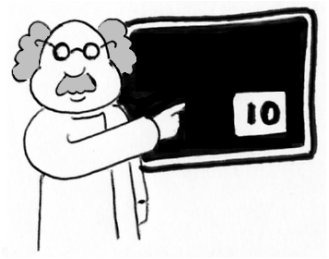


STARTER FOR 10...

2.3. Le Châtelier and K_c

Le Châtelier has lost his glasses. He can't remember which floor of his lab he left them on!

Consider the equilibrium below;

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g) \quad \Delta H = +40 \text{ kJ mol}^{-1}$$

Help Le Châtelier find his glasses by deciding what effect each of the changes in conditions **1**-**9** listed below will have on the value of K_c for this equilibrium.

Le Châtelier is currently in his office on the second floor

- If the change in conditions increase K_c, move Le Châtelier one floor up
- If the change in conditions decrease K_c, move Le Châtelier one floor down
- If the change in conditions have no effect on K_c, Le Châtelier doesn't move

Unless stated otherwise assume that all conditions other than the one mentioned remain constant.

1. Adding a catalyst to the reaction mixture .....

2. Adding CO_2 to the reaction mixture.....

3. Increasing the pressure of the system .....

4. Increasing the reaction temperature .....

5. Adding CO to the reaction mixture.....

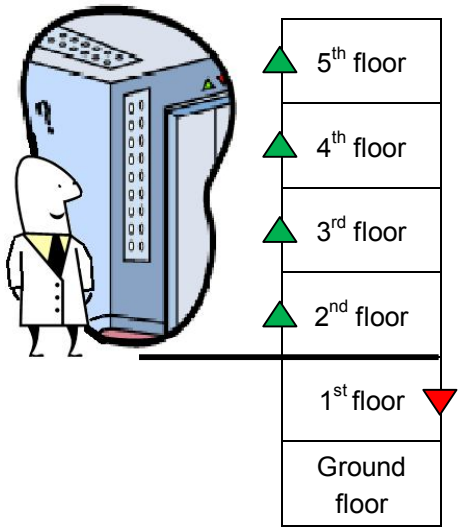
6. Decreasing the reaction temperature.....

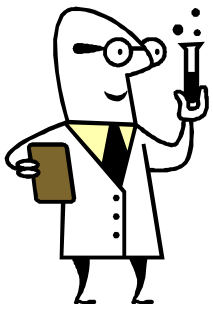
7. Increasing the volume of the reaction container.....

8. Increasing the amount of H_2 gas in the reaction mixture .....

9. Increasing the surface area of the catalyst.....

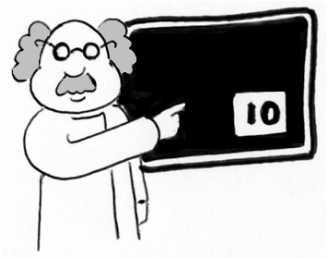
(9 marks)





Le Châtelier will find his glasses on the ..... floor.

(1 mark)



STARTER FOR 10...

2. Equilibria answers

2.

	ethyl butanoate	+ water	⇌	butanoic acid	+ ethanol
Initial	1 mol	2 mol		0 mol	0 mol
Change	–0.3 mol	–0.3 mol		+0.3 mol	+0.3 mol
Equilibrium	0.7 mol	1.7 mol		0.3 mol	0.3 mol

(1 mark)

$$K_c = \frac{[\text{acid}]\,[\text{alcohol}]}{[\text{ester}]\,[\text{water}]} = \frac{[0.3\text{ mol} / V]\,[0.3\text{ mol} / V]}{[0.7\text{ mol} / V]\,[1.7\text{ mol} / V]} = \underline{0.076 \text{ no units}}$$

(1 mark for value, 1 mark for units)

3. No. of moles in 50 cm^3 of water;

Mass = 50 cm^3 × 1 g cm^{-3} = 50 g

Moles = 50 g / 18 g mol^{-1} = 2.78 mol *(1 mark)*

Substituting into the equilibrium;

	butanol +	ethanoic acid	⇌	ester	+ water
Initial	x mol	0.5 mol		0 mol	2.78 mol
Change	–0.25 mol	–0.25 mol		+0.25 mol	+0.25 mol
Equilibrium	(x – 0.25) mol	0.25 mol		0.25 mol	3.03 mol

$$K_c = \frac{[\text{ester}]\,[\text{water}]}{[\text{butanol}]\,[\text{ethanoic acid}]} = \frac{[0.25\text{ mol} / V]\,[3.03\text{ mol} / V]}{[(x - 0.25\text{ mol}) / V]\,[0.25\text{ mol} / V]}$$ *(1 mark)*

Knowing that K_c = 3.0 under the reaction conditions;

$$3.0 = \frac{[0.25\text{ mol} / V]\,[3.03\text{ mol} / V]}{[(x - 0.25\text{ mol}) / V]\,[0.25\text{ mol} / V]} = \frac{0.7575}{0.25x - 0.0625}$$

$3.0\,(0.25x - 0.0625) = 0.7575$

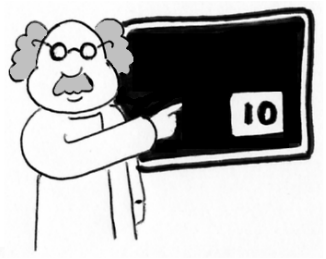
$0.75x - 0.1875 = 0.7575$

$0.75x = 0.945$

$\underline{x = 1.26 \text{ mol}}$ *(1 mark)*

2.3 Le Châtelier and K_c

	Effect on K_c	Location of Le Châtelier
1. Adding a catalyst to the reaction mixture	no change	2nd floor
2. Adding CO_2 to the reaction mixture	no change	2nd floor



STARTER FOR 10...

2. Equilibria answers

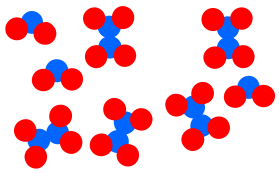
3. Increasing the pressure of the system	no change	2nd floor
4. Increasing the reaction temperature	increases	3rd floor
5. Adding CO to the reaction mixture	no change	3rd floor
6. Decreasing the reaction temperature	decreases	2nd floor
7. Increasing the volume of the reaction container	no change	2nd floor
8. Increasing the amount of H_2 gas in the reaction mixture	no change	2nd floor
9. Increasing the surface area of the catalyst	no change	2nd floor

(9 marks)

Le Châtelier can find his glasses on the 2nd floor …… they were in his office all along! *(1 mark)*

2.4. The equilibrium constant, K_p

1. *4 marks – one for each box fully completed correctly*

Equilibrium	$2\ H_2(g) + O_2(g) \rightleftharpoons 2\ H_2O(g)$	$2\ NO_2(g) \rightleftharpoons N_2O_4(g)$	$PCl_5 \rightleftharpoons PCl_3 + Cl_2$
Composition of equilibrium mixture	1 mol H_2 5 mol O_2 4 mol H_2O		10% PCl_5 55% PCl_3 35% Cl_2
Mole fractions	H_2 = 0.1 O_2 = 0.5 H_2O = 0.4	NO_2 = ⅜ or 0.375 N_2O_4 = ⅝ or 0.625	PCl_5 = 0.1 PCl_3 = 0.55 Cl_2 = 0.35
Total pressure	20 kPa	100 atm	46,000 Pa
Partial pressures	H_2 = 2 kPa O_2 = 10 kPa H_2O = 8 kPa	NO_2 = 37.5 atm N_2O_4 = 62.5 atm	PCl_5 = 4,600 Pa PCl_3 = 25,300 Pa Cl_2 = 16,100 Pa
Expression for K_p	$K_p = \frac{(P_{H_2O})^2}{(P_{H_2})^2 (P_{O_2})}$	$K_p = \frac{(P_{N_2O_4})}{(P_{NO_2})^2}$	$K_p = \frac{(P_{PCl_3})(P_{Cl_2})}{(P_{PCl_5})}$
Value of K_p	$K_p = 8^2 / (2^2 \times 10)$ K_p = 1.6 kPa^{-1}	$K_p = 62.5 / 37.5^2$ K_p = 0.0444 atm^{-1}	$K_p = \frac{(25{,}300 \times 16{,}100)}{4{,}600}$ K_p = 88,550 Pa

(6 marks, 1 for each correct expression for K_p and 1 for each correct value for K_p with correct units)