15.2 The Equilibrium Constant, K

The Relationship between K_p and K_c

$$2\ NOBr(g) \rightleftharpoons 2\ NO(g) + Br_2(g)$$

$$K_c = \frac{[NO]^2[Br_2]}{[NOBr]^2} \quad ; \quad K_p = \frac{P_{NO}^2\ P_{Br_2}}{P_{NOBr}^2}$$

How are K_c and K_p related ?

$PV = nRT$

$P = (n/V)RT$

$(n/V) \rightarrow mol.\ell^{-1}$ $= [\ ]RT$

$$K_p = \frac{P_{NO}^2\ P_{Br_2}}{P^2_{NOBr}}$$

$$= \frac{[NO]^2(RT)^2[Br_2](RT)}{[NOBr]^2(RT)^2}$$

$$= \frac{[NO]^2[Br_2]}{[NOBr]^2} \times \frac{(RT)^3}{(RT)^2}$$

$$K_p = K_c(RT)^3(RT)^{-2}$$
$$= K_c(RT)^{3-2}$$

3 - 2 = mol gas products - mol gas reactants

2 NO(g) & $Br_2(g)$ — 2 NOBr

3 - 2

$$K_p = K_c(RT)^{\Delta n}$$

Δn = mol of gas products - mol of gas reactants

15.2 The Equilibrium Constant, K

The Relationship between K_p and K_c

The equilibrium constant, **Kc**, for the following reaction is **2.90×10^{-2} at 1260 K**.

Calculate Kp for this reaction at this temperature.

$$2\ SO_3(g) \Leftrightarrow 2\ SO_2(g) + O_2(g)$$

$R = 0.0821\ L.atm.mol^{-1}.K^{-1}$

Kp = ?.00

a) 1
b) 2
c) 3 ✓
d) 4
e) 3

$$K_p = K_c(RT)^{\Delta n}$$

$$\Delta n = 2 + 1 - 2 = 1$$

$$K_p = 2.90 \times 10^{-2} \times (0.0821 \times 1260)$$
$$= 2.99$$

15.2 **The Equilibrium Constant, K**

Manipulating Equilibrium Constant Expressions

a) Multiply by a constant
b) Reverse the reaction.
c) Combining reactions.

a) Multiple by a constant.

1. $SO_2(g) + \frac{1}{2} O_2(g) \Leftrightarrow SO_3(g)$
2. $2 SO_2(g) + O_2(g) \Leftrightarrow 2 SO_3(g)$

$$K_1 = \frac{[SO_3]}{[SO_2][O_2]^{1/2}} \qquad K_2 = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

Rxn 2. = 2 × Rxn 1.

$$K_2 = K_1^2$$

b) Reverse the reaction.

1. $2 SO_3(g) \Leftrightarrow 2 SO_2(g) + O_2(g)$
2. $2 SO_2(g) + O_2(g) \Leftrightarrow 2 SO_3(g)$

$$K_1 = \frac{[SO_2]^2[O_2]}{[SO_3]^2} \qquad K_2 = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

Rxn 2. = -1 × Rxn 1.

$$K_2 = K_1^{-1}$$

c) Combining reactions.

1. $C(s) + \frac{1}{2} O_2(g) \Leftrightarrow CO(g)$
2. $C(s) + \frac{1}{2} O_2(g) \Leftrightarrow CO(g)$
3. $2 C(s) + O_2(g) \Leftrightarrow 2 CO(g)$

$$K_1 = \frac{[CO]}{[O_2]^{1/2}} \qquad K_2 = \frac{[CO]}{[O_2]^{1/2}} \qquad K_3 = \frac{[CO]^2}{[O_2]}$$

Rxn 3. = Rxn 1. + Rxn 2.

$$K_3 = K_1 \times K_2$$

15.2 The Equilibrium Constant, K

Manipulating Equilibrium Constant Expressions

The equilibrium constant, **Kc**, for the following reaction is 0.25 at 500K

$$2\,PCl_5(g) \Leftrightarrow 2\,PCl_3(g) + 2\,Cl_2(g)$$

Calculate **Kc** at this temperature for:

$$PCl_3(g) + Cl_2(g) \Leftrightarrow PCl_5$$

Kc = ?.0

a) 1
b) 2 ✓
c) 3
d) 4
e) 3

Compare : $PCl_3(g) + Cl_2(g) \Leftrightarrow PCl_5(g)$

To : $2\,PCl_5(g) \Leftrightarrow 2\,PCl_3(g) + 2\,Cl_2(g)$

The reaction of interest is:-

a) Reversed
b) Multiplied by ½

$$K_c = (0.25)^{-1 \times \frac{1}{2}}$$
$$= (0.25)^{-\frac{1}{2}}$$
$$= \frac{1}{\sqrt{0.25}}$$
$$= 2$$

15.3 Using Equilibrium Constants in Calculations

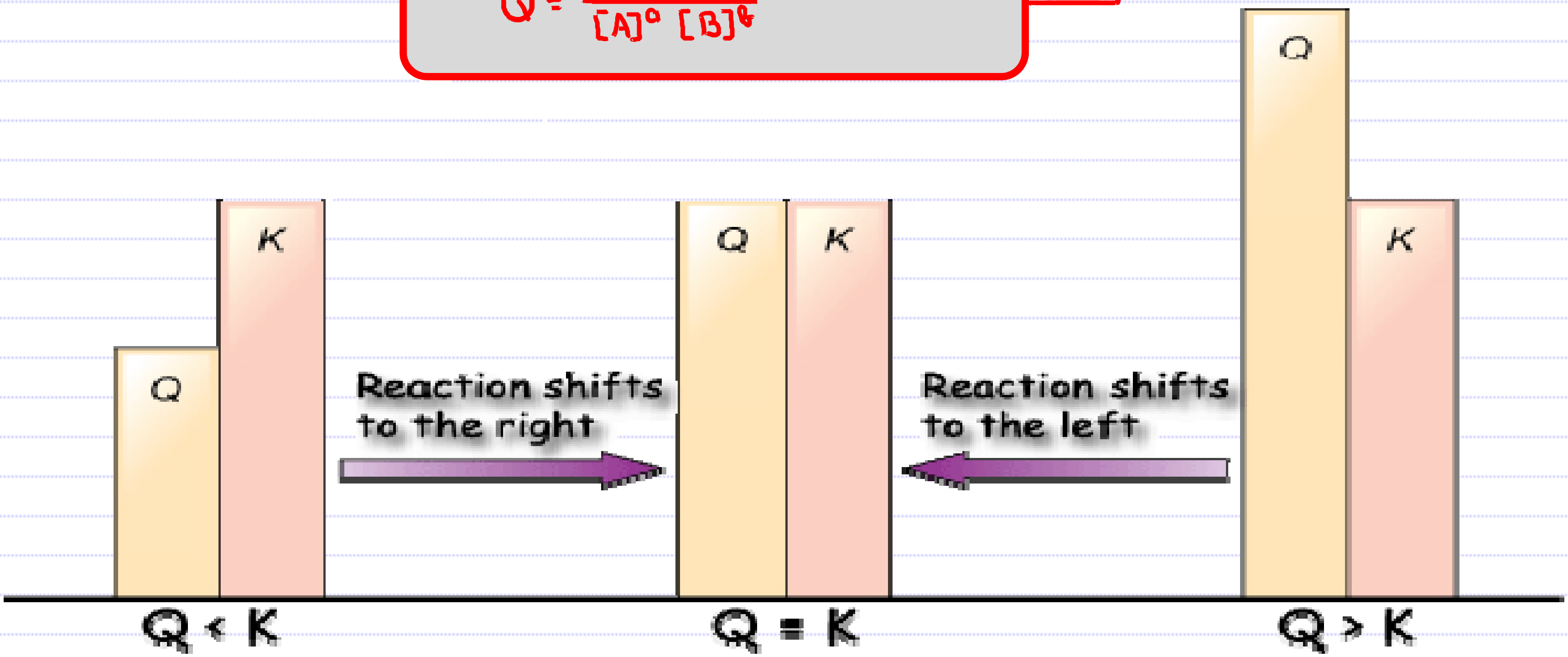
Determining Whether a System Is at Equilibrium – Q

Q = Reaction Quotient

$$aA + bB \rightleftharpoons cC + dD$$

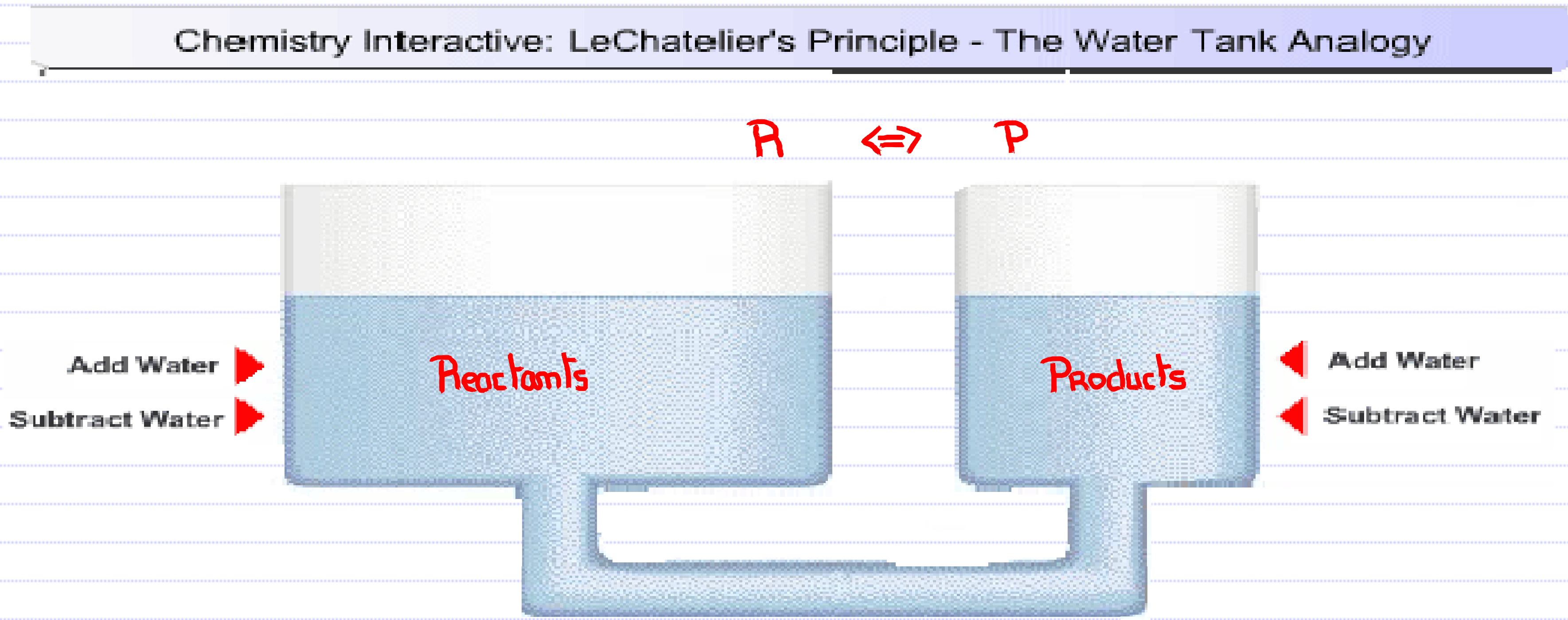
$$Q = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

- $Q < K$
- $Q > K$
- $Q = K$



15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

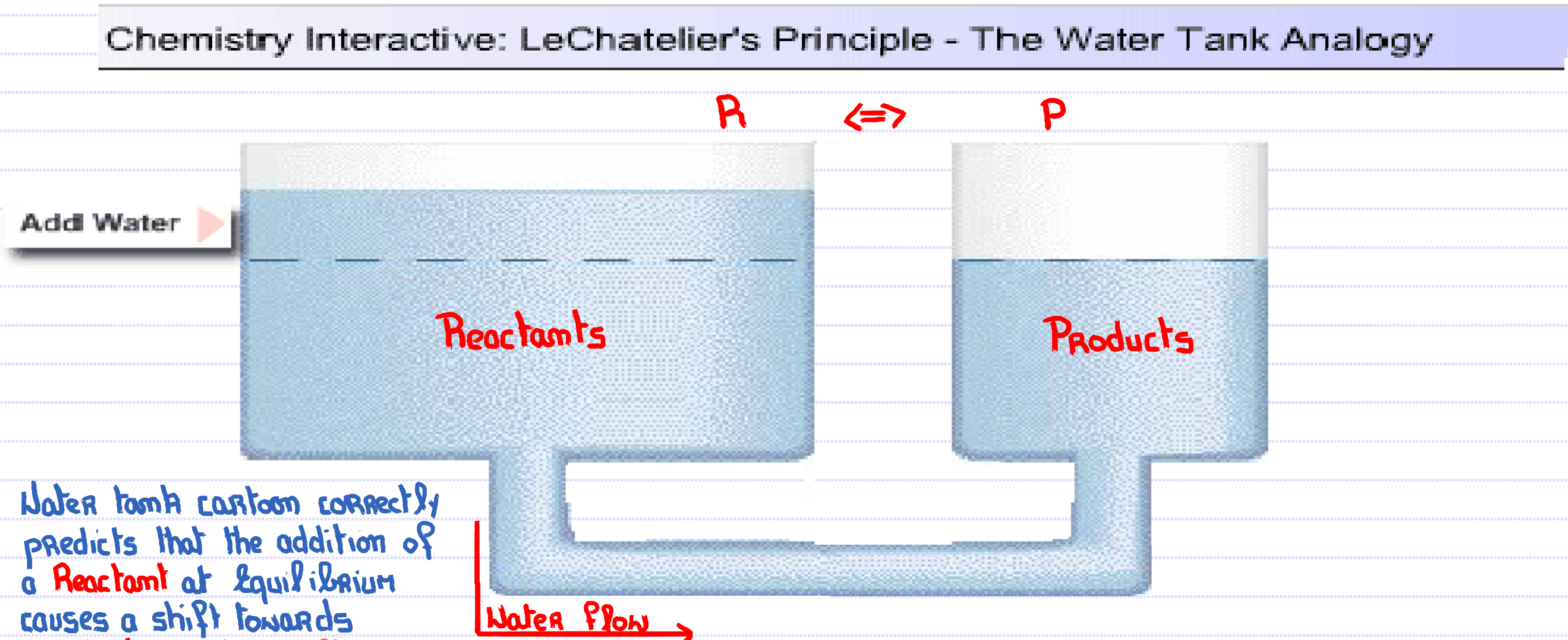
Addition or Removal of a Reactant or Product



See Class Web Site

15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

Addition of a Reactant.



Water tank cartoon correctly predicts that the addition of a Reactant at Equilibrium causes a shift towards Products ... chemically why is this prediction correct?

$$Q = \frac{[\text{Products}]}{[\text{Reactants}]}$$ } @ Equilibrium $Q = K$

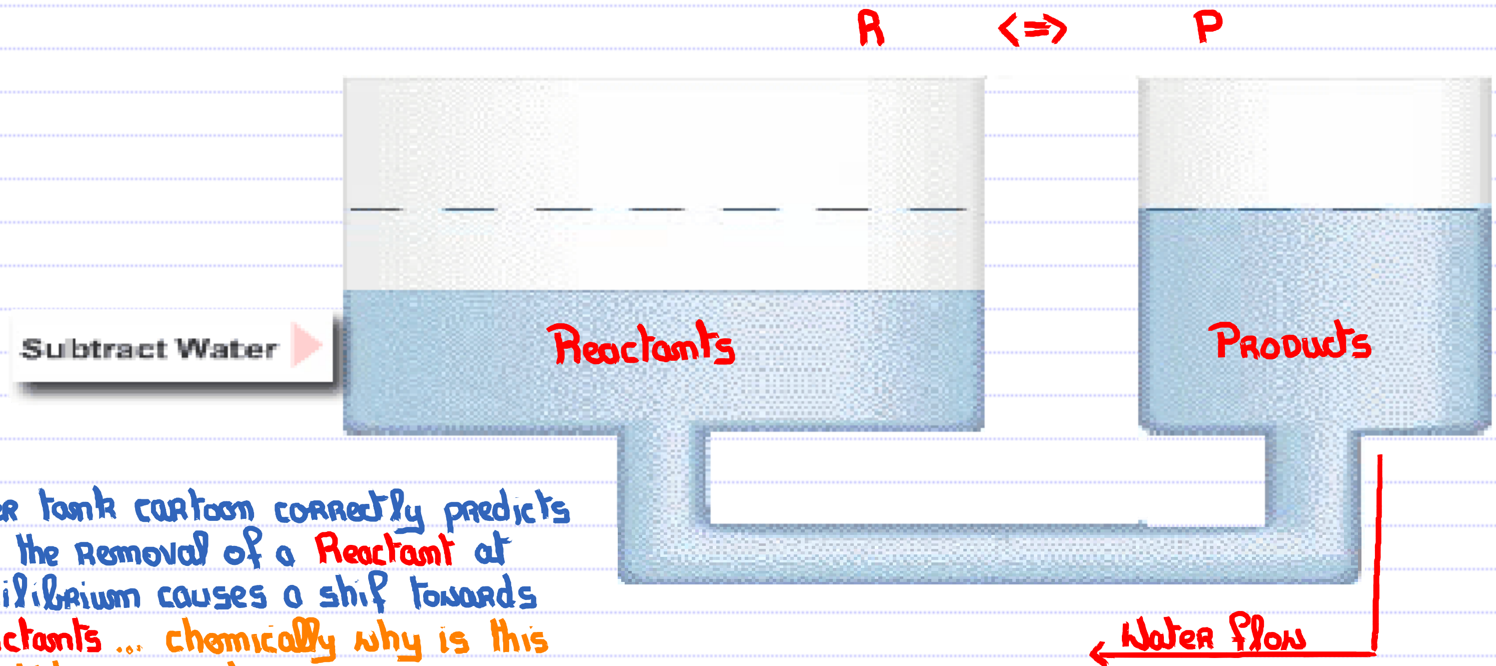
Addition of a Reactant causes $Q \downarrow$, thus now $Q < K$

↳ Shift towards Products until again $Q = K$

15.4 Disturbing a Chemical Equilibrium: Le Chatelier's Principle

Removing an Reactant.

Chemistry Interactive: LeChatelier's Principle - The Water Tank Analogy



Water tank cartoon correctly predicts that the removal of a Reactant at Equilibrium causes a shif towards Reactants ... chemically why is this prediction correct.

$$Q = \frac{[\text{Products}]}{[\text{REACTANTS}]}$$ } @ Equilibrium, $Q = K$

Removal of a Reactant causes $Q\uparrow$, thus now $Q > K$

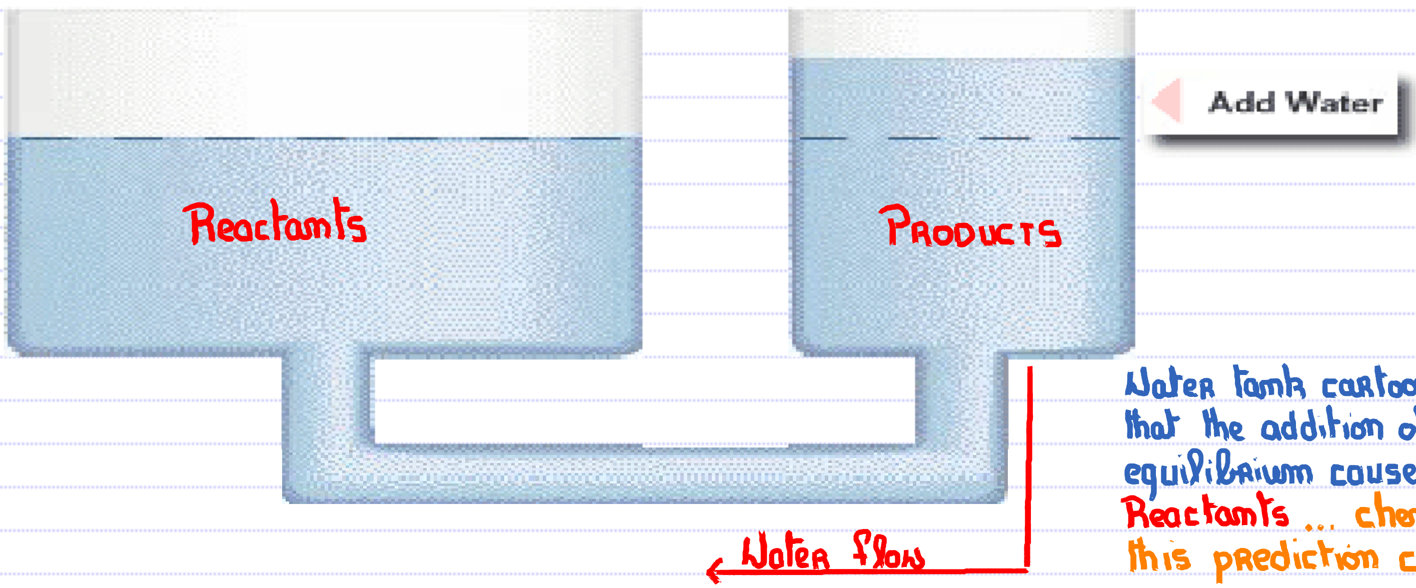
→ Shift towards Reactants until $Q = K$ again.

15.4 **Disturbing a Chemical Equilibrium: Le Chatelier's Principle**

Adding a Product.

Chemistry Interactive: LeChatelier's Principle - The Water Tank Analogy

R ⟺ P



Water tank cartoon correctly predicts that the addition of a Product at equilibrium causes a shift towards Reactants ... chemically why is this prediction correct?

$Q = \frac{[Products]}{[Reactants]}$ } @ Equilibrium, Q = K

Addition of Product causes Q ↑

Q > K

→ Shift towards Reactants until Q = K again