Name _____ Date _____ Period _____

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Equilibrium Virtual Lab

Chemistry and AP Chemistry

Open **activities.zornscience.org/equilibrium-lab/** and follow each step. Show your work with units.

Objective

Disturb the equilibrium $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ by changing **concentration**, **volume**, and **temperature**. Use Q_c and K_c to explain which way the reaction shifts.

NGSS alignment: HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

Practices and concepts: Analyzing and interpreting data; Constructing explanations; Stability and change; Cause and effect.

AP alignment: 7.3 Reaction Quotient and Equilibrium Constant; 7.9 Introduction to Le Châtelier's Principle; 7.10 Reaction Quotient and Le Châtelier's Principle. Skills 5.F (calculate an unknown quantity) and 6.F (connect experimental results to chemical concepts).

Meet the simulation

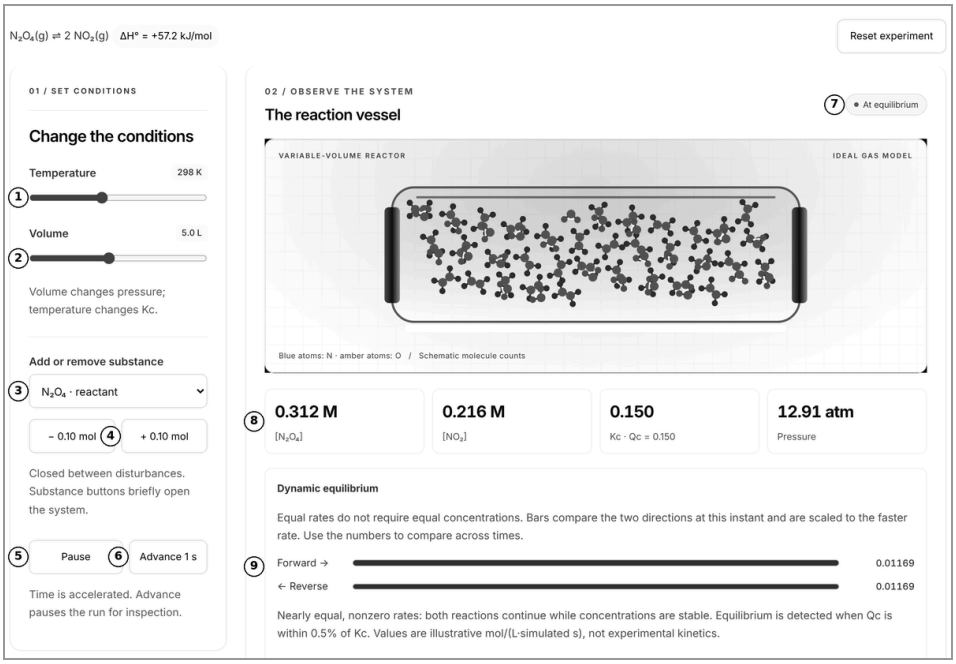


Figure 1. The Equilibrium Sandbox. The dark vessel is shown inverted for printing.

1. Temperature slider (270 to 340 K).
2. Volume slider (1.0 to 10.0 L).
3. Choose N_2O_4 or NO_2.
4. Remove or add 0.10 mol.
5. Pause and Resume.
6. Advance 1 simulated second.
7. Status: At equilibrium, Shifting right, or Shifting left.
8. Readouts: $[N_2O_4]$, $[NO_2]$, K_c and Q_c, pressure.
9. Forward and reverse rates.

The concentration vs. time graph is below the vessel. Use the arrow keys on a slider for exact values.

Pre-lab

1. Write the K_c expression for $N_2O_4(g) \rightleftharpoons 2NO_2(g)$. If $Q_c < K_c$, which way does the reaction shift?

2. The forward reaction is endothermic ($\Delta H° = +57.2$ kJ/mol). Predict the shift when the system is (a) heated and (b) compressed to a smaller volume.

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Procedure (use for Parts A, B and C)

1. Select **Reset experiment**, then **Pause** right away. Record the starting values (row 0).
2. Make the one change listed for that row while paused. Record the values **right after** the change (the "immediate" row) and the status.
3. Select **Resume**. Wait until the status says **At equilibrium** (up to about 50 s for cooling). Record the new equilibrium values.

Row	Change	When	$[N_2O_4]$ (M)	$[NO_2]$ (M)	K_c	Q_c	Status
0	None (298 K, 5.0 L)	start					
A	Add 0.30 mol NO_2 (choose NO_2, select **+ 0.10 mol** 3 times)	immediate					
		new eq.					
B	Compress: Volume to **2.0 L**	immediate					
		new eq.					
C1	Heat: Temperature to **340 K**	immediate					
		new eq.					
C2	Cool: Temperature to **280 K**	immediate					
		new eq.					

Reset experiment before each part so every part starts from row 0.

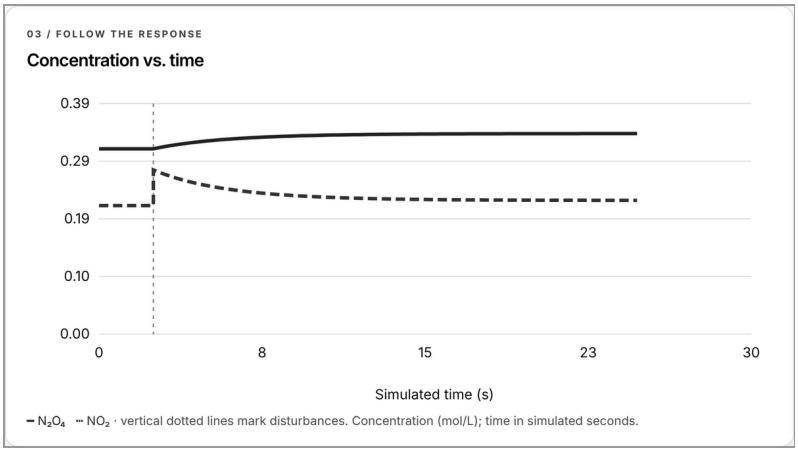


Figure 2. Part A on the graph: solid line N_2O_4, dashed line NO_2. The dotted vertical line marks the change.

On the graph, a sudden jump is the change you made. The smooth curve after it is the reaction shifting. When both lines are flat, the system is at equilibrium again.

3. Part A: Show how to calculate the immediate Q_c from your concentrations. Compare it with K_c and state the direction of the shift.

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4. Part A: Show that the new equilibrium concentrations give $K_c = 0.150$ again. Is the new $[NO_2]$ higher or lower than at the start (0.216 M)? Why?

5. Part B: Compressing from 5.0 L to 2.0 L made both concentrations jump by the same factor. What is that factor and why? Then explain the shift using the number of gas molecules and the pressure readout (record it right after compressing and at the new equilibrium).

6. Part C: Which change altered the value of K_c? Explain why heating shifts this reaction right but cooling shifts it left.

7. NO_2 is a brown gas and N_2O_4 is colorless. Use Part C to predict whether a sealed tube of the mixture looks darker in hot water or in ice water.

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Analysis

8. Look at the rate panel at the start (row 0) and right after the change in Part A. At equilibrium, are the reactions stopped? What happens to the two rates right after you add NO_2?

9. (AP extension) Use your row 0 data to calculate K_p at 298 K. Use $K_p = K_c(RT)^{\Delta n}$ with R = 0.08206 L·atm/(mol·K).

10. (AP extension) In Part B the vessel was compressed. Use your new equilibrium data to show that K_c did not change even though the composition did. What fraction of the gas molecules are NO_2 before and after?

11. The simulation is an ideal model. Give two ways a real N_2O_4/NO_2 experiment would be different.

Conclusion

12. Write a claim that answers the objective: how does the system respond to a change in concentration, volume, and temperature? Support it with evidence (Q_c and K_c values) and explain your reasoning.

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