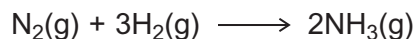


3 Ammonia can be manufactured by the Haber Process.

The equation for the reaction that occurs is shown below.



3 (a) The table below contains some bond enthalpy data.

| | $\text{N} \equiv \text{N}$ | $\text{H}-\text{H}$ | $\text{N}-\text{H}$ |
|---|----------------------------|---------------------|---------------------|
| Mean bond enthalpy / kJ mol^{-1} | 944 | 436 | 388 |

3 (a) (i) Use data from the table to calculate a value for the enthalpy of formation for one mole of ammonia.

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(3 marks)

3 (a) (ii) A more accurate value for the enthalpy of formation of ammonia is -46 kJ mol^{-1} . Suggest why your answer to part **3 (a) (i)** is different from this value.

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(1 mark)



- 3 (b)** The table below contains some entropy data.

| | H ₂ (g) | N ₂ (g) | NH ₃ (g) |
|---|--------------------|--------------------|---------------------|
| $S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$ | 131 | 192 | 193 |

Use these data to calculate a value for the entropy change, with units, for the formation of one mole of ammonia from its elements.

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(3 marks)

- 3 (c)** The synthesis of ammonia is usually carried out at about 800 K.

- 3 (c) (i)** Use the ΔH value of -46 kJ mol^{-1} and your answer from part **3 (b)** to calculate a value for ΔG , with units, for the synthesis at this temperature.
(If you have been unable to obtain an answer to part **3 (b)**, you may assume that the entropy change is $-112 \text{ J K}^{-1} \text{mol}^{-1}$. This is not the correct answer.)

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(3 marks)

- 3 (c) (ii)** Use the value of ΔG that you have obtained to comment on the feasibility of the reaction at 800 K.

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(1 mark)

