Equilibrium & Le Chatelier’s Principle

1. What 2 characteristics define a system at equilibrium?
The forward and reverse reaction rates are equal & the concentrations of the reactants and products are constant.

2. What 3 factors are considered to be stresses on an equilibrium system?
Changes in Temperature, Pressure and Concentration.

3. How does a system at equilibrium respond to a stress?
It will proceed in the direction which relieves the stress.

4. What does “heat” as a product of this reaction indicate? (is it absorbed or released?)
   a. \( \text{CH}_4 + \text{O}_2 \leftrightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{heat} \) (890.3 kJ)

   Heat is released (exothermic).

4b. What does “heat” as a reactant in this reaction indicate? (is it absorbed or released?)
   a. \( \text{NaCl} (s) + \text{heat} \rightarrow \text{Na}^+ + \text{Cl}^- \)

   Heat is absorbed (endothermic).

Using Le Chatelier’s principle, predict how each of the changes would affect the equilibrium systems Ex: Shifts to right (towards products), shifts to left (towards reactants), No change occurs

<table>
<thead>
<tr>
<th>5. ( \text{N}_2(g) + 3 \text{H}_2(g) \leftrightarrow 2 \text{NH}_3(g) + 92 \text{ kJ} )</th>
<th>6. ( \text{CO} (g) + 2 \text{H}_2 (g) \leftrightarrow \text{CH}_3\text{OH} (g) + 18 \text{ kJ} )</th>
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</table>
| a. **Stress:** Adding extra \( \text{H}_2 \)  
  **Relief:** use excess \( \text{H}_2 \)  
  **How:** Shifts \( \rightarrow \) | a. **Stress:** Adding CO  
  **Relief:** Use up excess CO  
  **How:** \( \text{CO} (g) + 2 \text{H}_2 (g) \rightarrow \text{CH}_3\text{OH} (g) + 18 \text{ kJ} \) |
| b. **Stress:** Extra \( \text{NH}_3 \) (ammonia) is added  
  **Relief:** ammonia is broken down into reactants  
  **How:** \( \text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g) + 92 \text{ kJ} \) | b. **Stress:** Removing heat  
  **Relief:** Produce more heat  
  **How:** \( \text{CO} (g) + 2 \text{H}_2 (g) \rightarrow \text{CH}_3\text{OH} (g) + 18 \text{ kJ} \) |
| c. **Stress:** Adding extra \( \text{N}_2 \)  
  **Relief:** Use up excess \( \text{N}_2 \)  
  **How:** \( \text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g) + 92 \text{ kJ} \) | c. **Stress:** Removing \( \text{CH}_3\text{OH} \)  
  **Relief:** Produce more \( \text{CH}_3\text{OH} \)  
  **How:** \( \text{CO} (g) + 2 \text{H}_2 (g) \rightarrow \text{CH}_3\text{OH} (g) + 18 \text{ kJ} \) |
| d. **Stress:** Removing \( \text{H}_2 \)  
  **Relief:** Stop using/Form more \( \text{H}_2 \)  
  **How:** \( \text{N}_2(g) + 3 \text{H}_2(g) \leftrightarrow 2 \text{NH}_3(g) + 92 \text{ kJ} \) | d. **Stress:** Increasing the pressure  
  **Relief:** reduce pressure by reducing the number of moles  
  **How:** \( \text{CO} (g) + 2 \text{H}_2 (g) \rightarrow \text{CH}_3\text{OH} (g) + 18 \text{ kJ} \)  
  \( \begin{array}{c|c} \text{3 moles} & \text{1 mole} \end{array} \) |
| e. **Stress:** The pressure is increased  
  **Relief:** reduce pressure by reducing the number of moles  
  **How:** \( \text{N}_2(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g) + 92 \text{ kJ} \)  
  \( \begin{array}{c|c} \text{4 moles} & \text{2 moles} \end{array} \) | e. **Stress:** Adding Heating  
  **Relief:** Stop producing/use up excess heat  
  **How:** \( \text{CO} (g) + 2 \text{H}_2 (g) \rightarrow \text{CH}_3\text{OH} (g) + 18 \text{ kJ} \) |


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<th>f. <strong>Stress:</strong> The pressure is decreased</th>
<th>f. <strong>Stress:</strong> Decreasing the pressure</th>
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<tbody>
<tr>
<td><strong>Relief:</strong> increase pressure by increasing the number of moles</td>
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<td><strong>How:</strong> $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g}) + 92 \text{kJ}$</td>
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<td>1 mole</td>
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<th>g. <strong>Stress:</strong> Heating the system</th>
<th>g. <strong>Stress:</strong> Removing $\text{H}_2$</th>
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<tbody>
<tr>
<td><strong>Relief:</strong> Stop producing/use up excess heat</td>
<td><strong>Relief:</strong> stop using up/produce more $\text{H}_2$</td>
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<td><strong>How:</strong> $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g}) + 92 \text{kJ}$</td>
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7. $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{C}_2\text{H}_6(\text{g}) + \text{heat}$

You want to shift the reaction $\rightarrow$ (to the right) to produce more $\text{C}_2\text{H}_6$.

What would you do to the following variables to make that happen? (increase/ decrease & why?)

<table>
<thead>
<tr>
<th></th>
<th>a) Pressure:</th>
<th>c) Amount of $\text{H}_2(\text{g})$:</th>
<th>E) Temperature:</th>
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<tbody>
<tr>
<td></td>
<td>Increase</td>
<td>Increase</td>
<td>Decrease</td>
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<tr>
<th></th>
<th>b) Amount of $\text{C}_2\text{H}_4(\text{g})$:</th>
<th>d) Amount of $\text{C}_2\text{H}_6(\text{g})$:</th>
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<tr>
<td></td>
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