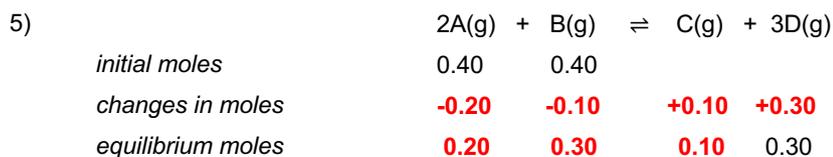
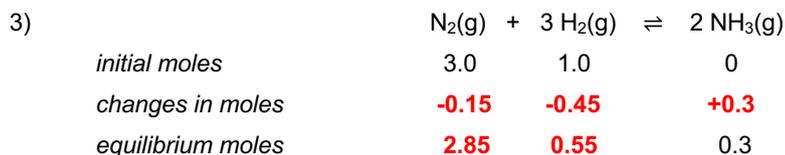
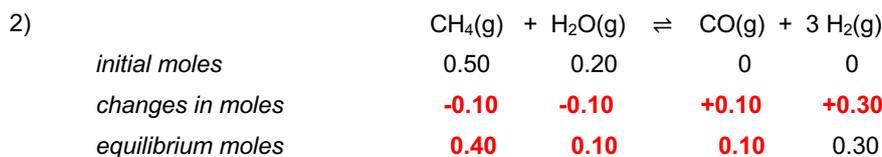
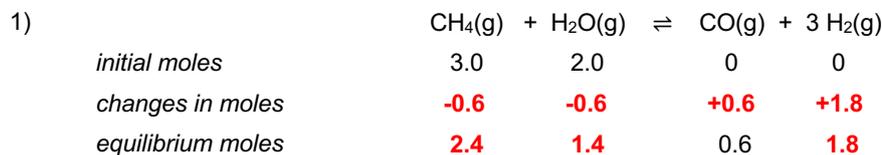




PART 1 – Equilibrium quantities



PART 2 – K_p expressions and units

	equilibrium	K _p	units (assume all pressures are in Pa)
1	$\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$	$K_p = \frac{(p\text{NH}_3)^2}{(p\text{N}_2) (p\text{H}_2)^3}$	Pa⁻²
2	$\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$	$K_p = \frac{(p\text{PCl}_3) (p\text{Cl}_2)}{(p\text{PCl}_5)}$	Pa
3	$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2 \text{HI}(\text{g})$	$K_p = \frac{(p\text{HI})^2}{(p\text{H}_2) (p\text{I}_2)}$	No units
4	$2 \text{O}_3(\text{g}) \rightleftharpoons 3 \text{O}_2(\text{g})$	$K_p = \frac{(p\text{O}_2)^3}{(p\text{O}_3)^2}$	Pa
5	$\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + 3 \text{H}_2(\text{g})$	$K_p = \frac{(p\text{CO}) (p\text{H}_2)^3}{(p\text{CH}_4) (p\text{H}_2\text{O})}$	Pa²
6	$\text{CO}(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons \text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g})$	$K_p = \frac{(p\text{CH}_4) (p\text{H}_2\text{O})}{(p\text{CO}) (p\text{H}_2)^3}$	Pa⁻²
7	$2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$	$K_p = \frac{(p\text{SO}_3)^2}{(p\text{O}_2) (p\text{SO}_2)^2}$	Pa⁻¹
8	$\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2 \text{NO}_2(\text{g})$	$K_p = \frac{(p\text{NO}_2)^2}{(p\text{N}_2\text{O}_4)}$	Pa

PART 3 – Mole fractions and partial pressures

Mole fraction If you have 10 moles of a mixture of gases, of which 3 moles is O₂, then the mole fraction of O₂ in the mixture is $\frac{3}{10}$ or 0.3 (or even 30%, but it is not usually expressed as a %)

$$\text{mole fraction of gas A in a mixture of gases} = \frac{\text{moles of gas A}}{\text{total moles of gas in the mixture}}$$

Note that the sum of all the mole fractions in a mixture should add up to 1

Partial pressure Imagine a mixture of gases with a total pressure of 100 kPa.
If the mole fraction of gas A in that mixture is $\frac{3}{10}$, then that gas makes up 30 kPa (i.e. $\frac{3}{10}$) of the total pressure. The contribution that each gas makes to the total pressure is called the partial pressure of that gas; therefore the partial pressure of gas A is 30 kPa.

$$\text{partial pressure of gas A} = \text{mole fraction of gas A} \times \text{total pressure in a mixture of gases}$$

Note that the sum of all the partial pressures is the total pressure.

1)	CH ₄ (g) + H ₂ O(g) ⇌ CO(g) + 3 H ₂ (g)	total pressure = 255 kPa
<i>initial moles</i>	2.00 2.00 0 0	
<i>changes in moles</i>	-1.20 -1.20 +1.20 +3.60	
<i>equilibrium moles</i>	0.80 0.80 1.20 3.60	total moles = 6.40
<i>mole fraction</i>	0.125 0.125 0.1875 0.5625	sum of mole fractions = 1.00
<i>partial pressure</i>	31.9 kPa 31.9 kPa 47.8 kPa 143.4 kPa	sum of partial pressures = 255 kPa
2)	N ₂ (g) + 3 H ₂ (g) ⇌ 2 NH ₃ (g)	total pressure = 45.0 MPa
<i>initial moles</i>	0.800 1.000 0	
<i>changes in moles</i>	-0.200 -0.600 +0.400	
<i>equilibrium moles</i>	0.600 0.400 0.400	total moles = 1.40
<i>mole fraction</i>	0.429 0.286 0.286	sum of mole fractions = 1.00
<i>partial pressure</i>	19.3 MPa 12.9 MPa 12.9 MPa	sum of partial pressures = 45 MPa
3)	2 SO ₂ (g) + O ₂ (g) ⇌ 2 SO ₃ (g)	total pressure = 2.0 MPa
<i>initial moles</i>	5.00 4.00 0	
<i>changes in moles</i>	-1.50 -0.75 +1.50	
<i>equilibrium moles</i>	3.50 3.25 1.50	total moles = 8.25
<i>mole fraction</i>	0.424 0.394 0.182	sum of mole fractions = 1.00
<i>partial pressure</i>	0.848 MPa 0.788 MPa 0.364 MPa	sum of partial pressures = 2.0 MPa
4)	H ₂ (g) + I ₂ (g) ⇌ 2 HI(g)	total pressure = P
<i>initial moles</i>	1.50 1.00 0	
<i>changes in moles</i>	-0.80 -0.80 +1.60	
<i>equilibrium moles</i>	0.70 0.20 1.60	total moles = 2.50
<i>mole fraction</i>	0.28 0.08 0.64	sum of mole fractions = 1.00
<i>partial pressure</i>	0.28P 0.08P 0.64P	sum of partial pressures = P

PART 4 – K_p problems

Example: Gases A, B and C are in equilibrium. $2 \text{ A(g)} + \text{ B(g)} \rightleftharpoons 2 \text{ C(g)}$

- a) At equilibrium, there are 2.0 moles of A, 2.5 moles of B and 1.5 moles of C. The total pressure is 500 kPa. Calculate the value of K_p

	2 A(g)	+	B(g)	⇌	2 C(g)	
equilibrium moles	2.0		2.5		1.5	total moles = 6.0
mole fraction	$\frac{2.0}{6.0}$		$\frac{2.5}{6.0}$		$\frac{1.5}{6.0}$	total of mole fractions = 1
partial pressures	$\frac{2.0}{6.0} \times 500$		$\frac{2.5}{6.0} \times 500$		$\frac{1.5}{6.0} \times 500$	
partial pressures	166.7 kPa		208.3 kPa		125 kPa	total of partial pressures = 500 kPa

$$K_p = \frac{(p_C)^2}{(p_A)^2 (p_B)} = \frac{(125)^2}{(166.7)^2 (208.3)} = 0.0027 \text{ kPa}^{-1}$$

- b) If the total pressure of this equilibrium was increased, explain what would happen to the yield of C and the value of K_p

**equilibrium shifts right
to side with fewer gas molecules
to lower the pressure
so yield of C increases
no change to K_p as it is a constant only affected by temperature**

- c) The forward reaction is exothermic. If the temperature of this equilibrium was increased, explain what would happen to the yield of C and the value of K_p

**equilibrium shifts left
in endothermic direction
to lower the temperature
so yield of C decreases
K_p decreases**