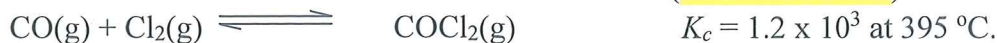


- 1) The reaction of steam and coke (a form of carbon) produces a mixture of carbon monoxide and hydrogen (water gas). The reaction is given below; write the K_c expression for the reaction.



$$K_c = \frac{[CO][H_2]}{[H_2O]}$$

- 2) If the equilibrium concentrations of Cl_2 and $COCl_2$ are the same at $395^\circ C$, find the equilibrium concentration of CO in the reaction shown below: (ans: $8.3 \times 10^{-4} M$)



$$K_c = \frac{[COCl_2]}{[CO][Cl_2]} = 1.2 \times 10^3$$

$$\frac{1}{[CO]} = 1.2 \times 10^3$$

$$[CO] = 8.3 \times 10^{-4} M$$

- 3) The equilibrium constant for the reaction given below is 7.07 at 718 K.



What is the K_c value at 718 K for the two reactions given below?

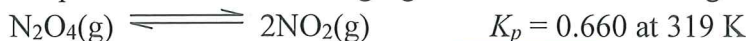


$$\text{inv. } K_c \therefore \frac{1}{K_c} = \frac{1}{7.07} = \boxed{0.141}$$



$$\text{twice } K_c \therefore K_c^2 = (7.07)^2 = \boxed{50.0}$$

- 4) Consider the equilibrium between dinitrogen tetroxide and nitrogen dioxide:



- a) What is the value of K_c for this reaction? (ans: 0.0252)

- b) What is value of K_p for the reaction $2NO_2(g) \rightleftharpoons N_2O_4(g)$ (ans: 1.52)

- c) If the equilibrium partial pressure of $NO_2(g)$ is 0.332 atm, what is the equilibrium partial pressure of $N_2O_4(g)$? (ans: 0.167 atm)

(a) $K_p = K_c(RT)^{\Delta n}$

$$K_c = \frac{K_p}{(RT)^{\Delta n}}$$

$$= \frac{0.660}{(0.0821 \times 319)^{2-1}}$$

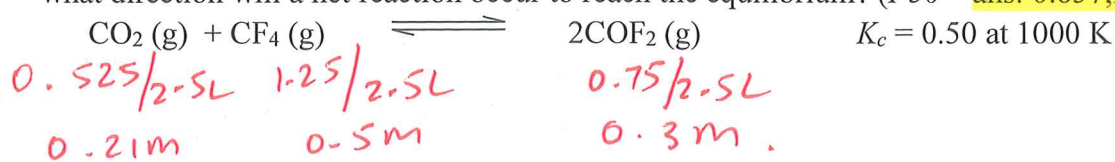
$$= \boxed{0.0252}$$

(b) inverse $K_p \quad \frac{1}{K_p} = \frac{1}{0.660} = \boxed{1.52}$

(c) $K_p = \frac{(P_{NO_2})^2}{(P_{N_2O_4})}$; $0.660 = \frac{(0.332)^2}{P_{N_2O_4}}$

$$P_{N_2O_4} = 0.167 \text{ atm}$$

- 5) If a 2.50 L vessel at 1000 °C contains 0.525 mol CO₂, 1.25 mol CF₄, and 0.75 mol COF₂, in what direction will a net reaction occur to reach the equilibrium? (P50 – ans: 0.857, left)



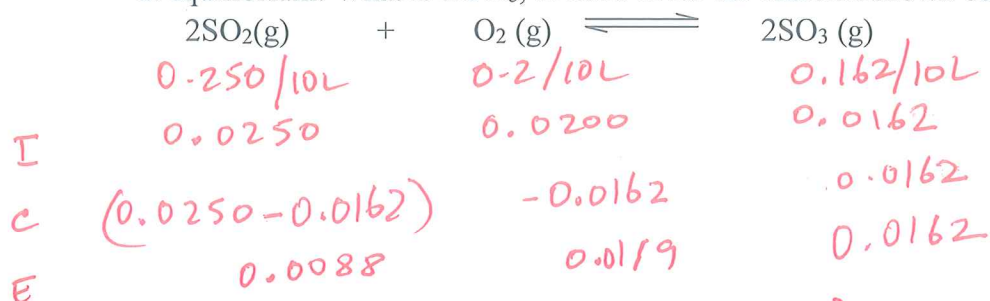
$$Q_c = \frac{[\text{COF}_2]^2}{[\text{CO}_2][\text{CF}_4]} = \frac{(0.3)^2}{(0.21)(0.5)} = 0.857$$

$$Q_c > K_c$$

$0.857 \quad 0.5$

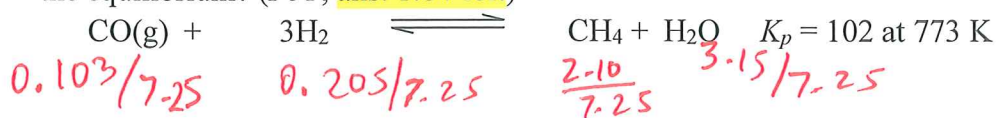
eq. proceeds to reactants **left**.

- 6) In a 10.0 L vessel at 1000 K, 0.250 mol SO₂ and 0.200 mol O₂ react to form 0.162 mol SO₃ at equilibrium. What is the K_c, at 1000 K for the reaction shown below? (ans: 2.8 x 10²)



$$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} = \frac{(0.0162)^2}{(0.0088)^2 (0.0119)} = 2.8 \times 10^2$$

- 7) The following substances are added to a 7.25 L flask at 773 °C contains 0.103 mol CO, 0.205 mol H₂, 2.10 mol CH₄ and 3.15 mol H₂O. In what direction will a net reaction occur to reach the equilibrium? (P51; ans: 1.84-left)



$$Q_c = \frac{(0.2897)(0.4345)}{(0.0142)(0.0283)^3} = 3.91 \times 10^5$$

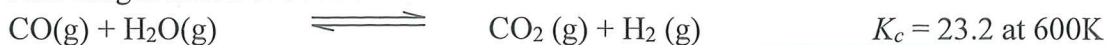
$$Q_p = Q_c (RT)^{\Delta n} = 3.91 \times 10^5 \times (0.0821 \times 773)^{-2} = 97.1$$

$$Q_p < K_p$$

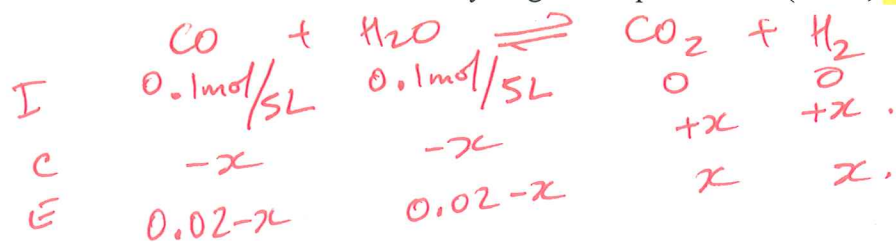
$97.1 \quad 102$

reactants going forward.

- 8) Starting with 0.100 mol each of CO and H₂O in a 5.00 L flask, equilibrium is established in the following reaction at 600K:



What is the concentration of hydrogen at equilibrium? (P12A; ans: 0.0165M)

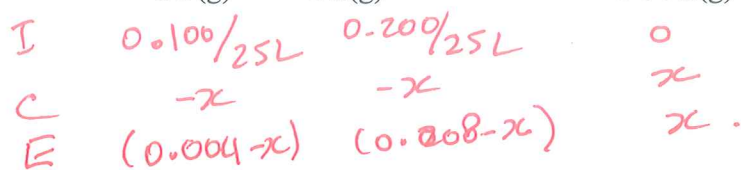


$$K_c = 23.2 = \frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]} = \frac{(x)(x)}{(0.02-x)(0.02-x)} = \frac{x^2}{(0.02-x)^2}$$

take square root of both: $4.82 = \frac{x}{0.02-x}$

$$\boxed{x = 0.0165\text{M}}$$

- 9) Starting with 0.100 mol CO and 0.200 mol CO₂ in a 25.0 L flask, how many mols of COCl₂ will be present at equilibrium? (P13A; ans: 8.5 x 10⁻² mol)



$$K_c = 1.2 \times 10^3 = \frac{x}{(0.004-x)(0.008-x)} = \frac{x}{3.20 \times 10^{-5} - 0.01200x + x^2}$$

Cross multiply:

$$1.2 \times 10^3 x^2 - 14.4x + 3.84 \times 10^{-2} = x$$

$$1.2 \times 10^3 x^2 - 15.4x + 3.84 \times 10^{-2} = 0$$

divide all by 1.2 x 10³ to make quadratic eq. easier.

$$\uparrow \quad x^2 - \frac{1.28 \times 10^{-2}}{b} x + \frac{3.2 \times 10^{-5}}{c} = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{1.28 \times 10^{-2} \pm \sqrt{(1.28 \times 10^{-2})^2 - 4(1)(3.2 \times 10^{-5})}}{2(1)}$$

$$x = 3.4 \times 10^{-3} \text{M} \text{ or } 9.4 \times 10^{-3} \text{M} \quad \leftarrow \text{too large!}$$

$$3.4 \times 10^{-3} \frac{\text{mol}}{\text{L}} \times 25\text{L} = \boxed{8.5 \times 10^{-2} \text{ mol}}$$

10) The reaction between carbon monoxide and steam is given below.

$\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$ $\Delta H = -41\text{KJ}$; $K_c = 9.03$ at 698 K
Using LeChatlier's principles predict which direction the equilibrium will proceed when the following changes are made.

a) Carbon monoxide is added \rightarrow

b) Carbon dioxide is removed \rightarrow

c) The reaction is heated up \leftarrow

d) The reaction vessel is compressed to half its volume *no change.*

e) A catalyst is added *no change.*

f) A 1 L of argon is added to the reaction vessel *no change.*