

1. The following reaction is used in industry to make sulfur trioxide gas,  $\text{SO}_3$ .



This preparation is carried out in the presence of a catalyst.

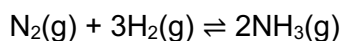
Explain the conditions of temperature and pressure that could be used to obtain the maximum equilibrium yield of sulfur trioxide.

Discuss the importance of a compromise between equilibrium yield and reaction rate when deciding the operational conditions for this process.

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**3. Ammonia,  $\text{NH}_3$ , is manufactured by the chemical industry from nitrogen and hydrogen gases.**



$$\Delta H = -92 \text{ kJ mol}^{-1}$$

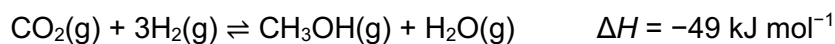
- An iron catalyst is used which provides several benefits for sustainability.
- The chemical industry uses operational conditions that are different from the conditions predicted to give a maximum equilibrium yield.

\* Use your understanding of Chemistry to explain the above statements.

Your response should be well-developed, showing a line of reasoning which is clear and logically structured.

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4. In the manufacture of methanol, carbon dioxide and hydrogen are reacted together in the reversible reaction shown below.



High pressures and low temperatures would give a maximum equilibrium yield of methanol.

- i. Explain this statement in terms of le Chatelier's principle.

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[3]

- ii. Explain why the actual conditions used by the chemical industry might be different.

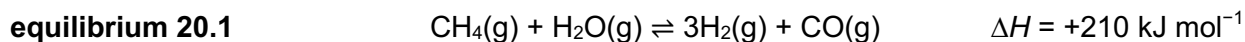
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[2]

6. Hydrogen gas is manufactured by the chemical industry using the reaction of methane and steam. This is a reversible reaction, shown in **equilibrium 20.1** below.



Explain, in terms of le Chatelier's principle, the conditions of pressure and temperature for a maximum yield of hydrogen from **equilibrium 20.1**, and explain why the operational conditions used by the chemical industry may be different.

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[4]