RATES & CHEMICAL EQUILIBRIUM

Checklist

Make sure you can ….

- Explain what reaction rate is and list the factors which affect the rate of chemical reactions
- Use Collision theory to explain how the various factors affect the rate of chemical reactions
- Sketch and interpret graphs to show:
  - changes in energy
  - the effect of changing the rate of a reaction
  - energy distribution of molecules
- Explain how a catalyst affect reaction rate
- Explain: Open and closed systems, a reversible reaction, Dynamic equilibrium
- List factors which influence the position of an equilibrium
- Write down an expression for the equilibrium constant (Kc)
- Perform calculations based on Kc values and explain significance of Kc value
- State and use Le Chatelier's principle
- Apply of reaction rate and equilibrium principles to important industrial applications e.g. Haber process, contact process and Ostwald process
- Sketch and interpret graphs to show:
  - the rate of reaction in a closed system
  - the change in concentrations or amounts of reactants and products for a closed system

Exam Questions

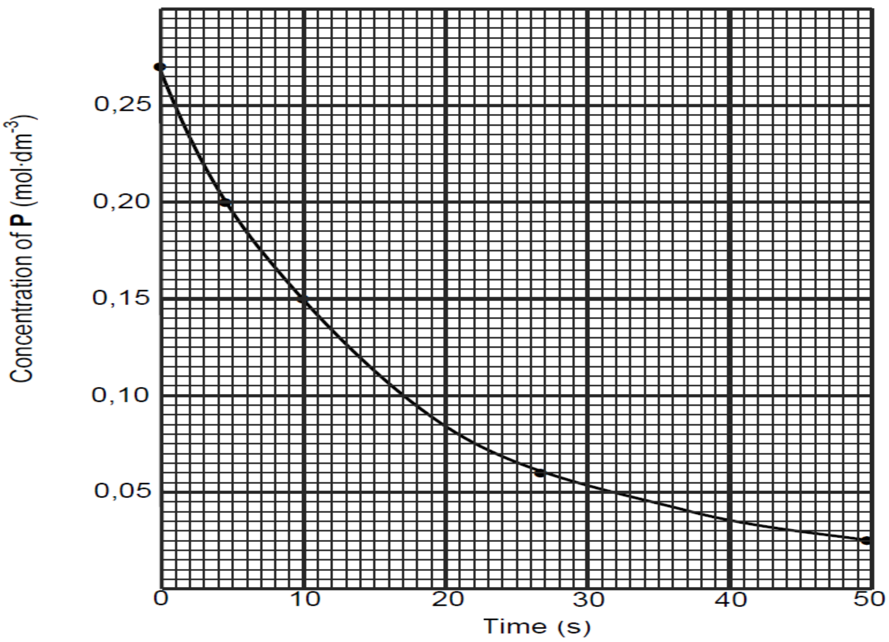
Question 1

(Adapted from February/March 2014, Paper 2, Question 6)

The graph below shows the decomposition of gas **P** according to the following equation:

$$P(g) \rightarrow 2Q(g) + R(g) \quad \Delta H < 0$$

Graph of concentration of P versus time



1.1 Define the term *rate of reaction* in words by referring to the graph. (2)

1.2 At which time, 10 s or 30 s, does the decomposition take place at a higher rate? Refer to the graph to give a reason for the answer. (2)

1.3 Write down the initial concentration of **P**(g) (1)

1.4 The decomposition is carried out in a 2 dm^3 container.

Calculate the average rate (in $mol \cdot s^{-1}$) at which **P**(g) is decomposed in the first 10 s. (6)

1.5 Draw a potential energy diagram for the reaction. Clearly indicate the following on the diagram:

- Positions of the reactants and products
- Activation energy (E_a) for the forward reaction (3)

1.6 An increase in temperature will increase the rate of decomposition of P(g).

Explain this statement in terms of the collision theory. (3)

Question 2

A small quantity of cobalt chloride powder is dissolved in ethanol resulting into a blue solution. When few drops of water are carefully added to the blue solution the colour changes to the light pink. The following equilibrium has been established:

$$[CoCl_4]^{2-}(aq)(\textbf{blue}) + 6H_2O(l) \rightleftharpoons [Co(H_2O)_6]^{2+}(aq)(\textbf{pink}) + 4Cl^-(aq)$$

To investigate some of the factors which affect this equilibrium, the following experiments are performed.

Experiment 1: A small quantity of concentrated HCl is added to the solution.

Observation: The solution turns deep blue

Experiment 2: The beaker with the solution is cooled by immersing it in ice water.

Observation: The colour of the solution changes to pink

2.1 How was the equilibrium affected in experiment 1? (2)

2.2 Explain you answer in 2.1. In terms of Le Chatelier's principle. (3)

2.3 From the results of the experiment 2 determine the sign of ΔH for this reaction. (2)

[7]

Question 3

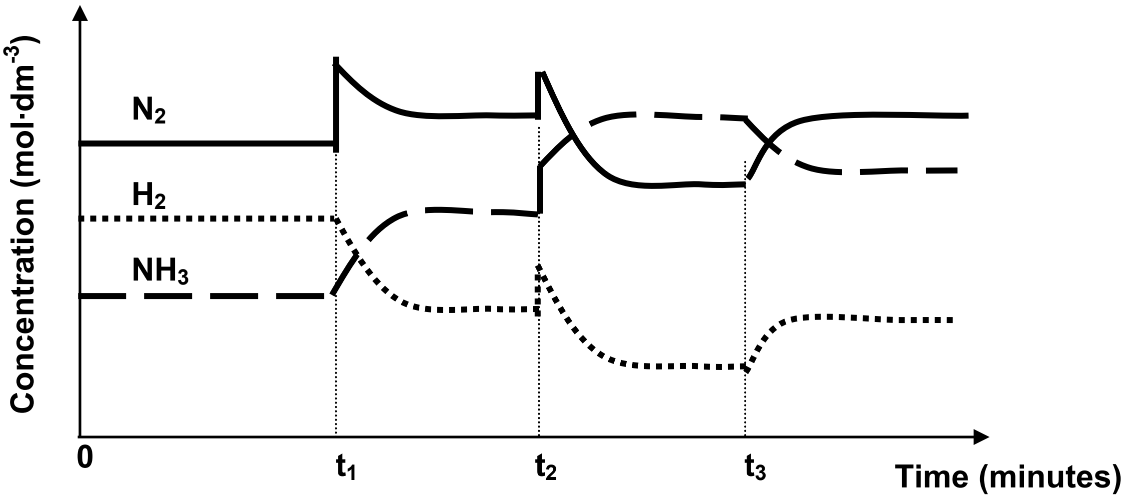
(Adapted from DBE Feb 2011, Paper 2, Question 7)

A fertiliser company produces ammonia on a large scale at a temperature of 450 °C. The balanced equation below represents the reaction that takes place in a sealed container.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$

To meet an increased demand for fertiliser, the management of the company instructs their engineer to make the necessary adjustments to increase the yield of ammonia.

In a trial run on a small scale in the laboratory, the engineer makes adjustments to the TEMPERATURE, PRESSURE and CONCENTRATION of the equilibrium mixture. The graphs below represent the results obtained



3.1 Identify the changes made to the equilibrium mixture at each of the following times:

3.1.1. t_1 (2)

3.1.2. t_2 (2)

3.1.3. t_3 (2)

3.2 At which of the above time(s) did the change made to the reaction mixture lead to a higher yield of ammonia? Write down only t_1 and/or t_2 and/or t_3. (2)

3.3 The engineer now injects 5 mol N_2 and 5 mol H_2 into a 5 dm^3 sealed empty container. Equilibrium is reached at 450 °C. Upon analysis of the equilibrium

Mixture, he finds that the mass of NH_3 is 20,4 g.

Calculate the value of the equilibrium constant (K_c) at 450 °C (9).

[17]

SOLUTIONS TO RATES & CHEMICAL EQUILIBRIUM

Question 1

1.1. Rate of change of concentration (of P) ✓ or The change in concentration (of P) ✓ per unit time/per second .

1.2. 10s✓, the slope of the graph at 10s is greater than at 30s✓

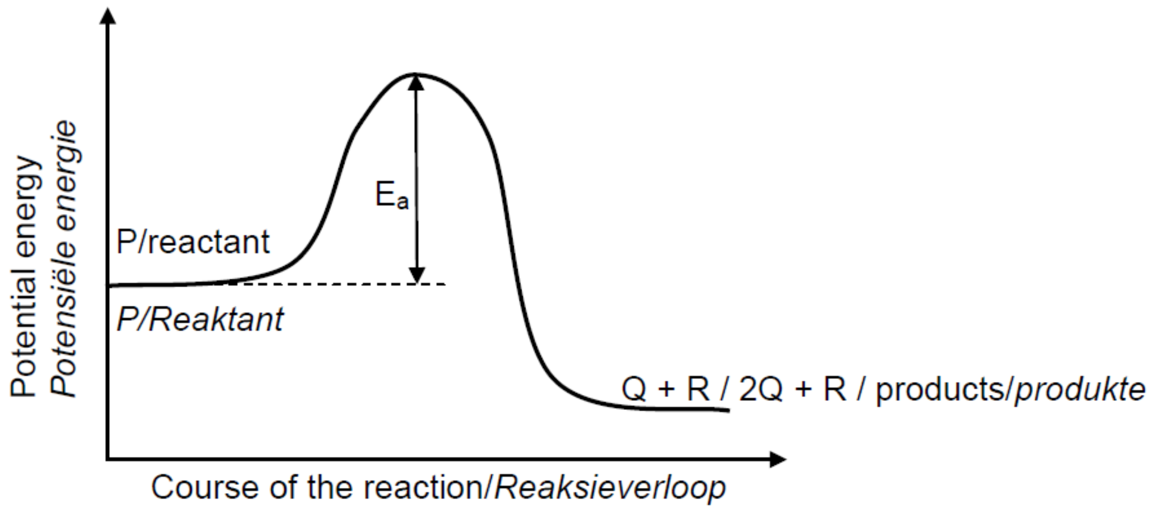
1.3. 0,27 $mol.dm^{-3}$

1.4. n = cV ✓
= (0,27)(2) ✓
= 0,54 mol
At t = 10 s
n = cV
= (0,15)(2) ✓
= 0,3 mol

Therefore the reaction rate=0,3-0.54/10-0

=-0,024 $mol.s^{-1}$

1.5.



1.6. More molecules with sufficient kinetic energy. More effective collisions per unit time.

Question 2

2.1. Equilibrium shifted to the left or reverse reaction was favoured

2.2. By adding HCl the equilibrium is disturbed as the concentration of Cl^- ions has been Increased. According to Le Chatalier's principle the reaction that uses up Cl^- ions will be favoured. i.e. reverse reaction is favoured.

2.3. $\Delta H < 0$

Question 3

3.1.1. Concentration of Nitrogen was increased.
3.1.2. Pressure on the system was increased.
3.1.3. Temperature was increased.
3.2. t_1 and t_2
3.3.

$n(NH_3) = m/M$
$= 20,4/17$
$= 1,2$ mol

	N_2	H_2	NH_3
Molar ratio	1	3	2
Initial quantity (mol)	5	5	0
Change (mol)	0,6	1,8	1,2
Quantity at equilibrium (mol)	4,4 ✓	3,2 ✓	1,2 ✓✓
Concentration ($mol \cdot dm^{-3}$)	0,88	0,64	0,24

$K_c = [NH_3]^2/[N_2][H_2]^3$
$= (0.24)^2/(0.88)(0.64)^3$
$= 0.25$