Water Gas Shift Reaction: This is a way to produce hydrogen industrially.
This reaction is **exothermic** and its ΔH value is **negative**. Therefore, energy is produced on the right side of the equation.

$CO_{(g)} + H_2O_{(g)} \leftarrow \rightarrow CO_{2(g)} + H_{2(g)}$ **+ heat** **<--- *Notice that "+ heat" is now added in***

Disruption to Equlibrium	Which direction does the equilibrium shift?	Will this increase or decrease?	Explain why: which reaction rate is changing (forward or reverse), and why?
Remove CO_2 gas	Right	H_2 Increase	Reverse reaction rate slows due to less CO_2 Forward reaction therefore now favored
Add CO gas	Right	H_2 Increase	Forward reaction rate speeds up due to more CO
Remove H_2 gas	Right	CO_2 Increase	Reverse reaction slows due to less H_2 Forward reaction therefore now favored
Add H_2O gas	Right	CO Decrease	Forward reaction rate speeds up to to more H_2O
Increase temperature	Left	CO_2 Decrease	More heat speeds up reverse reaction Reverse reaction causes things to cool back down
Cool the reactor (reduce temp.)	Right	H_2 Increase	Less heat slows down reverse reaction FW reaction dominates and heats things back up

How can you setup this equilibrium system to create as much H_2 gas as possible?
Cause right shift: add more CO and H_2O, remove CO_2 and H_2, and run reaction at a low temperature.

Haber Process: Ammonia is difficult to produce from nitrogen gas, but Fritz Haber figured out how to do it using Le Chatelier's Principle. The reaction is **exothermic,** so ΔH is negative and energy is produced on the product side.

$N_{2(g)} + 3H_{2(g)} \leftarrow \rightarrow 2NH_{3(g)}$ **+ heat** **<--- *Notice that "+ heat" is now added in***

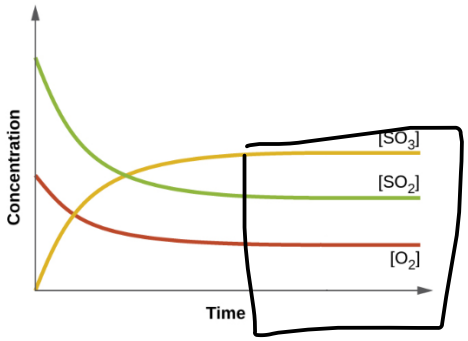
Disruption to Equlibrium	Which direction does the equilibrium shift?	Will this increase or decrease?	Explain why: which reaction rate is changing (forward or reverse), and why?
Increase pressure (count gas moles)	Right	H_2 Decrease	Shifts to the side with less moles of gas (right), Results in lower pressure at new equilibrium
Decrease pressure (count gas moles	Left	NH_3 Decrease	Shifts to the side with more moles of gas (left), Results in higher pressure at new equilibrium
Increase temperature	Left	N_2 Increase	More heat speeds up reverse reaction
Decrease temperature	Right	H_2 Decrease	Less heat slows down reverse reaction, so forward reaction will now be dominant
Add N_2 gas	Right	Temperature Increase	More N_2 speeds up forward reaction; Forward reaction produces heat to increase Temp
Remove H_2 gas	Left	Temperature Decrease	Forward reaction slows due to less H_2; Reverse reaction dominates, absorbing heat
Add NH_3 gas	Left	Temperature Decrease	Reverse reaction speeds up due to more NH_3; Reverse reaction absorbs heat and cools the temp.
Remove NH_3 gas	Right	H_2 Decrease	Reverse reaction slows down due to less NH_3; Forward reaction is therefore now favored.

How can you setup this equilibrium system to produce the most NH_3 product?
Shift the reaction to the right: add more N_2 and H_2, increase the pressure (compress more gas into a smaller volume), remove the NH_3 as it is being produced to slow the reverse reaction, and run the reaction at a cold temperature to keep the reverse reaction slow.

Use the graph to answer the questions:

$2SO_2 + O_2 \leftrightarrows 2SO_3$

1) Draw a box around the part(s) of the graph when the system is at equilibrium.
2) During the other part of the graph, is the reaction shifting left or shifting right? How do you know?
   RIGHT: because SO_3 is increasing, while SO_2 and O_2 decrease.
3) During the equilibrium shift, which reaction rate is faster?
   Forward reaction is faster than reverse reaction.



Use the graph to answer the questions.

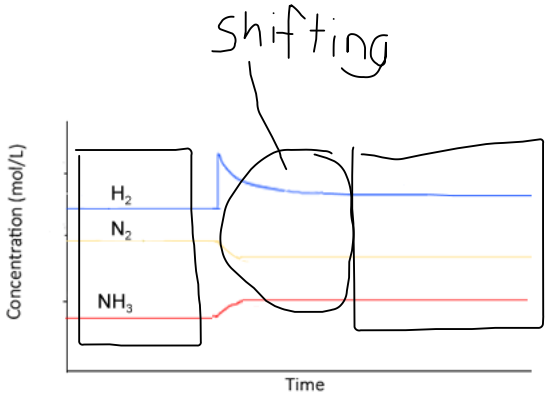
$N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_{3(g)}$

Draw a box around the part(s) of the graph when the system is at equilibrium.

What disturbance was made to the system? Label this part of the graph.
H_2 is added (seen where the the line spikes upward)

What direction does the graph shift as a result of the disturbance?
Poor wording here (sorry)… the H_2 graph line goes down, which means H_2 is decreasing. This means the equilibrium is shifting right.

Circle and label the part of the graph when the equilibrium is shifting.



Is the reaction shifting left or right? **RIGHT**

Explain how you know which way the reaction shifted: talk about which concentration are increasing or decreasing.
The chemicals on the left side (H_2 and N_2) are decreasing / being used up. The substance on the right (NH_3) is increasing.

Which reaction rate is faster while the reaction is initially at equilibrium? (Huge hint: this is a trick question)
Neither. The reaction rates are equal at equilibrium.

Which reaction rate is faster during the shift?
Forward reaction.

What is the cause of the change in reaction rate? (Remember what factors that affect reaction rates…)
Higher concentration of H_2.
H_2 is a reactant for the forward reaction. Increasing reactant concentration increases reaction rate, because it increases the likelihood of collisions between H_2 and N_2.