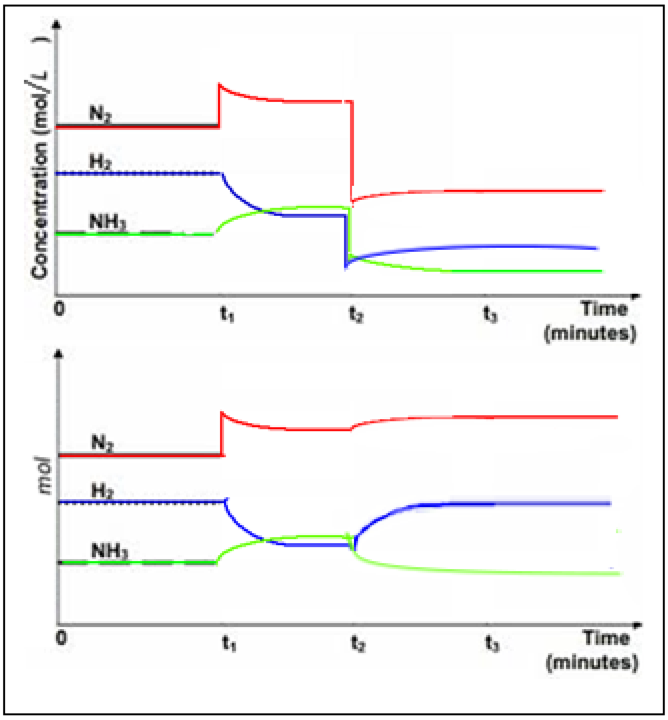
Revision 4

1) The following reaction is at equilibrium in a sealed container as shown by the two graphs on the right representing concentration and mol.
   $3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$ ΔH = negative

   a) On each graph sketch the change that would occur and how the system would move to partially undo the change if:
      - N_2 was added to the system at t_1 and equilibrium was reached before t_2.
      - The volume of the container was doubled at t_2 and equilibrium was reached before t_3.
      - At t_3 a catalyst was added to the reaction vessel.
      - At t_3 a catalyst was added to the reaction vessel.



2) In the heat, chickens hyperventilate in order to cool down. This severely reduces the amount of carbon dioxide present in their lungs. Heat stressed chickens produce eggs with thinner and more fragile shells than chickens grown in cooler climates. This is due to a reduction in the amount of calcium carbonate deposited in the shell of hotter climate chickens.

   In the lungs the following equilibrium is set up between the carbon dioxide in the air and the carbon dioxide in the blood.

   $CO_2(g) \rightleftarrows CO_2(aq)$

   In the blood the following equilibrium below is set up.

   $CO_2(aq) + H_2O(l) \rightleftarrows H_2CO_3(aq) \rightleftarrows 2H^+(aq) + CO_3^{-2}(aq)$

   In the tissues, where the egg shell is formed, yet another equilibrium is set up.

   $CO_3^{-2}(aq) + Ca^{2+}(aq) \rightleftarrows CaCO_3(s)$

   Apply your knowledge of Le Chatelier's Prinicple to the following questions.

   a) Suggest why hyperventilating reduces the amount of carbon dioxide in the blood.

   Hyperventilating reduces the amount of $CO_2(g)$ in the lungs and drives the equilibrium system shown below to the left thus reducing $CO_2(aq)$ in the blood.

   $CO_2(g) \rightleftarrows CO_2(aq)$

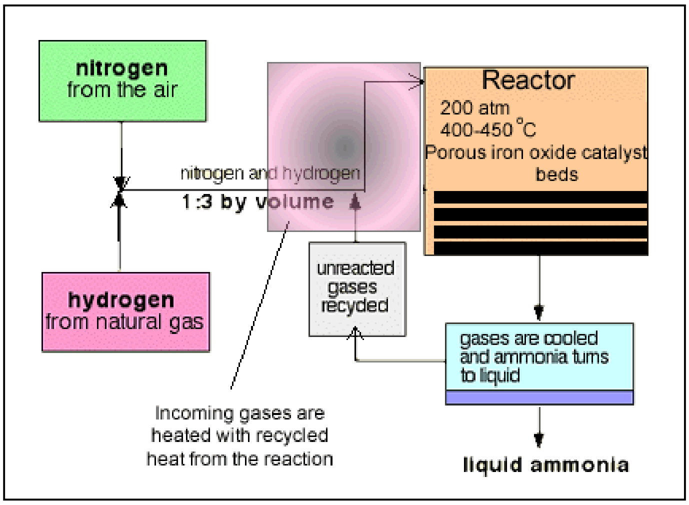
b) Explain how hyperventilating directly causes the development of thin eggshells.

Once the CO_2(aq) decreases the equilibrium labelled 1) will move in a net backward direction to partially undo the decrease in the CO_2 concentration.
This will cause a decrease in the [CO_3^{-2}] and drive the equilibrium labelled 2) in a net backward direction to partially undo the change. This depletes the $CaCO_3$ available.
1) - $CO_2(aq) + H_2O(l) \rightleftarrows H_2CO_3(aq) \rightleftarrows 2H^+(aq) + CO_3^{-2}(aq)$

2) - $CO_3^{-2}(aq) + Ca^{2+}(aq) \rightleftarrows CaCO_3(s)$

c) Providing carbonated drinking water to the chickens prevents the production of thin eggshells and restores the shells to natural state. Explain why.
Providing carbonated drinking water increases the [CO_2] in the blood and drives all equilibriums in a net forward direction.

3) Ammonia is produced commercially via the Haber process.
$3H_2(g) + N_2(g) \rightleftarrows 2NH_3\ (g)\ (\Delta H = -92\ \text{kJ/mol})$
The industrial process is simplified in the diagram below.



High yield and a fast rate are essential for commercial viability of this process.

a) Describe the conditions that increase the rate of the reaction.
-Increase rate = high temperatures and high pressure

b) Describe the conditions that maximise yield.
-Increase yield = low temperatures and high pressure

c) Explain how the conditions for maximising yield and rate are at odds with each other.
Low temperatures may produce high yield but decrease the rate of the reaction.

d) Looking at the diagram above, of the industrial process for ammonia synthesis, explain how high yield and rate are achieved at a commercial level?
Use of porous beds of catalysts to increase rate. Porous beds increase the surface area of the catalyst.
Compromise temperature of 400 °C – 450°C
Pressure at 200 atm is sufficiently high to increase rate and yield without been too high and expensive to maintain.
Ammonia is constantly removed.

4) KSCN, $Fe(NO_3)_3$ and FeSCN (NO3)$_2$ were added to 2.00 litres of distilled water at 20°C in a sealed vessel and allowed to reach equilibrium. The initial concentrations of each species were 0.200M KSCN(aq) and 0.0351 M $Fe(NO_3)_3$ M and 2.10 $FeSCN^{2+}$ M

Given that the equilibrium constant for the reaction below at 20 °C is provided, answer the following questions.

$SCN^-(aq) + Fe^{3+}(aq) \rightleftarrows FeSCN^{2+}(aq)$ ΔH = negative k_c = 1.1 x 10^2 M^- at 20°C

a) After equilibrium is established

i. Will the $[SCN^-]$ be lower, or higher than 0.200 M or remain unchanged once equilibrium is established. Explain.

The initial value of the K_c is given by the expression below.

=> $[FeSCN^{2+}] / ([SCN^-] [Fe^{3+}])$

=> 2.10 /(0.200 X 0.0351) = 299 M^-

This is in excess of the K_c at 20°C and so the system will move in a net backward direction hence restoring the k_c value of 1.1 x 10^2 M^-

=> the $[SCN^-]$ will increase as the system moves in net backward reaction.

ii. What will the value of the equation quotient be once equilibrium is established.

Since no temperature change the value of the reaction quotient will return to K_c (1.1 x 10^2 M^-)

iii. The volume of the reaction vessel is doubled and the system is allowed to reach equilibrium once more.

a. What happens to the $[SCN^-]$

increase, [✓ decrease,] remain unchanged

Explain

Since the volume is doubled all concentrations are halved, the system will respond to partially undo the dilution of all the species by moving in a net backward direction (side of most particles). Once equilibrium is restored the overall concentration of SCN^- will be lower than the initial concentration, as the change is only partially undone.

b. what happens to the number of mol of SCN^- at this new equilibrium.

[✓ increase,] decrease, remain unchanged

Explain

Since the system moves in a net backward direction the amount, in mol, of SCN^- will increase overall.

b) In another experiment conducted at 20°C it was found that the concentrations of Fe^{3+} and SCN^- were both 0.234 M.

i. Find the $[FeSCN^{2+}]$.

=> $[FeSCN^{2+}] / ([SCN^-] [Fe^{3+}])$ = 111 M^-

=> $[FeSCN^{2+}]$ /(0.234 X 0.234) = 111 M^-

=> $[FeSCN^{2+}]$ = 0.0548 X 111 = 6.08 M

ii. The temperature was then increased to 100°C.

How will the $[SCN^-]$ change? ***[✓ increase,] decrease, remain unchanged.*** Explain

Since the reaction is endothermic the system will respond to a temperature increase by moving in a net backward direction thus partially undoing the temperature increase, the [SCN$^-$] will, therefore, increase.