

Q1.Hydrogen can be manufactured from the reaction of steam with methane.



(a) The table contains some enthalpy of formation and entropy data.

Substance	$\Delta H_{\ominus_f} / \text{kJ mol}^{-1}$	$S_{\ominus} / \text{J K}^{-1} \text{mol}^{-1}$
$\text{CH}_4(\text{g})$	-75	186
$\text{H}_2\text{O}(\text{g})$	-242	189
$\text{CO}(\text{g})$	-111	198
$\text{H}_2(\text{g})$	0	131
$\text{CO}_2(\text{g})$	-394	214

(i) Use data from the table to calculate the enthalpy change, ΔH , for the reaction of steam with methane.

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(ii) Use data from the table to calculate the entropy change, ΔS , for the reaction of steam with methane.

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- (b) Use your values of ΔH and ΔS from parts (a)(i) and (a)(ii) to calculate the temperature above which this reaction is feasible.

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- (c) The temperature used for this manufacture of hydrogen is usually about 1300 K.

Suggest **one** reason, other than changing the position of equilibrium, why this temperature is used rather than the value that you calculated in part (b).

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- (d) Hydrogen can also be obtained by reaction of carbon monoxide with steam.



- (i) Explain, using a calculation, why this reaction should **not** occur at 1300 K.

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- (ii) Explain how the conditions for the reaction could be changed to allow this reaction to take place.

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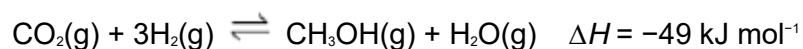
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(2)

(Total 15 marks)

Q2. The table below contains some entropy data relevant to the reaction used to synthesise methanol from carbon dioxide and hydrogen. The reaction is carried out at a temperature of 250 °C.

Substance	CO ₂ (g)	H ₂ (g)	CH ₃ OH(g)	H ₂ O(g)
Entropy (S°) / J K ⁻¹ mol ⁻¹	214	131	238	189



- (a) Use this enthalpy change and data from the table to calculate a value for the free-energy change of the reaction at 250 °C. Give units with your answer.

Free-energy change = Units =

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- (b) Calculate a value for the temperature when the reaction becomes feasible.

Temperature = K

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- (c) Gaseous methanol from this reaction is liquefied by cooling before storage.

Draw a diagram showing the interaction between two molecules of methanol.
Explain why methanol is easy to liquefy.

Diagram

Explanation

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(Total 10 marks)

- Q3.(a)** A co-ordinate bond is formed when a transition metal ion reacts with a ligand.

Explain how this co-ordinate bond is formed.

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- (b) Describe what you would observe when dilute aqueous ammonia is added dropwise, to excess, to an aqueous solution containing copper(II) ions. Write equations for the reactions that occur.

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- (c) When the complex ion $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ reacts with 1,2-diaminoethane, the ammonia molecules but not the water molecules are replaced.

Write an equation for this reaction.

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- (d) Suggest why the enthalpy change for the reaction in part (c) is approximately zero.

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- (e) Explain why the reaction in part (c) occurs despite having an enthalpy change that is approximately zero.

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(Total 11 marks)

Q4. The following table shows some enthalpy change and entropy change data.

	$\Delta H / \text{kJ mol}^{-1}$	$\Delta S / \text{J K}^{-1} \text{mol}^{-1}$
$\text{AgCl(s)} \longrightarrow \text{Ag}^{\text{(g)}} + \text{Cl}^{\text{(g)}}$	+905	
$\text{AgCl(s)} \longrightarrow \text{Ag}^{\text{(aq)}} + \text{Cl}^{\text{(aq)}}$	+77	+33
$\text{AgF(s)} \longrightarrow \text{Ag}^{\text{(aq)}} + \text{F}^{\text{(aq)}}$	-15	to be calculated
$\text{Ag}^{\text{(g)}} \longrightarrow \text{Ag}^{\text{(aq)}}$	-464	

- (a) Define the term **enthalpy of hydration** of an ion.

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- (b) Use data from the table to calculate a value for the enthalpy of hydration of the chloride ion.

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- (c) Suggest why hydration of the chloride ion is an exothermic process.

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- (d) Silver chloride is insoluble in water at room temperature.

Use data from the table to calculate the temperature at which the dissolving of silver chloride in water becomes feasible.
Comment on the significance of this temperature value.

Calculation of temperature

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Significance of temperature value

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- (e) When silver fluoride dissolves in water at 25 °C, the free-energy change is -9 kJ mol^{-1} .

Use this information and data from the table to calculate a value, with units, for the entropy change when silver fluoride dissolves in water at 25 °C.

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(Total 13 marks)