Units 5 & 6 Exam: Equilibrium and Gases Name Key

1. When a rxn has reached equilibrium:
a. the molecules are in a passive state; therefore, no more products are formed.
b. the products are reacting, while the reactants are passive.
c. the reactants are reacting, while the products are passive.
d. both reactants and products are formed continuously.

2. Which of the following changes will change the position of equilibrium?
a. allow more rxn time to pass
b. remove some products
c. add a catalyst
d. all of these

3. At equilibrium, $[PSCl_3]$=1.00M, $[PCl_3]$=0.000784M, while K=1.3×10^{-29}. Calculate $[S_8]$.

$$8PSCl_3(g) \rightleftharpoons 8PCl_3(g) + S_8(g)$$

a. 1.00 M b. 1.6×10^{-26} M
c. 9.5×10^{-5} M d. 94.88 M

4. Calculate the equilibrium constant for the following rxn: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ knowing that: $[PCl_5]$=0.00325M, $[PCl_3]$=2.52M, and $[Cl_2]$=0.02175 M at equilibrium
a. 16.9 b. 0.0296 c. 33.7 d. 7.82

5. What is the equilibrium constant of the reverse rxn for the previous problem?
a. 0.059 b. 3.82 c. 5.81 d. 0.128

6. Which of the cpds of the following rxn would not appear in an equilibrium expression?
$AgNO_3(aq) + HCl(aq) \rightleftharpoons AgCl(s) + HNO_3(aq)$
a. HCl b. $AgNO_3$ c. AgCl d. HNO_3

7. 0.05 moles of PCl_5 and 5.00 moles of PCl_3 are introduced into an evacuated 1.00 L chamber. Calculate the equilibrium concentration of PCl_3, knowing that K = 33.3.

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

a. 0.0063 b. 5.04 c. 0.0453 d. 1.50

8. 0.125 mol of oxygen is added to carbon in a 0.250 L container. The mixture equilibrates at 500 K. Calculate the equilibrium concentration of carbon monoxide, knowing that K = 0.086

$$C(s) + O_2(g) \rightleftharpoons 2CO(g)$$

a. 0.19 b. 0.100 c. 1.00 d. 0.041

9. For a certain rxn, Q = 2.33, while K = 3.54. What do you expect to happen?
a. the rxn will proceed forward
b. the rxn will proceed backward
c. the rxn will proceed away from equilibrium
d. the direction cannot be determined

10. Calculate the equilibrium pressure of nitrogen dioxide when the equilibrium pressures of the nitric oxide and oxygen are 0.01 and 0.5 atm, respectively. Kp=10,000 at 200 K.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

a. 22.4 atm b. 0.707 atm c. 500 atm d. 3.98 atm

11. For the following rxn, calculate the concentration of C(aq) at equ. when 0.135M B sol'n is allowed to react with A.

$$A(l) + B(aq) \rightleftharpoons C(aq) + D(aq) \quad K=1.5\times10^{-10}$$

a. 0.01353 M b. 4.5×10^{-6} M
c. 0.203×10^{-10} M d. 2.03 M

12. Which of the following changes will not affect the equilibrium position of the following eqn?

$$A(g) + 4B(s) \rightleftharpoons 2C(g) + D(g) + E(s)$$

a. removal of A b. increase in pressure
c. addition of E d. addition of C

13. What would you change to increase the yield of the rxn in #12 if ΔH = -258 kJ?
a. add B b. decrease temperature
c. increase temperature d. remove E

14. A 325 L sample of a gas at 80.0°C is heated until a final volume of 32.5 L is reached. What is the final temp of the gas at constant pressure?
a. 3.53×10^{4} K b. 151 K
c. 1.08×10^{3} K d. 1.34×10^{3} K

15. A 50.0 L cylinder at temp of 47°C and a pressure of 50.0 atm contains how many molecules of gas per mL?
a. 5.73×10^{22} b. 2.30×10^{22}
c. 2.30×10^{19} d. 6.75×10^{18}

16. A 50.0 L cylinder of Cl_2 at 20.0°C and a pressure of 103, 401 torr springs a leak. The following day the pressure is found to be 41,361 torr. How many moles of chlorine gas escaped during this time?
a. 170 mol b. 280 mol c. 85.0 mol d. 113 mol

17. Tin reacts with HCl to produce H_2 and tin(II) chloride. How many liters of H_2 are produced at 27°C and a pressure of 710 torr, if 2.80 g of tin reacts with excess HCl?

$$Sn(s) + 2HCl(aq) \rightarrow SnCl_2(aq) + H_2(g)$$

a. 0.620 L b. 0.320 L c. 2.00 L d. 1.25 L

18. Calculate the final pressure, in atm, after 9.06 g of krypton reacts with 10.0 g of fluorine at 300 K in a 10.0 L container.

$Kr(g) + F_2(g) \rightarrow KrF_2(s)$

a. 0.591atm b. 0.384atm c. 0.700atm d. 1.90atm

19. Calculate the density, in g/L, of $SO_2(g)$ at 37®C and a pressure of 1440 torr.

a. 6.0 g/L b. 15.0 g/L c. 2.38 g/L d. 4.76 g/L

20. Calculate the total pressure, in atm, for three different gases at partial pressures of 144.0 cm, 800.0 mm, and 1.3 m Hg.

a. 1.90 atm b. 2.58 atm c. 1.06 atm d. 4.66 atm

21. Gas A diffuses twice as fast as gas B. Gas B has a molecular weight = 60.0 g/mol. What is the molar mass of gas A?

a. 15.0g/mol b. 120g/mol c. 30g/mol d. 90g/mol

22. The rate of effusion of freon-12 to freon-11 is 1.07:1. The molar mass of freon-11 is 137.4 g/mol. Calculate the molar mass in g/mol, of freon-12.

a. 100 b. 182 c. 121 d. 118

M1C ans key (solutions)

(3) $8PSCl_3 \rightleftharpoons 8PCl_3 + S_8$

I			
C			
E	1.00	.000784	?

$$K_p = \frac{[PCl_3]^8[S_8]}{[PSCl_3]^8} = 1.3\times10^{-29}$$

$$\frac{(.000784)^8(x)}{(1)^8} = 1.3\times10^{-29}$$

$$1.3\times10^{-29} = 1.427\times10^{-25}(x)$$

$$\boxed{x = 9.1\times10^{-5}\ M}$$

(4) $K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]}$

$$K_c = \frac{(2.52)(0.02175)}{0.00325} = \boxed{16.9}$$

(5) $K' = \frac{1}{K_c} = \frac{1}{16.9} = \boxed{0.059}$

(8) not included in K_{eq} ⇒ ignore it

$$C(s) + O_2(g) \rightleftharpoons 2CO(g)$$

I	—	$\frac{.125\ mol}{.250\ L}$	0
C	—	$-x$	$+2x$
E	—	$0.5-x$	$2x$

$$K = 0.086 = \frac{(2x)^2}{.5-x}$$ assume x is small

$$4x^2 = (.5-0)(.086)$$

$$x^2 = \frac{0.043}{4} \Rightarrow x = 0.10\,M$$

$$[CO]_{eq} = 2x = 2(0.10\,M) = \boxed{0.20\,M}$$

(10)

	$2NO$	$+ O_2$	$\rightleftharpoons 2NO_2$
I	.01	.5	0
C	$-2x$	$-x$	$+2x$
E	$.01-2x$	$.5-x$	$2x$

$$K_P = 10{,}000 = \frac{P_{NO_2}^2}{P_{NO}^2 P_{O_2}}$$

(10)

$$2NO + O_2 \rightleftharpoons 2NO_2$$

I			
C			
E	.01	.5	

$$K_P = 10{,}000 = \frac{(P_{NO_2})^2}{(.01)^2(0.5)} \Rightarrow \boxed{P_{NO_2} = 0.707\ atm}$$

(11) $A(s) + B(aq) \rightleftharpoons C(aq) + D(aq)$ ← does not affect K_{eq} ⇒ ignore it

I	—	.135	0	0
C	—	−x	+x	+x
E	—	.135 − x	x	x

$K = 1.5 \times 10^{-10} = \frac{(x)(x)}{.135 - x}$ assume x is small

$x^2 = 2.025 \times 10^{-11} \Rightarrow$ **$x = 4.5 \times 10^{-6}$ M**

(14) $V_1 = 325\,L$

$T_1 = 80^\circ C \xrightarrow{+273} 353K$

$V_2 = 32.5\,L$

$T_2 = ?$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_1 T_2 = V_2 T_1$$

$$T_2 = \frac{V_2 T_1}{V_1} = \frac{(32.5L)(353K)}{325L}$$

$$\boxed{T_2 = 35.3K}$$

(15) $V = 50\ L$

$t = 47^\circ C \xrightarrow{+273} 320\ K$

$P = 50\ atm$

? molecules per mL

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(50\ atm)(50\ L)}{\left(.0821 \frac{L\ atm}{mol\ K}\right)(320\ K)}$$

$$n = 95.2\ mol$$

$$95.2\ mol \left| \frac{6.02 \times 10^{23}\ molecules}{1\ mol} \right. = 5.73 \times 10^{25}\ molecules$$

$$\frac{molecules}{mL} = \frac{5.73 \times 10^{25}\ molecules}{50{,}000\ mL}$$

$$\boxed{\frac{molecules}{mL} = 1.1 \times 10^{21}}$$

this does not match an answer choice

sorry! there must be a mistake

(16) $V = 50\ L$

$T = 20^\circ C \xrightarrow{+273} 293K$

$P_1 = 103,401\ torr \xrightarrow{\div 760} 136.05\ atm$

$P_2 = 41,361\ torr \xrightarrow{\div 760} 54.42\ atm$

$$PV = nRT$$

$$\frac{n}{P} = \frac{V}{RT} = constant$$

Therefore, $\frac{n_1}{P_1} = \frac{n_2}{P_2}$

$$n_1 = \frac{P_1 V_1}{RT_1} = \frac{(136.05\ atm)(50\ L)}{\left(.0821 \frac{L \cdot atm}{mol \cdot K}\right)(293K)}$$

$$n_1 = 282.8\ moles$$

$$\frac{n_1}{P_1} = \frac{n_2}{P_2}$$

$$n_1 P_2 = n_2 P_1$$

$$n_2 = \frac{n_1 P_2}{P_1} = \frac{(282.8\ mol)(54.42\ atm)}{136.05\ atm}$$

$$n_2 = 113.12\ mol$$

$$n_1 - n_2 = 282.8\ mol - 113.12\ mol$$

$$= \boxed{169.68\ mol}$$

(17)

$$Sn(s) + 2HCl(aq) \rightarrow SnCl_2(aq) + H_2(g)$$

2.80 g — ? L

27°C = 300 K

710 torr → .934 atm

$$2.80\text{ g Sn} \left|\frac{1\text{ mol Sn}}{119\text{ g Sn}}\right|\left|\frac{1\text{ mol } H_2}{1\text{ mol Sn}}\right| = 0.0235\text{ mol } H_2$$

$$n = \frac{PV}{RT} \qquad \frac{PV = nRT}{P} = \frac{(.0235\text{ mol})\left(.0821\frac{L\cdot atm}{mol\cdot K}\right)(300\text{ K})}{0.934\text{ atm}}$$

$$= \boxed{0.62\text{ L}}$$

(18)

$$Kr + F_2 \rightarrow KrF_2(s)$$

300 K, 10.0 L, P_T = ?

9.06 g ÷ 84 g/mol = .108 mol (limiting (R))

10.0 g ÷ 38 g/mol = .263 mol

.263 mol − .108 mol = 0.155 mol excess gas = n

$P_T = P_{F_2}$ b/c Kr is completely consumed

$$PV = nRT \qquad P = \frac{nRT}{V} = \frac{(.155\text{ mol})\left(.0821\frac{L\cdot atm}{mol\cdot K}\right)(300\text{ K})}{10\text{ L}}$$

$$\boxed{P = 0.38\text{ atm}}$$

(19) ? g/L of $SO_{2(g)}$

at 37°C & 1440 torr $\xrightarrow{\div 760}$ 1.89 atm

310 K

$n = \frac{m}{M}$

$PV = nRT$

$PV = \frac{m}{M}RT$

$PVM = mRT$

$\frac{m}{V} = \frac{PM}{RT}$

$\frac{m}{V} = \frac{(1.89\,atm)(64\,g/mol)}{(.0821\,\frac{L\cdot atm}{mol\cdot K})(310\,K)} = \boxed{4.75\,g/L}$

(20) P_T = ? atm

P_1 = 144 cm Hg $\xrightarrow{10\,mm = 1\,cm}$ 1440 mm Hg

P_2 = 800 mm Hg $\rightarrow$ 800 mm Hg

P_3 = 1.3 m Hg $\xrightarrow{1000\,mm = 1\,m}$ 1300 mm Hg

$P_T = P_1 + P_2 + P_3 = 3540$ mm Hg $\xrightarrow{\div 760}$ $\boxed{4.66\,atm}$

(21)

$$\frac{rate_A}{rate_B} = \sqrt{\frac{M_B}{M_A}}$$

$$\frac{2}{1} = \sqrt{\frac{M_B}{60\ g/mol}}$$

$$4 = \frac{M_B}{60}$$

$$\boxed{M_B = 240\ g/mol}$$

$$\frac{2}{1} = \sqrt{\frac{60\ g/mol}{M_A}}$$

$$4 = \frac{60}{M_A}$$

$$\frac{4 \cdot M_A}{4} = \frac{60}{4}$$

$$\boxed{M_A = 15\ g/mol}$$

(22)

$$\frac{rate_{12}}{rate_{11}} = \sqrt{\frac{137.4\ g/mol}{M_{12}}}$$

$$\frac{1.07}{1} = \sqrt{\frac{137.4}{M_{12}}}$$

$$1.14 = \frac{137.4}{M_{12}}$$

$$1.14 \times M_{12} = 137.4$$

$$\boxed{M_{12} = 120.5\ g/mol}$$

FREE RESPONSE SECTION Name_____

I. 1.0 L of hydrogen gas is collected over water at 308 K at a pressure of 728 torr when iron reacts with excess hydrochloric acid.

a) What is the balanced equation for this reaction given that iron will have an oxidation state of +2 when it bonds to chloride?

b) What is the partial pressure of hydrogen gas if the vapor pressure of water is 42.2 torr at 308 K?

c) How many moles of hydrogen gas was produced?

d) How many grams of iron must have reacted?

e) Suppose a student accidentally used the wrong temperature, say 25°C, when he/she was looking up the value for the vapor pressure of water. How would this affect the calculated value for the number of moles of oxygen gas produced? Justify your answer.

II. $HF(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + F^-(aq)$ $K_a = 7.2 \times 10^{-4}$

Hydrofluoric acid, HF(aq), dissociates in water as represented by the equation above.

a) Write the equilibrium-constant expression for the dissociation of HF(aq) in water.

b) Calculate the molar concentration of H_3O^+ in a 0.40 M HF(aq) solution.

HF(aq) reacts with NaOH(aq) according to the reaction represented below.

$$HF(aq) + OH^- \rightarrow H_2O(l) + F^-(aq)$$

A volume of 15 mL of 0.40 M NaOH is added to 25 mL of 0.40 M HF(aq) solution. Assume that volumes are additive.

c) Calculate the number of moles of HF(aq) remaining in the solution.

d) Calculate the molar concentration of $F^-(aq)$ in the solution.

III. Give the balanced, net ionic equations for the following reactions and then answer the question that follows.

a) Sulfur trioxide gas is added to excess water.

What is the name of the product formed?

b) Solid magnesium carbonate is heated.

Classify this reaction.

c) Chlorine gas is bubbled into a solution of sodium bromide.

What are the oxidation states of each halogen before and after the reaction?

(30pts) Free Response Soln's

I. (a) $Fe + 2HCl \rightarrow H_2 + FeCl_2$ (1pt)

1.0 L, 308 K, (728 torr) $\div 760 \rightarrow .958$ atm

(b) $P_{H_2} = ?$ if $P_{H_2O} = (42.2 \text{ torr}) \div 760 \rightarrow .0555$ atm

$P_{H_2} = P_T - P_{H_2O}$

$P_{H_2} = .958 \text{ atm} - .0555 \text{ atm} = \boxed{0.90 \text{ atm}}$ (2pt)

(c) $n_{H_2} = ?$

$$n_{H_2} = \frac{P_{H_2} V}{RT} = \frac{(0.90 \text{ atm})(1.0 \text{ L})}{\left(.0821 \frac{\text{L-atm}}{\text{mol-K}}\right)(308 \text{ K})} = 0.0356 \text{ mol}$$

$\boxed{n_{H_2} = 0.036 \text{ mol}}$ (1pt)

(d) $$0.036 \text{ mol } H_2 \left| \frac{1 \text{ mol Fe}}{1 \text{ mol } H_2} \right| \frac{56 \text{ g Fe}}{1 \text{ mol Fe}} = \boxed{2.0 \text{ g Fe}}$$ (1pt)

(e) This temp would be lower.

$n = \frac{PV}{RT}$ ← If smaller, then $\boxed{n \text{ would be bigger}}$ (1pt)

— OR —

low T ⇒ low P_{H_2O} ⇒ too high of a P_{H_2} calculation ⇒ since P is in the numerator ⇒ n would be too high

II. (a) $K = \dfrac{[H_3O^+][F^-]}{[HF]}$ (1pt)

does not affect Keq. Ignore it.

(b)

$$HF + H_2O_{(l)} \rightleftharpoons H_3O^+ + F^-$$

			0	0
I	0.4	—	+x	+x
C	−x	—	x	x
E	0.4−x	—		

$K = 7.2\times10^{-4} = \dfrac{x^2}{.4-x}$ assume x is small

$x^2 = 2.88\times10^{-4}$

$x = \boxed{0.017M = [H_3O^+]}$ (3pt)

(c)

$$HF + OH^- \rightarrow H_2O + F^-$$

HF: 25mL, 0.4M, M×L = .01 mol

OH^-: 15mL, 0.4M, M×L = .006 mol ← limiting (R) (1pt)

.006 mol reacts because 1:1 ratio (1pt)

? mol HF remaining

excess HF = .01 mol − .006 mol = $\boxed{0.004 mol}$ (1pt)

(d) $[F^-] = ?$

1 mol OH^- : 1 mol F^- ⟹ .006 mol of F^- produced (1pt)

$\dfrac{.006 mol}{25mL+15mL} = \dfrac{.006 mol}{.04L} = \boxed{0.015M}$ (1pt)

III. (a) $\overset{+6\ -6}{SO_3} + H_2O \rightarrow \cancel{H_2}\overset{+2\ +6\ -8}{\cancel{SO_4}}$ $2H^+ + SO_4^{2-}$

5pts

sulfuric acid

(b) $MgCO_{3(s)} \rightarrow MgO + CO_2$

5pts

Decomposition

(c) $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$

5pts

Cl: $0 \rightarrow -1$

Br: $-1 \rightarrow 0$