Equilibrium and experimental design

A chemist is tasked with investigating the yield of ammonia at different temperatures.

The equilibrium system is given below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ/mol or kJ}$$

Three different trials were set up in a 1 litre reaction vessel.
Each trial had an initial mixture of 1.00 mol of N_2 and 3.00 mol of H_2. The temperatures that were used for each mixture were 100 ^oC , 300 ^oC and 500 ^oC. After 30 seconds the scientist measured the concentration of NH_3 present at each trial.

1. Using Le Chatelier's principle, explain how the mixture will respond at each temperature?

   The yield, amount of NH_3, will decrease at higher temperatures 1----- mark
   as the exothermic reaction will shift backwards towards reactants as the temperature increases partially absorbing some of the heat energy 1-----mark
2. Identify one flaw in the experimental design that could impact on the validity of the scientist's conclusion on the relationship between temperature and yield.

   Taking one measurement assumes that the reaction has reached equilibrium. This may not be the case especially at the lower temperatures of 100 ^oC.

3. Suggest a change in the procedure that would overcome the flaw stated in question 2. above and explain why this will lead to a conclusion with high validity.

   Constant monitoring of the NH_3 until constant $[NH_3]$ is achieved. 1-----mark
   Once constant $[NH_3]$ is achieved we can be confident the reaction has reached equilibrium. 1----mark

4. Suggest one other variable that must be kept constant if the relationship between temperature and yield is to properly be investigated. Explain why this is important.

   Pressure 1-----mark
   Pressure will also influence the yield. For example high pressure leads to higher yield 1----mark
   As the equilibrium moves to the right, to least particles, in order to partially reduce the pressure 1-----mark

5. What is the scientist really measuring in this experiment over the three trials.
   Rate of reaction over the first 30 seconds. 1-----mark

6. Consider the graph shown in figure 1. It shows the concentration of NH_3 over time as graphed by the scientist during trial 1 using a temperature of 300 °C.

   a. Draw the graph you expect would be produced at 100 °c and at 500 °C. Clearly label each graph. 2 marks

   Accurately showing a greater rate, gradient is steep, at 500 °C and slower rate, gradient is less steep, at 100 °C when compared to the 300 °C graph. 1---- mark

   Greater yield at 100 °C and lower yield at 500 °C, when compared to the 300 °C 1--- mark

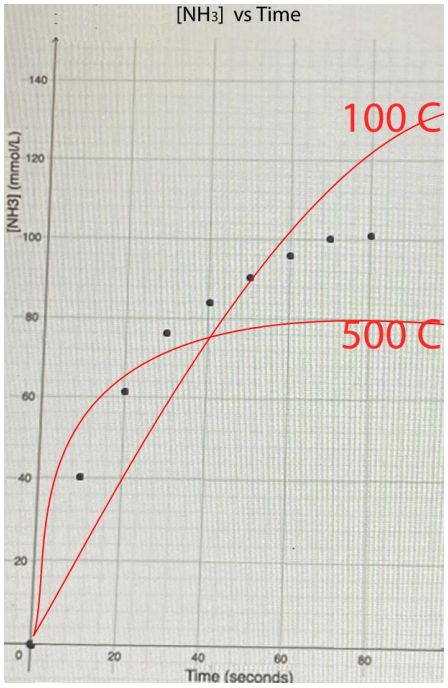

Figure 1

   b. Give an explanation for each graph.

   i. *At 500 °C the average kinetic energy is higher, hence, more frequent collisions with energy equal or greater to the E_a . The rate will, therefore, be greater 1-----mark*
   but the yield will be lower as exothermic reactions have lower yield at high temperatures as the equilibrium shifts to the left to partially undo the high temperature. 1-----mark

   ii. *At 100 °C the average kinetic energy is lower, hence, less frequent collisions with energy equal or greater to the E_a . The rate will, therefore, be lower 1-----mark*
   but the yield will be higher as exothermic reactions have higher yield at low temperatures as the equilibrium shifts to the right to partially increase the low temperature. 1-----mark