AP Worksheet 7c (Le Châtelier's Principle)

For the following reaction, write how each of the changes will affect the indicated quantity. (For a chemical added, write how it would respond after the addition.

heat + $NO_2(g) \rightleftarrows 2NO(g) + O_2(g)$ $\Delta H° = +62kJ$

Change	$[NO_2]$	[NO]	$[O_2]$	K value
1. Some NO_2 added	↑ then ↓	↑	↑	same
2. Some O_2 added	↑	↓	↑ then ↓	same
3. Some NO_2 removed	↓ then ↑	↓	↓	same
4. Some O_2 removed	↓	↑	↓ then ↑	same
5. The temperature is increased	↓	↑	↑	Δ
6. The temperature is decreased	↑	↓	↓	Δ
7. Pressure is increased (and the container volume decreased)	↑	↓	↓	same
8. Pressure is decreased (so the container volume increases)	↓	↑	↑	same

1. Assume that each of the reactions below are at equilibrium. Using your knowledge of Le Châtelier's principle, explain carefully how the system will respond to the change.

   a. $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ Change: The volume is increased

   system will shift right towards $PCl_3 + Cl_2$ create more P

   b. $2NO_2(g) \rightleftharpoons NO_3(g) + NO(g)$ Change: More NO is added

   system will shift left towards NO_2 to use up extra NO

2. The Haber process is used to produce ammonia commercially.

   a. 1.00 mol of N_2 and 3.00 mols of H_2 are mixed together to produce ammonia according to the reaction below. At equilibrium in a 1.00 L vessel, only 50.0% of the N_2 that was present originally remains. Calculate K_c for this reaction at this temperature.

$N_2 + 3H_2 \rightleftharpoons 2NH_3$ + heat $\Delta H = -92$ kJ

	N_2	$3H_2$	$2NH_3$
I	1.00M	3.00M	0
C	−x	−3x	+2x
E	.50M	3−3x	+2x
	x = .50M	1.50M	1.00M

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

$= \frac{(1.00M)^2}{(.500M)(1.50M)^3}$

$= .593$

b. Predict how each of the following chanes would affect the percentage of ammonia in the equilibrium mixture.

(i) Adding a catalyst
no change (only get there faster)

(ii) Increasing the total pressure
higher % of NH_3
Rxn shifts right toward NH_3 to side w/ fewest moles

(iii) Using a high temperature
lower % of NH_3
Rxn is exothermic. Extra heat used to produce reactants

3. Consider the Haber Process described in number 2. Under typical conditions a mixure of 1 mole of nitrogen gas to every 3 moles of hydrogen gas are exposed to the temperatures shown in the table below and equilibrium is established. In each case, the system is under a total pressure of 10.0 atm.

Temperature in °C	Partial pressure of NH_3 in atm
355	0.741
455	0.211
555	0.081

total $P = 10.0$ atm
$P_{H_2} + P_{N_2} + P_{NH_3} = 10.0$
$P_{H_2} = 3P_{N_2}$

$10.00 - .741 = 9.259$ atm

a. For each temperature, calculate the partial pressure of each reactant.

355°C:
$4P_{N_2} = P_{H_2} + P_{N_2} = 9.259$ atm
$P_{N_2} = 2.31$ atm
$P_{H_2} = 6.94$ atm

455:
$4P_{N_2} = 9.789$
$P_{N_2} = 2.45$ atm
$P_{H_2} = 7.34$ atm

555°C: $4P_{N_2} = 9.919$
$P_{N_2} = 2.48$ atm
$P_{H_2} = 7.44$ atm

b. For each temperature, calculate K_p.

$$K_p = \frac{(P_{NH_3})^2}{(P_{N_2})(P_{H_2})^3}$$

355°C:
$K_p = \frac{(.741)^2}{(2.31)(6.94)^3} = 7.11 \cdot 10^{-4}$

455°C:
$K_p = 4.60 \cdot 10^{-5}$

555°C
$K_p = 6.42 \cdot 10^{-6}$

c. Explain how the data is consistent with the ΔH for the reaction.

As heat is added to the Rxn, the reaction produces more reactants (shown by K_p and the pressures) to

d. The experiment is repeated and the conditions adjusted so the total pressure is 40.0 atm. The partial pressure of ammonia at equilibrium under these conditions is 11.4 atm.

(i) Without doing any calculations, comment upon the significance of the data in terms of Le Châtelier's principle.
increasing the pressure will cause the reaction to shift to the products, which has fewer moles) to relieve the extra P

(ii) Calculate K_p under the new conditions.

$P_{H_2} = 3P_{N_2}$

$P_{N_2} + P_{H_2} + P_{NH_3} = 40.0$ atm
$P_{N_2} + P_{H_2} + 11.4$ atm $= 40.0$ atm
$P_{N_2} + P_{H_2} = 28.6$ atm
$4P_{N_2} = 28.6$ atm
$P_{N_2} = 7.15$ atm
$P_{H_2} = 21.5$ atm

$$K_p = \frac{(P_{NH_3})^2}{(P_{N_2})(P_{H_2})^3} = \frac{(11.4)^2}{(7.15)(21.5)^3} = .00183$$

e. The reaction is often carried out using a catalyst. What is the purpose of the catalyst and how does it affect the value of K for the reaction?

the catalyst does not affect K.
It only increases the rate of the forward & reverse reactions so equilibrium is reached faster