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

Stress	Shift	[CO]	[H_2O]	[CO_2]	[H_2]
Add $CO_{2(g)}$	L	↑	↑		
Increase temperature	L	↑	↑		
Remove $H_2O_{(g)}$	L	↑	↑=↓		
Increase volume	–	↓	↓		
Add $H_{2(g)}$	L	↑	↑		
Increase pressure	–	↑	↑		
Inject $Ar_{(g)}$	–	–	–	–	–

III) Equilibrium Graphs

Changes to an equilibrium system have been described in the last section. In this section, we will graphically represent concentration changes.

Things to remember: • amounts of (s) and (ℓ) affected by shifts, but not their [conc.]

1) Solid and liquid concentrations always remain constant.
• in chemia, for our purposes, (s) and (ℓ) will NOT cause a shift

2) When there is a temperature change, there are no immediate changes in concentration (spikes). The only changes are gradual (due to the shift) for (g) and (aq).

3) Changes in pressure result in immediate changes to gas concentrations, followed by a **possible** shift that will cause gradual changes in all (g) and (aq) substances.

4) A concentration change for a substance shows an immediate change for that substance, followed by gradual changes for the other (g) and (aq) substances.

Graph the changes for the following system:

$$2SO_{2(g)} + O_{2(g)} \Leftrightarrow 2SO_{3(g)} + \text{energy}$$

a) increase in temperature
b) add $SO_{2(g)}$
c) add a catalyst
d) decrease volume

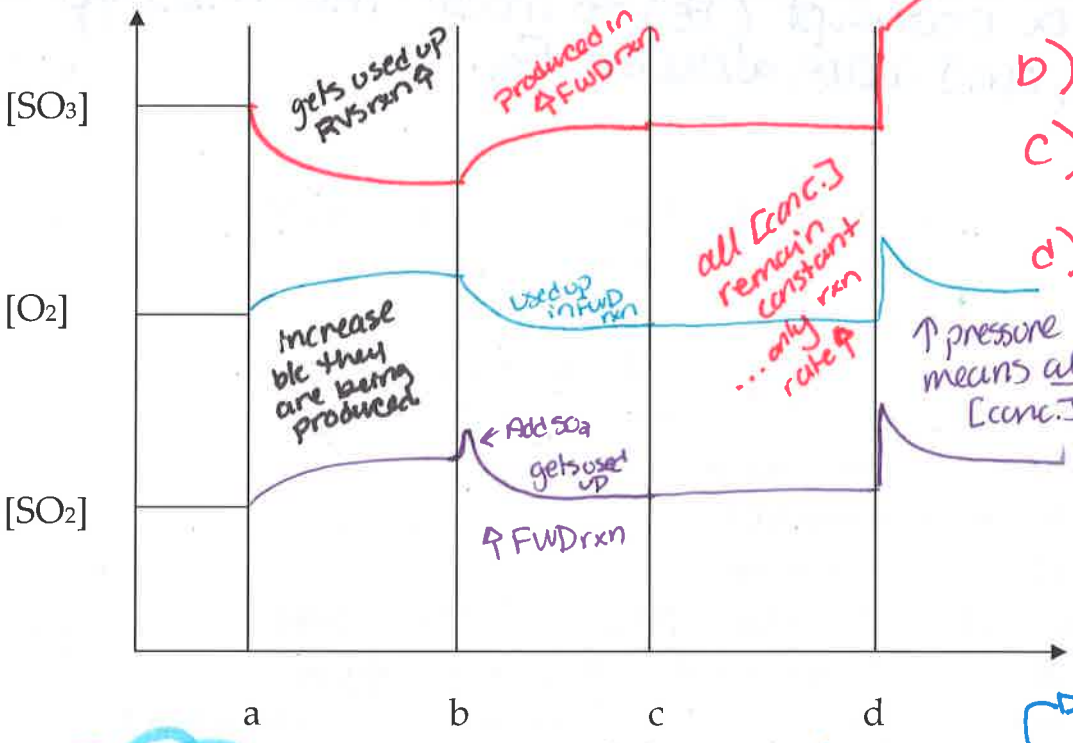
↑ in pressure favors side with least gas molecules.

a) ↑ Temp → shift

b) ↑ $[SO_2]_g$ → shift

c) no shift ∴ [conc.] constant

d) ↓ volume means ↑ Pressure → shift.



explosion killed lab assistant

1901 - LeChatelier tried to make NH_3 from Na + Ha

1908 - was successfull 1918 - nobel prize ... but also war criming

Haber Process

The Haber Process for making ammonia (NH_3) was developed by German chemist Fritz Haber prior to World War I. In order for Germany to make TNT, which contains nitrogen, they needed a source of nitrates from soil, which they were purchasing from Chile. However, the British cut off the shipping lines from Chile once the war began. Haber had to develop a process to make ammonia (NH_3) from N_2. The ammonia could then be used as a precursor for TNT. Getting N_2 to react is very difficult due to its triple bond. However, Haber manipulated an equilibrium system to maximize the yield (amount) of NH_3.

*animation *The Haber Process:* $N_{2(g)} + 3H_{2(g)} \Leftrightarrow 2NH_{3(g)} + 92.4kJ$

To maximize the yield of ammonia, the equilibrium must be shifted right (max) as much as possible. What should the temperature and pressure conditions be (high or low) to achieve this? low (400°C) temperature & high (200atm) pressure

*1931 German chemist Carl Bosch won the nobel prize for chem for transforming the process to an even larger scale

What else did Haber do to maximize the yield of ammonia?

1) The constant removal of NH_3 from the system causes/drives a permanent shift to the right.

2) Added a catalyst (Fe) to make the rates go faster, and have a lower Ea.

Assignment 4: Graph each system below.

1) $2C_{(s)} + O_{2(g)} \Leftrightarrow 2CO_{(g)}$ $\Delta H = -97kJ$

stresses: a) decrease volume c) add CO
b) add O_2 d) increase temperature

2) $SO_{3(g)} + NO_{(g)} \Leftrightarrow NO_{2(g)} + SO_{2(g)}$ + energy

stresses: a) increase temperature
b) remove some $NO_{2(g)}$
c) decrease pressure

3) $CH_{4(g)} + H_2O_{(g)} \Leftrightarrow CO_{(g)} + 3H_{2(g)}$ $\Delta H = +50kJ$

stresses: a) increase temperature d) decrease volume
b) decrease temperature e) add something which reacts
c) decrease pressure with H_2O

4) Make a graph for the Haber Process with each stress:
(a) decrease temp (b) increase pressure (c) remove NH_3

5) Hebden p. 55 #27, 28