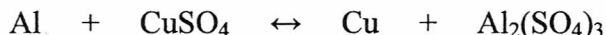
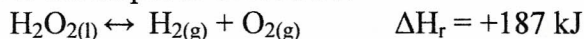


Chemistry 122
Worksheet: Chemical Equilibrium

1. What is the percent yield if you experimentally produce 3.65 g of copper when 1.87 g of aluminum reacts with 9.65 g of copper (II) sulfate?



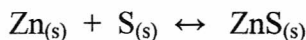
2. Hydrogen peroxide is decomposed as follows:



Predict the direction of equilibrium shift by each of the following imposed changes:

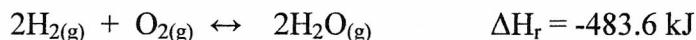
a) Increase the $[\text{H}_2]$	Answer	shift left
b) Decrease the $[\text{O}_2]$	Answer	shift right
c) Decrease the total pressure	Answer	shift right
d) Increase the temperature	Answer	shift right
e) Add MnO_2 as a catalyst	Answer	no change

3. Zinc and sulfur react to produce zinc sulfide, according to the following reaction.

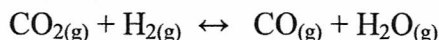


If 25.0 g of zinc, and 30.0 g of sulfur are mixed, 12.8 g of zinc sulfide is found at equilibrium. Determine the limiting reagent, and calculate the percent yield.

4. For the equilibrium listed below, list four stresses that could be placed on the system in an attempt to maximize the amount of product formed.



5. Consider the following reaction:

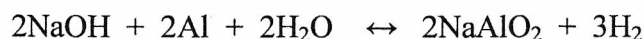


Calculate the value of the equilibrium constant, K , for the above system, if 0.1908 moles of CO_2 , 0.0908 moles of H_2 , 0.0092 moles of CO , and 0.0092 moles of H_2O vapour were present in a 2.00 L reaction vessel at equilibrium.

6. K for $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$ is 32.0. At equilibrium, $[\text{H}_2] = 0.400$ and $[\text{I}_2] = 0.0500$. What does $[\text{HI}]$ equal?

These three problems are meant to be challenging. Give them a try!

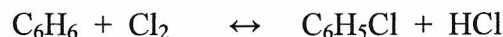
7. Aluminum dissolves in an aqueous solution of NaOH according to the following reaction:



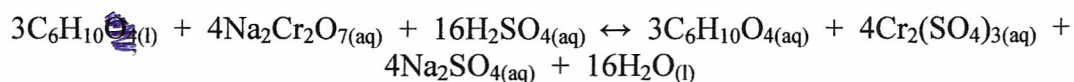
If 84.1 g of NaOH and 51.0 g of Al react:

- Which is the limiting reagent?
- How much of the other reagent remains?
- What mass of hydrogen is produced

8. A research supervisor told a chemist to make 100.0 g of chlorobenzene from the reaction of benzene and chlorine, and to expect a yield no higher than 65%. What is the minimum quantity of benzene that can give 100.0g of chlorobenzene if the yield is 65%? The equation for the reaction is:



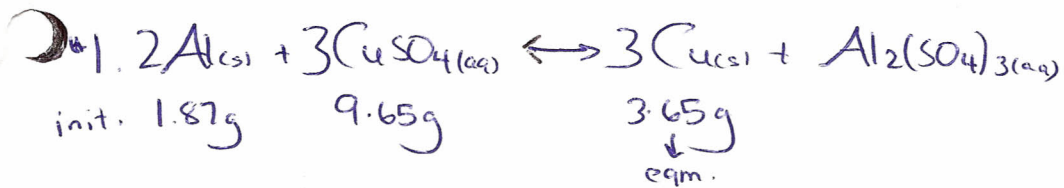
9. Adipic acid, $\text{C}_6\text{H}_{10}\text{O}_4$, is a raw material for the making of nylon and it can be prepared in the laboratory by the following reaction between cyclohexene, C_6H_{10} , and sodium dichromate, $\text{Na}_2\text{Cr}_2\text{O}_7$ in sulphuric acid.



There are side reactions. These plus losses of product during its purification reduce the overall yield. A typical yield of purified adipic acid is 68.6%.

- To prepare 12.5 grams of adipic acid in 68.6% yield requires how many grams of cyclohexene?
- The only available supply of sodium dichromate is its dihydrate, $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$. Since the reaction occurs in an aqueous medium, the water in the dihydrate causes no problems, but it does contribute to the mass of what is taken of this reactant! How many grams of this dihydrate are also required in the preparation of 12.5 grams of adipic acid in a yield of 68.6%?

WORKSHEET: CHEMICAL EQUILIBRIUM



If Al is L.R.

$$1.87\text{g Al} \times \frac{1\text{ mol Al}}{26.98\text{g Al}} \times \frac{3\text{ mol Cu}}{2\text{ mol Al}} \times \frac{63.54\text{g Cu}}{1\text{ mol Cu}} = 6.61\text{g Cu}$$

If CuSO₄ is L.R.

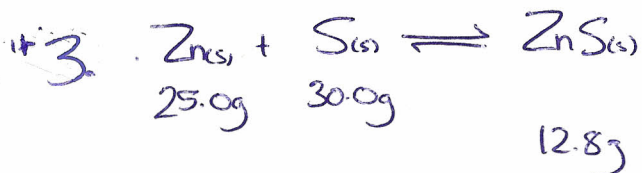
$$9.65\text{g CuSO}_4 \times \frac{1\text{ mol CuSO}_4}{159.60\text{g CuSO}_4} \times \frac{3\text{ mol Cu}}{3\text{ mol CuSO}_4} \times \frac{63.54\text{g Cu}}{1\text{ mol Cu}} = 3.84\text{g Cu}$$

\therefore CuSO₄ is L.R.

$$\% \text{ yield} = \frac{\text{exp}}{\text{theor.}} \times 100\%$$

$$\% \text{ yield} = \frac{3.65\text{g}}{3.84\text{g}} \times 100\%$$

$$\% \text{ yield} = 95.1\%$$



If Zn is L.R.

$$25.0\text{g Zn} \times \frac{1\text{ mol Zn}}{65.39\text{g Zn}} \times \frac{1\text{ mol ZnS}}{1\text{ mol Zn}} \times \frac{97.45\text{g ZnS}}{1\text{ mol ZnS}} = 37.26\text{g ZnS}$$

If S is L.R.

$$30.0\text{g S} \times \frac{1\text{ mol S}}{32.06\text{g S}} \times \frac{1\text{ mol ZnS}}{1\text{ mol S}} \times \frac{97.45\text{g ZnS}}{1\text{ mol ZnS}} = 91.19\text{g ZnS}$$

\therefore Zn is L.R.

$$\% \text{ yield} = \frac{\text{exp}}{\text{theor.}} \times 100\%$$

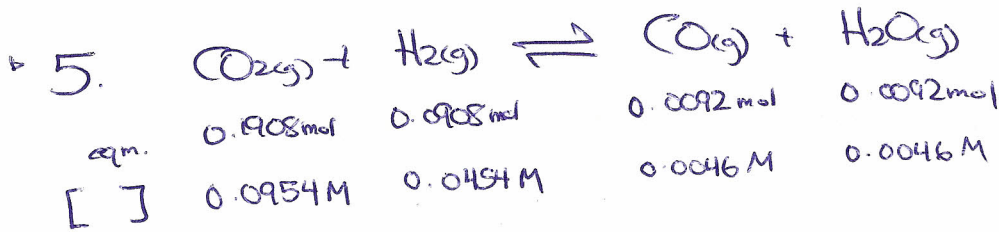
$$\% \text{ yield} = \frac{12.8\text{g}}{37.26\text{g}} \times 100\%$$

$$\% \text{ yield} = 34.4\%$$



$$\Delta H_r = -483.6 \text{ kJ}$$

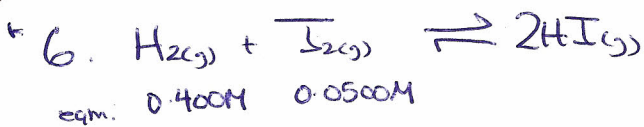
- ① Increase $[\text{H}_2(\text{g})]$, $[\text{O}_2(\text{g})]$
- ② Cool system
- ③ Decrease $[\text{H}_2\text{O}(\text{g})]$
- ④ Increase pressure
- ⑤ Decrease volume



$$K = \frac{[\text{CO}(\text{g})][\text{H}_2\text{O}]}{[\text{CO}_2(\text{g})][\text{H}_2(\text{g})]}$$

$$K = \frac{[0.0046][0.0046]}{[0.0954 \text{ M}][0.0454 \text{ M}]}$$

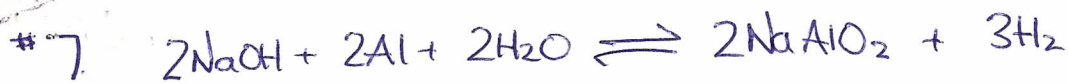
$$K = 4.89 \times 10^{-3}$$



$$K = \frac{[\text{HI}(\text{g})]^2}{[\text{H}_2(\text{g})][\text{I}_2(\text{g})]} = 32.0$$

$$[\text{HI}(\text{g})] = \sqrt{32.0 [0.400 \text{ M}][0.0500 \text{ M}]}$$

$$[\text{HI}(\text{g})] = 0.800 \text{ M}$$



init. 84.1g 51.0g

i) IF NaOH is L.R.

$$84.1\text{g NaOH} \times \frac{1\text{ mol NaOH}}{40.00\text{g NaOH}} \times \frac{3\text{ mol H}_2}{2\text{ mol NaOH}} \times \frac{2.02\text{g H}_2}{1\text{ mol H}_2} = 6.37\text{g H}_2$$

IF Al is L.R.

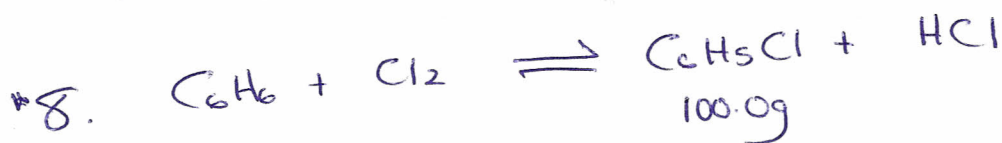
$$51.0\text{g Al} \times \frac{1\text{ mol Al}}{26.98\text{g Al}} \times \frac{3\text{ mol H}_2}{2\text{ mol Al}} \times \frac{2.02\text{g H}_2}{1\text{ mol H}_2} = \underline{5.73\text{g H}_2}$$

Al is L.R.

$$\text{ii) } 51.0\text{g Al} \times \frac{1\text{ mol Al}}{26.98\text{g Al}} \times \frac{2\text{ mol NaOH}}{2\text{ mol Al}} \times \frac{40.00\text{g NaOH}}{1\text{ mol NaOH}} = 75.6\text{g NaOH used}$$

$$\text{Amount xs reagent: } 84.1\text{g} - 75.6\text{g} = \underline{8.5\text{g NaOH}}$$

iii) 5.73g H₂ produced.

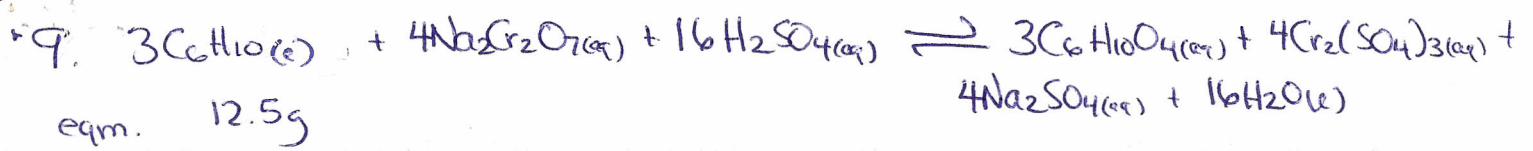


$$\% \text{ yield} = \frac{\text{exp}}{\text{theor}} \times 100\%$$

$$0.65 = \frac{100.0\text{g}}{\text{theor.}}$$

$$\text{theor. yield} = \frac{100.0\text{g}}{0.65} = 153.85\text{g}$$

$$153.85\text{g C}_6\text{H}_5\text{Cl} \times \frac{1\text{ mol C}_6\text{H}_5\text{Cl}}{112.56\text{g C}_6\text{H}_5\text{Cl}} \times \frac{1\text{ mol C}_6\text{H}_6}{1\text{ mol C}_6\text{H}_5\text{Cl}} \times \frac{78.12\text{g C}_6\text{H}_6}{1\text{ mol C}_6\text{H}_6} = \underline{106.8\text{g}}$$



eqm. 12.5g

% yield = 68.6%

$$\% \text{ yield} = \frac{\text{exp}}{\text{theor.}} \times 100\%$$

$$\text{theor. yield} = \frac{12.5 \text{ g}}{0.686}$$

$$\boxed{\text{theor. yield} = 18.22 \text{ g}}$$

$$18.22 \text{ g C}_6\text{H}_{10}\text{O}_4 \times \frac{1 \text{ mol C}_6\text{H}_{10}\text{O}_4}{146.16 \text{ g C}_6\text{H}_{10}\text{O}_4} \times \frac{3 \text{ mol C}_6\text{H}_{10}}{3 \text{ mol C}_6\text{H}_{10}\text{O}_4} \times \frac{82.16 \text{ g C}_6\text{H}_{10}}{1 \text{ mol C}_6\text{H}_{10}} = \boxed{10.2 \text{ g C}_6\text{H}_{10}}$$

$$b) \quad 18.22 \text{ g C}_6\text{H}_{10}\text{O}_4 \times \frac{1 \text{ mol C}_6\text{H}_{10}\text{O}_4}{146.16 \text{ g C}_6\text{H}_{10}\text{O}_4} \times \frac{4 \text{ mol Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}}{3 \text{ mol C}_6\text{H}_{10}\text{O}_4} \times \frac{298.02 \text{ g Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}}{1 \text{ mol Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}}$$

$$= \boxed{49.5 \text{ g Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}}$$