18 This question is about free energy changes, ΔG, enthalpy changes, ΔH, and temperature, T.

(a) The Gibbs' equation is shown below.

$$\Delta G = \Delta H - T\Delta S$$

A chemist investigates a reaction to determine how ΔG varies with T.
The results are shown in **Fig. 18.1**.

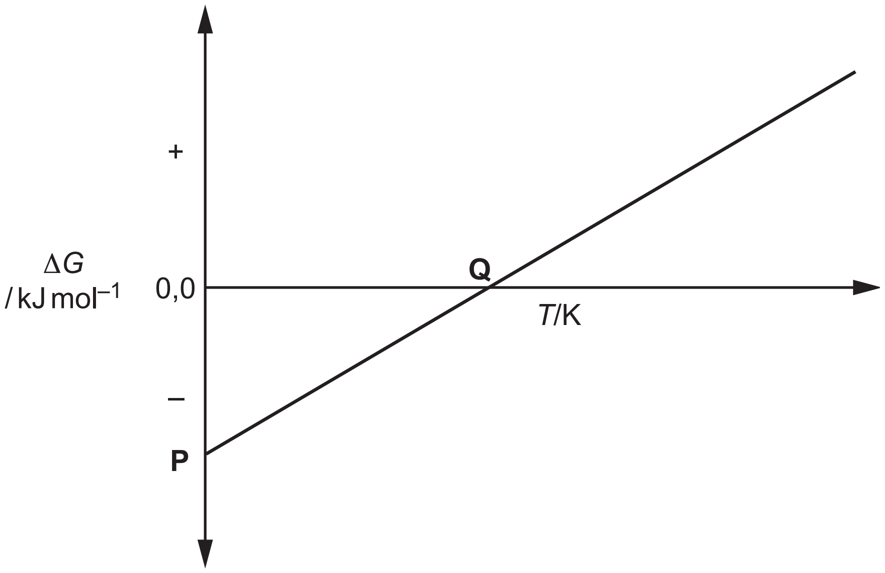

Fig. 18.1

What is significant about the gradient of the line and the values **P** and **Q** shown in **Fig. 18.1**? Explain your reasoning.

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.... **[4]**

(b) Iron can be extracted from its ore Fe_3O_4 using carbon.
Several equilibria are involved including **equilibrium 18.1**, shown below.

equilibrium 18.1 $Fe_3O_4(s) + 4C(s) \rightleftharpoons 3Fe(s) + 4CO(g)$ $\Delta H = +676.4\ kJ\ mol^{-1}$
$\Delta S = +703.1\ J\ K^{-1}\ mol^{-1}$

(i) Why is **equilibrium 18.1** a *heterogeneous* equilibrium?

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.... **[1]**

(ii) Write the expression for K_p for **equilibrium 18.1**.

[1]

(iii) The forward reaction in **equilibrium 18.1** is only feasible at high temperatures.

- Show that the forward reaction is **not** feasible at 25 °C.
- Calculate the minimum temperature, in K, for the forward reaction to be feasible.

minimum temperature = ... K **[3]**

(iv) Another equilibrium involved in the extraction of iron from Fe_3O_4 is shown below.

$$Fe_3O_4(s) + 4CO(g) \rightleftharpoons 3Fe(s) + 4CO_2(g) \qquad \Delta H = -13.5\,\text{kJ mol}^{-1}$$

Enthalpy changes of formation, $\Delta_f H$, for Fe_3O_4(s) and CO_2(g) are shown in the table.

Compound	**$\Delta_f H$ / kJ mol^{-1}**
Fe_3O_4(s)	–1118.5
CO_2(g)	–393.5

Calculate the enthalpy change of formation, $\Delta_f H$, for CO(g).

$\Delta_f H$, for CO(g) = ... kJ mol^{-1} **[3]**