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Chemical Equilibrium: exercises

1. The equilibrium constant for this reaction (at 100 °C) is Keq = 0.772:

$$H_2\ (g) + CO_2\ (g) \rightleftarrows H_2O\ (g) + CO\ (g)$$

Determine:

a) the concentrations at equilibrium, if the volume of the container is 10 L and the initial composition is 2 moles of H_2 and 2 moles of CO_2.

b) the new concentrations at equilibrium if 0.5 mol of H_2 are added after reaching the first equilibrium

2. The equilibrium constant for this reaction (at 425 °C) is Keq = 54.8:

$$H_2\ (g) + I_2\ (g) \rightleftarrows 2\ HI\ (g)$$

Determine:

a) the concentrations at equilibrium if 0.6 moles of HI are heated in a 500 mL-flask.

b) the new concentrations at equilibrium if 0.1 mol of H_2 are added after reaching the first equilibrium

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3. A 0.5 L-flask, at 725 °C, is charged with 0.4 moles of ammonia. When equilibrium is reached 0.1 mol of ammonia remain in the flask. Determine the equilibrium constant for this reaction (in terms of concentration)

$$3\ H_2\ (g) + N_2\ (g) \rightleftarrows 2\ NH_3\ (g)$$

4. At 150 °C, 69% of dinitrogen tetraoxide is dissociated when pressure is 4 atm.

$$N_2O_4\ (g) \rightleftarrows 2\ NO_2\ (g)$$

Determine:
a) Kp
b) the pressure for which equilibrium is reached when the percent dissociation is 80 %

5. The equilibrium constant for this reaction (at 986 °C) is Keq = 0.63:

$$H_2O\ (g) + CO\ (g) \rightleftarrows H_2\ (g) + CO_2\ (g)$$

A flask is charged with 1 mol of water vapour and 3 moles of CO and equilibrium is reached at 986 °C and 2 atm.

Determine:
a) the number of moles of hydrogen at equilibrium
b) the partial pressure of all components at equilibrium

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6. A 10 L-container is charged with 0.61 moles of CO_2 and 0.39 moles of H_2 and the mixture is heated to 1250 °C. When the equilibrium is reached 0.35 moles of CO_2 are found inside. Determine:

$$H_2\ (g) + CO_2\ (g) \rightleftarrows H_2O\ (g) + CO\ (g)$$

a) the composition of the other gases
b) the values of Kc and Kp at that temperature

7. In a 10 L-container the composition of the mixture at equilibrium (at 80 °C) is: 0.3 mol PCl_5, 0.7 mol PCl_3, and 0.7 mol Cl_2. Determine:

$$PCl_5\ (g) \rightleftarrows PCl_3\ (g) + Cl_2\ (g)$$

a) the equilibrium constants Kc and Kp
b) if 0.3 mol of chlorine gas is added after equilibrium has been reached, the number of moles of each component when equilibrium is reached again.

8. At 185 °C and 1 atm antimony pentachloride ($SbCl_5$) dissociates partially. Its percent dissociation is 30% and the products of this dissociation are antimony trichloride ($SbCl_3$) and chlorine. Determine:
a) the dissociation equation for 1 mole of antimony pentachloride and the equilibrium constants at that temperature
b) the pressure needed to increase the percent dissociation to 60%

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9. Determine what happens in these reactions when equilibrium is disturbed as follows

$$N_2\ (g) + 3\ H_2\ (g) \rightleftarrows 2\ NH_3\ (g) \qquad \Delta H < 0$$

$$C\ (s) + H_2O\ (g) \rightleftarrows CO\ (g) + H_2\ (g) \qquad \Delta H > 0$$

a) increase in pressure b) increase in temperature
c) increase in the amount of hydrogen d) addition of a catalyst

10. A 10 L-container is charged with 2 moles of H_2 and 2 moles of CO_2 at 100 °C. The equilibrium constant in terms of concentration is 0.772. Determine:

$$H_2\ (g) + CO_2\ (g) \rightleftarrows H_2O\ (g) + CO\ (g)$$

a) the concentrations at equilibrium of all components
b) Kp and the total pressure at equilibrium

11. Determine what happens in this reactions when equilibrium is disturbed as follows

$$4\ NH_3\ (g) + 3\ O_2\ (g) \rightleftarrows 2\ N_2\ (g) + 6\ H_2O\ (g) \qquad \Delta H < 0$$

a) decrease in pressure b) increase in temperature
c) elimination of water d) addition of a catalyst

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12. A 100 L-container is charged with 2 moles of H_2 and 4 moles of I_2 and the mixture is heated to 400 °C. At that temperature the equilibrium constant is Kc=55. Determine:

$$H_2\ (g) + I_2\ (g) \rightleftarrows 2\ HI\ (g)$$

a) the number of moles of all components at equilibrium
b) if the container is opened and the external pressure is 1 atm, the direction of flow of gases

13. At 1127 °C the pressure of a mixture of ozone and oxygen at equilibrium is 18.1 atm. If the percent dissociation of ozone is 97 %, determine

$$2\ O_3\ (g) \rightleftarrows 3\ O_2\ (g)$$

a) the value of Kp
b) when the equilibrium is disturbed by heating, the concentration of ozone increases and the concentration of oxygen decreases. ¿Is the process exothermic or endothermic?