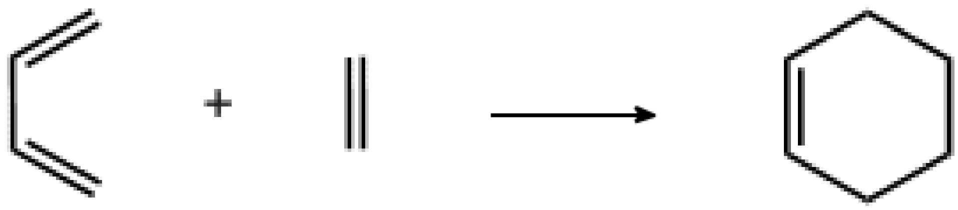
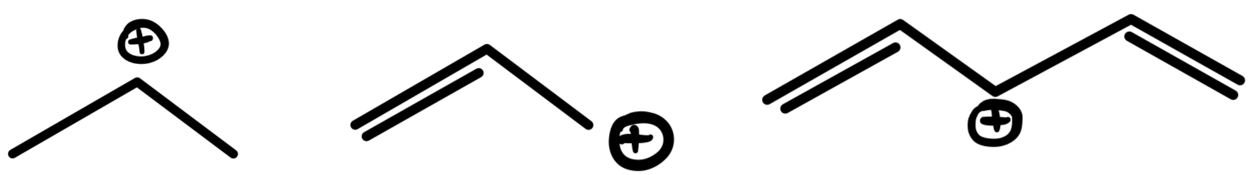
HARD PACKET 1

Team ID: ________________

1. The following is a simple representation of an organic synthesis process known as the Diels-Alder reaction. Draw electron pushing arrows on the reactants to make the product.



2. Rank the following cations in order from longest to shortest wavelength. (Hint: energy is inversely proportional to wavelength)



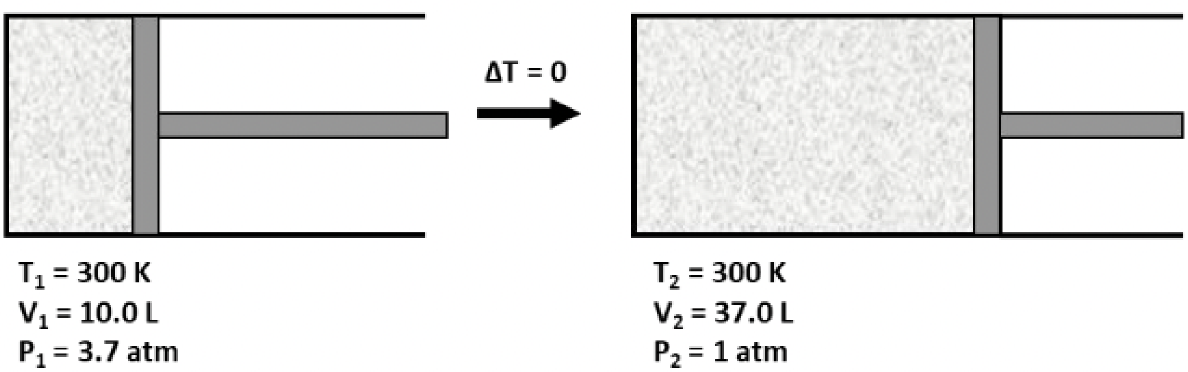
3. Which of the following gas molecules will have the lowest root-mean-square speed at 150˚C: SF_6, CCl_4, or H_2O

HARD PACKET 2 Team ID: __________________

1. A sample of nitrogen gas effuses at a rate four times that of an unknown gas. What is the molecular weight of the unknown gas in g/mol? (Hint: $\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$)

2. A 14.5 L closed vessel contains 1.49 g H_2O, 4.32 g CO_2, and 3.21 g SO_3. At 40˚C, what is the pressure in the vessel (in atm)? Assume these gases behave ideally.

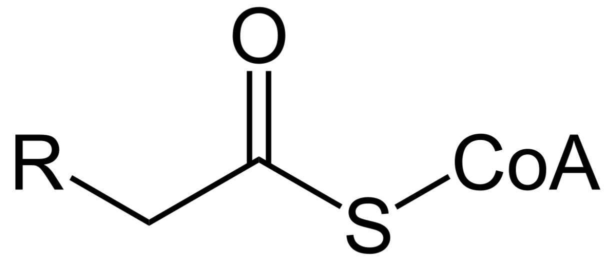
3. Considering the ideal gas as the system, calculate the heat transferred to/from the surroundings ($q_{surroundings}$) in the process below. This expansion is performed against a constant external pressure of 1 atm.



HARD PACKET 3

Team ID: __________________

1. In the conversion of acetyl-CoA (shown below) to carbon dioxide, is carbon oxidized or reduced?



2. Suppose you are conducting an experiment to study two silver salts, AgBr and AgCl. They have solubility product constants of $7.7 * 10^{-13}$ and $1.6 * 10^{-10}$, respectively. You begin with a solution of 0.10M Br^- and 0.10M Cl^- and gradually add in Ag^+. What percent of Br^- remains in solution when AgCl first precipitates?

3. Billy conducts an electron diffraction experiment. There are 2 slit openings lined up top to bottom with the appropriate width for diffraction. Billy will fire trillions of electrons upon the slits. How many detectors should Billy use if they want the diffraction pattern to appear as if there is only a single slit?

HARD PACKET 4 Team ID: __________________

1. The photoelectric effect describes the emission of electrons from a material, oftentimes a metal, when electromagnetic radiation hits its surface. The equation $KE_{max} = E_p - \phi$ describes the maximum kinetic energy of the ejected electrons in terms of E_p, the energy of the incoming photon, and ϕ, the work function. ϕ for gold is $8.17 \cdot 10^{-19}$J and light with a frequency of $1.00 \cdot 10^{15}$s^{-1} is shined on a gold plate. If there are ejected electrons, what is the speed of the ejected electrons? If there are no ejected electrons, write "no electrons are ejected."

2. Pu-244 undergoes beta-decay at a half-life of 16 hours. If a chemist starts with a sample of 512 g of Pu-244 and allows it to undergo beta-decay, how much of the original sample remains after 4 days?

3. Calculate the pH of a $1.00 \times 10^{-2} M\ H_2SO_4$ solution. (K_{a1} is very large, consider the first dissociation step as totally complete; $K_{a2} = 1.2 \times 10^{-2}$)

HARD PACKET 5 Team ID: ___________________

1. How many more chlorine atoms are present in a 3-chloropentane molecule compared to a 2-chloropentane molecule?

2. An 80 mL aqueous solution contains 0.7 g of hydrofluoric acid (initial amount) dissolved in water. Calculate the pH of the solution (K_a of HF = 6.6×10^{-4} at 25° C; MW HF = 20.01 g/mol).

3. The percent dissociation of a solution with an initial amount of 0.3 M of nitrous acid is 1.3%. A 0.3 M solution of hydrocyanic acid has the same percent dissociation. Calculate the pOH of the solution with hydrocyanic acid.

HARD PACKET 6 Team ID: __________________

1. $2\ SO_{2\ (g)} + O_{2\ (g)} \rightarrow 2\ SO_{3\ (g)}$ is one of the essential reactions involved in the industrial production of H_2SO_4. Suppose at the beginning of the reaction, there are 100L of mixed gasses: 7% is SO_2, 11% is O_2, 82% is N_2. At the end of the reaction, the total volume of the gas becomes 97.2L. What percentage of SO_2 was converted? (Assume that the total pressure and temperature remain constant throughout the reaction, and the gasses behave ideally) (3 significant figures)

2. You are performing a titration to determine the concentration of the weak monoprotic acid HA ($K_a = 2.0 * 10^{-3}$) using a strong monoprotic base B with a concentration of 1M ($K_b = 8.6 * 10^{3}$). You know that the initial concentration of HA is 1.6M and that the equivalence point is reached when you add exactly 50 mL of B. Determine the pH value of the solution at the equivalence point. (Temperature = 25ºC)

3. A Na_2SO_3 solid is exposed to the air for an extended period of time. Some of the Na_2SO_3 is oxidized by the oxygen in the air. To determine the purity of the Na_2SO_3, a 3.5g sample is taken from the solid and reacted with excess H_2SO_4. 560 mL of gas is produced under standard conditions. What is the purity in percent of the Na_2SO_3 solid?

HARD PACKET 7 Team ID: ___________________

1. Calculate the pH once 5 mL of 1M HCl is added to 500 mL of a buffer solution of 0.4M CH_3COOH (a weak acid) and 0.1M CH_3COO^-. (Given: K_b (CH_3COO^-) = 5.56×10^{-10})

2. What happens to the boiling point of water when you dissolve rock climbing chalk (magnesium carbonate) in it?

3. A certain amount of SO_2 (a L) and H_2S (b L) are mixed under room temperature and normal atmospheric pressure. They react to form yellow solids (S) and water. If the volume of the gasses after reaction is only ¼ of the volume before the reaction, what is the ratio of a:b? (There are two possible ratios, list both of them).

HARD PACKET 8 Team ID: ___________________

1. A mixture contains Na_2S, Na_2SO_3, Na_2SO_4. Knowing that there is 38% of sulfur in this mixture (by mass). What is the percentage of oxygen (by mass)?

2. A/an _____________ is a mixture of two compounds with well-defined boiling points that cannot be separated through fractional distillation.

3. Write the chemical formula of Cobalt (III) oxalate

HARD PACKET 9 Team ID: ___________________

1. Given the following reaction: ½ N_2 (g) + O_2 (g) → NO_2(g) $\Delta H_f = +33.2$ kJ

If you have 2.1 L (at STP) of N_2, which is the limiting reagent, how much heat is needed for the reaction to use up all the N_2. (1 mol = 22.4L at STP)

2. An unknown gas AB decomposes into A and B in the following reaction:

$$AB_{(g)} \rightleftharpoons A_{(g)} + B_{(g)}$$

10g of AB is sealed into an evacuated 1.000L container at 100℃. After equilibrium is reached, the total pressure in the container is 3.50 atm. Given the molar mass of AB is 134.96g/mol, calculate the equilibrium constant K for the decomposition reaction above.

3. Consider the following decomposition reaction of an unknown gas AB:

$$2AB_{(g)} \rightleftharpoons A_{2\,(g)} + B_{2(g)}$$

50g of AB is sealed into a 1.5L evacuated container and heated to 500℃. The equilibrium constant of this reaction at this temperature is 2.59 x 10^{-5}. Find the equilibrium partial pressure of AB to 3 significant figures given the total pressure at equilibrium is 6.45atm.

HARD PACKET 10 Team ID: ___________________

1. The following is the equations and K_a values of the dissociation of an unknown weak diprotic acid, H_2A:

$$H_2A + H_2O \rightleftharpoons HA^- + H_3O^+ \quad K_{a1} = 4.3 \times 10^{-7}$$
$$HA- + H_2O \rightleftharpoons A^{2-} + H_3O^+ \quad K_{a2} = 5.6 \times 10^{-11}$$

A 0.12M solution of H_2A is titrated with 0.1M solution of NaOH. Given that 150mL of the NaOH solution is required to reach the first equivalence point of H_2A, what is the pH of the solution at the second equivalence point?

2. According to solvent leveling, what is the strongest acid that can exist in water?

3. According to solvent leveling, what is the strongest base that can exist in water?