

FACTFILE: GCE CHEMISTRY

4.4 EQUILIBRIUM



Learning Outcomes

Students should be able to:

- 4.4.1** calculate equilibrium concentrations given suitable data;
- 4.3.2** calculate the numerical values, with units, for equilibrium constants, K_c , given suitable data limited to homogeneous systems;

In some cases K_c has no units because there are equal number of moles on both sides of the equation and they **cancel** each other out in the K_c expression.

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

$$\text{Units of } K_c = \frac{(\text{mol dm}^{-3})^{c+d}}{(\text{mol dm}^{-3})^{a+b}}$$

The equilibrium constant, K_c

For the equilibrium $aA + bB \rightleftharpoons cC + dD$
The equilibrium constant (K_c) is defined by the expression

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

where $[A]$ represents the concentration of A in mol dm^{-3} in the equilibrium mixture and a is the balancing number for A in the equation for the reaction. The same applies to B, C and D.

To find the units of K_c , simply substitute the units of concentration (mol dm^{-3}) into the K_c expression. Hence the units are in terms of concentration in mol dm^{-3} but the overall power depends on the balancing numbers in the equation for the reaction.

Examples for homogeneous systems

Homogeneous means that all the species are in the same phase.

Equation	K_c	Units
$\text{CH}_3\text{CH}_2\text{OH} + \text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O}$	$K_c = \frac{[\text{CH}_3\text{COOCH}_2\text{CH}_3][\text{H}_2\text{O}]}{[\text{CH}_3\text{COOH}][\text{CH}_2\text{CH}_2\text{OH}]}$	$\frac{(\text{mol dm}^{-3})^2}{(\text{mol dm}^{-3})^2}$ = no units
$\text{PCl}_5 \rightleftharpoons \text{PCl}_3 + \text{Cl}_2$	$K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]}$	$\frac{(\text{mol dm}^{-3})^2}{(\text{mol dm}^{-3})}$ = mol dm^{-3}
$2\text{HI} \rightleftharpoons \text{H}_2 + \text{I}_2$	$K_c = \frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]^2}$	$\frac{(\text{mol dm}^{-3})^2}{(\text{mol dm}^{-3})^2}$ = no units
$2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$	$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]}$	$\frac{1}{(\text{mol dm}^{-3})}$ = $\text{mol}^{-1} \text{dm}^3$

The larger the value of K_c the more products will be present in the equilibrium mixture

Calculating K_c

Example 1

1.33 moles of PCl_5 were heated to 500 K in a vessel of volume 15 dm^3 . The equilibrium mixture contained 0.80 mol of chlorine. Calculate a value for K_c .

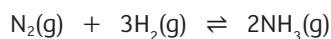


	PCl_5	PCl_3	Cl_2
Initial moles	1.33	0	0
Change in moles	x moles used	x moles produced	x moles produced
Equilibrium moles	$1.33-x$	x	x
	At equilibrium there are 0.80 mol of Cl_2 hence $x = 0.8$		
Equilibrium moles	$1.33-0.8 = 0.53$	0.8	0.8
Equilibrium concentration (moles/vol dm^3)	$\frac{0.53}{15} = 0.035$	$\frac{0.8}{15} = 0.053$	$\frac{0.8}{15} = 0.053$

$$K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]} = \frac{0.053 \times 0.053}{0.035} = 0.080 \text{ mol dm}^{-3}$$

Example 2

A mixture of 1 mol of nitrogen and 3 mol of hydrogen were allowed to come to equilibrium in a container of volume 0.5 dm^3



0.240 mol of ammonia were present at equilibrium. Calculate a value for K_c and state its units.

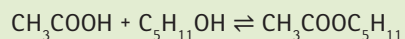
	N_2	3H_2	2NH_3
Initial moles	1	3	0
Change in moles (in ratio according to equation)	x moles used	3x moles used	2x moles produced
Equilibrium moles	$1-x$	$3-3x$	$2x$
	At equilibrium there are 0.240 mol of NH_3 $0.240 = 2x$ $x = 0.120$		
	$1-0.120 = 0.880$	$3 - (3 \times 0.120) = 2.640$	0.240
Equilibrium concentration (moles/vol dm^3)	$\frac{0.88}{0.5} = 1.76$	$\frac{2.64}{0.5} = 5.28$	$\frac{0.240}{0.5} = 0.480$

$$K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} = \frac{(0.480)^2}{(1.76)(5.28)^3} = 0.000889 \text{ mol}^{-2}\text{dm}^6$$



Revision Questions

- 1 1.1 g of pentan-1-ol and 1.2 g of ethanoic acid were mixed. Equilibrium was established at 298K.



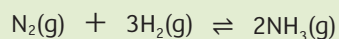
- (i) Write an expression for the equilibrium constant, K_c , for this reaction.

[1]

- (ii) At equilibrium 0.6 g of ethanoic acid remained. Calculate the value of K_c .

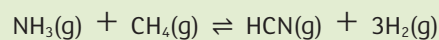
[4]

- 2 Which one of the following represents the units of K_c for the equilibrium shown below?



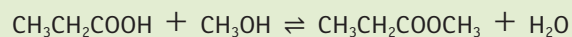
- A $\text{mol}^{-2} \text{dm}^{-6}$
B $\text{mol}^{-2} \text{dm}^6$
C $\text{mol}^2 \text{dm}^{-6}$
D $\text{mol}^2 \text{dm}^6$

- 3 If ammonia (0.2 mol) and methane (0.2 mol) are placed in a 1 dm³ container and heated to 500°C, it is found that 0.1 mol of hydrogen cyanide and 0.3 mol of hydrogen are produced at one atmosphere pressure. Calculate the equilibrium constant, K_c , for the reaction under these conditions and state its units.



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- 4 1 mol of propanoic acid, 1 mol of methanol and 2 mol of water were mixed and allowed to reach equilibrium.



At equilibrium 0.5 mol of methyl propanoate was present. The value of K_c for this reaction is

- A 1.00
B 1.25
C 5.00
D 10.00

