Equilibrium Homework Booklet Name Mr B Period________

how all work in the question booklet.

1. Which of the following applies to a chemical equilibrium:

I. Forward reaction rate = reverse reaction rate ✓
II. Equilibrium can be acheived in either direction. ✓
III. Macroscopic properties are constant. ✓
IV. [Reactant] = [Product] X

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

2. Which of the factors below is **not** a condition necessary for equilibrium?
A. equal forward and reverse reaction rates
B. a closed system
C. equal concentrations of reactants and products
D. a constant temperature

3. For the equilibrium system below:

$$Cu_{(s)} + 2\,Ag^{+1}{}_{(aq)} \leftrightarrows 2\,Ag_{(s)} + Cu^{+2}{}_{(aq)}$$

We would know the system is at equilibrium because
A. the mass of $Cu_{(s)}$ remains constant
B. the mass of the entire system remains constant   it would whether at equilibrium or not
C. $[Cu^{+2}] = [Ag^{+1}]$
D. $[Cu^{+2}] = 2[Ag^{+1}]$

4. Consider the following:

random ?

$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2NH_{3\,(g)} + \text{energy}$$

What positions do minimum enthalpy and maximum entropy tend towards?

	Minimum Enthalpy	Maximum Entropy
A.	products	~~products~~
B.	products	reactants
C.	~~reactants~~	~~products~~
D.	~~reactants~~	reactants

5. Consider the following:

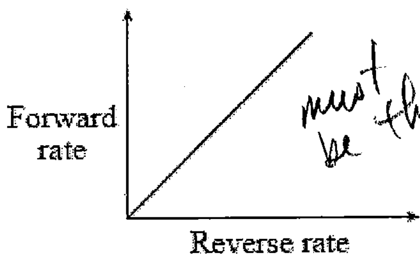
$$2N_{2(g)} + O_{2(g)} + \text{Energy} \overset{?}{\leftrightarrows} 2\,N_2O_{(g)}$$

What positions to minimum enthalpy and maximum entropy tend towards?

	Minimum Enthalpy	Maximum Entropy
A.	products	products
B.	reactants	products
C.	reactants	reactants
D.	products	reactants

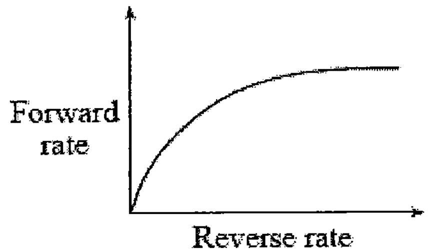
6. At different conditions, the relationship between the forward and reverse rates of reactions in an equilibrium system can be best represented by:

A.

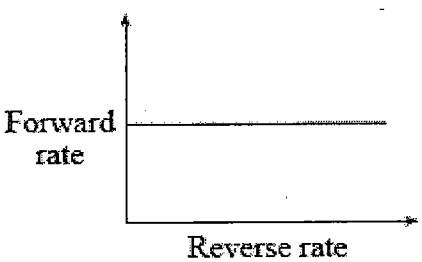


must be the same

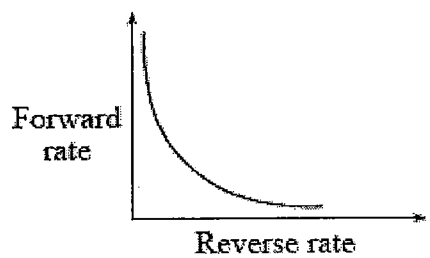
B.



C.



D.



7. In which of the following will entropy and enthalpy factors favour the establishment of an equilibrium?
   A. $2C_{(s)} + 2H_{2(g)} \Rightarrow C_2H_{4(g)}$ $\Delta H = +52.3$ kJ react + react
   B. $2C_2H_{6(g)} + 7O_{2(g)} \Rightarrow 4CO_{2(g)} + 6H_2O_{(g)}$ $\Delta H = -1560$ kJ prod + prod
   C. $Mg_{(s)} + 2\,HCl_{(aq)} \Rightarrow MgCl_{2(aq)} + H_{2(g)} + 425$ kJ prod + prod
   D. $CaCO_{3(s)} + 178 \text{ kJ} \Rightarrow CaO_{(s)} + CO_{2(g)}$

8. In which of the following will entropy and enthalpy factors favour the reactants?
   A. $2C_{(s)} + 2H_{2(g)} \Rightarrow C_2H_{4(g)}$ $\Delta H = +52.3$ kJ
   B. $2C_2H_{6(g)} + 7O_{2(g)} \Rightarrow 4CO_{2(g)} + 6H_2O_{(g)}$ $\Delta H = -1560$ kJ
   C. $CaCO_{3(s)} + 178 \text{ kJ} \Rightarrow CaO_{(s)} + CO_{2(g)}$
   D. $Mg_{(s)} + 2\,HCl_{(aq)} \Rightarrow MgCl_{2(aq)} + H_{2(g)} + 425$ kJ

9. In which of the following will the driving forces of minimum enthalpy and maximum entropy oppose one another?

A. $4CO_{2\,(g)} + 6\,H_2O_{(g)} \rightarrow 2C_2H_{6\,(g)} + 7\,O_{2\,(g)}$ $\Delta H = +3122$ kJ change to +1560

B. $2CO_{(g)} + O_{2\,(g)} \rightarrow 2\,CO_{2\,(g)}$ $\Delta H = -566$ kJ

C. $2C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$ $\Delta H = -221$ kJ

D. $2N_{2(g)} + O_{2\,(g)} \rightarrow 2N_2O_{(g)}$ $\Delta H = +164$ kJ

10. In order for a chemical reaction to go to completion, how must the entropy and enthalpy change?

	Entropy	Enthalpy
A.	decreases	increases
B.	increases	decreases
C.	increases	increases
D.	decreases	decreases

11. For the reacting system:

$$2\,Li_{(s)} + 2\,H_2O_{(l)} \rightarrow 2\,LiOH_{(aq)} + H_{2\,(g)} \quad \Delta H = -433\text{ kJ}$$

What will entropy and enthalpy factors favor?

	Entropy	Enthalpy
A.	reactants	products
B.	reactants	reactants
C.	products	products
D.	products	reactants

12. Which of the following reactions is accompanied by an increase in enthalpy? ∴ endo

A. $4HCl_{(g)} + O_{2\,(g)} \leftrightarrows 2H_2O_{(g)} + 2\,Cl_{2\,(g)}$ $\Delta H = -111.4$ kJ

B. $2SO_{3\,(g)} \leftrightarrows 2SO_{2\,(g)} + O_{2\,(g)}$ $\Delta H = +197$ kJ

C. $2NO_{(g)} + O_{2\,(g)} \leftrightarrows 2NO_{2\,(g)} + 113\text{kJ}$

D. $2H_{2\,(g)} + O_{2\,(g)} - 484\text{ kJ} \leftrightarrows 2H_2O_{(g)}$

13. Consider the following reaction:

$$C_3H_{8\,(g)} + 5\,O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 4\,H_2O_{(g)} \quad \Delta H = -2202\text{ kJ}$$

Which of the following applies to the forward reaction?

	Entropy	Enthalpy
A.	decreases	decreases
B.	decreases	increases
C.	increases	decreases
D.	increases	increases

14. Consider the following reaction:

$$PCl_{3\,(g)} + Cl_{2\,(g)} \rightarrow PCl_{5\,(g)} \qquad \Delta H = +102\ kJ$$

Which of the following applies to the forward reaction?

	Entropy	Enthalpy
A.	decreases	decreases
B.	decreases	increases
C.	increases	increases
D.	increases	decreases

15. Consider the following reaction:

$$Ca_{(s)} + 2H_2O_{(l)} \rightarrow H_{2\,(g)} + Ca(OH)_2\,(aq) \qquad \Delta H = -102\ kJ$$

Which of the following applies to the forward reaction?

	Entropy	Enthalpy
A.	decreases	decreases
B.	decreases	increases
C.	increases	increases
D.	increases	decreases

16. Two substances are mixed and no reaction occurs. With respect to enthalpy and entropy, which of the following could explain why no reaction occurs?

	Enthalpy	Entropy
A.	decreases	increases
B.	decreases	decreases
C.	increases	decreases
D.	increases	increases

∴ entropy & enthalpy both favour reactants

17. Which of the following forward reaction changes would result in the most products?

	Entropy	Enthalpy
A.	decreasing	increasing
B.	increasing	increasing
C.	increasing	decreasing
D.	decreasing	decreasing

18. In which of the following reactions do the tendencies for minimum enthalpy and maximum entropy both favour reactants?

A. $2BrCl_{(g)} \leftrightarrows Br_{2\,(g)} + Cl_{2\,(g)}$ $\Delta H = -293\ kJ$

B. $CaCO_{3\,(s)} \leftrightarrows CaO_{(s)} + CO_{2\,(g)}$ $\Delta H = +175\ kJ$

C. $3O_{2\,(g)} \leftrightarrows 2O_{3\,(g)}$ $\Delta H = +285\ kJ$

D. $N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2NH_{3\,(g)}$ $\Delta H = -92\ kJ$

19. Consider the following equation:

$$NH_4NO_{3\,(s)} \overset{?}{\leftrightarrows} N_2O_{(g)} + 2H_2O_{(g)} \qquad \Delta H = -37\ kJ$$

Which of the following is true?

	Enthalpy	Entropy	Outcome
A.	favours products	favours products	reaction goes to completion
B.	favours products	favours reactants	reaction reaches equilibrium
C.	favours reactants	favours reactants	reaction does not occur
D.	favours reactants	favours products	reaction reaches equilibrium

20. Consider the following:

$$2SO_{2\,(g)} + O_{2\,(g)} \leftrightarrows 2\,SO_{3\,(g)}$$

0 0 Some

Initially, SO_3 is added to an empty flask. How do the rate of the reverse reaction and $[SO_3]$ change as the system proceeds to equilibrium?

	Reverse Rate	$[SO_3]$
A.	decreases	decreases
B.	increases	decreases
C.	decreases	increases
D.	increases	increases

21. Some Fe^{+3} and SCN^- were mixed and established the following equilibrium:

$$Fe^{+3}_{(aq)} + SCN^-_{(aq)} \leftrightarrows FeSCN^{+2}_{(aq)}$$

Some Some none

What happened to the forward rate and the $[Fe^{+3}]$ as equilibrium was established?

	forward rate	$[Fe^{+3}]$
A.	decreased	decreased
B.	increased	decreased
C.	decreased	increased
D.	increased	increased

22. Consider the following equilibrium:

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

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

	Forward rate	Reverse rate
A.	increase	increase
B.	decrease	increase
C.	decrease	decrease
D.	increase	decrease

23. Consider the following equilibrium:

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

How will the forward and reverse equilibrium reaction rates change when H_2 is removed from the system?

	Forward rate	Reverse rate
A.	increase	increase
B.	decrease	increase
C.	decrease	decrease
D.	increase	decrease

24. Consider the following equilibrium:

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

How will the forward and reverse equilibrium reaction rates change when the temperature is lowered within the system?

	Forward rate	Reverse rate
A.	increase	increase
B.	decrease	increase
C.	decrease	decrease
D.	increase	decrease

25. Consider the following equilibrium:

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

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

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

26. Consider the following system at equilibrium:

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

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

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

27. Consider the following equilibrium system:

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{(g)} \qquad \Delta H = -9.4 \text{ kJ}$$

In an experiment, the equilibrium concentrations of the chemical species were measured before and after a stress was added. The results are displayed:

Chemical species	[ ] before stress was applied	[ ] after stress was applied
H_2	0.050 M	0.070 M
I_2	0.050 M	0.070 M
HI	0.40 M	0.56 M

Which one of the following stresses would be consistent with the above data?

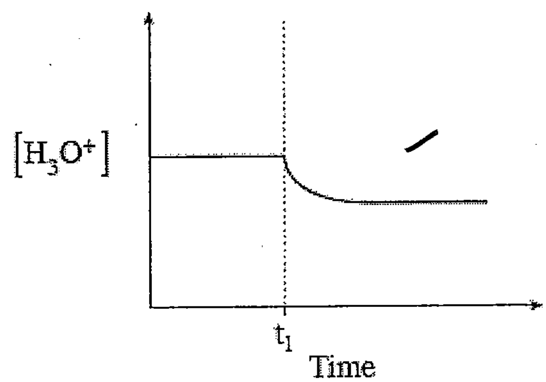
A. a decrease in pressure
B. an increase in temperature
C. the addition of H_2
D. the addition of HI

draw graph

28. Consider the following equilibrium:

$$CH_3COOH_{(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3COO^-_{(aq)} + H_3O^+_{(aq)} + \text{heat}$$

A stress was applied at time t_1 and the data was plotted on the following graph:

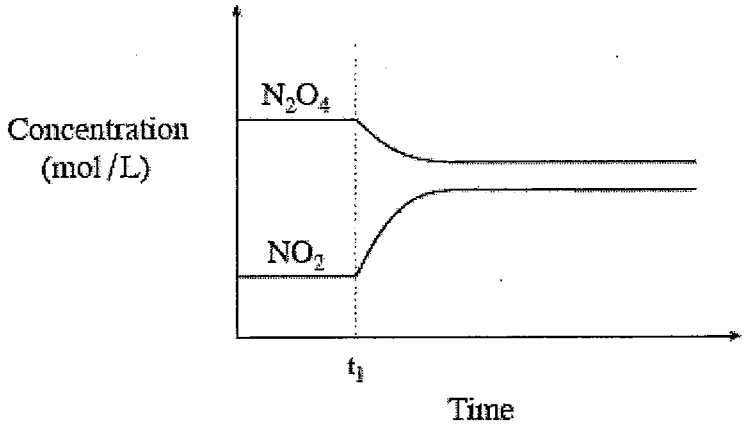


The stress that occured at time = t_1 is a result of

A. the addition of CH_3COO^{-1}
B. increasing the volume of the container
C. the addition of H_2O
D. decreasing the temperature

29. Consider the following equilibrium reaction:

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



At time t_1, heat is applied to the system. Which of the following best describes the equilibrium reaction and the change in K_{eq}?

Move to after 52!

Forward reaction	K_{eq}
A. endothermic	decreases
B. endothermic	increases
C. exothermic	increases
D. exothermic	decreases

can't do until after Keq!

30. Consider the following equilibrium:

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

Which two stresses will cause the equilibrium to shift to the left?

A. decrease $[H_2]$ and decrease [CO]
B. decrease $[H_2]$ and increase [CO]
C. increase $[H_2]$ and increase [CO]
D. increase $[H_2]$ and decrease [CO]

31. Consider the following:

$$2SO_{2(g)} + O_{2\,(g)} \leftrightarrows 2SO_{3(g)} + \text{energy}$$

Which of the following two stresses will each cause the system to shift to the right?

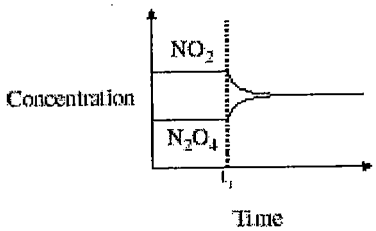
A. increase temperature and decrease $[SO_3]$
B. decrease temperature and increase $[SO_2]$
C. decrease temperature and decrease the $[O_2]$
D. increase temperature and increase $[SO_3]$

32. Consider the following equilibrium:

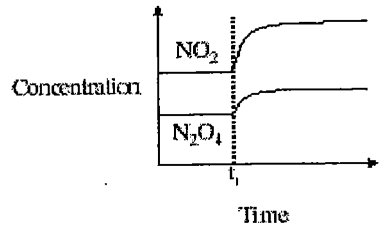
$$N_2O_{4(g)} + \text{energy} \leftrightarrows 2\,NO_{2(g)}$$

Which of the following graphs shows the result of adding a catalyst at time t_1?

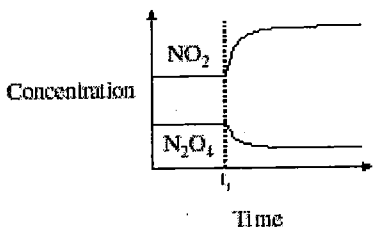
A.



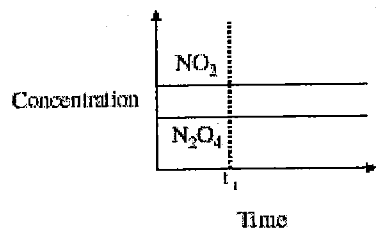
B.



C.



D.

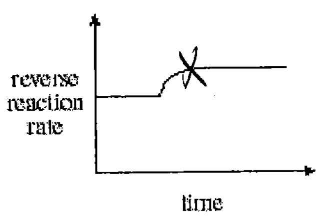


33. When the temperature of an exothermic equilibrium is decreased, which of the following will happen?

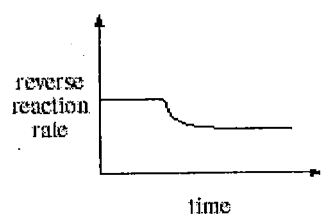
A. Equilibrium shifts right and [reactant] ~~increases~~
B. Equilibrium shifts ~~left~~ and [product] decreases
C. Equilibrium shifts ~~left~~ and [product] increases
D. Equilibrium shifts right and [reactant] will decrease

34. Temperature is gradually decreased then held constant in an exothermic equilibrium. Which of the following represents the change in the reverse reaction rate?

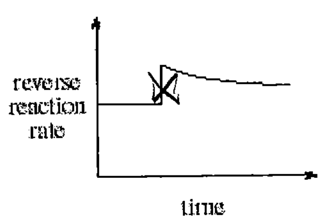
A.



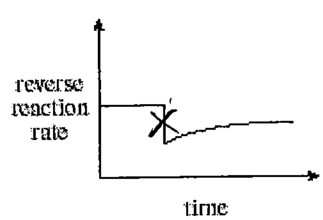
B.



C.



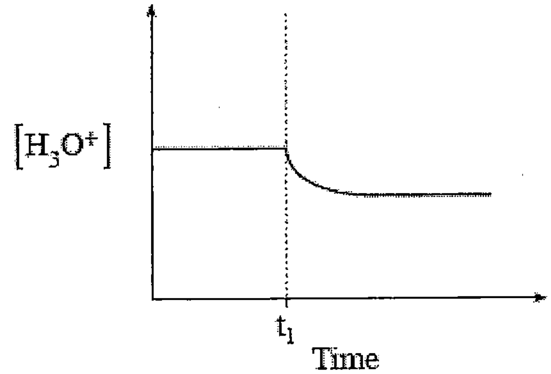
D.

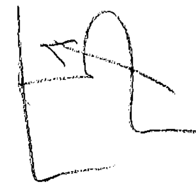


35. Consider the following equilibrium:

$$CH_3COOH_{(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3COO^-_{(aq)} + H_3O^+_{(aq)} + \text{heat}$$

A stress was applied at time t_1 and the data was plotted on the following graph:





The stress that occured at time = t_1 is a result of

A. the addition of H_3O^{+1}
B. adding an inhibitor
C. increasing the temperature
D. the addition of H_2O

36. Consider the following equilibrium:

$$\text{energy} + 2KClO_{3\,(s)} \leftrightarrows 2KCl_{(s)} + 3O_{2\,(g)}$$

Which of the following will cause a shift to the left?

A. increasing pressure ✓
B. increasing the temperature ✗
C. adding an inhibitor ✗
D. grinding up the KCl ✗

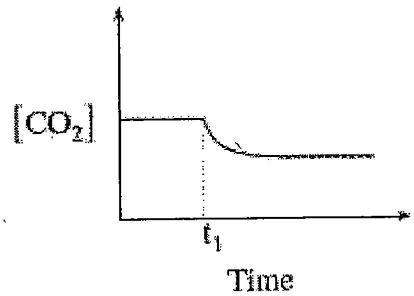
can't change [ ] of solid.

37. Consider the following equilibrium:

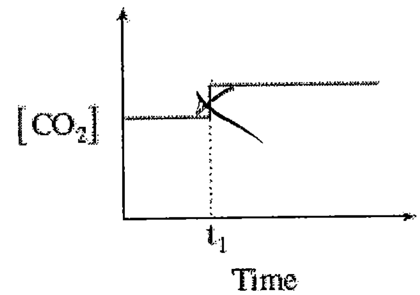
$$CaCO_{3\,(s)} \rightleftarrows CaO_{(s)} + CO_{2\,(g)} \qquad \Delta H = +175\text{ kJ}$$

Which of the following diagrams best represents the change in the concentration of CO_2 as temperature is decreasesd at time t_1?

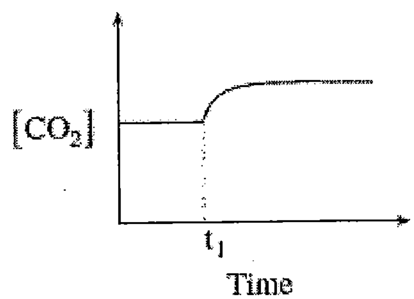
A.



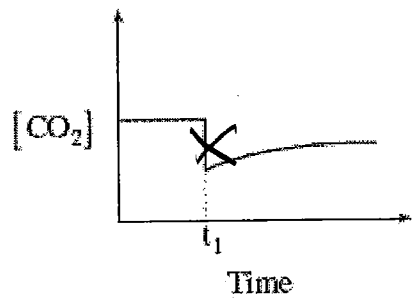
B.



C.



D.



38. The following equation represents the catalyzed decomposition of O_3 (ozone):

$$O_{(g)} + Cl_{(g)} + O_{3\,(g)} \rightleftarrows 2O_{2\,(g)} + Cl_{(g)}$$

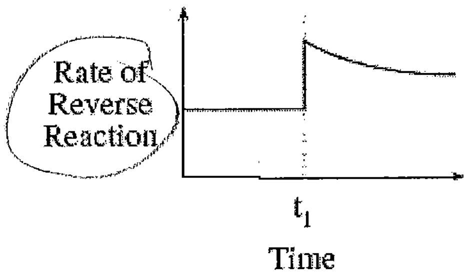
Which of the following statements is true?

A. The catalyst ~~O~~ speeds up both the forward and reverse rates.
B. The catalyst ~~O~~ speeds up only the forward rate.
C. The catalyst Cl speeds up both the forward and reverse rates.
D. The catalyst Cl speeds up ~~only~~ the forward rate.

39. Consider the following equilibrium:

$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2NH_{3\,(g)} + \text{energy}$$

The following diagram represents the rate of the reverse reaction:



Which of the following stresses explains what happened at t_1?

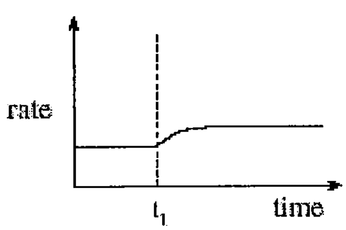
A. $[NH_3]$ decreased
B. $[NH_3]$ increased
C. $[H_2]$ increased
D. $[N_2]$ decreased

40. Consider the following equilibrium:

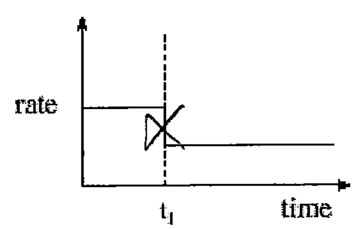
$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{(g)} + CO_{(g)}$$

Which of the following graphs best represents the forward rate of reaction when H_2O is added to the above equilibrium at time = t_1?

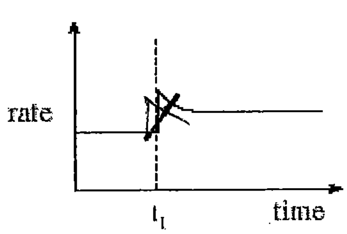
A.



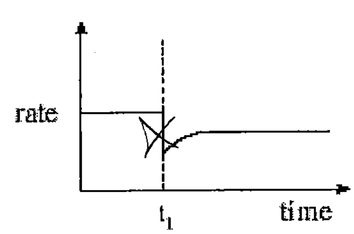
B.



C.



D.

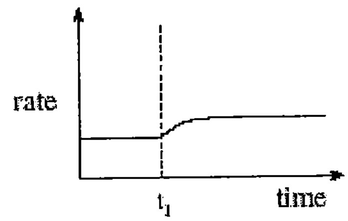


41. Consider the following equilibrium:

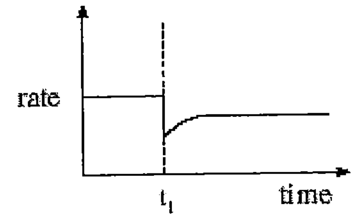
$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{(g)} + CO_{(g)}$$ no shift.

Which of the following graphs best represents the forward reaction rate when the volume of the container is increased at time = t_1?

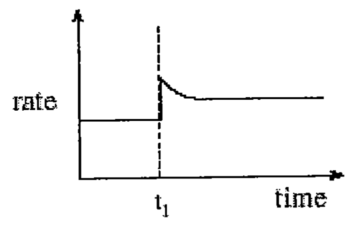
A.



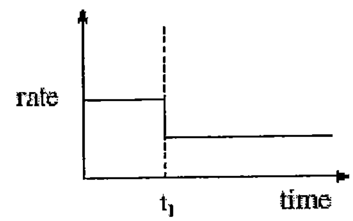
B.



C.



D.

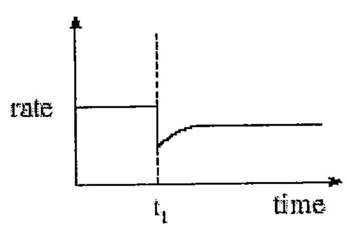


42. Consider the following equilibrium:

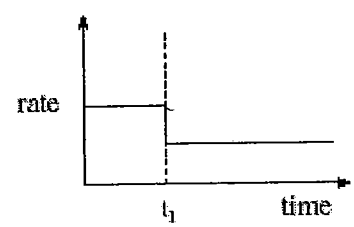
$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{(g)} + CO_{(g)}$$

Which of the following graphs best represents the reverse reaction rate when some H_2O is removed from the above equilibrium at time = t_1?

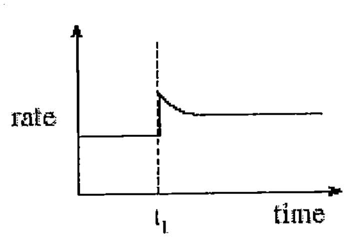
A.



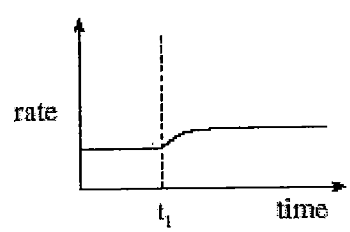
B.



C.



D.

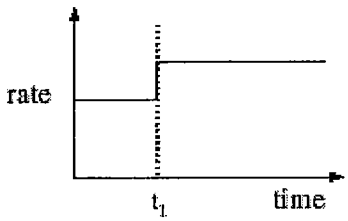


45. Consider the following equilibrium:

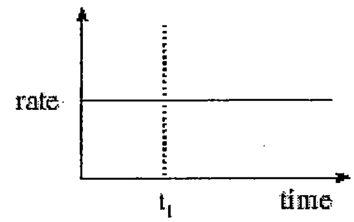
$$H_{2(g)} + Br_{2(g)} \leftrightarrows 2\,HBr_{(g)} + \text{energy}$$ no shift

Which of the following shows the forward reaction rate when the volume of the container is increased at time = t_1?

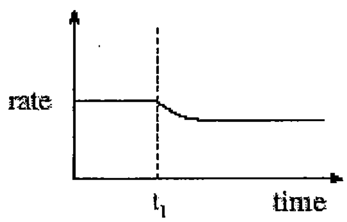
A.



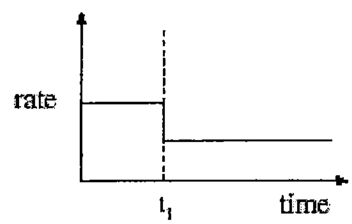
B.



C.



D.



46. Consider the following equilibrium:

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

If the volume of the system is decreased, how will the reaction rates in the new equilibrium compare with the rates of the original equilibrium?

	Forward Rate	Reverse Rate
A.	decreases	decreases
B.	decreases	increases
C.	increases	increases
D.	increases	decreases

47. Consider the following equilibrium:

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

If the temperature of the system is increased, how will the reaction rates in the new equilibrium compare with the rates of the original equilibrium?

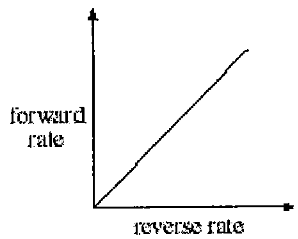
	Forward Rate	Reverse Rate
A.	decreases	decreases
B.	decreases	increases
C.	increases	increases
D.	increases	decreases

48. Consider the following reaction:

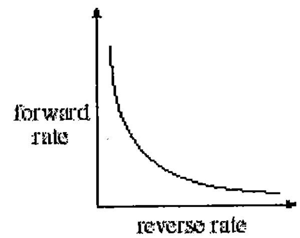
$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2NH_{3\,(g)}$$

Which of the following diagrams represents what happens to the forward and reverse reaction rates when the catalyst Fe_3O_4 is added?

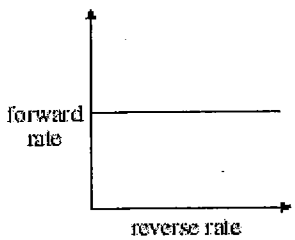
A.



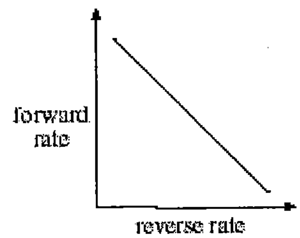
B.



C.



D.



49. Consider the following equilibrium:

randomness

$$\underset{\text{yellow}}{2CrO_4^{-2}}{}_{(aq)} + 2H^+_{(aq)} \leftrightarrows \underset{\text{orange}}{Cr_2O_7^{-2}}{}_{(aq)} + \cancel{H_2O}_{(l)} + \text{energy}$$

a. Is the forward reaction endothermic or exothermic? Explain.

exothermic. Randomness favours reactants
∴ Energy must favour products in order to be an equilibrium ∴ exothermic.

b. When OH^{-1} is added, the color of the solution turns from orange to yellow. Explain using LeChatelier's Principle.

stress : $[H^+]\downarrow$

shift $\leftarrow$ to minimize the stress

∴ $[CrO_4^{-2}]\uparrow$ and $[Cr_2O_7^{-2}]\downarrow$

∴ yellow ↑ and orange ↓

50. The Haber Process is used to produce ammonia commercially according to the following equilibrium:

$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2NH_{3\,(g)} \qquad \Delta H = -92\ kJ$$

Which of the following conditions will produce the highest yield of ammonia?

A. decrease temperature and decrease pressure
B. decrease temperature and increase pressure
C. increase temperature and increase pressure
D. increase temperature and decrease pressure

51. Limestone is decomposed to make quicklime (CaO) according to the following equilibrium:

$$CaCO_{3\,(s)} + 175\ kJ \leftrightarrows CaO_{(s)} + CO_{2\,(g)}$$

Which of the following conditions would produce the greatest yield of CaO?

	Temperature	Pressure
A.	high	low
B.	high	high
C.	low	low
D.	low	high

52. Consider the following equilibrium system:

$$2SO_{2(g)} + O_{2(g)} \leftrightarrows 2SO_{3(g)} \qquad K_{eq} = 1.2 \times 10^4$$

If additional SO_2 is added the system, what happens to the equilibrium and the value of K_{eq}?

	Equilibrium	K_{eq}
A.	no change	no change
B.	shifts right	no change
C.	shifts left	decreases
D.	shifts right	increases

53. Consider the following equilibrium:

$$H_{2(g)} + I_{2\,(g)} \leftrightarrows 2\ HI_{(g)} \qquad K_{eq} = 50.0$$

What is the value for K_{eq} for the same reaction rewritten as

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

$\frac{1}{50}$

A. 0.0200
B. 50.0
C. -50.0
D. 25.0

54. Consider the following equilibrium:

$$2\,CrO_4{}^{-2}{}_{(aq)} + 2\,H^+{}_{(aq)} \leftrightarrows Cr_2O_7{}^{-2}{}_{(aq)} + \cancel{H_2O}_{(l)}$$

What is the K_{eq} expression?

A. $\dfrac{[Cr_2O_7{}^{2-}]}{[2CrO_4{}^{2-}][2H^+]}$

B. $\dfrac{[Cr_2O_7{}^{2-}][\cancel{H_2O}]}{[CrO_4{}^{2-}]^2[H^+]^2}$

C. $\dfrac{[CrO_4{}^{2-}]^2[H^+]^2}{[Cr_2O_7{}^{2-}]}$

D. $\dfrac{[Cr_2O_7{}^{2-}]}{[CrO_4{}^{2-}]^2[H^+]^2}$

55. Consider the following equilibrium:

$$\cancel{Fe_2O_3}_{(s)} + 3CO_{(g)} \leftrightarrows \cancel{2Fe}_{(s)} + 3\,CO_{2(g)}$$

Identify the equilibrium constant expression.

A. $K_{eq} = \dfrac{[3CO_2]^3\,[2\,Fe]^2}{[3CO]^3\,[Fe_2O_3]}$

B. $K_{eq} = \dfrac{[CO]^3\,[Fe_2O_3]}{[CO_2]^3\,[Fe]^2}$

C. $K_{eq} = \dfrac{[CO_2]^3}{[CO]^3}$

D. $K_{eq} = \dfrac{[3CO_2]}{[3CO]}$

56. Consider the following equilibrium:

$$CO_{(g)} + 2\,H_{2(g)} \leftrightarrows CH_3OH_{(g)} \qquad \Delta H = -91kJ$$

Which of the factors below would increase the concentration of the CH_3OH at equilibrium?

A. a decrease in pressure ✗
B. an addition of CO ✓
C. an increase in temperature ✗
D. an increase in the volume ✗

Same

57. Consider the following equilibrium:

$$\cancel{CaCO_3}_{(s)} + 2HF_{(g)} \leftrightarrows \cancel{CaF_2}_{(s)} + H_2O_{(g)} + CO_{2(g)}$$

$\dfrac{[HF]^2\,K_{eq}}{[CO_2]}$ $\quad K_{eq} = \dfrac{[H_2O][CO_2]}{[HF]^2}$

Which of the following represents the equilibrium $[H_2O]$?

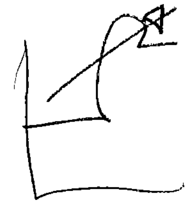
A. $[H_2O] = \dfrac{K_{eq}[HF]^2}{[CO_2]}$

B. $[H_2O] = \dfrac{K_{eq}[HF]^2[\cancel{CaCO_3}]}{[CO_2]CaF_2]}$

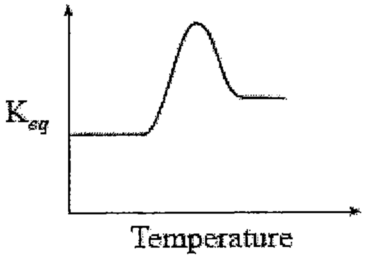
C. $[H_2O] = \dfrac{[HF]^2}{K_{eq}\,[CO_2]}$

D. $[H_2O] = \dfrac{[HF]^2[\cancel{CaCO_3}]}{K_{eq}\,[CO_2]CaF_2]}$

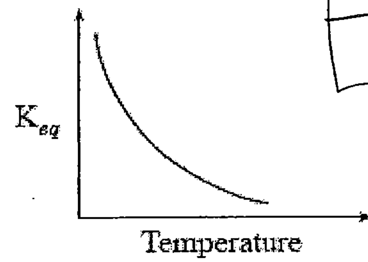
58. Which of the following best describes the relationship between K_{eq} and temperature for an endothermic forward reaction?



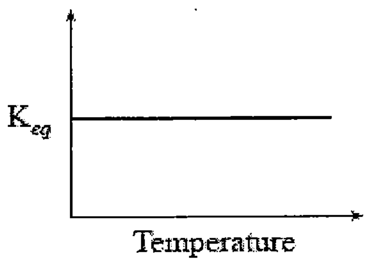
A.



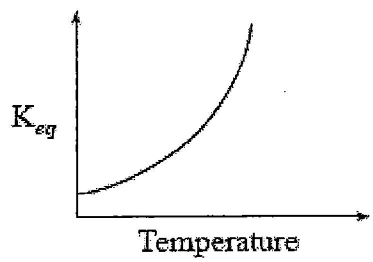
B.



C.

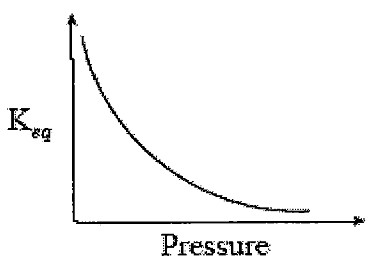


D.

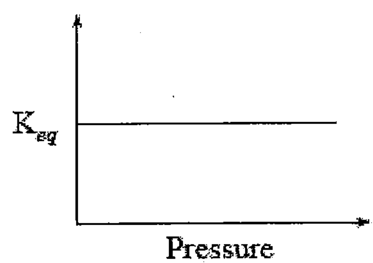


59. The relationship between K_{eq} and the pressure of a gaseous equilibrium at constant temperature can be best described by:

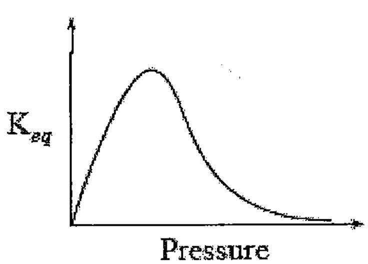
A.



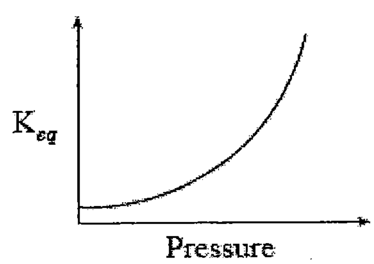
B.



C.

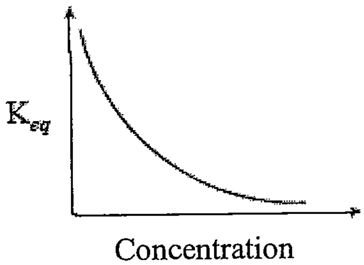


D.

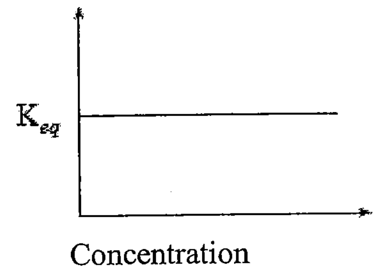


60. The relationship between K_{eq} and the concentrations of reactants in the same equilibrium system at constant temperature can best be described by

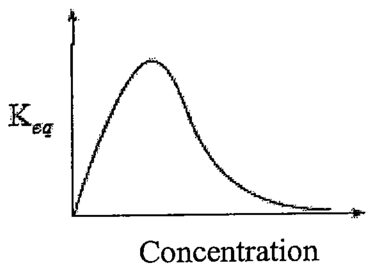
A.



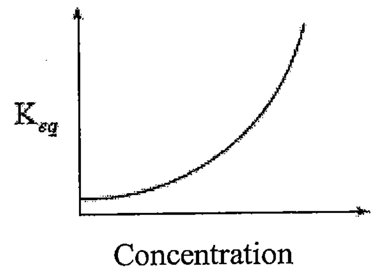
B.



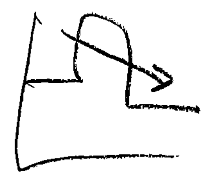
C.



D.



61. What will cause the K_{eq} for an exothermic reaction to increase?



A. increasing temperature
B. decreasing temperature
C. increasing [reactant]
D. decreasing [product]

62. What will cause the value of K_{eq} for an endothermic reaction to increase?

A. decrease [products]
B. decrease the temperature
C. increase [products]
D. increase the temperature

63. What will cause the value of K_{eq} for an exothermic reaction to decrease?

A. decreasing the pressure
B. decreasing the temperature
C. increasing the pressure
D. increasing the temperature

64. Consider the following equilibrium:

Remove for next year

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

How are K_{eq} and $[N_2O_4]$ affected by the addition of Ne (an inert gas) into the container at constant volume?

	K_{eq}	$[N_2O_4]$
A.	increases	decreases
B.	decreases	increases
C.	no change	no change
D.	no change	increases

65. Consider the following equilibrium system:

$$2NO_{(g)} + Cl_{2(g)} \leftrightarrows 2NOCl_{(g)} \qquad \Delta H = -77kJ$$

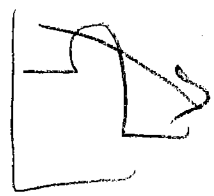
In which direction will the equilibrium shift and what happens to the value of K_{eq} when the volume of the system is increased?

	Shift	K_{eq}
A.	right	stays constant
B.	left	decreases
C.	right	increases
D.	left	stays constant

66. Consider the following equilibrium system:

$$2NO_{(g)} + Cl_{2(g)} \leftrightarrows 2NOCl_{(g)} \qquad \Delta H = -77kJ$$

In which direction will the equilibrium shift and what happens to the value of K_{eq} when the temperature of the system is decreased?



	Shift	K_{eq}
A.	left	stays constant
B.	left	decreases
C.	right	increases
D.	right	stays constant

67. Consider the following equilibrium system:

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

In which direction will the equilibrium shift and what happens to the value of K_{eq} when the temperature of the system is increased?

	Shift	K_{eq}
A.	left	stays constant
B.	left	decreases
C.	right	increases
D.	right	stays constant

68. The following equilibrium is established in a 1.0 L container:

$$\text{heat} + CH_{4\,(g)} + 2H_2S_{(g)} \leftrightarrows CS_{2\,(g)} + 4H_{2\,(g)}$$

If some CH_4 is added to the system, what happens to the net concentration of CH_4 and the value of K_{eq}?

after shifting

	$[CH_4]$	K_{eq}
A.	decreased	remains constant
B.	decreased	increased
C.	increased	remains constant
D.	increased	increased

69. The following equilibrium is established in a 1.0 L container:

$$\text{heat} + CH_{4\,(g)} + 2H_2S_{(g)} \leftrightarrows CS_{2\,(g)} + 4H_{2\,(g)}$$

If some heat is removed from the system, what happens to the net concentration of CH_4 and the value of K_{eq}?

$K_{eq} = \frac{[prod]}{[react]}$ $\quad \frac{10}{2} = 5 \quad \frac{5}{4} = 1.25$

	$[CH_4]$	K_{eq}
A.	decreased	remains constant
B.	increased	remains constant
C.	decreased	increased
D.	increased	decreased

70. The following equilibrium is established in a 1.0 L container:

$$\text{heat} + CH_{4\,(g)} + 2H_2S_{(g)} \leftrightarrows CS_{2\,(g)} + 4H_{2\,(g)}$$

If the volume of the container is reduced to 0.50 L, what happens to the net concentration of CH_4 and the value of K_{eq}?

	$[CH_4]$	K_{eq}
A.	decreased	remains constant
B.	increased	remains constant
C.	decreased	increased
D.	increased	decreased

71. A container is initially filled with pure SO_3. After a period of time, the following equilibrium is established:

$$\underset{0}{2\,SO_{2\,(g)}} + \underset{0}{O_{2\,(g)}} \leftrightarrows \underset{\text{some}}{2\,SO_{3\,(g)}} \qquad K_{eq} = 7.0 \times 10^{25}$$

What does this equilibrium mixture contain?

A. mostly products
B. equal amounts of reactants and products
C. 3/5 reactants and 2/5 products
D. mostly reactants

72. Which of the following reactions will proceed furthest toward completion?

A. $2H_2O_{(g)} \leftrightarrows 2H_{2(g)} + O_{2(g)}$ $K_{eq} = 7.3 \times 10^{-18}$

B. $C_2H_{4(g)} + H_{2(g)} \leftrightarrows C_2H_{6(g)}$ $K_{eq} = 9.0 \times 10^{19}$

C. $2HBr_{(g)} \leftrightarrows H_{2(g)} + Br_{2(g)}$ $K_{eq} = 7.0 \times 10^{-20}$

D. $Si_{(s)} + O_{2(g)} \leftrightarrows SiO_{2(s)}$ $K_{eq} = 2.0 \times 10^{142}$

73. In which of the following equilibria does the concentration of reactants equal the concentration of products?

A. $H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)}$ $K_{eq} = 1.00$

B. $CO_{2(g)} + H_{2(g)} \leftrightarrows CO_{(g)} + H_2O_{(g)}$ $K_{eq} = 0.279$

C. $N_2O_{4(g)} \leftrightarrows 2NO_{2(g)}$ $K_{eq} = 0.71$

D. $H^+_{(aq)} + OH^-_{(aq)} \leftrightarrows H_2O_{(l)}$ $K_{eq} = 1.0 \times 10^{14}$

+ 81, 85, 84

74. Consider the following equilibrium:

$$PCl_{5(g)} \leftrightarrows PCl_{3(g)} + Cl_{2(g)} \quad Keq = 9.0 \times 10^{-2}$$

In a 1.0 L container an equilibrium mixture contains 6.0×10^{-3} mol PCl_5 and 1.0×10^{-2} mol PCl_3. How many moles of Cl_2 are also present at equilibrium?

A. 5.4×10^{-2}

B. 1.5×10^{-1}

C. 5.4×10^{-6}

D. 6.7×10^{-4}

$K_{eq} = \frac{[PCl_3][Cl_2]}{[PCl_5]}$

$9.0 \times 10^{-2} = \frac{(1.0 \times 10^{-2})[Cl]}{(6.0 \times 10^{-3})}$

$[Cl^-] = .054\,M$

$\frac{.054\text{ mol}}{L} \times 1.0\,L =$ .054 moles

75. Consider the following equilibrium:

nope.

$$PCl_{5(g)} \leftrightarrows PCl_{3(g)} + Cl_{2(g)} \quad Keq = 9.0 \times 10^{-3}$$

move to 98 or 99

In a 1.0 L container an equilibrium mixture contains 2.5×10^{-3} mol PCl_5 , 1.0×10^{-2} mol PCl_3 and 1.0×10^{-2} mol of Cl_2. How does the equilibrium shift and why?

A. $K_{eq} < K_{trial}$ and equilibrium shifts left

B. $K_{eq} < K_{trial}$ and equilibrium shifts ~~right~~

C. $K_{eq} > K_{trial}$ and equilibrium shifts left

D. $K_{eq} > K_{trial}$ and equilibrium shifts ~~right~~

do on Ktrial

$K_T = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(1.0 \times 10^{-2})(1.0 \times 10^{-2})}{2.5 \times 10^{-3}}$

$.0090 < .040$

$= .040$

76. Consider the following:

$$N_2O_{4\,(g)} \leftrightarrows 2\,NO_{2\,(g)}$$

An equilibrium mixture contains 4.0×10^{-2} mol of N_2O_4 and 1.5×10^{-2} mol of NO_2 in a 1.0 L flask. What is the K_{eq}?

A. 7.5×10^{-1}
B. 5.6×10^{-3}
C. 1.8×10^{2}
D. 3.8×10^{-1}

$K_{eq} = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(1.5\times10^{-2})^2}{(4.0\times10^{-2})}$

$= .005625$

77. Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \leftrightarrows CH_3OH_{(g)}$$

At equilibrium it was found that $[CO] = 0.105$ mol/L, $[H_2] = 0.250$ mol/L and $[CH_3OH] = 0.00261$mol/L. Which of the following is the equilibrium constant value?

A. 0.398
B. 10.0
C. 9.94×10^{-2}
D. 2.51

$K_{eq} = \frac{[CH_3OH]}{[CO][H_2]^2} = \frac{(.00261)}{(.105)(.250)^2}$

$= .397714$

78. Consider the following equilibrium:

$$CH_{4\,(g)} + H_2O_{\,(g)} \leftrightarrows CO_{\,(g)} + 3H_{2\,(g)} \qquad K_{eq} = 5.67$$

An equilibrium mixture of this system was found to contain the following concentrations: $[CH_4] = 0.59$ M, $[H_2O] = 0.63$ M, $[CO] = 0.25$ M. What was the equilibrium $[H_2]$?

A. 0.64 M
B. 8.4 M
C. 0.26 M
D. 2.0 M

$K_{eq} = \frac{[CO][H_2]^3}{[CH_4][H_2O]}$ $5.67 = \frac{(.25)(H_2)^3}{(.59)(.63)}$

$[H_2]^3 = 8.43$ $[H_2] = 2.0352$

79. Consider the following equlibrium:

energy + $CH_{4\,(g)} + H_2O_{\,(l)} \leftrightarrows CO_{\,(g)} + 3H_{2\,(g)}$

At equilibrium, 1.2 mol CH_4, 1.2 mol H_2O, 0.080 mol CO and 0.040 mol H_2 are present in a 1.0 L container. What is the value of K_{eq}?

A. 2.7×10^{-3}
B. 2.3×10^{5}
C. 3.6×10^{-6}
D. 4.3×10^{-6}

$K_{eq} = \frac{[CO][H_2]^3}{[CH_4]} = \frac{(.080)(.040)^3}{(1.2)}$

$= 4.266 \times 10^{-6}$

Ask what happened between 78 + 79

80. Consider the following equilibrium:

$$2SO_{2(g)} + O_{2\,(g)} \leftrightarrows 2SO_{3(g)} + \text{energy}$$

do after ICE box

Initially, some SO_3 is placed into a 3.0 L container. At equilibrium there is 0.030 mol SO_2 present. What is the $[O_2]$ at equilibrium?

A. 0.0050 mol/L
B. 0.030 mol/L
C. 0.015 mol/L
D. 0.010 mol/L

$2SO_2 + O_2 \rightleftharpoons 2SO_3$

$2SO_2$	O_2	$2SO_3$
0	0	some
+2x	+x	−2x
$\frac{.030}{3.0L}$	?	

$[SO_2] = .010M$

81. Consider the following equilibrium:

$$Cl_{2(g)} + 2NO_{(g)} \leftrightarrows 2NOCl_{(g)} \qquad K_{eq} = 5.0$$

At equilibrium $[Cl_2] = 1.0$ M and $[NO] = 2.0$ M. What is the [NOCl] at equilibrium?

A. 4.5 M
B. 10 M
C. 0.80 M
D. 0.89 M

$K_{eq} = \frac{[NOCl]^2}{[Cl_2][NO]^2}$ $\quad 5.0 = \frac{[NOCl]^2}{(1.0)(2.0)^2}$

$[NOCl]^2 = 20 \quad [NOCl] = 4.472$

82. Consider the following equilibrium:

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

after ICE box

$2NH_3$	N_2	$3H_2$
some	0	0
	+x	+3x
	.030	.090

Initially, some NH_3 is placed into a 1.0 L container and allowed to reach equilibrium. At equilibrium there is 0.030 mol N_2 present. What is the $[H_2]$ at this equilibrium?

A. 0.060 mol/L
B. 0.090 mol/L
C. 0.010 mol/L
D. 0.030 mol/L

83. Consider the following:

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

Initially, some HI is placed into a 1.0 L container. At equilibrium there is 0.010 mol H_2, 0.010 mol of I_2 and 0.070 mol of HI present. How many moles of HI were initially placed into the container?

A. 0.080 mol
B. 0.070 mol
C. 0.060 mol
D. 0.090 mol

$H_2 + I_2 \rightleftharpoons 2HI$

H_2	I_2	$2HI$
0	0	Some
+x	+x	−2x
.010	.010	.070

84: Consider the following equilibrium and the table of experimental data:

$N_2O_{4(g)} \leftrightarrows 2NO_{2(g)}$

$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$

	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

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

$K_{eq} = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(.0125)^2}{(.0337)} = 4.64\times10^{-3}$

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

$= \frac{(.0141)^2}{(.0429)} = 4.63\times10^{-3}$

85. Consider the following equilibrium:

$Cr_2O_7^{-2}{}_{(aq)} + 2OH^-{}_{(aq)} \leftrightarrows 2CrO_4^{-2}{}_{(aq)} + H_2O_{(l)}$ $\quad K_{eq} = 4.14$

The concentration of ions at equilibrium was measured at a specific temperature and found to be $[Cr_2O_7^{-2}] = 0.100$ M and $[OH^-] = 0.020$ M. What is the equilibrium $[CrO_4^{-2}]$?

A. 1.3×10^{-2} M
B. 2.0×10^{-1} M
C. 3.1×10^{-3} M
D. 1.7×10^{-4} M

$K_{eq} = \frac{[CrO_4^{-2}]^2}{[Cr_2O_7^{-2}][OH^-]^2}$ $\qquad 4.14 = \frac{[CrO_4^{-2}]^2}{(.100)(.020)^2}$

$1.656\times10^{-4} = [CrO_4^{-2}]^2$

$[CrO_4^{-2}] = .012868$

86. Consider the following equilibrium:

$2NO_{(g)} + 2H_{2(g)} \leftrightarrows N_{2(g)} + 2H_2O_{(g)}$

Initially, 0.100 mol NO, 0.0500 mol H_2 and 0.100 mol H_2O are placed in a 1.0 L (1.00) container. At equilibrium, $[H_2O] = 0.138$ M. What is the value of K_{eq}?

A. 1.5×10^{-3}
B. 1.3×10^{3}
C. 3.5
D. 6.5×10^{2}

$2NO$	$+ 2H_2$	$\rightleftarrows N_2$	$+ 2H_2O$
.100M	.0500M	0	.100
$-2x$	$-2x$	$+x$	$+2x$
.062	.012	.019	.138 M

$K_{eq} = \frac{[H_2O]^2[N_2]}{[NO]^2[H_2]} = \frac{(.138)^2(.019)}{(.062)^2(.012)} = 653.681$

$\frac{.0003646}{.000000553}$ $\qquad .100 + 2x = .138 \qquad x = .019$ M

87. Consider the following equilibrium:

$$2N_2O_{(g)} \leftrightarrows 2N_2{}_{(g)} + O_2{}_{(g)}$$

$2N_2O$	$\rightleftharpoons 2N_2$	$+ O_2$
.800M	0	0
$-2x$	$+2x$	$+x$
.020	.780	.390

Initially, 0.800 mol N_2O is placed in a 1.00L container. At equilibrium, the $[N_2]$ is found to be 0.780 M. What is the value of K_{eq}?

change

A. ~~1.7×10^{-3}~~
B. 1.2×10^{3}
C. 5.9×10^{2}
D. 1.5×10^{1}

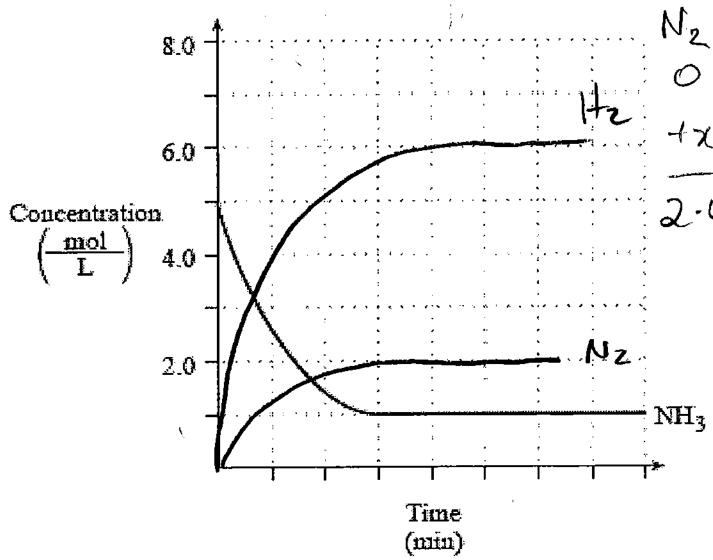
$$K_{eq} = \frac{[N_2]^2[O_2]}{[N_2O]^2} = \frac{(.780)^2(.390)}{(.020)^2}$$

$= 593$

88. Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + \text{energy}$$

A 1.00 L container is filled with 5.0 mol NH_3 and the system proceeds to equilibrium as indicated by the graph.



N_2	$+ 3H_2$	$\rightleftharpoons 2NH_3$
0	0	5.0
$+x$	$+3x$	$-2x$
2.0 M	6.0 M	1.0 M

$\therefore x = 2.0\,M$

a. Draw and label the graph for N_2 and H_2.

b. Calculate the K_{eq} for $N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_3{}_{(g)}$

$$K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(1.0)^2}{(2.0)(6.0)^3}$$

$= 2.3148 \times 10^{-3}$

$= 2.3 \times 10^{-3}$

89. Consider the following equlibrium:

energy + $CO_{2\,(g)}$ + $2H_2O_{(l)}$ ⇆ $CH_{4\,(g)}$ + $2O_{2\,(g)}$

Initally, 0.450 moles of CO_2, 0.480 moles of H_2O, 0.250 moles of CH_4 and 0.500 moles of O_2 are placed in a 5.00 L container and allowed to reach equilibrium.

a. When equilibrium is reached, the $[O_2]$ is 0.0700 M. Calculate the K_{eq} of the equilibrium.

$CO_2 + 2H_2O \rightleftharpoons CH_4 + 2O_2$

$\frac{.450}{5.00}$ = .0900 $\frac{.250}{5.00}$ = .0500 $\frac{.500}{5.00}$ = .100 M

$+x$ $-x$ $-2x$

$+.015$ $-.015$

.1050   .0350   .0700

$.100 - 2x = .0700$

$x = .0150$

$K_{eq} = \frac{[CH_4][O_2]^2}{[CO_2]} = \frac{(.0350)(.0700)^2}{(.1050)}$

$= 1.63 \times 10^{-3}$

b. Are reactants or products favored? reactants Explain your answer.

$K_{eq} < 1$

c. How would the following stresses affect the equilibrium? Complete the table below using the arrows indicated.

shift left (from shock) ←   increased rate of forward reaction after equilibrium reestablished ↑
shift right (from shock) →   decreased rate of forward reaction after equlibrium reestablished ↓
no shift -   no change in rate -

Stress (shock) introduced	Equilibrium shift	$[CO_2]$ (after shifting)	Forward reaction rate (after equilibrium is back)
Decrease pressure	→	↓	↓
add $CH_{4\,(g)}$	←	↑	↑
increase temperature	→	↓	↑
add catalyst	—	—	↑
increase volume of container	→	↓	↓
remove some $CO_{2\,(g)}$	←	↓	↓

same

90. Consider the following equilibrium:

$$3I_{2\,(g)} + 3\,F_{2(g)} \leftrightarrows 2IF_{2\,(g)} + I_4F_{2\,(g)}$$

Initially 2.00×10^{-1} mol of I_2 and 3.00×10^{-1} mol of F_2 and 1.00×10^{-1} mol of I_4F_2 are put into a 10.00 L flask. At equilibrium $[IF_2]$ is 2.00×10^{-3} M Calculate the value of K_{eq}.

$3I_2(g) + 3F_2(g) \rightleftarrows 2IF_2 + I_4F_2$

$\frac{6}{20}$ $x = .00100$ M

$3I_2(g)$	$3F_2(g)$	$2IF_2$	I_4F_2
$\frac{.200}{10.00}$ = .0200	$\frac{.300}{10.00}$	0	$\frac{.100 \text{ mol}}{10.00 \text{ L}}$ = .0100
−.0030 −3x	−3x	+2x	+x +.0010
.0170 M	.0270 M	.00200 M	.0110

$$K_{eq} = \frac{[IF_2]^2[I_4F_2]}{[I_2]^3[F_2]^3} = \frac{(.0020)^2(.0110)}{(.0170)^3(.0270)^3}$$

$= 455.0033769$

$= 455$

91. Consider the following:

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

Initally, 0.200 mol of H_2 and 0.200 mol I_2 are added to an empty 2.00 L container. At equilibrium $[I_2]$ is 0.020 mol/L. Calculate the value of K_{eq}.

$H_2 + I_2 \rightleftarrows 2HI$

$.100 - x = .020$

$x = .080$

H_2	I_2	$2HI$
$\frac{.200}{2.00}$	$\frac{.200}{2.00}$	0
−x	−x	+2x
.020	.020	.16 M

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = \frac{(.16)^2}{(.02)^2} = 64$$

92. Consider the following equilibrium:

$$SO_{3\,(g)} + NO_{(g)} \leftrightarrows NO_{2\,(g)} + SO_{2\,(g)}$$

In an experiment, 0.100 moles of SO_3 and 0.100 moles of NO are placed in a 1.00 L container. When equilibrium is achieved, $[NO_2] = 0.0414$ mol/L. Calculate the K_{eq} value.

SO_3	+ NO	⇄ NO_2	+ SO_2
$\frac{.100}{1.00}$	$\frac{.100}{1.00}$	0	0
$-x$	$-x$	$+x$	$+x$
.0586	.0586	.0414	.0414
.059	.059		

$0 + x = .0414$

$x = .0414$

$$K_{eq} = \frac{[NO_2][SO_2]}{[SO_3][NO]} = \frac{(.0414)^2}{(.059)^2} = .49|2375 = .49$$

if all sig figs kept $\frac{(.0414)^2}{(.0586)^2} = .499|102$

$= .499$

93. Consider the following equilibrium:

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{(g)} \qquad K_{eq} = 49.5 \text{ at } 440^\circ C$$

get rid of?

If 5.0 M HI is initally placed into a container at 440° C, what will be the equilibrium [HI]?

A. 3.9 M
B. 4.8 M
C. 0.33 M
D. 4.4 M

H_2	+ I_2	⇄ 2HI
0	0	5.0 M
$+x$	$+x$	$-2x$
x	x	$5.0-2x$

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} \qquad \sqrt{49.5} = \sqrt{\frac{(5.0-2x)^2}{(x)^2}}$$

$$7.03562 = \frac{5.0-2x}{x}$$

$7.03562x = 5.0 - 2x$

$9.03562x = 5.0$

$x = \frac{5.0}{9.03562}$

$x = .55336$

$\therefore [HI] = 5.0 - 2(.55336)$

$= 5.0 - 1.1067$

$= 3.9$

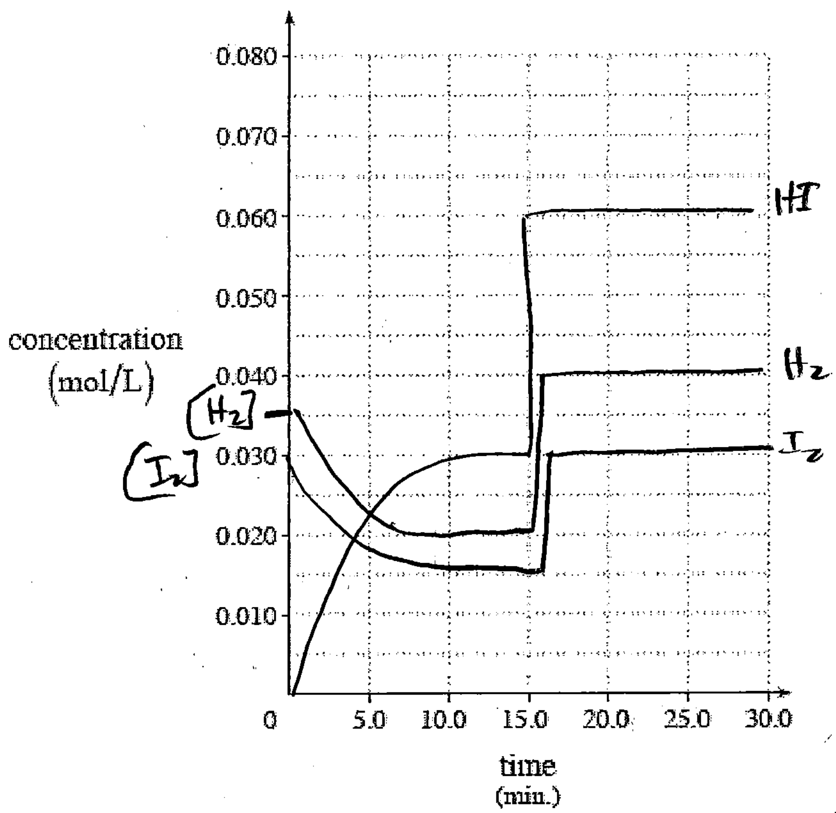
94. Consider the following equilibrium:

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

A 2.0 L container is initally filled with 0.070 mol of H_2 and 0.060 mol of I_2.

$H_2 + I_2 \rightleftarrows 2HI$

H_2	I_2	$2HI$
.035	.030	0
$-x$	$-x$	$+2x$
.020	.015	.030M



Equilibrium is reached after 15.0 minutes, at which time there are 0.060 mol of HI present.

a. Sketch the graph for $[H_2]$ $[I_2]$ and [HI] for the first 15 minutes.

b. Calculate the K_{eq} for this equilibrium at 15 minutes.

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = \frac{(.030)^2}{(.020)(.015)} = 3.0$$

c. At 15 minutes, the volume of the container is decreased from 2.0 to 1.0 L. Sketch what the graph would look like from 15.0 minutes until 30.0 minutes with this shock and the new equilibrium that will occur.

no shift (no where to shift)

d. How will the K_{eq} change with this stress at 15.0 minutes?

$$\text{(check)}\ K_{eq} = \frac{(.060)^2}{(.040)(.030)} = 3.0$$

95. Consider the following:

$$H_{2\,(g)} + Br_{2\,(g)} \leftrightarrows 2\,HBr_{(g)} \qquad K_{eq} = 12.0$$

Initially, 0.080 mol H_2 and 0.080 mol of Br_2 are placed into a 4.00 L container. What is the [HBr] at equilibrium?

H_2	$+ Br_2$	$\rightleftarrows 2HBr$
.020	.020	0
$-x$	$-x$	$+2x$
$.020-x$	$.020-x$	$2x$

$$K_{eq} = \frac{[HBr]^2}{[H_2][Br_2]}$$

$$\sqrt{12.0} = \sqrt{\frac{(2x)^2}{(.020-x)^2}}$$

$$2\sqrt{3} = \frac{2x}{(.020-x)}$$

$$.040\sqrt{3} - 2\sqrt{3}x = 2x$$

$$.040\sqrt{3} = (2+2\sqrt{3})x$$

$$\frac{.040\sqrt{3}}{2+2\sqrt{3}} = x$$

$$\frac{.069282}{5.4641} = x$$

$$x = .01267948 6$$

$$\therefore [HBr] = 2(.012679486)$$

$$= .025359$$

$$= .025$$

Check

$$K_{eq} = \frac{(.025358972)^2}{(.020 - .012679486)^2}$$

$$= 11.9999 = 12 \checkmark$$

96. Consider the following equilibrium:

$$N_{2\,(g)} + O_{2\,(g)} \leftrightarrows 2NO_{(g)} \qquad K_{eq} = 0.0095$$

Initially, 0.15 mol N_2 and 0.15 mol O_2 were placed in a 1.0 L container. Calculate the concentration of all species at equilibrium.

$N_2 + O_2 \rightleftarrows 2NO$

N_2	O_2	$2NO$
.15	.15	0
$-x$	$-x$	$+2x$
$.15-x$	$.15-x$	$2x$

$K_{eq} = \frac{[NO]^2}{[N_2][O_2]}$

$\sqrt{.0095} = \sqrt{\frac{(2x)^2}{(.15-x)^2}}$

$.097468 = \frac{2x}{.15-x}$

$.01462 - .097468x = 2x$

$\frac{.01462}{2.097468} = \frac{2.097468x}{2.097468}$

$x = 6.97\times10^{-3}$

$\therefore [N_2] = [O_2] = .15 - .00697$
$= .14303$
$= .14$

$[NO] = 2(.00697)$
$= .01394$
$= .014$

check $\frac{(.01394)^2}{(.14303)^2} = .0094999$ ✓

97. Consider the following equilibrium:

$$NH_2COONH_{4\,(s)} \leftrightarrows CO_{2\,(g)} + 2NH_{3\,(g)} \qquad K_{eq} = 0.108$$

Initially, 2.00 moles of NH_2COONH_4 are placed in a 500.0 mL container. Calculate $[NH_3]$ at equilibrium.

$NH_2COONH_4 \rightleftarrows CO_2 + 2NH_3$

NH_2COONH_4	CO_2	$2NH_3$
	0	0
	$+x$	$+2x$
	x	$2x$

$K_{eq} = [CO_2][NH_3]^2$

$.108 = (x)(2x)^2$

$\frac{.108}{4} = \frac{4x^3}{4}$

$.027 = x^3$

$x = .30$

$\therefore [NH_3] = 2x = .60\ M$

do 75 as example

98. Consider the following equilibrium:

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

A flask is filled with NOCl, NO and Cl_2. Initially, there was a total of 5.0 moles of gases present. When equilibrium is reached, there is a total of 6.0 moles of gases present. Which of the following explains this observation?

A. The reaction shifted ~~left~~ because $K_{trial} < K_{eq}$.
B. The reaction shifted right because $K_{trial} < K_{eq}$.
C. The reaction shifted ~~left~~ because K_{trial} ~~>~~ K_{eq}.
D. The reaction shifted right because K_{trial} ~~>~~ K_{eq}.

$K_T = \cancel{[NO]}$ ∴ shifted to side with more gas particles

so $\longrightarrow$

$K_{eq} \xrightarrow{} K_T$ ∴ $K_{eq} > K_T$

99. Consider the following equilibrium:

$$CO_{(g)} + 2H_{2(g)} \leftrightarrows CH_3OH_{(g)}$$

Some CO, H_2 and CH_3OH were placed in a 1.0 L container. When equilibrium was established, the [CO] had increased. Which of the following is true?

so $\longleftarrow$

A. Trial $K_{eq} > K_{eq}$ so reaction shifted ~~right~~ to reach equilibrium.
B. Trial K_{eq} ~~<~~ K_{eq} so reaction shifted ~~right~~ to reach equilibrium.
C. Trial K_{eq} ~~<~~ K_{eq} so reaction shifted left to reach equilibrium.
D. Trial $K_{eq} > K_{eq}$ so reaction shifted left to reach equilibrium.

$K_{eq} < K_T$

100. Consider the following equilibrium:

put in state.

$$N_2O_{4(g)} \leftrightarrows 2NO_2 \quad K_{eq} = 9.5 \times 10^{-3}$$

Initially, 0.060 mol N_2O_4 and 0.020 mol NO_2 are placed in a 2.00 L container. Determine the direction in which the reaction will proceed in order to reach equilibrium.

A. It will shift to the ~~left~~ because K_{trial} ~~<~~ K_{eq}.
B. It will shift to the right because $K_{trial} < K_{eq}$.
C. It will shift to the right because K_{trial} ~~>~~ K_{eq}.
D. It will shift to the ~~left~~ because K_{trial} ~~>~~ K_{eq}.

$$K_T = \frac{[NO_2]^2}{[N_2O_4]} = \frac{(.010)^2}{(.030)} = .003\overline{3}$$

$K_{eq} \quad K_T$

$.0095 > .0033$

so $\longrightarrow$

101. Consider the following equilibrium:

$$CO_{(g)} + H_2O_{(g)} + \text{energy} \leftrightarrows CO_{2\,(g)} + H_{2\,(g)} \qquad K_{eq} = 0.425$$

Initially there are 0.180 mol of CO, 0.180 mol of H_2O, 0.160 mol of CO_2 and 0.160 mol of H_2 in a 2.00 L container.

a. Is the container of gases at equilibrium? If not, which way will the equilibrium shift to reach equilibrium?

$$K_T = \frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{(.0800)(.0800)}{(.0900)(.0900)} = .790$$

$\therefore K_{eq} < K_T$

$.425 \qquad .790$

$\therefore$ shift $\leftarrow$

b. Calculate the [CO] and [CO_2] when equilibrium is reached.

CO	$+ H_2O$	$\rightleftarrows CO_2$	$+ H_2$
$.0900$	$.0900$	$.0800$	$.0800$
$+x$	$+x$	$-x$	$-x$
$.0900+x$	$.0900+x$	$.0800-x$	$.0800-x$

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

$$\sqrt{.425} = \sqrt{\frac{(.0800-x)^2}{(.0900+x)^2}}$$

$$.652 = \frac{.0800-x}{.0900+x}$$

$.05867 + .652x = .0800 - x$

$$1.652x = \frac{.021327}{1.652}$$

$x = .0129$

$\therefore [CO] = .0900 + .0129 = .1029\,M$

$[CO_2] = .0800 - .0129 = .0671\,M$

c. What could be done to the equilibrium to increase the K_{eq}? shift right

heat it up.

Check $\dfrac{(.0671)^2}{(.1029)^2} = .42522$ ✓

Check $\frac{(.342857)^2}{(.0800-.0514)^2} = 143.99999$ ✓

102. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)} \qquad K_{eq} = 144$$

Initially 0.480 mol of HI, 0.160 mol of H_2 and 0.160 mol of I_2 are placed in a 2.00 L container and allowed to reach equilibrium.

a. Which way will the equilibrium shift in order to reach equilibrium?

$$K_T = \frac{[HI]^2}{[H_2][I_2]} = \frac{(.240)^2}{(.0800)(.0800)} = 9 \qquad \begin{matrix} K_{eq} & > & K_T \\ 144 & & 9 \end{matrix}$$

b. What will be the [HI] at equilibrium?

H_2	+ I_2	$\rightleftharpoons 2HI$
.0800	.0800	.240
$-x$	$-x$	$+2x$
$.0800-x$	$.0800-x$	$.240+2x$

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} \qquad \sqrt{144} = \sqrt{\frac{(.240+2x)^2}{(.0800-x)^2}}$$

$$12.0 = \frac{.240+2x}{.0800-x}$$

$$.96 - 12.0x = .240 + 2x$$

$$\frac{.72}{14} = \frac{14x}{14} \qquad x = .0514$$

$\therefore [HI] = .240 + 2(.051428571) = .342857 = .343\,M$

103. Given the following reaction:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)} \qquad K_{eq} = 64$$

Equal moles of H_2, I_2 and HI are placed in a 1.0 L container. Use calculations to determine the direction the reaction will proceed in order to reach equilibrium.

$$K_T = \frac{[HI]^2}{[H_2][I_2]} = \frac{x^2}{x^2} = 1 \qquad \begin{matrix} K_{eq} & > & K_T \\ 64 & & 1 \end{matrix}$$

$\therefore$ shift right

104. Consider the following equilibrium:

Get rid of?

$$H_{2\,(g)} + I_{2\,(g)} \leftrightarrows 2HI_{(g)} \qquad K_{eq} = 49.5 \text{ at } 440^{\circ}\text{ C}$$

If 0.120 M H_2, 0.120 M I_2 and 0.844 M HI are initially placed into a container at 440° C, which of the following is true as equilibrium is approached?

A. $[H_2]$ remains the same.
B. $[H_2]$ decreases significantly
C. $[I_2]$ decreases significantly
D. $[HI]$ decreases significantly

$$K_T = \frac{[HI]^2}{[H_2][I_2]} = \frac{(.844)^2}{(.120)^2} = 49.4677\overline{7} \approx 49.5$$

$\therefore$ K_{eq} 49.5 = K_T 49.5

$\therefore$ no shift

F9 Review

105. Consider the following:

$$\underset{\text{some}}{2HBr_{(g)}} \leftrightarrows \underset{0}{H_{2(g)}} + \underset{0}{Br_{2(g)}}$$

Initially HBr is added to an empty flask. How do the rate of the reverse reaction and the [HBr] change as the system proceeds to equilibrium?

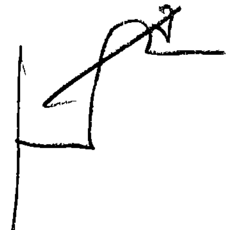
	Reverse Rate	[HBr]
A.	increases	~~increases~~
B.	increases	decreases
C.	~~decreases~~	decreases
D.	~~decreases~~	~~increases~~

106. In which of the following equations does entropy most favour reactants?

A. $NH_4Cl_{(s)} \leftrightarrows NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$ prod
B. $SnO_{2\,(s)} + 2H_{2\,(g)} \leftrightarrows Sn_{(s)} + 2H_2O_{(g)}$ tie
C. $\frac{1}{2}N_{2\,(g)} + O_{2\,(g)} \leftrightarrows NO_{2\,(g)}$ ✓
D. $4PH_{3\,(g)} \leftrightarrows P_{4\,(g)} + 6H_{2\,(g)}$

107. When the temperature of an endothermic equilibrium is increased, which of the following will happen?

A. Equilibrium shifts right and [reactant] ~~increases~~
B. Equilibrium shifts ~~left~~ and [product] increases
C. Equilibrium shifts right and [reactant] will decrease
D. Equilibrium shifts ~~left~~ and [product] ~~decreases~~



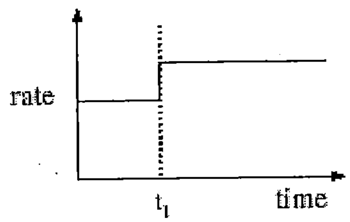
108. Consider the following equilibrium:

$$H_{2(g)} + Br_{2(g)} \leftrightarrows 2\,HBr_{(g)} + \text{energy}$$

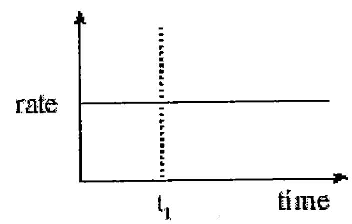
no shift because same # of particles on both sides

Which of the following shows the **reverse** rate of reaction when the volume is decreased at time = t_1?

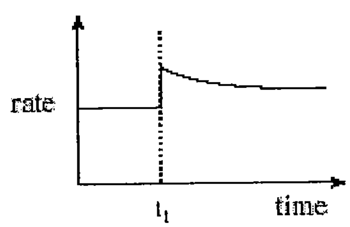
A.



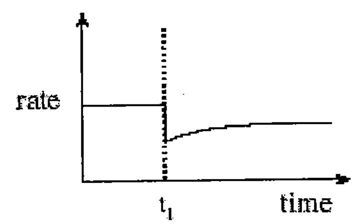
B.



C.



D.



109. Consider the following reaction for the Haber Process for ammonia production:

$$N_{2\,(g)} + 3H_{2\,(g)} \leftrightarrows 2\,NH_{3\,(g)} \qquad \Delta H = -92\text{ kJ}$$

The system is normally maintained at a temperature of approximately 500° C. Why is the temperature of 1000°C not used?

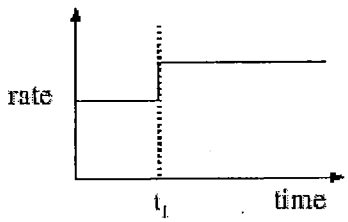
A. The equilibrium would shift to the right, reducing % yield.
B. The equilibrium would shift to the left, reducing % yield.
C. The forward reaction would change from exothermic to endothermic and equilibrium would be lost.
D. Too many collisions would decrease the number of successful collisions thus reducing the % yield.

110. Consider the following equilibrium:

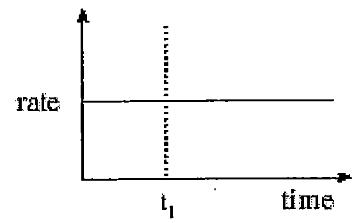
$$H_{2(g)} + Br_{2(g)} \leftrightarrows 2\,HBr_{(g)} + \text{energy}$$

Which of the following shows the forward reaction rate when the temperature is decreased at time = t_1?

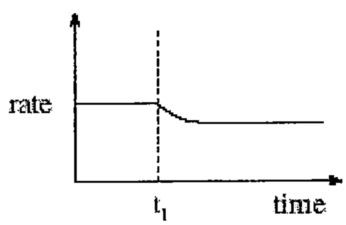
A.



B.



C.



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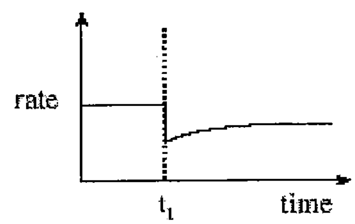


111. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)} \qquad \Delta H = -71.9\text{ kJ}$$ Change to −9.4kJ

Which of the following would allow you to conclude that the system has reached equilibrium?

A. $[H_{2(g)}] = [I_{2(g)}]$ ✗
B. The temperature remains constant ✓
C. The gas pressure remains constant would be even if not at equilibrium
D. $[H_{2(g)}] = 2[HI_{(g)}]$

112. Which reaction has the following equlibrium expression?

$$K_{eq} = \frac{[NO_2]^4[H_2O]^6}{[NH_3]^4[O_2]^7}$$ must be H_2O (g)

A. $4\,NO_{2\,(g)} + 6\,H_2O_{(l)} \leftrightarrows 4\,NH_{3\,(g)} + 7O_{2\,(g)}$
B. $4\,NH_{3\,(g)} + 7O_{2\,(g)} \leftrightarrows 4\,NO_{2\,(g)} + 6\,H_2O_{(g)}$
C. $4\,NO_{2\,(g)} + 6\,H_2O_{(g)} \leftrightarrows 4\,NH_{3\,(g)} + 7O_{2\,(g)}$
D. $4\,NH_{3\,(g)} + 7O_{2\,(g)} \leftrightarrows 4\,NO_{2\,(g)} + \cancel{6\,H_2O}_{(l)}$

113. Consider the following equilbrium:

$$CO_{2(g)} + 2H_2O_{(g)} \leftrightarrows CH_{4(g)} + O_{2(g)}$$

Which of the options below indicates that the reactants are favoured?

A. K_{eq} is slightly greater than 1

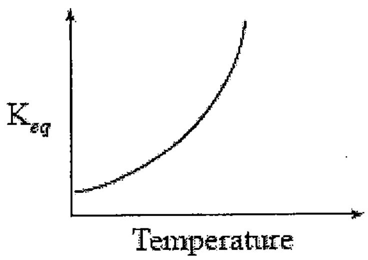
B. K_{eq} is slightly less than 1

C. K_{eq} is zero

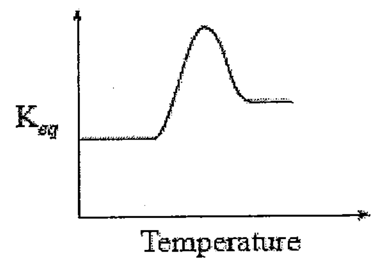
D. K_{eq} is very large

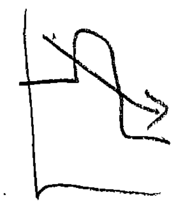
114. Which of the following best describes the relationship between K_{eq} and temperature for an exothermic forward reaction?

A.

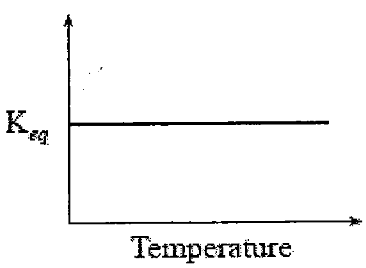


B.

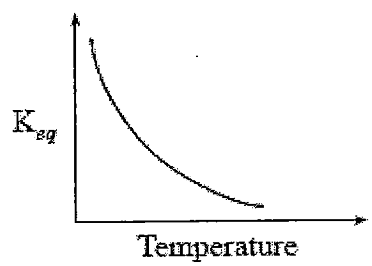




C.



D.



as temp ↓ ↑

Keq ↑ ↓

115. What will cause the value of K_{eq} for an exothermic reaction to increase?

A. decrease the temperature

B. increase the temperature

C. decrease the volume

D. increase the volume

116. Consider the following equilibrium:

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

A solution of $Ba(NO_3)_2$ is added, and a precipitate of $BaCrO_4$ forms. What could you add to the solution to dissolve the precipitate, and predict the equilibrium shift and change to K_{eq}.

	Add	Equilibrium shift	K_{eq}
A.	H_2O	left	remains constant
B.	$Cr_2O_7^{-2}$	left	decreases
C.	H^+	right	remains constant
D.	CrO_4^{-2}	right	increases

117. Consider the following equilibrium:

$$C_{(s)} + H_2O_{(l)} \leftrightarrows CO_{(g)} + H_{2(g)}$$

At equilibrium, 4.0×10^{-2} mol H_2, 4.0×10^{-2} mol CO, 1.0×10^{-2} mol H_2O and 1.0×10^{-2} mol C were present in a 1.0 L container. What is the value of K_{eq}?

$K_{eq} = \underline{[CO][H_2]} = (4.0 \times 10^{-2})(4.0 \times 10^{-2})$

$= 1.6 \times 10^{-3}$

118. Consider the following equilibrium:

$$2POCl_{3\,(g)} \leftrightarrows 2PCl_{3\,(g)} + O_{2\,(g)}$$

3.00 moles of $POCl_3$ were put into a 2.00 L container and allowed to reach equilibrium. At equilibrium $[O_2] = 0.0250$ M.

a. Use the concepts of entropy and enthalpy to predict whether or not the forward reaction will be endothermic or exothermic.

forward reaction is endothermic.

b. List three ways that you could shift the equilibrium to the product side.

(1) ↑ temp

(2) $[POCl_3]$ ↑ or $[PCl_3]$ ↓ or $[O_2]$ ↓

(3) increase volume.

c. Calculate the K_{eq} for the above container when equilibrium is reached.

$2POCl_3$	$\rightleftharpoons$	$2PCl_3$	+	O_2
$\frac{3.00 \text{ moles}}{2.00 \text{ L}}$		0		0
$-2x$		$+2x$		$+x$
$(1.50 - .0500) = 1.45$		.0500		.0250

$$K_{eq} = \frac{[PCl_3]^2[O_2]}{[POCl_3]^2}$$

$$= \frac{(.0500)^2(0.0250)}{(1.45)^2}$$

$$= 2.972657 \times 10^{-5}$$

$$= 2.97 \times 10^{-5}$$

119. Consider the following equlibrium:

$$2CrO_4^{-2}{}_{(aq)} + 2H^+{}_{(aq)} \leftrightarrows Cr_2O_7^{-2}{}_{(aq)} + H_2O_{(l)} \quad + \text{energy}$$

Initally, 0.450 moles of $Cr_2O_7^{-2}$, 0.480 moles of H_2O, 0.250 moles of CrO_4^{-2} and 0.500 moles of H^+ are placed in a 5.00 L container and allowed to reach equilibrium.

a. When equilibrium is reached, the $[Cr_2O_7^{-2}]$ is 0.100 M. Calculate the K_{eq} of the equilibrium.

$$2CrO_4^{-2} + 2H^+ \rightleftharpoons Cr_2O_7^{-2} + H_2O$$

$2CrO_4^{-2}$	$2H^+$	$Cr_2O_7^{-2}$	H_2O
$\frac{.250\text{ moles}}{5.00\text{ L}}$	$\frac{.500\text{ moles}}{5.00\text{ L}}$	$\frac{.450\text{ moles}}{5.00\text{ L}}$ (.0900)	
$-2x$	$-2x$	$+x$	
$(.0500 - .020)$	$(.100 - .020)$	$.100M$	

$x = .0100$

$$K_{eq} = \frac{[Cr_2O_7^{-2}]}{[CrO_4^{-2}]^2[H^+]^2} = \frac{(.100)}{(.030)^2(.080)^2} = 1.7361 \times 10^4 = 1.74 \times 10^4$$

b. Are reactants or products favored? products Explain your answer. $K_{eq} > 1$

c. How would the following stresses affect the equilibrium? Complete the table below using the arrows indicated.

shift left (from shock)	←	increased rate of forward reaction after equilibrium reestablished	↑
shift right (from shock)	→	decreased rate of forward reaction after equlibrium reestablished	↓
no shift	-	no change in rate	-

Stress (shock) introduced	Equilibrium shift	$[Cr_2O_7^{-2}]$ (after shifting)	Forward reaction rate (after equilibrium is back)
Decrease pressure	—	—	—
add $CrO_4^{-2}{}_{(aq)}$	→	↑	↑
increase temperature	←	↓	↑
add inhibitor	—	—	↓
increase volume of container	—	—	—
remove some $Cr_2O_7^{-2}{}_{(aq)}$	→	↓	↓

120. Consider the following equilibrium:

$$CO_{2\,(g)} + H_{2\,(g)} \leftrightarrows H_2O_{(g)} \quad \text{ }O_{(g)} \qquad K_{eq} = 0.36$$

Initially, 0.240 moles and CO_2, 0.240 moles of H_2, 0.150 moles of H_2O and 0.150 moles of CO are placed in a 3.00 L container.

a. Is the container at equilibrium? No.
If not, which way will the equilibrium shift in order to reach equilibrium.
Support your answer with calculations.

$$K_T = \frac{[H_2O][CO]}{[CO_2][H_2]} = \frac{(.0500)^2}{(.0800)^2} = .391$$

$$K_{eq} < K_T$$
.36 .39

∴ shift left.

b. Calculate the [CO] and [CO_2] at equilibrium.

CO_2	$+ H_2$	$\rightleftarrows H_2O$	$+ CO$
.0800	.0800	.0500	.0500
+x	+x	−x	−x
.0800 + x	.0800+x	.0500 − x	.0500 − x

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

$$.36 = \frac{(.0500 - x)^2}{(.0800 + x)^2}$$

$$\frac{.60}{1} = \frac{.0500 - x}{.0800 + x}$$

$$.0480 + .60x = .0500 - x$$

$$1.60x = \frac{.0020}{1.60}$$

$$x = 1.25 \times 10^{-3}$$

∴ $[CO] = .0500 - .00125 = .04875$
$= .0488\ M$

$[CO_2] = .0800 + .00125 = .08125$
$= .0812\ M$

Check $\frac{(.04875)^2}{(.08125)^2}$

$= .36$ ✓