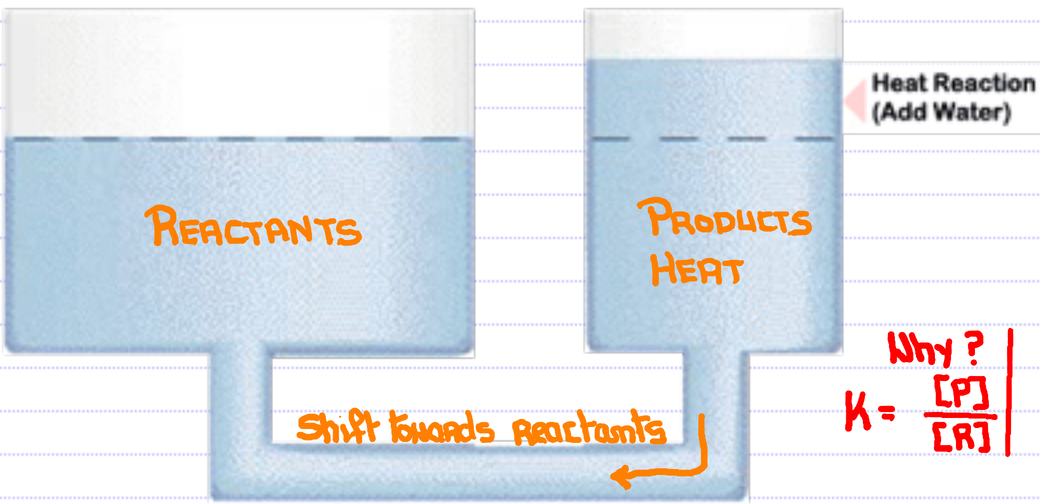
7.7 What Is Le Chatelier's Principle

Changing the Temperature – Exothermic

→ Reaction that gives off heat.
'Heat is a product'

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



If we heat this reaction ... it's the equivalent of adding a product ... thus reaction shifts towards reactants.

Why? $K = \frac{[P]}{[R]}$ | Heat is not part of the expression but the water tank is correct in its prediction! [R]↑, [P]↓, thus K must ↓.

K is temperature dependant, it's value changes as T changes.

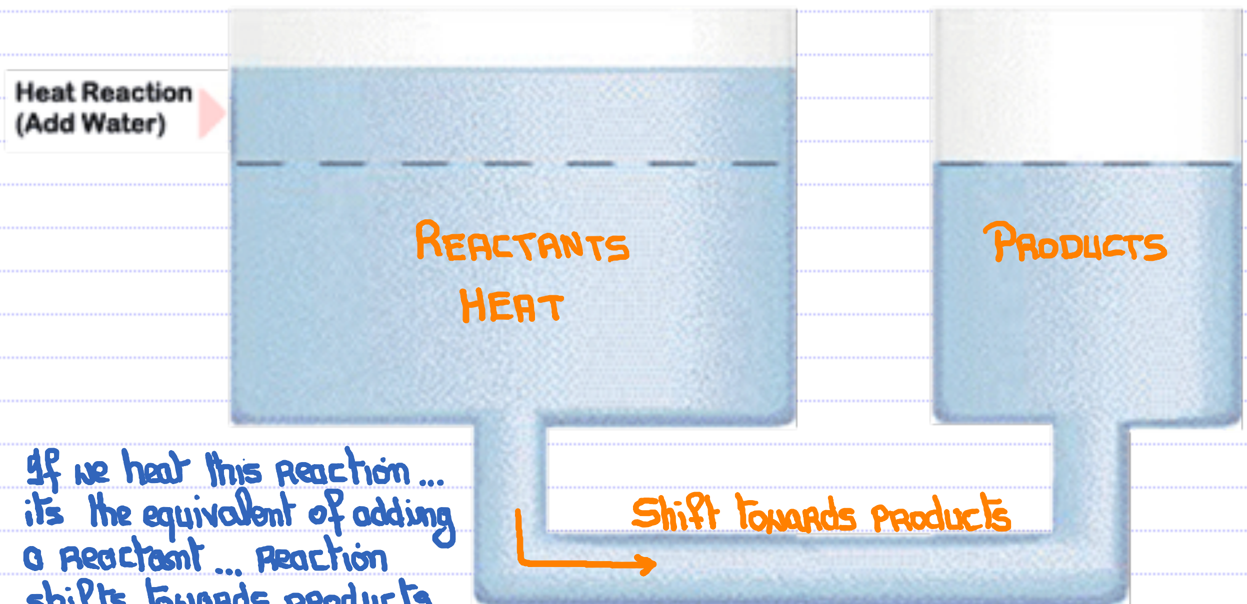
EXOTHERMIC RXN: T↑, K↓ meaning less products.
T↓, K↑ meaning more products.

7.7 What Is Le Chatelier's Principle

Changing the Temperature – Endothermic

→ Reaction that requires heat.
'Heat is a reactant'

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



Remember from previous slide, as T changes, so does K.

Endothermic:

T↑, K↑

T↓, K↓

If we heat this reaction... it's the equivalent of adding a reactant... reaction shifts towards products.

Why? $K = \frac{[P]}{[R]}$ | Heat is not part of the expression but the water tank does correctly predict what happens! [P]↑, [R]↓, thus K↑

7.7 What Is Le Chatelier's Principle

Changing the Temperature – Summary

1) EXOTHERMIC : R ⇔ P + 'heat'
2) ENDOTHERMIC : R + 'heat' ⇔ P

ACTION	EQUILIBRIUM SHIFT	WHY
1) Add heat (heat the Rxn.)	Shift towards reactants	K↓
Remove heat (cool the Rxn.)	Shift towards products	K↑
2) Add heat (heat the Rxn.)	Shift towards products	K↑
Remove heat (cool the Rxn.)	Shift towards reactants	K↓

a) Adding or removing reactants or products does not change the value of K.

b) Heating or cooling a reaction does change the value of K.
Whether K increases or decreases depends on whether the reaction is exothermic or endothermic.

7.7 What Is Le Chatelier's Principle

Changing the Temperature

The production of ammonia is an exothermic process –

$$N_2(g) + 3\,H_2(g) \Leftrightarrow 2\,NH_3(g)$$

To maximize the $[NH_3]$ at equilibrium it is best to

a) Heat the reaction

b) Cool the reaction ✓

c) Leave it as is!

$N_{2(g)} + 3\,H_{2(g)} \Leftrightarrow 2\,NH_{3(g)}$ + heat.

↳ Want to maximize this.

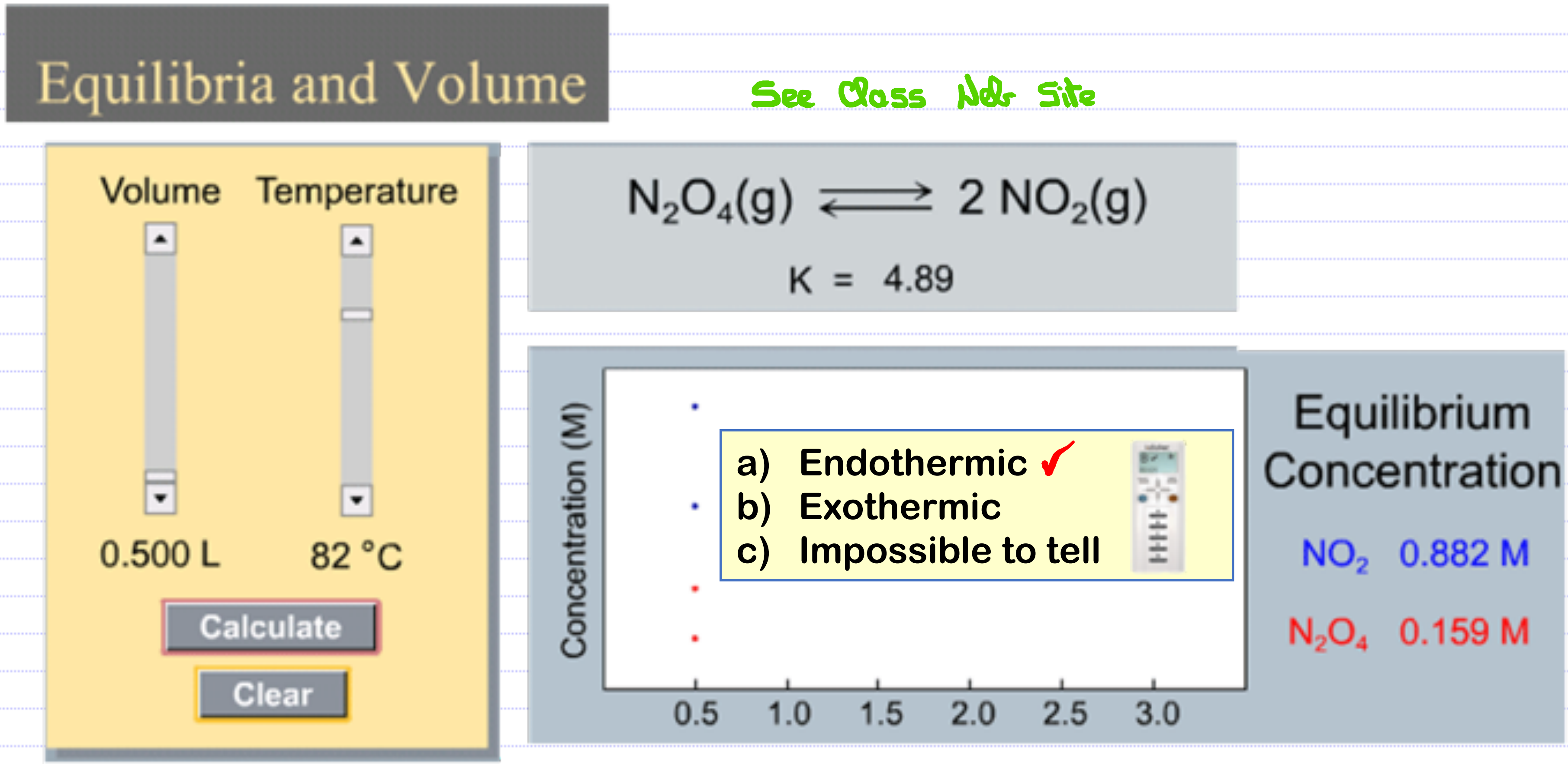
Remove a product ... heat

Cool the reaction.

7.7 What Is Le Chatelier's Principle

Changing the Temperature

See Class Notes Site



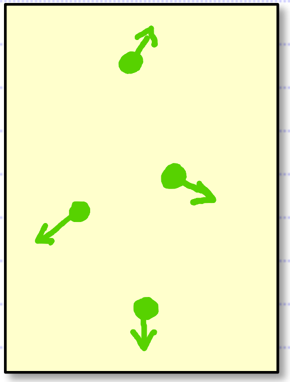
What is happening to K as you increase T ?

K↑, thus it must be endothermic.

What Is Le Chatelier's Principle

Changing the Pressure – Gas Phase Equilibria

PRESSURE : Force per unit area.



1) Collisions

2) Momentum

$$R \rightleftharpoons P$$

$$K = \frac{[P]}{[R]} \qquad [\ ] = \frac{\#\,mol}{V\,(L)}$$

GAS REACTIONS : ● = Gas molecule.

a) ● ⇌ ●

$$K = \frac{[P]}{[R]}$$

b) ● ⇌ ● + ●

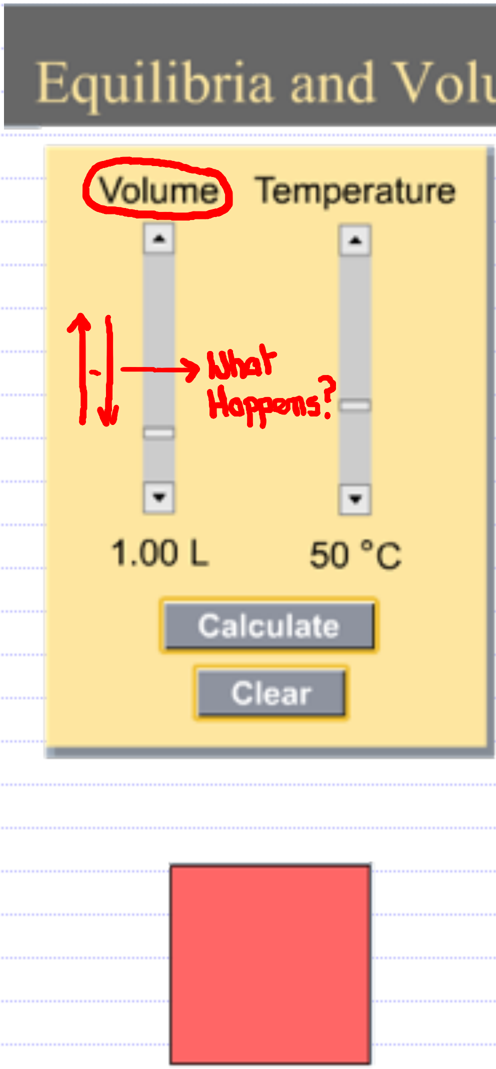
$$K = \frac{[P][P]}{[R]}$$

c) ● + ● ⇌ ●

$$K = \frac{[P]}{[R][R]}$$

7.7 What Is Le Chatelier's Principle

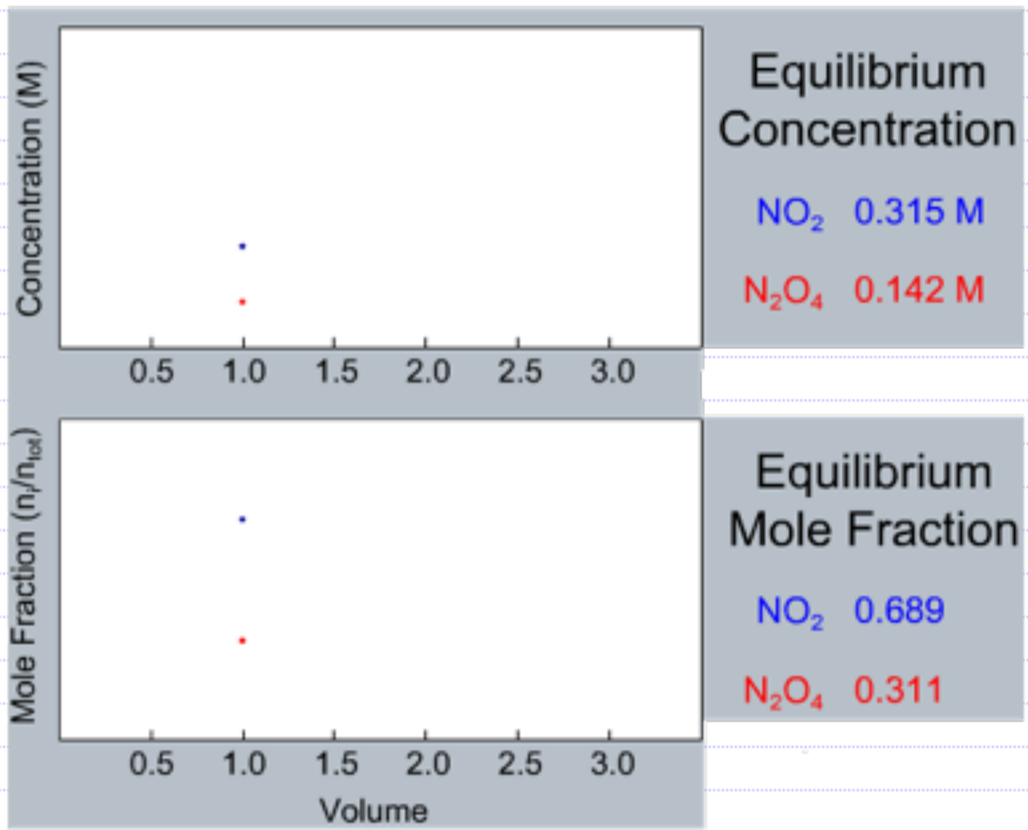
Changing the Pressure – Gas Phase Equilibria



See Class Web Site.

$$N_2O_4(g) \rightleftharpoons 2\,NO_2(g)$$

K = 0.699



7.7 What Is Le Chatelier's Principle

Changing the Pressure – Gas Phase Equilibria

Reactants (g) ⇔ Products (g)

Action	Equilibrium Shift
Volume ↑, ie P ↓	Towards the side with the greater number of gas molecules in an effort to restore the pressure — If it can ?
Volume ↓, ie P ↑	Towards the side with the fewest number of gas molecules in an effort to reduce the pressure — If it can ?

8.8 What Is Le Chatelier's Principle

Changing the Pressure – Summary

	Action	Equilibrium Shift	Why?
1)	$O_3(g) + NO(g) \rightleftharpoons O_2(g) + NO_2(g)$		● + ● ⇌ ● + ●
	V↑, P↓	No shift	$\frac{[O_2][NO_2]}{[O_3][NO]}$
	V↓, P↑	No shift	This ratio is unaffected by either action, system remains at equilibrium.
2)	$2\,NOCl(g) \rightleftharpoons 2\,NO(g) + Cl_2(g)$		● + ● ⇌ ● + ● + ●
	V↑, P↓	Towards products	$\frac{[NO]^2[Cl_2]}{[NOCl]^2}$
	V↓, P↑	Towards reactants	This ratio is changed by either action, shifts to restore ratio back to K.
3)	$N_2(g) + 3H_2(g) \rightleftharpoons 2\,NH_3(g)$		● + ● + ● + ● ⇌ ● + ●
	V↑, P↓	Towards reactants	$\frac{[NH_3]^2}{[N_2][H_2]^3}$
	V↓, P↑	Towards products	This ratio is changed by either action, shifts to restore ratio back to K.

7.7 Le Chatelier's and Hemoglobin

$Hb + 2O_2(g) \Longleftrightarrow Hb(O_2)_2$