

Le Chatelier's Principle – NO₂/N₂O₄ tubes

Description: Le Chatelier's principle is demonstrated by invoking a color change inside a sealed tube containing NO₂ (brown) and N₂O₄ (colorless) gases at equilibrium. The equilibrium shifts when the temperature changes inside the vessel.

Materials:

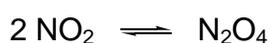
NO ₂ tubes (Dabney 125)	4 L beakers
Ice water	Ring stand
Hot water	

Procedure:

For large lecture halls, project demonstration using a document camera.

1. Submerge one tube in the hot water bath (not boiling) and one tube in an ice water bath. The tube in the hot water bath will darken while the tube in the ice bath will lose color. The original color of the tubes returns once the tubes are removed from the water bath and reach room temperature.

Discussion: Nitrogen dioxide is a reddish brown gas while N₂O₄ is colorless. According to the thermodynamic data for this system, the dimerization of NO₂ (shown below) is an exothermic reaction.



As temperature is increased, the above reaction equilibrium shifts to the left, generating a higher concentration of NO₂, resulting in the darkening of the reddish brown color inside the tube. Conversely, cooling the reaction shifts the equilibrium to the right, producing more N₂O₄ which is colorless.

	ΔH_f° (kJ/mol)	ΔG_f° (kJ/mol)	ΔS_f° (J/mol•K)
NO ₂	33.18	51.31	240.06
N ₂ O ₄	9.16	97.89	304.29

Temp. (°C)	ΔG (kJ/mol N ₂ O ₄)	K _c
23	-5.13	8.03
70	3.14	0.334
100	8.41	0.0665

Data obtained from "The NBS Tables of Chemical Thermodynamic Properties," J. Phys. Chem. Ref. Data 11, Supp. 2, 1982.

Safety: Handle the tubes with extreme care. NO₂ is extremely toxic and lethal even at concentrations as low as 200 ppm. Inhalation may result in delayed but severe pulmonary irritation. Should a tube break during the demonstration, immediately evacuate the classroom and contact safety personnel.

References:

Shakhashiri, B. Z. In *Chemical Demonstrations: A Handbook for Teachers of Chemistry*; The University of Wisconsin Press: 1985; Vol. 2, p 180-183.

Leenson, I. A. *J. Chem. Educ.* **2000**, *77*, 1652.

Hennis, A. D.; Highberger, C. S.; Schreiner, S. *J. Chem. Educ.* **1997**, *74*, 1340.

Yu, Q.; Gao, H. *J. Chem. Educ.* **1997**, *74*, 233.

Video:

http://www.youtube.com/watch?v=DA_wiqieC5s

<http://www.youtube.com/watch?v=tIGrBcgANSY>