

# HL Paper 2

Enthalpy changes depend on the number and type of bonds broken and formed.

The table lists the standard enthalpies of formation,  $\Delta_f H^\ominus$ , for some of the species in the reaction above.

	$\text{CH}_4(\text{g})$	$\text{H}_2\text{O}(\text{g})$	$\text{CO}(\text{g})$	$\text{H}_2(\text{g})$
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	-74.0	-242	-111	

Enthalpy changes depend on the number and type of bonds broken and formed.

a. Hydrogen gas can be formed industrially by the reaction of natural gas with steam. [3]



Determine the enthalpy change,  $\Delta H$ , for the reaction, in kJ, using section 11 of the data booklet.

Bond enthalpy for  $\text{C}\equiv\text{O}$ :  $1077 \text{ kJ mol}^{-1}$

b.i. Outline why no value is listed for  $\text{H}_2(\text{g})$ . [1]

b.ii. Determine the value of  $\Delta H^\ominus$ , in kJ, for the reaction using the values in the table. [1]

c. The table lists standard entropy,  $S^\ominus$ , values. [1]

	$\text{CH}_4(\text{g})$	$\text{H}_2\text{O}(\text{g})$	$\text{CO}(\text{g})$	$\text{H}_2(\text{g})$
$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$	+186	+189	+108	+131

Calculate the standard entropy change for the reaction,  $\Delta S^\ominus$ , in  $\text{J K}^{-1}$ .



d. Calculate the standard free energy change,  $\Delta G^\ominus$ , in kJ, for the reaction at 298 K using your answer to (b)(ii). [1]

e. Determine the temperature, in K, above which the reaction becomes spontaneous. [1]

## Markscheme

a. bonds broken:  $4(\text{C}-\text{H}) + 2(\text{H}-\text{O})/4(414) + 2(463)/2582 \text{ kJ}$

bonds made:  $3(\text{H}-\text{H}) + \text{C}\equiv\text{O}/3(436) + 1077/2385 \text{ kJ}$

$\Delta H = \text{IBE}_{\text{bonds broken}} - \text{IBE}_{\text{bonds made}} = 2582 - 2385 = -197 \text{ kJ}$

Award [3] for correct final answer.

Award [2 max] for -197 kJ.

[3 marks]

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**M Carnoy**



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