Hydrogen can be made by the reaction of methane with steam in a reaction that reaches a state of dynamic equilibrium in a closed system.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

At temperature **T**, in a container of volume 12 dm^3, 2.00 moles of methane is mixed with 10.00 moles of steam. At equilibrium, it is found that there are 4.50 moles moles of hydrogen.

a What is happening when the system is in dynamic equilibrium?

both reactions are taking place simultaneously and at the same rate

b Write an expression for the equilibrium constant K_c, and state its units.

$$K_c = \frac{[CO][H_2]^3}{[CH_4]\,[H_2O]} \qquad \text{mol}^2\ \text{dm}^{-6}$$

c Calculate the value of the equilibrium constant K_c at this temperature.

	$CH_4(g)$ +	$H_2O(g)$ ⇌	$CO(g)$ +	$3H_2(g)$
moles at start	**2.00**	**10.00**	**0**	**0**
change in moles	**–1.50**	**–1.50**	**+1.50**	**+4.50**
moles at equilibrium	**0.50**	**8.50**	**1.50**	**4.50**

$$K_c = \frac{[CO][H_2]^3}{[CH_4]\,[H_2O]} = \frac{\left(\frac{1.50}{12}\right)\left(\frac{4.5}{12}\right)^3}{\left(\frac{0.50}{12}\right)\left(\frac{8.50}{12}\right)} = 0.22\ mol^2\ dm^{-6}$$

d What happens to the yield of hydrogen and the value of K_c if the pressure is increased? Explain your answer.

equilibrium position moves left to side with fewer gas molecules to oppose increase in pressure

decreases yield of H_2

no change in K_c

e What happens to the yield of hydrogen and the value of K_c if the temperature is increased? Explain your answer.

equilibrium position moves right in endothermic direction to oppose increase in temperature

increases yield of H_2

K_c increases

f Calculate K_c and state its units for this equilibrium at the same temperature: $CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$

$$K_c = \frac{1}{0.22} = 4.5\ mol^{-2}\ dm^6$$