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CHEMISTRY 12: **PRACTICE EQUILIBRIUM TEST**

PART 1 - Multiple Choice *Choose the letter that corresponds to the best answer.*

B 1. Given this system: $4\ HCl_{(g)} + O_{2(g)} \leftrightarrow 2\ H_2O_{(g)} + 2\ Cl_{2(g)} + 98\ kJ$
The equilibrium will shift to the right as a result of
a) adding a catalyst
b) removing Cl_2
c) increasing the volume
d) increasing the temperature

B 2. Consider the following equilibrium: $N_{2(g)} + 3\ H_{2(g)} \leftrightarrow 2\ NH_{3(g)}$ $\Delta H = -92\ kJ$ EXO

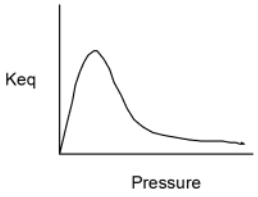
When the temperature is increased, the equilibrium shifts to the
a) left and Keq increases.
b) left and Keq decreases.
c) right and Keq increases.
d) right and Keq decreases.

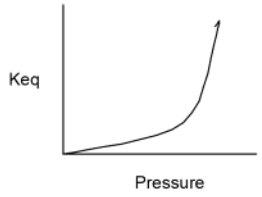
D 3. Consider the following reaction at equilibrium: $CO_{(g)} + H_2O_{(g)} \leftrightarrow CO_{2(g)} + H_{2(g)} + \text{energy}$

Some H_2O is removed from the equilibrium system at constant volume and a new equilibrium is established. Compared to the original equilibrium, the rates of the forward and reverse reactions for the new equilibrium have

	Forward Rate	Reverse Rate
a)	Increased	Decreased
b)	Increased	Increased
c)	Decreased	Increased
d)	Decreased	Decreased

D 4. The relationship between Keq and the pressure of a gaseous equilibrium at constant temperature can be described by

a)


c)


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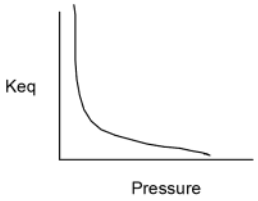

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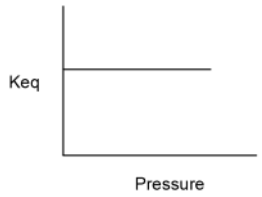
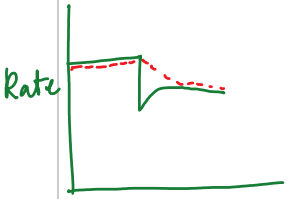
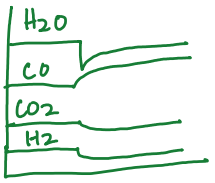






C 5. An indication that an equilibrium system favors the reactants is a
a) large Keq c) small Keq
b) positive ΔH d) low activation energy

B 6. Which procedure causes an increase in the value of Keq for the following reaction?
$CaCO_{3\,(s)} \leftrightarrow CaO_{(s)} + CO_{2(g)}$ $\Delta H = -74.8$ kJ
a) Increase the volume c) Increase the temperature
b) Decrease the temperature d) Finely powder the $CaCO_{3\,(s)}$

D 7. What is the equilibrium constant expression for the following reaction?
$3 Fe_{(s)} + 4 H_2O_{(g)} \leftrightarrow Fe_3O_{4(s)} + 4 H_{2(g)}$

a) $\frac{[Fe_3O_4][H_2]^4}{[Fe]^3[H_2O]^4}$ b) $\frac{[Fe]^3[H_2O]^4}{[Fe_3O_4][H_2]^4}$ c) $\frac{[H_2O]^4}{[H_2]^4}$ d) $\frac{[H_2]^4}{[H_2O]^4}$

A 8. Which of the following equilibria, all at the same temperature, favors the products to the GREATEST extent.
a) $H_2\,(g) + I_2\,(g) \leftrightarrow 2\,HI\,(g)$ Keq = 55
b) $2\,HCl\,(g) \leftrightarrow H_2\,(g) + Cl_2\,(g)$ Keq = 1.5×10^{-3}
c) $CO_2\,(g) + H_2\,(g) \leftrightarrow CO(g) + H_2O(g)$ Keq = 1.6×10^{1}
d) $N_2\,(g) + O_2\,(g) \leftrightarrow 2\,NO\,(g)$ Keq = 0.087

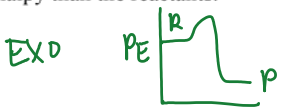
B 9. Consider the following equilibrium system:
$2\,O_3\,(g) \leftrightarrow 3\,O_2\,(g)$; Keq = 55
If 0.060 mol of O_3 and 0.30 mol of O_2 are introduced into a 1.0 L vessel, the
a) Keq < Q and the $[O_2]$ increases as equilibrium is established.
b) Keq > Q and the $[O_2]$ increases as equilibrium is established.
c) Keq < Q and the $[O_2]$ decreases as equilibrium is established.
d) Keq > Q and the $[O_2]$ decreases as equilibrium is established.

D 10. In an endothermic equilibrium system, the
a) minimum enthalpy and maximum entropy both favor products.
b) minimum enthalpy and maximum entropy both favor reactants.
c) minimum enthalpy favors products and maximum entropy favors reactants.
d) minimum enthalpy favors reactants and maximum entropy favors products.

PART 2 - *Answer true (T) ["A" on your Scantron] or false (F) ["B" on your Scantron] for each of the following statements based on the reaction:*

$2\,SO_{3(g)} \leftrightarrow 2\,SO_{2(g)} + O_{2(g)} + 215$ kJ

F 11. After equilibrium is established, increasing the concentration of SO_2 causes an increase in the concentration of O_2.
F 12. Adding more SO_3 to the equilibrium system causes Keq to change.
T 13. Increasing the temperature increases the rate of the forward reaction.
F 14. The addition of a catalyst increases the yield of the product.
T 15. The products have more entropy than the reactants.
F 16. The products have more enthalpy than the reactants.



PART 3 - Written Answers *Answer the following questions:*

17. $PCl_5\,(s) + H_2O\,(g) \rightleftarrows 2\,HCl\,(g) + POCl_3\,(g)$

Predict the effect on the position of the equilibrium (which way will the shift be) for (1 mark each):

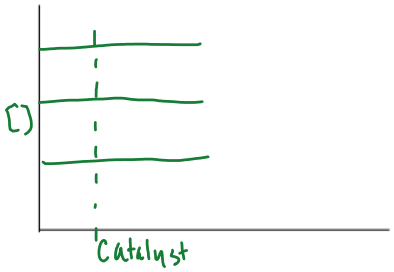
a) decreased volume left

b) increased concentration of $POCl_3$ left

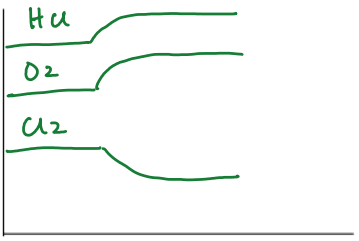
18. Show the following situations graphically (concentration vs. time graph). (2 marks each)

$2\,HCl_{(g)} + O_{2\,(g)} \rightleftarrows H_2O_{(l)} + Cl_{2\,(g)} + 98\ kJ$

a) adding a catalyst



b) increasing temperature



PART 4 – Calculations *Show all work for full marks.*

19. $2\,NO\,(g) + O_2\,(g) \leftrightarrow 2\,NO_2\,(g)$

At 227°C in a 2.00 L container there are 0.266 mol NO, 0.120 mol O_2, and 2.320 mol NO_2 at equilibrium. Calculate the equilibrium constant. (3 marks)

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]} = \frac{(2.320\ mol/2.00L)^2}{(0.266\ mol/2.00L)^2(0.120\ mol/2.00L)} = 1270$$

20. $2\,NO_2\,(g) \leftrightarrow N_2O_4\,(g)$

At 55°C, Keq for the above reaction is 1.15. If initially there is $[NO_2] = 0.60$ M and $[N_2O_4] = 0.60$ M, determine if the equilibrium shifts or if it is at equilibrium. (3 marks)

use Q

$$Q = \frac{[N_2O_4]}{[NO_2]^2} = \frac{(0.60)}{(0.60)^2} = 1.67$$

$$K_{eq} = \frac{[N_2O_4]}{[NO_2]^2} = 1.15$$

$K_{eq} < Q$

1.15 1.67

Shifts left

21. $4\ NH_3\ (g) + 5\ O_2\ (g) \leftrightarrow 4\ NO\ (g) + 6\ H_2O\ (g)$

In a 2.00 L flask, 4.00 mol of NH_3 and 5.00 mol of O_2 are placed and allowed to come to equilibrium. When the equilibrium is established, it is found that the [NO] is 0.960 M. From this information, calculate Keq. (4 marks)

R	$4NH_3$	+	$5O_2$	⇌	$4NO$	+	$6H_2O$
I	2.00 M		2.50 M		0		0
C	$-4x$		$-5x$		$+4x$		$+6x$
E	$2.00-4x$		$2.50-5x$		$4x$		$6x$
	$=2.00-4(0.24)$		$=2.50-5(0.24)$		$=0.960$		$=6(0.24)$
	$=1.04$		$=1.30$				$=1.44$

$\frac{4x}{4} = \frac{0.960}{4}$

$x = 0.24$

$K_{eq} = \frac{[NO]^4[H_2O]^6}{[NH_3]^4[O_2]^5} = \frac{(0.960)^4(1.44)^6}{(1.04)^4(1.30)^5} = \boxed{1.74}$

22. $H_2\ (g) + I_2\ (g) \leftrightarrow 2\ HI\ (g)$; Keq = 1.00×10^2

Equal moles of H_2 and I_2 are placed in a 1.00 L container. At equilibrium, the [HI] = 0.22 M. Calculate the initial $[H_2]$. (3 marks)

R	H_2	+	I_2	⇌	$2HI$
I	y		y		0
C	$-x$		$-x$		$+2x$
E	$y-x$		$y-x$		$2x$
	$=y-0.11M$		$=y-0.11M$		$=0.22M$

$\frac{2x}{2} = \frac{0.22M}{2}$

$x = 0.11M$

$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = 100$

$\sqrt{\frac{(0.22)^2}{(y-0.11)^2}} = \sqrt{100}$

$\frac{0.22}{y-0.11} = 10$

$0.22 = 10(y-0.11)$

$0.22 = 10y - 1.1$

$0.22 + 1.1 = 10y$

$1.32 = 10y$

$\frac{1.32}{10} = y$

$0.132 = y$

∴ Initial $[H_2] = \boxed{0.13M}$

23. $CO\,(g) + H_2O\,(g) \leftrightarrow CO_2\,(g) + H_2\,(g)$

Into a 1.00 liter flask, 0.750 moles of each of the reactants and 1.20 moles of each of the products are placed. If the equilibrium constant for this reaction is 2.00, calculate the concentration of CO at equilibrium. (5 marks)

	CO	$+\ H_2O$	$\rightleftharpoons\ CO_2$	$+\ H_2$
I	0.750	0.750	1.20	1.20
C	$+x$	$+x$	$-x$	$-x$
E	$0.750+x$	$0.750+x$	$1.20-x$	$1.20-x$

← use Q to determine direction of shift.

$$Q = \frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{(1.20)^2}{(0.750)^2} = 2.56$$

$K_{eq} < Q$ ∴ shifts left

$$2.00 < 2.56$$

$$K_{eq} = \frac{[CO_2][H_2]}{[CO][H_2O]} = 2.00$$

$$\sqrt{\frac{(1.20-x)^2}{(0.750+x)^2}} = \sqrt{2.00}$$

$$\frac{(1.20-x)}{(0.750+x)} = \sqrt{2.00}\,(0.750+x)$$

$$1.20 - x = 1.06066 + 1.41421x$$

$$\frac{0.13934}{2.41421} = \frac{2.41421x}{2.41421}$$

$$0.0577\ M = x$$

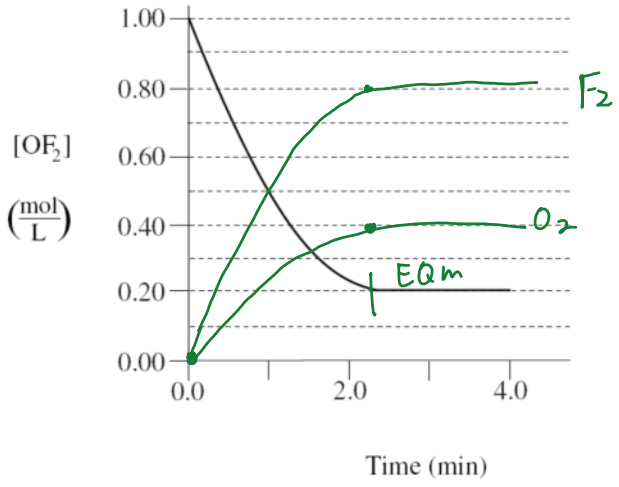
$[CO]$ @ EQM $= 0.750 + x$

$= 0.750 + 0.0577$

$= \boxed{0.808\ M}$

24. Consider the following equilibrium: $O_{2(g)} + 2\ F_{2(g)} \leftrightarrow 2\ OF_{2(g)}$

Initially, some OF_2 was placed in a 1.0 L container and allowed to react. The amount of OF_2 was monitored over 4 minutes and the following graph was produced:



R	O_2	$+2F_2$	$\rightleftharpoons$	$2OF_2$
I	0	0		1.00
C	+x	+2x		−2x
E	x	2x		= 0.20
	= 0.40	= 2(0.40)		
		= 0.80		

$1.00 - 2x = 0.20$

$\frac{-2x}{-2} = \frac{-0.80}{-2}$

$x = 0.40$

$$K_{eq} = \frac{[OF_2]^2}{[O_2][F_2]^2} = \frac{(0.20)^2}{(0.40)(0.80)^2} = 0.16$$

a. Calculate the value of Keq.

b. Add lines representing the changes in concentration for both O_2 and F_2 over the same 4-minute time interval.