Worksheet 2-2
LeChatelier's Principle

Name Key

1. In order to decide what effect a ***change in total pressure*** will have on an equilibrium system with gases, what is the first thing you should do when given the balanced equation?

Count the # moles on reactant vs. product side

2. Predict which way the following equilibrium systems will shift when the ***total pressure*** is ***increased***.(NOTE: Some may have no shift)

a). $N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)}$ ..... Answer No shift.

b). $2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$ ..... Answer right.

c). $4NH_{3(g)} + 5O_{2(g)} \rightleftarrows 4NO_{(g)} + 6H_2O_{(g)}$..... Answer left

3. Which way will the following equilibrium shift if the ***total pressure*** on the system is ***decreased***?

$2C_2H_{6(g)} + 7O_{2(g)} \rightleftarrows 4CO_{2(g)} + 6H_2O_{(g)}$ Answer right →

4. Explain why a flask filled with $NO_{2(g)}$ and $N_2O_{4(g)}$ will get **darker** when heated. Use the equation: $N_2O_{4(g)}$ (colourless) + Heat $\rightleftarrows 2NO_{2(g)}$ (dark brown)

Heating will cause equilibrium to shift right, producing more NO_2 which is dark brown.

5. State ***Le Chatelier's Principle***.

When a stress is applied to a system at equilibrium the equil. will shift to counteract the stress.

6. ***Hydrogen peroxide*** is decomposed as follows:

$$H_2O_{2(l)} \rightleftarrows H_{2(g)} + O_{2(g)} \quad \Delta H = +187\ kJ$$

Predict the ***direction of equilibrium shift*** by each of the following imposed changes:

a) ***Increase*** the $[H_2]$ ..... Answer left

b) ***Decrease*** the $[O_2]$ ..... Answer right

c) ***Decrease*** the ***total pressure*** ..... Answer right

d) ***Increase*** the ***temperature***..... Answer right.

e) Add MnO_2 as a ***catalyst***..... Answer no shift

7. Consider the following reaction at equilibrium:

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

a) Addition of more H_2 gas to the container will do what to the rate of the forward reaction?

Answer increase it

b) If, for a while, the rate of the *forward* reaction is ***greater than*** the rate of the *reverse* reaction, what will happen to the [HI]?

Answer [HI] increase

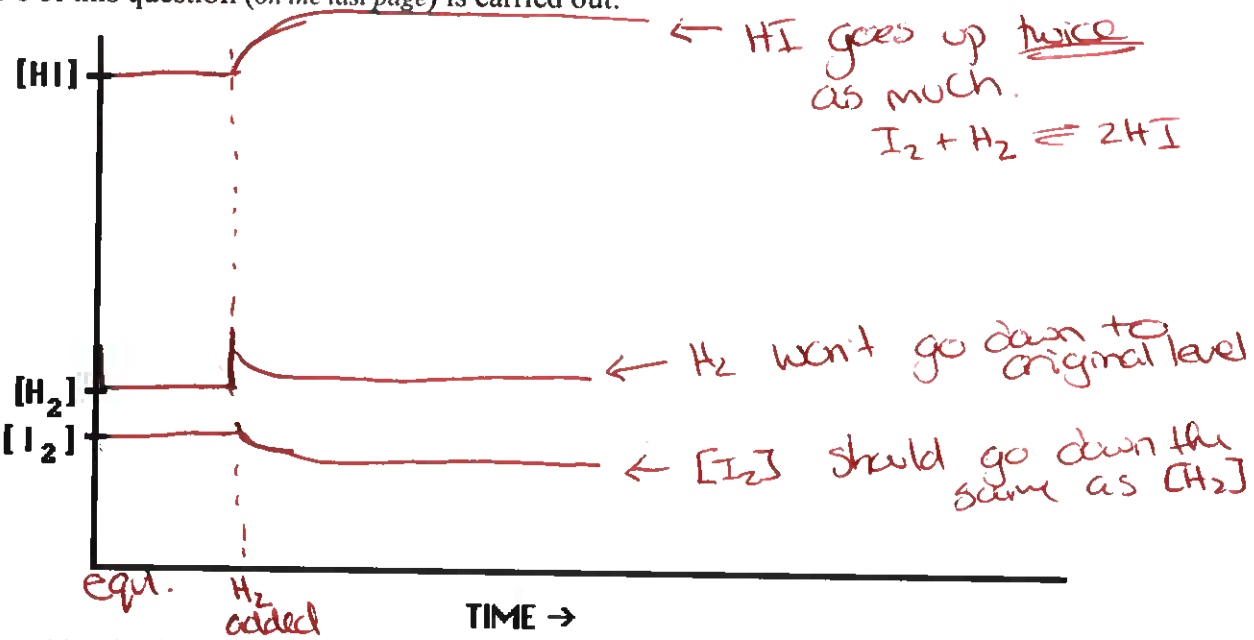
c) As the [HI] is increased, what will happen to the rate of the *reverse* reaction?

Answer it will increase

d) When the rate of the *reverse* reaction once again becomes ***equal*** to the rate of the *forward* reaction, a new equilibrium has been reached.

e) Since the rate of the *forward* reaction was, for a while, greater than the rate of the *reverse* reaction, the new equilibrium will have a slightly higher concentration of HI and a slightly lower concentration of H_2 & I_2

f) Sketch a graph of the relative concentrations of each species as the process outlined in **a-e** of this question (*on the last page*) is carried out.



8. Consider the following equilibrium and state which way (left or right) the equilibrium shifts when each of the changes below are made.

3 mol gas 5 mol gas

$$Heat + CH_{4(g)} + 2H_2S_{(g)} \rightleftarrows CS_{2(g)} + 4H_{2(g)}$$

a) CH_4 gas is added ..... Answer right

b) CS_2 gas is removed..... Answer right.

c) H_2 gas is added ..... Answer left

d) The *total volume* of the container is decreased ..... Answer left

e) The *temperature* is increased ..... Answer right

f) The *total pressure* is decreased ..... Answer right.

g) Helium gas is added to increase the total pressure.... Answer no shift He does not take part in rxn

9. Using the following equilibrium, state what would happen to the equilibrium *partial pressure of CH_3OH gas* when each of the following changes are made:

$$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} \qquad \Delta H = -75.2\ kJ$$

3 1

a) CO gas is added to the container ..... Answer right P_{CH_3OH} ↑

b) The *temperature* is increased ..... Answer left P_{CH_3OH} ↓

c) The *total pressure* of the system is increased..... Answer ~~left~~ right P_{CH_3OH} ↑

3 1

$CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)} \quad \Delta H = -75.2\ kJ$

d) H_2 gas is removed from the system..... Answer left. P_{CH_3OH} ↓

e) A *catalyst* is added..... Answer no change

f) The *total volume* of the container is increased..... Answer left P_{CH_3OH} ↓

PV

10. For the reaction:

$2NO_{(g)} + Cl_{2(g)} \rightleftarrows 2NOCl_{(g)} \quad \Delta H = -77\ kJ$

3 2

state the **optimal pressure and temperature conditions** necessary for maximum production of NOCl.(*high or low?*)

1. high pressure 2 low temperature

11. For the reaction:

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

4 2

state the *optimal conditions* for a **high yield** of ***ammonia*** ***(NH_3)***. (*high or low?*)

1. high pressure 2 low temperature

12. Given the following equilibrium system, state which way the equilibrium will shift when the changes below are made:

$2C_2H_{6(g)} + 7O_{2(g)} \rightleftarrows 4CO_{2(g)} + 6H_2O_{(g)} + heat$

9 10

a) The *volume* of the container is halved..... Answer ~~left~~ left

P↑

b) The *temperature* is decreased ..... Answer right

c) CO_2 is added to the container..... Answer left.

d) The *total pressure* is increased ..... Answer left

e) O_2 gas is removed from the system ..... Answer left

f) Neon gas is added to increase the total pressure ..... Answer no change

h) A *catalyst* is added..... Answer no change

13. Using the equilibrium: $N_{2(g)} + O_{2(g)} + heat \rightleftarrows 2NO_{(g)}$

Explain why nitric oxide (NO) does ***not*** generally form in the atmosphere but ***is*** formed in the internal combustion engine of an automobile or during a lightning storm.

Nature favours min entropy ∴ favouring the reactants. No change in entropy. In an automobile the addition of heat drives the rxn forward.

14. Explain why a syringe containing NO_2 gas will first get *darker* and ***then lighter*** in colour when compressed. Use the equilibrium equation:

1 mol g 2 mol g

$$N_2O_{4(g)} + heat \rightleftarrows 2NO_{2(g)}$$

colourless *brown*

It will get darker as immediate ↑ $[NO_2]$ As equilibrium shifts left ⇐ it will become less.

15. Explain why a flask containing NO_2 will get *lighter* in colour when put into *ice water*. Use the equation:

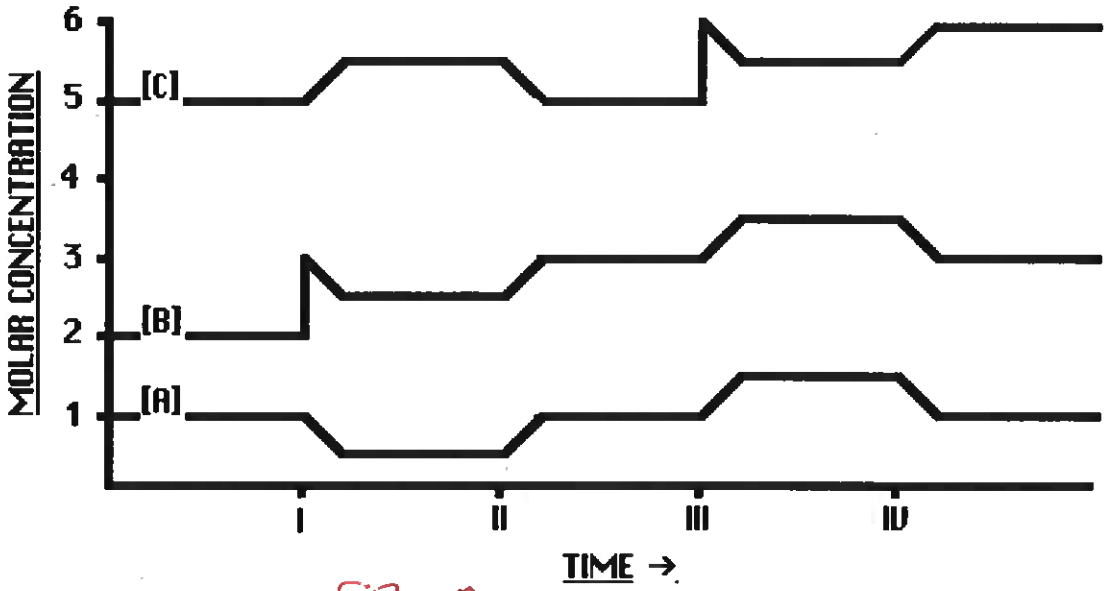
$$N_2O_{4(g)} + heat \rightleftarrows 2NO_{2(g)}$$

colourless *brown*

The ice water will remove heat from the system making the eq. shift ⇐ left.

16. 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:

$$A_{(g)} + B_{(g)} \rightleftarrows C_{(g)} \qquad \Delta H = -65\ kJ$$



a) At time I, the [B] ↑

b) At time II, the Temp ↑

c) At time III, the [C] ↑

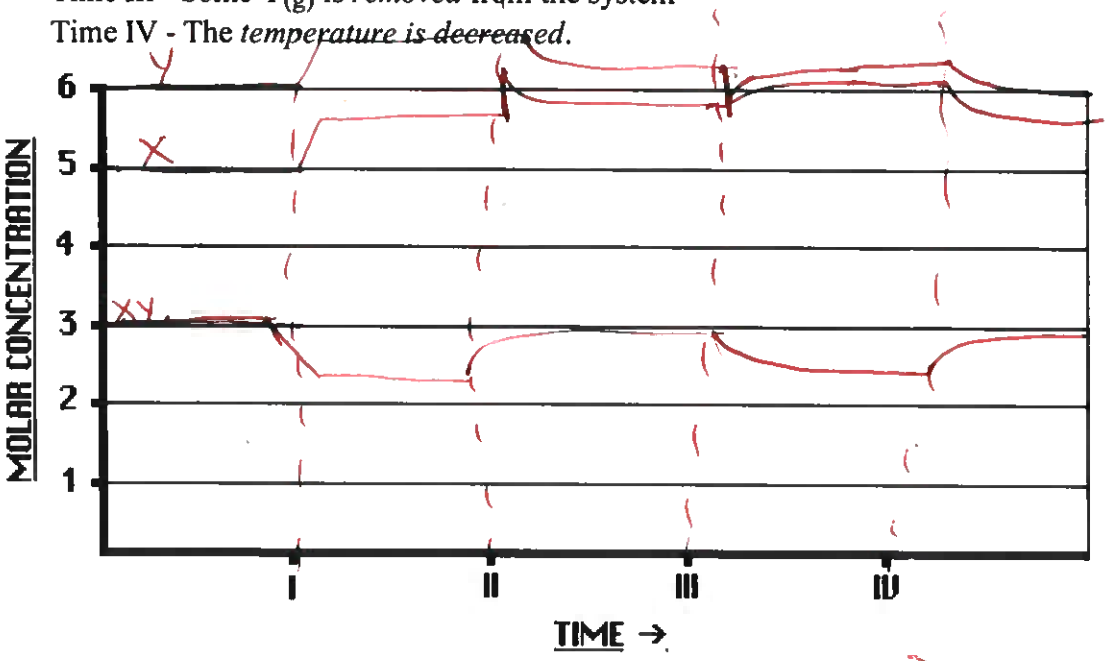
d) At time IV, the Temp ↓

17. Given the equilibrium equation:

$$XY_{(g)} + heat \rightleftarrows X_{(g)} + Y_{(g)}$$

If initially, at equilibrium, the [XY] = 3.0 M, the [X] = 5.0 M and the [Y] = 6.0 M, draw a graph *similar to the one in question 16* showing qualitatively what happens to the concentrations of each species as the following changes are made to the system:

Time I - The *temperature is increased.*
Time II - Some $X_{(g)}$ is *added* to the system
Time III - Some $Y_{(g)}$ is *removed* from the system
Time IV - The *temperature is decreased.*



18. For each of the following reactions, predict whether the ***entropy*** increases or decreases.

a) $2H_{2(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)}$..... Answer ↓

b) $2SO_{3(g)} \rightleftarrows 2SO_{2(g)} + O_{2(g)}$..... Answer ↑

c) $MgCO_{3(s)} + 2H_3O^+_{(aq)} \rightleftarrows Mg^{2+}_{(aq)} + 3H_2O_{(l)} + CO_{2(g)}$

Answer ↑

d) $Ag^+_{(aq)} + Cl^-_{(aq)} \rightleftarrows AgCl_{(s)}$..... Answer ↓

e) $2C_2H_{2(g)} + 5O_{2(g)} \rightleftarrows 4CO_{2(g)} + 2H_2O_{(g)}$..... Answer ↓

f) $NH_{3(g)} + HCl_{(g)} \rightleftarrows NH_4Cl_{(s)}$..... Answer ↓

19. On the basis of **enthalpy** and **entropy**, predict whether each of the following reactions would be ***spontaneous as written*** or not at room temperature.

a) $N_{2(g)} + 2O_{2(g)} \rightleftarrows 2NO_{2(g)} \quad \Delta H = +67.7\ kJ$

Minimum enthalpy favours (reactants/products) ..... reactants

Maximum entropy favours (reactants/products) ..... reactants

Spontaneous as written? (yes/no) ..... Answer no

b) $2C_{(s)} + O_{2(g)} \rightleftarrows 2CO_{(g)} + 110\ kJ$

Minimum enthalpy favours (reactants/products) ..... ~~reactants~~ products

Maximum entropy favours (reactants/products) ..... products

Spontaneous as written? (yes/no) ..... Answer ~~equilibrium~~ yes

c) $2Pb(NO_3)_{2(s)} + 597\ kJ \rightleftarrows 2PbO_{(s)} + 4NO_{2(g)} + O_{2(g)}$

Minimum enthalpy favours (reactants/products) ..... reactants

Maximum entropy favours (reactants/products) ..... products

Spontaneous as written? (yes/no) ..... Answer equilibrium will be achieved.