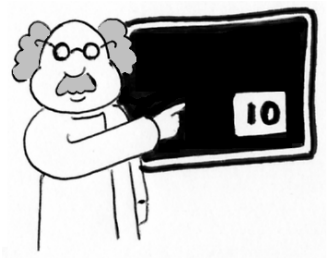

STARTER FOR 10...

8.3. Equilibria and industry

A number of industrial processes involve reversible reactions. In these cases, Le Châtelier's principle can be used to help find the best conditions for obtaining the maximum reaction yield.

1. Decide which set of conditions **A** – **C** would result in the highest yield of the desired product for each of the equilibria (a) – (c) below; (2 marks)

(a) **Production of hydrogen iodide**
$H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$ ΔH +53 kJ mol^{-1}

(b) **Making hydrogen**
$CH_4(g) + H_2O(g) \rightleftharpoons 3\,H_2(g) + CO(g)$ ΔH +206 kJ mol^{-1}

(c) **Production of methanol**
$CO(g) + 2\,H_2(g) \rightleftharpoons CH_3OH(g)$ ΔH –91 kJ mol^{-1}

A: low temperature
high pressure

B: high temperature
low pressure

C: high temperature
pressure has no effect

2. Another industrial process involving a reversible reaction is the production of sulphuric acid in the **Contact Process**. The first stage of the process is shown below;

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g) \quad \Delta H\ -196\ kJ\ mol^{-1}$$

(a) i. Use Le Châtelier's principle to explain why, at a given pressure, the percentage yield of sulfur trioxide increases with a lowering of the overall temperature. (3 marks)

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ii. To increase the rate of the reaction, a vanadium pentoxide catalyst is used. Explain what effect this has on the overall percentage yield of sulfur trioxide. (2 marks)

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(b) The reaction is run at pressures close to atmospheric pressure. Use Le Châtelier's principle to explain why this choice of pressure is unexpected and give a possible explanation for why it is chosen. (3 marks)

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Two disturbances which could be made without changing the amount of reagents or products in the system which would result in a shift of the equilibrium to the right are increasing the temperature of the system or lowering the pressure of the system. (2 marks for any two)

4. $CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$ ΔH –46 kJ mol^{-1}

Two disturbances which would result in an increase in the percentage yield of ethanol are a lowering of the temperature of the system or a increase in the pressure of the system. (2 marks for any two)

5. $HCOOH + CH_3OH \rightleftharpoons HCOOCH_3 + H_2O$ ΔH 0 kJ mol^{-1}

Two disturbances which would result in no change in the position of the equilibrium are a change in system temperature or addition of a catalyst. (2 marks for any two)

8.3. Equilibria and industry

1. (a) **Production of hydrogen iodide, Conditions C:** high temperature and pressure has no effect
$H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$ ΔH +53 kJ mol^{-1}

(b) **Making hydrogen, Conditions B:** high temperature and low pressure
$CH_4(g) + H_2O(g) \rightleftharpoons 3\,H_2(g) + CO(g)$ ΔH +206 kJ mol^{-1}

(c) **Production of methanol, Conditions A:** low temperature and high pressure
$CO(g) + 2\,H_2(g) \rightleftharpoons CH_3OH(g)$ ΔH –91 kJ mol^{-1}

(1 correct, 1 mark; all 3 correct, 2 marks)

2. (a) i. The reaction is exothermic in the forward direction (1 mark). Therefore lowering the temperature of the system shifts the equilibrium in favour of the forward, exothermic reaction (1 mark) to return the temperature to its original value (1 mark). Therefore the percentage yield of sulfur trioxide is increased.

ii. Addition of a catalyst has no effect on the position of the equilibrium and therefore does not affect the overall yield (1 mark). This is because the catalyst speeds up the rate of both the forward and reverse reaction equally (1 mark).

(b) At low pressures the equilibrium is shifted to the side with the highest number of moles of gas (1 mark) in order to return the pressure to its original value (1 mark). Therefore at atmospheric pressures the yield of sulfur dioxide would be low. Higher pressures are not used because of the expensive equipment costs associated with running reactions at high pressures (1 mark)