

**Exercise A** The reaction  $A \rightarrow B$  with  $\Delta G_r^\circ = -2000$  J/mole at 298 K.

- Compute  $Q$  and  $\Delta G_r$  when  $P_A = 0.1$  bar and  $P_B = 1.5$  bar.
- Is the reaction spontaneous when  $P_A = 0.1$  bar and  $P_B = 1.5$  bar?
- If the reaction starts with  $P_A = 1.00$  bar and  $P_B = 0$ , and  $P_{\text{Total}}$  is constant, what is the value of  $P_B$  at equilibrium?

**Problem 1** For the system in Exercise A starting at  $P_A = 1.00$  bar,  $n_A = 1.00$  moles and  $P_B = 0$ , sketch a quantitative plot of  $G$  versus  $\xi$ . Assume  $G_{A,\text{molar}} = +3000$  J/mole

**Problem 2** The reaction  $C \rightarrow D$  with  $\Delta G_f^\circ(C) = +5000$  J/mole and  $\Delta G_r^\circ = +3000$  J/mole.

- Compute  $\Delta G_f^\circ(D)$
- At  $P_C = P_D = 1$  bar, does the reaction need to shift to reactants or to products to reach equilibrium?
- At  $P_C = 25$  bar and  $P_D = 15$  bar, does the reaction need to shift to reactants or products to reach equilibrium?
- $\Delta G_r = -2447$  J/mole in a system where  $P_C + P_D$  always equals 1.000 bar. What are the values of  $P_C$  and  $P_D$ ?

**Exercise B** For the reaction  $2 \text{NH}_3 \rightarrow 2 \text{N}_2 + 3 \text{H}_2$ ,  $K_p = 1.6 \times 10^{-4}$  at 673 K.

- Compute  $\Delta G_r^\circ$  at 673 K.
- Compute  $Q$  and  $\Delta G_r$  if the pressure of each compound is 1.00 bar
- Compute  $Q$  and  $\Delta G_r$  if the pressure of each compound is 0.01 bar
- Compute  $Q$  and  $\Delta G_r$  if the pressure of each compound is 1 Torr
- Is the reaction spontaneous under either condition (ii) or (iii)?

**Exercise C** For the reaction  $A \rightarrow B + 2C$ ,  $K_p = 5.0 \times 10^5$  at 298 K. The reaction starts with  $P(A) = 3.0$  bar and  $P(B)=P(C) = 0$  bar.

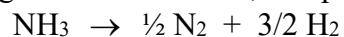
- compute the pressure of all three gases at equilibrium if the system is at constant volume
- compute the pressure of all three gases at equilibrium if the system is at constant pressure at an initial volume of  $0.200 \text{ m}^3$ .

**Problem 3** From the data given in Exercise B, for the reaction starting with  $P(\text{NH}_3) = 2.0$  bar and  $P(\text{N}_2)=P(\text{H}_2) = 0$  bar (at 673 K):

- compute the pressure of all three gases at equilibrium if the system is a constant volume
- compute the pressure of all three gases at equilibrium if the system is a constant pressure at an initial volume of  $0.015 \text{ m}^3$ .

**Problem 4**

From the data given in Exercise B, compute the value of  $K_p$  and  $\Delta G_r^\circ$  for the reaction:



**Exercise D.** The dissociation of  $\text{I}_2(\text{g})$  into atomic iodine has been studied at various temperatures. Given the data below, find  $\Delta H^\circ$  and  $\Delta S^\circ$  for the dissociation of  $\text{I}_2$ .

T(K)	K
872	$1.81 \times 10^{-4}$
973	$1.80 \times 10^{-3}$

**Problem 5.** From the data in Exercise E, estimate K at 1000 K.

**Exercise E** Consider the reaction  $\text{A}(\text{g}) \rightarrow 2\text{B}(\text{g}) + \text{C}(\text{s})$ , for which  $\Delta H_r^\circ = +50 \text{ kJ/mole}$ . If the reaction starts at equilibrium, which way will the reaction shift (if it shifts at all) if:

- The temperature is increased
- The volume of the reaction container is doubled.
- some B is selectively removed
- a little C is selectively removed while maintaining the total volume of gases constant

**Problem 6** Consider the gas-phase reaction  $\text{Cl} + \text{O}_2 \rightarrow \text{ClOO}$ , for which  $\Delta H_r^\circ < 0$ . If the reaction starts at equilibrium, which way will the reaction shift (if it shifts at all) if:

- The temperature is increased
- The volume of the reaction container is doubled.
- Cl is selectively removed.