**Q1.** Ammonia can be manufactured by the Haber Process.

The equation for the reaction that occurs is shown below.

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

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

| | N ≡ N | H–H | N–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.

| | $H_2(g)$ | $N_2(g)$ | $NH_3(g)$ |
|---|---|---|---|
| $S\ominus$ / J K$^{-1}$ 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 Δ*H* value of –46 kJ $mol^{-1}$ and your answer from part (b) to calculate a value for Δ*G*, 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 J $K^{-1}$ $mol^{-1}$. This is not the correct answer.)

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**(3)**

(ii) Use the value of Δ*G* 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
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Process **2** Fermentation of glucose to form ethanol

Process **3** Complete combustion of ethanol
$CH_3CH_2OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

(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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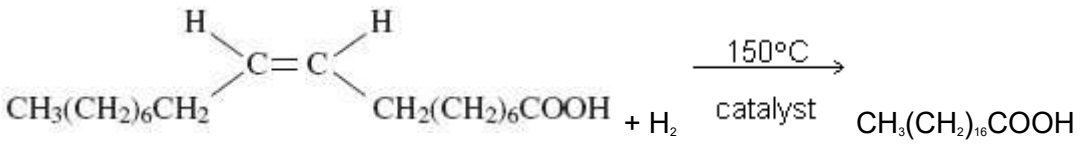
**(1)**

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




oleic acid

stearic acid

(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.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(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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**(2)**

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

$$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(g) \qquad \Delta H = -242 \text{ kJ mol}^{-1}$$

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 ≡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)**