Kp

(1) When A is heated in a closed system to 400°C, the following equilibrium is set up:

$$A_{(g)} \rightleftharpoons B_{(g)} + C_{(g)}$$

The equilibrium partial pressures of the three gases were found to be: A 5.1 kPa B 95 kPa C 95 kPa. Calculate kp at this temperature.

$$k_p = \frac{P_B \times P_C}{P_A} \qquad k_p = \frac{95 \times 95}{5.1}$$

$$k_p = 1800 \text{ kPa}$$

② This refers to the equilibrium $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

A vessel containing only dinitrogen tetraoxide was held at a temperatu of 350k until equilibrium was established. The equilibrium pressure was 123 kPa and the mole fraction of nitrogen dioxide was found to be 0·800. Calculate the value of K_p at this temperature.

	N_2O_4	$\rightleftharpoons 2NO_2$
mole fractions	1 − 0·800 = 0·200	0·800
partial pressures (kPa)	0·200 × 123 = 24·6	0·800 × 123 98·4

$$K_p = \frac{P^2_{NO_2}}{P_{N_2O_4}} \qquad K_p = \frac{(98{\cdot}4)^2}{24{\cdot}6}$$

$$K_p = 393{\cdot}6 \text{ KPa}$$

③ A mixture of nitrogen and hydrogen in the mole ratio 1:3 (as required by the equation) was heated to 700K and a pressure of 79 atmosphere in the presence of an iron catalyst. The equilibrium mixture was found to contain the following proportions of gases (by volume): N_2 21%, H_2 63, NH_3 16%. Calculate the value for K_p at this temperature.

	$N_{2(g)}$ +	$3H_{2(g)}$ ⇌	$2NH_{3(g)}$
mole fractions	0.21	0.63	0.16
Partial pressures (atm)	0.21 × 79 = 16.6	0.63 × 79 = 49.8	0.16 × 79 = 12.6

$$K_p = \frac{P^2_{NH_3}}{P_{N_2}\, P^3_{H_2}} \qquad K_p = \frac{(12.6)^2}{(16.6)(49.8)^3}$$

$$K_p = \underline{7.74 \times 10^{-5}\ atm^{-2}}$$

UNITS = $\frac{\cancel{atm} \times \cancel{atm}}{\cancel{atm} \times \cancel{atm} \times atm \times atm}$

units = atm^{-2}

④ A mixture of nitrogen and hydrogen in the mole ratio 1:3 (as required by the equation) was heated to 700K and a pressure of 79 atmosphere in the presence of an iron catalyst. The equilibrium mixture was found to contain 16% of ammonia by volume. Calculate the value for Kp at this temperature.

	$N_{2(g)}$ +	$3H_{2(g)}$	$\rightleftharpoons 2NH_{3(g)}$
	(must be made up of ·84 between them)		
mole fractions	0.84/4 = 0.21	∴ 0.84 − 0.21 = 0.63	0.16
Partial pressure (atm)	0.21 × 79 = 16.59	0.63 × 79 = 49.77	0.16 × 79 = 12.64

$$Kp = \frac{P^2NH_3}{(PN_2)(P^3H_2)} \qquad Kp = \frac{(12.64)^2}{16.59 \times (49.77)^3}$$

$$Kp = 7.81 \times 10^{-4}$$

⑤ Hydrogen and Iodine were heated in a closed container at 1100k until equilibrium was reached:

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$$

The equilibrium partial pressures were hydrogen 50kPa; iodine 50kPa; and the total equilibrium pressure was 350 kPa. find K_p.

$$K_p = \frac{P^2HI}{PH_2 \times PI_2}$$

$350 - (50 \times 2) = 250 = HI$

$$K_p = \frac{(250)^2}{(50 \times 50)}$$

$K_p = 25$ NO UNITS

(6) 0.200 moles of dinitrogen tetroxide, N_2O_4, were allowed to reach equilibrium at 25°C according to the equation:

$$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$$

The equilibrium mixture contained 4.60g of nitrogen dioxide and the equilibrium pressure was 0.431 atmospheres. find K_p at 25°C.

$$\frac{4.60}{46} = 0.100\text{mol}$$

	N_2O_4	$\rightleftharpoons$	$2NO_2$
start	0.200		0
Eq	0.2 − (0.1/2) = 0.150		0.100
mole fraction	0.150/0.250 = 0.6		0.100/0.250 = 0.4
partial pressure	0.6 × 0.431 = 0.2586		0.4 × 0.431 = 0.1724

$$K_p = \frac{P^2NO_2}{PN_2O_4} \qquad K_p = \frac{(0.1724)^2}{0.2586} \qquad K_p = 0.115\text{ atm}$$

UNITS = $\frac{\cancel{atm} \times atm}{\cancel{atm}}$

⑦ $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$ $\quad K_p = 3.89$ atm

When the above equilibrium was established at 350 K, the partial pressure of N_2O_4 was found to be 0.200 atm. Calculate the partial pressure of the NO_2, and the total pressure.

$$K_p = \frac{P^2_{NO_2}}{P_{N_2O_4}}$$

$$3.89 \times 0.200 = P^2_{NO_2}$$

$$\sqrt{3.89 \times 0.200} = 0.882 \text{ atm} \rightarrow \underline{NO_2}$$

$\therefore$ $0.882 + 0.200 = 1.08$ atm total pressure

(8) $N_2O_{4(g)} \rightleftharpoons 2NO_2$ $K_p = 3.89$ atm @ 350K

When 1.00 mole of dinitrogen tetroxide was heated to 350K in a closed container, the equilibrium mixture was found to contain 0.600 mole of nitrogen dioxide. Calculate the total pressure at equilibrium, and the partial pressures of N_2O_4 and NO_2.

	N_2O_4	$\rightleftharpoons$ $2NO_2$
Start	1.00	0
Eq	1.00 − (0.600/2) =	0.600
mole fractions	0.700/1.30 = 0.5385	0.600/1.30 = 0.4615
Partial pressures	0.5385 × P	0.4615 × P

$$K_p = \frac{P^2_{NO_2}}{P_{N_2O_4}} \qquad 3.89 = \frac{(0.4615 \times P)^2}{(0.5385 \times P)}$$

$$3.89 = \frac{(0.4615)^2 \times P}{0.5385} \qquad \frac{3.89 \times 0.5385}{(0.4615)^2} = P$$

$P = 9.84$ atm <u>total</u>

$9.84 \times 0.5385 = 5.30$ atm N_2O_4

$9.84 \times 0.4615 = 4.54$ atm N