Methanol is formed when carbon dioxide and hydrogen react.

$$CO_2(g) + 3\,H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Table 5 contains enthalpy of formation and entropy data for these substances.

Table 5

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta_f H$ / kJ mol^{-1}	–394	0	–201	–242
S / J K^{-1} mol^{-1}	214	131	238	189

. **1** Use the equation and the data in **Table 5** to calculate the Gibbs free-energy change (ΔG), in kJ mol^{-1}, for this reaction at 890 K

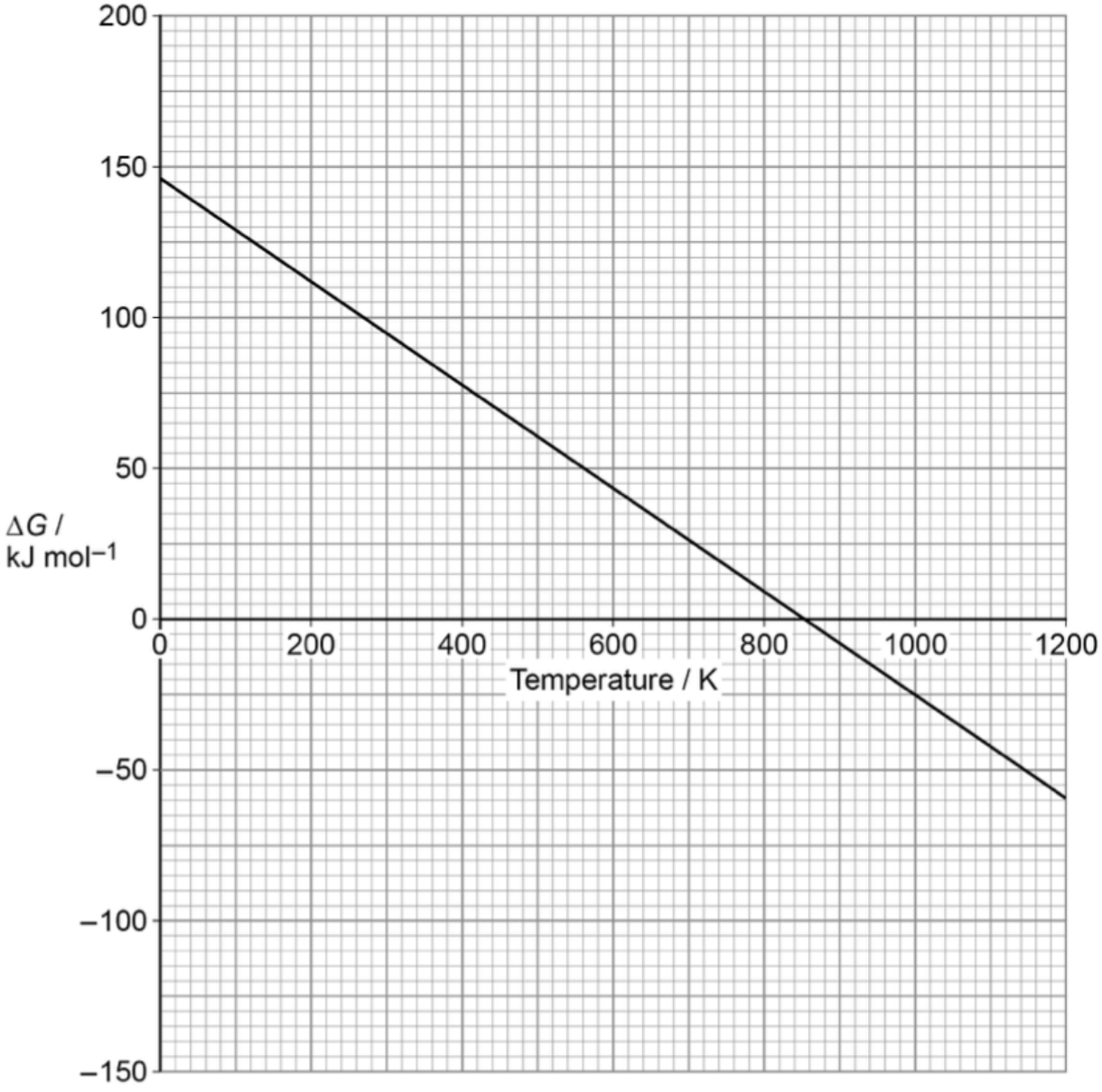
[6 marks]

ΔG _____ kJ mol^{-1}

Figure 4 shows how the Gibbs free-energy change varies with temperature in a different gas phase reaction.

The straight line graph for this gas phase reaction has been extrapolated to zero Kelvin.

Figure 4



. 2 Use the values of the intercept and gradient from the graph in **Figure 4** to calculate the enthalpy change (ΔH), in kJ mol^{-1}, and the entropy change (ΔS), in J K^{-1} mol^{-1}, for this reaction.

[4 marks]

ΔH _____ kJ mol^{-1}

ΔS _____ J K^{-1} mol^{-1}

. 3 State what **Figure 4** shows about the feasibility of the reaction.

[1 mark]

_____

_____

_____

A mixture of 1.0 mol of nitrogen and 3.0 mol of hydrogen is left to reach equilibrium at 700 K.

Calculate the total pressure, in atmospheres, needed to produce a yield of 0.30 mol of ammonia at 700 K.
Give your answer to an appropriate number of significant figures.

You must show your working.

[$K_p = 7.76 \times 10^{-5}$ atm^{-2} at 700 K]

(5)