Le Chatelier's principle

Chemistry · Class 11 Chemistry: Equilibrium (Le Chatelier's principle, Kp and Kc)

The trap

✗ Most students think

~~A catalyst, or a hotter "cleaner" burn, will cut the NO coming out of an engine.~~

✓ Actually

$N_2 + O_2 \rightleftharpoons 2NO$ is **endothermic**, so more heat means **more NO**. A catalyst speeds both directions equally: equilibrium comes sooner, but its **position and K do not change**.

The concept in 5 lines

1. At **equilibrium** the forward and backward reactions run at equal speed; **$K_c = [NO]^2 / ([N_2][O_2])$**.
2. **Le Chatelier:** a disturbed equilibrium shifts in the direction that reduces the change.
3. $N_2 + O_2 \rightleftharpoons 2NO$ has **$\Delta H = +180$ kJ mol^{-1}**: higher temperature → shifts right, more NO, **K increases**. Only temperature changes K.
4. A **catalyst** lowers the activation energy of both directions equally: equilibrium is reached sooner, position and K unchanged.
5. **$\Delta n(gas) = 2 - 2 = 0$**, so pressure has no effect and Kp = Kc; adding N_2 or O_2 (or removing NO) shifts right.

Remember

$$N_2 + O_2 + heat \rightleftharpoons 2NO$$

Why it matters

Equilibrium gave NEET **1, 2, 2, 3 and 3 questions** from 2021 to 2025; "what shifts K and what does not" is asked almost every year.

Previous-year question, solved

NEET 2025

Higher yield of NO in $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ can be obtained at [$\Delta H = +180.7$ kJ mol^{-1}]: A. higher temperature B. lower temperature C. higher concentration of N_2 D. higher concentration of O_2. Choose the correct answer.

Answer: A, C and D only

1. **A ✓** ΔH is positive (endothermic): adding heat shifts the equilibrium right and K increases.
2. **B ✗** Lower temperature does the opposite and shifts it left.
3. **C ✓ D ✓** Adding a reactant (N_2 or O_2) makes the system use it up by shifting right.
4. Pressure is not offered: with Δn(gas) = 0 it would not help.

Wording lightly paraphrased; the answer choices were combinations of A to D.

Practice: try each one before you check the answers

Q1 NEET pattern A catalyst is added to $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ at equilibrium at constant temperature. What happens to (a) the amount of NO and (b) the value of K?

Q2 JEE Main pattern For which reaction does increasing the pressure (by reducing the volume) have **no** effect on the equilibrium? (1) $N_2 + 3H_2 \rightleftharpoons 2NH_3$ (2) $PCl_5 \rightleftharpoons PCl_3 + Cl_2$ (3) $H_2 + I_2 \rightleftharpoons 2HI$ (4) $2SO_2 + O_2 \rightleftharpoons 2SO_3$

Q3 Class 11 The Haber process, $N_2 + 3H_2 \rightleftharpoons 2NH_3$, is **exothermic** ($\Delta H \approx -92$ kJ mol^{-1}). How does raising the temperature affect the yield of ammonia and the value of K? Compare it with the NO reaction.

Q4 KCET pattern In $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$ at equilibrium, some NO is removed from the vessel, keeping the temperature constant. In which direction does the equilibrium shift, and does K change?

Q5 A / B Pressure doubled: does NO's share of the gas mixture rise or stay the same? (A) Rises (B) Stays the same

Answers

1. (a) **No change** in the amount of NO. (b) **K stays the same.** A catalyst lowers the activation energy of the forward and backward reactions by the same amount, so both speed up equally. It only helps the system **reach** equilibrium faster.
2. **(3) $H_2 + I_2 \rightleftharpoons 2HI$.** Gas moles: 2 on the left, 2 on the right, so $\Delta n(gas) = 0$, exactly like $N_2 + O_2 \rightleftharpoons 2NO$. In (1) and (4) higher pressure shifts right (fewer moles on the right); in (2) it shifts left.
3. For an exothermic reaction, heat is a **product**. Raising the temperature shifts the equilibrium **left**: less NH_3, and **K decreases**. The NO reaction is endothermic, so for it the effect is the opposite: higher temperature gives more NO and a larger K. (Industry still runs the Haber process at about 700 K with a catalyst, because at low temperature the reaction is too slow.)
4. It shifts **forward (right)** to replace some of the NO that was removed. **K does not change**, because the temperature is constant; only the concentrations readjust until $[NO]^2 / ([N_2][O_2])$ equals K again.
5. **It stays the same.** Count the gas moles in $N_2 + O_2 \rightleftharpoons 2NO$: 2 on the left, 2 on the right, so **$\Delta n(gas) = 0$**. Le Chatelier says higher pressure favours the side with fewer gas moles, but here neither side has fewer, so the equilibrium does not shift. Doubling the pressure doubles every concentration, yet $[NO]^2 / ([N_2][O_2])$ stays equal to K, and NO's share of the mixture is unchanged. Only **temperature** (or adding N_2 or O_2) would change how much NO forms.

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