Equilibrium and Le Chatelier's Principle Practice Problems

① $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $K = 6.0 \times 10^{-2}$ @ $T = 500\ °C$

To determine which way the rxn shifts to establish equilibrium, you must calculate "Q" for the given concentrations, then compare Q to K. (you are trying to see if the given conc. are equilibrium conc. If not the value of Q in comparison to K will tell you in which direction the rxn will shift to reach ⇌)

$$Q = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Ⓐ $Q = \dfrac{(1.0 \times 10^{-3})^2}{(1.0 \times 10^{-5})(2.0 \times 10^{-3})^3} = 12500000$

Q > K ∴ Shift left (reverse)

since Q & K are $\frac{P}{R}$, to make Q = K (i.e. reach ⇌) Q must get smaller, thus [P] must decr & [R] must incr ∴ rxn shifts in reverse direction

Ⓑ $Q = \dfrac{(2.00 \times 10^{-4})^2}{(1.50 \times 10^{-5})(3.54 \times 10^{-1})^3} = .0601 = 6.01 \times 10^{-2}$

Q = K ∴ RXN is at equilibrium, NO SHIFT

Ⓒ $Q = \dfrac{(1.0 \times 10^{-4})^2}{(5.0)(1.0 \times 10^{-2})^3} = .0020$

Q < K ∴ SHIFT RIGHT (FORWARD)

② $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ $K = 5.10$ @ $T = 700\ K$

	$CO(g)$	$H_2O(g)$	$CO_2(g)$	$H_2(g)$
I	1.000 mol	1.000 mol	1.000 mol	1.000 mol
C	−x	−x	+x	+x
E	1−x	1−x	1+x	1+x

V: 1.000 L

(* since you determined the system shifts → subtract from Reactants & Add to Products

* Start w/ amounts of all reactants & products so ask yourself, "is the system @ ⇌ under these conditions? If not, in which direction will the system shift to reach ⇌?"

How do you answer this? Calculate Q!

$$Q = \frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{(1)(1)}{(1)(1)} = 1$$

← volume = 1 L ☺

Q < K ∴ SHIFT →

$= 1 - .386$
$= .614$ mol CO = mol H_2O

$= 1 + .386$
$= 1.386$ mol CO_2 = mol H_2

$$K = \frac{[CO_2][H_2]}{[CO][H_2O]}$$

$$5.10 = \frac{(1+x)(1+x)}{(1-x)(1-x)}$$

$$\sqrt{5.10}(1-x) = 1 + x$$

x = .386 mol

∴ $[CO_2] = [H_2] = 1.386$ M
$[CO] = [H_2O] = .614$ M
} @ ⇌

③ $H_{2(g)} + F_{2(g)} \rightleftharpoons 2HF_{(g)}$

	H_2	F_2	$2HF$
I	3.000 mol	3.000 mol	3.000 mol
C	$-x$	$-x$	$+2x$
E	$3-x$ $= 3-2.29$ $= .71$ mol H_2	$3-x$ $= .71$ mol F_2	$3+2x$ $= 3+2(2.29)$ $= 7.58$ mol HF

$[H_2] = [F_2] = \frac{.71 \text{ mol}}{1.5 \text{ L}} = .473 \text{ M}$

$[HF] = \frac{7.58 \text{ mol}}{1.5 \text{ L}} = 5.05 \text{ M}$

∴ @ ⇌ $[H_2] = [F_2] = .473$ M
$[HF] = 5.05$ M

$K = 1.15 \times 10^2$ @ T = ?

$V = 1.500$ L

$$Q = \frac{[HF]^2}{[H_2][F_2]} = \frac{(3\text{ mol}/1.5\text{ L})^2}{(3\text{ mol}/1.5\text{ L})(3\text{ mol}/1.5\text{ L})} = \frac{(3\text{ mol}/1.5\text{ L})^2}{(3\text{ mol}/1.5\text{ L})^2} = 1$$

$Q < K$ ∴ SHIFT →

$$K = \frac{[HF]^2}{[H_2][F_2]}$$

$$1.15 \times 10^2 = \frac{(3+2x)^2}{(3-x)^2}$$

$$10.7 = \frac{3+2x}{3-x}$$

$32.1 - 10.7x = 3 + 2x$
$x = 2.29$ mol

④ $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

@⇌ 2.71 atm ? atm

$K_p = 0.133$

* since given equilibrium value & K_p (can only plug in ⇌ values into K_p), use K_p expression to solve for the unknown equilibrium pressure.

$$K_p = \frac{(P_{NO_2})^2}{P_{N_2O_4}}$$

$$0.133 = \frac{(P_{NO_2})^2}{2.71}$$

$P_{NO_2} = .600$ atm

⑤ OMIT

:)

⑥ $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ $V = 1.00$ L

$K = ?$

@ $\rightleftharpoons$ 2.00×10^{-3} mol Cl_2

	PCl_5	PCl_3	Cl_2
I	8.70×10^{-3} mol	0.298 mol	0 mol
C	$-x$	$+x$	$+x$
E	$8.70 \times 10^{-3} - x$	$0.298 + x$	$x = 2.00 \times 10^{-3}$ mol

$= 8.70 \times 10^{-3} - 2.00 \times 10^{-3} = .0067$ mol PCl_5

$= 0.298 + 2.00 \times 10^{-3} = .3$ mol PCl_3

$\frac{.0067 \text{ mol } PCl_5}{1.00 \text{ L}} = \boxed{6.70 \times 10^{-3} \text{ M } PCl_5}$

$\frac{.3 \text{ mol } PCl_3}{1.00 \text{ L}} = \boxed{.300 \text{ M } PCl_3}$

$\frac{2.00 \times 10^{-3} \text{ mol } Cl_2}{1.0 \text{ L}} = \boxed{2.00 \times 10^{-3} \text{ M } Cl_2}$

* Plug in $\rightleftharpoons$ values into K_c

$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$

$K_c = \frac{(.300)(2.00 \times 10^{-3})}{6.70 \times 10^{-3}}$

$\boxed{K_c = .0896}$

⑦ $As_4O_6(s) + 6C(s) \rightleftharpoons As_4(g) + 6CO(g)$

a) shift left. Adding CO will cause Q to be greater than K. Thus, more reactants must be made to reestablish equilibrium.

b) No shift. As_4O_6 is a solid, thus it does not affect Q.

c) shift right. Removing As_4 will cause Q to be less than K. Thus, more products must be made to reestablish equilibrium.

⑧ Decreasing volume = shift to side w/ less moles of gas

a) $P_4(s) + 6Cl_2(g) \rightleftharpoons 4PCl_3(l)$

6 mol gas vs. zero mol gas ∴ shift right

b) $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$

2 mol gas vs. 1 mol gas ∴ shift right

c) $PCl_3(g) + 3NH_3(g) \rightleftharpoons P(NH_2)_3(g) + 3HCl(g)$

4 mol gas vs. 4 mol gas ∴ no shift

⑨ increase T = favor side without heat

a) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ $\Delta H = 181$ kJ

Endo! Heat is reactant, thus rxn favors products when T increases. Since [products] increases, **K increases.**

b) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -198$ kJ

Exo! Heat is product, thus rxn favors reactants when T increases. Since [reactants] increases, **K decreases.**