

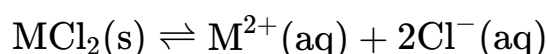
Saturated MCl_2 Solution Equilibrium Analysis

<https://gemini.google.com/app/d0374ec371ce21ec>

Response: Here is the step-by-step evaluation of each option to determine the correct statement regarding a **saturated aqueous solution of MCl_2** :

Analysis of the Equilibrium

When $\text{MCl}_2(\text{s})$ dissolves, it dissociates according to:



The solubility product constant expression at a given temperature is:

$$K_{sp} = [\text{M}^{2+}][\text{Cl}^{-}]^2 = 1.0 \times 10^{-8} \text{ mol}^3\text{dm}^{-9}$$

Because K_{sp} is a constant at constant temperature, the ion product $[\text{M}^{2+}][\text{Cl}^{-}]^2$ in a saturated solution remains fixed.

Evaluating the Options

- **(1) Evaporation of water from the solution increases M^{2+} and chloride ion concentrations of the solution.**
 - **Incorrect:** Evaporating water causes excess MCl_2 to precipitate out to maintain the equilibrium concentration. The solution remains saturated, so the concentrations of M^{2+} and Cl^{-} remain constant.
- **(2) Chloride ion concentration of the solution can be increased by adding $\text{NaCl}(\text{s})$.**
 - **Correct:** Adding a highly soluble salt like $\text{NaCl}(\text{s})$ introduces additional Cl^{-} ions into the solution (the common ion effect). As NaCl dissolves completely, $[\text{Cl}^{-}]$ increases. (To satisfy K_{sp} , some MCl_2 will precipitate, thereby decreasing $[\text{M}^{2+}]$ while net $[\text{Cl}^{-}]$ increases above its initial value).
- **(3) The solution cannot be acidified by adding HCl .**
 - **Incorrect:** Adding HCl introduces H^{+} ions, which acidifies the solution.
- **(4) Chloride ion concentration of the solution cannot be increased above $1.0 \times 10^{-4} \text{ mol dm}^{-3}$.**
 - **Incorrect:** Let s be the molar solubility of MCl_2 :

$$K_{sp} = (s)(2s)^2 = 4s^3 = 1.0 \times 10^{-8}$$

$$s^3 = 2.5 \times 10^{-9} \implies s \approx 1.36 \times 10^{-3} \text{ mol dm}^{-3}$$

Therefore, the initial concentration of chloride ions is:

$$[\text{Cl}^-] = 2s \approx 2.7 \times 10^{-3} \text{ mol dm}^{-3}$$

This value is already significantly higher than $1.0 \times 10^{-4} \text{ mol dm}^{-3}$, and as noted in option (2), it can be increased further by adding external sources of Cl^- .

- **(5) Chloride ion concentration of the solution can be lowered by adding distilled water and maintaining the saturated condition.**
 - **Incorrect:** As long as the solution remains saturated (with solid MCl_2 present), adding distilled water will simply dissolve more solid until equilibrium is re-established, keeping $[\text{Cl}^-]$ constant.

Conclusion

The correct statement is **(2)**.
