Problem Set 2

1. For an atomic orbital with n = 4, $l = 3$, $m_l = 0$, what is the maximum number of electrons that the orbital can hold?
   a. 1
   b. 2
   c. 8
   d. 18

2. Approximately how many CO_2 molecules are produced by the complete combustion of 1 L of C_8H_{18}, the main component of gasoline? The density of C_8H_{18} is 703 g/L.
   a. 1 x 10^{25} molecules
   b. 2 x 10^{25} molecules
   c. 3 x 10^{25} molecules
   d. 4 x 10^{25} molecules

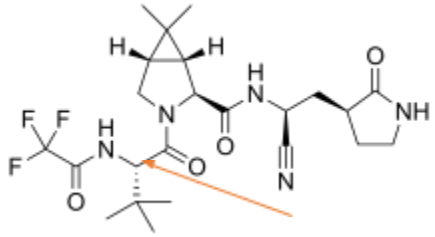
3. Following # 3, what is the approximate mass of H_2O produced in the combustion reaction?
   a. 1 kg
   b. 2 kg
   c. 3 kg
   d. 4 kg

4. A package of kimchi ramen (pictured below) contains both sodium carbonate and potassium carbonate. Although sodium can be found in many other salt forms in kimchi ramen, potassium is only found in the form of potassium carbonate. Elemental analysis of the product, which weighs 90.6 g, reveals 0.386% potassium by mass. Approximately how much potassium carbonate would you consume if you were to finish one of these?

   a. 0.618 g
   b. 0.718 g
   c. 0.886 g
   d. 1.236 g

(Questions 6 – 8 refer to the molecule in Figure 1.

Figure 1: Nirmatrelvir (also known as Paxlovid), a drug developed by Pfizer and commonly used to treat COVID-19



5. How many π-bond electrons are in the structure in Figure 1? If you have learned about electron delocalization, please ignore its contributions.
    a. 5
    b. 6
    c. 10
    d. 12

6. What is the molecular geometry about the carbon atom indicated with an arrow in the above figure?
    a. Tetrahedral
    b. T-shaped
    c. Trigonal pyramidal
    d. Octahedral

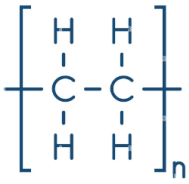
7. Which of the following is true about the chemical structure of the molecule in Figure 1 ?
    a. It cannot form hydrogen bonds with water
    b. It cannot have any van der Waals or dispersion interactions with other molecules
    c. Its intramolecular C-F bonds are stronger than its C-H bonds
    d. None of the above

8. The ideal gas model is a simple yet very useful method for describing the properties of gases. Which of the following is true?
    a. The pressure and volume of an ideal gas are inversely proportional
    b. For an ideal gas in a closed container, increasing the temperature of the gas by a factor of 2 would also increase the pressure inside the container by the same factor.
    c. Both sides of the ideal gas equation have units of energy
    d. All of the above are true

9. If the temperature of a chemical reaction is doubled, by what factor does its rate constant change? (E_a = activation energy, R = gas constant, T = temperature)
    a. 2
    b. $e^{\frac{E_a}{2RT}}$
    c. $e^{-\frac{E_a}{2RT}}$
    d. e^2

10. a mL of x M acid (H_2A, strong acid) are titrated to the equivalence point with b mL of y M NaOH. Derive and expression for the initial concentration of the acid in terms of a,b and y? (you will need to enter the formula on your submission.

11. a mL of x M acid (H_2A, strong acid) are titrated to the equivalence point with b mL of y M NaOH. Assume a = 10 mL, x = 1.0 M, and y = 1.0 M. If you overshot the equivalence point by 100 mL, what would be the approximate concentration of Na^+ ions in the resulting solution?
    a. 12 M
    b. 0.92 M
    c. 1.2 M
    d. 9.2 M

12. Which of the following will have the highest boiling point?
    a. a 6 carbon length unsaturated hydrocarbon with a carboxylic acid functional group
    b. a 6 carbon length saturated hydrocarbon with a tertiary carbon centre
    c. 
    d. an primary straight chain alcohol with a molecular weight of 102 g

(Questions 14 – 16) The first ionization energy of an element is the energy required to remove the first electron from a gaseous atom of that element. In other words, it is the energy required for the following reaction:

$$A_{(g)} \rightarrow A^+_{(g)} + e^-$$

where A stands for any element.

13. The first ionization energy of Na is 496 kJ for 1 mol of atoms. How much energy does this correspond to, in eV, for 1 Na atom? (1 eV = 1.602 x 10^{-19} J)
    a. 5.14 eV
    b. 0.00514 eV
    c. 8.24 eV
    d. 8.24 x 10^{-19} eV

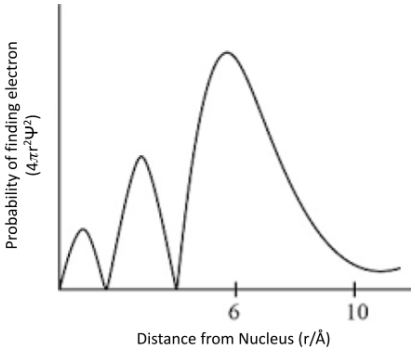
14. Light and other forms of electromagnetic radiation can interact with atoms and molecules. One of the things it can do is remove electrons from them. What wavelength of light is needed to remove 1 electron from a sodium atom?
    a. 150 nm
    b. 1.50 x 10^{21} nm
    c. 241 nm
    d. 2.41 x 10^5 nm

15. Compared to sodium, the first ionization energies for potassium would be _____, and for chlorine it would be _____.
    a. higher, lower
    b. lower, higher
    c. higher, higher
    d. lower, lower

16. Which of the following reactions will form a precipitate?
    a. $Al^{3+}_{(aq)} + Cl^{-}_{(aq)} \rightarrow AlCl_3$
    b. $Ag^{+}_{(aq)} + NO_3^{-}{}_{(aq)} \rightarrow AgNO_3$
    c. $Ba^{2+}_{(aq)} + Br^{-}_{(aq)} \rightarrow BaBr_2$
    d. $Ca^{2+}_{(aq)} + PO_4^{3-}{}_{(aq)} \rightarrow Ca_3(PO_4)_2$

17. For a reversible chemical reaction $A + B \rightleftharpoons C + D$, in one experiment the concentration of A is doubled and in another experiment the concentration of B is halved. The equilibrium constant _____ for the first one and _____ for the 2nd one.
    a. doubles, halves
    b. halves, doubles
    c. stays the same, stays the same
    d. none of the above

18. The following graph plots the probability of finding an electron against the electron's distance from the nucleus. Which of the following options corresponds to the orbital plotted on the graph?



    a. 2s
    b. 2p
    c. 3s
    d. 3d

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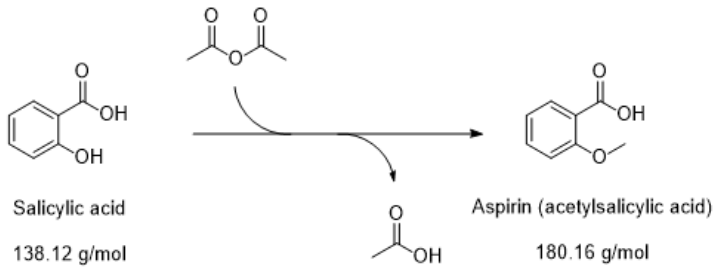
(Questions 19 – 20) Aspirin is a blood thinner that is commonly used to reduce the risks of heart attack and stroke. It can be made from salicylic acid via the reaction shown below:



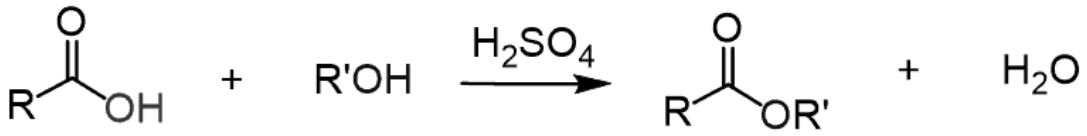
19. A daily dose of Aspirin for an adult contains 162.5 mg. Assuming that you have a robot that can do the reaction and purify the product for you to obtain a final yield of 90.0%, how much salicylic acid would you need to feed the robot to make one daily dose of Aspirin?
    a. 0.112 g
    b. 0.125 g
    c. 0.138 g
    d. 0.163 g

20. Salicylic acid has a higher melting point compared to Aspirin. Why?
    a. In a sample of salicylic acid, there are more hydrogen bonds compared to Aspirin
    b. In a sample of salicylic acid, there are more van der Waals interactions compared to Aspirin
    c. In a sample of salicylic acid, there are more dispersion interactions compared to Aspirin
    d. All of the above

21. Upon dissolving 0.20 mol of a weak monoprotic acid, HA, in 300 mL of distilled water the pH of the solution is 5.6. Calculate the pKa of the weak monoprotic acid HA.
    a. 5.42
    b. 9.98
    c. 11.02
    d. 5.60

22. 5.3 g of acetic acid (pKa = 4.76) and 7.2 g of hydrocyanic acid (pKa = 9.20) are dissolved in 200 mL of distilled water. Using the given pKa values, calculate the pH of the resulting solution.
    a. 2.91
    b. 4.54
    c. 3.55
    d. 2.56

(Questions 23 – 24) Fischer esterification reactions, shown below, may be catalyzed by the addition of acid.



23. Using your knowledge of catalysts, which of the following statements best represents the addition of acid catalyst to the Fischer esterification reaction.

    a. Pushes reaction equilibrium to products, making their formation faster and more favourable
    b. Lowers activation energy by increasing energy of reactants
    c. Lowers activation energy by decreasing energy of transition state complex
    d. Lowers activation energy by decreasing energy of reactants

24. Assuming the reaction is first order with respect to the alcohol and the equilibrium constant for a specific esterification reaction is K_{eq} = 2.32, and the rate constants are $k_{(cat)}$ = 4.679×10^{-4} s^{-1} (catalyzed) k = 3.627×10^{-5} s^{-1} (uncatalyzed), calculate the time taken, to the nearest minute, to reach equilibrium for an initial alcohol concentration of 0.30 M and carboxylic acid concentration of 2.00 M.

$$rate = k \times [alcohol]$$

    a. 97 min (catalyzed); 1251 min (uncatalyzed)
    b. 2 min (catalyzed); 31 min (uncatalyzed)
    c. 58 min (catalyzed); 747 min (uncatalyzed)
    d. 5 min (catalyzed); 69 min (uncatalyzed)

25. Copper (II) sulfate crystals easily absorb atmospheric water vapor to form hydrates. When 30.46 g of copper (II) sulfate crystals are completely dehydrated, they weigh in at 22.75 g. Find the water of hydration for the sample of copper (II) sulfate crystals.

    a. monohydrate
    b. trihydrate
    c. pentahydrate
    d. heptahydrate