Question 2

ΔG° of relevant reactions:

$C + O_2 \leftrightarrow CO_2$	$-394(10)^3 - 0.836T$
$CO \leftrightarrow C + \frac{1}{2}O_2$	$-112.9(10)^3 - 86.5T$
$Fe_3O_{4,(s)} \leftrightarrow 3Fe_{(s)} + 2O_{(g)}$	$-(-1103.1(10)^3 + 307.4T)$
$FeO \leftrightarrow Fe + \frac{1}{2}O_2$	$-(264(10)^3 + 64.6T)$
$3Fe_2O_3 \leftrightarrow Fe + 3O_2$	$-(-815(10)^3 + 251.1T)$

1. $\mathbf{\frac{1}{4}Fe_3O_4 + CO \leftrightarrow \frac{3}{4}Fe + CO_2}$; $\Delta G^\circ_{rxn} = -231.125(10)^3 - 164.186T$ J

   $\frac{1}{4}\big[Fe_3O_{4,(s)} \leftrightarrow 3Fe_{(s)} + 2O_{(g)}\big]$

   $C + O_2 \leftrightarrow CO_2$

   $CO \leftrightarrow C + \frac{1}{2}O_2$

2. $\mathbf{FeO + CO \leftrightarrow Fe + CO_2}$; $\Delta G^\circ_{rxn} = -545.1(10)^3 + 150.264T$ J

   $FeO \leftrightarrow Fe + \frac{1}{2}O_2$

   $C + O_2 \leftrightarrow CO_2$

   $CO \leftrightarrow C + \frac{1}{2}O_2$

3. $\mathbf{Fe_3O_4 + CO \leftrightarrow FeO + CO_2}$; $\Delta G^\circ_{rxn} = -592.2(10)^3 + 199.264T$ J

   $Fe_3O_4 \leftrightarrow 3Fe + 2O_2$

   $3\big[Fe + \frac{1}{2}O_2 \leftrightarrow FeO\big]$

   $C + O_2 \leftrightarrow CO_2$

   $CO \leftrightarrow C + \frac{1}{2}O_2$

4. $\mathbf{3Fe_2O_3 + CO \leftrightarrow 2Fe_3O_4 + CO_2}$; $\Delta G^\circ_{rxn} = -360.7(10)^3 + 131.831T$ J

   $3Fe_2O_3 \leftrightarrow Fe + 3O_2$

   $\frac{2}{3}\big[3Fe + 2O_2 \leftrightarrow Fe_3O_4\big]$

   $C + O_2 \leftrightarrow CO_2$

   $CO \leftrightarrow C + \frac{1}{2}O_2$

Plotting

$\Delta G = -RT \ln k$
$k = \exp \frac{-\Delta G^\circ}{RT} = \frac{P_{CO_2}}{P_{CO}}$

Let the vertical axis be: $\frac{P_{CO}}{P_{CO}+P_{CO_2}}$

vertical axis in terms of k: $\frac{P_{CO}}{P_{CO}+kP_{CO}} = \frac{1}{1+k}$

equations for phase boundary curves

For each reaction $i = 1 \ldots 4$:

$$\Delta G_i^\circ(T) = a_i + b_i T \quad \Rightarrow \quad K_i(T) = \exp\left(\frac{-\Delta G_i^\circ(T)}{RT}\right)$$

and the plotted ordinate is

$$\%\mathrm{CO}_i(T) = 100 \cdot \frac{1}{1 + K_i(T)}.$$

Use $R = 8.314462618\ \mathrm{J\,mol^{-1}\,K^{-1}}$ and the coefficients (in J/mol, T in K):

$$\begin{aligned}
\Delta G_1^\circ &= -231.125 \times 10^3 - 164.186\,T, \\
\Delta G_2^\circ &= -545.1 \times 10^3 + 150.264\,T, \\
\Delta G_3^\circ &= -592.2 \times 10^3 + 199.264\,T, \\
\Delta G_4^\circ &= -360.7 \times 10^3 + 131.831\,T.
\end{aligned}$$