In-class **group exercise** on equilibrium calculations: Practice for using the ICE approach. (Solve these by yourself and then you can check the solutions in the following pages)

1) Nitrogen gas reacts with oxygen gas to form dinitrogen pentoxide gas. Write down the balanced equation, making all coefficients integers. Write down the K_c , K_p expressions. If $K_c = 1.20 \times 10^1$ but note that K_c here is given per mole of N_2 reacted, what is the K_c for your balanced equation? What is K_p at 25°C for your balanced equation?

2) Copper(II) hydroxide is a sparingly soluble solid with a K_{sp} of 1.6×10^{-19}.
a) What is the molar solubility of this compound?
b)Assuming that the hydroxide ions in solution are only from the dissolution of this compound, what is the value of $[OH^-]$?

3) The acid ionization constant of cyanic acid (HOCN) is 3.5×10^{-4}. What is $[H^+]$ due to the self-ionization of this acid if we dissolve 0.100 moles HOCN to make 1.0 L of solution? First, use (a) the 5% rule. Compare and see if the 5% rule is valid. If not, re-solve the problem using the quadratic equation.

4) The decomposition of sulfur trioxide gas to oxygen gas and sulfur dioxide gas has a K_c of 4.10×10^{-6}. What are the concentrations of all the gases if we initially have 0.500 M of SO_3 gas in an air-tight container?

Solutions:

In-class **group exercise** on equilibrium calculations: Practice for using the ICE approach.

1) Nitrogen gas reacts with oxygen gas to form dinitrogen pentoxide gas. Write down the balanced equation, making all coefficients integers. Write down the K_c , K_p expressions. If $K_c = 1.20 \times 10^1$ but note that K_c here is given per mole of N_2 reacted, what is the K_c for your balanced equation? What is K_p at 25°C for your balanced equation?

Solution: Balanced equation is **$2\ N_2(g) + 5\ O_2(g) \Longleftrightarrow 2\ N_2O_5(g)$**

The given K_c is for: $N_2 + (5/2)\ O_2 \Longleftrightarrow N_2O_5$

So for our equation, $\mathbf{K_c} = (1.20 \times 10^1)^2 = \mathbf{1.44 \times 10^2}$

$K_c = \dfrac{[N_2O_5]^2}{[N_2]^2[O_2]^5}$ and $K_p = \dfrac{P^2_{N_2O_5}}{P^2_{N_2}P^5_{O_2}}$ note value of R used

$K_p = K_c(RT)^{\Delta n} = (1.44 \times 10^2)\ \{(0.0821)(298)\}^{(2-(2+5))} = \dfrac{144}{(24.5)^5} = \mathbf{1.63 \times 10^{-5}}$

2) Copper(II) hydroxide is a sparingly soluble solid with a K_{sp} of 1.6×10^{-19}.
a) What is the molar solubility of this compound?
b)Assuming that the hydroxide ions in solution are only from the dissolution of this compound, what is the value of $[OH^-]$?

(a) $Cu(OH)_2(s) \Longleftrightarrow \underset{x}{Cu^{2+}(aq)} + 2\ \underset{2x}{OH^-(aq)}$ $K_{sp} = 1.6 \times 10^{-19} = [Cu^{2+}][OH^-]^2 = x(2x)^2 = 4x^3$

so, $x^3 = \dfrac{1.6 \times 10^{-19}}{4}$ => $x = \mathbf{3.42 \times 10^{-7}}$

(b) $[OH^-] = 2x = 2(3.42 \times 10^{-7}) = \mathbf{6.84 \times 10^{-7} M}$

3) The acid ionization constant of cyanic acid (HOCN) is 3.5×10^{-4}. What is $[H^+]$ due to the self-ionization of this acid if we dissolve 0.100 moles HOCN to make 1.0 L of solution? First, use (a) the 5% rule. Compare and see if the 5% rule is valid. If not, re-solve the problem using the quadratic equation.

Solution: $\underset{0.100-x}{HOCN} \Longleftrightarrow \underset{x}{H^+} + \underset{x}{OCN^-}$ $K_{sp} = 3.5 \times 10^{-4} = \dfrac{[H^+][OCN^-]}{[HOCN]} = \dfrac{x^2}{0.100 - x}$

Using 5% rule:

x<5% of 0.100 and so, $x^2 = (0.100)(3.5 \times 10^{-4})$ => $x = \sqrt{3.5 \times 10^{-5}} = 5.9 \times 10^{-3}$

checking: $(5.9 \times 10^{-3}/0.100) \times 100\% = 5.9\% > 5\%$ so we need the quadratic equation:

Use quadratic equation: $x^2 + 3.5 \times 10^{-4}\ x - 3.5 \times 10^{-5} = 0$;

$$x = \frac{-3.5 \times 10^{-4} \pm \sqrt{(3.5 \times 10^{-4})^2 - 4(1)(-3.5 \times 10^{-5})}}{2(1)}$$

(compare)

$$x = \frac{-3.5 \times 10^{-4} \pm \sqrt{(3.5 \times 10^{-4})^2 - 4(1)(-3.5 \times 10^{-5})}}{2(1)} = \frac{-3.5 \times 10^{-4} \pm 1.2 \times 10^{-2}}{2} = 5.8 \times 10^{-3} M$$

4) The decomposition of sulfur trioxide gas to oxygen gas and sulfur dioxide gas has a K_c of $4.10x10^{-6}$. What are the concentrations of all the gases if we initially have 0.500 M of SO_3 gas in an air-tight container?

Solution:Let's use ICE approach:

	$2SO_3(g)$ <==>	$O_2(g)$ +	$2SO_2(g)$	
initial:	0.500			
change	-2x	+x	+2x	(here let x = $[O_2]$ formed)
equil	(0.500-2x)	x	2x	

$$K_c = 4.1x10^{-6} = \frac{[O_2][SO_2]^2}{[SO_3]^2} = \frac{x(2x)^2}{(0.500-2x)^2}$$

This give us: $(.250 - 2x + 4x^2)(4.10x10^{-6}) - 4x^3 = 0$ (3rd order polynomial – hard to solve by exact methods)

Try an approximation: 5% rule: assume that x<< 0.50 (justification? Because K_c is "very small")

so, we can write:

$$K_c = 4.10x10^{-6} = \frac{[O_2][SO_2]^2}{[SO_3]^2} = \frac{x(2x)^2}{(0.500-2x)^2} \approx \frac{x(2x)^2}{(0.500)^2}$$

$4x^3 = (0.500^2)(4.10x10^{-6}) = 1.025\ x10^{-6}$ or, $x = (2.56x10^{-7})^{1/3} =$ **$6.35x10^{-3}$M**

it is $\frac{6.35x10^{-3}}{0.500} x100\%$ = 1.3% < 5% so the 5% rule is satisfied.

The final answers are:

$[SO_3]$=0.500-2x = 0.500 M - 2($6.35x10^{-3}$ M) = 0.487 M

$[O_2]$ = x = $6.35x10^{-3}$M $[SO_2]$ = 2x = 2($6.35x10^{-3}$ M) = $1.27x10^{-2}$ M