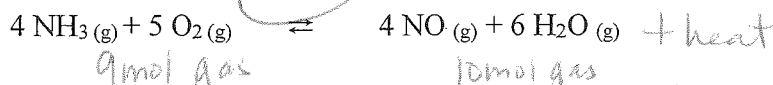


Key

Problem Set B: Applying Le Châtelier's Principle

The oxidation of ammonia is a reversible exothermic reaction that proceeds as follows:



For each situation described in the table, indicate an increase or decrease in overall concentration from the initial equilibrium conditions to the newly re-established equilibrium conditions.

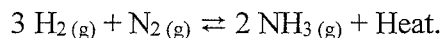
Component	Stress	Equilibrium Concentrations			
		[NH ₃]	[O ₂]	[NO]	[H ₂ O]
NH ₃	addition	↑	↓	↑	↑
	removal	↓	↑	↓	↓
O ₂	addition	↓	↑	↑	↑
	removal	↑	↓	↓	↓
NO	addition	↑	↑	↑	↓
	removal	↓	↓	↓	↑
H ₂ O	addition	↑	↑	↓	↑
	removal	↓	↓	↑	↓
		[NH ₃]	[O ₂]	[NO]	[H ₂ O]
Increase in temperature		↑	↑	↓	↓
Decrease in temperature		↓	↓	↑	↑
Increase in pressure		↑	↑	↑	↑
Decrease in pressure		↓	↓	↓	↓
Addition of a catalyst		—	—	—	—
An inert gas is added		—	—	—	—

Problem Set C: Le Châtelier's Principle

State the direction in which each of the following equilibrium systems would be shifted upon the application of the following stresses.

1.	$2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g}) + \text{energy}$	decreased temperature	<u>Right</u>
2.	$\text{C}(\text{s}) + \text{CO}_2(\text{g}) + \text{energy} \rightleftharpoons 2 \text{CO}(\text{g})$	increased temperature	<u>Right</u>
3.	$\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g})$	increased total pressure	<u>Left</u>
4.	$\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$	decreased total pressure	<u>No shift</u>
5.	$2 \text{NOBr}(\text{g}) \rightleftharpoons 2 \text{NO}(\text{g}) + \text{Br}_2(\text{g})$	decreased total pressure	<u>Right</u>
6.	$3 \text{Fe}(\text{s}) + 4 \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{Fe}_3\text{O}_4(\text{s}) + 4 \text{H}_2(\text{g})$	addition of $\text{Fe}(\text{s})$	<u>No shift</u>
7.	$2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$	addition of catalyst	<u>No shift</u>
8.	$\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$	removal of $\text{CO}_2(\text{g})$	<u>Right</u>
9.	$\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$	addition of He	<u>No shift</u>

Consider the following equilibrium system for questions #10-16:



State the effect each of the following will have on the equilibrium system:

- | | | |
|-----|---|-----------------|
| 10. | More N_2 is added to the system | <u>Right</u> |
| 11. | Some NH_3 is removed from the system | <u>right</u> |
| 12. | The temperature is increased | <u>left</u> |
| 13. | The volume of the vessel is increased | <u>Left</u> |
| 14. | A catalyst was added | <u>no shift</u> |
| 15. | An inert gas was added at constant pressure | <u>no shift</u> |

- 16 (a) A catalyst is added to the above reaction and equilibrium is allowed to re-establish. Compare the rates of the forward and reverse reactions of the new equilibrium system to that of the original equilibrium system.

Forward Rate has ↑ Reverse Rate has ↑

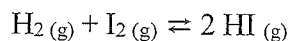
- (b) If the temperature was increased in the above reaction and a new equilibrium was established. Compare the rates of the forward and reverse reactions of the new equilibrium system to that of the original equilibrium system.

Forward Rate has ↑ Reverse Rate has ↑

- (c) The volume of the container was increased in the above reaction and a new equilibrium was established. Compare the rates of the forward and reverse reactions of the new equilibrium system to that of the original equilibrium system.

Forward Rate has ↓ Reverse Rate has ↓

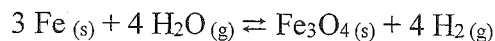
Consider the following equilibrium system



Predict the shift, if any, observed when each of the following stresses are applied to the system.

17. The volume of the vessel is increased None
 18. The pressure is increased None
 19. A catalyst is added None

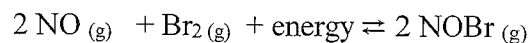
Consider the following equilibrium system:



Predict the shift, if any, observed when each of the following stresses are applied to the system.

20. The volume of the vessel is decreased None
 21. The pressure is decreased None
 22. More Fe is added to the system None
 23. Some Fe₃O₄ is removed from the system None
 24. A catalyst is added to the system None

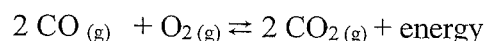
Consider the following equilibrium:



Predict the shift, if any, observed when each of the following stresses are applied to the system.

25. The volume of the vessel is increased Left
 26. The pressure is decreased Left
 27. More Br₂ is added to the system Right
 28. Some NO is removed from the system Left
 29. A catalyst is added to the system None

Some CO was added to the equilibrium below and a new equilibrium was established.



30. Compare the rates of the forward and reverse reactions of the new equilibrium system to that of the original equilibrium system.

Forward Rate has ↑ Reverse Rate has ↑

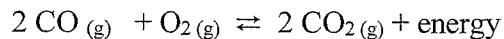
31. Compared to the original concentrations, after the shift, have the new concentrations increased or decreased?

[CO] ↑ [O₂] ↓ [CO₂] ↑

32. Did the equilibrium shift favour the formation of reactants or products?

products

A catalyst was added to the equilibrium below and a new equilibrium was established.



33. Compared to the original system, the rates of the forward and reverse reactions of the new equilibrium.

Forward Rate has ↑ Reverse Rate has ↑

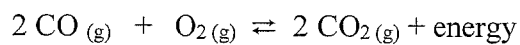
34. Compared to the original concentrations, after the shift, have the new concentrations increased or decreased?

[CO] ↓ [O₂] ↓ [CO₂] ↑

35. Did the equilibrium *shift* favour the formation of reactants or products?

No

The volume of the container was decreased and a new equilibrium was established.



36. Compare to the original system, the rates of the forward and reverse reactions of the new equilibrium.

Forward Rate has ↑ Reverse Rate has ↑

37. Compared to the original concentrations, after the shift, have the new concentrations increased or decreased? [CO] ↑ [O₂] ↑ [CO₂] ↑

38. Did the equilibrium shift favor the formation of reactants or products? products