<u>STUDY GUIDE</u> - *Ch.2.2 - An element's properties depend on the structure of its atoms.* **NAME: ____________________**

- **<u>PHYSICALLY PRINT OUT</u> this PDF and <u>HANDWRITE</u> (with a black or blue pen) your answers directly on this PDF.** *Typed or digitally-written work is **<u>not</u>** be accepted. Do **<u>not</u>** answer questions on separate paper.*
- **Importantly, study guides are <u>NOT GROUP PROJECTS</u>!!!** *You, and you alone, are to answer the questions as you **<u>read</u>** your assigned textbook. You are **<u>not</u>** to share answers with other students. You are **<u>not</u>** to copy any answers from any other source, including the internet.*
- **Get in the habit of writing <u>LEGIBLY</u>, neatly, and in a <u>medium-sized font.</u>** *AP essay readers and I will skip grading anything that cannot be easily read so start perfect your handwriting, and don't write so large you can't add all the relevant details and key elaborations in the space provided.*
- **<u>SCAN</u> physical documents in color and with good resolution. Then, upload your final work as <u>PDFs</u> to Archie.** *Avoid uploading dark, shaded, washed out, side ways, or upside down scans of homework. Keep completed physical study guides organized in your biology binder to use as future study and review tools.*
- **<u>READ FOR UNDERSTANDING</u> and not merely to complete an assignment.** ***<u>First</u>**, read a section quickly to get an overview of the topic covered. Then, read it a **<u>second</u>** time slowly, paraphrasing each paragraph **<u>out loud</u>** and analyzing every figure. Finally, read it a **<u>third</u>** time as you answer the study guide questions if assigned and to start building your memory. Try to write answers out in your own words when possible and to purposefully and accurately use all new terminology introduced.*

1. What is an **<u>atom</u>**?

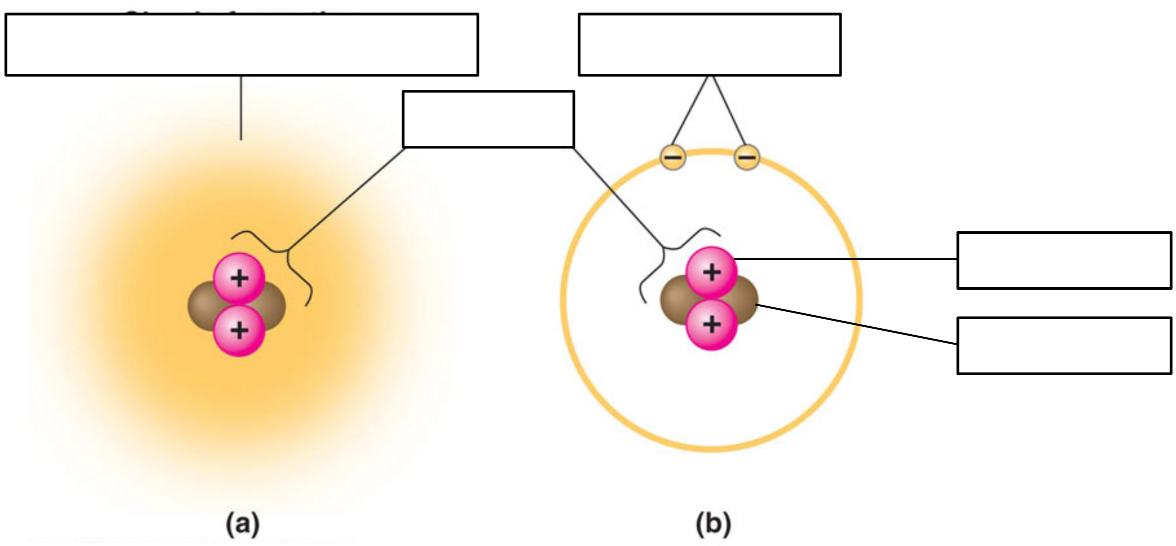
2. a. Three subatomic particles of an atom include the neutron, proton, and electron. How do these differ in terms of **<u>electrical charge</u>**?

   1. **<u>Neutron</u>** =

   2. **<u>Proton</u>** =

   3. **<u>Electron</u>** =

   b. Label the model of a helium atom (He) below, indicating the location of its neutrons, protons, and electrons.

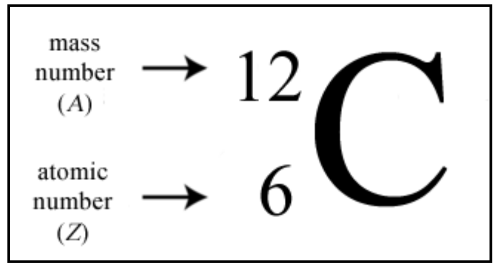


3. **All atoms of the same element share the same number of ______________** *(even if the number of neutrons and electrons may vary from one element to another).*

4. What is an atom's **atomic number (Z)**?

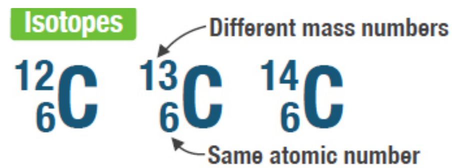
5. **If an atom is neutral in overall net charge**, the charges in the atom cancel each other out when you add up all the positive charges from protons and all the negative charges from electrons. In a neutral atom, what do you know about the **number of electrons that exist in that atom's electron cloud**?

6. What is an individual atom's **mass number (A)**?

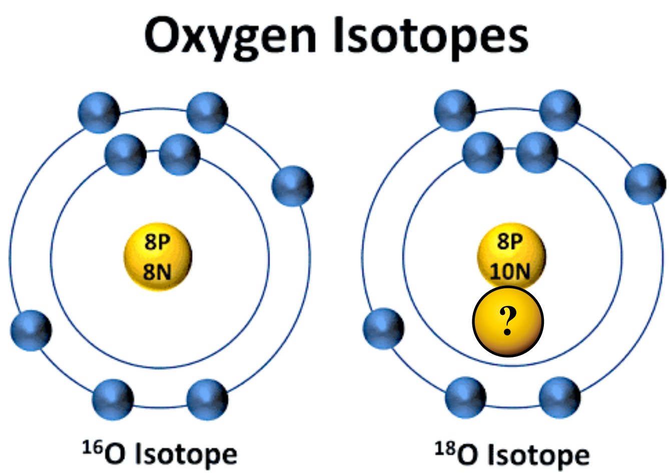


7. If you know an atom's atomic number and mass number, what other information can you determine about this atom?

8. Atoms of an element may come in different forms. What exactly is an **isotope**?



9. a. As you learn from your text, the **element carbon** is composed of atoms of carbon that, though they all have an **atomic number of 6** *(6 protons)*, exist naturally in one of three isotopic forms: C-12, C-13, and C-14. Isotopes of oxygen also exist.



Based on the information provided in the figure above regarding the contents of the electron cloud and the nucleus of isotope O-16, how is the composition of the electron cloud the same **or** different in the isotope O-18?

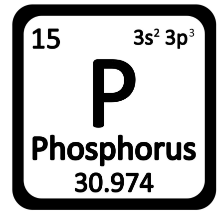
b. Compare and contrast the composition of the nucleus of an O-16 atom with that of an O-18 atom?

Compare *(in what way are the two the same)* =

Contrast *(in what way are the two different)* =

10. **FYI: While the mass number is a count of the total number of protons and neutrons in one atom's nucleus, an element’s atomic mass or atomic weight is the weighted average mass of an atom of that element based on the relative natural abundance of that element's possible isotopes.** For example, the atom carbon-12 has a mass number of 12 daltons or amu (due to it having 6 protons and 6 neutrons, each weighing 1 dalton or 1 amu, electrons having a negligible mass 1/2000 that of a proton or a neutron). Carbon-12 is not the only atom that makes up the element carbon, however. While 98.93% of all carbon atoms are carbon-12, 1.07% of carbon atoms are carbon-13 (with a mass of 13 daltons). An even smaller fraction of carbons are carbon-14. Hence, the atomic mass or atomic weight of the element carbon is actually 12.011 daltons. This value is an average value of the element's mass taking into account the masses and relative abundance of all carbon isotopes in nature.

   a. To the right, find the symbol for phosphorous from the **Periodic Table of Elements** to use as a reference if and as needed. Phosphorus (P) has 23 known isotopes. With only the information obtainable from the image to your right, what is the **mass number of P-32**? *(Remember, numbers are meaningless without proper units!)*



   b. What are the **number of protons** and **number of neutrons** in P-32?

   c. What is the **atomic mass/atomic weight of Carbon**? *(Don’t forget those units!)*

11. What is a **radioactive isotope**?

12. What changes in **how a radioactive isotope of an element behaves in a particular chemical reaction** compared to how a non-radioactive isotope of that same element behaves in that same chemical reactions?

13. Stable, nuclei of nonradioactive isotopes do not change. Over time, though, **the particles in the nuclei of unstable isotopes rearrange in order to gain a more stable configuration. This process is called radioactive decay. During decay, energy is also given off. This energy is called radiation.** The unstable starting isotope is called a parent isotope and this parent isotope decays into a more stable daughter isotope. Daughter isotopes may be atoms of the same element or may even change into atoms of different elements. Because it is unstable, **what happens to the nucleus of Carbon-14 over time**?

14. **Though the type and amount of radiation *(the amount of energy & types of nuclear particles)* emitted by radioactive atoms of certain elements can damage biological molecules like DNA**, **radioactive elements, in low doses, are useful tools in medicine.** Explain why radioactive isotopes can function as effective **tracers** to track chemical processes in the body of organisms?

15. We can use the fact that radioactive isotopes' nuclei decay over time to determine the actual age of rocks surrounding fossils or of fossils themselves found in layers of sedimentary rock. For various types of radioactive isotopes of different elements, scientists have calculated the fixed rate at which a certain quantity of a "parent" isotope decays into its "daughter" isotope. This fixed rate of decay is referred to as the isotope's **half life**. Define this term.

16. What do scientists do when they engage in **radiometric dating** using radioactive isotopes of elements?

17. Read the SCIENTIFIC SKILLS EXERCISE: Calibrating a Standard Radioactive Isotope Decay Curve & Interpreting Data.

    a. What is the **half life of radioactive carbon-14 or ^{14}C**?

    b. Why does the ratio of ^{12}C to ^{14}C **not** change over time *in living* organisms even though some carbon-14, including those C-14 atoms in our cells, is always decaying into nitrogen?

    c. What happens to the ^{12}C **and** to the ^{14}C isotope concentrations after the organism dies?

    ^{12}C concentration after death:

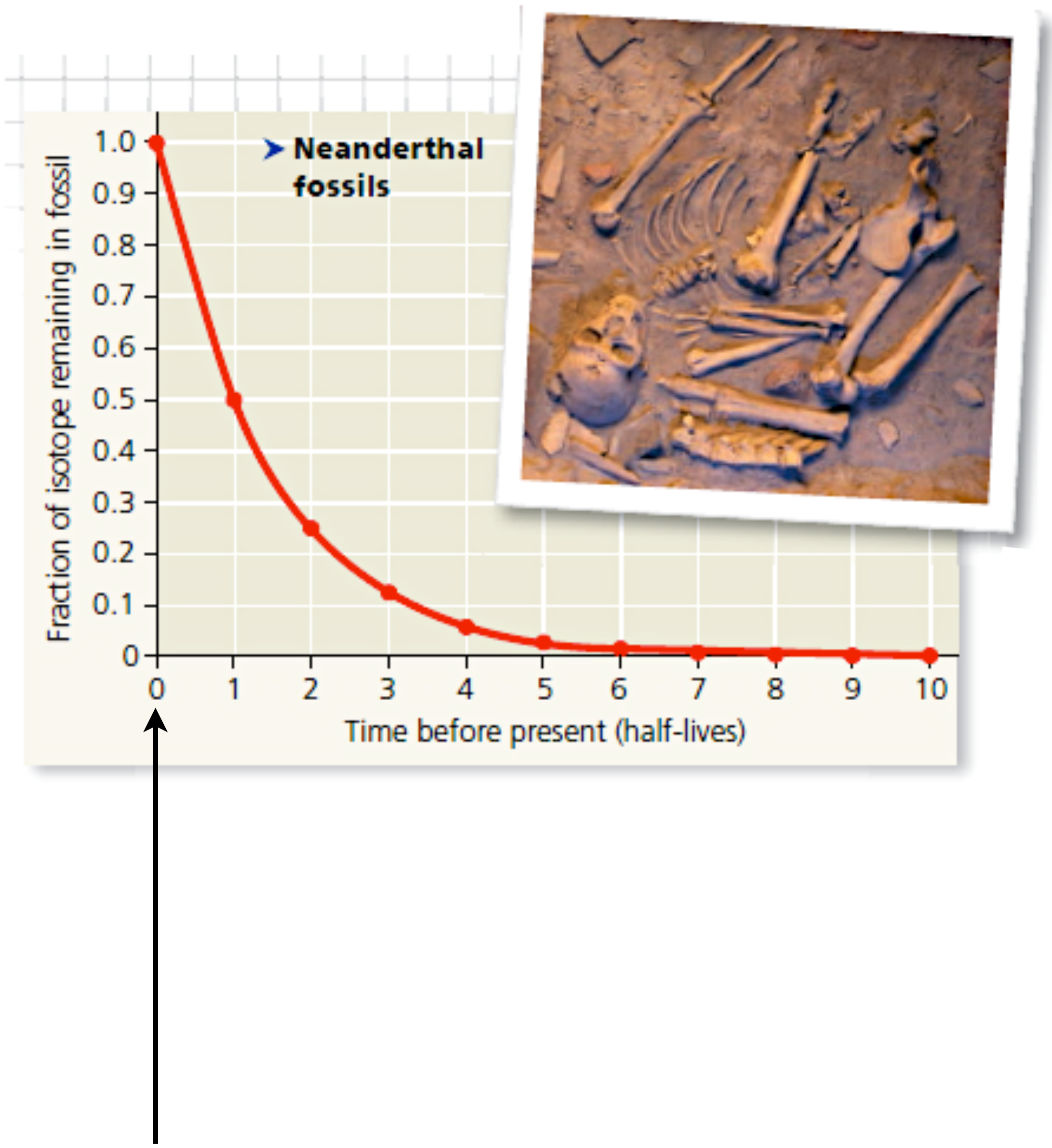
    ^{14}C concentration after death:

    d. Using an understanding of the half life of ^{14}C and the proportion of carbon isotopes in nature, how can scientists use radiometric dating *(which in this case is also sometimes called **carbon dating**)* to calculate the age of a carbon-based fossil?

e. In this skills exercise, a Neanderthal fossil was found that only had a fraction of the ^{14}C in it compared to the original amount of ^{14}C found in the atmosphere and, thus, the original amount of ^{14}C assumed to have been present in the Neanderthal when it was alive. The graph below is a generic graph that can be used to represent any radioactive isotope's decay over time.

1 & 2. On the graph, the x-axis represents the time before present day, with present day being at position 0. For each radioactive isotope, **one half life represents a certain amount of time for 50% of that radioactive isotope to decay.** Recall how many years make up one half life of carbon-14 decay (the answer you gave above). Let's add to the x-axis of this graph the amount of time in years that has passed after each half-life of carbon-14 has been reached.

- Draw a vertical arrow from below the graph pointing to the data point for half-life = 1 and write the fraction (in decimals rounded to three significant figures) of ^{14}C that remains after that amount of half-lives **and** write how many total years have passed after that number of half-lives of ^{14}C have passed. Follow the example for data point 0 half-lives already added to the graph below. Do the same for data points 2-8 half-lives.



^{14}C fraction: 1.00

Total Years Passed: 0

3. Reachers found that the fossil had 0.0078 as much ^{14}C in it as would have been originally present in the atmosphere and, thus, when Neanderthal were alive. Approximate where **0.0078 falls on your y-axis** and, on the graph above, draw a horizontal line from that position on the y-axis that intersects with the red graphed curve. At this point of intersection, now draw a vertical line that runs from your graphed curve down and intersects with your x-axis in order to show how you approximate the number of half-lives that have passed since the Neanderthal died and started loosing ^{14}C due to decay.

   a. Based on your estimation, how many half-lives have passed since the Neanderthal died?

   b. Based on your estimation, what is the approximate age of this fossil in years *(rounded off to the nearest thousand)*. **Always show your calculation work in an organized, logical manner.**

   Researchers cite evidence that modern humans (H. sapiens) established themselves in this region in Europe 39,000-42,000 years ago. It looks like modern humans and Neanderthals both may have coexisted in Europe for a while.

4. **Carbon dating can only be used to date fossils that are up to 75,000 years old**, but not older.

   a. Can C-14 be used to date dinosaur bones, most dinosaurs going extinct 65.5 million years ago? Explain why or why not.

   b. Radioactive Uranium U-235 has a half-life of 704 million years. If it was incorporated into dinosaur bones, could it be used to date the dinosaur fossils? Explain why or why not. *Hint: You may run into a problem using U-235 for dating theses terrestrial dinosaurs, can you figure out why?*

Let's return to the main text in your book again and learn about the Energy levels of Electrons.

18. Of the three subatomic particles discussed above, electrons, protons, neutrons, w**hich are directly involved in chemical reactions between atoms**?

19. a. Define **Energy.**

b. What is **Potential Energy**?

20. Circle, **true** or **false** = **Matter prefers being in the state of lowest possible potential energy.**

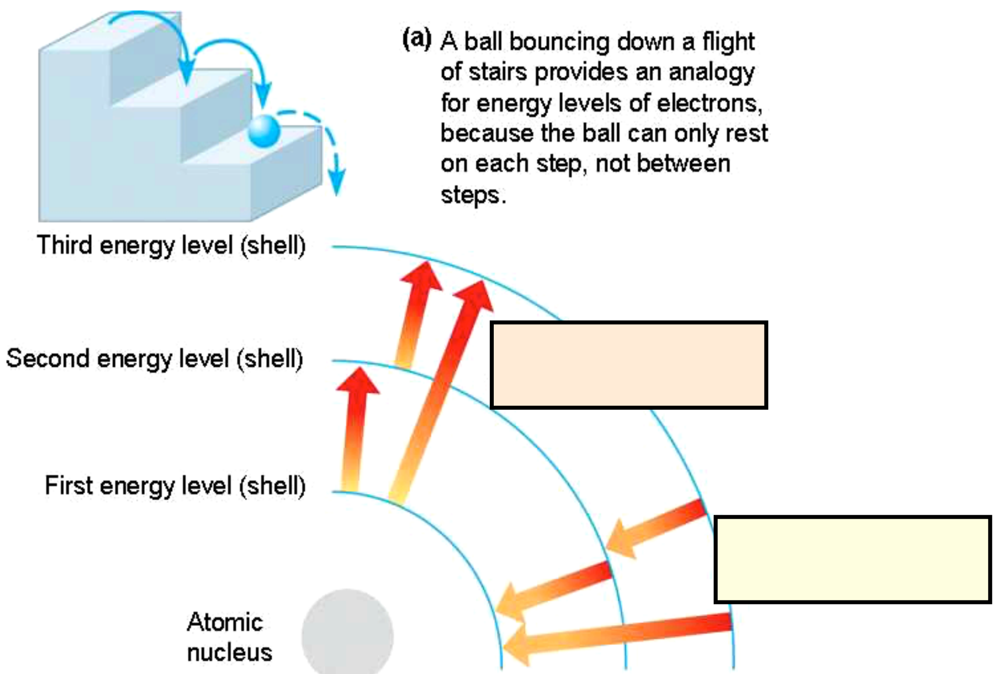
21. Why do **electrons have potential energy**?

22. a. Electrons are found in different ______________________________ in the atom's electron cloud, **each with a characteristic average distance and energy level**.

b. **Electrons in which shell have the lowest amount of potential energy**?

c. How does an **electron move from a lower energy shell to a higher shell and from a higher shell to a lower one**?

23. Fill in the diagram below, highlighting the **movement of electrons among different energy shells** as it relates to the concept of **potential energy**.



(b) An electron can move from one level to another only if the energy it gains or loses is exactly equal to the difference in energy between the two levels. Arrows indicate some of the step-wise changes in potential energy that are possible.

24. Electrons tend to occupy the lowest available state of potential energy in the electron cloud. This means, they occupy the first energy shell first. **How many electrons can the first energy shell of an atom hold**?

25. As the number of protons increase in a neutral atom, so do the number of electrons in the electron cloud. **How many electrons can occupy the second energy shell**?

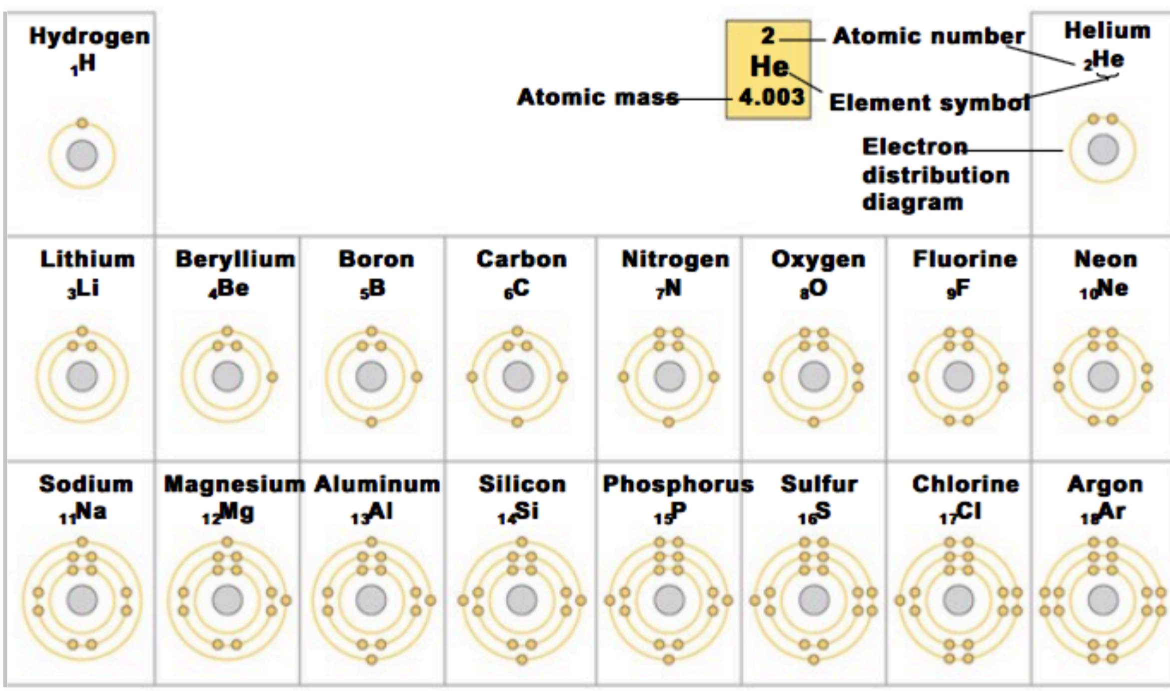
26. a. Which specific electrons in the electron cloud determine the **chemical behavior** of an atom?

    b. What do we call these electrons?

    c. What do we call the electron shell these electrons occupy?

27. Unlike atoms with unfilled valence shells, what is different about an **atom with a fully filled valence shell**?

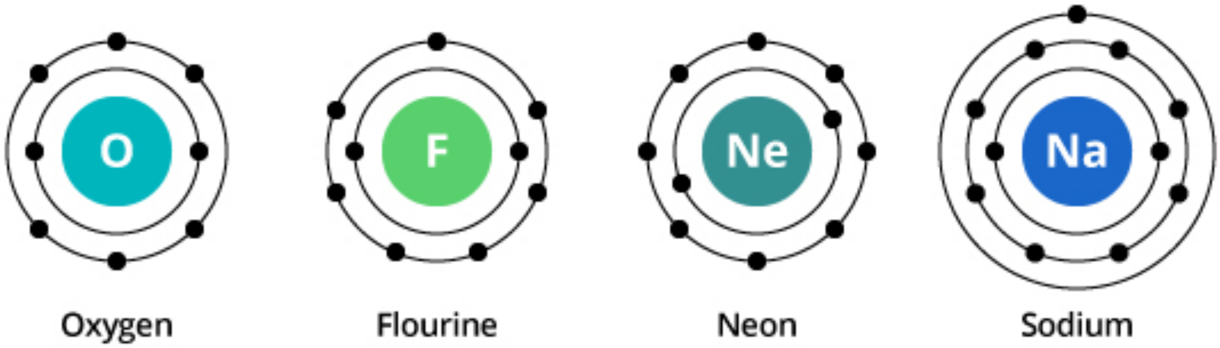
28. a. As you analyze the portion of the Periodic Table of Elements shown below, what do all atoms of the different elements have in common **as you move across a row or across the "period"**?



    b. What do all atoms of the different elements have in common **as you move down a column, or down a "group"**?

*(Check your answers to question 28.a. & b. by going to the Ch.2.2 **Concept Check Question #4** in Appendix A of your textbook)*

29. Here are some **electron distribution diagrams** for various atom. Let's focus on the neutral atom of **sodium** below.



a. How many total electrons does it have?

b. How many protons does it have?

c. How many valence electrons does it have?

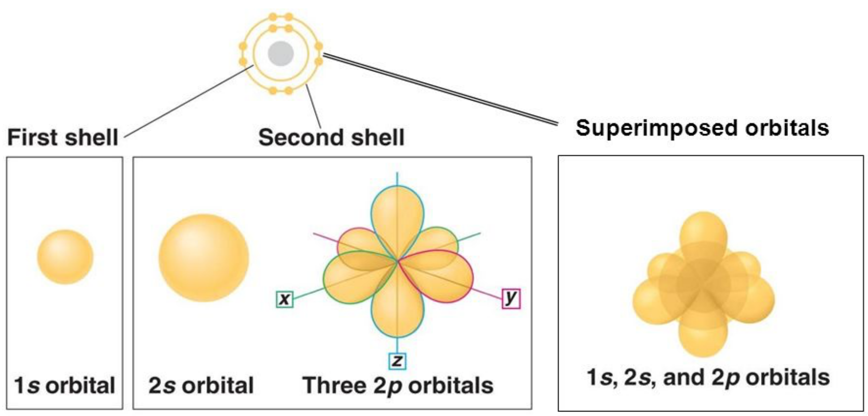
d. Circle the valence electrons in the diagram.

30. Electron shells are usually represented as concentric circles around the nucleus, the circles representing the *average* distance between electrons in that shell and the nucleus. In reality, however, the electrons occupy various orbitals of distinct shapes and orientations. What is an **orbital**?

31. a. What is the **total number of electrons that can be found within any one orbital**?

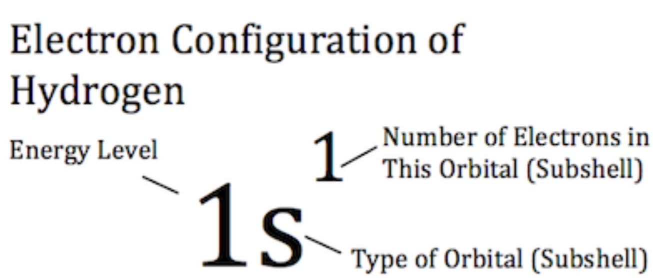
b. Which type of **orbital occupies the first electron shell**?

c. Which types of **orbitals can occupy the second electron shell**?

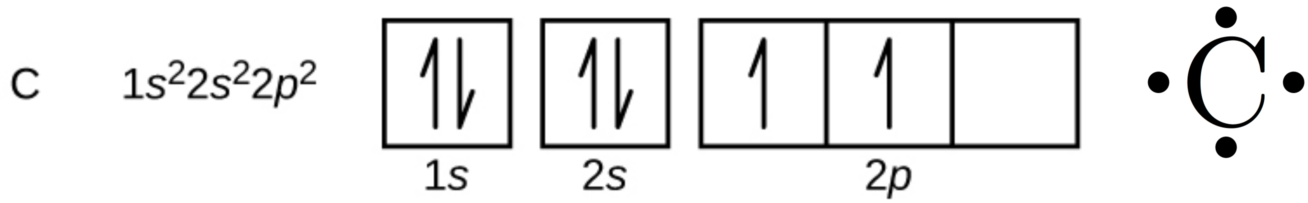


d. Remember, **the reactivity of an atom, the ability of that atom to react with another atom, comes about because of the presence of unpaired electrons in one or more orbitals of the atom's outermost valence shell.** ***An atom with a filled outer valence shell*** ***(the one s orbital in atoms with one energy shell or the outermost s and three p orbitals in atoms with more than one energy shell)*** ***is inert or nonreactive, while one that does not have all outermost orbitals filled will react with other atoms in order to acquire a more stable valence electron configuration.***

- In atoms with only one energy shell (ex: Hydrogen and Helium), the one valence *s* orbital (1*s*) can hold up to two electrons maximum. No other orbital can exist in the first energy shell. Once the 1*s* orbital has two electrons, the atom is considered inert, or a noble gas, as is the case with Helium. Hydrogen, however, which has one electron in the 1*s* orbital and so will react with other atoms to try to gain a second electron, at least for part of the time.



- In atoms with two energy shells (ex: Carbon and Oxygen), the outermost energy shell can hold up to 8 valence electrons in total. The inner *s* orbital (1*s*) holds two electrons, the outermost *s* orbital (2s) holds up to two electrons, and three *p* orbitals ($2p_x$, $2p_y$, and $2p_z$) hold up to 6 valence electrons, two per each type of 2*p* orbital. Carbon, for example, has a total of 6 electrons in its electron cloud, 2 in the first energy level's 1*s* orbital and 4 in the second energy level. Of these 4 outermost valence shell electrons, 2 are found in the 2*s* orbital, 1 is located in one 2*p* orbital, and another 1 is found in another 2*p* orbital, for a total of 2 electrons held in 2p orbitals. Carbon will thus react with other atoms because its valence shell is not completely filled. It has 4 valence electrons and not 8.



Let's review a few items...

32. A lithium atom has 3 protons and 4 neutrons, what is its mass number? *Explain and don't forget those units!*

33. A nitrogen atoms has 7 protons and the most common isotope of nitrogen has 7 neutrons. A radioactive isotope of nitrogen has 8 neutrons. Write the atomic number and mass number of this radioactive nitrogen as a chemical symbol with a subscript and superscript.

34. a. Using fluorine's Periodic Table of Elements information, how many valence electrons does fluorine have?

b. How many electron shells does fluorine have?

c. Name the orbitals that are occupied in a neutral fluorine atom. *(Think of the electron configuration for F)*

d. How many electrons are needed to fill the valence shell?

(Check your answers to question 32 by going to the Ch.2.2 ***Concept Check Question #1*** *in Appendix A of your textbook)*
(Check your answers to question 33 by going to the Ch.2.2 ***Concept Check Question #2*** *in Appendix A of your textbook)*
(Check your answers to question 34 by going to the Ch.2.2 ***Concept Check Question #3*** *in Appendix A of your textbook)*