

Interpreting the Equilibrium Constant

1a. Answer the following as True or False:

a) The concentration of a pure solid and a liquid can be omitted from the equilibrium constant as the concentration ratio of these is equal to 1.	True
b) The equilibrium expression for the reaction $\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3\text{H}_2(\text{g})$ can be written as: $\text{Keq} = \frac{[\text{CH}_4][\text{H}_2\text{O}]}{[\text{CO}][\text{H}_2]}$	False
c) A Keq value higher than 1 means the equilibrium lies to the left.	False
d) $Q > K$ means the reverse reaction must occur for equilibrium to be reached.	True
e) Increasing the concentration of the reactants will increase the equilibrium constant.	False

b. Rewrite the statements identified as FALSE so they are correct.

b) $\text{Keq} = \frac{[\text{CO}][\text{H}_2]^3}{[\text{CH}_4][\text{H}_2\text{O}]}$

c) $K > 1$ means the equilibrium lies to the right, as there is a higher concentration of products.

e) Increasing the concentration of reactants will not affect the equilibrium constant (Only a change to the temperature will change the equilibrium constant.)

2. Haemoglobin is a protein within the blood that contains iron. It is responsible for carrying oxygen to cells of the body. Each haemoglobin molecule can carry 4 oxygen molecules.

This reaction is shown as: $\text{Hb}(\text{aq}) + 4\text{O}_2(\text{aq}) \rightleftharpoons \text{Hb}(\text{O}_2)_4(\text{aq})$

a) Write an equilibrium expression for this reaction.

$$\text{Keq} = \frac{[\text{Hb}(\text{O}_2)_4]}{[\text{Hb}][\text{O}_2]^4}$$

When a person is exposed to carbon monoxide gas the haemoglobin molecule replaces oxygen with carbon monoxide molecules, limiting the blood's ability to supply cells with oxygen.

b) i - Write the balanced chemical equation for this reaction

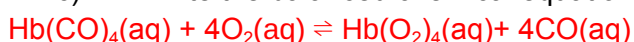


ii - Write an equilibrium expression for this reaction.

$$\text{Keq} = \frac{[\text{Hb}(\text{CO})_4]}{[\text{Hb}][\text{CO}]^4}$$

To reverse the effects of carbon monoxide poisoning, a person must be supplied with a mask of pure oxygen for a period of time. Eventually, the carboxyhaemoglobin will produce oxygenated haemoglobin and carbon monoxide will be released to be exhaled out of the lungs.

c) i - Write the balanced chemical equation for this reaction



ii - Write an equilibrium expression for this reaction.

$$K_{eq} = \frac{[\text{Hb}(\text{O}_2)_4][\text{CO}]^4}{[\text{Hb}(\text{CO})_4][\text{O}_2]^4}$$

3. When would you expect to see water in an equilibrium expression?

When it is in a gaseous state as water vapour or when water is acting as a reactant, not just a solvent.

4. Hydrogen chloride gas is produced exothermically from a reaction between hydrogen and chloride gases.

a) Write a balanced equation and hence an equilibrium expression for this reaction.



$$K_{eq} = \frac{[\text{HCl}]^2}{[\text{H}_2][\text{Cl}_2]}$$

b) What would happen to the value of the equilibrium constant if heat is added to the system?

The addition of heat would shift the reaction to the left as it would move to absorb the extra heat and thus lower the temperature of the system. This shift would result in higher concentrations of reactants and decrease the concentration of the products, therefore the K_{eq} decreases.

c) Why does temperature affect the equilibrium constant?

The equilibrium constant is the ratio of products to reactants for a specific temperature. When the temperature is changed the system will adjust to minimise the change. This leads to a new ratio as equilibrium is reestablished and so a new value for the equilibrium constant.

d) Write the equilibrium expression for the reverse reaction, in which hydrogen chloride is decomposed into hydrogen and chloride gases.

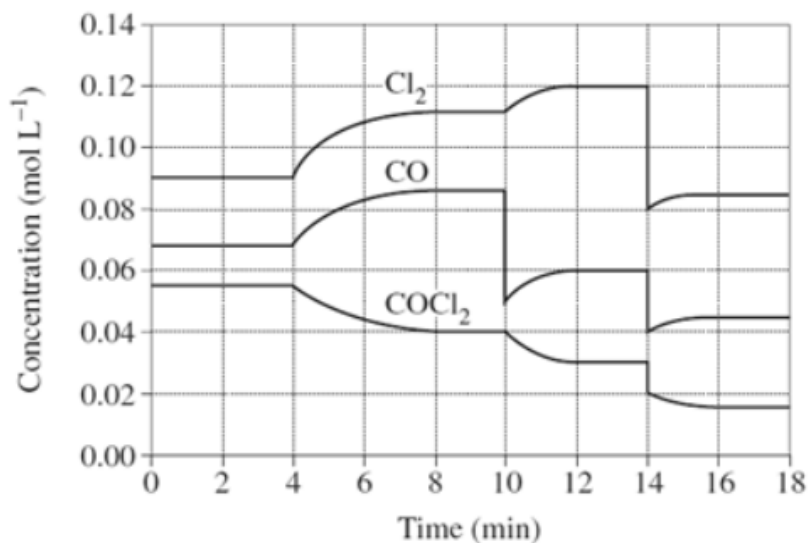
$$K_{eq} = \frac{[\text{H}_2][\text{Cl}_2]}{[\text{HCl}]^2}$$

e) What is the relationship between the K_{eq} of the forward reaction and the K_{eq} of the reverse reaction?

If both the forward and reverse reaction occur at the same temperature, then the K_{eq} of the reverse reaction will be the reciprocal of the forward reaction.

5. The decomposition of phosgene gas into carbon monoxide and chlorine gas is an endothermic reaction.

Study the graph below:



a) Write a balanced equation for this reaction.



b) Explain the change that occurs to the system at 4 minutes.

At 4 minutes the concentration of the products increases and that of the reactant decreases indicating an increase in temperature. As the reaction is endothermic, an increase in temperature would drive the reaction forward according to Le Chatelier's Principle in favour of the production of products as a way to absorb the heat added.

c) Explain the change that occurs to the system at 10 minutes.

Due to the steep drop in the graph, CO has been removed from the system. According to Le Chatelier's Principle, the drop in product concentration will drive the reaction forward in order to produce more CO.

d) Explain what change, if any, would be seen in the equilibrium constant between the changes occurring at 4 minutes and 10 minutes.

As the temperature increases at 4 minutes, the equilibrium constant will increase as the concentration of the products becomes larger than the reactants. There will be no change to the equilibrium constant at 10 minutes as the temperature remains constant.

6. The equilibrium constant for the butane \rightleftharpoons isobutane reaction is 2.5 at 25 °C.

At equilibrium, which form of butane has a higher concentration? Why?

Isobutane would be in higher concentration as $K > 1$ meaning that the concentration of products is higher than the concentration of reactants.