Le Châtelier's Principle: If a system at equilibrium is subjected to a stress, the equilibrium will shift in the direction that relieves that stress and re-balances equilibrium.

- Types of Stress:
  - concentration
  - temperature
  - pressure (for gases only)
  - catalyst

Concentration [X] ← substance units: M (molarity)

- Effect:
  - when you add (increase concentration) something, equilibrium shifts away from it
  - when you take away (decrease concentration) something, equilibrium shifts towards it
- Examples: For each of the following equations, determine in which direction the equilibrium point would shift, given a change in concentration.

add away
take towards

1) $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ Increase [CO] right
2) $2\,HBr(g) \rightleftharpoons H_2(g) + Br_2(g)$ Increase [Br_2] left
3) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ Decrease [PCl_3] right
4) $N_2(g) + O_2(g) \rightleftharpoons 2\,NO(g)$ Decrease [O_2] left

- For each of the equations found below, determine which substances will increase and decrease "after" the change to the equilibrium system has been made.

5) Given the equation: $2\,H_2O(v) \rightleftharpoons 2\,H_2(g) + O_2(g)$

If there is an increase in [H_2]...

add away

a. The reaction will shift to the left
b. The following substances will increase in concentration: $H_2O(v)$
c. The following substances will decrease in concentration: $H_2(g) + O_2(g)$

stuff that chosen arrow points towards (stuff being produced)
stuff that chosen arrow points away from (stuff being used up or acting as a reactant)

6) Given the equation: $N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$

If there is a decrease in [H_2]...

a. The reaction will shift to the left
b. The following substances will increase in concentration: $N_2(g) + H_2(g)$
c. The following substances will decrease in concentration: $NH_3(g)$

3

Temperature / heat

- Effect: heat can be considered a reactant or product, just like with concentration
  → use the add away / take towards rule

- Examples: For each of the following equations, determine in which direction the equilibrium point would shift, given a change in temperature.

7) $N_2 (g) + 3 H_2 (g) \rightleftharpoons 2 NH_3 (g) + 91.8 kJ$ ↑ add away Inc. temp. left
8) $H_2 (g) + I_2 (g) + 53.0 kJ \rightleftharpoons 2 HI (g)$ ↓ take towards Dec. temp. left
9) $2 H_2 (g) + O_2 (g) \rightleftharpoons 2 H_2O (v) + 483.6 kJ$ ↑ add away Inc. temp. left
10) $4NH_3 (g) + 5 O_2 (g) \rightleftharpoons 4 NO (g) + 6 H_2O (g) + 297.2 kJ$ Dec. temp. right
11) $N_2 (g) + O_2 (g) + 182.6 kJ \rightleftharpoons 2 NO (g)$ take towards Dec. temp. left

↑P ↓V take towards

Pressure or Volume *Only for gases!

- Effect:
  - If pressure is increased (decrease volume), there is less room for gas particles, so equilibrium shifts to side with fewer moles of gas (g).
  - If pressure is decreased (increase volume), there is more room for gas particles, so shift to side w/ more moles of g.
  - * If there are an equal # of moles of g on both sides, no effect.

- Examples: For each of the following equations, determine in which direction the equilibrium point would shift, given a change in pressure/volume.

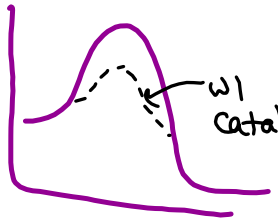
*only count moles of (g) phase

12) $PCl_5 (g) \rightleftharpoons PCl_3 (g) + Cl_2 (g)$ (1 → 2) Inc. pressure left
13) $4 NH_3 (g) + 5 O_2 (g) \rightleftharpoons 4 NO (g) + 6 H_2O (l)$ (9 → 4) don't count Dec. pressure left
14) $N_2 (g) + O_2 (g) \rightleftharpoons 2 NO (g)$ (2 → 2) Dec. pressure no effect
15) $2 C_2H_6 (g) + 7 O_2 (g) \rightleftharpoons 4 CO_2 (g) + 6 H_2O (g)$ (9 → 10) Inc. volume right
16) $N_2 (g) + 3 H_2 (g) \rightleftharpoons 2 NH_3 (g)$ (4 → 2) Dec. volume right

↓V ↑P

Catalyst

- Effect: a catalyst speeds up the rates of both the forward and reverse reactions equally, so there is NO EFFECT on the equilibrium.



4