Le Châtelier: How to FRQ

1. Identify stress (change) to the system.
2. Identify effect of stress on the equilibrium system: shift right, shift left, or no shift?
3. Explain how the shift you identified will counteract the original stress to re-establish equilibrium
4. Connect your explanation to the question asked (aka, answer the question. ;D)

Example FR Explanations

Example #1: If the temperature of an exothermic reaction changes from 25°C to 50°C, what is the effect on equilibrium constant, K?

↑T

- *Stress?* Increasing temperature (exo rxn)
- *Effect of stress?* Shift left (or shift towards reactants)
- *Counteract stress?* Use up added heat
- *Answer question (effect on K):* increasing [reactants], decreasing [products] decreases value of K.

Final Answer: Increasing the temperature of an exothermic reaction will cause the system to shift left to use up the added heat and re-establish equilibrium. This shift increases the concentration of reactants and decreases the concentration of products, therefore the value of K decreases.

Example #2: For the reaction A(g) + B(g) ⇌ C(g), adding more A(g) to the reaction vessel will have what effect on the concentration of B(g)?

↑[A]

- *Stress?* Adding A(g) = increasing [A], a reactant
- *Effect of stress?* Shift right (or shift towards products)
- *Counteract stress?* Use up some of the added A(g)
- *Answer question (effect on concentration of B):* decrease [B], because using up some A to create products also uses up B.

Final Answer: Adding more A(g) will increase the concentration of A, a reactant, and so the system will shift right to use up some of the extra A by making more product. Using up some A to make products will also use up some B, and so the concentration of B will decrease as the system shifts to re-establish equilibrium.

Example #3: For the reaction A(g) + B(s) ⇌ C(g), removing some B(s) from the reaction container will have what effect on the reaction mixture?

↓B(s)

- *Stress?* No stress occurs: solids are not included in the equilibrium constant expression, K
- *Effect of stress?* n/a
- *Counteract stress?* n/a
- *Answer question (effect on rxn mixture):* no effect on location of equilibrium for the reaction mixture

Final Answer: Removing some B(s) will have no effect, because solids are not included in the equilibrium constant expression, *K*, and thus don't affect the location of equilibrium for the reaction mixture.

Free Response Practice!

1. In the following reaction at chemical equilibrium, what is the effect on the reaction mixture if the volume of the reaction container is decreased? Explain.

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

2 gas 2 gas

1) Stress? ↓ V
2) Effect? none
3) Counteract? n/a
4) Answer: no effect

Decreasing the volume of the container will have no effect on the rxn mixture, b/c the rxn has an equal # of moles of gaseous reactants + gaseous products.

2. Consider the following endothermic reaction at chemical equilibrium. When the temperature of the reaction mixture is increased, what is the effect on $CaCO_3(s)$? Explain.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

1) Stress? ↑ T (endo rxn)
2) Effect? shift right
3) Counteract? use up some added heat
4) Answer: ↓ amount of $CaCO_3$ (s)

★Note: $[CaCO_3]$ stays the same b/c solids have a constant concentration, but its quantity can still change ★

Increasing the temp. of an endothermic rxn will cause the system to shift right to use up some added heat. This will use up some $CaCO_3(s)$, a reactant, decreasing the amount of $CaCO_3(s)$ present.

3. Adding additional KCl will have what effect on the reaction mixture, if the mixture was originally at chemical equilibrium? Explain.

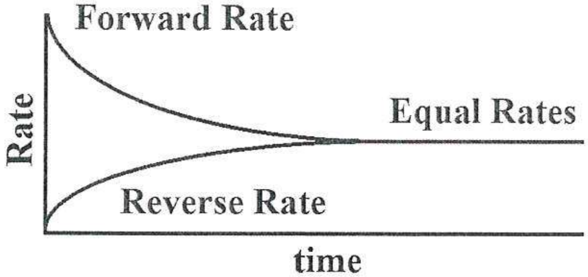
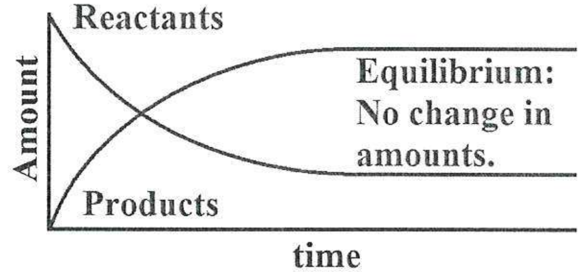
$$2\ KClO_3(s) \rightleftharpoons 2\ KCl(s) + 3\ O_2(g)$$

1) Stress? Adding KCl (s)
2) Effect? none
3) Counteract? n/a
4) Answer? no effect.

Adding more KCl(s) will not affect equilibrium position of the rxn mixture, b/c solids are not included in the equilibrium constant expression, K, so they don't affect the position of equilibrium.

Quick Review: Equilibrium Graphs

Equilibrium systems can be represented by two different graphs:

Rate of Reaction vs Time	[Reactants], [Products] vs Time
	

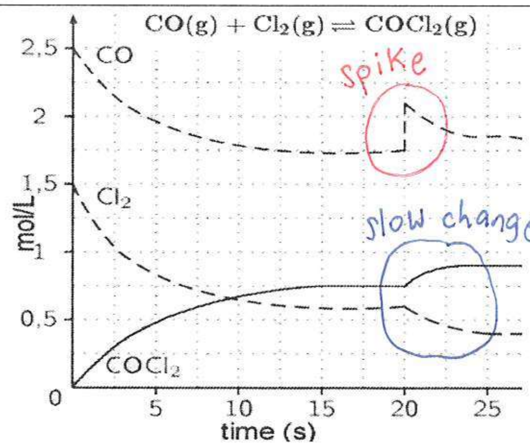
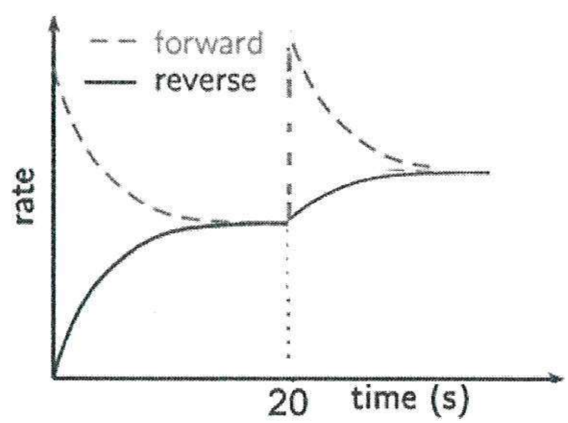
How can you use each graph to identify when equilibrium is reached?

a. **Rate of Reaction vs Time:** both forward and reverse reaction rates are equal.

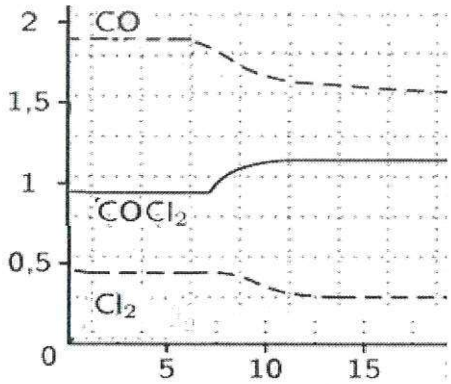
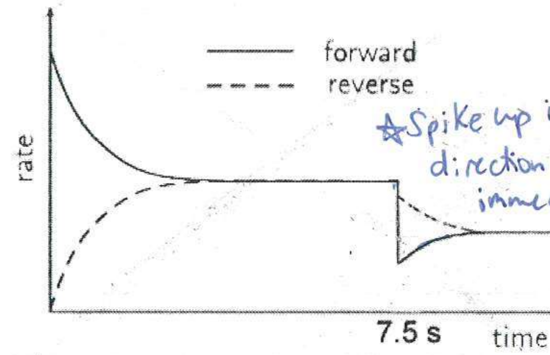
b. **[Reactants], [Products] vs Time:** concentrations of reactants and products are constant, but not necessarily equal.

Le Châtelier's Principle: Interpreting Equilibrium Graphs

1) Applied stress: Change in Concentration

<table>
<tr><th>Concentration vs. Time</th><th>Rate vs. Time</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Visual clues:
1) Spike in the concentration of one reactant or product
a. Spike UP if concentration increases
b. Spike DOWN if concentration decreases
2) Slow change in the concentration of all other reactants and/or products
➔ until all concentrations are constant again</td><td>Visual clues:
1) Spike in the rate of one direction
a. Spike UP if concentration increases
b. Spike DOWN if concentration decreases
2) Slow change in the other rate
3) until both rates are equal again</td></tr>
</table>

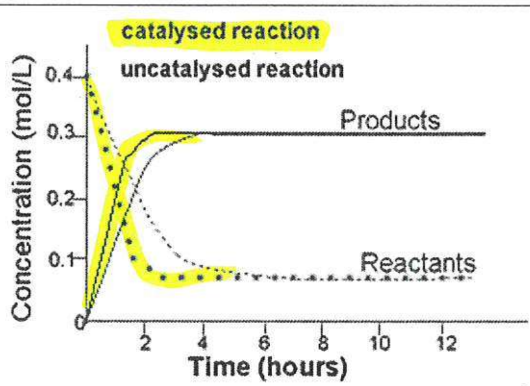
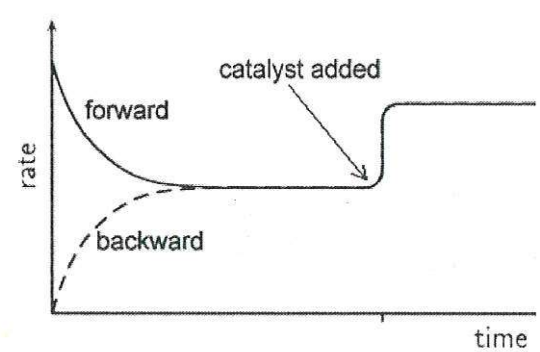
2) **Applied Stress:** Change in Temperature

Concentration vs. Time	**Rate** vs. Time
	 ★Spike up in direction of immediate shift
Visual clues: 1) Slow change in the concentration of all reactants and products ➔ until all concentrations are constant again 2) Direction of shift determines which side increases/decreases concentration	Visual clues: 1) Spike in the rate of **one** direction ~~a. Spike UP if temperature ______~~ ~~b. Spike DOWN if temperature ______~~ depends on endo vs. exo 2) ______ change in the other rate 3) until both rates are equal again

Reminder: **Nothing can ever completely undo the stress on the system!**

Shifts predicted by Le Châtelier's principle only partially counteract the stress.

3) **Applied stress:** Addition of a Catalyst

Concentration vs. Time	**Rate** vs. Time
	
Visual clues: ➔ System reaches equilibrium at the same concentrations but an earlier time	Visual clues: ➔ Rate of forward and backward reactions increases equally