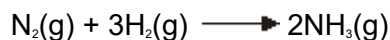


Q1. Ammonia can be manufactured by the Haber Process.

The equation for the reaction that occurs is shown below.



(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

(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)

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

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(1)

(b) The table below contains some entropy data.

	$\text{H}_2(\text{g})$	$\text{N}_2(\text{g})$	$\text{NH}_3(\text{g})$
$\text{Se} / \text{J K}^{-1} \text{ mol}^{-1}$	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)

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

- (i) Use the ΔH value of -46 kJ mol^{-1} and your answer from part (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 (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)

- (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)

(Total 11 marks)

Q2. Glucose, produced during photosynthesis in green plants, is a renewable source from

which ethanol can be made. Ethanol is a liquid fuel used as a substitute for petrol. The processes involved can be summarised as follows.

Process 1 Photosynthesis in green plants
 $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$

Process 2 Fermentation of glucose to form ethanol

Process 3 Complete combustion of ethanol
 $\text{CH}_3\text{CH}_2\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O}$

(a) State **three** essential conditions for the fermentation of aqueous glucose in Process 2.

Write an equation for the reaction that takes place during this fermentation.

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(4)

(b) It has been claimed that there is no net carbon (greenhouse gas) emission to the atmosphere when ethanol made by Process 2 is used as a fuel.

State the term that is used to describe fuels of this type.

Use the equations for Processes 1, 2 and 3 to show why it can be claimed that there is no net emission of carbon-containing greenhouse gases.

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(3)

- (c) Use the information from the equation for Process 3 above and the mean bond enthalpies from the table below to calculate a value for the enthalpy change for this process.

	C-H	C-C	C-O	O-H	C=O	O=O
Mean bond enthalpy / kJ mol ⁻¹	+412	+348	+360	+463	+743	+496

Give **one** reason why the value calculated from mean bond enthalpies is different from the value given in a data book.

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(4)

- (d) A student carried out a simple laboratory experiment to measure the enthalpy change for Process 3. The student showed that the temperature of 200 g of water increased by 8.0 °C when 0.46 g of pure ethanol was burned in air and the heat produced was used to warm the water.

Use these results to calculate the value, in kJ mol⁻¹, obtained by the student for this enthalpy change. (The specific heat capacity of water is 4.18 J K⁻¹ g⁻¹)

Give **one** reason, other than heat loss, why the value obtained from the student's results is less exothermic than a data book value.

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(4)
(Total 15 marks)

Q3. Hydrogen gas is used in the chemical industry.

(a) Tungsten is extracted by passing hydrogen over heated tungsten oxide (WO_3).

(i) State the role of the hydrogen in this reaction.

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(1)

(ii) Write an equation for this reaction.

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(1)

(iii) State **one** risk of using hydrogen gas in metal extractions.

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(1)

(b) Hydrogen is used to convert oleic acid into stearic acid as shown by the following equation.



- (i) Use your knowledge of the chemistry of alkenes to deduce the type of reaction that has occurred in this conversion.

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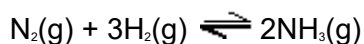
(1)

- (ii) State the type of stereoisomerism shown by oleic acid.

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(1)

- (c) Hydrogen reacts with nitrogen in the Haber Process. The equation for the equilibrium that is established is shown below.



- (i) State Le Chatelier's principle.

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(1)

- (ii) Use Le Chatelier's principle to explain why an increase in the total pressure of this equilibrium results in an increase in the equilibrium yield of ammonia.

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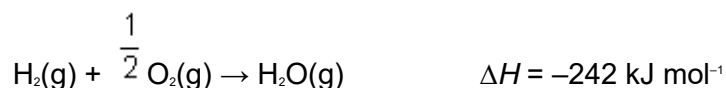
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(2)

- (d) Hydrogen reacts with oxygen in an exothermic reaction as shown by the following equation.



Use the information in the equation and the data in the following table to calculate a value for the bond enthalpy of the H–H bond.

	O-H	O=O
Mean bond enthalpy / kJ mol ⁻¹	+ 463	+ 496

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(3)
(Total 11 marks)

Q4. A method of synthesising ammonia directly from nitrogen and hydrogen was developed by Fritz Haber. On an industrial scale, this synthesis requires a high temperature, a high pressure and a catalyst and is very expensive to operate.

- (a) Use the data given below to calculate a value for the enthalpy of formation of ammonia

Bond	N \equiv N	H - H	N - H
Mean bond enthalpy/kJ mol ⁻¹	945	436	391

(3)

- (b) A manager in charge of ammonia production wished to increase the daily production of ammonia and reduce the production costs. How would a chemist explain the factors that would influence the commercial efficiency of this production process?

(8)
(Total 11 marks)