Chemistry 12 II 4

Equilibrium II

(pg 50-55)

Name:
Date:
Block:

1. **Le Châtelier's Principle**
2. **Equilibrium Graphs**

Le Châtelier's Principle

When a person is stressed, their body will work in some way to alleviate the imposed stress.

Le Châtelier's Principle: An equilibrium system subjected to a stress will __shift__ to partially alleviate the stress and __restore__ equilibrium.

- Whenever a system is stressed, it alleviates it by altering the concentration of reactants or products.

When a system responds by changing some **reactants into products**, the response is referred to as "__shift__ __right__" because the products are on the right side of the chemical equation.

$A + B \rightleftharpoons AB$

When a system responds by changing some **products back into reactants**, the response is referred to as "__shift__ __left__" because the reactants are on the left side of the chemical equation.

$A + B \rightleftharpoons AB$

Stresses – Changes in conditions:

1. **Concentration**

$$2\ NOCl_{(g)} \leftrightharpoons 2\ NO_{(g)} + Cl_{2\,(g)}$$

In which direction will the reaction shift to alleviate the stress. Compare the concentration of each substance before the stress:

will spike up, then slowly decrease as the shift away from reactants occurs

- Addition of $NOCl_{(g)}$:
  - Shift: Right
  - [NOCl] ↑↓ [NO] ↑ [Cl$_2$] ↑

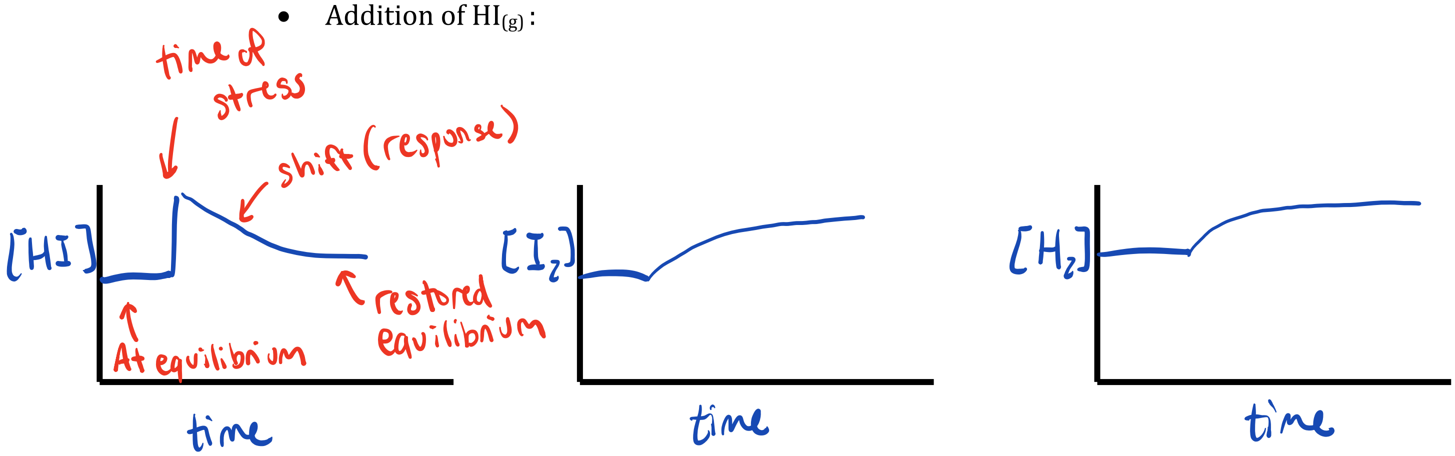
rxn has shifted towards products

- Addition of $NO_{(g)}$:
  - Shift: Left
  - [NOCl] ↑ [NO] ↑↓ [Cl$_2$] ↓
- Removal of $NO_{(g)}$:
  - Shift: Right
  - [NOCl] ↓ [NO] ↓↑ [Cl$_2$] ↑
- Removal of $Cl_{2(g)}$:
  - Shift: Right
  - [NOCl] ↓ [NO] ↑ [Cl$_2$] ↓↑

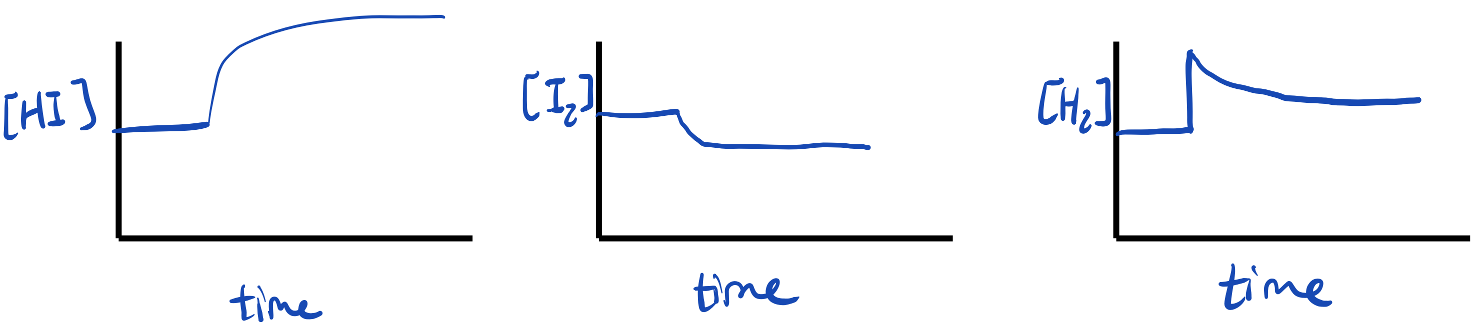
$H_{2\,(g)} + I_{2\,(g)} \rightleftharpoons 2\,HI_{(g)}$

In which direction will the reaction shift to alleviate the stress:

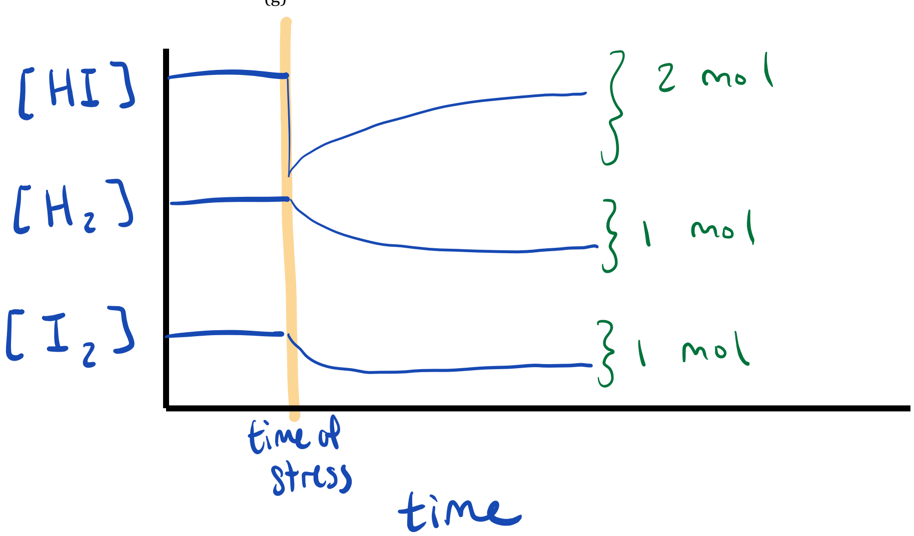
- Addition of $HI_{(g)}$:



- Addition of $H_{2\,(g)}$:



- Removal of $HI_{(g)}$:



For every 2 mol of HI, 1 mol of H_2 and 1 mol of I_2 reacts

Consider the following equilibrium system:

$$2\ SO_{2\ (g)} + O_{2\ (g)} \leftrightharpoons 2\ SO_{3\ (g)}$$

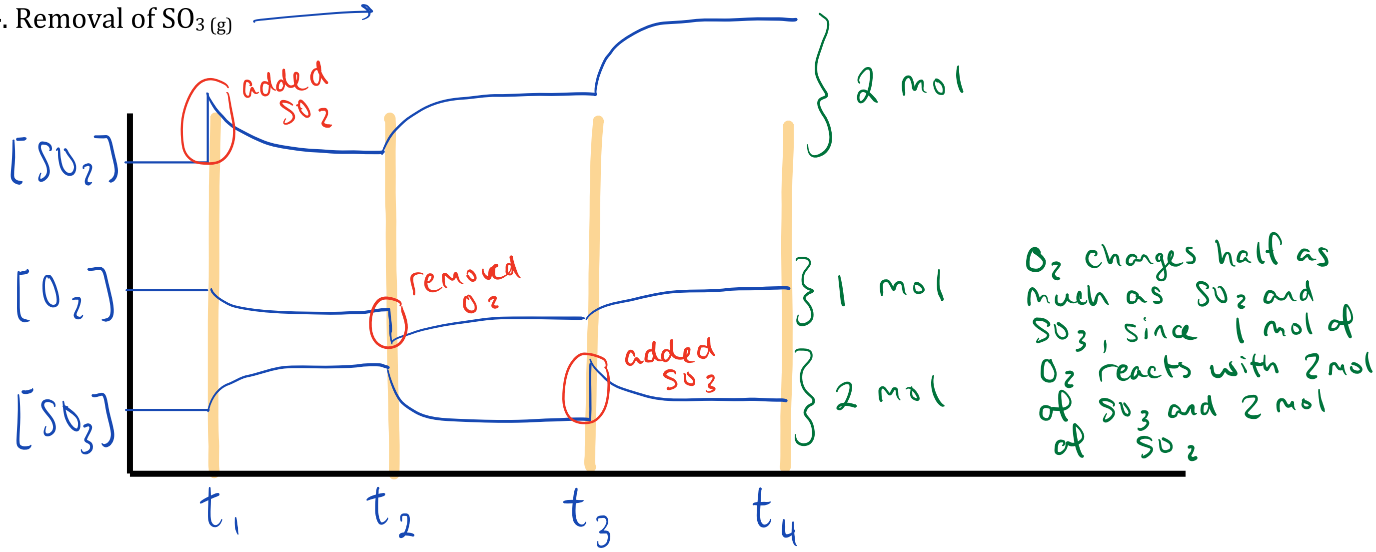
Explain in terms of forward and reverse reaction rates how the equilibrium would respond to each of the following changes:

t_1 1. Addition of $SO_{2\ (g)}$ →

t_2 2. Removal of $O_{2\ (g)}$ ←

t_3 3. Addition of $SO_{3\ (g)}$ ←

t_4 4. Removal of $SO_{3\ (g)}$ →



Application:

Hemoglobin is the protein in red blood cells that transports oxygen to cells throughout your body. Each hemoglobin (Hb) molecule attaches to four oxygen molecules:

$$Hb_{(aq)} + 4\ O_{2\ (aq)} \leftrightharpoons Hb(O_2)_{4\ (aq)}$$

In which direction does the above equilibrium shift in each of the following situations:

a) At high elevations the air pressure is lowered reducing the $[O_2]$ in the blood.

Shift left

b) At high altitude, climbers breathe pressurized oxygen from a tank to increase the $[O_2]$ in the blood.

Shift right

c) People who live at higher altitudes produce more hemoglobin. (more Hb)

Shift right

d) Carbon monoxide poisoning occurs when carbon monoxide molecules bind to hemoglobin instead of oxygen molecules. Carboxyhemoglobin is even redder than oxyhemoglobin; therefore, one symptom of carbon monoxide poisoning is a flushed face. (less Hb)

Shift left

2. Temperature

*no spikes

- The system will shift to remove some of the added kinetic energy or to replace some of the remove kinetic energy.

$$181\text{ kJ} + N_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2\,NO_{(g)} \qquad \Delta H = +181\text{ kJ/mol}$$

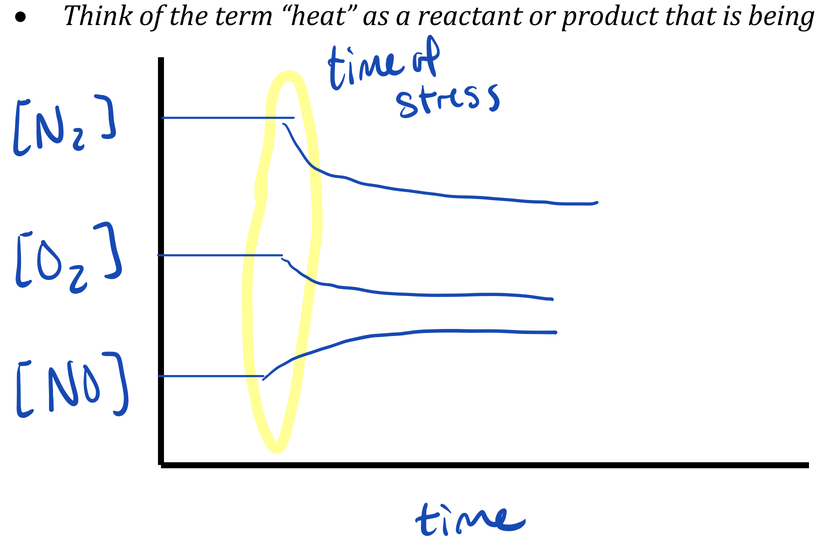
1. Is this an endothermic or exothermic reaction?

   endothermic

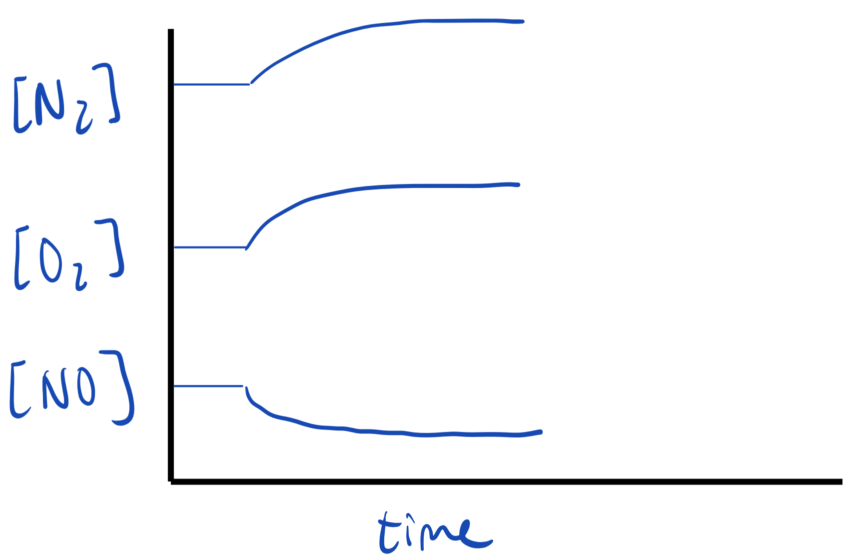
2. Rewrite the equation with "heat" as a reactant or product.

   $$181\text{ kJ} + N_{2\,(g)} + O_{2\,(g)} \rightleftharpoons 2NO_{(g)}$$

3. If the system is heated, in which direction will the system shift to restore equilibrium?
   - *Think of the term "heat" as a reactant or product that is being added or consumed.*



4. If the system is cooled, in which direction will the system shift to restore equilibrium?
   - *Think of the term "heat" as a reactant or product that is being added or consumed.*

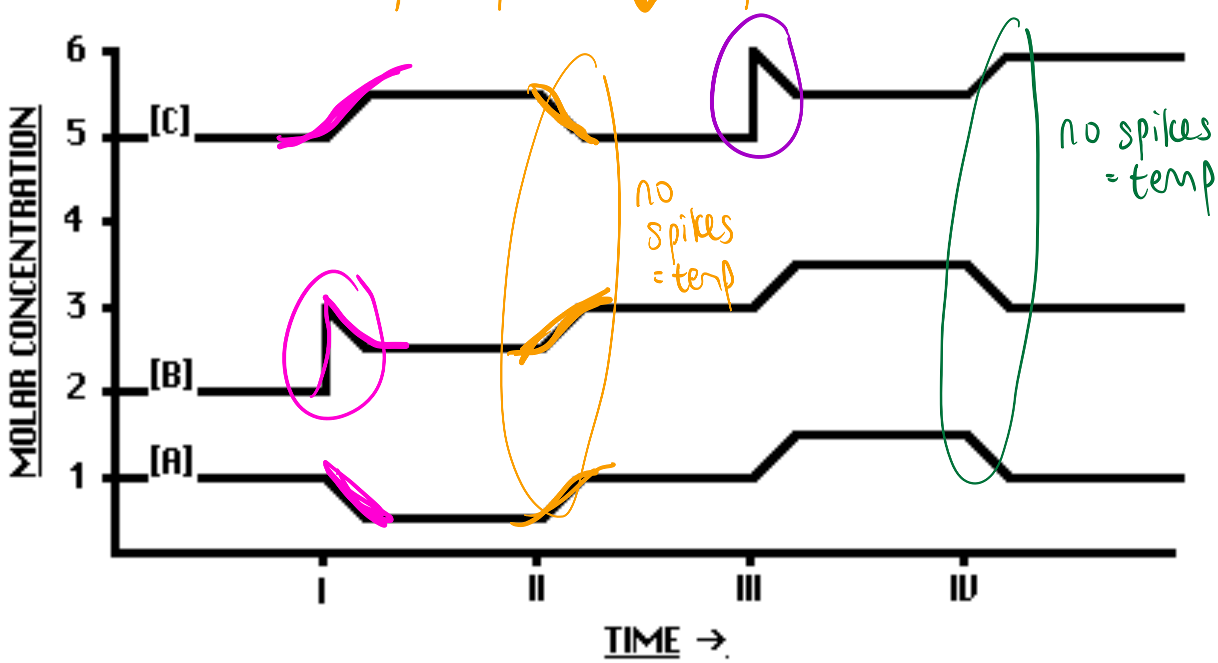


Example:

Given the following graph showing the concentrations of species A, B and C, state what changes in **temperature** or **concentration** are responsible for each of the shifts shown on the graph. The equilibrium equation is:

$$A(g) + B(g) \rightleftarrows C(g) \qquad \Delta H = -65\ kJ$$

+ heat ← exo



a) At time I, the reaction shifted right. The stress is added B.

b) At time II, the reaction shifted left. The stress is increased temp.

c) At time III, the reaction shifted left. The stress is added C.

d) At time IV, the reaction shifted right. The stress is decreased temp.

*ALL spikes

3. Pressure/Volume (only gases)

- The system will respond to volume changes by shifting to relieve some of the added pressure or to replace some of the lost pressure.
- Recall from Chemistry 11:
  - *Avogadro's Hypothesis: Equal volumes of different gases, measured the same temperature and pressure, have equal numbers of particles.*

$\frac{22.4 L}{1 mol}$ @STP

$$PCl_{3 (g)} + Cl_{2 (g)} \leftrightharpoons PCl_{5 (g)}$$

1. How many moles of gases are on each side?

   Reactant : 1 mol of PCl_3 & 1 mol of Cl_2 = (2)

   Product : 1 mol of PCl_5 = (1)

2. (t₁) If the volume was increased… (or pressure was decreased)
   a. What would happen to the concentration of each gas?

      All [gas] will decrease

   b. Will the equilibrium shift? If so, towards which side?

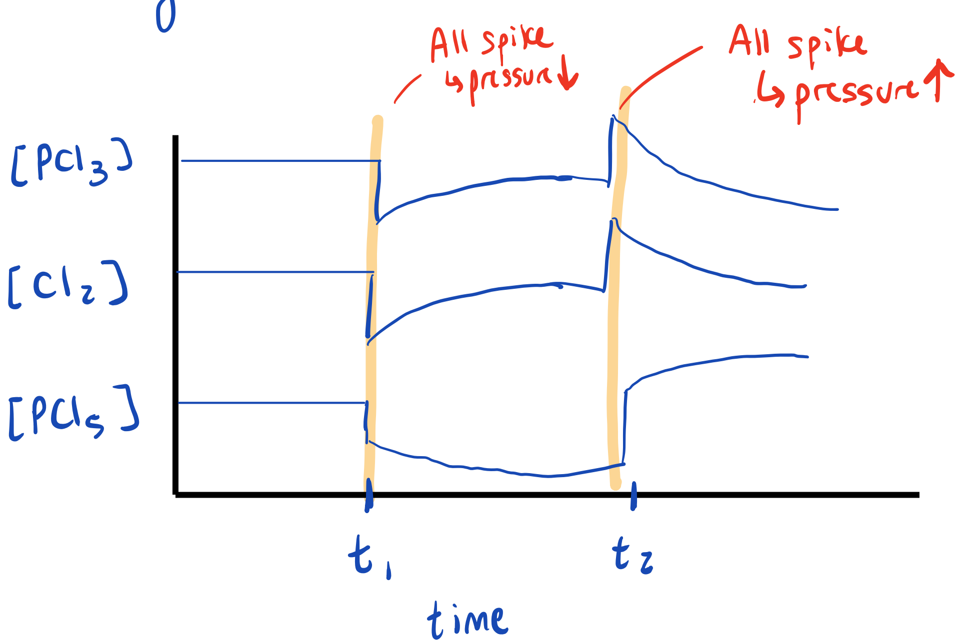
      yes - shifts left (to the side with more molecules)

3. (t₂) If the pressure was increased… (or volume was decreased)
   a. What would happen to the concentration of each gas?

      All [gas] will increase

   b. Will the equilibrium shift? If so, towards which side?

      yes - shift right (to the side with fewer molecules)



$H_{2\,(g)} + F_{2\,(g)} \leftrightharpoons 2\,HF_{(g)}$

1. How many moles of gases are on each side?

   Reactant : 2

   Product : 2

t1

2. If the volume was increased… (or pressure was decreased)
   a. What would happen to the concentration of each gas?

      All [gas] decrease

   b. Will the equilibrium shift? If so, towards which side?

      No shift (same # of molecules on both sides)

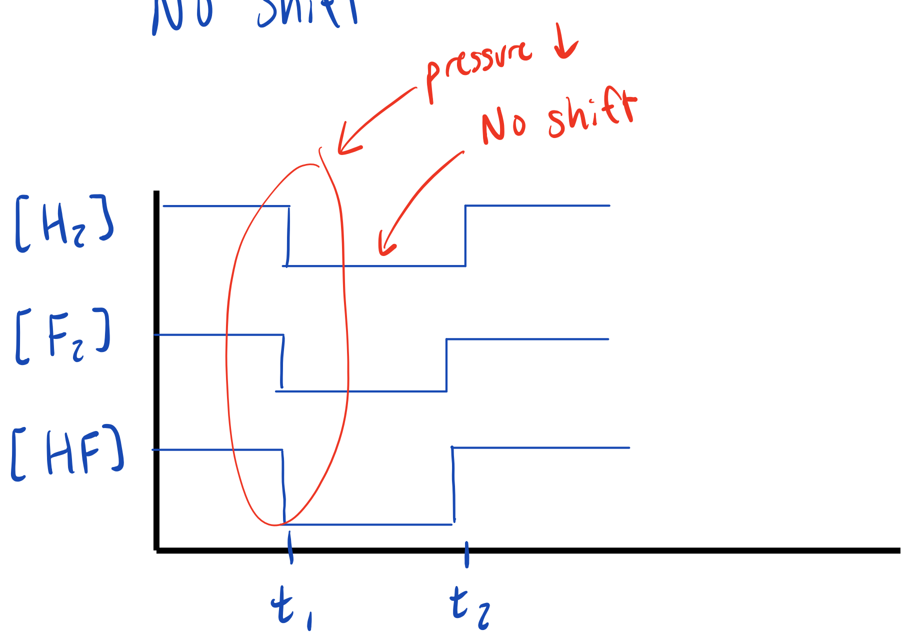
t2

3. If the pressure was increased… (or volume was decreased)
   a. What would happen to the concentration of each gas?

      All [gas] increase

   b. Will the equilibrium shift? If so, towards which side?

      No shift



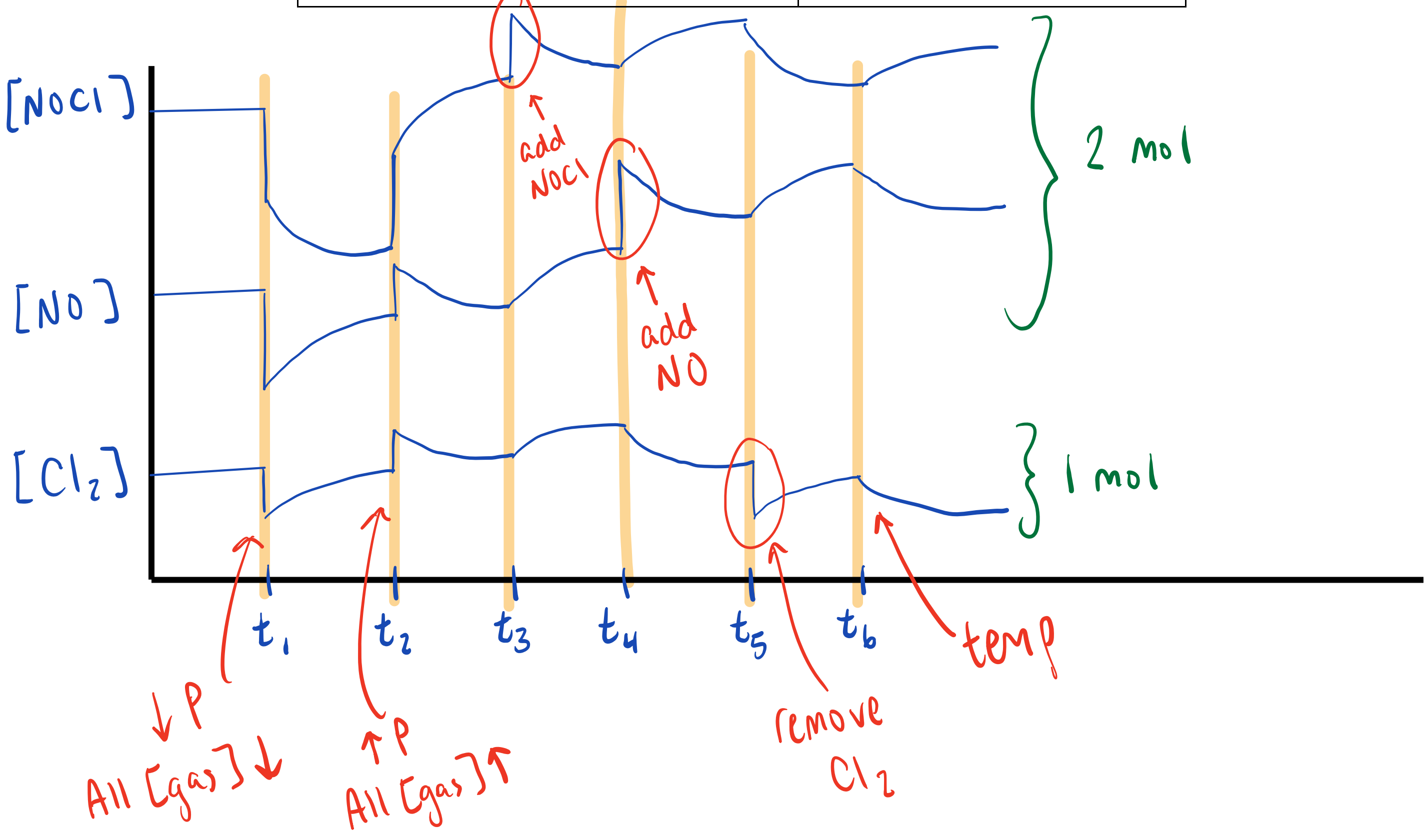
4. Catalyst

- Does not change or shift the equilibrium
- Forward and reverse rates are increased by same amount

2 mol 3 mol

$2\ NOCl_{(g)} \leftrightharpoons 2\ NO_{(g)} + Cl_{2\,(g)} + \text{heat}$

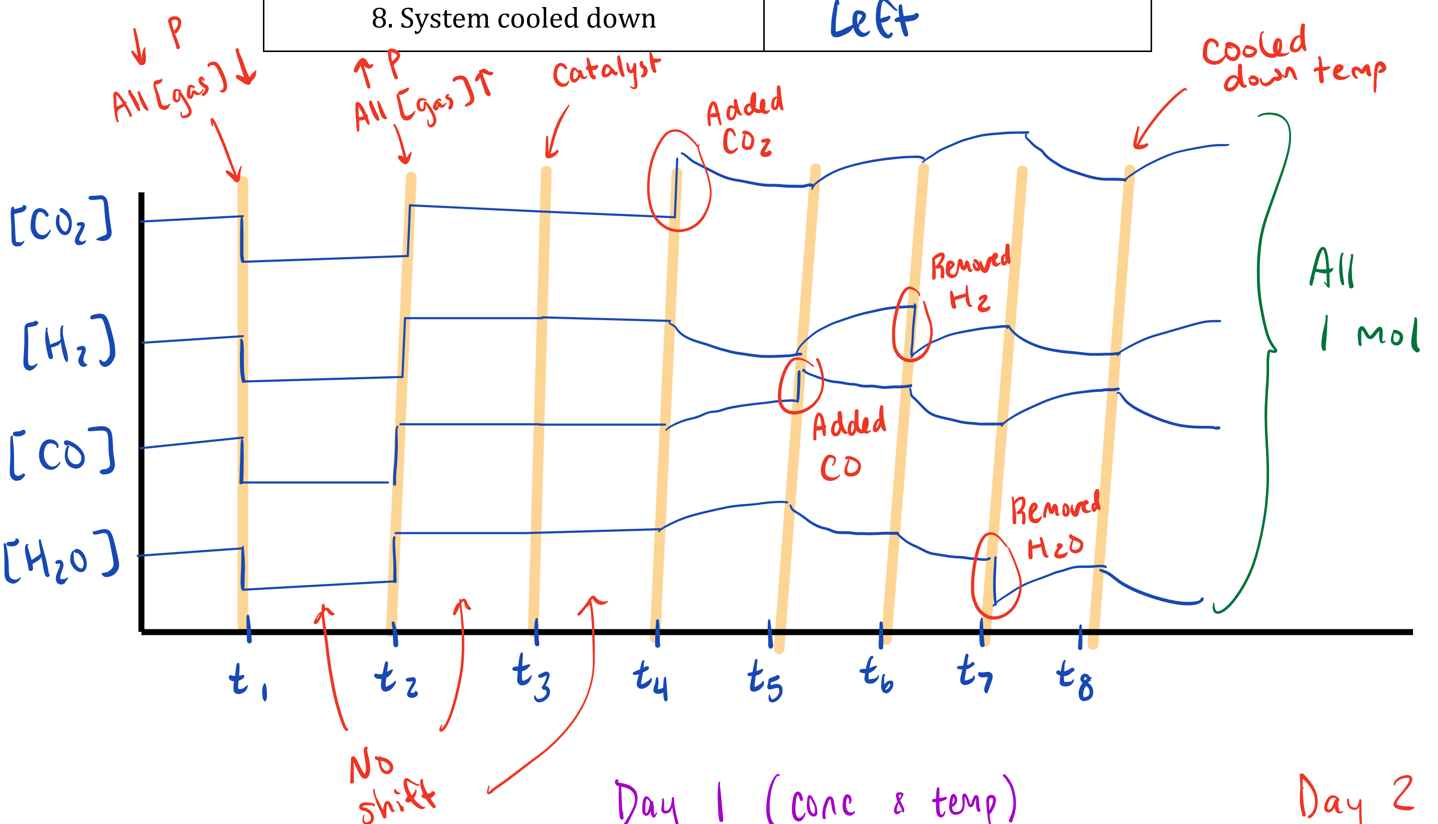
Stress:	**Equilibrium shift:**
t_1 1. Increase in volume (↓ P)	right
t_2 2. Decrease in volume (↑ P)	left
t_3 3. Addition of reactant	right
t_4 4. Addition of NO	left
t_5 5. Removal of Cl_2	right
t_6 6. Increase heat	left



2 mol | 2 mol

$CO_{2(g)} + H_{2(g)} + heat \rightleftharpoons CO_{(g)} + H_2O_{(g)}$

Stress:	Equilibrium shift:
1. Increase in volume (↓P)	No shift, but all spike down (Same # of molecules on both sides)
2. Increase in pressure (↑P)	No shift, but all spike up
3. Addition of catalyst	No shift and no spike
4. Addition of CO_2	Right
5. Addition of CO	Left
6. Removal of H_2	Left
7. Removal of H_2O	Right
8. System cooled down	Left



Day 1 (conc & temp) #1, 5, 7, 8 abd, 14 | Day 2 All

Le Chatelier's Principle Worksheet

Hebden Read pg. 50-53, Questions pg. 54 #17-28

Day 1 Just answer Q's on conc & temp | Day 2 All