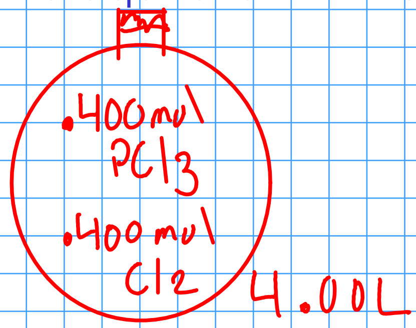
$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \quad K_c = 49$$

If you add 0.400 moles of each reactant to a 4.00 L reaction vessel, what is the composition of the equilibrium mixture?



Initial conditions

Start with the equilibrium expression:

$$K_c = \frac{[PCl_5]}{[PCl_5][Cl_2]} = 49$$

... these are EQUILIBRIUM concentrations!

	INITIAL	Δ	Equilibrium
$[PCl_3]$	$\frac{.400 \text{ mol}}{4.00 L} = 0.100 M$	$-x$	$.100 - x$
$[Cl_2]$	$\frac{.400 \text{ mol}}{4.00 L} = 0.100 M$	$-x$	$.100 - x$
$[PCl_5]$	0	$+x$	x

$$\frac{[PCl_5]}{[PCl_5][Cl_2]} = \boxed{\frac{x}{(.100 - x)(.100 - x)} = 49}$$

We need to solve this expression for 'x'!

We start by rearranging the equation in an attempt to isolate 'x'.

$$\frac{x}{(.100-x)(.100-x)} = 49$$

$$\frac{x}{(.100-x)^2} = 49$$

$$x = 49(.100-x)^2$$

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

$$x = 49(0.0100 - .200x + x^2)$$

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

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

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

This equation is a QUADRATIC equation:

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

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

Each quadratic equation has TWO solutions. However, only ONE of these solutions makes chemical sense!

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

from + from −

$$x = \cancel{0.157} \quad \text{OR} \quad 0.0639$$

This value for 'x' results in NEGATIVE equilibrium concentrations for both phosphorus trichloride and chlorine. Negative concentrations are NOT physically possible.

$$x = 0.0639$$

	Initial	Δ	Equilibrium
$[PCl_5]$	0	$+x$	x
$[Cl_2]$	$\frac{.400\text{ mol}}{4.00\text{ L}} = .100$	$-x$	$0.100 - x$
$[PCl_3]$	$\frac{.400\text{ mol}}{4.00\text{ L}} = .100$	$-x$	$0.100 - x$

$x = 0.0639\ \underline{M}$

$[PCl_5] = x = 0.0639\ \underline{M} \times 4.00\text{ L} = .256\text{ mol } PCl_5$

$[Cl_2] = 0.100 - x = 0.0361\ \underline{M} \times 4.00\text{ L} = .144\text{ mol } Cl_2$

$[PCl_3] = 0.100 - x = 0.0361\ \underline{M} \times 4.00\text{ L} = .144\text{ mol } PCl_3$

Concentrations at equilibrium

Number of moles in reaction vessel at equilibrium

Quick comparison of initial and equilibrium states:

Initial		Equilibrium
0.400 mol PCl_3	$\longrightarrow$	0.144 mol PCl_3
0.400 mol Cl_2		0.144 mol Cl_2
0 mol PCl_5		0.256 mol PCl_5

$K_c = 49$

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.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \quad K_c = 0.0123$$

$$K_c = 0.0123 = \frac{[NO]^2}{[N_2][O_2]}$$

... we need to solve for these concentrations at equilibrium.

	INITIAL	Δ	EQUILIBRIUM
$[NO]$	0	$+2x$	$2x$
$[N_2]$	$\frac{.850\text{ mol}}{8.00\text{ L}} = 0.10625\text{ M}$	$-x$	$.10625 - x$
$[O_2]$	$\frac{.850\text{ mo}}{8.00\text{ L}} = 0.10625\text{ M}$	$-x$	$.10625 - x$

$$0.0123 = \frac{[NO]^2}{[N_2][O_2]} = \boxed{\frac{(2x)^2}{(.10625-x)(.10625-x)} = .0123}$$

... solve this expression for 'x'!

$$\frac{(2x)^2}{(.10625-x)(.10625-x)} = .0123$$

	EQUILIBRIUM
[NO]	$2x$
$[N_2]$	$.10625-x$
$[O_2]$	$.10625-x$

$$\frac{(2x)^2}{(.10625-x)^2} = 0.0123$$

$$\sqrt{\frac{(2x)^2}{(.10625-x)^2}} = \sqrt{0.0123}$$

$$\frac{2x}{.10625-x} = 0.110905$$

$$2x = 0.110905(.10625-x)$$

$$2x = 0.0117837 - 0.110905x$$

$$2.110905x = 0.0117837$$

$$x = 0.00558$$

$$\boxed{[NO] = 2x = 0.0112\ \underline{M}} \quad (0.089\ mol)$$

$$[N_2] = [O_2] = .10625 - x = 0.101\ M \quad (0.805\ mol)$$