Chemical Equilibrium OLI Course Questions:

**Reversible reactions and chemical equilibrium**

Indicate true or false for each.

A limiting reagent calculation will give final concentrations when:

|  |  |
| --- | --- |
| The forward reaction proceeds to completion. |  |
| The reverse reaction proceeds to completion. |  |
| The system is at equilibrium. |  |
| The change in concentration of products is proportional to the change in concentration of reactants. |  |
|  |  |

Indicate true or false for each.

At equilibrium:

|  |  |
| --- | --- |
| The concentration of every species in a solution remains constant. |  |
| All reactions have stopped. |  |
| The strongest reaction will go to completion. |  |
| The rate of the forward reaction is equal to the rate of the reverse reaction. |  |
| There will be equal concentrations of products and reactants. |  |
| The forward and reverse reactions are equally strong. |  |

A + B <=> C + D is an equilibrium system and initial concentrations are:

[A] = 2 M         [B] = 1 M         [C] = 0 M         [D] = 2 M.

Indicate yes or no whether each value is a possible equilibrium concentration for A.

|  |  |
| --- | --- |
| 1.5 |  |
| 2.0 |  |
| 0.5 |  |
| 1.1 |  |
| 1.0 |  |
| 2.1 |  |
| 1.9 |  |
|  |  |

**Reversible Reactions and chemical equilibrium:**

What does it mean for a system to be at equilibrium?

**LeChatlier’s Principle: General Formulation:**

Indicate whether each statement is true or false. When a reaction shifts to the left:

|  |  |
| --- | --- |
| More products are converted into reactants. |  |
| More reactants are converted into products. |  |
| A possible "stress" may have been the addition of products. |  |
| A possible "stress" may have been the removal of reactants. |  |
| The system is at equilibrium. |  |
| The reaction rate of the forward reaction increases more than the reverse reaction. |  |

Indicate for each points in the heart lung system whether the hemoglobin/oxygen reaction is at equilibrium?

|  |  |
| --- | --- |
| Immediately after entering the lungs. |  |
| As hemoglobin leaves the lungs. |  |
| Immediately after entering the muscles. |  |
| As hemoglobin travels from the muscles to the heart. |  |

For the hemoglobin reaction Hb + O2 <--> HbO2, indicate whether each change will cause a shift to the right, to the left, or if you cannot tell from the given information.

|  |  |
| --- | --- |
| Increased amount of O2. |  |
| Decreased amount of O2. |  |
| Increased amount of HbO2. |  |
| Decreased amount of HbO2. |  |
| Decreased amount of Hb. |  |
| Increased temperature |  |

What does it mean for a system to shift to the left or right?

**Concentration**:

Consider the reaction: 2 H2S (g) + O2 (g) <=> 2 S(s) + 2 H2O (g) ΔH = -221.19 kJ/mol

If O2(g) is added to the reaction vessel, what happens to the amount of S(s)?

1.  It increases.
2.  It decreases.
3.  No change.
4.  Cannot tell from information given

In the reaction: 2 H2S (g) + O2 (g) <=> 2 S(s) + 2 H2O (g) ΔH = -221.19 kJ/mol

Explain at the molecular level why the addition of O2 did or did not influence the amount of S(s).

The addition of O2 \_\_\_\_\_\_ influence the amount of Ss because: \_\_\_\_\_\_\_\_. So the amount of S\_\_\_\_\_\_ .

Consider the following reaction at equilibrium

2NH3(g) <=> N2(g) + 3H2(g)

If N2(g) is added to the reaction vessel what result is expected?

1.  Decrease in the concentration of NH3(g)
2.  Decrease in the concentration of H2(g)
3.  No change.
4.  Removal of all of the H2(g)

**Progress of Reaction**

Indicate whether each statement is true or false:

|  |  |
| --- | --- |
| Q indicates whether the reaction has progressed to the right or the left |  |
| Q tells whether the partial pressure is greater for reactants or products |  |
| Q is the ratio of products/reactants for any chemical reaction. |  |
| Q decreases as the reaction progresses towards product. |  |
| Q increases as the chemical equation moves left. |  |
| There is only one Q value for a given chemical reaction. |  |

**Law of Mass Action:**

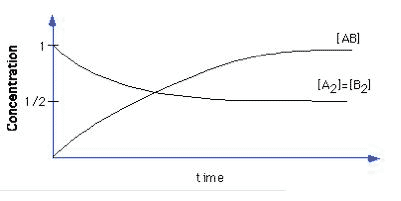
What information does the value of K provide?

Indicate true or false for each statement:

|  |  |
| --- | --- |
| K is the ratio of products/reactants only at equilibrium. |  |
| K is the ratio of products/reactants for any point in the progress of reaction. |  |
| K tells the concentrations of species at equilibrium. |  |
| K tells whether the system at equilibrium will be to the left or to the right. |  |
| K tells whether the forward or reverse reaction is stronger. |  |

Consider the reaction: A2 + B2 <=> 2AB

The graph plots the concentrations of reactants and products over time.



What is the value of the equilibrium constant?

1.  1
2.  2
3.  1/2
4.  4

In the previous reaction: A2 + B2 <=> 2AB

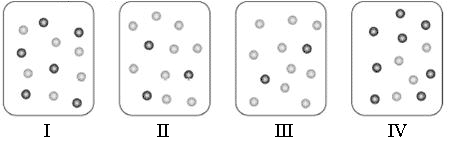
Explain how you determined the value of K.

1.  I selected the point at which the concentration of reactants equal concentration of products.
2.  I used Q=K at equilibrium and plugged in the values where the concentrations were equal.
3.  I used Q=K at equilibrium and plugged in the values where the concentrations were flat.
4.  I used a different strategy.

Match the reaction to one of the containers at equilibrium.

Identify which molecule is black and which is white.

A*(g)* <=> B*(g)* K = 2



The container matching this expression is:

1.  I
2.  II
3.  III
4.  IV

In this reaction, A is

1.  black
2.  white
3.  can't tell

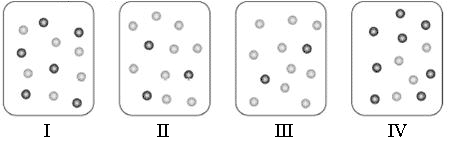
In this reaction, B is

1.  black
2.  white
3.  can't tell

Match the reaction to one of the containers at equilibrium.

Identify which molecule is black and which is white.

C*(g)* <=> 2 D*(g)* K = 6



The container matching this expression is:

1.  I
2.  II
3.  III
4.  IV

In this reaction, C is

1.  black
2.  white
3.  can't tell

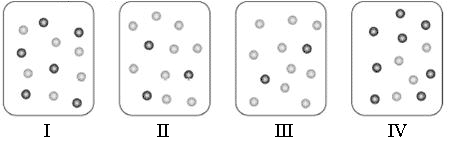
In this reaction, D is

1.  black
2.  white
3.  can't tell

Match the reaction to one of the containers at equilibrium.

Identify which molecule is black and which is white.

2E*(g)* <=> F*(g)* K = 1



The container matching this expression is:

1.  I
2.  II
3.  III
4.  IV

In this reaction, E is

1.  black
2.  white
3.  can't tell

In this reaction, F is

1.  black
2.  white
3.  can't tell

**Equilibrium is dynamic:**

Describe what it means for equilibrium to be dynamic. Use a saturated solution of table salt (NaCl) in water as an example. (A saturated solution is formed by adding so much salt to water, that solid salt remains at the bottom of the solution.)

What is occuring at a microscopic level? What is occuring at a macroscopic level?

Indicate whether each statement is true or false:

|  |  |
| --- | --- |
| At equilibrium forward and backward reactions occur at the same rate. |  |
| If the forward rate increases, the reverse reaction rate necessarily decreases. |  |
| If a chemical system has progressed all the way to the left, the reverse reaction rate is zero. |  |
| When forward rate is equal to the reverse rate, the concentrations are equal. |  |
| If Q is greater than K, the reaction will shift to the left. |  |

Comparing Q to K:

Consider the reaction:

N2+3H2 <=> 2NH3 . The equilibrium constant at 400°C is K=0.5

Suppose we make a mixture with the following concentrations:

[NH3] = 1.0M, [N2] = 1.0M, [H2] = 1.0M

In which direction will the reaction shift?

1.  N2 + 3H2 => 2NH3
2.  N2 + 3H2 <= 2NH3
3.  The system is at equilibrium and will not shift in either direction.
4.  Cannot tell from given information.

Consider the following reaction:

2NO (g) + O2 (g) <=> 2 NO2 (g) The equilibrium constant at 750°C is K =0.1969

A reaction container containing NO(g), O2(g) and NO2(g) has the following partial pressures:

PNO = 1.23atm PO2= 0.65atm PNO2 = 0.44atm

The mixture in the vessel \_\_\_\_\_ at equilibrium and the reaction will \_\_\_\_\_ to reach equilibrium.



Consider the following reaction occurring in water:

A + 2 B <=> C . The equilibrium constant at 25°C is K= 2.0

You prepare a solution at 25°C and measure the concentrations [A] = 0.15 M, [B] = 0.27 M, [C]=0.18 M. Is this solution at equilibrium? If not, to reach equilibrium will the above reaction proceed to the left or to the right?

1.  A + 2 B => C
2.  A + 2 B <= C
3.  The system is at equilibrium and will not progress further in either direction.
4.  Cannot tell from given information.

**Equilibrium vs. limiting reagents**

Indicate true or false for each.

|  |  |
| --- | --- |
| When a reaction has gone to completion, all of the reactants must have zero concentrations. |  |
| Reactions that progress to completion are reversible. |  |
| Reactions that progress to completion have K values that approach infinity. |  |
| If a reaction progesses to completion, all molecular motion has ceased. |  |
| Limiting reagent calculations can determine concentrations for reactions that progress all the way towards the right or left. |  |

**Limiting Reagents using ICE tables**

Elemental phosphorus, P4, reacts vigorously with oxygen to produce P4O10 via the following reaction:

P4 + 5O2 => P4O10

How much P4O10 will be produced from 2.45g of P4 and 5.23 g O2. How much of the excess reactant will remain after the reaction?

 \_\_\_\_ g of P4O10 will be produced.

\_\_\_\_\_ g of O2 will remain.

Lead acetate combines with sodium chloride to form the nearly insoluble compound lead chloride via the following reaction:

Pb(C2H3O2)2(*aq*) + 2 NaCl(*aq*) => PbCl2(*s*) + 2 NaC2H3O2(aq)

Assuming this reaction goes to completion, how many grams of solid lead (II) chloride are formed when 250 mL of a 1.50M solution of lead acetate is mixed 125 mL of 3.40M sodium chloride?

\_\_\_ g of PbCl2(*s*) will be produced.

**Calculations of intermediate values of K**

1.00 atm of H2 (g) is mixed with 0.50 atm of I2 (g) at 555oC and the following reaction is allowed to come to equilibrium.

H2(*g*) + I2(*g*) <=> 2HI(*g*)

K = 54.6

What are the final pressures of H2(g), I2(g) and HI(g)?

PH2 = \_\_\_\_\_ atm

PI2=\_\_\_\_\_\_  atm

PHI= \_\_\_\_\_\_ atm

Calculations for Large and Small values of K

Consider the reaction:

2 A + B <=>2 C K = 1.0 x 108

10.0 ml of 2.0M A is mixed with 10.0 ml of 2.0M B.

For which species, do you need to do an equilibrium calculation to determine the concentration, i.e. which are minority species?

1.  A
2.  B
3.  C
4.  none

Consider the dissociation of a duplex DNA sequence (AC)/(TG):

(AC)/(TG) <=> (AC) + (TG)       K = 1.0 x 10-6

Consider a 2.0 mM solution of (AC)/(TG).

Which of the following are minority species in this solution? (check all that apply)

1.  (AC)/(TG)
2.  (AC)
3.  (TG)

Consider the dissociation of a duplex DNA sequence (AC)/(TG):

(AC)/(TG) <=> (AC) + (TG)       K = 1.0 x 10-6

Consider a 2.0 mM solution of (AC)/(TG).

What is the concentration [(AC)/(TG)] at equilibrium?

[(AC)/(TG)] =  mM

What are the concentrations [(AC)] and [(TG)] at equilibrium?

[AC] =  mM

[TG] =  mM

Consider binding of a protein to a drug:

protein + drug <=> protein:drug K = 1.2 x 108

1.0 ml of a 2.5 mM solution of drug is added to 5.0 ml of a 1.0 M solution of protein.

What are concentrations [drug] and [protein:drug] at equilibrium?

[drug] =  mM

[protein:drug] =  mM

What is the concentration of free [protein] at equilibrium?

[protein] =  mM

Consider the following reaction:

2 A + B <=> 4 C + 2 D

K = 2.4 x 10-12

A solution is prepared by mixing the following solutions together:

25.0 ml of 4.0 M A

25.0 ml of 4.0 M B

25.0 ml of 4.0 M C

25.0 ml of 4.0 M D

What are the concentrations of A, B, C and D when the system reaches equilibrium?

A= \_\_\_\_\_ B = \_\_\_\_\_\_\_ C= \_\_\_\_\_\_\_\_\_ D= \_\_\_\_\_\_\_

Virtual Labs:

LeChatlier's Principle Lab: Exploring the Cobalt Chloride reaction

Reversible Reactions Lab: Determining the equilibrium constant for the binding of dye to a DNA duplex