# WUCT: Individual Exam Sample

1. The air we breathe consists of mainly nitrogen and oxygen but also trace amounts of many other gases, such as carbon dioxide, helium, methane and hydrogen. For the purpose of this question, air can be approximated to be a system of three gases: nitrogen, oxygen and argon, with a total pressure of 1 atm and a temperature of 295 K.

   a. Given that the mass percent of nitrogen, oxygen, and argon are 78%, 21%, and 1% respectively, answer the following questions.

   i. Find the partial pressures of each gas.

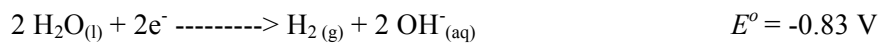   ii. What are the densities of each gas in air?

iii. What is the composition of air by volume?

b.  A sample of air is placed in a 2 L container, with all other conditions the same.

    i.   How many moles of nitrogen are in the container? (Assume the partial pressure of nitrogen is 0.8 atm)

ii. If 0.5 moles of argon was added to the container how would the partial pressure of each gas change?

2. Any alkali metal upon addition to water would result in an explosive reaction. The weakest reaction would be the lithium with water reaction, while the cesium with water reaction is the most explosive. Lithium reacts with water according to the following reactions:

$$2 \; H_2O_{(l)} + 2e^- \; \text{---------}\!> H_{2\,(g)} + 2 \; OH^-_{(aq)} \qquad\qquad E^o = \text{-}0.83 \; V$$
$$Li^+_{(aq)} + e^- \; \text{---------}\!> Li_{(s)} \qquad\qquad E^o = \text{-}3.05 \; V$$

a) Write the overall **balanced** reaction of lithium with water and calculate the overall standard reduction potential.

b) If the reaction occurs at a pH of 9, calculate the equilibrium constant of the reaction at T = 295 K.

3. Hydrogen gas is a popular clean alternative to fossil fuels and can be produced as either a primary product or coproduct from coal. In this production process, the $H_2$ to CO ratio must be adjusted for downstream process requirements, often accomplished by the water gas shift reaction:

$$CO(g) + H_2O(g) \; \rightleftharpoons \; H_2(g) + CO_2(g)$$
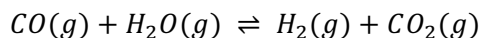
a. What is the equilibrium expression for this reaction, $K_p$?

b.  1.50 atm of CO and a certain amount of $H_2O$ gas is added into a rigid evacuated 3.50 L container at 400.°C. If the equilibrium $H_2$ to CO mole ratio is 3:1, how many moles of $H_2O$ gas was added into the container? ($K_p = 12.0$)

c.  What is the change in Gibbs Free Energy of the reaction?

d.  The standard entropy change for the water gas shift reaction is -42.26 J/K. Assuming the standard entropy change does not vary with temperature, calculate the enthalpy change of the reaction at 400.°C.