EQUILIBRIUM AHL (HL only)

Please ensure that you have also completed the Core (SL & HL) questions

1. (a) Consider the equilibrium:

$$N_2\,(g) + O_2\,(g) \rightleftharpoons 2NO\,(g)$$

(i) Write an expression for the equilibrium constant, K_c, for the reaction.

[1]

$(K_c =) \dfrac{[NO]^2}{[N_2][O_2]}$ ✓

(ii) At a temperature, T, $K_c = 1.6 \times 10^{-3}$. If the initial concentrations of N_2 and O_2 are each 2.0 mol dm^{-3}, (0 mol dm^{-3} of NO initially) calculate the concentration of NO at equilibrium.

[3]

	N_2	+ O_2	⇌ 2NO
R	1	: 1	: 2
I	2.0	2.0	0
C	$-x$	$-x$	$+2x$
E	$2.0-x$	$2.0-x$	$2x$

$K_c = \dfrac{(2x)^2}{(2.0-x)(2.0-x)}$ ✓

$1.6\times10^{-3} = \dfrac{(2x)^2}{(2.0-x)^2}$ square root both sides.

$0.04 = \dfrac{2x}{2.0-x}$

$0.08 - 0.04x = 2x$

$0.08 = 2.04x$ $x = \dfrac{0.08}{2.04} = 0.039$ ✓ $[NO]_{eqm} = 0.078$ mol dm^{-3} ✓

correct answer scores 3

(iii) Using **section 1 and 2** of the data booklet, calculate the standard Gibb's free energy change, ΔG°, for this reaction, in kJ, if temperature T = 1400°C.

[3]

$\Delta G^{\circ} = -RT\ln K$

$T = 1400 + 273 = 1673$ ✓

$R = 8.31 \times 10^{-3}$ kJ $K^{-1} mol^{-1}$ ✓

$\Delta G^{\circ} = -0.00831 \times 1673 \times \ln 1.6\times10^{-3}$

$= -$ 〃 × 〃 × $-6.437...$

$= +89.5$ kJ ✓

correct answer scores 3

(iv) State and explain what your answer to (iii) suggests about the position of equilibrium.

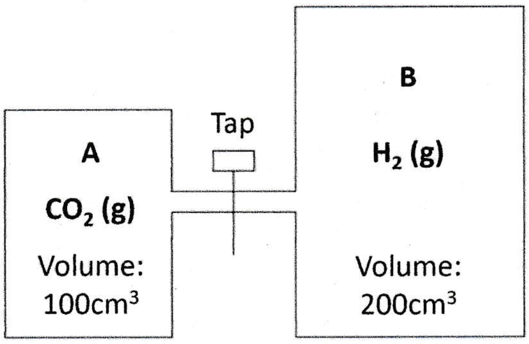
[1]

ΔG° is positive so the equilibrium must lay to the left / reactants. ✓

2. An experiment is carried out to investigate the following equilibrium:

$CO_2 (g) + 2H_2 (g) \rightleftharpoons CH_3OH (g) \quad \Delta H = -91 \text{ kJ mol}^{-1}$

Chamber **A** contains 1.00 mol of CO_2 (g) and chamber **B** contains 2.00 mol of H_2 (g).



(a) What **initial** pressure change will occur, if any, when the tap is opened.

[1]

No change in total pressure (both chambers at same pressure) ✓

(b) Write an expression for, and calculate the theoretical value of K_c, if the maximum yield of CH_3OH in this experiment is 90%. Give your answer to 3 significant figures.

[5]

	CO_2 +	$2H_2$ ⇌	CH_3OH	
R	1 :	2 :	1	
I	1.00	2.00	0	n. of moles
C	−0.90	−1.80	+0.90	
E	0.10	0.20	0.90	(moles) ← ✓
[E]	0.10/0.3	0.20/0.3	0.90/0.3	(concentration)
	= 0.33̇3̇	0.66̇6̇	3.00	← ✓ concs.

$K_c = \frac{[CH_3OH]}{[CO_2][H_2]^2}$ ✓

$= \frac{3.00}{0.33\dot{3} \times (0.66\dot{6})^2}$

$= \frac{3.00}{0.148148...}$

= 20.25 ✓ = 20.3 ✓ (3 sig figs) ✓ (3 sig figs)

Correct answer scores 4/5 (3 sig figs)

(c) How will the initial pressure have changed when the experiment reaches equilibrium. Explain your reasoning.

[2]

It will have decreased because ✓
3 moles of gas on left & one mole of right ✓

Total 16 marks (24 minutes)