

Equilibrium constants and shifts

AP Chemistry · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems cover the core of AP Chemistry Unit 7: writing K , comparing Q with K , solving ICE tables and predicting shifts with Le Chatelier's principle. They run from expressions and short predictions to quadratic solutions, graphs and multi-step stress problems. Show your ICE tables and always state units where K has them.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 7

Problem 1 Writing K expressions (easy)

Write the equilibrium constant expression for each.

1. $\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$, K_c
2. $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$, K_c
3. $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$, K_c

Problem 2 What the size of K says (easy)

Three reactions have $K = 3.0 \times 10^{12}$, 1.0 and 2.0×10^{-20} at the same temperature.

1. Identify which one mostly goes to products.
2. Identify which one has comparable amounts of reactants and products.
3. Identify which one hardly reacts.

Problem 3 Which way does it go? (easy)

For $2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{SO}_3(\text{g})$, $K_c = 25$. A mixture has $[\text{SO}_2] = 0.10 \text{ M}$, $[\text{O}_2] = 0.10 \text{ M}$ and $[\text{SO}_3] = 0.10 \text{ M}$.

1. Calculate Q .
2. Predict the direction of change.

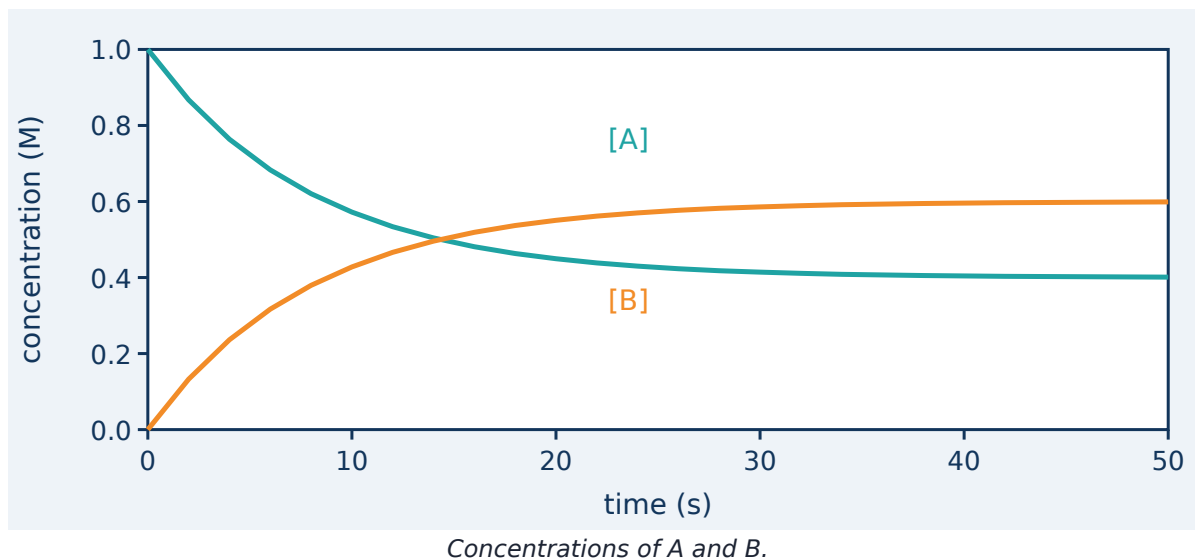
Problem 4 Le Chatelier directions (easy)

$\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g})$, $\Delta H < 0$. State the direction of shift (right, left or none) for each.

1. Add N_2 .
2. Remove NH_3 .
3. Compress the mixture.
4. Raise the temperature.
5. Add a catalyst.

Problem 5 Reading an equilibrium graph (easy)

The graph shows $A \rightleftharpoons B$.



1. State the time at which equilibrium is reached.
2. Read the equilibrium concentrations.
3. Calculate K .
4. State whether the reactions have stopped.

Problem 6 Changing the equation (easy)

For $A \rightleftharpoons B$, $K = 5.0$.

1. Calculate K for $B \rightleftharpoons A$.
2. Calculate K for $2 A \rightleftharpoons 2 B$.
3. Calculate K for $\frac{1}{2}A \rightleftharpoons \frac{1}{2}B$.

Problem 7 K from measurements (easy)

At equilibrium $H_2(g) + I_2(g) \rightleftharpoons 2 HI(g)$ has $[H_2] = 0.050 M$, $[I_2] = 0.050 M$ and $[HI] = 0.40 M$.

1. Write the expression for K_c .
2. Calculate K_c .

Problem 8 K_p from K_c (medium)

$N_2O_4(g) \rightleftharpoons 2 NO_2(g)$ has $K_c = 0.20$ at $350 K$ ($R = 0.08206 L atm mol^{-1} K^{-1}$).

1. State Δn .
2. Calculate K_p .
3. Calculate K_p for $2 NO_2 \rightleftharpoons N_2O_4$.

Problem 9 A perfect-square ICE table (medium)

$H_2(g) + I_2(g) \rightleftharpoons 2 HI(g)$, $K_c = 64$. Aarav in Pune starts with $0.50 M H_2$ and $0.50 M I_2$.

1. Set up an ICE table.

- Solve for x .
- State all equilibrium concentrations.

Problem 10 Finding K from an ICE table (medium)

$\text{CO(g)} + 2 \text{H}_2\text{(g)} \rightleftharpoons \text{CH}_3\text{OH(g)}$ starts with 1.00 M CO and 2.00 M H_2 . At equilibrium $[\text{CH}_3\text{OH}] = 0.30 \text{ M}$.

- Calculate $[\text{CO}]$ and $[\text{H}_2]$ at equilibrium.
- Calculate K_c with units.

Problem 11 Starting from a mixture (medium)

$\text{N}_2\text{O}_4\text{(g)} \rightleftharpoons 2 \text{NO}_2\text{(g)}$, $K_c = 0.20$. A flask holds 0.10 M N_2O_4 and 0.30 M NO_2 .

- Calculate Q and predict the direction.
- Calculate the equilibrium concentrations.

Problem 12 Temperature and colour (medium)

$2 \text{NO}_2\text{(g)}$ (brown) $\rightleftharpoons \text{N}_2\text{O}_4\text{(g)}$ (colourless), $\Delta H = -57 \text{ kJ}$. Emma in Leeds puts a sealed tube of the mixture in hot water.

- Predict the colour change.
- State what happens to K .
- Explain using Q and K .

Problem 13 Compression and Q (medium)

$2 \text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2 \text{SO}_3\text{(g)}$ is at equilibrium with $[\text{SO}_2] = 0.20 \text{ M}$, $[\text{O}_2] = 0.10 \text{ M}$ and $[\text{SO}_3] = 0.40 \text{ M}$.

- Calculate K_c .
- The volume is halved. Calculate the new Q .
- Predict the shift and compare with the number of moles of gas.

Problem 14 A heterogeneous equilibrium (medium)

$\text{C(s)} + \text{CO}_2\text{(g)} \rightleftharpoons 2 \text{CO(g)}$. At equilibrium $P(\text{CO}_2) = 0.20 \text{ atm}$ and $P(\text{CO}) = 0.80 \text{ atm}$.

- Write K_p and calculate it.
- State the effect of adding more solid carbon.
- $P(\text{CO}_2)$ is raised to 0.50 atm with $P(\text{CO}) = 0.80 \text{ atm}$; calculate Q and predict the shift.

Problem 15 Adding equilibria (medium)

(1) $\text{N}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2 \text{NO(g)}$, $K_1 = 4.0 \times 10^{-31}$. (2) $2 \text{NO(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2 \text{NO}_2\text{(g)}$, $K_2 = 6.0 \times 10^{12}$.

- Write the sum of the two reactions.
- Calculate its equilibrium constant.

Problem 16 A quadratic ICE table (hard)

$\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$, $K_c = 0.0500$. Wanjiru in Nairobi starts with 0.200 M PCl_5 only.

1. Set up the equation in x .
2. Solve for x .
3. Calculate the equilibrium concentrations and the percentage of PCl_5 that dissociates.

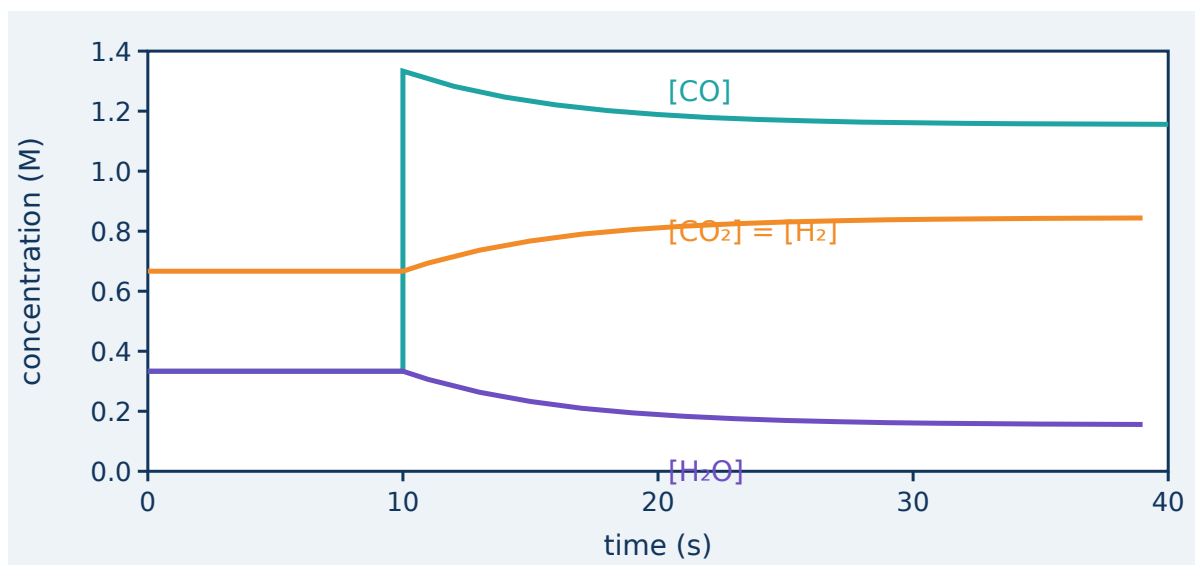
Problem 17 The small- x approximation (hard)

$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{NO}(\text{g})$, $K_c = 1.0 \times 10^{-4}$. Start with 0.80 M N_2 and 0.20 M O_2 .

1. Write the ICE equation.
2. Use the approximation to solve for $[\text{NO}]$.
3. Check that the approximation is valid.

Problem 18 A stress and a new equilibrium (hard)

$\text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}_2(\text{g}) + \text{H}_2(\text{g})$, $K_c = 4.0$. Start with 1.0 M CO and 1.0 M H_2O . At equilibrium $[\text{CO}_2] = [\text{H}_2] = 0.667 \text{ M}$ and $[\text{CO}] = [\text{H}_2\text{O}] = 0.333 \text{ M}$. A further 1.0 M CO is then added.

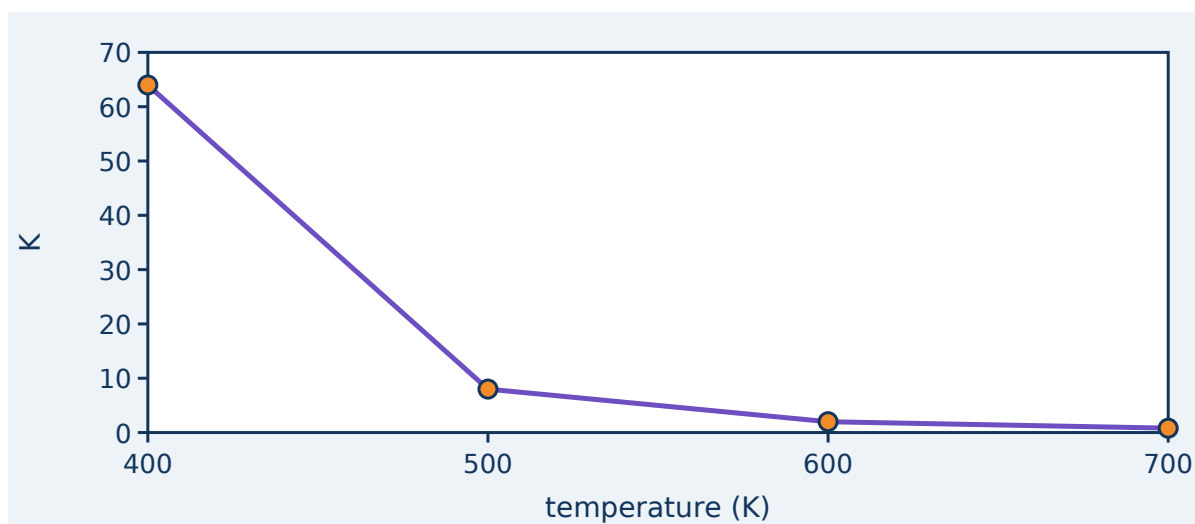


A second portion of CO is added at 10 s.

1. Calculate Q just after the addition.
2. Predict the shift.
3. Calculate the new equilibrium concentrations.

Problem 19 Deducing ΔH from K (hard)

The graph shows K for a gas-phase reaction.



K for a gas-phase reaction at four temperatures.

1. State the sign of ΔH and justify it.
2. Predict how the yield changes if the temperature is raised.
3. The reaction has 3 mol of gas on the left and 2 mol on the right. Predict the effect of raising the pressure.
4. Explain why a catalyst is still used in industry.

Problem 20 Cobalt chloride equilibrium (hard)

$[\text{Co}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ (pink) + 4 $\text{Cl}^{-}(\text{aq}) \rightleftharpoons [\text{CoCl}_4]^{2-}(\text{aq})$ (blue) + 6 $\text{H}_2\text{O}(\text{l})$, $\Delta H > 0$.

1. Write K_c .
2. Predict the colour change when you add concentrated HCl, add water, and heat the solution.
3. For $[\text{CoCl}_4]^{2-} = 0.0020 \text{ M}$, $[\text{Co}(\text{H}_2\text{O})_6]^{2+} = 0.010 \text{ M}$ and $[\text{Cl}^{-}] = 0.50 \text{ M}$, $K_c = 5.0 \text{ M}^{-3}$. Calculate Q and predict the direction.