Le Châtelier's Principle and Perturbations

Student Worksheet | `g10_u04_w15`

I can: use a stated equilibrium model and evidence card to predict a bounded response to a concentration, volume, temperature, or catalyst perturbation.
Classroom model: For $A(aq) + B(aq) \rightleftharpoons C(aq)$ at one temperature, $K_c = 2.00\ \mathrm{M}^{-1}$ and $Q_c = [C]/([A][B])$. A perturbation can make Q_c differ from K_c, after which the system can undergo net change toward a new equilibrium. Direction predictions do not specify speed, mechanism, or exact final concentrations. For gas/temperature cards, use only the stated model information. All prompts are data/simulation analyses; no chemical handling is requested.

Card	$[A]$ (M)	$[B]$ (M)	$[C]$ (M)	What just happened?
E	0.200	0.300	0.120	equilibrium state
P	0.200	0.300	0.180	C added instantly
R	0.200	0.300	0.0600	C removed instantly
S	0.400	0.300	0.120	A added instantly

Other evidence cards: (1) Gas model $2G(g) \rightleftharpoons H(g)$: decreasing volume raises pressure; use particle-count comparison only. (2) Temperature model $U(aq) + \text{heat} \rightleftharpoons V(aq)$: K_c changes from 2.00 at 298 K to 5.00 at 318 K. (3) Catalyst card: at fixed temperature and amounts, a catalyst is introduced; a concentration-time graph shows both directions reach a flat region sooner.

1. In a perturbation model, what is meant by a "new equilibrium"?

2. Calculate Q_c for card E. What does its comparison with K_c show?

3. Calculate Q_c for card P immediately after C is added. Predict net direction.

4. For card P, name one concentration that initially tends to increase and one that initially tends to decrease.

5. Calculate Q_c for card R immediately after C is removed. Predict net direction.

6. Calculate Q_c for card S immediately after A is added. Predict net direction.

7. Explain why "the system cancels the change" is an inaccurate slogan for card P. Replace it with a more precise statement.

8. Compare cards P and R. What evidence gives opposite direction predictions?

9. For $2G(g) \rightleftharpoons H(g)$, which side has fewer gas particles per reaction event? Under the stated model, what direction is favored by decreasing volume?

10. Why would a volume/pressure slogan be unsafe to apply to a system with equal numbers of gas particles on both sides?

11. The forward direction of $U + \text{heat} \rightleftharpoons V$ is endothermic. What change in K_c is reported when temperature rises from 298 K to 318 K? What net direction is consistent with that evidence for an old equilibrium mixture?

12. Why should a temperature change not be treated as merely "adding a reactant concentration"?

13. A student says, "The catalyst pushes equilibrium toward products." Correct the claim using the catalyst card.

14. According to the catalyst card, what can change? What should remain unchanged at fixed temperature and conditions?

15. A catalyst is added while concentrations are not at equilibrium. What can you predict cautiously about its effect on the approach, and what can you not infer from the card alone?

16. A card reports $Q_c = 0.80$ and $K_c = 2.00$ after a concentration perturbation at the stated temperature. Predict net direction and identify the needed condition check.

17. A card reports $Q_c = 2.00$ and $K_c = 2.00$ after waiting. What does that support? What does it not reveal about how fast the adjustment was?

18. For $F(aq) + G(s) \rightleftharpoons H(aq)$, why does adding more pure $G(s)$ not appear as a new concentration term in the classroom expression? State one caveat.

19. A graph shows $[C]$ falls immediately after removal, then rises to a new plateau. What evidence would distinguish a new equilibrium plateau from a momentary flat measurement?

20. Write a cautious CER statement for one evidence card. Include the perturbation, a Q_c/K_c or particle/temperature comparison, predicted net direction, and one limitation.