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H Bio. per. 3
11 / 18 / 14

Basic Chemistry Study Guide

1. What are the three fundamental subatomic particles within the atom?
   a. proton
   b. neutron
   c. electron
2. Where are these particles located in the atom?
   a. protons, neutrons exist in the nucleus
   b. electron exist in orbitals of sublevels of different energy levels
3. What is the charge of each of these particles?
   a. protons = +1 ($2 * (\frac{2}{3}) + 2 * (-\frac{1}{3})$)
   b. neutron = 0 ($2 * (-\frac{1}{3}) + 2 * (\frac{2}{3})$)
   c. electron = -1
4. How do these particles compare in mass and charge?
   a. mass:
      i. $p^+ \approx n^0 \approx 2000 * e^-$ (protons and neutrons are much greater in mass than electrons)
   b. charge
      i. $p^+ > n^0 > e^-$
      ii. p^+ has opposite charge of e^- (despite large differences in mass)
5. What do these particles determine about an atom?
   a. the number of protons determines the atomic number of the element
   b. the number of neutrons determines the isotope (and therefore atomic mass, mass number)
   c. the number of electrons determines the charge (and therefore the ion)
6. Can any of the three fundamental subatomic particles of an atom be broken down into smaller sub-subatomic particles? If so, which ones?
   a. protons are made of two up quarks (+⅔) and one down quark (-⅓)
   b. neutrons are made of two down quarks (-⅓) and one up quark (+⅔)
   c. electrons are a fundamental particle of matter, and cannot be broken down
7. What is a radioisotope? What does it mean if an atom decays? Why does an atom decay? During decay, how does an atom change? Is there any way to determine if an isotope will be radioactive? How?
   a. also known as a radioactive isotope, a radioactive nuclide, or a radionuclide, a radioisotope is an unstable isotope of an element that goes through radioactive decay (see below). An atom is unstable when its nucleus's neutron/proton ratio is far from the stable neutron/proton ratio (that begins at 1:1 but gradually increases), and the "strong nuclear force" cannot keep the neutrons and protons together in the nucleus. There are many more radioisotopes than stable isotopes
   b. radioactive decay is when an atom spits off particles and energy from its nucleus to become more stable. There are multiple types of radioactive decay that differ in the ways that the atoms change. The major ones are:
      i. α (alpha) decay
         1. an alpha particle (${}^{4}_{2}He^{+2}$) particle is spit out by the nucleus
         2. mass number decreases by four, atomic number decreases by two
      ii. β^- (beta-minus) decay
         1. $n^0 \rightarrow p^+ + e^- + \bar{v}_e$ and sometimes gamma rays
         2. mass number stays the same, atomic number increases by one
      iii. β^+ (beta-plus) decay
         1. $p^+ \rightarrow n^0 + e^+ + v_e$ and sometimes gamma rays
         2. mass number stays the same, atomic number decreases by one

   c. you can predict if an atom is radioactive if its ratio of neutrons to protons is too high or low
8. If you look at the decay chain of U-238, what is happening? What does the decay chain show us?
   a. it goes through a series of fourteen decays (both α and β decays) until it becomes stable as lead
   b. it shows how a single decay of an atom will not always make it stable- atoms may need to go through a long decay chain like this to become stable
9. Why can radioisotopes be dangerous to people? How can they also be helpful? What are some specific example of positive uses of radioisotopes? (Provide examples of your own)
   a. radioisotopes can be dangerous to people because both the particles and energy emitted by the decay (α and β particles, as well as gamma rays) can harm large molecules essential to life, especially DNA, by increasing the chance of irregular and broken bonds, potentially leading to cancer and other disorders
   b. radioisotopes can be helpful because they behave like stable isotopes but give off particles that can be used as scientific "tracers" to show cancer in PET scans. They can also be used to kill cells, especially the fastest growing ones (cancer cells), which is used in chemotherapy
10. What are some key differences between a nuclear reaction and a chemical reaction? What happens in a nuclear reaction? What happens in a chemical reaction? Are mass and energy conserved in both types of reactions?
    a. a nuclear reaction involves the nucleus and radioactive decay, for an element to become stable. An atom may become a totally different element in an atomic reaction. They can give off much more energy and be much more dangerous than chemical reactions
    b. a chemical reaction involves the valence electrons and the bonding or breaking of bonds between elements. An atom cannot become a different element, but its properties can change when bonded
    c. only in a chemical reaction is energy and mass conserved (law of mass and conservation). However, in nuclear reactions, energy may be converted to mass and vice versa (special relativity: $E = mc^2$)
11. How is atomic number different from mass number?
    a. atomic number is constant for all the isotopes of an element, and it is the number of protons in that elements' atoms
    b. mass number is the number of protons plus the number of neutrons in a specific isotope of an element
    c. they both are always whole numbers. $MN \geq AN$, $MN \approx 2AN$
12. How is the atomic mass of an isotope similar yet different from its mass number?
    a. atomic mass is similar to the mass number in value
    b. atomic mass is a decimal (except C-12), measured in amu
    c. mass number is a natural number ($MN\%1 = 0, MN > 0$)
13. Why is the atomic mass of an isotope close in value to the mass number, but not exactly equal to the mass number?
    a. because the protons and the neutrons each equal about 1amu, and the electrons are close to 0amu, $AM = mass\ p^+ + mass\ n^0 + mass\ e^- \approx 1p^+ + 1n^0 + 0e^- = \#p^+ + \#n^0 = MN$
14. How is the relative atomic mass of an element different than the atomic mass of an isotope?
    a. relative atomic mass is an average of the atomic masses of all the isotopes of an element, taking into account their relative abundance
    b. atomic mass is the mass of one isotope of an element
15. How does one calculate the relative atomic mass for an element?
    a. given a list of the masses and relative abundances (percentages) of the isotopes of an element, you have to add the masses multiplied by their percentages
    b. example:

i. given:

Relative Abundance	**Atomic Mass**
50%	10amu
25%	8amu
20%	5amu
5%	20amu

ii. solve: $RAM = 0.5 * 10 + 0.25 * 8 + 0.2 * 5 + 0.05 * 20 = 5 + 2 + 1 + 1 = 9amu$

16. What is an electron configuration? What does it tell you on a very basic/general level? What do the coefficients tell us? What do the letters stand for? What do the superscripts tell us? Could you figure out how many valence electrons are in an atom of an element by looking at the electron configuration? If given an electron configuration, could you figure out which element it was for?
    a. an electron configuration tells us how many electrons are in an atom, where they are located (which sublevel), and the order in which they fill up the sublevels. The largest element's electron configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6$ or [Rn] $4f^{14} 5d^{10} 6p^6$
    b. the coefficients tell us the energy level of the sublevel (because an sublevel exists in multiple energy levels)
    c. the letters stand for different sublevels (in this order: s^2, p^6, d^{10}, f^{14})
    d. the superscripts tell us how many electrons are in the sublevel
    e. yes- you add up the superscripts (the electrons) of the sublevels of the highest electron level
    f. yes- you add up all the superscripts to find the number of electrons; because the atom is neutral ($\#p^+ = \#e^-$, look for the element with that atomic number
17. What are valence electrons? Why are they important?
    a. valence electrons are the electrons in the outermost energy level
    b. they determine an element's chemical properties (therefore, a the periodic table is grouped by families and periods)
18. How many valence electrons do atoms have when they are the most stable? Are there any exceptions to this that you know? If so, what are they? Why do these exceptions make sense?
    a. eight electrons makes a stable shell (the octet rule)
    b. He is the only exception
    c. He has a full valence shell - its valence shell (the first energy level) can only hold two electrons, unlike all the other energy levels
19. How can you determine the number of valence electrons a neutral atom of an element has?
    a. the easiest way is to look on the periodic table. All elements in period 1 have 1 valence electron, 2 have 2, 13 - 3, 14 - 4, 15 - 5, 16 - 6, 17 - 7, 18 - 8 (exception: He).
20. How does the number of valence electrons relate to the charge that atoms of an element will have, if they become ions?
    a. the charge is the number of missing or extra electrons. For example, a $^{+2}$ charge would indicate two missing electrons, and vice versa
21. How can the number of valence electrons help you to predict how many bonds an element will form with other atoms, if they will form covalent bonds?
    a. an atom will usually covalently bond as many times to make its outer shell full (with either eight or two valence electrons). For example, a carbon atom with four valence electrons will usually bond four times to become stable with eight valence electrons

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22. How can you predict if atoms of an element will form ionic or covalent bonds with atoms of another element? What is electronegativity, and what is its connection here?
    a. you can predict atoms' bonds by the differences in electronegativities between the atoms. If the difference in electronegativities is greater than 1.7, than it is generally ionic, and a difference less than 1.7 would usually be a covalent bond
    b. electronegativity is the tendency of an atom to attract electrons of other atoms' electrons
        i. the higher the electronegativity, the stronger the pull
        ii. the highest and lowest electronegativities are the most chemically reactive, because they are close to having a full or empty shell and are either very willing to take an electron or lose one
        iii. scale 0-4 (Pauling scale)
            1. two most unstable elements:
                a. fluorine is the highest (4)
                b. francium is the lowest (~0.7)
        iv. dependent on number of protons and number of electrons levels
            1. the more the protons (for the same # of energy levels), the stronger the electronegativity, because the higher number of electrons and protons will create a stronger pull and the atom will become slightly smaller, which allows the nucleus to become a little bit closer to the outside of the atom, which will allow it to exert more of a positive charge
            2. the larger the atom, the farther away the nucleus is from the edge of the atom. Therefore, the more the energy levels, the less the electronegativity
        v. electronegativity differences can create polar molecules, which have special properties
23. If covalent bonds are formed between atoms, how can you tell if the *bonds* are polar or not? If the bonds are polar, how can you tell if the *molecules* are polar or not?
    a. if the electronegativities between the two atoms are between 0.4 to 1.7, then the bond is generally considered polar, because one is strong enough to have a negative charge
    b. you will need to know the structure of the molecule to know whether or not it is polar. Even if three weaker atoms are to be connected to a strong atom such as fluorine, the molecule will not need to be polar, because the three weaker atoms could be spread out equally around the fluorine and exert an equal, neutral charge
24. Contrast what is happening with the valence electrons of the atoms that are being held together by ionic bonds with those that are being held together by covalent bonds.
    a. in an ionic bond, the electron of the less electronegative atom(s) is completely removed from the electron shell of that atom and placed into the electron shell of the stronger atom(s), and one atom becomes negative with a full shell and the other positive with an empty shell
    b. in a molecular bond, the valence electrons are "shared" by both atoms- the valence electrons are in both atoms' valence shell and the atoms have to stay together to do so. They are not given up nor "stolen" from other atoms
25. Why don't we have molecules of ionic compounds? If we don't have molecules of ionic compounds, then what does the formula for an ionic compound tell us?
    a. in an ionic compound, because one atom completely "steals" an electron away from the other atom, the two atoms do not have to stay together, and therefore the two atoms are attracted to each other, but they do not have to stay "together"- right next to each other- in a molecule
    b. the formula of an ionic compound tells us the ratio that the elements exist in, because the elements will have to have a fixed ratio to remain stable and neutral
26. We do have molecules of molecular compounds. What does the formula for a molecular compound tell us?

    a. it tells us how many atoms are in the molecule, because the numbers of atoms remain in a fixed ratio (like in ionic compounds) for the molecule to remain neutral

27. What is the difference between intramolecular bonds and intermolecular bonds? Of the two, which are stronger?
    a. intramolecular bonds are covalent bonds, and they keep a molecule together- intermolecular bonds exist between the molecules, including hydrogen bonds
    b. intramolecular bonds are always stronger than intermolecular bonds
28. Why is water such a good solvent? What types of substances (polar, nonpolar, or ionic) does it dissolve well? Why?
    a. water is a good solvent because it is strongly polar
        i. it attaches to the negative and positive parts of ions and polar molecules and pulls on it
        ii. if the positive or negative pull of the water molecule is stronger than the pull that keeps the ionic or polar covalent compound together, it dissolves (dissociates) that solution
        iii. water is the "universal solvent" - very good at dissolving (dissociation)
    b. it dissolves ionic and polar substances, because they have a positive or negative side that the water can attach to and pull on
29. What are hydrogen bonds? What do they form between? What is their significance when it comes to water? What are some other important characteristics of water that relates to the hydrogen bonding?
    a. hydrogen bonds are weak intermolecular bonds often used to hold atoms in their functional shape
    b. hydrogen bonds exist between hydrogen and another atom
    c. because water is strongly polar (and the hydrogen atoms are strongly positive), hydrogen bonds form in water and give it unique properties
        i. cohesion and adhesion
        ii. density
        iii. specific heat
        iv. they release energy to form and vice versa
30. How does hydrogen bonding affect the density of liquid and solid water? How does the uniqueness of ice's density benefit life?
    a. in liquid water, the bonds between the water molecules are loose and constantly form and reform between the molecules as they move past each other, allowing water to flow. Because they are not stable, they are packed together and weak, and liquid water is dense
    b. in solid water (ice), the bonds between the water molecules are rigid and spread out into crystals. This allows ice to be less dense than water, and it can float on top of water (only element to do so)
    c. the ability of ice to float on water is important to insulate bodies of water in times of extreme cold- they freeze from the top down, trapping heat
31. What is cohesion? What is adhesion? What are some applications of these? How are these properties of water beneficial?
    a. cohesion is the tendency of like molecules to stick together
    b. adhesion is the tendency of unlike molecules to stick together
    c. cohesion allows for:
        i. surface tension:
            1. water striders
            2. droplets of water
    d. cohesion and adhesion allows for:
        i. capillary action:
            1. many plants depend on capillary action to bring water all the way up to their leaves
            2. adhesion allows the water to stick to the little tubes in the tree and be pulled up

            3. cohesion pulls up more water molecules to cycle through the tree and eventually evaporate, which allows water to constantly cycle through the plant

32. What is specific heat? Does water have a high or low specific heat? Why does that matter and benefit life? What are some examples?
    a. specific heat is the amount of energy (in calories) required to raise one gram of a substance by one degree Celsius
    b. water has an extremely high specific heat of one calorie
        i. unit of calorie based off of water
        ii. this is because of hydrogen bonds absorb (heat energy) when they break, which slows down heating, and vice versa (the hydrogen bonds store energy, and the energy of creating or breaking hydrogen bonds when cooling or heating needs to be overcome in addition to actually heating the water molecules)
    c. this property allows for the regulation of temperatures, especially in the sea, but also on coastal land and sea breezes
        i. water temperature changes by much fewer degrees during the day than land or air, therefore allowing for a more constant temperature for more stable life
36. What is the primary difference between atoms and molecules?
    a. atoms are smaller than molecules
    b. molecules (molecular compounds) are made up of multiple atoms kept together by covalent bonds
37. What are the primary differences with elements and compounds, as well as with mixtures? How would you define them?
    a. element = pure substance that cannot be broken down into other substances by normal means
        i. made up of only one type of atom
        ii. can exist as a single atom or diatomic or triatomic molecules
    b. compound = substance formed when two or more elements are chemically bonded together in ionic or covalent bonds, and exist in fixed ratios
        i. always made up of multiple atoms, and of different atoms
    c. mixture = aggregate (whole formed by combining separate pieces) formed of two or more elements not chemically bonded together, in which the elements do not exist in fixed proportions
38. Why is the periodic table named the *periodic* table?
    a. it is organized into rows and columns, known as *periods* and families. The organization and patterns of the periods are important to its organization
39. Why are the rows called periods? Provide some specific examples of quantitative aspects of the elements within the rows that rise or fall consistently from left to right in every row.
    a. the rows are called periods because certain characteristics consistently increase or decrease, and there is a pattern of characteristics that is the same for every row, because each family has similar characteristics
    b. characteristics that increase regularly:
        i. electronegativity
        ii. size
            1. number of protons (atomic number)
            2. relative atomic mass
            3. mass numbers
40. Why are the columns called families? How are they similar?
    a. they are similar in terms of chemical properties because they all have the same number of valence electrons
41. Why are metals located on the periodic table? What do they have in common?
    a. they are located on the left of the periodic table, mostly from families 1 to 12

   b. common characteristics
      i. low electronegativities
         1. tend to become positive ions when bonding with nonmetals
      ii. conductivity
      iii. ductility
      iv. malleability
      v. shiny
      vi. high melting point
      vii. high density
      viii. hard
      ix. mostly solids

42. Where are the nonmetals located on the periodic table? What do they have in common?
   a. they are located on the right of the periodic table, from families 14 to 18
   b. common characteristics:
      i. opposite of metals (see above)
43. What are the metalloids (a.k.a. semimetals)? Where are they found on the periodic table? Why does this make sense?
   a. they are elements with some properties of metals, some properties of nonmetals, and some intermediate characteristics, such as semiconductivity
   b. they are located straddling the zig-zag between the metals and the nonmetals. This makes sense because the elements are intermediates between metals and nonmetals
44. What are the most common elements (by mass) in the human body?
   a. oxygen
   b. carbon
   c. hydrogen
   d. nitrogen
45. What are trace elements? What are some examples of trace elements? Are trace elements important? Why? What happens if you don't have trace elements in your body? What are specific examples?
   a. trace elements are elements that are needed in small quantities in your body
   b. they are necessary
   c. examples are iron and iodine
   d. deficiencies can cause health problems:
      i. iron deficiency can cause anemia
      ii. iodine deficiency can cause goiters