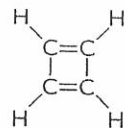


- (20 marks) (a) What is the microscopic definition of the entropy? (b) What is the macroscopic (thermodynamic) definition of the entropy? (c) A box of ideal gas undergoes the free expansion (irreversibly), without doing any work, from 1 atm, 1L, 298K to 0.5 atm, 2L, 298K. Calculate its entropy change per mole using the both definitions. Are they the same? If they are not, why? (The Boltzmann constant is $k_B = 1.38 \times 10^{-23}$ J/K.)
- (15 marks) Mix 100 mL 0.3M acetic acid and 100 mL 0.3M sodium acetate to make a buffer solution. The acetic acid has $K_a = 10^{-4.8}$. How much NaOH(s) can be added into the solution before the pH changes to 5.8?
- (15 marks) Draw all the possible Lewis structures for SO_3 molecule and predict its geometry using the VSEPR theory.



- (15 marks) Suppose that you are studying the (unstable) planar molecule C_4H_4 as the following structure. Draw the possible molecular orbitals of its π bond.
- (15 marks) What are the number of unpaired electrons for the ions $[\text{Mn}(\text{CN})_6]^{3-}$ and $[\text{Mn}(\text{Cl})_6]^{3-}$? Explain your reasoning.
- (20 marks) A box contains pure oxygen molecule at 1 atm, room temperature 298K. Calculate (a) the average kinetic energy of one molecule, (b) the root mean square velocity of a molecule. (c) Suppose that the molecule can be viewed as a sphere with the radius $r = 0.15$ nm, estimate the number of collisions per molecule within one second. (d) If one out of 100000 collisions will make a reaction, one can estimate the reaction rate using the answer of (c). What is the order of this reaction. (The Boltzmann constant is $k_B = 1.38 \times 10^{-23}$ J/K.)

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