 # 1. (10 points) Short Answer Questions

a) How much heat (in kJ) must be transferred to a 2.0 L of water in a pot to raise its temperature from 25 °C to 85 °C: (1 pt) **+ 502 kJ (q = msΔT)**

b) Indicate the oxidation state of the underlined atom: (2 pts)

$\underline{Fe}_2O_3$: **3+**

$\underline{Cl}O_2^-$: **3+**

c) The standard heat of formation of solid potassium chlorate is -430.12 kJ. Write the chemical equation for the reaction to which this value applies (include phases). (1 pt)

$$K(s) + Cl_2(g) + 3/2\ O_2(g) \Longrightarrow KClO_3(s)$$

d) Number of atoms in 0.220 mol of CCl_4: (1 pt) **6.62×10^{23} atoms**

e) You take a 1.0 L volume of gas at 250 K. You expand the gas to a 4.0 L volume and simultaneously heat the vessel to 500 K. The pressure of the gas: *(circle one)* **(1 pt)**

DOUBLES [✓ HALVES] QUADRUPLES STAYS CONSTANT

f) Give the precise chemical symbol for the following: (1 pt)

Number of neutrons	Number of protons	Number of electrons	**Chemical Symbol**
20	19	18	${}^{39}_{19}K^{+}$

g) Four balloons are filled to the same volume with one of the following gases. If a small hole is made in each balloon, which one will deplete faster? *(circle one)* **(1 pt)**

Kr Xe [✓ N_2] SO_3

h) Provide the name or formula for the following: (2 pts)

dinitrogen tetraoxide	**N_2O_4**
FeO	**iron (II) oxide**

 # 2. (10 points) A parachute manufacturer decides to start making its own adipic acid ($H_2C_6H_8O_4$), one of the main components of nylon polymers. It uses a controlled reaction between cyclohexane (C_6H_{12}) and O_2 shown here (not balanced):

$$2\ C_6H_{12}(l) \quad + 5\, O_2(g) \quad \rightarrow 2\ H_2C_6H_8O_4(l) \quad + 2\ H_2O(g)$$

MM = 84.16 g/mol 32.00 g/mol 146.1 g/mol

The reaction uses 28.0 g of cyclohexane and 32.0 g of oxygen, and allows the isolation of 40.2 g of adipic acid. What are the theoretical yield of adipic acid and the % yield of the reaction?

DETERMINING THE LIMITING REAGENT:

$$28.0\text{ g } C_6H_{12} = 0.333\text{ mol}$$

$$32.0\text{ g } O_2 = 1.00\text{ mol}$$

$$\text{Ideal mol ratio: } = \frac{O_2}{C_6H_{12}} = \frac{5\ O_2}{2\ C_6H_{12}} = 2.5$$

$$\text{Actual mol ratio: } = \frac{O_2}{C_6H_{12}} = \frac{1.00\text{ mol}}{0.333\text{ mol}} = 3.0 > 2.5$$

Hence: C_6H_{12} is limiting (excess of O_2)

THEORETICAL YIELD:

$$?\text{ g acid} = 28.0\text{ g } C_6H_{12} \bullet \frac{\text{mol } C_6H_{12}}{84.16\text{ g } C_6H_{12}} \bullet \frac{1\text{ mol acid}}{1\text{ mol } C_6H_{12}} \bullet \frac{146.1\text{ g acid}}{\text{mol acid}}$$

$$= 48.6\text{ g adipic acid}$$

ACTUAL YIELD:

$$\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \bullet 100\% = \frac{40.2\text{ g}}{48.6\text{ g}} \bullet 100\%$$

$$= 82.7\ \%$$

Theoretical Yield: 48.6 g **% Yield:** 82.7 %

 # 3. (10 points) In photography, black and white transparencies (black pictures on a transparent background) are produced from the oxidation (*bleaching*) of the metallic silver covering the film to silver ions. Dichromate ions are commonly used as oxidizing agents, in an acidic solution. The following half reactions are involved in the redox process:

$$Cr_2O_7^{2-} \rightarrow Cr^{3+}$$
$$Ag \rightarrow Ag^+$$

a) Determine the overall balanced redox reaction equation. (6 pts)

HALF-REACTIONS AND BALANCING OF ELECTRONS:

$$\begin{array}{l} \text{reduction : } 6\ e^- + 14\ H^+ + Cr_2O_7^{-2} \longrightarrow 2\ Cr^{3+} + 7H_2O \\ \text{oxidation : } \quad Ag \longrightarrow Ag^+ + 1\ e^- \\ \hline \text{reduction : } 6\ e^- + 14\ H^+ + Cr_2O_7^{-2} \longrightarrow 2\ Cr^{3+} + 7H_2O \\ \text{oxidation (x6) : } \quad 6\ Ag \longrightarrow 6\ Ag^+ + 6\ e^- \end{array}$$

OVERALL BALANCED REDOX:

$$\boxed{14\ H^+ + Cr_2O_7^{-2} + 6\ Ag \longrightarrow 6\ Ag^+ + 2\ Cr^{3+} + 7\ H_2O}$$

b) A black and white negative film is covered with 6.15 g of metallic silver. What is the minimum volume (in mL) of a 0.300 M $K_2Cr_2O_7$ that must be added to the bleaching bath to ensure a complete oxidation of the metallic silver present? (4 pts)

SOLUTION:

$$\begin{aligned} ?\ \text{mL of } K_2Cr_2O_7 &= 6.15\ \text{g Ag} \bullet \frac{\text{mol Ag}}{107.8\ \text{g Ag}} \bullet \frac{1\ \text{mol } K_2Cr_2O_7}{6\ \text{mol Ag}} \bullet \frac{1\ \text{L}}{0.300\ \text{mol } K_2Cr_2O_7} \bullet \frac{1000\ \text{mL}}{\text{L}} \\ &= 31.7\ \text{mL of } K_2Cr_2O_7\ \text{solution} \end{aligned}$$

Answer: **31.7 mL**

 # 4. (10 points) A 4.50 g sample of ammonium nitrate is introduced into an evacuated 2.80 L flask and then sealed and heated to 250 °C, causing the following decomposition:

$$NH_4NO_3(s) \rightarrow N_2O\ (g) + 2\ H_2O\ (g)$$

MM = *80.04 g/mol* *44.01 g/ml* *18.02 g/mol*

a) What is the total gas pressure *in mmHg* in the flask once the $NH_4NO_3(s)$ has completely decomposed (assume a complete conversion to the products)? (5 pts)

$$? \text{ mol gas formed} = 4.50 \text{ g } NH_4NO_3 \bullet \frac{\text{mol } NH_4NO_3}{80.04 \text{ g } NH_4NO_3} \bullet \frac{3 \text{ mol of gas formed}}{1 \text{ mol } NH_4NO_3} = 0.1687 \text{ mol of gas}$$

$$\text{since } PV = nRT, \qquad P = \frac{nRT}{V} = \frac{0.1687 \text{ mol} \bullet 0.08206 \frac{\text{atm L}}{\text{K mol}} \bullet 523 \text{ K}}{2.80 \text{ L}} = 2.59 \text{ atm}$$

$$P(\text{in mmHg}) = 2.59 \text{ atm} \bullet \frac{760 \text{ mmHg}}{\text{atm}} = 1968 \text{ mmHg}$$

Answer: **1.97×10^3 mmHg**

b) Pure N_2O*(g)* (also known as nitrous oxide or laughing gas) can be used in a mixture with O_2*(g)* as an anesthetic. In a particular mixture of this type, the partial pressures of N_2O*(g)* and O_2*(g)* are 580 mmHg and 186 mmHg respectively. Calculate the mass percentage of N_2O*(g)* in the mixture. (MM O_2 = 32.00 g/mol) (5 pts)

MOLAR FRACTIONS:

$$\chi_{N_2O} = \frac{P_{N_2O}}{P_{total}} = \frac{580 \text{ mmHg}}{760 \text{ mmHg}} = 0.757$$

$$\chi_{O_2} = \frac{P_{O_2}}{P_{total}} = \frac{186 \text{ mmHg}}{760 \text{ mmHg}} = 0.243$$

MOLAR MASS FOR 1 MOL OF GAS:

$$MM = 0.757 \bullet 44.01 \text{ g/mol} + 0.243 \bullet 32.00 \text{ g/mol} = 41.09 \text{ g/mol}$$

MOLAR MASS FOR 1 MOL OF GAS:

$$\% \ N_2O = \frac{\text{mass of } N_2O}{\text{MM of gas}} \bullet 100\% = \frac{\chi_{O_2} \bullet \text{MM of } N_2O}{\text{MM of gas}} \bullet 100\% = \frac{0.757 \bullet 44.01 \text{ g/mol}}{41.40 \text{ g/mol}} \bullet 100\% = 81.1\ \%$$

Answer: **81.1 %**

 # 5. (10 points) The standard enthalpies for the combustion of glucose ($C_6H_{12}O_6$) and for the fermentation of glucose to ethanol (C_2H_6O) are shown below:

Combustion: $C_6H_{12}O_6(s) + 6\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(g)$ **ΔH° = -2808 kJ**

Fermentation: $C_6H_{12}O_6(s) \rightarrow 2\ C_2H_6O(l) + 2\ CO_2(g)$ **ΔH° = -72 kJ**

a) How much work is performed by the system during the combustion of glucose at 25 °C? (3 pts)

Δn = # mol gas in products - # mol gas in reactants

= 12 mol – 6 mol = 6 mol

W_{system} = - PΔV = - ΔnRT = - 6 mol • 8.31451 J K^{-1} mol^{-1} • 298 K

= -14873 J = -14.873 kJ

Answer: -14.9 kJ

b) Explain briefly the significance of the sign (+ *or* -) of your answer in a). (2 pts)

(-) negative work is done by the system on the surroundings (expansion of the gas)

c) Provide a balanced equation that shows the combustion of ethanol $C_2H_6O(l)$. (2 pts)

$$\boxed{C_2H_6O(l) + 3\ O_2(g) \longrightarrow 2\ CO_2(g) + 3\ H_2O\ (g)}$$

d) Use the standard enthalpies of the reactions provided in the question to calculate the standard enthalpy for the combustion of 1 mol of ethanol $C_2H_6O(l)$. (3 pts)

$$\boxed{\begin{array}{lll} & C_6H_{12}O_6(s) + 6\ O_2(g) \longrightarrow 6\ CO_2(g) + 6\ H_2O\ (g) & \Delta H° = -2808\ kJ \\ (+) & 2\ C_2H_6O(l) + 2\ CO_2(g) \longrightarrow C_6H_{12}O_6(s) & \Delta H° = +72\ kJ \\ \hline & 2\ C_2H_6O(l) + 6\ O_2(g) \longrightarrow 4\ CO_2(g) + 6\ H_2O\ (g) & \Delta H° = -2736\ kJ \\ (/2) & C_2H_6O(l) + 3\ O_2(g) \longrightarrow 2\ CO_2(g) + 3\ H_2O\ (g) & \Delta H° = -1368\ kJ \end{array}}$$

Answer: -1368 kJ