

$$\frac{(x)}{(0.100-x)(0.100-x)} = 49$$

$$\frac{x}{(0.100-x)^2} = 49$$

$$x = 49(0.100-x)^2$$

$$\downarrow (a-b)^2 = a^2 - 2ab + b^2$$

$$x = 49(0.0100 - 0.200x + x^2)$$

$$x = 0.49 - 9.8x + 49x^2$$

$$0 = 0.49 - 10.8x + 49x^2$$

$$c = 0.49, \quad b = -10.8, \quad a = 49$$

$$x = \frac{10.8 \pm \sqrt{(-10.8)^2 - 4(49)(0.49)}}{2(49)} = \frac{10.8 \pm \sqrt{20.6}}{98}$$

$$x = \cancel{0.157} \text{ or } \underline{x = 0.0639}$$

The QUADRATIC EQUATION:

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Each quadratic has two solutions (see the +/- part of the equation), but only one of them will be the correct chemical solution.

The quadratic has TWO solutions, but only ONE of those is possible chemically. Which?

($x = 0.157$ doesn't work because it would lead to impossible concentrations of phosphorus trichloride and chlorine! See the chart on the previous page!)

Species	[Initial]	Δ	[Equilibrium]
PCl_5	0	+X	X
PCl_3	$\frac{0.400 \text{ mol}}{4.00 \text{ L}} = 0.100$	-X	$0.100 - X$
Cl_2	$\frac{0.400 \text{ mol}}{4.00 \text{ L}} = 0.100$	-X	$0.100 - X$

$$X = 0.0639$$

To get the concentrations of each species at equilibrium, we just plug our calculated "x" value into the chart.

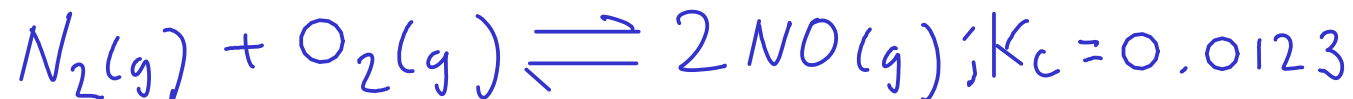
$$[\text{PCl}_5] = X = 0.0639 \text{ M PCl}_5$$

$$[\text{PCl}_3] = 0.100 - X = 0.0361 \text{ M PCl}_3$$

$$[\text{Cl}_2] = 0.100 - X = 0.0361 \text{ M Cl}_2$$

These values make sense, since $K_c = 49$ (and we expect more product - the pentachloride - at equilibrium!)

An 8.00 L reaction vessel at 3900C is charged with 0.850 mol of nitrogen and oxygen gases. Find the concentration of all species at equilibrium.



$$K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]} = 0.0123$$

To solve, we must express all three concentrations in terms of a single variable.

Species	[Initial]	Δ	[Equilibrium]
N_2	$\frac{0.850 \text{ mol}}{8.00 \text{ L}} = 0.10625$	$-x$	$0.10625 - x$
O_2	$\frac{0.850 \text{ mol}}{8.00 \text{ L}} = 0.10625$	$-x$	$0.10625 - x$
NO	0	$+2x$	$2x$

We let "x" equal the decrease in nitrogen concentration.

$$K_c = \frac{(2x)^2}{(0.10625 - x)(0.10625 - x)} = 0.0123$$

$$\frac{(2x)^2}{(0.10625 - x)^2} = 0.0123$$

We need to solve for "x"...

$$\frac{(2x)^2}{(0.10625 - x)^2} = 0.0123$$

We could solve this via the quadratic equation (since it's second order)

$$\sqrt{\frac{(2x)^2}{(0.10625 - x)^2}} = \sqrt{0.0123}$$

We can also take the square root of both sides, since the entire left hand side is squared!

$$\frac{2x}{0.10625 - x} = 0.1109053651$$

$$2x = (0.1109053651)(0.10625 - x)$$

$$2x = 0.011783695 - 0.1109053651x$$

$$2.1109053651x = 0.011783695$$

$$x = 0.005822943$$

$$[N_2] = 0.10625 - x = 0.101 \text{ M } N_2$$

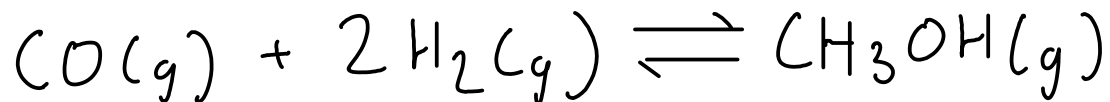
$$[O_2] = 0.10625 - x = 0.101 \text{ M } O_2$$

$$[NO] = 2x = 0.0112 \text{ M } NO$$

Species	[Equilibrium]
N_2	$0.10625 - x$
O_2	$0.10625 - x$
NO	$2x$

Makes sense with our constant $K_c = 0.0123$

- Pressure can affect a GAS-PHASE equilibrium ... sometimes. How?

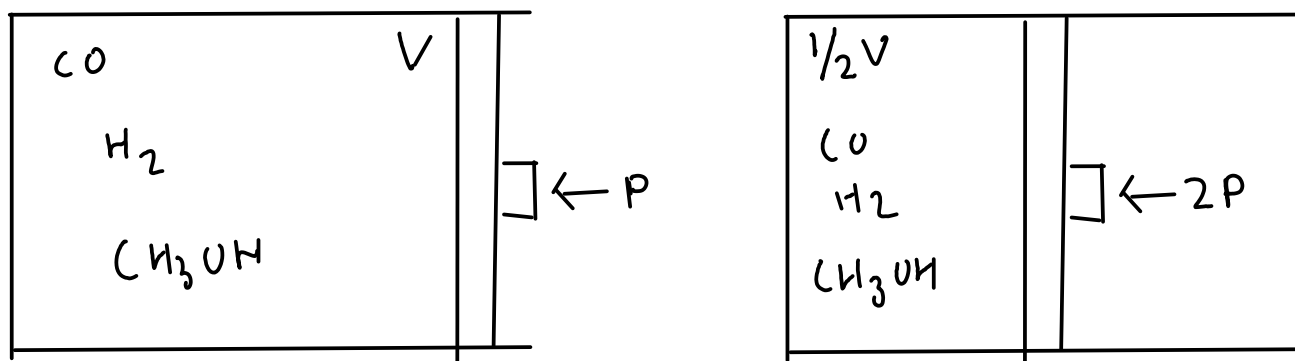


... how might pressure affect this equilibrium?

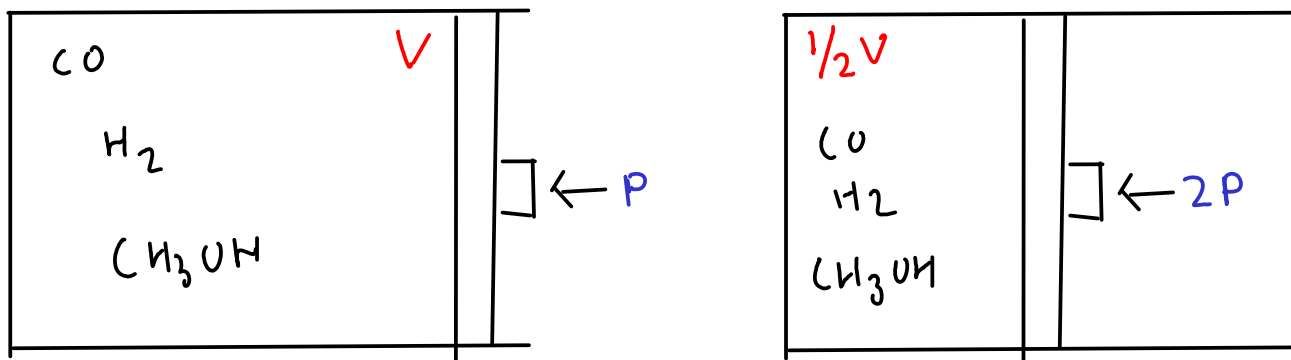
- If the change in pressure CHANGES CONCENTRATIONS, then this equilibrium would be disturbed and Le Chateleur's Principle would apply.

- Adding an INERT GAS would change pressure, but would it change concentration of the gases? NO - so addition of argon would have no effect on the equilibrium!

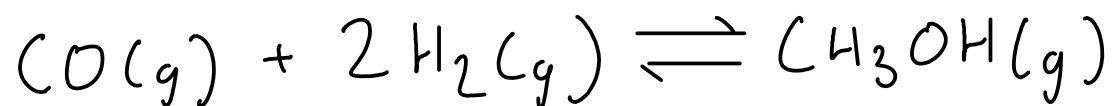
- What about COMPRESSION?



... compression increases pressure by DECREASING total volume.



... but this volume change affects ALL concentrations the same way. In this example, each concentration is DOUBLED.



$$K_c = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2} = \frac{(1)}{(1)(1)^2} = 1$$

For simplicity,
let's assume
 $K_c = 1$, and all
concs = 1M

Doubling
concentrations
gives $Q =$

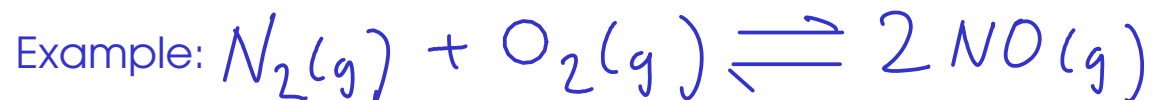
$$\frac{2}{(2)(2)^2} = \frac{1}{4}$$

$Q < K_c$, so equilibrium shifts to the RIGHT, forming more methanol at the expense of hydrogen and carbon monoxide.

In general, compressing an equilibrium reaction in the gas phase will cause the equilibrium to shift towards the side with fewer moles of gas. This causes the pressure to decrease.

In general, decompressing an equilibrium reaction in the gas phase will cause the equilibrium to shift towards the side with more moles of gas. This causes the pressure to increase.

HOWEVER, this can only be true IF there's a side of the reaction with more moles of gas than the other. If both sides of the reaction have the SAME number of moles of gas, then a pressure change will NOT affect the equilibrium.



... would not respond to a pressure change.

¹¹⁹ FACTORS THAT MAY AFFECT EQUILIBRIUM

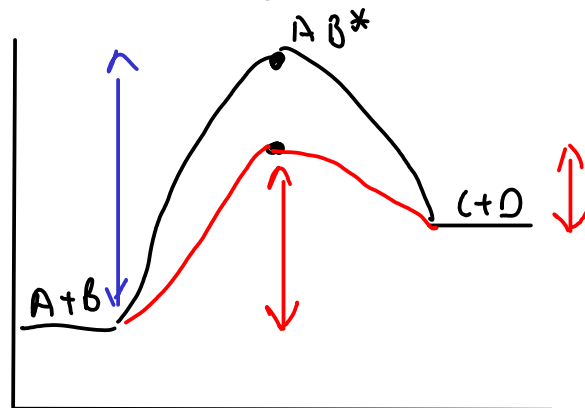
① TEMPERATURE (effect depends on whether reaction is endothermic or exothermic)

- Changes rate of reaction, too!
- ... changes K_c

② PRESSURE - only for gas-phase reactions which have different numbers of moles of gas on each side of the equilibrium. Otherwise, no effect.

- ... no change of K_c

③ CATALYSTS - do NOT affect equilibrium, but make the equilibrium state occur more quickly.



The catalyst raises BOTH forward and reverse rates, so it doesn't affect the composition of the equilibrium mixture!

④ CONCENTRATION - Le Chateleur's Principle applies for changing concentrations. An equilibrium will shift to counteract a change in concentration of reactant or product.

- ... doesn't change K_c .

ACID/BASE EQUILIBRIUM

- Several scientific theories exist that define acid-base chemistry. We will discuss THREE of these theories.
- These theories differ in the way that acids, bases, and their associated reactions are defined.
- Typically, the newer theories include MORE chemicals under the umbrella of "acid-base chemistry"!

THREE ACID-BASE THEORIES

- ① Arrhenius theory
- ② Bronsted-Lowry theory
- ③ Lewis theory

ARRHENIUS THEORY

- The oldest model of acid-base chemistry!

- Only applicable to systems where WATER is the solvent!

ACIDS are substances that ionize in water to increase the concentration of HYDRONIUM ION



Hydronium ion

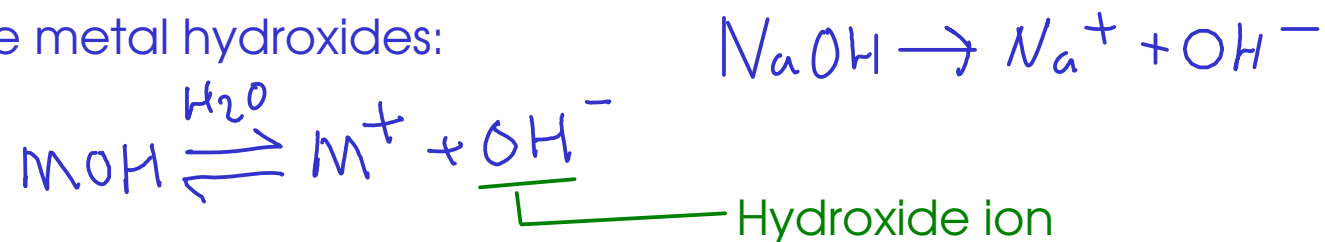


"Hydrogen ion" - doesn't really exist as a free ion in water, but a convenient simplification!

ARRHENIUS THEORY

BASES are substances that ionize in water to increase the concentration of HYDROXIDE ION

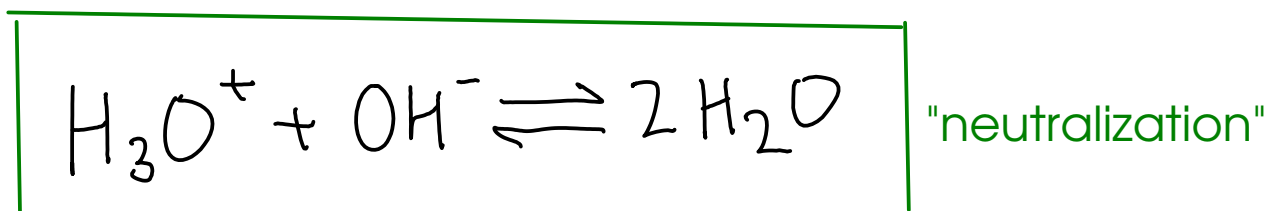
For soluble metal hydroxides:



For other Arrhenius bases:



An Arrhenius acid base reaction can be represented by:



or, using hydrogen ion instead of hydronium



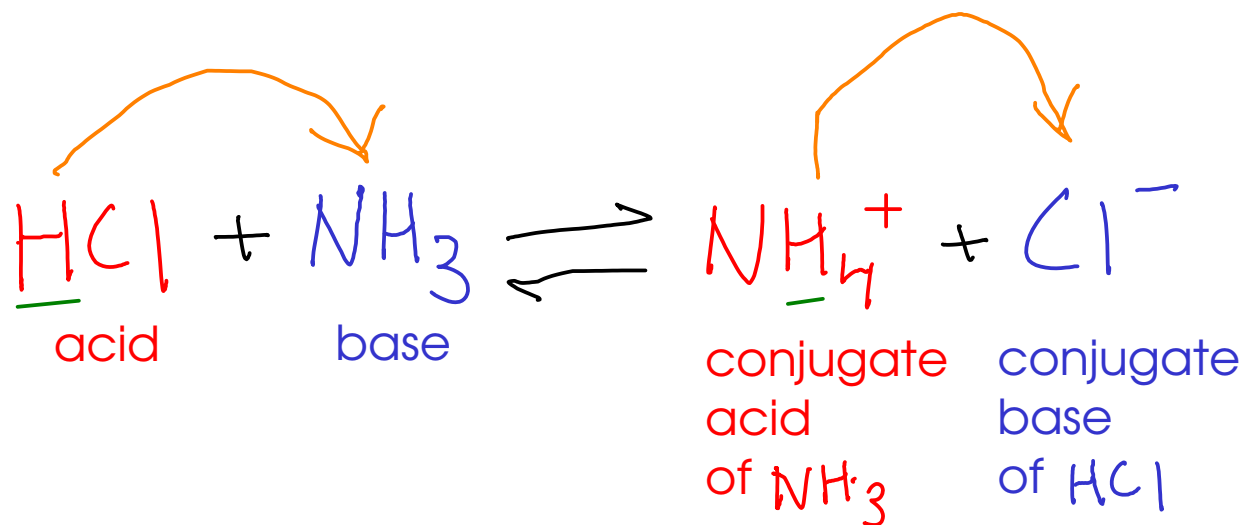
BRONSTED-LOWRY THEORY

- Bronsted-Lowry theory views acid-base reactions as PROTON TRANSFER reactions!

H^+ ions!

ACIDS are PROTON DONORS

BASES are PROTON ACCEPTORS



A CONJUGATE PAIR is an acid and a base that differ by a proton!