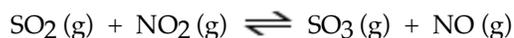


Name _____

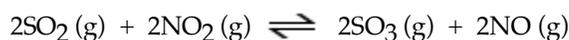
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

- 1) At equilibrium, _____.
- A) the rates of the forward and reverse reactions are equal
 - B) the rate constants of the forward and reverse reactions are equal
 - C) all chemical reactions have ceased
 - D) the value of the equilibrium constant is 1
 - E) the limiting reagent has been consumed
- 2) Which one of the following will change the value of an equilibrium constant?
- A) adding other substances that do not react with any of the species involved in the equilibrium
 - B) varying the initial concentrations of reactants
 - C) changing temperature
 - D) varying the initial concentrations of products
 - E) changing the volume of the reaction vessel

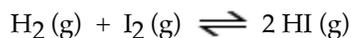
- 3) The value of K_{eq} for the following reaction is 0.25:



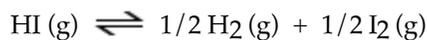
The value of K_{eq} at the same temperature for the reaction below is _____.



- A) 0.062 B) 16 C) 0.25 D) 0.50 E) 0.12
- 4) The value of K_{eq} for the equilibrium

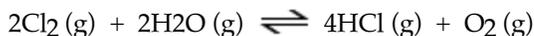


is 794 at 25°C. At this temperature, what is the value of K_{eq} for the equilibrium below?

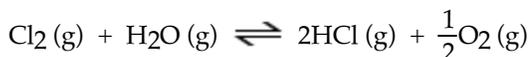


- A) 0.035 B) 0.0013 C) 28 D) 397 E) 1588

5) The K_{eq} for the equilibrium below is 7.52×10^{-2} at 480°C .

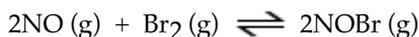


What is the value of K_{eq} at this temperature for the following reaction?

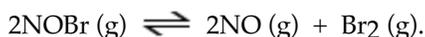


- A) 0.150 B) 0.274 C) 0.0376 D) 5.66×10^{-3} E) 0.0752

6) At 1000 K, the equilibrium constant for the reaction



is $K_p = 0.013$. Calculate K_p for the reverse reaction,



- A) 0.99 B) 1.1 C) 0.013 D) 1.6×10^{-4} E) 77

7) The expression for K_{eq} for the reaction below is _____.



- A) $\frac{P_{\text{CO}_2} P_{\text{H}_2\text{O}}^2}{P_{\text{CH}_4}}$
B) $\frac{P_{\text{CH}_4}}{P_{\text{H}_2\text{O}}^2 P_{\text{CO}_2}}$
C) $\frac{[\text{Cu}] P_{\text{CO}_2} P_{\text{H}_2\text{O}}^2}{[\text{CuO}]^4 P_{\text{CH}_4}}$
D) $\frac{P_{\text{CH}_4}}{P_{\text{CO}_2} P_{\text{H}_2}^2}$
E) $\frac{P_{\text{CO}_2} P_{\text{H}_2\text{O}}^2}{P_{\text{CuO}}}$

8) Acetic acid is a weak acid that dissociates into the acetate ion and a proton in aqueous solution:



At equilibrium at 25°C a 0.100 M solution of acetic acid has the following concentrations:

$[\text{HC}_2\text{H}_3\text{O}_2] = 0.0990 \text{ M}$, $[\text{C}_2\text{H}_3\text{O}_2\text{G}] = 1.33 \times 10^{-3} \text{ M}$, and $[\text{H}^+] = 1.33 \times 10^{-3} \text{ M}$. The equilibrium constant, K_{eq} , for the ionization of acetic acid at 25°C is _____.

- A) 5.71×10^4 B) 1.79×10^{-5} C) 1.75×10^{-7} D) 5.71×10^6 E) 0.100

9) At 200°C, the equilibrium constant for the reaction below is 2.40×10^3 .



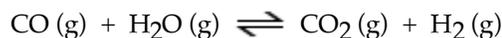
A closed vessel is charged with 36.1 atm of NO. At equilibrium, the partial pressure of O₂ is _____ atm.

- A) 35.7 B) 18.1 C) 1.50×10^{-2} D) 6.00 E) 294

10) How is the reaction quotient used to determine whether a system is at equilibrium?

- A) The reaction is at equilibrium when $Q < K_{\text{eq}}$.
B) The reaction is at equilibrium when $Q > K_{\text{eq}}$.
C) At equilibrium, the reaction quotient is undefined.
D) The reaction quotient must be satisfied for equilibrium to be achieved.
E) The reaction is at equilibrium when $Q = K_{\text{eq}}$.

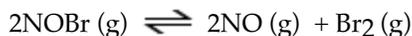
11) In the coal-gasification process, carbon monoxide is converted to carbon dioxide via the following reaction:



In an experiment, 0.35 mol of CO and 0.40 mol of H₂O were placed in a 1.00-L reaction vessel. At equilibrium, there were 0.19 mol of CO remaining. K_{eq} at the temperature of the experiment is _____.

- A) 0.75 B) 1.0 C) 5.47 D) 1.78 E) 0.56

12) Nitrosyl bromide decomposes according to the following equation.



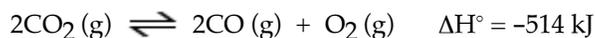
A sample of NOBr (0.64 mol) was placed in a 1.00-L flask containing no NO or Br₂. At equilibrium the flask contained 0.46 mol of NOBr. How many moles of NO and Br₂, respectively, are in the flask at equilibrium?

- A) 0.46, 0.23 B) 0.18, 0.090 C) 0.46, 0.46 D) 0.18, 0.360 E) 0.18, 0.18

13) In which of the following reactions would increasing pressure at constant temperature not change the concentrations of reactants and products, based on Le Chatelier's principle?

- A) $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
B) $2\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{N}_2\text{O}(\text{g})$
C) $\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$
D) $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$
E) $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g})$

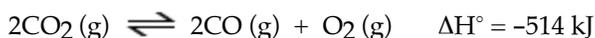
14) Consider the following reaction at equilibrium:



Le Chatelier's principle predicts that adding $\text{O}_2(\text{g})$ to the reaction container will _____.

- A) decrease the partial pressure of $\text{CO}_2(\text{g})$ at equilibrium
- B) decrease the value of the equilibrium constant
- C) increase the partial pressure of $\text{CO}_2(\text{g})$ at equilibrium
- D) increase the value of the equilibrium constant
- E) increase the partial pressure of $\text{CO}(\text{g})$ at equilibrium

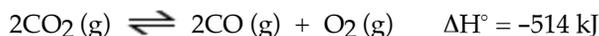
15) Consider the following reaction at equilibrium:



Le Chatelier's principle predicts that an increase in temperature will _____.

- A) increase the partial pressure of $\text{O}_2(\text{g})$
- B) decrease the value of the equilibrium constant
- C) increase the partial pressure of CO
- D) decrease the partial pressure of $\text{CO}_2(\text{g})$
- E) increase the value of the equilibrium constant

16) Consider the following reaction at equilibrium.



Le Chatelier's principle predicts that the equilibrium partial pressure of $\text{CO}(\text{g})$ can be maximized by carrying out the reaction _____.

- A) at high temperature and high pressure
- B) at high temperature and low pressure
- C) at low temperature and low pressure
- D) at low temperature and high pressure
- E) in the presence of solid carbon

17) The effect of a catalyst on an equilibrium is to _____.

- A) increase the rate at which equilibrium is achieved without changing the composition of the equilibrium mixture
- B) increase the rate of the forward reaction only
- C) shift the equilibrium to the right
- D) increase the equilibrium constant so that products are favored
- E) slow the reverse reaction only

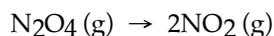
18) The following equilibrium is readily established:



At equilibrium at 373 K, a 1.00-L reaction vessel contains 0.0106 mol of SO_2Cl_2 and 0.0287 mol each of SO_2 and Cl_2 . What is K_{eq} for the reaction at 373 K?

- A) 12.8 B) 2.72 C) 0.0781 D) 2.39 E) 0.418

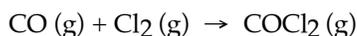
19) Dinitrogen tetroxide partially decomposes according to the following equilibrium:



A 1.000-L flask is charged with 3.00×10^{-2} mol of N_2O_4 . At equilibrium, 2.36×10^{-2} mol of N_2O_4 remains. K_{eq} for this reaction is _____.

- A) 0.723
B) 1.92×10^{-4}
C) 6.93×10^{-3}
D) 0.391
E) 0.212

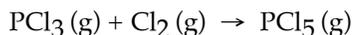
20) The K_{eq} for the reaction below is 1.49×10^8 at 100°C :



In an equilibrium mixture of the three gases, $P_{\text{CO}} = P_{\text{Cl}_2} = 8.60 \times 10^{-4}$ atm. The partial pressure of the product, phosgene (COCl_2), is _____ atm.

- A) 2.01×10^{14} B) 1.72×10^{11} C) 1.28×10^5 D) 4.96×10^{-15} E) 1.10×10^2

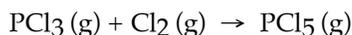
21) Phosphorous trichloride and phosphorous pentachloride equilibrate in the presence of molecular chlorine according to the reaction:



$K_{\text{eq}} = 2.01$ at 500 K. A 1.000-L reaction vessel is charged with 0.990 mol of PCl_5 and allowed to equilibrate at this temperature. The equilibrium partial pressure of PCl_3 is _____ atm.

- A) 0.702 B) 4.25 C) 4.50 D) 36.4 E) 0.496

22) Phosphorous trichloride and phosphorous pentachloride equilibrate in the presence of molecular chlorine according to the reaction:



$K_{\text{eq}} = 2.01$ at 500 K. A 1.000-L reaction vessel is charged with 0.300 mol of PCl_5 and allowed to equilibrate at this temperature. The equilibrium partial pressure of PCl_5 is _____ atm.

- A) 10.1 B) 0.386 C) 2.24 D) 2.48 E) 0.211

2004 Free Response – Form B



For the reaction represented above, the value of the equilibrium constant, K_p is 3.1×10^{-4} at 700 K.

a) Write the expression for the equilibrium constant, K_p , for the reaction.

b) Assume that the initial partial pressures of the gases are as follows:

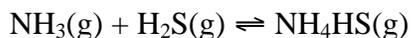
$$P(\text{N}_2) = 0.411 \text{ atm}, P(\text{H}_2) = 0.903 \text{ atm}, \text{ and } P(\text{NH}_3) = 0.224 \text{ atm}.$$

i) Calculate the value of the reaction quotient, Q , at these initial conditions.

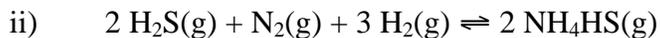
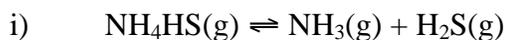
ii) Predict the direction in which the reaction will proceed at 700. K if the initial partial pressures are those given above. Justify your answer.

c) Calculate the value of the equilibrium constant, K_c , given that the value of K_p for the reaction at 700. K is 3.1×10^{-4} .

d) The value of K_p for the reaction represented below is 8.3×10^{-3} at 700. K.



Calculate the value of K_p at 700. K for each of the reactions represented below.



Answer Key

Testname: CH_13_PRAC_TEST_EQUILIBRIUM.TST

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

- 1) A
ID: chem9b 15.1-1
- 2) C
ID: chem9b 15.1-7
- 3) A
ID: chem9b 15.1-12
- 4) A
ID: chem9b 15.1-15
- 5) B
ID: chem9b 15.1-18
- 6) E
ID: chem9b 15.1-24
- 7) A
ID: chem9b 15.1-27
- 8) B
ID: chem9b 15.1-31
- 9) B
ID: chem9b 15.1-35
- 10) E
ID: chem9b 15.1-38
- 11) E
ID: chem9b 15.1-39
- 12) B
ID: chem9b 15.1-42
- 13) E
ID: chem9b 15.1-47
- 14) C
ID: chem9b 15.1-50
- 15) B
ID: chem9b 15.1-51
- 16) C
ID: chem9b 15.1-52
- 17) A
ID: chem9b 15.1-54
- 18) D
ID: chem9b 15.2-2
- 19) C
ID: chem9b 15.2-3
- 20) E
ID: chem9b 15.2-4
- 21) B
ID: chem9b 15.2-8

Answer Key

Testname: CH_13_PRAC_TEST_EQUILIBRIUM.TST

22) A

ID: chem9b 15.2-9

AP Chem Practice Test
Ch. 13 - Equilibrium

③ The second equation is 2x the stoichiometry of the 1st one, so the equilibrium constant for the 2nd equation is the square of the first one.

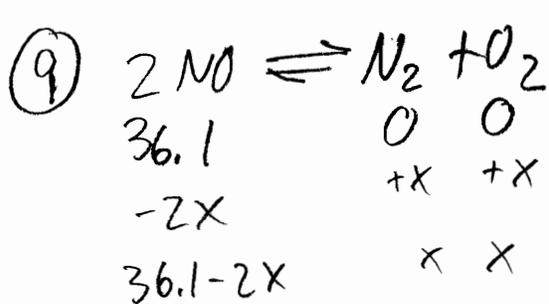
④ The 2nd equation was arrived at by reversing the 1st, and then cutting it in half stoichiometrically. Thus the K for the second equation is $\frac{1}{\sqrt{794}} = 0.035$

⑤ The 2nd equation is 1/2 of the first equation, so the 2nd equation's K = $\sqrt{\text{1st equation's K}}$

⑥ $K_p \#1 = 0.013$, so $K_p \#2 = \frac{1}{0.013} = 77$

⑦ leave out solids for that problem

⑧
$$K = \frac{[H^+][C_2H_3O_2^-]}{[HC_2H_3O_2]} = \frac{[1.33 \times 10^{-3}][1.33 \times 10^{-3}]}{0.0990} = 1.79 \times 10^{-5}$$



$$K = 2400 = \frac{x^2}{(36.1-2x)^2}$$

$$2400 = \left(\frac{x}{36.1-2x}\right)^2$$

$$\sqrt{2400} = \frac{x}{36.1-2x}$$

$$49.0 = \frac{x}{36.1-2x}$$

$$(36.1-2x)(49.0) = x$$

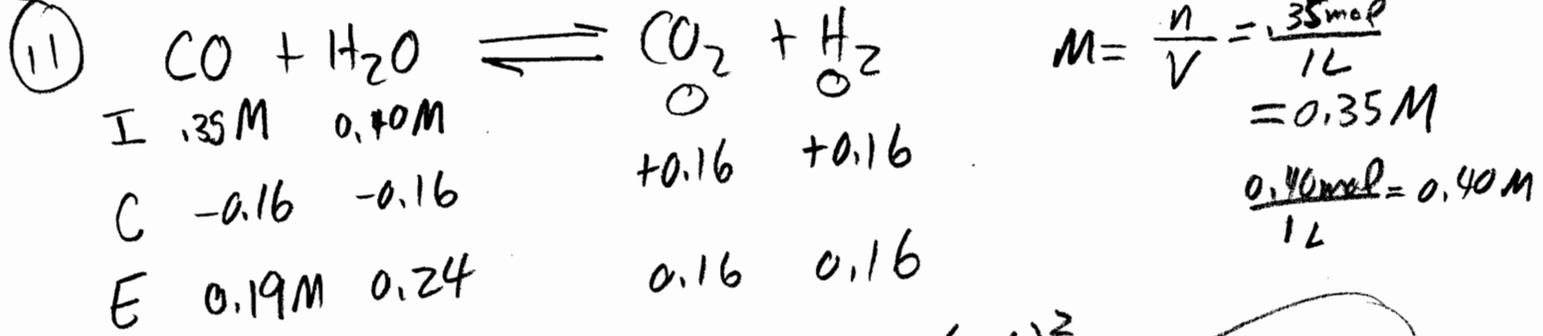
$$1768.53 - 97.98x = x$$

$$1768.53 = 98.98x$$

$$17.9 = x$$

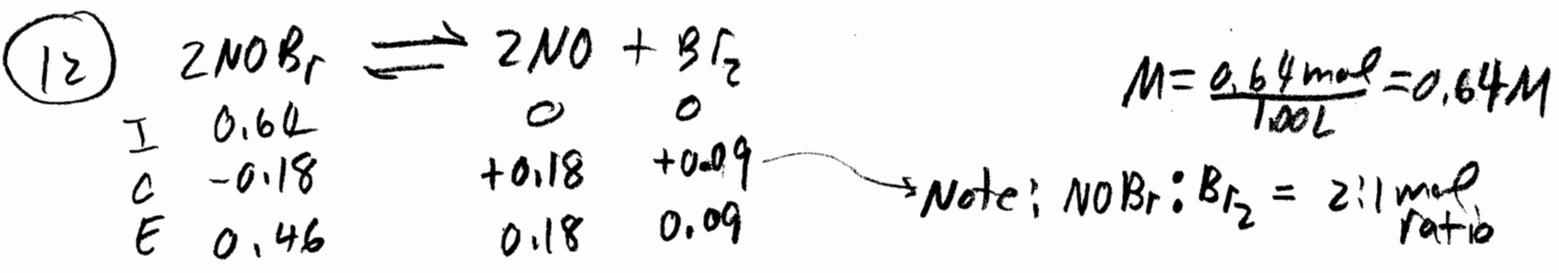
$$\hookrightarrow x = P_{O_2} = 17.9$$

10 E



$0.19 - 0.35 = -0.16 \text{ M}$

$K = \frac{(0.16)^2}{(0.19)(0.24)} = 0.56$



Note: $\text{NOBr} : \text{Br}_2 = 2:1$ mol ratio

$\Delta[\text{NOBr}] = 0.46 - 0.64 = -0.18$

$0.18 \text{ M} = \frac{x \text{ mol}}{1.00 \text{ L}}$

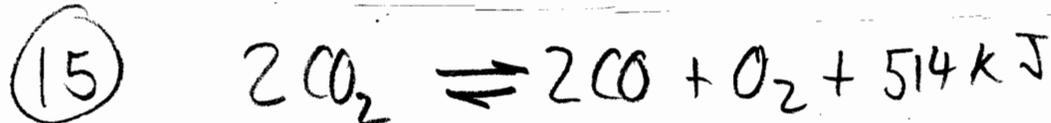
$x \text{ mol} = 0.18 \text{ mol NO}$
 and 0.09 mol Br_2

13 E, $\Delta n = 0$
 (same # of mol of gas on each side of eqn.)

14 Add $\text{O}_2 \Rightarrow$ causes $Q > K \Rightarrow$ causes rxn to shift left in response.

When rxn shifts left:

- a) P_{CO_2} increases
- b) K does not change
- c) P_{CO_2} increases
- d) K does not change
- e) P_{CO} decreases

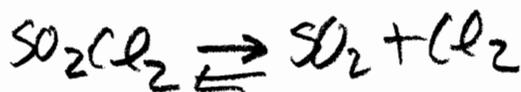


" $\Delta H_{\text{rxn}}^\circ = -514 \text{ kJ}$ " means that heat is produced in this exothermic reaction. You can think of heat as a product. The reaction shifts to the left, since increasing the T requires that heat (a product) be added to the system. Also, the equilibrium constant will decrease: $[\text{CO}]$ and $[\text{O}_2]$ decrease and $[\text{CO}_2]$ increases.

(16) C, low temp (removes heat, drives rxn to right because this produces heat) and low P (fewer moles of gas on right side).

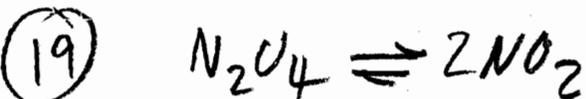
(17) A, no effect on K

(18)



$$K = \frac{[\text{SO}_2][\text{Cl}_2]}{[\text{SO}_2\text{Cl}_2]} = \frac{(0.0287)(0.0287)}{0.0106} = 0.0778$$

I am not sure why the answer key is wrong.

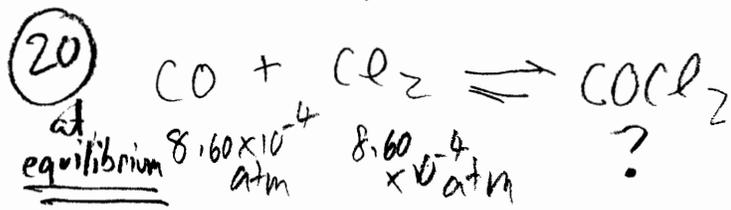


I	0.0300M	0
C	-x	+2x
E	0.0236M	2x

$$\Delta [\text{N}_2\text{O}_4] = 0.0236 - 0.0300 = 0.0064 \text{ M} = x$$

$$2x = 2 \times 0.0064 = 0.0128 \text{ M}$$

$$K = \frac{[0.0128]^2}{0.0236} = 6.94 \times 10^{-3}$$



$$K = \frac{P_{\text{COCl}_2}}{(P_{\text{CO}})(P_{\text{Cl}_2})} = 1.49 \times 10^8$$

$$P_{\text{COCl}_2} = (1.49 \times 10^8)(8.60 \times 10^{-4})^2$$

$$P_{\text{COCl}_2} = 110 \text{ atm}$$

$$= 1.10 \times 10^2 \text{ atm}$$

21) That "K_{eq}" is a "K_p". As far as I know, this fact should have been stated in the problem.

$$PV = nRT$$

$$P = \frac{(0.990 \text{ mol})(0.08206 \frac{\text{L atm}}{\text{K mol}})(500 \text{ K})}{1.000 \text{ L}} = 40.6 \text{ atm}$$

	PCl_3	$+$	Cl_2	\rightleftharpoons	PCl_5
I	0		0		40.6 atm
C	+x		+x		-x
E	x		x		40.6 - x

$$K_p = 2.01 = \frac{40.6 - x}{x^2}$$

$$2.01 x^2 = 40.6 - x$$

$$2.01 x^2 + x - 40.6 = 0$$

a = 2.01
 b = 1
 c = -40.6

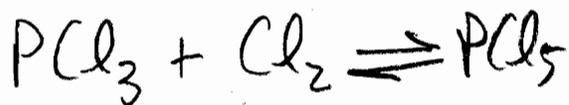
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-1 \pm \sqrt{1^2 - (4)(2.01)(-40.6)}}{(2)(2.01)}$$

$$= \frac{-1 \pm \sqrt{1 + 326.4}}{2(2.01)}$$

$$= \frac{-1 \pm \sqrt{327.4}}{2(2.01)} = \frac{-1 + 18.09}{4.02} = \frac{17.09}{4.02} = 4.25 = P_{\text{Cl}_2}$$

(22)

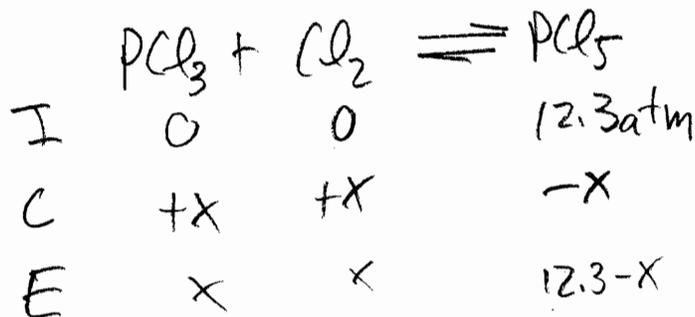


$$K_p = 2.01$$

$$T = 500\text{K}$$

$$P_{\text{PCl}_5} = \frac{nRT}{V} = \frac{(0.300 \text{ mol})(0.08206 \frac{\text{Latm}}{\text{Kmol}})(500\text{K})}{1.00 \text{ L}}$$

$$= 12.3 \text{ atm}$$



$$K_p = 2.01 = \frac{12.3-x}{x^2}$$

$$2.01x^2 = 12.3 - x$$

$$2.01x^2 + x - 12.3 = 0$$

$$a = 2.01$$

$$b = 1$$

$$c = -12.3$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-1 \pm \sqrt{1 - (4)(2.01)(-12.3)}}{(2)(2.01)}$$

$$= \frac{-1 \pm \sqrt{1 + 98.892}}{4.02}$$

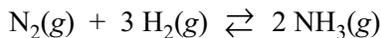
$$= \frac{-1 \pm \sqrt{99.892}}{4.02}$$

$$x = \frac{-1 + 10}{4.02} = \frac{9}{4.02} = 2.24$$

$$P_{\text{PCl}_5} = 12.3 - 2.24 = 10.1 \text{ atm}$$

AP[®] CHEMISTRY
2004 SCORING GUIDELINES (Form B)

Question 1



1. For the reaction represented above, the value of the equilibrium constant, K_p , is 3.1×10^{-4} at 700. K.

(a) Write the expression for the equilibrium constant, K_p , for the reaction.

$K_p = \frac{p_{\text{NH}_3}^2}{p_{\text{N}_2} \times p_{\text{H}_2}^3}$	1 point for pressure expression 1 point for correct substitution
--	---

(b) Assume that the initial partial pressures of the gases are as follows:

$$p_{\text{N}_2} = 0.411 \text{ atm}, \quad p_{\text{H}_2} = 0.903 \text{ atm}, \quad \text{and} \quad p_{\text{NH}_3} = 0.224 \text{ atm}.$$

(i) Calculate the value of the reaction quotient, Q , at these initial conditions.

$Q = \frac{p_{\text{NH}_3}^2}{p_{\text{N}_2} \times p_{\text{H}_2}^3} = \frac{(0.224)^2}{(0.411)(0.903)^3}$ $Q = 0.166$	1 point for calculation of Q with correct mass action expression <u>Note:</u> must be consistent with part (a)
---	---

(ii) Predict the direction in which the reaction will proceed at 700. K if the initial partial pressures are those given above. Justify your answer.

Since $Q > K_p$, the numerator must decrease and the denominator must increase, so the reaction must proceed from right to left to establish equilibrium.	1 point for direction or for stating that $Q > K_p$ 1 point for explanation
--	--

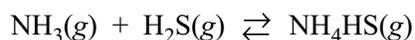
(c) Calculate the value of the equilibrium constant, K_c , given that the value of K_p for the reaction at 700. K is 3.1×10^{-4} .

$K_p = K_c(RT)^{\Delta n}$ $\Delta n = 2 - 4 = -2$ $K_p = K_c(RT)^{-2}$ $3.1 \times 10^{-4} = K_c(0.0821 \frac{\text{L atm}}{\text{mol K}} \times 700 \text{ K})^{-2}$ $3.1 \times 10^{-4} = K_c(57.5)^{-2}$ $3.1 \times 10^{-4} = K_c(3.0 \times 10^{-4})$ $1.0 = K_c$	1 point for calculating Δn 1 point for correct substitution and value of K_c
---	---

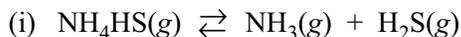
AP[®] CHEMISTRY
2004 SCORING GUIDELINES (Form B)

Question 1 (cont'd.)

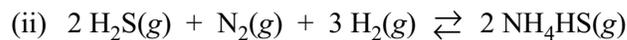
(d) The value of K_p for the reaction represented below is 8.3×10^{-3} at 700. K.



Calculate the value of K_p at 700. K for each of the reactions represented below.



$K_p = \frac{1}{8.3 \times 10^{-3}} = 1.2 \times 10^2$	1 point for the calculation of K_p
--	--------------------------------------



$2 \times [\text{NH}_3(g) + \text{H}_2\text{S}(g) \rightleftharpoons \text{NH}_4\text{HS}(g)] \quad K_p = (8.3 \times 10^{-3})^2$ $\text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_3(g) \quad K_p = 3.1 \times 10^{-4}$	1 point for squaring K_p for NH_4HS or for multiplying K_p 's
$2 \text{H}_2\text{S}(g) + \text{N}_2(g) + 3 \text{H}_2(g) \rightleftharpoons 2 \text{NH}_4\text{HS}(g)$ $K_p = (8.3 \times 10^{-3})^2 (3.1 \times 10^{-4}) = 2.1 \times 10^{-8}$	1 point for correct K_p