Concentration-Time Graphs - Worksheet

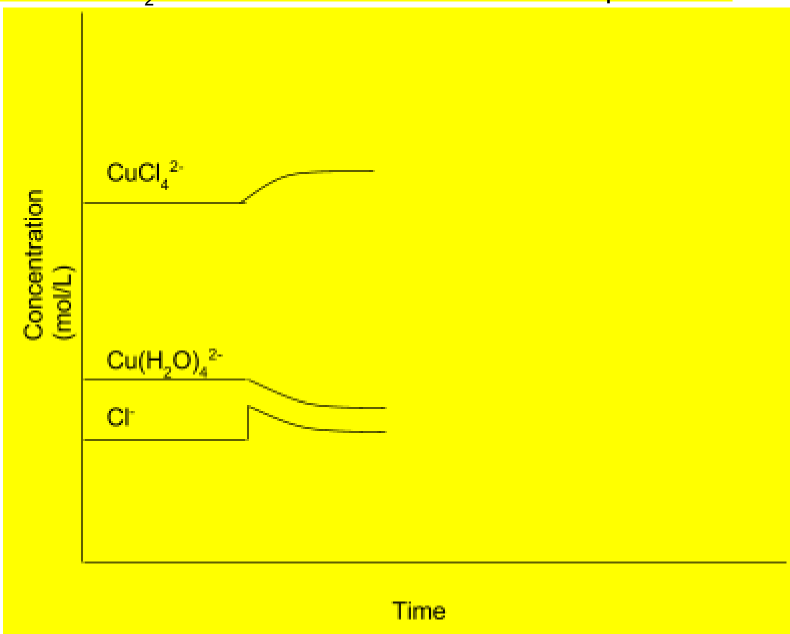
1. In a solution of copper(II) chloride, the following equilibrium exists:

   $CuCl_4^{2-}{}_{(aq)}$ + 4 $H_2O_{(l)}$ ⇋ $Cu(H_2O)_4^{2+}{}_{(aq)}$ + 4 Cl^{1-}

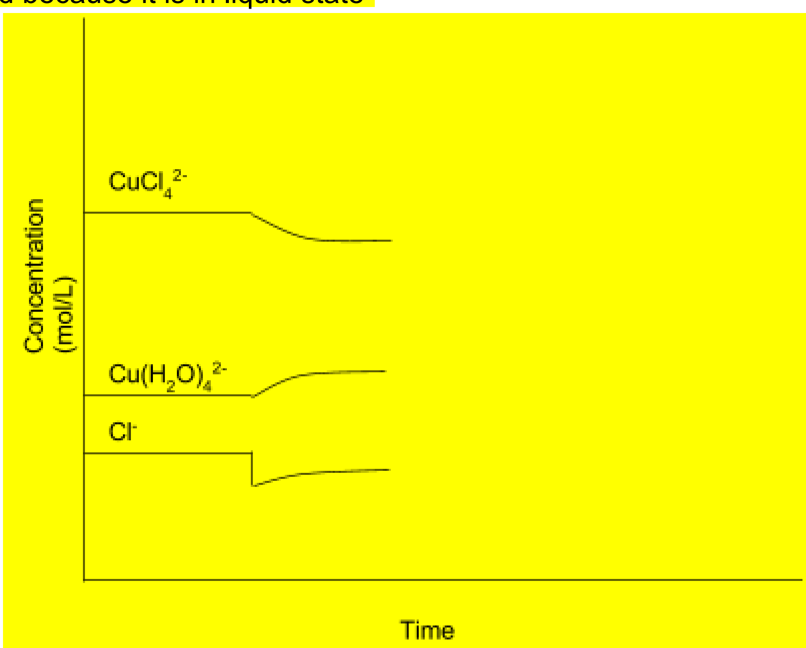
   dark green   blue

   Predict the shift in the equilibrium and draw a graph of concentration versus time for relevant reactants to communicate the shift after the following stresses are applied to the system:

   a. Hydrochloric acid is added Initial increase in [Cl^-]; system response is to shift to reactants. *Note: H_2O is not included because it is in liquid state*



   b. Silver nitrate is added Initial decrease in [Cl^-] since addition of Ag^+ will cause a precipitate of AgCl; system response is to shift to products. *Note: H_2O is not included because it is in liquid state*



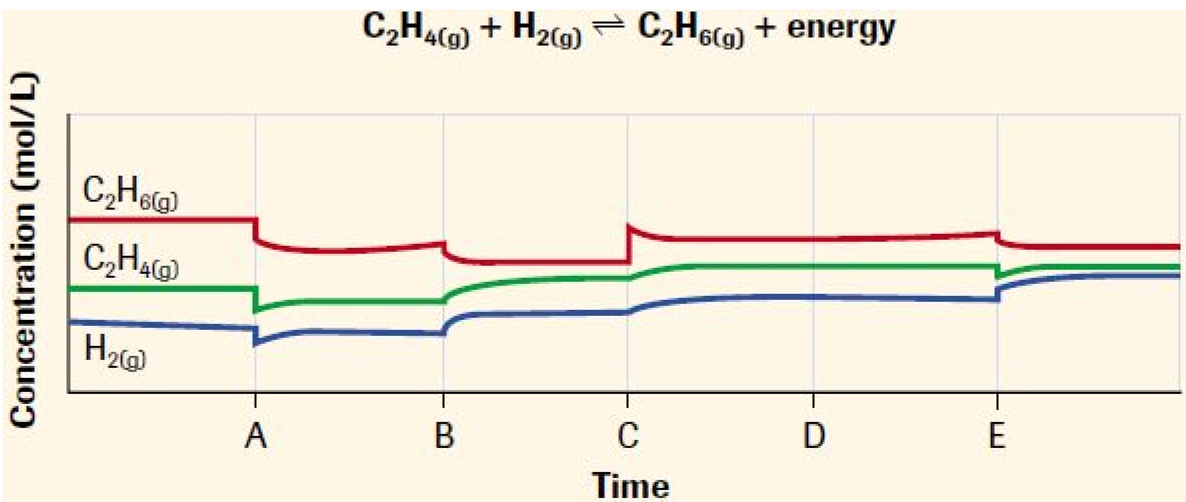
2. The two oxyanions of chromium(IV) are the orange dichromate ion, $Cr_2O_7^{2-}{}_{(aq)}$, and the yellow chromate ion, $CrO_4^{2-}{}_{(aq)}$. Explain why a solution containing the following equilibrium system turns yellow when sodium hydroxide is added.

$$Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons 2\ CrO_4^{2-}{}_{(aq)} + 2\ H^+{}_{(aq)}$$

orange yellow

When NaOH solution is added the OH^- reacts with the H^+ creating H_2O and reducing the concentration of H^+. Thus the system will respond to the change by shifting to the products, reducing the H_2O concentration and raising the H^+ concentration. Since it shifts to the products we produce more of the yellow substance thus the solution becomes yellow.

3. Identify the nature of the change imposed on the equilibrium system, shown below, at each of the times indicated A, B, C, D, and E.



A - P↓/V↑ - you can tell because the initial drop in all concentrations occurred then the system responded by shifting to the reactants to produce more gas molecules thus raising the pressure.

B - T↑ - you can tell because none of the initial concentrations changed but the system response shifted to the reactants thus lowering the amount of KE present in the system, effectively lowering the temp.

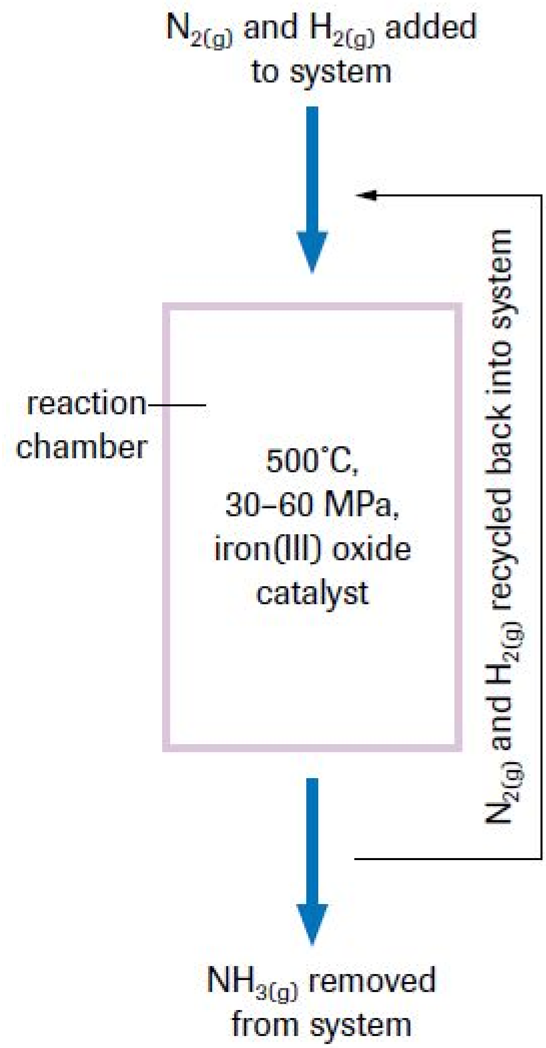
C - $[C_2H_{6\ (g)}]$↑ - seen by the initial change and the response by the system to move toward the reactant side thus lowering the $[C_2H_{6\ (g)}]$

D - no change occurred - also possible that a catalyst was added as it would not change the equilibrium

E - $[C_2H_4]$↓ - the system responds by shifting the the reactants thus raising the $[C_2H_4]$. - This one is tricky because of the way the graph was drawn, on a test or other evaluation the initial change would be more obvious.

The Haber Process

Do some research regarding the Haber Process to help you answer the following questions, take a look at the Useful Links section of the school website as a starting point:



4. What can ammonia be used for?

   Ammonia can be used for fertilizer, the synthesis of nylon, and the production of hundreds of other chemicals. It is also used to make explosives.

5. Write a balanced chemical equation for the Haber Process.

   $N_{2\,(g)} + 3\,H_{2\,(g)} \rightleftharpoons 2\,NH_{3\,(g)} + 92.4\text{ kJ}$

6. Examine the image to the right. Describe how Haber manipulated each of the following factors to produce an optimal yield of ammonia. Using Le Châtelier's Principle, explain which direction (forward or reverse) each change would favour.

   a. temperature

      An intermediate temperature of about 500℃ is used. This is a compromise between the low temperature required for a desirable equilibrium state (i.e. shift to products) and the high temperature needed for a satisfactory rate.

   b. pressure

      Very high pressure is used, between 30 and 60 MPa. This would shift the reaction to the products in order for the reaction to try and oppose the pressure change. Equipment needed for extremely high pressures is very expensive so most of the time 35 MPa is used.

   c. concentration

      The NH_3 is removed by liquifying it under conditions at which H_2 and N_2 remain as gases. The unreacted H_2 and N_2 are then recycled back into the reaction vessel to raise the concentration of reactants. Both of these changes shift the equilibrium to the product side of the reaction. This will maximize the yield of the ammonia.

7. What else did Haber do to achieve a reasonable reaction rate for this process?

   Under the conditions listed above the reaction does take quite a while to reach equilibrium. In order to achieve a reasonable reaction rate Haber added a catalyst, iron(III) oxide, to achieve a reasonable reaction rate.

8. Why was the development of the Haber Process a significant factor in World War I?

   It actually extended World War I. The Germans no longer had to import nitrogen containing compounds. Instead, they could manufacture ammonia and use that to make explosives. They no longer had to worry about naval blockades cutting off their supply of nitrogen containing compounds.