Applying Le Châtelier's Principle

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

$$4\ NH_{3\,(g)} + 5\ O_{2\,(g)} \Leftrightarrow 4\ NO_{\,(g)} + 6\ H_2O_{\,(g)}$$

Le Châtelier's Principle allows us to predict the changes that occur in an equilibrium reaction to compensate for any stress that is placed upon the system. For each situation described in the table, indicate an increase or decrease in overall concentration from before to after a new equilibrium has been established.

Component Stress		Equilibrium Concentrations			
		$[NH_3]$	$[O_2]$	$[NO]$	$[H_2O]$
NH_3	addition				
	removal				
O_2	addition				
	removal				
NO	addition				
	removal				
H_2O	addition				
	removal				

	$[NH_3]$	$[O_2]$	$[NO]$	$[H_2O]$
Increase in temperature				
Decrease in temperature				
Increase in pressure				
Decrease in pressure				
Addition of a catalyst				

2) State the direction in which each of the following equilibrium systems would be shifted upon the application of the following stress listed beside the equation.

a) $2\ SO_{2\,(g)} + O_{2\,(g)} \Leftrightarrow 2\ SO_{3\,(g)}$ + energy	decrease temperature
b) $C_{\,(s)} + CO_{2\,(g)}$ + energy $\Leftrightarrow 2\ CO_{\,(g)}$	increase temperature
c) $N_2O_{4\,(g)} \Leftrightarrow 2\ NO_{2\,(g)}$	increase total pressure
d) $CO_{\,(g)} + H_2O_{\,(g)} \Leftrightarrow CO_{2\,(g)} + H_{2\,(g)}$	decrease total pressure
e) $2\ NOBr_{\,(g)} \Leftrightarrow 2\ NO_{\,(g)} + Br_{2\,(g)}$	decrease total pressure
f) $3\ Fe_{\,(s)} + 4\ H_2O_{\,(g)} \Leftrightarrow Fe_3O_{4\,(s)} + 4\ H_{2\,(g)}$	add $Fe_{(s)}$
g) $2\ SO_{2\,(g)} + O_{2\,(g)} \Leftrightarrow 2\ SO_{3\,(g)}$	add catalyst
h) 8. $CaCO_{3\,(s)} \Leftrightarrow CaO_{\,(s)} + CO_{2\,(g)}$	remove $CO_{2\,(g)}$
i) $N_{2\,(g)} + 3\ H_{2\,(g)} \Leftrightarrow 2\ NH_{3\,(g)}$	increase $[H_{2\,(g)}]$

3) Consider the following equilibrium system:

$$3\ H_{2\,(g)} + N_{2\,(g)} \Leftrightarrow 2\ NH_{3\,(g)} + \text{heat}$$

State what affect each of the following will have on this system:

a) More N_2 is added to the system

b) Some NH_3 is removed from the system

c) The temperature is increased

d) The volume of the vessel is increased

e) A catalyst was added

f) If a catalyst was added to the above reaction and a new equilibrium was established. Compare to the original system, the rates of the forward and reverse reactions of the new equilibrium.

Forward Rate has Reverse Rate has

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

Forward Rate has Reverse Rate has

h) If the volume of the container was increased in the above reaction and a new equilibrium
was established. Compare to the original system, the rates of the forward and reverse reactions of the new equilibrium.

Forward Rate has Reverse Rate has

4) Consider the following equilibrium system

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

State what effect each of the following will have on this system in terms of shifting.

a) The volume of the vessel is increased

b) The pressure is increased

c) A catalyst is added

5) Consider the following equilibrium system:

$$3\ Fe_{(s)} + 4\ H_2O_{(g)} \Leftrightarrow Fe_3O_{4\,(s)} + 4\ H_{2\,(g)}$$

State what effect each of the following will have on this system in terms of shifting.

a) The volume of the vessel is decreased

b) The pressure is decreased

c) More Fe is added to the system

d) Some Fe_3O_4 is removed from the system

e) A catalyst is added to the system

6) Consider the following equilibrium:

$$2NO_{(g)} + Br_{2\,(g)} + \text{energy} \Leftrightarrow 2NOBr_{(g)}$$

State what affect each of the following will have on this system in terms of shifting.

a) The volume of the vessel is increased

b) The pressure is decreased

c) More Br_2 is added to the system

d) Some NO is removed from the system

e) A catalyst is added to the system

7) Consider the following equilibrium:
Some CO was added to the system and a new equilibrium was established.

$$2CO_{(g)} + O_{2\,(g)} \Leftrightarrow 2CO_{2\,(g)} + \text{energy}$$

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

Forward Rate has Reverse Rate has

b) Compared to the original concentrations, after the shift, have the new concentrations increased or decreased?

[CO] $[O_2]$ $[CO_2]$

c) Did the equilibrium shift favour the formation of reactants or products?

8) A catalyst was added to the system at constant volume and a new equilibrium was established.

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

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

Forward Rate has Reverse Rate has

b) Compared to the original concentrations, after the shift, have the new concentrations increased or decreased?

[CO] $[O_2]$ $[CO_2]$

c) Did the equilibrium shift favour the formation of reactants or products?

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

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

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

Forward Rate has Reverse Rate has

b) Compared to the original concentrations, after the shift, have the new concentrations increased or decreased?

[CO] $[O_2]$ [$CO_2]$

c) Did the equilibrium shift favor the formation of reactants or products?

10) The chromate and dichromate ions set up an equilibrium as follows:

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

yellow orange

Describe how the above equilibrium will shift after each stress below:

	shift	color change
a) Increase in $[H^+]$		
b) Increase in $[CrO_4^{2-}]$		
c) Increase in $[Cr_2O_7^{2-}]$		
d) Decrease in $[H^+]$		
e) Decrease in $[CrO_4^{2-}]$		
f) Increase in temperature		
g) Decrease in temperature		
h) Add $HCl_{(aq)}$		
i) Add NaOH		

11) The copper (II) ion and copper (II) hydroxide complex exist in equilibrium as follows:

$$Cu(OH)_{2\,(aq)} + 4\ H_2O_{(l)} \Leftrightarrow Cu(H_2O)_4^{2+}{}_{(aq)} + 2\ OH^-{}_{(aq)} + 215\ kJ$$

violet light blue

Describe how the above equilibrium will shift after each stress below:

	shift	color change
a) Increase in $[Cu(H_2O)_4^{2+}]$		
b) Add NaOH		
c) Increase in $[Cu(OH)_2]$		
d) Decrease in $[Cu(H_2O)_4^{2+}]$		
e) Decrease in $[Cu(OH)_2]$		
f) Increase temperature		
g) Decrease temperature		
h) Add $KCl_{(aq)}$		
i) Add $HCl_{(aq)}$		

12)Consider the equilibrium that follows:

$$4\ HCl_{(g)} + 2\ O_{2\,(g)} \Leftrightarrow 2\ H_2O_{(l)} + 2\ Cl_{2\,(g)} + 98\ kJ$$

(yellow)

Describe how the above equilibrium will shift after each stress below:

shift color change

a) Increase in temperature

b) Increase [HCl]

c) Decrease in $[Cl_2]$

d) Decrease temperature

e) Add $NaOH_{(aq)}$
(reacts with HCl)

13)Consider the equilibrium that follows:

$Cu^{+}_{(aq)} + Cl^{-}_{(aq)} \Leftrightarrow CuCl_{(s)}$ $\Delta H = +\ 98\ kJ$

(green)

Describe how the above equilibrium will shift after each stress below:

shift color change

a) Increase in temperature

b) Increase [HCl]

c) Add NaCl

d) Decrease temperature

e) Add $NaOH_{(aq)}$
(check your solubility table for a possible reaction)

f) Add $CuCl_{(s)}$

g) Add $AgNO_{3\,(aq)}$
(check your solubility table for a possible reaction)

h) Add $CuNO_{3\,(aq)}$

i) Add $Cu(NO_3)_{2\,(aq)}$

14)Consider the following equilibrium system.

$$I_{2(g)} + Cl_{2(g)} \Leftrightarrow 2\ ICl_{(g)} + \text{energy}$$

Label the graph that best represents each of the following stresses and shift.

- adding $I_{2(g)}$
- increasing the temperature
- decreasing the pressure
- removing $Cl_{2(g)}$