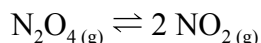


<u>3.1</u>	<u>3.2</u>	<u>3.3</u>	<u>3.4</u>	<u>3.5</u>	<u>3.6</u>	<u>3.7</u>	<u>Total</u>
2	1	4	1	6	6	24	44

### Dimerization Thermodynamics (CODS-CT Team Round Pt. 2 #1)

$\text{NO}_2$  causes the brown color of smog. At 300 K, the following reaction can occur with equilibrium constant  $K_p = 0.10$ :



**3.1** Draw the Lewis Structures of  $\text{NO}_2$  and  $\text{N}_2\text{O}_4$

**3.2** Smog is browner on hot days than on cold days. Is the formation of  $\text{N}_2\text{O}_4$  from  $\text{NO}_2$  exothermic or endothermic?

**3.3** What are the Constant Pressure ( $C_{p,m}$ ) and Constant Volume ( $C_{v,m}$ ) Molar Heat Capacities of  $\text{NO}_2$  and  $\text{N}_2\text{O}_4$  respectively according to the equipartition theorem?

The values of  $S_m^\circ(300 \text{ K})$  for  $\text{NO}_2$  and  $\text{N}_2\text{O}_4$  are  $240.1 \text{ J}/(\text{mol K})$ ,  $304.3 \text{ J}/(\text{mol K})$  at 300 K.

**3.4** What is the change in entropy for the dimerization of  $\text{NO}_2$  at 300 K?

**3.5** What is the change in entropy for the dimerization of  $\text{NO}_2$  at constant pressure at 400 K?

Hint: Recall that  $dS = dq/T$  for some infinitesimal heat transfer at temperature T. You may need to use the heat capacities from **3.3**

0.1 mol of  $\text{N}_2\text{O}_4(\text{g})$  is added to a container and allowed to equilibrate at 300 K at which point it has volume  $V_i = 1 \text{ L}$ . The sample of gas is allowed to expand reversibly and isothermally (the temperature is always 300 K) to a final volume of  $V_f = 5 \text{ L}$ . (You may assume that the expansion is carried out such that the sample is always at equilibrium)

**3.6** Ignoring the formation of  $\text{NO}_2$ , how much work is done by the gas reversibly expanding from 1 L to 5 L?

Hint:

The work done by a single gas expanding in a piston is  $dW = -PdV$  for an infinitesimal increase in volume. At each point in this reversible expansion,  $P = nRT/V$ , so  $dW = -nRT/V dV$ . From here the amount of work done can be computed via integration.

**3.7** How much work is actually done by the gas in Joules, taking into account formation of  $\text{NO}_2$ ?

Hint:

You will need to modify the approach from **3.6** to solve this problem and potentially make some approximations.