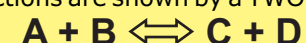


## Some chemical reactions are reversible.

This means that when products are formed :  
\* these products simultaneously react  
\* to become the original reactants again.

Reversible reactions are shown by a TWO WAY ARROW.



Reversible reactions are possible only if the system is **CLOSED** :

- \* no substances can enter or leave the system
- \* it is a system of constant mass.

At some time during the reaction :

the **RATE of the FORWARD REACTION** would **equal** to the **RATE of the REVERSE REACTION**.

The reaction is said to be in **EQUILIBRIUM**.

At this time for all the substances,

- \* concentrations would be constant
- \* mass and mols would be constant.

The **CONCENTRATIONS AT EQUILIBRIUM** of each substance is put together in a formula to create a number called the Equilibrium Constant  $K_c$ . (No units)  
eg.



$$K_c = \frac{[C]^2[D]^3}{[A][B]^2}$$

N.B. The concentrations are raised to the balancing numbers.

useful equations

$$c = \frac{m}{V} \quad \text{or} \quad [n] = cV \quad V = \frac{m}{c}$$

$$m = nM$$

## Typical Examples

### 1. Given : $A + 2B \rightleftharpoons 2C$

The reaction started with 5 mols of A and 12 mols of B in a 10dm<sup>3</sup> vessel. When equilibrium was reached, only 1 mol of A was present. Calculate the  $K_c$ .

Draw a grid and fill in the given. The first three rows are in mols, and the last row is concentration, calculated from  $c = \frac{m}{V}$   
(Black = given figures Red = calculated figures)  
Follow the sequence of arrows, starting at 5 mols.

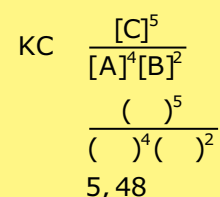
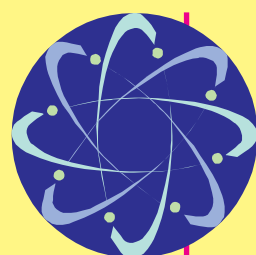
Study the figures	A	+	2B	$\rightleftharpoons$	2C
start	5		12		0
reaction	4		8		8
equil. mols	1		4		8
equil. conc. (V=10dm <sup>3</sup> )	0,1M		0,4M		0,8M

Now the last row is used to calculate  $K_c$ .

$$K_c = \frac{[C]^2}{[A][B]^2} = \frac{(0,8)^2}{(0,1)(0,4)^2} = 40$$

2. Complete the following grid yourself. The volume is given as 2dm<sup>3</sup>. Hint : follow the arrows, start at 2.

	4A	+	2B	$\rightleftharpoons$	5C
start	2		3,2		0
reaction	0,8				
equil. mols					
equil. conc. (V= 2dm <sup>3</sup> )					



Complete the following tables yourself, and calculate the  $K_c$ . Follow the arrows from the given starts.

3. Start at 6

	H <sub>2</sub>	+	I <sub>2</sub>	$\rightleftharpoons$	2HI
start	6		5		0
reaction	4				
equil. mols					
equil. conc (V = 10dm <sup>3</sup> )					

4. Start at 0,6M

	2SO <sub>2</sub>	+	O <sub>2</sub>	$\rightleftharpoons$	2SO <sub>3</sub>
start	3		2		0
reaction					
equil. mols					
equil. conc (1dm <sup>3</sup> )			0,6M		

5. Start at 0,4M

	N <sub>2</sub>	+	3H <sub>2</sub>	$\rightleftharpoons$	2NH <sub>3</sub>
start	2,7		7,8		0
reaction					
equil. N					
equil. conc (V=6dm <sup>3</sup> )					0,4M

### More Details

The subscripts for each substance must be considered.

**aq.** = aqueous  
**g** = gas  
**s** = solid  
**l** = pure liquid

The  $K_c$  uses only substances with aq. and g. Substances marked s and l are pure substances and do not have a concentration.



$$K_c = \frac{[B]^2}{[D]^3} \quad (A_{(s)} \text{ and } C_{(l)} \text{ are ignored})$$

### Reminder : When a reaction is in EQUILIBRIUM

RATE : forward rate equals reverse rate

MASSSES : all are constant

CONC. : all are constant

### SHIFT (Le' Chateliers Principle)

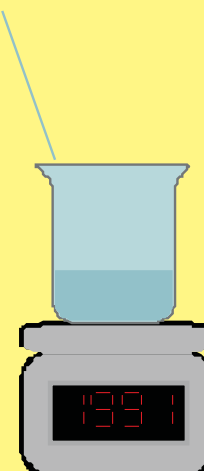
Consider ONLY the masses.

The masses can now be changed by altering the :

- \* **Concentration** (by adding or removing substances)
- \* **Pressure** (by changing the volume)
- \* **Temperature** (by heating or cooling)

When a **MASS CHANGE** has occurred, it is said that there is a **SHIFT**.

- \* If more products than before is now present :  
\* **FORWARD SHIFT FAVOURED**
- \* If more reactants than before is now present  
\* **REVERSE SHIFT FAVOURED**

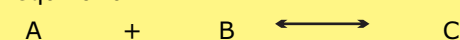


## CONCENTRATION

### Example 1

Study the table of information. The green writing indicates the effects.

The reaction is in equilibrium



[A] is now increased by adding additional A	
shift	forward shift is favoured
rates	BOTH rates increased, forward more
masses	decrease      increase
Kc	no change

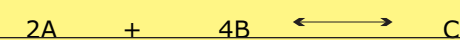
### N.B.

When A was added to the equilibrium

- \* both rates increased, but the forward was faster.
- \* a forward shift was favoured.
- \* the other masses changed accordingly.
- \* the  $K_c$  remained constant.

### Example 2

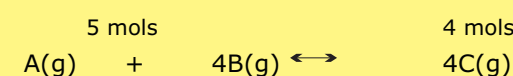
The reaction is in equilibrium.



[C] is now increased by adding additional C	
shift	reverse shift favoured
rates	both rates increased, reverse more
masses	increase      increase
Kc	no change

## PRESSURE

The reaction is in equilibrium. When pressure is changed, identify which side of the equation has more/less mols. An increased pressure favours the lesser mols.



The pressure of the system is now increased	
shift	forward shift is favoured
rates	BOTH rates increased, forward more
masses	decrease      decrease      increase
Kc	no change

## TEMPERATURE

When a **temperature** is changed, you must first determine whether the reaction is **exothermic** or **endothermic**. This is usually determined from  $\Delta H$  and is commonly stated for the forward reaction.

**Assume Temperature is increased.**

**If the reaction has  $\Delta H > 0$  :**

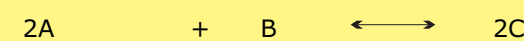
forward reaction is endothermic,  
and the increased temperature favours forward shift

**If the reaction has  $\Delta H < 0$**

**forward reaction is exothermic**  
**and the increased temperature favours reverse shift.....**

### Example 1

The reaction is in equilibrium and  $\Delta H > 0$ .  
(Hence the forward reaction is endothermic.)

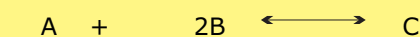


the temperature is now increased	
shift	forward shift is favoured
rates	BOTH rates increased, forward more
quantities	decrease      decrease      increase
Kc	increase

Only **TEMPERATURE** can change the  $K_c$  for a particular reaction. The  $K_c$  changes in accordance to the yield.

### Example 2

The reaction is in equilibrium and  $\Delta H < 0$ .  
(Hence the forward reaction is exothermic.)



the temperature is now increased	
shift	reverse shift favoured
rates	both rates increased, reverse more
quantities	increase      increase      decrease
Kc	decrease

### CATALYSTS

Catalysts have

- NO EFFECT on SHIFT
- NO EFFECT on MASS/MOLS/CONCENTRATIONS
- NO EFFECT on  $K_c$ .

Catalysts only **INCREASES** the RATE of a reaction.

### SATURATED SOLUTION

the **solute** is in **equilibrium** with the **solvent**.  
the **rate of dissolving** equals the **rate of crystallizing**

### LE' CHATELIERS PRINCIPLE

If the conditions of concentration, pressure or temperature of an equilibrium reaction is changed in any way, the reaction which tends to cancel the effect of this change will be favoured.

### Complete the following table

All the reactions are in equilibrium. The change is indicated. You must predict the effect.

### Example 1

$\Delta H > 0$

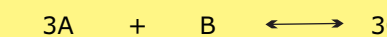


### decrease temperature

shift	
Rates	
quantities	
Kc	

### Example 2

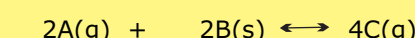
$\Delta H < 0$



### decrease temperature

shift	
rates	
quantities	
Kc	

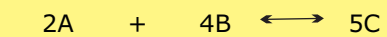
### Example 3



### decrease pressure

shift	
rates	
quantities	
Kc	

### Example 4



### decrease [B]

shift	
rates	
Quantities	
Kc	

