Chemistry 12

Equilibrium Practice Test

Name: Key
Date:
Block:

Multiple Choice:

D 1. A system will proceed to equilibrium in an attempt to achieve a balance between

A. maximum enthalpy and maximum entropy.
B. minimum enthalpy and minimum entropy.
C. maximum enthalpy and minimum entropy.
D. minimum enthalpy and maximum entropy.

D 2. Consider the reaction:

$$BaCO_{3(s)} + \text{heat} \leftrightharpoons BaO_{(s)} + CO_{2(g)}$$

Which of the following observations will indicate that the reaction has most likely achieved equilibrium?

Constant macroscopic properties (colour, pH, temp, pressure)

A. The mass of the system becomes constant.
B. The concentration of $BaO_{(s)}$ becomes constant.
C. All the $BaCO_{3(s)}$ is consumed.
D. The gas pressure of the system becomes constant.

A 3. Consider the following reaction at equilibrium:

heat + $CO_{2(g)} + NO_{(g)} \leftrightharpoons NO_{2(g)} + CO_{(g)}$ $\Delta H = +82$ kJ

Which procedure will cause this equilibrium to shift to the left?

A. A decrease in the temperature.
B. An increase in the temperature.
C. A decrease in the volume of the system.
D. An increase in the volume of the system.

B 4. Quicklime (CaO), is produced from limestone ($CaCO_3$), according to the equilibrium reaction:

heat + $CaCO_{3(s)} \leftrightharpoons CaO_{(s)} + CO_{2(g)}$

Which of the following procedures results in producing the maximum quantity of quicklime?

A. Lower the temperature and allow $CO_{2(g)}$ to escape.
B. Raise the temperature and allow $CO_{2(g)}$ to escape.
C. Lower the temperature and finely grind the $CaCO_3$.
D. Raise the temperature and finely grind the $CaCO_3$.

C 5. Which procedure causes an increase in the value of K_{eq} for the following reaction?

2 → 1

Increase $C_{(s)} + 2\,H_{2(g)} \leftrightharpoons CH_{4(g)}$ + heat $\Delta H = -74.8$ kJ

A. ~~Decrease~~ the volume.
B. Increase the temperature.
C. Decrease the temperature.
D. Finely powder the $C_{(s)}$.

$K_{eq} = \frac{[P]}{[R]}$ ↑ shift right

6. Explain your answer to the question above:

A ↓V / ↑P Shift to side with fewer particles

C Rxn is exo Shift right if temp ↓

A 7. Consider the following equilibrium:

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

This equilibrium will **not** shift when

A. a catalyst is added.
B. the volume is decreased. ←
C. the $[H_2O_{(g)}]$ is increased. →
D. the temperature is increased. Don't know if endo/exo

B 8. Consider the equilibrium below:

3 → 2

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

When the volume of the system is increased, the

A. equilibrium shifts left and the $[NO_2]$ increases.
B. equilibrium shifts left and the $[NO_2]$ decreases.
C. equilibrium shifts right and the $[NO_2]$ increases.
D. equilibrium shifts right and the $[NO_2]$ decreases.

9. Explain your answer to the question above:

- V ↑ / P ↓
- Shift to side w/ more particles
- Shift left
- $[N_2]$, $[O_2]$ ↑
- $[NO_2]$ ↓

B ____ 10. Consider the following equilibrium:

$C_{(s)} + 2\ H_{2(g)} \leftrightharpoons CH_{4(g)}$

The equilibrium constant expression is

A. $K_{eq} = \frac{[CH_4]}{[H_2]}$

B. $K_{eq} = \frac{[CH_4]}{[H_2]^2}$

C. $K_{eq} = \frac{[CH_4]}{[C][H_2]}$

D. $K_{eq} = \frac{[CH_4]}{[C][H_2]^2}$

heat + D ____ 11. Consider the following equilibrium:

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

Temperature	K_{eq}
227°C	2.24
486°C	33.3

The increase in K_{eq} shows that the

A. equilibrium shifts left and the reaction is exothermic.
B. equilibrium shifts left and the reaction is endothermic.
C. equilibrium shifts right and the reaction is exothermic.
D. equilibrium shifts right and the reaction is endothermic.

C ____ 12. Consider the following system:

6 → 4

$P_{4(s)} + 6\ H_{2(g)} \leftrightharpoons 4\ PH_{3(g)}$

Which of the following changes would cause the above system to shift right?

A. Add more P_4. (Solid)
B. Add a catalyst.
C. Increase pressure.
D. Increase surface area. (Solid)

B ____ 13. Given the following system:

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

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. $Na_2Cr_2O_7$

Na+ H+ Na+ Na+ OH- NO3 CrO4 2- Cr2O7 2-

C ____ 14. 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. $K_{eq} = [Br_{2(g)}][Br_{2(l)}]$

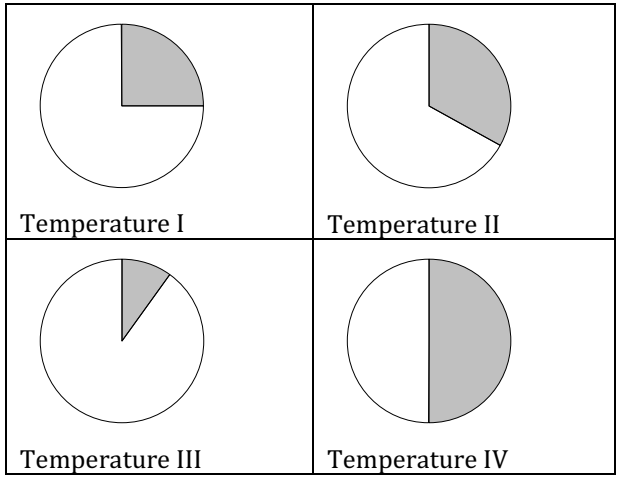
C

_____ 15. Consider the following equilibrium system:

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

The percent of I_2, (by volume) is determined in the above equilibrium at four different temperatures. The results are displayed in the following pie graphs:

Percent of I_2 (shaded area) at different temperatures:



From this data, the K_{eq} value for the above equilibrium is largest at temperature

A. I.
B. II.
C. III.
D. IV.

$K_{eq} = \frac{[P]}{[R]}$

16. Explain your answer to the question above:

Large K_{eq} favours products

III = smallest $[I_2]$
= largest [Products]

A

_____ 17. Which of the following equilibria, all at the same temperature, favours the products to the GREATEST extent?

A. $H_{2(g)} + I_{2(g)} \rightleftharpoons 2\ HI_{(g)}$ $K_{eq} = 5.5 \times 10^{1}$
B. $N_{2(g)} + O_{2(g)} \rightleftharpoons 2\ NO_{(g)}$ $K_{eq} = 8.7 \times 10^{-2}$
C. $2\ HCl_{(g)} \rightleftharpoons H_{2(g)} + Cl_{2(g)}$ $K_{eq} = 1.5 \times 10^{-3}$
D. $CO_{2(g)} + H_{2(g)} \rightleftharpoons CO_{(g)} + H_2O_{(g)}$ $K_{eq} = 1.6 \times 10^{1}$

18. Explain your answer to the question above:

Largest K_{eq} value

$K_{eq} = \frac{[Products]}{[Reactants]}$

Problems:

1. Given the following reaction at equilibrium:

$$\text{heat} + O_{2(g)} + 2CO_{(g)} + CaCO_{3(s)} \leftrightharpoons CaO_{(s)} + 3CO_{2(g)} \qquad \Delta H = +110 \text{ kJ}$$

For a) to d) below will the equilibrium shift left or right or not change if... (6 marks)

a) container volume is increased? No shift

b) some $CaCO_{3(s)}$ is removed? No shift

c) temperature is increased? Right

d) $CO_{2(g)}$ is added? Left

e) will K_{eq} increase, decrease or not change if $CO_{2(g)}$ is added? No change

f) will K_{eq} increase, decrease or not change if temperature is decreased? Decrease

2. Consider the following equilibrium system:

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

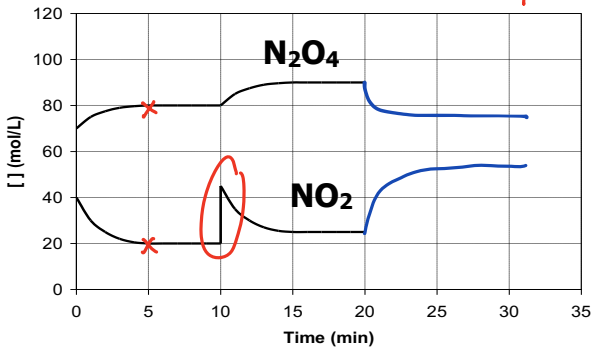
light yellow *colourless* *blood-red*

Cooling the equilibrium changes the colour from yellow to red. What effect will the decrease in temperature have on K_{eq}? Explain, using Le Chatelier's Principle. (2 marks)

- More red means shift right
- When temp ↓, shift right means rxn is exo
- [P] ↑, [R] ↓, K_{eq} ↑

3. The following graph represents concentration changes versus time for the equilibrium reaction:

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



a) At what time is equilibrium initially reached? 5 (1 mark)

b) Explain the changes that occur between 10 and 20 minutes. Indicate the stress applied and how the system responds. (2 marks)

- NO_2 added
- shift right

c) If the temperature of this system was increased at 20 minutes, **sketch directly on the graph** how the concentrations of both substances would change. (2 marks)

(see graph)

4. At 250°C, K_{eq} for the following reaction is 5.83×10^2.

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

If the equilibrium concentration of SO_2 is 0.012 M and that of O_2 is 0.049 M, what is the equilibrium concentration of SO_3 at 250°C? (3 marks)

$$K_{eq} = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = 583$$

$$\frac{(x)^2}{(0.012)^2(0.049)} = 583$$

$$x = [SO_3] = 0.064\ M$$

5. Consider the following equilibrium system:

$$H_{2(g)} + I_{2(g)} \leftrightharpoons 2\ HI_{(g)} \qquad K_{eq} = 7.1 \times 10^2$$

0.10 mol of each of the three gases in the above system are placed in a 1.0 L container and allowed to come to equilibrium,

a) Will the reaction proceed forwards or backwards? Show evidence with a calculation. (2 marks)

$$\text{Trial } K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.10)^2}{(0.10)(0.10)} = 1.0$$

Trial < Actual

shift right

b) What will be the equilibrium concentration of all 3 gases? (4 marks)

	H_2	+ I_2	$\rightleftharpoons$ $2\ HI$
I	0.10 M	0.10 M	0.10 M
C	$-x$	$-x$	$+2x$
E	$0.10-x$	$0.10-x$	$0.10+2x$

$$\sqrt{\frac{(0.10+2x)^2}{(0.10-x)^2}} = \sqrt{710}$$

$$x = 0.0895$$

$$[H_2] = [I_2] = 0.01\ M$$

$$[HI] = 0.28\ M$$

6. In a 1.00 L container, at equilibrium, the reaction below:

$N_2O_{2(g)} + H_{2(g)} \leftrightharpoons N_2O_{(g)} + H_2O_{(g)}$

was analyzed and found to contain 0.200 mol of N_2O_2, 0.300 mol of H_2, 0.500 mol of N_2O, and 0.500 mol of H_2O. If 0.100 mol of N_2O_2 is added, what will the new equilibrium concentrations be of both products?
(5 marks)

$K_{eq} = \frac{(0.500)^2}{(0.200)(0.300)} = 4.17$

	N_2O_2	+ H_2	⇌ N_2O	+ H_2O
OE	0.200M	0.300M	0.500M	0.500M
I	+ 0.100M			
C	−x	−x	+x	+x
E	0.300 − x	0.300 − x	0.500 + x	0.500 + x

$\sqrt{\frac{(0.500+x)^2}{(0.300-x)^2}} = \sqrt{4.17}$

$\frac{0.500+x}{0.300-x} = 2.042$

$0.6126 - 2.042x = 0.500 + x$

$-0.6126 \quad -x \quad -0.6126 \quad -x$

$-3.042x = -0.1126$

$-3.042 \quad -3.042$

$x = 0.0370$

$[N_2O] = [H_2O]$
$= 0.500 + 0.0370$
$= 0.537M$

7. A reaction mixture contained 0.240 mol of NO, 0.0860 mol of O_2 and 1.20 mol of NO_2 when at equilibrium in a 2.00L bulb. How many mol of O_2 had to be added to the mixture to increase the number of moles of NO_2 to 1.28 when equilibrium was re-established?

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

(5 marks)

$[NO] = 0.120M \quad [O_2] = 0.0430M \quad [NO_2] = 0.600M$

$K_{eq} = \frac{(0.600)^2}{(0.120)^2(0.0430)} = 581$

	2NO	+ O_2	⇌ $2NO_2$
OE	0.120M	0.0430M	0.600M
I		+x	
C	−0.040M	−0.020M	+0.040M
E	0.080M	0.0230 + x	0.640M

$\frac{(0.640)^2}{(0.080)^2(0.023+x)} = 581$

$\vdots$

$x = 0.0872M$

$\frac{0.0872\,mol}{1\,L} \times \frac{2.0\,L}{1} = 0.174\,mol$