Marks 5

- Equal volumes of carbon monoxide and hydrogen gas are introduced into a sealed 4.5 L flask at 1200 K and the following equilibrium is established.

$$CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g) \qquad \Delta H^\circ = -205.9 \text{ kJ mol}^{-1}$$

At equilibrium, the flask contains 0.22 mol of CH_4 and the total pressure in the flask is 46.4 atm. Calculate the amount of $H_2(g)$ (in mol) that was initially introduced into the flask.

In terms of moles, the reaction table is:

	$CO(g)$	$3H_2(g)$	$\rightleftharpoons$	$CH_4(g)$	$H_2O(g)$
initial	x	$\underline{x}$		**0**	**0**
change	$-y$	$-3y$		$+y$	$+y$
equilibrium	$x - y$	$x - 3y$		y	y

(Three H_2 molecules are lost for every one CO molecule and hence the change in the number of moles of CO(g) and H_2(g) are -*y* and -3*y* respectively).

As 0.22 mol of CH_4(g) is present at equilibrium, y = 0.22 mol.

The total number of moles present is therefore:

$$\text{total number of moles} = n_{CO(g)} + n_{H_2(g)} + n_{CH_4(g)} + n_{H_2O(g)}$$
$$= (x - y) + (x - 3y) + (y) + (y) = 2x - 2y = 2x - 0.44 \text{ mol}$$

As the pressure in the flask is 46.4 atm at equilibrium, the number of moles of gas at equilibrium is can be calculated from the ideal gas law, $PV = nRT$:

$$n = \frac{PV}{RT} = \frac{(46.4\,\text{atm}) \times (4.5\,\text{L})}{(0.08206\,\text{L atm K}^{-1}\,\text{mol}^{-1}) \times (1200\,\text{K})} = 2.12\,\text{mol}$$

Hence, 2x – 0.44 = 2.12 and x = 1.28 mol = initial number of moles of H_2(g)

Answer: **1.28 mol**

In a separate experiment, it is determined that the reaction is in equilibrium when the same 4.5 L flask contains 0.18 mol of CH_4, 0.24 mol of H_2O, 0.82 mol of CO and 0.65 mol of H_2 at 1200 K. Calculate the concentration equilibrium constant, K_c, for this temperature.

$$[CH_4(g)] = \frac{0.18\,\text{mol}}{4.5\,\text{L}} = 0.040\,\text{M}, \quad [H_2O(g)] = \frac{0.24\,\text{mol}}{4.5\,\text{L}} = 0.053\,\text{M}$$

$$[CO(g)] = = \frac{0.82\,\text{mol}}{4.5\,\text{L}} = 0.18\,\text{M}, \quad [H_2(g)] = \frac{0.65\,\text{mol}}{4.5\,\text{L}} = 0.14\,\text{M}$$

$$\text{Hence, } K_c = \frac{[CH_4(g)][H_2O(g)]}{[CO(g)][H_2(g)]^3} = \frac{(0.040) \times (0.53)}{(0.18) \times (0.14)^3} = 3.9$$

K_c = **3.9**