in Model 2 and the statements below to determine the phrase that best describes each rule. Circle the correct answer.

   a. Based on where a single electron is placed, the lowest potential energy electron in an atom is found in the ________ sublevel.

   1s 2s 3s

   b. Electrons will occupy a p-orbital only after ____________ .

   the previous s-orbital is half full

   the previous s-orbital is completely full

   the previous s-orbital is empty

   c. Electrons can begin to occupy energy levels with the next highest integer designation (e.g., 2 vs. 1, 3 vs. 2) only after __________________ on the energy level below it are occupied.

   half of the orbitals at least one of the orbitals all of the orbitals

11. The **Pauli exclusion principle** describes the restriction on the placement of electrons into the same orbital. The Pauli exclusion principle can be expressed as: “If two electrons occupy the same orbital, they must have ____________________.” Circle the correct answer.

    the same spin   opposite spins

12. **Hund’s rule** describes how electrons are distributed among orbitals of the same sublevel when there is more than one way to distribute them. Hund’s rule consists of two important ideas. Based on Model 2, circle the correct answer to each statement.

    a. Electrons will pair up in an orbital only when ____________________

    there is an even number of electrons in the sublevel

    all orbitals in the same sublevel have one electron

    b. When single electrons occupy different orbitals of the same sublevel, ____________________.

    they all have the same spin

    they all have different spins

    their spins are random

13. For each of the symbols below from Model 2, provide the name or description of the analogous component that was used in the boarding house model (Model 1).

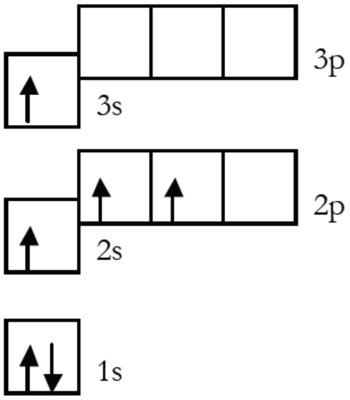
    a.

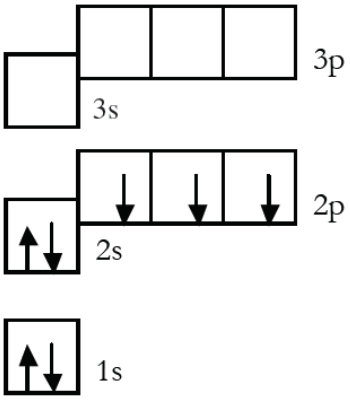
□	
□□□	
↑	
↑↓	
$1s^2\ 2s^2\ 2p^4$	

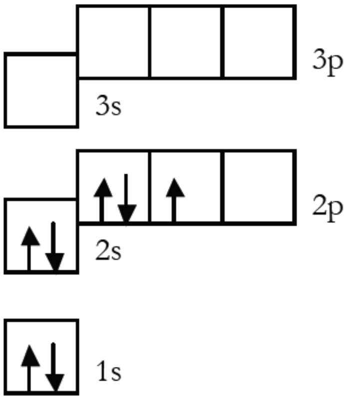
b. What characteristic of electrons is *not* well represented by the boarding house model?

c. How could the boarding house model be modified to better represent the relative energies of s and p sublevels?

14. Below are three answers generated by students in response to the prompt: “Provide an orbital energy level diagram for the ground state of a nitrogen atom.” In each case, indicate whether the answer is right or wrong, and if it is wrong, explain the error.



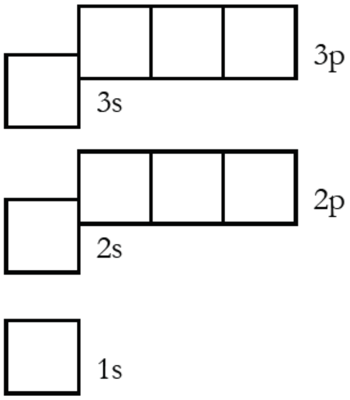




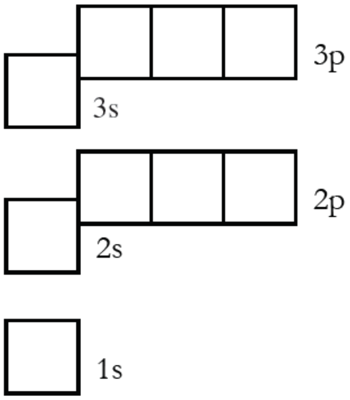
a.	b.	c.

15. Complete the ground state orbital energy level diagrams and write the corresponding electron configurations for:

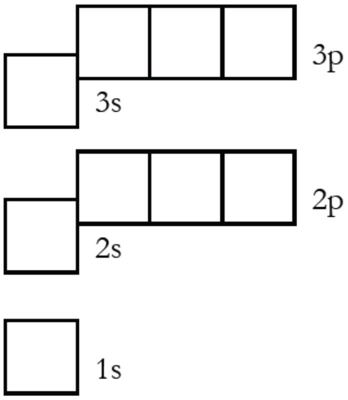
Sulfur



Silicon



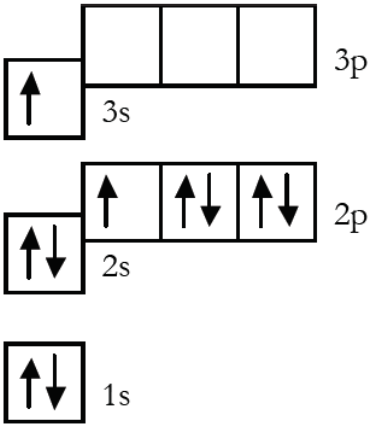
Neon



Sulfur	Silicon	Neon

Extension Questions

Model 3 – Orbital Diagram for an Atom of Element X



16. Consider the orbital diagram in Model 3.

    a. How many electrons are there in one atom of element X?

    b. Identify element X and provide its ground state electron configuration. Assume the atom is neutral.

    c. Is the arrangement of electrons in the orbital diagram in Model 3 higher in total potential energy or lower in total potential energy than the ground state electron configuration of element X? Explain your reasoning.

Read This!

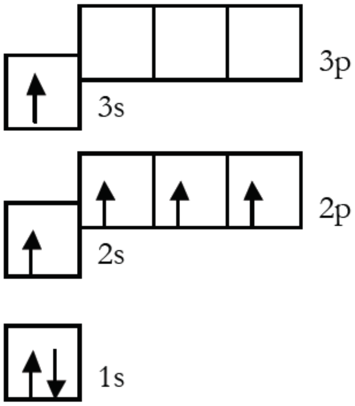
An **excited state electron configuration** is *any* electron configuration for an atom that contains the correct total number of electrons but has a higher total electron potential energy than the ground state electron configuration.

---

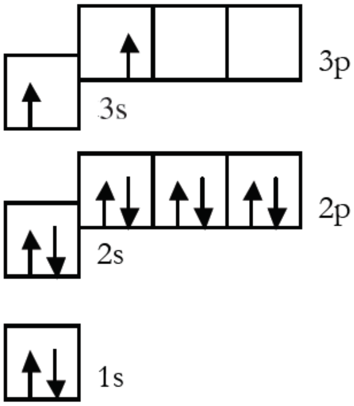
17. Write an electron configuration for element X that shows the atom in a different excited state than the one illustrated in Model 3.

18. Each orbital diagram shown below describes an excited state of an atom of a *different* element. Use the orbital diagrams to complete the table.

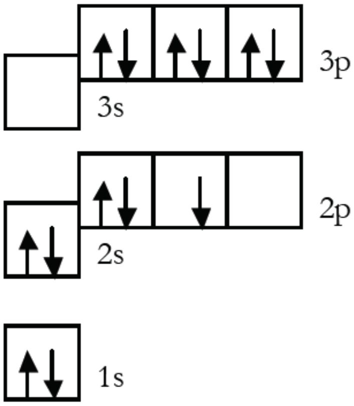
A



B



C

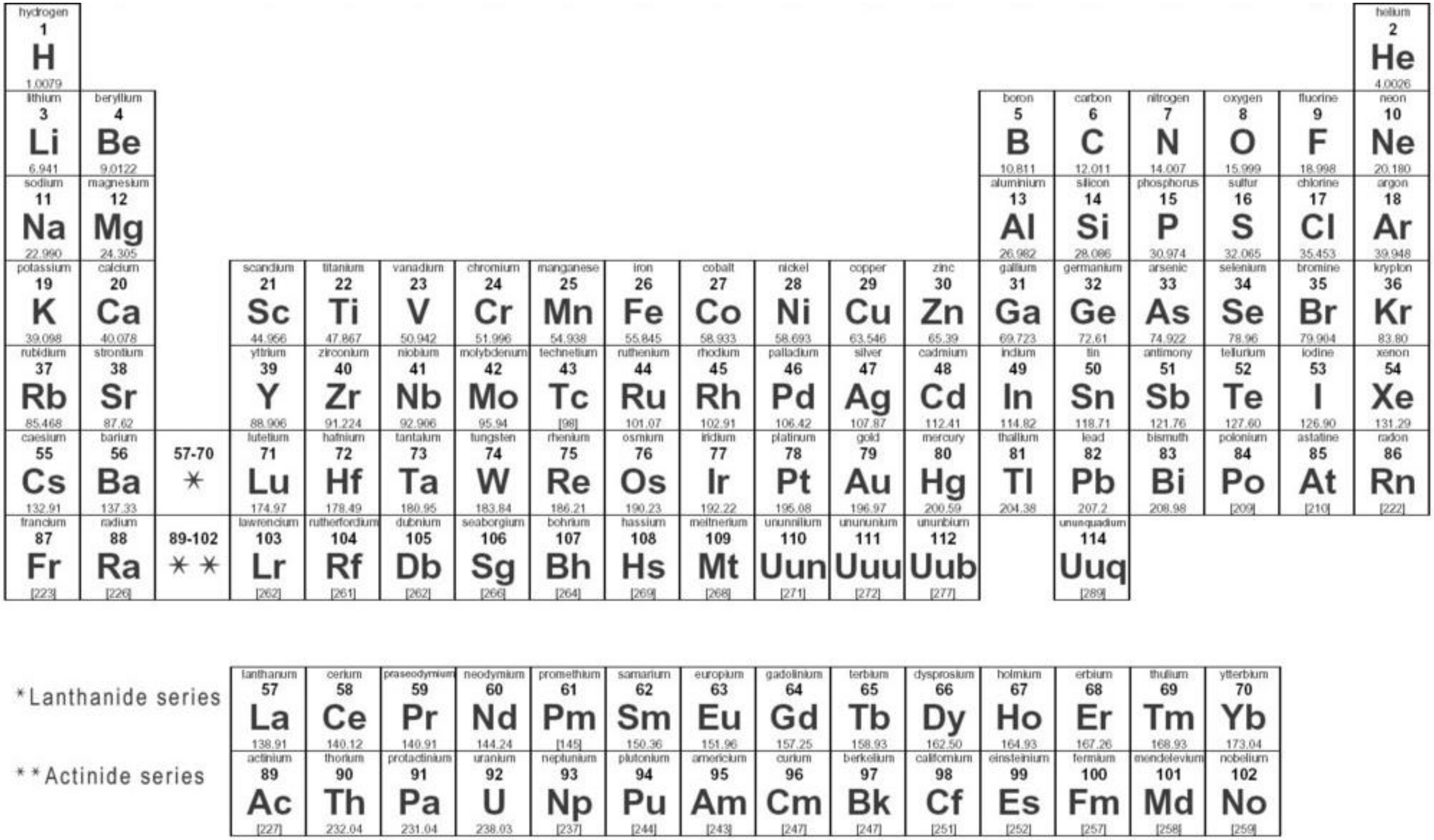


	A	**B**	**C**
Excited state electron configuration			
Identify the element			
Ground state electron configuration			

19. Complete the table for each of the excited state electron configurations given.

Excited state electron configuration	**Element name**	**Ground state electron configuration**	**Orbital diagram for ground state**
$1s^2\ 2s^1\ 2p^2$			
$1s^2\ 2s^2\ 2p^2\ 3s^2\ 3p^1$			

ACTIVITY #5 – ELECTRON CONFIGURATION BATTLESHIP!



hydrogen 1 H 1.0079																		helium 2 He 4.0026
lithium 3 Li 6.941	beryllium 4 Be 9.0122												boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305												aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078		scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80
rubidium 37 Rb 85.468	strontium 38 Sr 87.62		yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]		ununquadium 114 Uuq [289]				

*Lanthanide series	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
* *Actinide series	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

ACTIVITY #6 – ELECTRON CONFIGURATIONS - SUBLEVEL NOTATION PRACTICE

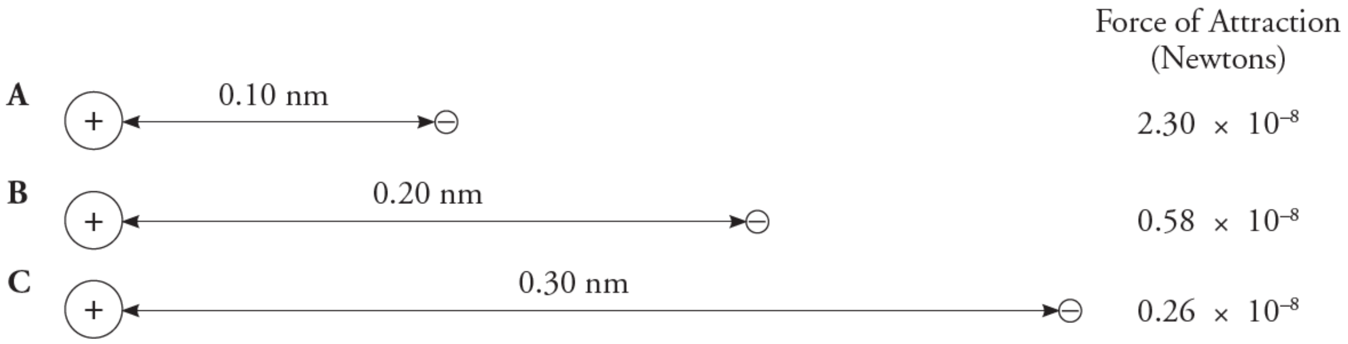
Element	Electron Configuration – Long Form	Electron Configuration – Noble Gas Form	# and location of valence electrons	Most common ion formed
Magnesium				
Nickel				
Potassium				
Cobalt				
Chlorine				
Phosphorus				
Manganese				
Calcium				
Lead				

ACTIVITY #7 – OPPOSITES ATTRACT…GETTING TO KNOW COULOMB'S LAW

Why?

Coulombic attraction is the attraction between oppositely charged particles. For example, the protons in the nucleus of an atom have attraction for the electrons surrounding the nucleus. This is because the protons are positive and the electrons are negative. The attractive force can be weak or strong. In this activity, you will explore the strength of attraction between protons and electrons in various atomic structures.

Model 1 – Distance and Attractive Force



1. What subatomic particles do these symbols represent in Model 1?

   ⊕ ⊖

2. Would you expect to observe attraction or repulsion between the subatomic particles in Model 1?

3. Consider the data in Model 1.

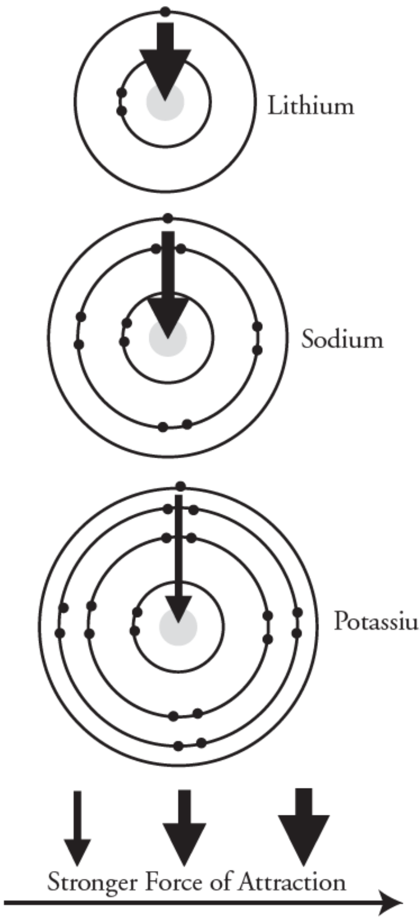
   a. What are the independent and dependent variables in the data?

   b. Write a complete sentence that describes the observed relationship between the independent and dependent variables in Model 1.

4. If the distance between a proton and electron is 0.50 nm, would you expect the force of attraction to be greater than or less than 0.26×10^{-8} N?

5. If two protons are 0.10 nm away from one electron, would you expect the force of attraction to be greater than or less than 2.30×10^{-8} N?

Model 2 – The Alkali Metals



6. Consider the diagrams in Model 2.
   a. What do the arrows represent?

   b. How does the thickness of the arrows relate to the property given in part *a*?

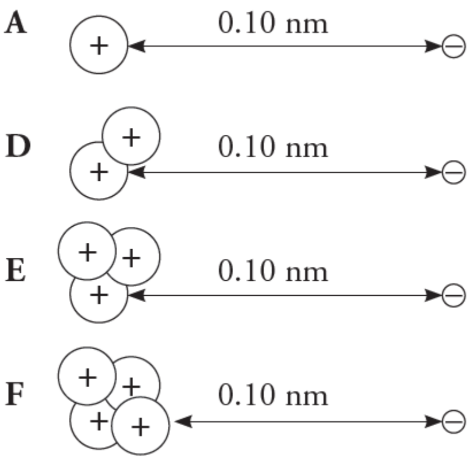
7. Using a periodic table, locate the elements whose atoms are diagrammed in Model 2. Are the elements in the same column or the same row?

8. Circle the outermost electron in each of the diagrams in Model 2.
   a. As you move from the smallest atom to the largest atom in Model 2, how does the distance between the outermost electron and the nucleus change?

   b. As you move from the smallest atom to the largest atom in Model 2, how does the attractive force between the outermost electron and the nucleus change?

   c. Are your answers to parts *a* and *b* consistent with the information in Model 1?

Model 3 – Number of Protons and Attractive Force



	Force of Attraction (Newtons)
A	2.30×10^{-8}
D	4.60×10^{-8}
E	6.90×10^{-8}
F	9.20×10^{-8}

9. Consider the data in Model 3.

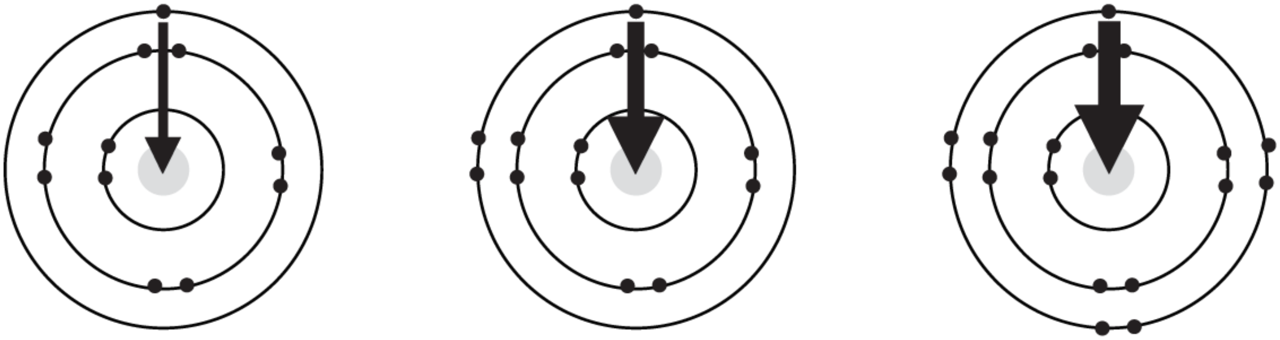
   a. What are the independent and dependent variables in the data?

   b. Write a complete sentence that describes the relationship between the independent and dependent variables in Model 3.

10. What would be the attractive force on a single electron if five protons were in the nucleus of an atom? Show mathematical work to support your answer.

11. Imagine that a second electron were placed to the left of a nucleus containing two protons (Model 3, set D). Predict the force of attraction on both the original electron and the second electron. Explain your prediction with a complete sentence.

Model 4 – Period 3 Elements



Sodium Aluminum Chlorine

13. Using the periodic table, locate the elements whose atoms are diagrammed in Model 4. Are the elements in the same column or the same row?

14. Circle the outermost electron(s) in each of the atoms in Model 4.

15. Which of the three atoms diagrammed in Model 4 has the strongest attraction for its outermost electron(s)?

16. Consider the information in Model 4.

    a. As you move from the smallest atom to the largest atom, does the distance between the outermost electron(s) and the nucleus change significantly?

    b. Can the differences in the attractive force shown by the arrows be explained by a change in the distance between the electron(s) and the nucleus?

    c. On the diagrams in Model 4, write the number of protons located in the nucleus of each atom.

    d. Can the differences in attractive forces shown by the arrows in Model 4 be explained by a change in the number of protons in the nucleus? If yes, explain the relationship in Model 4.

17. For each set of elements below, circle the element whose atoms will have a stronger attractive force between their outermost electron(s) and the nucleus.

    a. Ba and Ca *b.* Cr and Cu *c.* Ar and Xe

ACTIVITY #8 – THE PERIODIC TABLE IS PRETTY TRENDY

Pre-Lab

In this investigation you will examine several periodic trends, including atomic radius, ionization energy. You will be asked to interact with select atoms as you investigate these concepts.

1. Draw a picture to support a written definition of the word "radius."

2. Assuming atoms are shaped like spheres, what subatomic particles would be found in the center? What subatomic particles would be found around the perimeter?

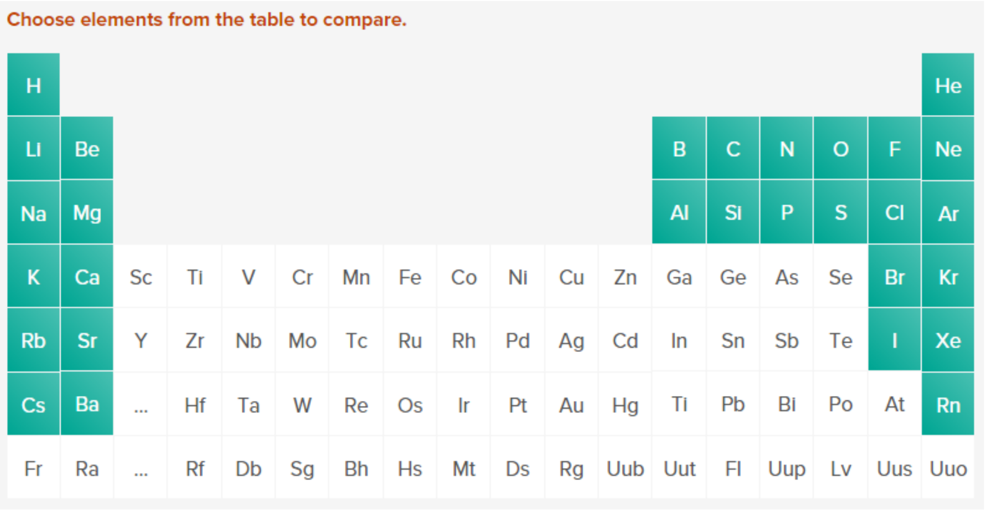
3. Keeping in mind your answers to questions 1 & 2, in your own words describe the meaning of "atomic radius"

4. What is an ion? What is a valence electron? How is an ion formed?

5. What do you think *ionization energy* means? Think about this in relation to your answer to question #4.

Procedure

Using your computer, tablet or mobile device, navigate to the website: http://www.teachchemistry.org/periodic-trends. You should see the picture below on your screen.

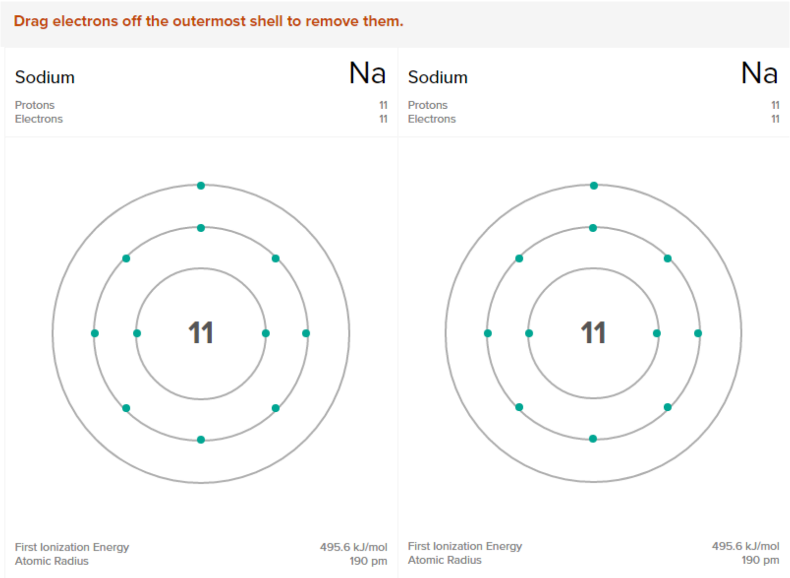


Choose elements from the table to compare.

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	Fl	Uup	Lv	Uus	Uuo

PART 1 - Atomic Radius

1. Choose any element shown in green from ***group 1*** on periodic table clicking the on the element symbol. You should see details about the element that you chose appear at the bottom of the screen. An example is shown below.



Drag electrons off the outermost shell to remove them.

Sodium	Na	Sodium	Na
Protons	11	Protons	11
Electrons	11	Electrons	11
First Ionization Energy	495.6 kJ/mol	First Ionization Energy	495.6 kJ/mol
Atomic Radius	190 pm	Atomic Radius	190 pm

   a. Select another element from **group 1** clicking on its symbol. Write the symbols and atomic number for each of the elements that you chose below:

b. Which element appears larger in the side-by-side comparison?

c. What is the value in picometers (pm) for the radius of each atom? Do these values support your answer for part b?

↻ ***Reset the selected data using the reset symbol.***

d. Next, choose an element from a **different group** by clicking on its symbol. Again choose a second element to compare from the same group. Write the symbols and atomic number for each of the elements that you chose below:

e. Which element appears larger in the side-by-side comparison?

f. What is the value in picometers (pm) for the radius of each atom? Do these values support your answer for part e?

g. Based on your answers in question 1 parts a-f, what is the general trend in the atomic radius of atoms **within the same group**? Give suggestions for why you think this trend exists based on your interaction with the elements.

2. Choose any element from ***period 2*** on the periodic table by clicking on the element symbol. You should see details about the element that you chose appear at the bottom of the screen.

    a. Select another element from the ***period 2*** by clicking on its symbol. Write the symbols and atomic number for each of the elements that you chose below:

    b. Which element appears larger in the side-by-side comparison?

    c. What is the value in picometers (pm) for the radius of each atom? Do these values support your answer for part b?

    d. Do your answers in part b & c surprise you? Explain.

↻ ***Reset the selected data using the reset symbol.***

    e. Choose an element from a different **period** by clicking on its symbol. Again choose a second element to compare from the same period. Write the symbols and atomic number for each of the elements that you chose below:

    f. Which element appears larger in the side-by-side comparison?

    g. What is the value in picometers (pm) for the radius of each atom? Do these values support your answer for part e?

h. Based on your answers in question 2 parts a-g, what is the general trend in the atomic radius of atoms *within the same period*?

i. Think about the possible *contributing factors to* the atomic radius trend within a period, specifically considering the protons in the nucleus, the electrons and the electron shells. List them below:

↻ ***Reset the selected data using the reset symbol.***

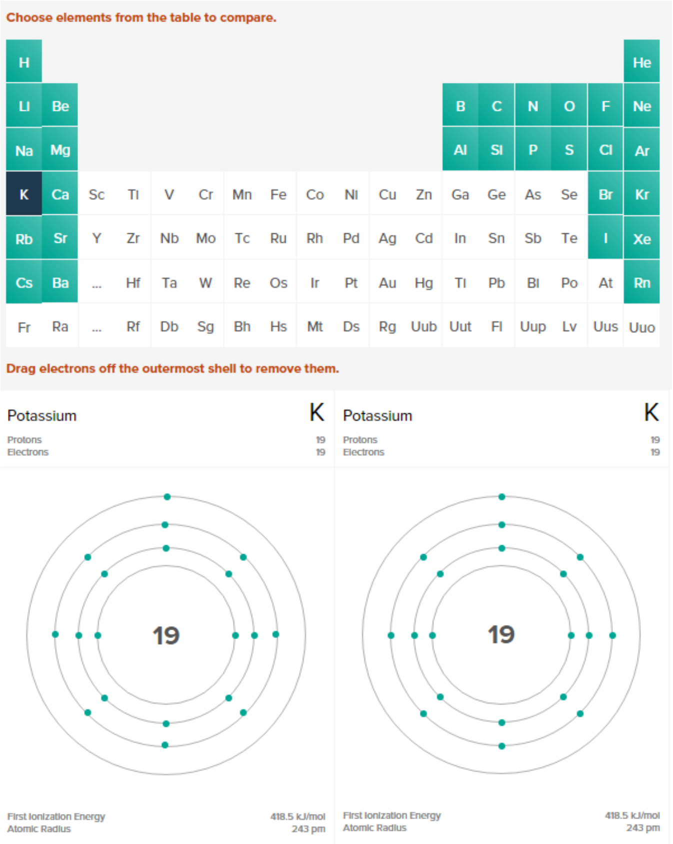
3. Based on what you have learned, and without the assistance of the periodic trends simulation, predict which element is larger in the following pairs of atoms:

   a. Be *or* Sr
   b. P *or* Ar
   c. Rb *or* S
   d. F *or* He
   e. Br *or* Ca
   f. Xe *or* Ba

Using the simulation, check your predicted answers to see if you are correct!

PART 2: Ionization energy

4. Choose an element from the ***Alkali Metal family*** (group 1) by clicking on the element symbol. You should see details about the element that you chose appear at the bottom of the screen. An example is shown below.



Choose elements from the table to compare.

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	Fl	Uup	Lv	Uus	Uuo

Drag electrons off the outermost shell to remove them.

Potassium	K	Potassium	K
Protons	19	Protons	19
Electrons	19	Electrons	19
First Ionization Energy	418.5 kJ/mol	First Ionization Energy	418.5 kJ/mol
Atomic Radius	243 pm	Atomic Radius	243 pm

a. Using your cursor attempt to ionize the atom that you chose by pulling a valence electron from the electron shell. Describe what happened. (Were you successful? Was it “easy” to remove the electron? Did the atom seem to have a strong hold on the electron?)

b. What was the ionization energy value for the atom that you chose?

c. Did any other information about the atom change after your attempt to ionize the atom?

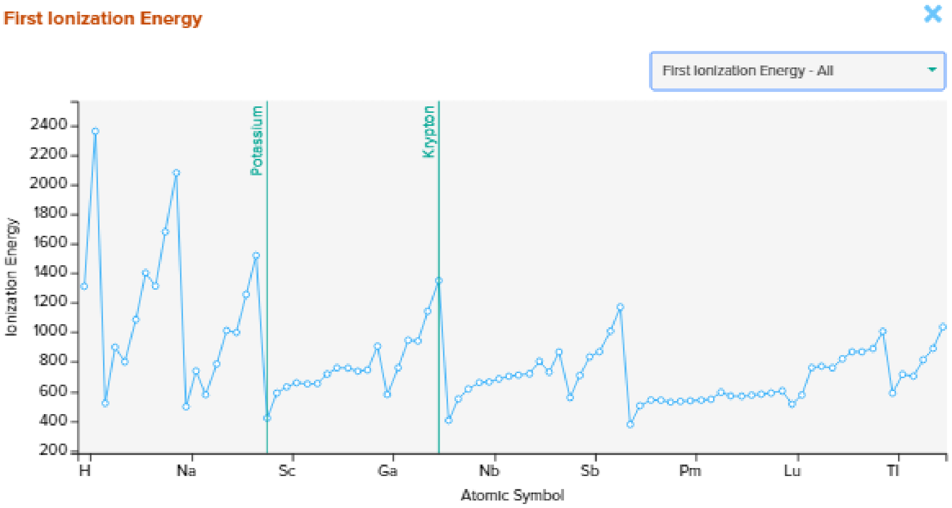
d. Now choose the Noble Gas element that is in the same period as the Alkali metal chosen in part a. Attempt to ionize this atom by pulling a valence electron from the electron shell. Describe what happened. (Were you successful? Was it “easy” to remove the electron? Did the atom seem to have a strong hold on the electron?)

e. What was the ionization energy value for the noble gas atom that you chose?

f. Make a comparison statement about the two elements that you interacted with in terms of why they require different amounts of ionization energy.

g. Next, with the two elements still selected click on the “Go to Graphs” button:

A graph should appear, you will need to ensure the “First Ionization Energy” filter is selected in the top right hand location of the graph, for example:



What trend in ionization energy do you observe for elements in the same period based on the data in the graph?

h. While still analyzing the graph, make a prediction about the trend in ionization energy between atoms in the same **group** on the periodic table. For example, do atoms with larger atomic numbers have greater ionization energy than atoms with small atomic numbers in the **same group**?

↻

Navigate back to the main page, and reset the data using the reset symbol.

i. Now choose two elements that are in the same group. How do their ionization energy values compare? Does this data support your prediction from part h?

5. Based on what you have learned, and without the assistance of the periodic trends simulation, organize the following lists of atoms *from lowest ionization energy to highest ionization energy:*

   a) S, Na, Al, Ar
   b) I, F, Br, Cl
   c) Rb, O, Si, Mg, He

Using the simulation, check your predicted answers to see if you are correct!

Conclusions:

Reflecting on what you have learned about both atomic radius and ionization energy at this point, which of the following statements best describe these trends?

- Atoms that have large atomic radii also have large values of ionization energy.

- Atoms that have small atomic radii will have large values of ionization energy.

Explain your choice referencing ***both*** the atomic model and subatomic particles:

ACTIVITY #9 – UNIT TEST REVIEW

1. Complete the following chart.

Chemical	**Number of Protons**	**Number of Neutrons**	**Number of Electrons**
^{55}Mn			
^{57}Mn			
$^{55}Mn^{2+}$			
$^{57}Mn^{4+}$			
	35	45	35
	35	46	35
	35	45	36

2. List all electromagnetic radiations (EMR) from low energy to high.

3. An FM radio station has a frequency of 88.9 MHz (1 MHz = 10^6 Hz, or cycles per second). What is the wavelength of this radiation in meters?

4. Violet light has a wavelength of about 410 nm. What is its frequency? Calculate the energy of one photon of violet light. What is the energy of 1.0 mol of violet photons?

5. Use the following word bank to fill in the blanks. You may not need to use all of the words:

Continuous spectrum
Uncertainty
Line spectrum
rise
high
location
quanta
quantum
energy levels
wave
low
fall
probability
photons
observing

a) Max Plank suggested that wavelengths of EMR emitted energy, not in a continuous fashion, but in "chunks" or "wave-particles" called _________________.

b) Long wavelengths of EMR have a ______________ frequency. These waves emit __________ energy "chunks".

c) Short wavelengths of EMR have a _____________ frequency. These waves emit __________ energy "chunks".

d) White light, when broken into its wavelengths by a prism, produces a "rainbow" called a _____________________.

e) Bohr noticed that atoms, when heated, produced their own specific wavelengths of light called ____________________. Each atom produces its own unique pattern

f) Bohr tried to explain this phenomenon by suggesting that electrons in atoms must be found in specific __________________. When these electrons __________ from a ___________ energy level to a ______________ energy level, they produce the specific wavelengths of light seen on a line spectrum.

g) Louis DeBroglie advanced Bohr's model by suggesting that electrons in atoms travel in a __________-like fashion.

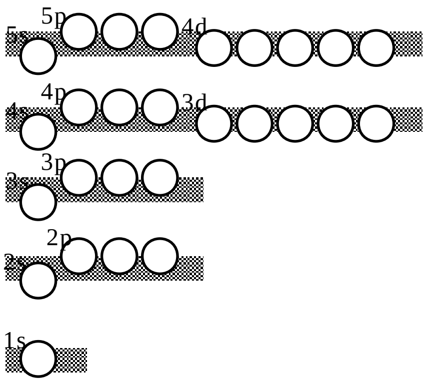
h) Schrödinger used some fancy math to calculate areas of ________________ of finding electrons within energy levels. The numbers used to describe the electrons positions are called _________________ numbers. These areas are also called ________________.

6. What type of orbitals are found in each of the following energy levels of an atom?

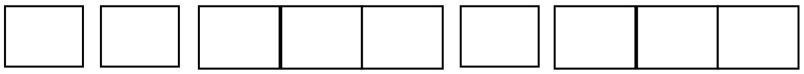
1 = ________ 2 = __________ 3 = ___________ 4 = _____________

7. Complete orbital diagrams for each of the following:

Strontium (Sr)

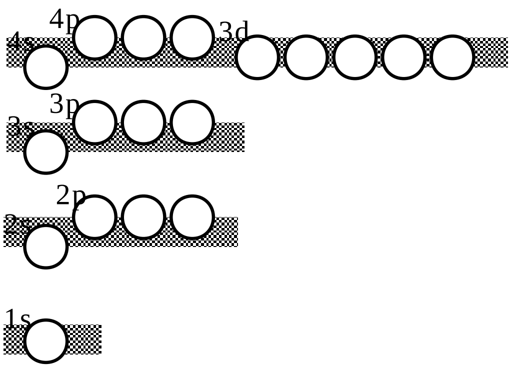


Phosphorus (P)



8. How many electrons in an arsenic, As, atom? ____

9. Draw the orbital diagram for As.

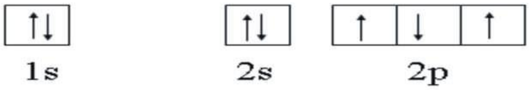


10. Draw a box around those electrons that would be called "valence electrons".

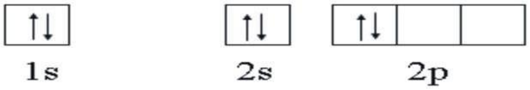
11. How many valence electrons in As? ____

12. Circle the correct orbital diagram. Change the incorrect ones to make them true.

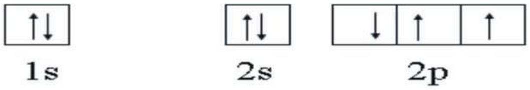
a.



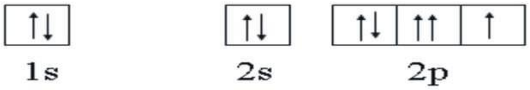
b.



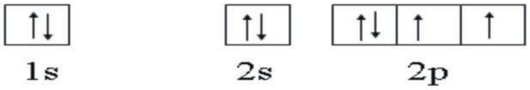
c.



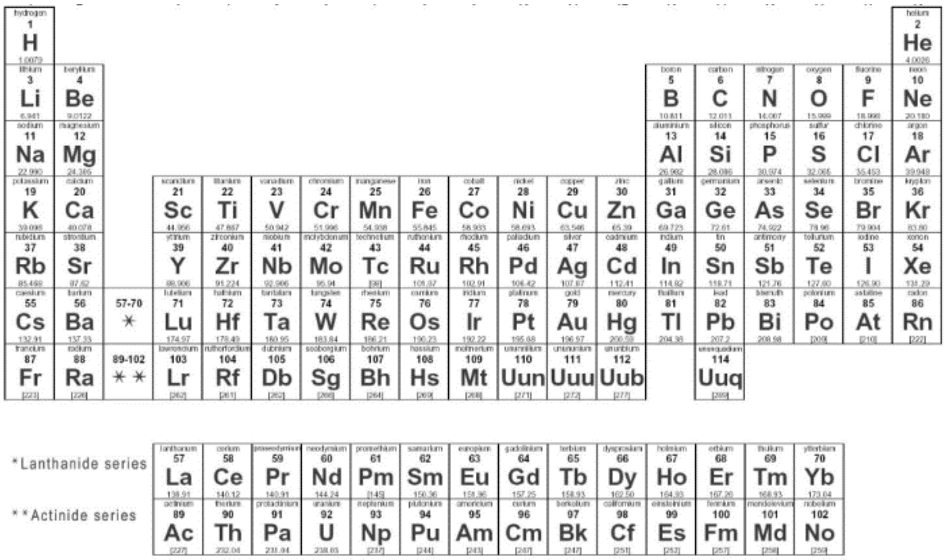
d.



e.



13. Colour/shade and label the s, p, d and f blocks of the periodic table below:



14. How many different variations are there of each of the following orbitals?

s p d f

15. How many electrons can be found in each of the following sub-energy levels?

4s 4p 4d 4f

16. How many elements are in each of the following rows of the periodic table?

4s 4d 4p 4f

17. Write the electron configurations of the following elements using both long and noble gas notation. Circle the valence electrons of each element. Identify the two most magnetic elements and explain why they are.

a) phosphorus

b) nickel

c) osmium

d) californium

e) titanium

18. Complete the following table

TERM	**DEFINITION**	**TREND ON P.T.**	**WHY**
Atomic Radius		→	Across:
		↓	Down:
Ionization Energy		→	Across:
		↓	Down:

19. Arrange the elements S, Ge, P, and Si in order of increasing atomic radius.

20. Arrange the elements Be, Ca, N, and P in order of increasing ionization energy.

21. Use the list of elements below to answer this question:

Sodium, sulphur, calcium, chlorine, argon, potassium

a) Arrange the elements in order of increasing atomic radius.

b) Arrange the elements in order of decreasing ionization energy.

c) Potassium is <u>more reactive</u> than sodium. Use your knowledge of atomic structure and periodic trends to explain why this is.

d) Calcium is <u>less reactive</u> than potassium. Use your knowledge of atomic structure and periodic trends to explain why this is.

Periodic Chart of Ions

Table of Polyatomic Ions

acetate	CH_3COO^-	dichromate	$Cr_2O_7^{2-}$	dihydrogen phosphate	$H_2PO_4^-$
ammonium	NH_4^+	cyanide	CN^-	silicate	SiO_3^{2-}
benzoate	$C_6H_5COO^-$	hydroxide	OH^-	sulphate	SO_4^{2-}
borate	BO_3^{3-}	iodate	IO_3^-	sulphite	SO_3^{2-}
carbonate	CO_3^{2-}	nitrate	NO_3^-	hydrogen sulphide	HS^-
hydrogen carbonate	HCO_3^-	nitrite	NO_2^-	hydrogen sulphate	HSO_4^-
chlorate	ClO_3^-	oxalate	$OOCCOO^{2-}$	hydrogen sulphite	HSO_3^-
hypochlorite	ClO^-	permanganate	MnO_4^-	thiocyanate	SCN^-
chromate	CrO_4^{2-}	phosphate	PO_4^{3-}	thiosulphate	$S_2O_3^{2-}$
		hydrogen phosphate	HPO_4^{2-}		

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H^+ hydrogen																	2 He helium
3 Li^+ lithium	4 Be^{2+} Beryllium											5 B boron	6 C carbon	7 N^{3-} nitride	8 O^{2-} oxide	9 F^- fluoride	10 Ne neon
11 Na^+ sodium	12 Mg^{2+} magnesium											13 Al^{3+} aluminum	14 Si silicon	15 P^{3-} phosphide	16 S^{2-} sulfide	17 Cl^- chloride	18 Ar argon
19 K^+ potassium	20 Ca^{2+} calcium	21 Sc^{3+} scandium	22 Ti^{4+} titanium (IV) Ti^{3+} titanium (III)	23 V^{5+} vanadium (V) V^{4+} vanadium (IV)	24 Cr^{3+} chromium (III) Cr^{2+} chromium (II)	25 Mn^{2+} manganese (II) Mn^{4+} manganese (IV)	26 Fe^{3+} iron (III) Fe^{2+} iron (II)	27 Co^{2+} cobalt (II) Co^{3+} cobalt (III)	28 Ni^{2+} nickel (II) Ni^{3+} nickel (III)	29 Cu^{2+} copper (II) Cu^+ copper (I)	30 Zn^{2+} zinc	31 Ga^{3+} gallium	32 Ge^{4+} germanium	33 As^{3-} arsenide	34 Se^{2-} selenide	35 Br^- bromide	36 Kr krypton
37 Rb^+ rubidium	38 Sr^{2+} strontium	39 Y^{3+} yttrium	40 Zr^{4+} zirconium	41 Nb^{5+} niobium (V) Nb^{3+} niobium (III)	42 Mo^{6+} molybdenum	43 Tc^{7+} technetium	44 Ru^{3+} ruthenium (III) Ru^{4+} ruthenium (IV)	45 Rh^{3+} rhodium	46 Pd^{2+} paladium (II) Pd^{4+} paladium (IV)	47 Ag^+ silver	48 Cd^{2+} cadmium	49 In^{3+} indium	50 Sn^{4+} tin (IV) Sn^{2+} tin (II)	51 Sb^{3+} antimony (III) Sb^{5+} antimony (V)	52 Te^{2-} telluride	53 I^- iodide	54 Xe xenon
55 Cs^+ cesium	56 Ba^{2+} barium	57 La^{3+} lanthanum	72 Hf^{4+} hafnium	73 Ta^{5+} tantalum	74 W^{6+} tungsten	75 Re^{7+} rhenium	76 Os^{4+} osmium	77 Ir^{4+} iridium	78 Pt^{4+} platinum (IV) Pt^{2+} platinum (II)	79 Au^{3+} gold (III) Au^+ gold (I)	80 Hg^{2+} mercury (II) Hg^+ mercury (I)	81 Tl^+ thallium (I) Tl^{3+} thallium (III)	82 Pb^{2+} lead (II) Pb^{4+} lead (IV)	83 Bi^{3+} bismuth (III) Bi^{5+} bismuth (V)	84 Po^{2+} polonium (II) Po^{4+} polonium (IV)	85 At^- astatide	86 Rn radon
87 Fr^+ francium	88 Ra^{2+} radium	89 Ac^{3+} actinium															

KEY

atomic number →	26		
	Fe^{3+}	←	ion charge
	iron (III)	←	stock name (IUPAC)
symbol →	Fe^{2+}		
	iron (II)		

58 Ce^{3+} cerium	59 Pr^{3+} praseodymium	60 Nd^{3+} neodymium	61 Pm^{3+} promethium	62 Sm^{3+} samarium (III) Sm^{2+} samium(II)	63 Eu^{3+} europium (III) Eu^{2+} europium(II)	64 Gd^{3+} gadolinium	65 Tb^{3+} terbium	66 Dy^{3+} dysprosium	67 Ho^{3+} holmium	68 Er^{3+} erbium	69 Tm^{3+} thulium	70 Yb^{3+} ytterbium (III) Yb^{2+} ytterbium (II)	71 Lu lutetium
90 Th^{4+} thorium	91 Pa^{5+} protactinium (V) Pa^{4+} protactinium(IV)	92 U^{6+} uranium (VI) U^{4+} uranium (IV)	93 Np^{5+} neptunium	94 Pu^{4+} plutonium (IV) Pu^{6+} plutonium (VI)	95 Am^{3+} americium (III) Am^{4+} americium (IV)	96 Cm^{3+} curium	97 Bk^{3+} berkelium (III) Bk^{4+} berkelium (IV)	98 Cf^{3+} californium	99 Es^{3+} einsteinium	100 Fm^{3+} fermium	101 Md^{2+} mendelevium(II) Md^{3+} mendelevium (III)	102 No^{2+} nobelium (II) No^{3+} nobelium (III)	103 Gd^{3+} lawrencium

PERIODIC TABLE OF THE ELEMENTS

14	Atomic Number
Si	Symbol
Silicon	Name
28.1	Atomic Mass

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4	63 **Eu** Europium 152.0	64 **Gd** Gadolinium 157.3	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0	71 **Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.