LE CHÂTELIER'S PRINCIPLE

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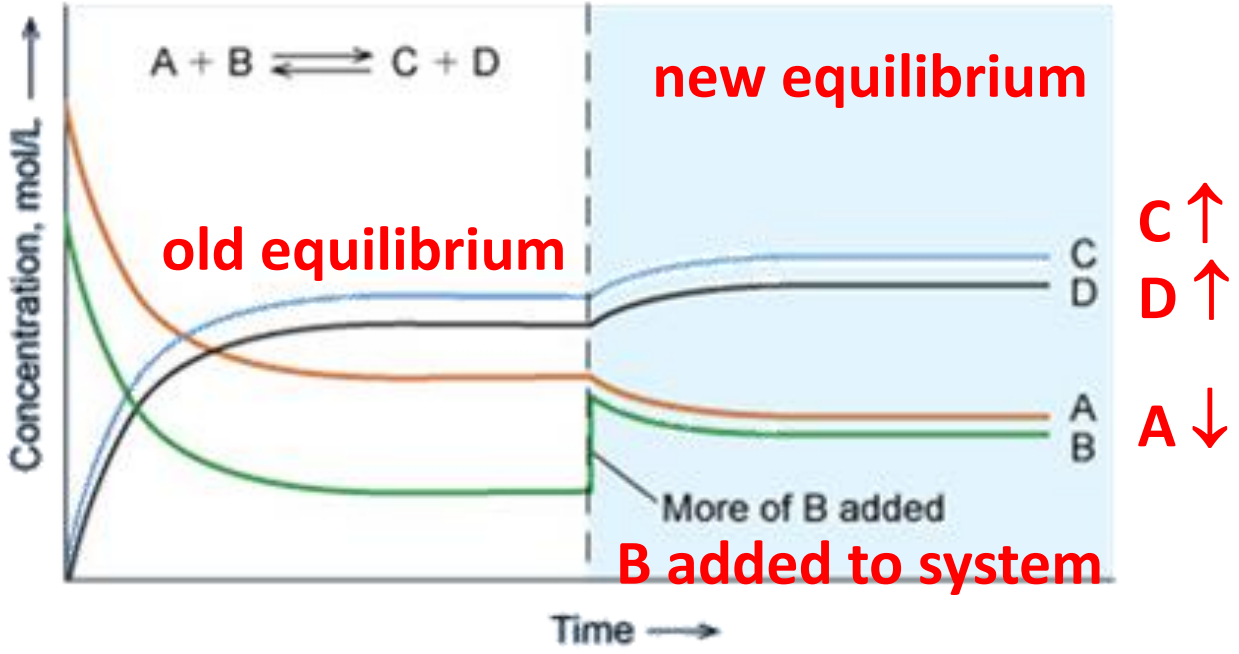
"when a system at equilibrium is disturbed by a change in temp., pressure, or conc., the system shifts its equilibrium to counteract this change."



STRESSES ON EQUILIBRIUM

- Concentration

Catalyst has no effect on equilibrium

  - Adding or removing a reactant or product
- Temperature
  - Heating or cooling a reaction
  - Dependent on if reaction is endo or exo
- Pressure
  - Depends ONLY on gases in a reaction
- A ***shift*** is when a stress is applied to a reaction and the system corrects the change to return to equilibrium

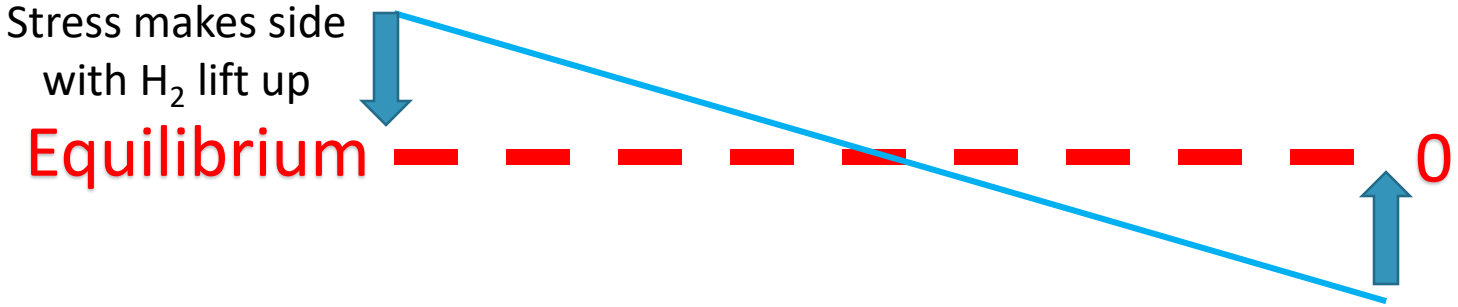
CHANGE IN CONCENTRATION

- If concentration (or amount) of a substance increases, then the reaction ***shifts away from the increase***

- If concentration (or amount) of a substance decreases, then the reaction ***shifts towards the decrease***

CONCENTRATION CHANGE EXAMPLE

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 92kJ$$

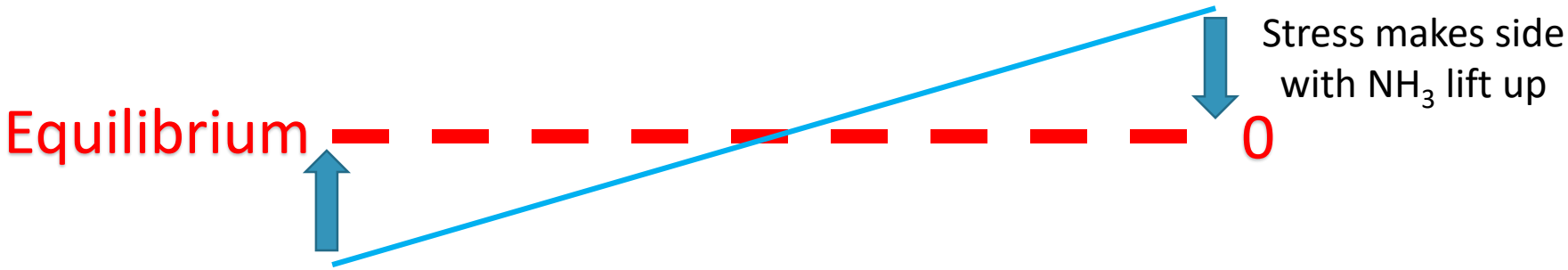


- **Stress: H_2 is added to the system**
  - What must be done to both sides of the reaction to go back to equilibrium?
- *Reaction shifts to side below equilibrium line:*
  - so will shift RIGHT towards ***products***

Shifts to side of rxn that must increase
Shifts away from side of rxn that must decrease

TRY THIS:

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 92kJ$$



- **Stress: NH_3 is added to the system**
  - What must be done to both sides of the reaction to go back to equilibrium?
- *Reaction shifts to side below equilibrium line:*
  - so will shift LEFT towards ***reactants***

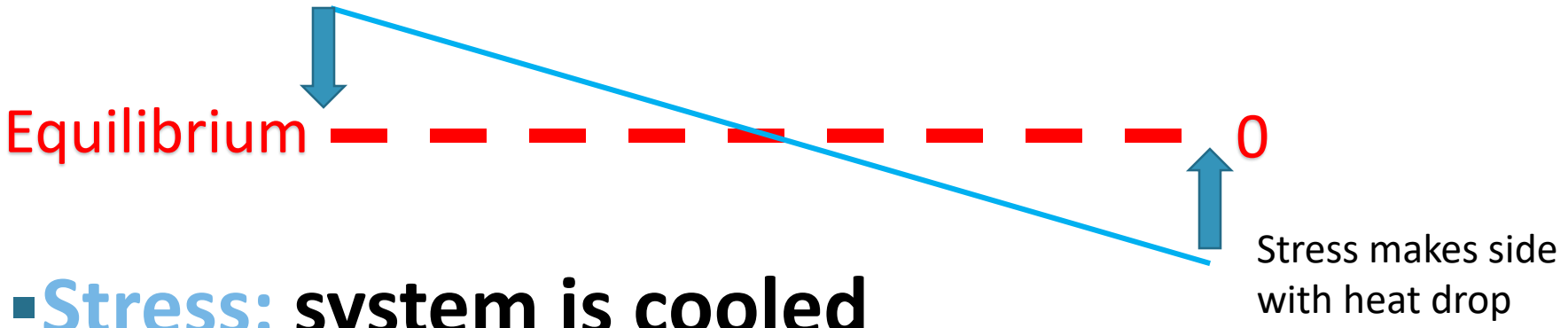
Shifts to side of rxn that must increase
Shifts away from side of rxn that must decrease

CHANGE IN TEMPERATURE

- Endothermic: A + B + energy → C + D
  - If temp increases, then the reaction ***shifts away from the increase,*** *towards* ***products***
  - If temp decreases, then the reaction ***shifts towards the decrease,*** *towards* ***reactants***
- Exothermic: A + B → C + D + energy
  - If temp increases, *towards* ***reactants***
  - If temp decreases, *towards* ***products***

TEMPERATURE CHANGE EXAMPLE

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 92kJ$$

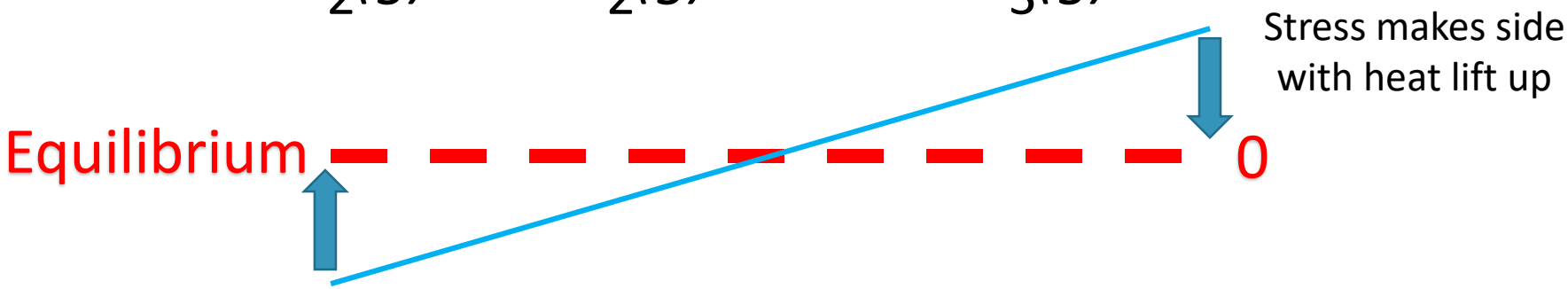


- **Stress: system is cooled**
  - What must be done to both sides of the reaction to go back to equilibrium?
- *Reaction shifts to side below equilibrium line:*
  - so will shift RIGHT towards ***products***

Shifts to side of rxn that must increase
Shifts away from side of rxn that must decrease

TRY THIS:

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 92kJ$$



- **Stress: system is heated**
  - What must be done to both sides of the reaction to go back to equilibrium?
- *Reaction shifts to side below equilibrium line:*
  - so will shift LEFT towards ***reactants***

Shifts to side of rxn that must increase
Shifts away from side of rxn that must decrease

CHANGE IN PRESSURE

- Only affects ***gases*** because affects volume of system
- Need to count # of moles of gases ***(coefficients)***
- **Increase in pressure** means decrease in volume, so the reaction will ***shift to the side with fewer moles of gas***
- **Decrease in pressure** means an increase in volume, so the reaction will ***shift to the side with more moles of gas***

PRESSURE CHANGE EXAMPLE

1 + 3 = 4 moles 2 moles

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 92kJ$$

- **Change: system pressure is decreased** V increases
  - What must be done to both sides of the reaction to go back to equilibrium?
- *Reaction shifts to side with more gas moles*
  - so will shifts LEFT towards ***reactants***

Shifts to side of rxn that must increase
Shifts away from side of rxn that must decrease

  - Reactants must increase & products must decrease to return to equilibrium

PRESSURE CHANGE EXAMPLE

1 + 3 = 4 moles 2 moles

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 92kJ$$

- **Change: system volume is decreased** — P increases
  - What must be done to both sides of the reaction to go back to equilibrium?
- *Reaction shifts to side with less gas moles*
  - so will shift RIGHT towards ***products***

Shifts to side of rxn that must increase
Shifts away from side of rxn that must decrease

  - Reactants must decrease & products must increase to return to equilibrium

TRY THIS ONE:

Predict how each of the following will affect the equilibrium:

$$H_2\,(g) + CO_2\,(g) + energy \leftrightarrow H_2O\,(g) + CO\,(g)$$

- Adding H_2O to the system ←
- Removing CO from the system →
- Adding H_2 to the system →
- Adding a catalyst **Nothing b/c only affects speed not reaction**
- Removing energy ←
- Increase the volume of the system

Nothing b/c equal # of moles

SAME ONE BUT IN TABLE FORM:

Predict how each of the following will affect the equilibrium:

$$H_2\,(g) + CO_2\,(g) + energy \leftrightarrow H_2O\,(g) + CO\,(g)$$

Stress	Direction of Shift	Effect on $[H_2]$	Effect on $[CO_2]$	Effect on $[H_2O]$	Effect on $[CO]$
Adding H_2O	LEFT	↑	↑	------	↓
Removing CO	RIGHT	↓	↓	↑	------
Adding H_2	RIGHT	------	↓	↑	↑
Add catalyst	No Change	———	———	———	———
Removing energy	LEFT	↑	↑	↓	↓
Increase volume	No Change	———	———	———	———