Equilibrium Test **v1** **2019** **Name: _____**

1. Which of the following statements best defines the dynamic nature of a chemical equilibrium?

A) The reactants transform completely into products. ✗
B) The macroscopic (visual) properties remain constant. ✓ True but it may not be at equilibrium
C) The masses of the reactants and the products are equal. ✗
D) The rates of the forward and reverse reactions are equal. ✓

MC ans	
1	D
2	A
3	C
4	A
5	C

/10

2. Which statement concerning the following equilibrium systems is FALSE?

1) $N_{2\,(g)} + 3\,H_{2\,(g)} \leftrightarrow 2\,NH_{3\,(g)}$ $K_{eq} = 2.66 \times 10^{-3}$
2) $2\,H_{2\,(g)} + S_{2\,(g)} \leftrightarrow 2\,H_2S_{\,(g)}$ $K_{eq} = 9.38 \times 10^{-5}$
3) $2\,H_2O_{(g)} + 2\,S_{(s)} \leftrightarrow 2\,H_2S_{(g)} + O_{2(g)}$ $K_{eq} = 5.31 \times 10^{-10}$
4) $H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{\,(g)}$ $K_{eq} = 54.4$

A) The formation of $NH_{3\,(g)}$ is favored in system 1. ✗
B) The formation of $HI_{(g)}$ is favored in system 4. ✓
C) The formation of H_2S is not favored in system 2. ✓
D) The formation of water is favored in system 3. ✓

3. What is the mathematical expression for K_{eq} of the equilibrium system represented by the following equation?

$$Cu_{(s)} + 2\,H_2SO_{4(aq)} \leftrightarrow CuSO_{4(aq)} + SO_{2(aq)} + 2\,H_2O_{(l)}$$

A) $K_c = \frac{[CuSO_4][SO_2][H_2O]^2}{[Cu][H_2SO_4]^2}$ B) $K_c = \frac{[CuSO_4][SO_2][H_2O]^2}{[H_2SO_4]^2}$ C) $K_c = \frac{[CuSO_4][SO_2]}{[H_2SO_4]^2}$ D) $K_c = [SO_2]$

4. What is the equilibrium constant for the following system if at equilibrium there are 3.0 mol/L of $NO_{2(g)}$ and 4.0 mol/L of $N_2O_{4(g)}$?

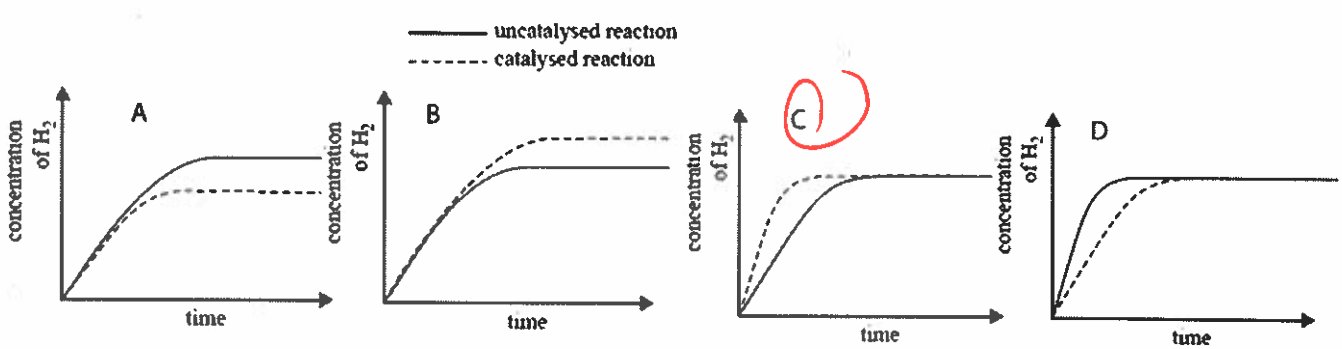
$$2\,NO_{2\,(g)} \leftrightarrow N_2O_{4\,(g)} + \text{Energy}$$

$K_{eq} = \frac{[N_2O_4]}{[NO_2]^2} = \frac{4.0}{(3.0)^2} = 0.44$

A) 0.44 B) 1.30 C) 0.75 D) 2.30

5. The reaction below is carried out with and without a catalyst in a sealed container. All other conditions are constant. Which graph correctly illustrates the $[H_2]$ over time?

$$CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$$



6. Apply Le Chatelier's Principle to the following equilibrium system. $E + N_{2\,(g)} + 2\,O_{2\,(g)} \leftrightarrow 2\,NO_{2\,(g)}$
What effect will each of the following changes have on the concentration of ammonia, $NO_{2(g)}$?
Circle correct answer

a) increasing the total pressure forward	INCREASE	DECREASE	NO CHANGE
b) increasing the temperature forward	INCREASE	DECREASE	NO CHANGE
c) increasing the concentration of $N_{2(g)}$ forward.	INCREASE	DECREASE	NO CHANGE

/3

7. A system reaches equilibrium according to the following equation:

$$4\,Fe_{(s)} + 3O_{2(g)} \rightleftarrows 2\,Fe_2O_{3(s)} + 1600\text{ kJ}$$

What effect will each of the following changes have on the concentration of $Fe_2O_{3(s)}$?

a) A decrease in temperature f	INCREASE	DECREASE	NO CHANGE
b) An decrease in pressure r	INCREASE	DECREASE	NO CHANGE
c) An addition of a catalyst	INCREASE	DECREASE	NO CHANGE

/3

Show your work and provide units for the following questions.

8. Use rate theory to mathematically show how the forward and reverse rates would change after doubling the pressure.

$$2B_{(s)} + 3H_{2(g)} \leftrightarrow B_2H_{6(g)} \quad \Delta H = +36\text{ kJ}$$

$rate_F = k[H_2]^3$
$= k \cdot 2^3$
$= 8k$

$rate_R = k[B_2H_6]$
$= k \cdot 2$
$= 2k$

/2

9. A student adds 3.0 moles of $N_{2(g)}$ and 6.0 moles of $O_{2\,(g)}$ to a 5.0 L container. At equilibrium 1.0 mole of $NO_{2\,(g)}$ is present. Calculate the equilibrium constant for this system.

$$N_{2\,(g)} + 2\,O_{2\,(g)} \leftrightarrow 2\,NO_{2\,(g)}$$

	N_2	$2O_2$	$2NO_2$
I	0.6	1.2	0
C	-0.1	-0.2	+0.2
E	0.5	1.0	0.2

$[N_2]_i = \frac{3.0\text{ mol}}{5.0\text{ L}} = 0.6\text{ M}$

$[O_2]_i = \frac{6.0\text{ mol}}{5.0\text{ L}} = 1.2\text{ M}$

$[NO_2]_{eq} = \frac{1.0\text{ mol}}{5.0\text{ L}} = 0.2\text{ M}$

$K_{eq} = \frac{[NO_2]^2}{[N_2][O_2]^2}$
$= \frac{(0.2)^2}{(0.5)(1.0)^2}$

$\boxed{K_{eq} = 0.08}$

/4

/2

10. A student adds 5.00M water vapour and carbon monoxide. The reaction is permitted to reach equilibrium. Find the equilibrium concentration of all reactants and products if the Keq is 0.0625.

	$H_2O_{(g)}$ +	$CO_{(g)}$ ↔	$H_{2(g)}$ +	$CO_{2(g)}$
I	5	5	0	0
C	−x	−x	+x	+x
E	5−x	5−x	+x	+x

$$K_{eq} = \frac{[H_2][CO_2]}{[H_2O][CO]}$$

$$0.0625 = \frac{x^2}{(5-x)^2}$$

$$\sqrt{0.0625} = \frac{x}{5-x}$$

$$\pm 0.25 = \frac{x}{5-x}$$

$$0.25(5-x) = x$$

$$1.25 - 0.25x = x$$

$$1.25 = 1.25x$$

$$x = 1$$

$$-0.25(5-x) = x$$

$$-1.25 + 0.25x = x$$

$$-1.25 = 0.75x$$

$$x = -1.\overline{6}$$

$[H_2O_{(g)}]$ = 4.00M

$[CO_{(g)}]$ = 4.00M

$[H_{2(g)}]$ = 1.00M

$[CO_{2(g)}]$ = 1.00M

11. **What are the final concentrations** of all reactants and products if the initial concentration of H_2 is 10.0 M and I_2 is 6.0 M. Show all your calculations.

	H_2	+ I_2	→ 2 HI
I	10	6	0
C	−x	−x	+2x
E	10−x	6−x	2x

Keq = 2

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$$

$$2 = \frac{(2x)^2}{(10-x)(6-x)}$$

$$2(60 - 10x - 6x + x^2) = 4x^2$$

$$120 - 32x + 2x^2 = 4x^2$$

$$\boxed{0 = 2x^2 + 32x - 120}$$

a = 2

b = 32

c = −120

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

$$= \frac{-32 \pm \sqrt{32^2 - 4(2)(-120)}}{2(2)}$$

$$= \frac{-32 \pm \sqrt{1024 + 960}}{4}$$

$$= \frac{-32 \pm \sqrt{1984}}{4}$$

x = 3.14

x = −19.1

$[H_2]$ = 6.86M

$[I_2]$ = 2.86M

[HI] = 6.28M

/8

Equilibrium Test **v2** **2019** **Name:** Answers.

1. Which of the following factors are necessary to establish dynamic chemical equilibrium?

1. an open system ✗
2. constant temperature ✓
3. a reversible reaction ✓
4. changing macroscopic properties ✗

A) 1 and 2 B) 1 and 4 C) 2 and 3 D) 3 and 4

2. Which statement concerning the following equilibrium systems is FALSE?

1) $N_{2\,(g)} + 3\,H_{2\,(g)} \leftrightarrow 2\,NH_{3\,(g)}$ $K_{eq} = 2.66 \times 10^{-3}$
2) $2\,H_{2\,(g)} + S_{2\,(g)} \leftrightarrow 2\,H_2S_{(g)}$ $K_{eq} = 9.38 \times 10^{-5}$
3) $2\,H_2O_{(g)} + 2\,S_{(s)} \leftrightarrow 2\,H_2S_{(g)} + O_{2(g)}$ $K_{eq} = 5.31 \times 10^{-10}$
4) $H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{(g)}$ $K_{eq} = 54.4$

A) The formation of $NH_{3\,(g)}$ is favored in system 1.
B) The formation of $HI_{(g)}$ is favored in system 4.
C) The formation of H_2S is not favored in system 2.
D) The formation of water is favored in system 3.

MC ans	
1	C
2	A
3	C
4	D
5	B

/10

3. What is the mathematical expression for K_{eq} of the equilibrium system represented by the following equation?

$$Cu_{(s)} + 2\,H_2SO_{4(aq)} \leftrightarrow CuSO_{4(aq)} + SO_{2(aq)} + 2\,H_2O_{(l)}$$

A) $K_c = \frac{[CuSO_4][SO_2][H_2O]^2}{[Cu][H_2SO_4]^2}$ B) $K_c = \frac{[CuSO_4][SO_2][H_2O]^2}{[H_2SO_4]^2}$ C) $K_c = \frac{[CuSO_4][SO_2]}{[H_2SO_4]^2}$ D) $K_c = [SO_2]$

4. What is the equilibrium constant for the following system if at equilibrium there are 3.5 mol/L of $NO_{2(g)}$ and 4.0 mol/L of $N_2O_{4(g)}$?

$$2\,NO_{2\,(g)} \leftrightarrow N_2O_{4\,(g)} + \text{Energy}$$

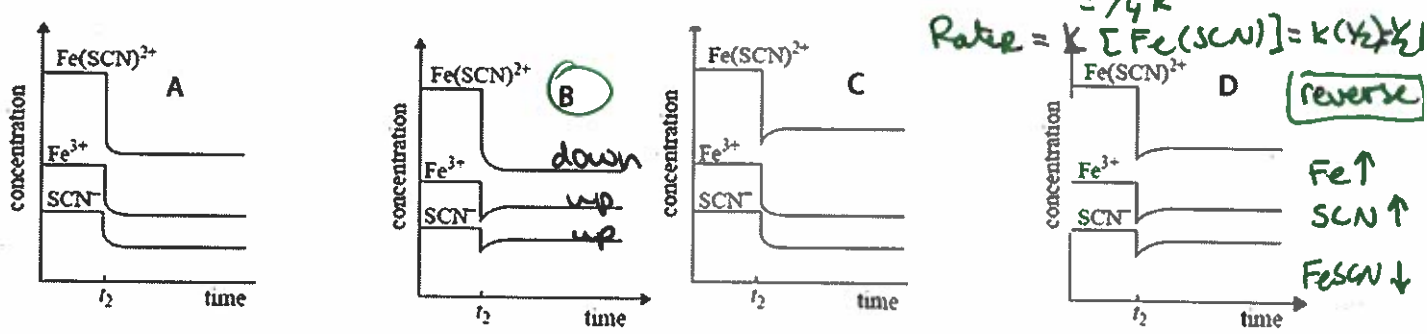
$K_{eq} = \frac{[N_2O_4]}{[NO_2]^2} = \frac{4.0}{(3.5)^2} = 0.33$

A) 3.06 B) 1.14 C) 0.57 D) 0.32

5. Which one of the following best represents the changes in concentration when the equilibrium mixture is diluted at time t2?

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons Fe(SCN)^{2+}(aq)$$

Rate F $= k\,[Fe^{3+}][SCN^-]$
$= k\,(1/2)(1/2)$
$= 1/4\,k$
Rate R $= k\,[Fe(SCN)] = k(1/2)$



6. Apply Le Chatelier's Principle to the following equilibrium system. **E + $N_{2(g)}$ + 2 $O_{2(g)}$ ↔ 2 $NO_{2(g)}$**
What effect will each of the following changes have on the concentration of ammonia, $NO_{2(g)}$?
Circle correct answer

a) decrease the total pressure R	INCREASE	DECREASE	NO CHANGE
b) decrease the temperature R	INCREASE	DECREASE	NO CHANGE
c) decrease the concentration of $N_{2(g)}$ R	INCREASE	DECREASE	NO CHANGE

/3

7. A system reaches equilibrium according to the following equation:

$$4\ Fe_{(s)} + 3O_{2(g)} \rightleftarrows 2\ Fe_2O_{3(s)} + 1600\ kJ$$

What effect will each of the following changes have on the concentration of $Fe_2O_{3(s)}$?

a) A increase in temperature R	INCREASE	DECREASE	NO CHANGE
b) An increase in pressure F	INCREASE	DECREASE	NO CHANGE
c) An addition of a catalyst	INCREASE	DECREASE	NO CHANGE

/3

Show your work and provide units for the following questions.

8. Use rate theory to mathematically show how the forward and reverse rates would change after doubling the pressure.

$$2B_{(s)} + 3H_{2(g)} \leftrightarrow B_2H_{6(g)} \quad \Delta H = +36\ kJ$$

$rate_F = k[H_2]^3$
$= k \cdot 2^3$
$= 8k$

$rate_R = k[B_2H_6]$
$= k \cdot 2$
$= 2k$

/2

9. A student adds 3.0 moles of $N_{2(g)}$ and 6.0 moles of $O_{2(g)}$ to a 4.0 L container. At equilibrium 1.0 mole of $NO_{2(g)}$ is present. Calculate the equilibrium constant for this system.

$$N_{2(g)} + 2\ O_{2(g)} \leftrightarrow 2\ NO_{2(g)}$$

$[N_2]_i = \frac{3.0\ mol}{4.0\ L} = 0.75\ M$

$[O_2]_i = \frac{6.0\ mol}{4.0\ L} = 1.5\ M$

$[NO_2]_{eq} = \frac{1.0\ mol}{4.0\ L} = 0.25\ M$

	N_2	$2O_2$	$2NO_2$
I	0.75	1.5	0
C	0.125	-0.25	+0.25
E	0.625	1.25	0.25

$K_{eq} = \frac{[NO_2]^2}{[N_2][O_2]^2}$

$= \frac{(0.25)^2}{(0.625)(1.25)^2} = 0.064$

/4

/12

10. A student adds 4.00M water vapour and carbon monoxide. The reaction is permitted to reach equilibrium. Find the equilibrium concentration of all reactants and products if the Keq is 0.0625.

	$H_2O_{(g)}$ +	$CO_{(g)}$ ↔	$H_{2(g)}$ +	$CO_{2(g)}$
I	4	4	0	0
C	$-x$	$-x$	$+x$	$+x$
E	$4-x$	$4-x$	x	x

$$K_{eq} = \frac{[H_2][CO_2]}{[H_2O][CO]}$$

$$0.0625 = \frac{x^2}{(4-x)^2}$$

$$\sqrt{0.0625} = \frac{x}{4-x}$$

$$\pm 0.25 = \frac{x}{4-x}$$

$$0.25(4-x) = x$$

$$1 - 0.25x = x$$

$$1 = 1.25x$$

$$0.8 = x$$

$$3.2 = 4 - x$$

$$-0.25(4-x) = x$$

$$-1 + 0.25x = x$$

$$-1 = 0.75x$$

$$\cancel{-1.3 = x}$$

$[H_2O_{(g)}]$ = 3.20M

$[CO_{(g)}]$ = 3.20M

$[H_{2(g)}]$ = 0.800 M

$[CO_{2(g)}]$ = 0.800 M

11. **What are the final concentrations** of all reactants and products if the initial concentration of H_2 is 9.0 M and I_2 is 6.0 M. Show all your calculations.

	H_2	+ I_2	→ 2 HI
I	9	6	0
C	$-x$	$-x$	$2x$
E	$9-x$	$6-x$	$2x$

Keq = 2

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$$

$$2 = \frac{(2x)^2}{(9-x)(6-x)}$$

$$2(9-x)(6-x) = 4x^2$$

$$(9-x)(6-x) = 2x^2$$

$$54 - 15x + x^2 = 2x^2$$

$$0 = x^2 + 15x - 54$$

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

$$= \frac{-15 \pm \sqrt{15^2 - 4(1)(-54)}}{2(1)}$$

$$= \frac{-15 \pm \sqrt{225 + 216}}{2}$$

$$= \frac{-15 \pm \sqrt{441}}{2}$$

$$= \frac{-15 \pm 21}{2}$$

$$\cancel{x = -18}$$

$$x = 3$$

$[H_2]$ = 6.0M

$[I_2]$ = 3.0M

$[HI]$ = 6.0M

/8

Equilibrium Test **v3** **2019** **Name: _____**

1. A certain chemical reaction establishes equilibrium. The equilibrium constant, Keq has a value of 2.5×10^{12}. Which of the following statements best describes the equilibrium?

Huge ↑ product.

A) The reaction can never establish equilibrium.
B) At equilibrium, there is a greater concentration of reactants than products.
C) At equilibrium, there is an equal concentration of reactants and products.
D) At equilibrium, there is a greater concentration of products than reactants. ✓

2. Which statement concerning the following equilibrium systems is FALSE?

1) $N_{2\,(g)} + 3\,H_{2\,(g)} \leftrightarrow 2\,NH_{3\,(g)}$ $K_{eq} = 2.66 \times 10^{-3}$
2) $2\,H_{2\,(g)} + S_{2\,(g)} \leftrightarrow 2\,H_2S_{(g)}$ $K_{eq} = 9.38 \times 10^{-5}$
3) $2\,H_2O_{(g)} + 2\,S_{(s)} \leftrightarrow 2\,H_2S_{(g)} + O_{2(g)}$ $K_{eq} = 5.31 \times 10^{-10}$
4) $H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{(g)}$ $K_{eq} = 54.4$

A) The formation of $NH_{3\,(g)}$ is favored in system 1.
B) The formation of $HI_{(g)}$ is favored in system 4.
C) The formation of H_2S is not favored in system 2.
D) The formation of water is favored in system 3.

MC ans	
1	D
2	A
3	C
4	D
5	A

/10

3. What is the mathematical expression for K_{eq} of the equilibrium system represented by the following equation?

$$Cu_{(s)} + 2\,H_2SO_{4(aq)} \leftrightarrow CuSO_{4(aq)} + SO_{2(aq)} + 2\,H_2O_{(l)}$$

A) $K_c = \frac{[CuSO_4][SO_2][H_2O]^2}{[Cu][H_2SO_4]^2}$ B) $K_c = \frac{[CuSO_4][SO_2][H_2O]^2}{[H_2SO_4]^2}$ C) $K_c = \frac{[CuSO_4][SO_2]}{[H_2SO_4]^2}$ D) $K_c = [SO_2]$

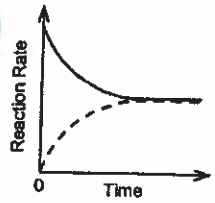
4. What is the equilibrium constant for the following system if at equilibrium there are 3.0 mol/L of $NO_{2(g)}$ and 4.0 mol/L of $N_2O_{4(g)}$?

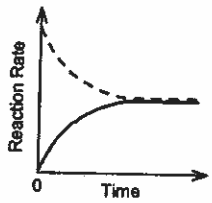
$$2\,NO_{2\,(g)} \leftrightarrow N_2O_{4\,(g)} + \text{Energy}$$

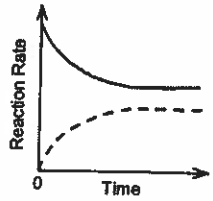
A) 2.30 B) 1.30 C) 0.75 D) 0.44

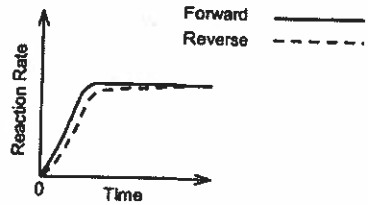
5. Steam, $H_2O_{(g)}$, and carbon monoxide, $CO_{(g)}$, are placed in a closed vessel at a high temperature and allowed to reach equilibrium. $H_2O_{(g)} + CO_{(g)} \leftrightarrow H_{2(g)} + CO_{2(g)}$

Which of the graphs below best represents the forward and reverse reaction rates from the start of the reaction until it reaches equilibrium?

A)


B)


C)


D)


6. Apply Le Chatelier's Principle to the following equilibrium system. $E + N_{2(g)} + 2\,O_{2(g)} \leftrightarrow 2\,NO_{2(g)}$
What effect will each of the following changes have on the concentration of ammonia, $NO_{2(g)}$?
Circle correct answer

a) increasing the total pressure F	INCREASE	DECREASE	NO CHANGE
b) addition of a catalyst	INCREASE	DECREASE	NO CHANGE
c) decreasing the concentration of $N_{2(g)}$ R	INCREASE	DECREASE	NO CHANGE

7. A system reaches equilibrium according to the following equation:

$$4\,Fe_{(s)} + 3O_{2(g)} \rightleftarrows 2\,Fe_2O_{3(s)} + 1600\text{ kJ}$$

What effect will each of the following changes have on the concentration of $Fe_2O_{3(s)}$?

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a) A decrease in temperature F	INCREASE	DECREASE	NO CHANGE
b) An decrease in pressure R	INCREASE	DECREASE	NO CHANGE
c) increasing the concentration of O_2 F	INCREASE	DECREASE	NO CHANGE

Show your work and provide units for the following questions.

8. Use rate theory to mathematically show how the forward and reverse rates would change after doubling the pressure.

$$2B_{(s)} + 3H_{2(g)} \leftrightarrow B_2H_{6(g)} \quad \Delta H = +36\text{ kJ}$$

$rate_F = k[H_2]^3$
$= k \cdot 2^3$
$= 8k$

$rate_R = k[B_2H_6]$
$= k \cdot 2$
$= 2k$

/2

9. A student adds 3.0 moles of $N_{2(g)}$ and 6.0 moles of $O_{2(g)}$ to a 6.0 L container. At equilibrium 1.0 mole of $NO_{2(g)}$ is present. Calculate the equilibrium constant for this system.

$$N_{2(g)} + 2\,O_{2(g)} \leftrightarrow 2\,NO_{2(g)}$$

	N_2	$2O_2$	$2NO_2$
I	0.50	1.0	0
C	$-0.08\overline{3}$	$-0.1\overline{6}$	$+0.1\overline{6}$
E	$0.41\overline{6}$	$0.8\overline{3}$	$0.1\overline{6}$

$[N_2]_i = \frac{3.0\text{ mol}}{6.0\text{ L}} = 0.50\text{ M}$

$[O_2]_i = \frac{6.0\text{ mol}}{6.0\text{ L}} = 1.0\text{ M}$

$[NO_2]_{eq} = \frac{1.0\text{ mol}}{6.0\text{ L}} = 0.1\overline{6}\text{ M}$

$K_{eq} = \frac{[NO_2]^2}{[N_2][O_2]^2}$

$= \frac{(0.1\overline{6})^2}{(0.41\overline{6})(0.8\overline{3})^2}$

$K_{eq} = 0.096$

/4

/12

each

10. A student adds 4.00M water vapour and carbon monoxide. The reaction is permitted to reach equilibrium. Find the equilibrium concentration of all reactants and products if the Keq is 0.0625.

	$H_2O_{(g)}$ +	$CO_{(g)}$ ↔	$H_{2(g)}$ +	$CO_{2(g)}$
I	4	4	0	0
C	$-x$	$-x$	$+x$	$+x$
E	$4-x$	$4-x$	x	x

$$K_{eq} = \frac{[H_2][CO_2]}{[H_2O][CO]}$$

$$0.0625 = \frac{x^2}{(4-x)^2}$$

$$\sqrt{0.0625} = \frac{x^2}{4-x}$$

$$\pm 0.25 = \frac{x}{4-x}$$

$$0.25(4-x) = x$$

$$1 - 0.25x = x$$

$$1 = 1.25x$$

$$0.8 = x$$

$$4 - x = 3.2$$

$$-0.25(4-x) = x$$

$$-1 + 0.25x = x$$

$$-1 = 0.75x$$

$$-1.3 = x$$

$[H_2O_{(g)}] = 3.20\,M$

$[CO_{(g)}] = 3.20\,M$

$[H_{2(g)}] = 0.800\,M$

$[CO_{2(g)}] = 0.800\,M$

11. **What are the final concentrations** of all reactants and products if the initial concentration of H_2 is 10.0 M and I_2 is 7.0 M. Show all your calculations.

	H_2	+ I_2	→ 2 HI
I	10	7	0
C	$-x$	$-x$	$+2x$
E	$10-x$	$7-x$	$2x$

Keq = 2

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]}$$

$$2 = \frac{(2x)^2}{(10-x)(7-x)}$$

$$2(10-x)(7-x) = 4x^2$$

$$(10-x)(7-x) = 2x^2$$

$$70 - 17x + x^2 = 2x^2$$

$$0 = x^2 + 17x - 70$$

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

$$= \frac{-17 \pm \sqrt{17^2 - 4(1)(-70)}}{2(1)}$$

$$= \frac{-17 \pm \sqrt{289 + 280}}{2}$$

$$= \frac{-17 \pm \sqrt{569}}{2}$$

$x = 3.43$ or $x = \cancel{-20.4}$

$[H_2] = 6.57\,M$

$[I_2] = 3.57\,M$

$[HI] = 6.86\,M$