Chemistry 12

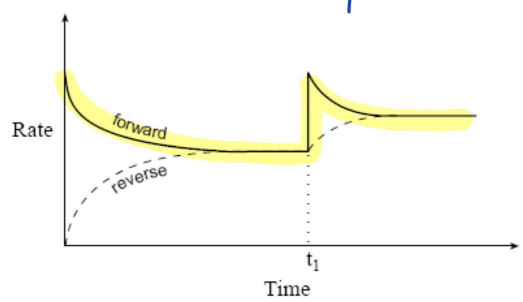
Equilibrium Review Package

Name: Key
Date:
Block:

I. <u>Multiple Choice</u>:

1. Consider the rate diagram below for the following reaction:

$$2\,HI_{(g)} \leftrightharpoons H_{2(g)} + I_{2\,(g)}$$



Which of the following occurs at time t_1?

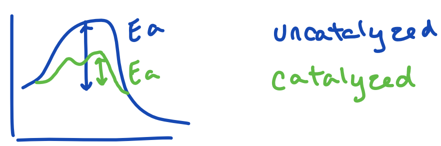
A. addition of H_2
B. addition of HI
C. addition of a catalyst
D. a decrease in volume

2. Chemical equilibrium is said to be dynamic because:

A. the reaction proceeds quickly.
B. the mass of the reactants is decreasing.
C. the macroscopic properties are constant.
D. both forward and reverse reactions are occurring.

3. Which reaction characteristics are changed by the addition of a catalyst to a reaction at constant temperature?

I. Activation energy
II. Equilibrium concentrations
III. Reaction enthalpy



A. I only
B. III only
C. I and II only
D. I, II and III

4. Given the following system:

$$2\,CrO_4{}^{2-}{}_{(aq)} + 2\,H^+{}_{(aq)} \leftrightharpoons Cr_2O_7{}^{2-}{}_{(aq)} + H_2O_{(l)}$$

Which of the following chemicals, when added to the above system at equilibrium, would result in a decrease in $[CrO_4{}^{-2}]$?

A. NaOH
B. HNO_3
C. Na_2CrO_4
D. Na_2Cr_2O7

5. Addition of a catalyst to an equilibrium system:

A. increases the value of K_{eq}
B. increases the yield of products.
C. has no effect on the rates of reaction.
D. increases the rate of formation of both reactants and product

6. Consider the following reaction:

$$2B_{(s)} + 3F_{2\,(g)} \leftrightharpoons 2BF_{3\,(g)}$$

The equilibrium expression is:

A. $K_{eq} = \frac{[2BF_3]}{[3F_2]}$

B. $K_{eq} = \frac{[F_2]^3}{[BF_3]^2}$

C. $K_{eq} = \frac{[BF_3]^2}{[F_2]^3}$

D. $K_{eq} = \frac{[BF_3]^2}{[B]^2[F_2]^3}$

7. The value of K_{eq} can be changed only by:

A. adding a catalyst.
B. changing the temperature.
C. changing the reactant concentration.
D. changing the volume of the container.

8. Consider the following equilibrium:

$$PCl_{3\,(g)} + Cl_{2\,(g)} \leftrightharpoons PCl_{5(g)}$$

When 0.40 mol of PCl_3 and 0.40 mol of Cl_2 are placed in a 1.00 L container and allowed to reach equilibrium, 0.244 mol of PCl_5 are present. From this information, the value of K_{eq} is

A. 0.10 B. 0.30 C. 3.3 D. 10

9. Consider the following equilibrium:

$$PCl_{5(g)} \leftrightharpoons PCl_{3\,(g)} + Cl_{2\,(g)} \qquad K_{eq} = 2.30$$

A 1.0 L container is filled with 0.05 mol PCl_5, 1.0 mol PCl_3, and 1.0 mol Cl_2. The system proceeds to the:

A. left because Trial $K_{eq} > K_{eq}$
B. left because Trial $K_{eq} < K_{eq}$
C. right because Trial $K_{eq} > K_{eq}$
D. right because Trial $K_{eq} < K_{eq}$

10. A sample of $X_{(g)}$ is placed in a vessel and brought to equilibrium according to the reaction:

$$X_{(g)} \leftrightharpoons Y_{(g)}$$

When the temperature is decreased, the concentration of Y in the reaction vessel increases. Which of the following could explain this observation?

A. The molecules are colliding with less energy, ~~so the reaction shifts to the right~~.
B. The reaction is endothermic, so when the temperature is decreased, the reaction shifts to the right.
C. When the temperature is decreased, the value of K_{eq} increases, so the reaction shifts to the right.
D. When the temperature is decreased, the ~~value of Trial K_{eq} also decreases,~~ so the reaction shifts to the right.

11. Consider the following equilibrium:

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

Nitrogen gas and oxygen gas react when placed in a closed container. As the reaction proceeds towards equilibrium, the rate of the reverse reaction:

A. increases as the [ ] of products decreases.
B. decreases as the [ ] of products decreases.
C. increases as the [ ] of products increases.
D. decreases as the [ ] of products increases.

12. Consider the following equilibrium:

$$2NO_{2\,(g)} \leftrightharpoons N_2O_{4\,(g)} + 59\text{ kJ}$$

For the above reaction:

A. both min. enthalpy and max. entropy favour products.
B. both min. enthalpy and max. entropy favour reactants.
C. min. enthalpy favours reactants and max. entropy favours products.
D. min. enthalpy favours products and max. entropy favours reactants.

13. Consider the following equilibrium:

$$2HI_{\,(g)} \leftrightharpoons H_{2\,(g)} + I_{2\,(g)}$$

At constant temperature and volume, more I_2 is added to the above equilibrium. A new state of equilibrium results from a shift to the:

A. left with a net decrease in $[H_2]$.
B. left with a net increase in $[H_2]$.
C. right with a net increase in $[H_2]$.
D. right with a net decrease in $[H_2]$.

14. Consider the following equilibrium:

$$2NOCl_{\,(g)} \leftrightharpoons 2NO_{\,(g)} + Cl_{2\,(g)}$$

In a 1.0 L container at equilibrium there are 1.0 mol NOCl, 0.70 mol NO and 0.40 mol Cl_2. At constant temperature and volume, 0.10 mol NOCl is added. The concentrations in the "new" equilibrium in comparison to the concentrations in the "old" equilibrium are:

	[NOCl]	[NO]	$[Cl_2]$
A.	new = old	new = old	new = old
B.	new > old	new > old	new > old
C.	new < old	new < old	new > old
D.	new < old	new > old	new > old

15. Consider the following equilibrium:

$$2H_2O_{\,(g)} \leftrightharpoons 2H_{2\,(g)} + O_{2\,(g)}$$

When 0.1010 mol H_2O is placed in a 1.000 L container, equilibrium is established. The equilibrium concentration of O_2 is 0.0010M. The equilibrium concentrations of H_2O and H_2 are:

	$[H_2O]$	$[H_2]$
A.	0.0990	0.0020
B.	0.1000	0.0010
C.	0.1005	0.0005
D.	0.1010	0.0020

16. Consider the following equilibrium: $2CO_{(g)} + O_{2(g)} \leftrightharpoons 2CO_{2(g)}$
The ratio used to calculate the equilibrium constant is:

Keq

A. $\frac{[2CO]^2[O_2]}{[2CO_2]^2}$

B. $\frac{[2CO_2]^2}{[2CO]^2[O_2]}$

C. $\frac{[CO]^2[O_2]}{[CO_2]^2}$

D. $\frac{[CO_2]^2}{[CO]^2[O_2]}$

17. Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \leftrightharpoons CH_3OH_{(g)} + 91\ kJ$$

A change in temperature of the above system increases the value of the equilibrium constant. The new state of equilibrium was established by a shift: (shift right) Keq

A. left as a result of a decrease in temperature.
B. right as a result of a decrease in temperature.
C. left as a result of an increase in temperature.
D. right as a result of an increase in temperature.

18. Consider the following equilibrium:

$$H_{2(g)} + S_{(s)} \leftrightharpoons H_2S_{(g)}$$

$$Keq = \frac{(1.0M)}{(0.050M)}$$

In a 1.0 L container at equilibrium there are 0.050 mol H_2, 0.050 mol S and 1.0 mol H_2S. The value of K_{eq} is:

A. 2.5×10^{-3} B. 5.0×10^{-2} C. 2.0×10^{1} D. 4.0×10^{2}

19. Consider the following equilibrium: then

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

At high temperature, H_2O and CO are placed in a closed container. As the system approaches equilibrium, the:

A. rate of the forward and reverse reactions both increase.
B. rate of the forward and reverse reactions both decrease.
C. rate of the forward reaction decreases and the rate of the reverse reaction increases.
D. rate of the forward reaction increases and the rate of the reverse reaction decreases.

20. Consider the following equilibrium:

$$N_2O_{4(g)} + 58\ kJ \leftrightharpoons 2NO_{2(g)}$$

1 2

The equilibrium shifts right when:

A. NO_2 is added.
B. N_2O_4 is removed.
C. the temperature is decreased.
D. the volume of the system is increased.

Pressure ↓
↳ shifts to side w/ more particles

21. In an endothermic equilibrium system, the:

A. minimum enthalpy and the maximum entropy both favour products.
B. minimum enthalpy and the maximum entropy both favour reactants.
C. minimum enthalpy favours products and the maximum entropy favours reactants.
D. minimum enthalpy favours reactants and the maximum entropy favours products.

22. An equilibrium system shifts left when the temperature is increased. The forward reaction is

A. exothermic and ΔH is positive.
B. exothermic and ΔH is negative.
C. endothermic and ΔH is positive.
D. endothermic and ΔH is negative.

A ⇌ B + heat

23. Given the following equilibrium system:

$$Br_{2\,(g)} \leftrightharpoons Br_{2\,(l)}$$

The equilibrium constant expression for the above system is:

A. $K_{eq} = \frac{[Br_{2(l)}]}{[Br_{2(g)}]}$

B. $K_{eq} = [Br_{2(g)}]$

C. $K_{eq} = \frac{1}{[Br_{2(g)}]}$

D. $K_{eq} = [Br_{2(g)}][Br_{2(g)}]$

24. Consider the following equilibrium:

$$\text{heat} + PCl_{5\,(g)} \leftrightharpoons PCl_{3(g)} + Cl_{2\,(g)} \quad \Delta H = +92.5\ kJ$$

When the temperature decreases, the equilibrium:

A. shifts left and K_{eq} value increases.
B. shifts left and K_{eq} value decreases.
C. shifts right and K_{eq} value increases.
D. shifts right and K_{eq} value decreases.

25. Consider the following equilibrium: $CH_{4\,(g)} + H_2O_{\,(g)} \leftrightharpoons CO_{\,(g)} + 3\,H_{2\,(g)}$ $K_{eq} = 5.7$

At equilibrium, the $[CH_4]$ = 0.40M, $[CO]$ = 0.30M and $[H_2]$= 0.80M. The $[H_2O]$ = is:

A. 0.067M
B. 0.11M
C. 2.2M
D. 5.3M

$5.7 = \frac{(0.30M)(0.80M)^3}{(0.40)(x)}$

$2.28x = 0.1536$

$x = 0.067M$

26. Consider the following equilibrium:

$$2O_{3\,(g)} \leftrightharpoons 3O_{2(g)} \qquad K_{eq} = 55$$

If 0.060 mol of O_3 and 0.70 mol of O_2 are introduced into a 1.0 L vessel, the

A. Trial K_{eq} > K_{eq} and the $[O_2]$ increases.
B. Trial K_{eq} < K_{eq} and the $[O_2]$ increases.
C. Trial K_{eq} > K_{eq} and the $[O_2]$ decreases.
D. Trial K_{eq} < K_{eq} and the $[O_2]$ decreases.

Trial $K_{eq} = \frac{(0.060M)^3}{(0.70)^2}$

$= 95 > K_{eq}$

27. Macroscopic properties become constant in an equilibrium system when:

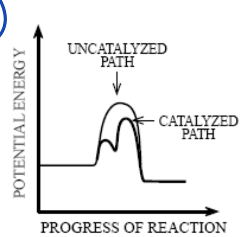
A. all reactions have stopped.
B. the reactants are completely used up.
C. maximum enthalpy has been reached.
D. forward and reverse reaction rates are equal.

28. In which of the following systems would the tendencies toward minimum enthalpy and maximum entropy be in opposition to each other?

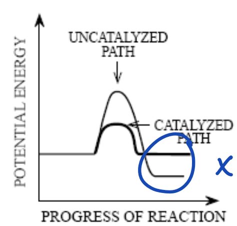
A. $Br_{2\,(l)}$ + heat ⇋ $Br_{2\,(g)}$
B. $NaOH_{(s)}$ ⇋ $Na^+_{(aq)}$ + $OH^-_{(aq)}$ + heat
C. $2\,C_{(g)} + 2\,H_{2\,(g)}$ ⇋ $C_2H_{4\,(g)}$ ΔH is positive
D. $2\,K_{(s)} + 2\,H_2O_{(l)}$ ⇋ $2\,K^+_{(aq)} + 2\,OH^-_{(aq)} + H_{2\,(g)}$ ΔH is negative

29. An uncatalyzed reaction was found to produce 40 kJ of energy in 10 minutes. When catalyzed, the same reaction produced 40 kJ of energy in 2 minutes. Which one of the following potential energy diagrams is consistent with the above data?

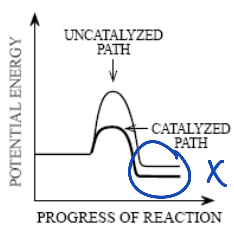
A.



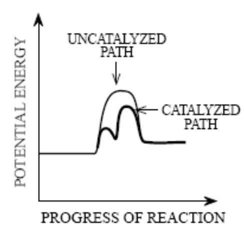
B.



C.



D.



30. Consider the following equilibrium system:

$$FeO_{(s)} + H_{2(g)} \leftrightharpoons Fe_{(s)} + H_2O_{(g)}$$

Which one of the following statements describes the effect that a decrease in volume would have on the position of equilibrium and the $[H_2]$ in the above system?

A. No shift, $[H_2]$ increases.
B. Shift right, $[H_2]$ increases.
C. Shift right, $[H_2]$ decreases.
D. No shift, $[H_2]$ remains constant.

31. Tooth enamel, $Ca_5(PO_4)_3OH$ establishes the following equilibrium:

$$Ca_5(PO_4)_3OH_{(s)} \leftrightharpoons 5\,Ca^{2+}_{(aq)} + 3PO_4^{3-}{}_{(aq)} + OH^-_{(aq)}$$

Which one of the following, when added to the above equilibrium system, would result in a shift to the right?

A. $H^+_{(aq)}$
B. $OH^-_{(aq)}$
C. $Ca^{2+}_{(aq)}$
D. $Ca_5(PO_4)_3OH_{(s)}$

32. An equal number of moles of $I_{2(g)}$ and $Br_{2(g)}$ are placed into a closed container and allowed to establish the following equilibrium:

$$I_{2(g)} + Br_{2(g)} \leftrightharpoons 2IBr_{(g)} \quad K_{eq} = 280$$

Which one of the following relates [IBr] to [I_2] at equilibrium?

A. [I_2] = [IBr]
B. [I_2] < [IBr]
C. [I_2] = 2[IBr]
D. [I_2] = 280[IBr]

change is proportional, conc. are not

$280 = \frac{[PRODUCTS]}{[reactants]}$

33. Consider the following equilibrium system:

$$2NO_{(g)} + O_{2(g)} \leftrightharpoons 2NO_{2(g)} \quad K_{eq} = 65$$

At equilibrium, the [NO] = 0.600 M and the [O_2] = 0.300 M. Using this data, the [NO_2] at equilibrium is:

A. 7.0 M B. 3.4 M C. 2.6 M D. 0.60 M

$65 = \frac{x^2}{(0.600)^2(0.300)}$

34. Consider the following equilibrium system:

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

1.00 mole of CO_2 and 2.00 moles of $H_{2(g)}$ are placed into a 2.00L container. At equilibrium, the [CO] = 0.31M. Based on this data, the equilibrium [CO_2] is:

A. 0.19 M B. 0.31 M C. 0.38 M D. 0.69 M

	CO_2	+ H_2	⇌ CO	+ H_2O
I	0.50M	1.00M	0M	0M
C	-0.31M	-0.31M	+0.31M	+0.31M
E	0.19M		0.31M	

35. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightharpoons 2\,HI_{(g)}$$

How will the forward and reverse equilibrium reaction rates change when additional H_2 is added to the system?

	Forward Rate	Reverse Rate
A.	increase	increase
B.	increase	decrease
C.	decrease	increase
D.	no change	no change

36. Consider the following system at equilibrium:

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

This equilibrium will shift right as the result of the addition of some extra H_2O. How will this shift affect the concentrations of the other gases?

	[CO]	[CO_2]	[H_2]
A.	increases	decreases	decreases
B.	increases	increases	decreases
C.	decreases	increases	increases
D.	decreases	decreases	increases

37. Consider the following equilibrium: 4 2

$N_{2(g)} + 3H_{2(g)} \leftrightharpoons 2NH_{3(g)}$

Which of the following factors will not alter the position of equilibrium?

A. a pressure decrease
B. a temperature increase
C. the presence of a catalyst
D. the addition of more $N_{2(g)}$

38. Which of the following is **least** likely to favour the formation of products?

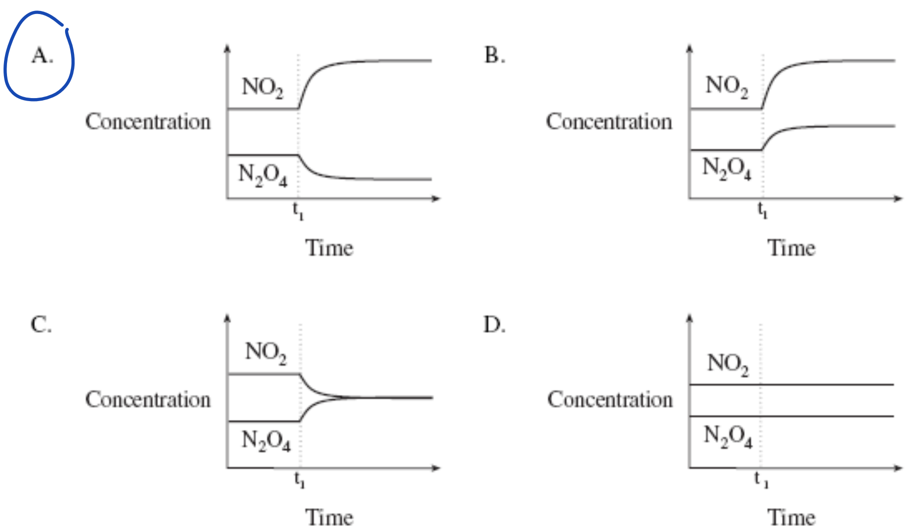
A. $2H_2O_{(g)} \leftrightharpoons 2\ H_{2(g)} + O_{2(g)}$ $K_{eq} = 7.3 \times 10^{-18}$
B. $N_2O_{(g)} + NO_{2(g)} \leftrightharpoons 3\ NO_{(g)}$ $K_{eq} = 4.2 \times 10^{-4}$
C. $N_2O_{4(g)} \leftrightharpoons 2NO_{2(g)}$ $K_{eq} = 4.5$
D. $SO_{2(g)} + NO_{2(g)} \leftrightharpoons NO_{(g)} + SO_{3(g)}$ $K_{eq} = 85$

Smallest Keq

39. Consider the following equilibrium:

$N_2O_{4(g)} + \text{energy} \leftrightharpoons 2NO_{2(g)}$

Which of the following graphs shows the result of increasing the temperature at time t_1?



40. Consider the following equilibrium and the table of experimental data:

$N_2O_{4(g)} + \text{energy} \leftrightharpoons 2NO_{2(g)}$

	Initial		Equilibrium	
	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$[NO_2]$
Trial 1	0.0400	0.0000	0.0337	0.0125
Trial 2	0.0200	0.0600	0.0429	0.0141

$Keq = \frac{(0.0125)^2}{(0.0337)} = 0.00464$

$Keq = \frac{(0.0141)^2}{(0.0425)} = 0.00464$

Which of the following represents the K_{eq} value?

A. 4.64×10^{-3}
B. 3.71×10^{-1}
C. 7.42×10^{-1}
D. 2.16×10^{2}

II. **Short Answers**:

1. Consider the following equilibrium system:

$$2NO_{(g)} + Cl_{2(g)} \leftrightharpoons 2NOCl_{(g)} \quad K_{eq} = 8.5$$

A closed flask is found to contain 0.40M $NO_{(g)}$, 0.32M $Cl_{2(g)}$ and 5.6M $NOCl_{(g)}$. Determine the direction the reaction proceeds to reach equilibrium.

Trial $K_{eq} = \frac{(5.6)^2}{(0.40)^2(0.32)} = 612.5 > 8.5$

Trial > K

Reaction shifts Left

2. Consider the following equilibrium system:

$$H_{2(g)} + I_{2(g)} \leftrightharpoons 2HI_{(g)}$$

The system is said to "shift right" as the result of the addition of **extra** $H_{2(g)}$. Describe the sequence of changes in both forward and reverse reaction rates as the system goes from the original equilibrium to the new equilibrium.

When $[H_2]\uparrow$, the forward rate $\uparrow$

↳ this makes $[HI]\uparrow$

↳ this makes the reverse rate $\uparrow$

At the newly re-established equilibrium, the forward & reverse rate are constant

3. Consider the following equilibrium system:

$$2COF_{2(g)} \leftrightharpoons CO_{2(g)} + CF_{4(g)} \quad K_{eq} = 2.00$$

A 2.00L container is filled with 0.500 mol of COF_2. Calculate the $[COF_2]$ at equilibrium.

	$2COF_2$	$\rightleftharpoons CO_2$	+ CF_4
I	0.25M	0M	0M
C	$-2x$	$+x$	$+x$
E	$0.25-2x$	x	x

$K_{eq} = \frac{[CO_2][CF_4]}{[COF_2]^2}$

$\sqrt{2.00} = \sqrt{\frac{x^2}{(0.25-2x)^2}}$

$1.414 = \frac{x}{0.25-2x}$

$0.35 - 2.8x = x$

$0.35 = 3.8x$

$x = 0.0923$

$[COF_2] = 0.25 - 2(x)$

$= 0.0653\,M$

4. Consider the following equilibrium system:

$$\text{heat} + Cu^{2+}_{(aq)} + 4Br^-_{(aq)} \rightleftarrows CuBr_4{}^{2-}_{(aq)}$$

blue *colourless* *green*

Cooling the equilibrium changes the colour from green to blue. What effect will the decrease in temperature have on K_{eq}? Explain, using Le Chatelier's Principle.

As the endothermic system is cooled, more reactants are being formed. This will decrease Keq

$K_{eq} = \frac{[\text{products}]}{[\text{REACTANTS}]}$

5. Consider the following:

$$CH_{4(g)} + H_2O_{(g)} \rightleftharpoons CO_{(g)} + 3H_{2(g)}$$

Initially, 0.0600 mol CH_4, 0.0800 mol H_2O, 0.280 mol CO and 0.740 mol H_2 are placed into a 4.00 L container. At equilibrium, the $[H_2]$ = 0.200M. What is the value of K_{eq}?

	CH_4	H_2O	CO	$3H_2$
I	0.015	0.020	0.070	0.185
C	-0.005	-0.005	+0.005	+0.015
E	0.010	0.015	0.075	0.200

$$K_{eq} = \frac{(0.075)(0.200)^3}{(0.010)(0.015)} = \boxed{4.00}$$

6. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)} \quad K_{eq} = 1.2 \times 10^{-2}$$

A 2.0 L flask is filled with 0.10 mol HI . Calculate the concentration of H_2 at equilibrium.

	H_2	I_2	2HI
I	0 M	0M	0.05M
C	+x	+x	-2x
E	x	x	0.05-2x

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

$$\sqrt{1.2 \times 10^{-2}} = \sqrt{\frac{(0.05-2x)^2}{x^2}}$$

$$0.1095x = 0.05 - 2x$$

$$2.1095x = 0.05$$

$$x = \boxed{0.024M = [H_2]}$$

7. A flask is initially filled with some HF. At equilibrium, the [HF]=0.80M. What is the $[H_2]$ at equilibrium?

$$2HF_{(g)} \rightleftharpoons H_{2(g)} + F_{2(g)} \qquad K_{eq} = 0.25$$

	2HF	H_2	F_2
I	x	0M	0M
C	-2y	+y	+y
E	0.80M	y	y

$$K_{eq} = \frac{[H_2][F_2]}{[HF]^2}$$

$$0.25 = \frac{y^2}{(0.80)^2}$$

$$0.16 = y^2$$

$$y = \boxed{0.40M = [H_2]}$$

Answers:

I. **Multiple Choice**:

1) B	11) C	21) D	31) A
2) D	12) D	22) B	32) B
3) A	13) A	23) C	33) C
4) B	14) B	24) B	34) A
5) D	15) A	25) A	35) A
6) C	16) D	26) C	36) C
7) B	17) B	27) D	37) C
8) D	18) C	28) A	38) A
9) A	19) C	29) A	39) A
10) C	20) D	30) A	40) A

II. **Short Answers**:

1) Equilibrium shifts left. Trial $K_{eq} = 6.1 \times 10^2$

2) When conc. of H_2 increases, rate forward increases. As time proceeds, more HI is produced, therefore, rate reverse will increase. At equilibrium, both rate forward and reverse are constant.

3) $[COF_2] = 0.0653M$

4) K_{eq} decreases

5) $K_{eq} = 4.00$

6) $[H_2] = 0.024M$

7) $[H_2]= 0.40M$