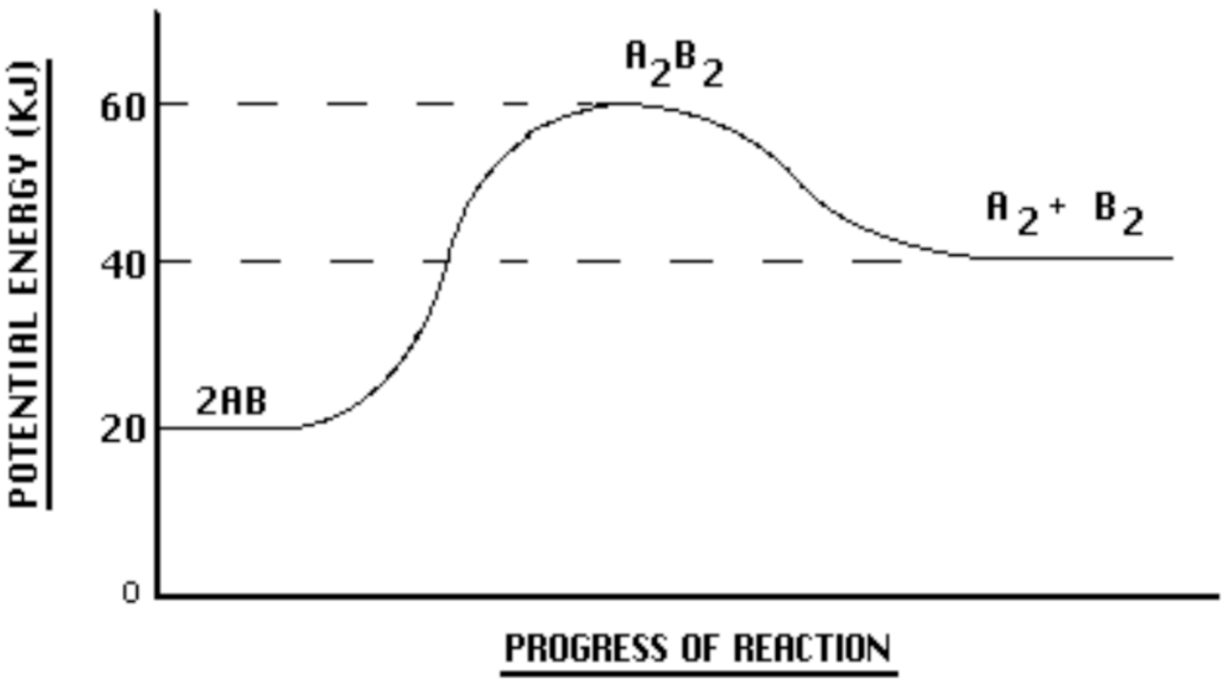
Chemistry 12

Unit 2 – Chemical Equilibrium Review

1. What two things are equal at ***equilibrium***?

_________________________________ and _________________________________

2. Consider the following *potential energy* diagram:



a) Which reaction, forward or reverse, will be affected *more* by an increase in temperature? _______________________________________

b) Write a thermochemical equation for the forward reaction using the numerical value for the heat. (put the heat in the reaction)

Answer ____

c) When the temperature is first raised, which reaction will increase *most* in rate, forward or reverse? ____

Explain why. ____

d) If the rate of the forward reaction is *faster* than the reverse reaction for awhile, what will happen to the $[A_2]$ and $[B_2]$? ____

e) If the $[A_2]$ and $[B_2]$ increases, what will happen to the rate of the *reverse reaction*?

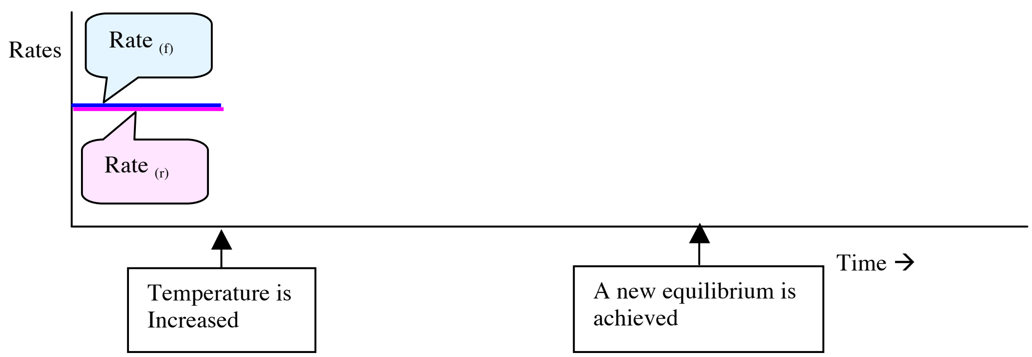
____

f) When the reverse reaction rate *catches up* to the forward reaction rate, the system is again at____

g) Since, for awhile, *the rate of the forward reaction was faster than the rate of the reverse reaction*, there would be an *increase* in the concentrations of ______________________ and a *decrease* in the concentration of _______________________________________ in the second equilibrium.

h) We can summarize by saying that the equilibrium has shifted to the _____________ as a result of increasing the temperature.

i) Draw a graph showing the **rates** of the *forward* and *reverse* reactions vs. time summarizing what happens in 2(c) to 2(f). (Check out which way things will shift!)



3. Consider the reaction:

$$A_{2(g)} + B_{2(g)} \rightleftarrows 2C_{(g)}$$

a) If one mole of A_2 and one mole of B_2 are placed in a 1.0 L container, an equilibrium is established in which $[A_2]$ and $[B_2]$ = 0.40 M and [C] = 1.2 M. If 2.0 moles of C are placed into another 1.0 L container at the same temperature, what will the final concentrations of all the species be? (*HINT: This is* <u>*not*</u> *a calculation. It deals with how equilibrium can be approached from the left or from the right.*)

$[A_2]$ = ________________ $[B_2]$ = _______________ [C] = ______________

b) Sketch ***two*** graphs showing each of the activities performed in 3a. The graphs are concentration vs. time.

(*Starting with 1 mole A_2 and 1 mole of B_2*)

(*Starting with 2 moles of C*)

4. Give ***five*** characteristics of the ***equilibrium*** state.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

5. Explain why the colour of NO_2 gas first gets **darker** and then gets *lighter* when compressed in a syringe. The equation is:

$$\underset{\text{colourless}}{N_2O_{4(g)}} \rightleftarrows \underset{\text{dark brown}}{2NO_{2(g)}}$$

____

____

____

____

6. Define ***enthalpy*** ____

7. Define ***entropy*** ____

8. For the reaction:

$$ZnCl_{2(aq)} + H_{2(g)} \rightleftarrows Zn_{(s)} + 2HCl_{(aq)} \qquad \Delta H = +152\ kJ$$

The tendency toward *minimum enthalpy* favours the ____________________ . The tendency toward *maximum entropy* favours the ______________________________

If the reactants are combined will the reaction *go to completion*, *not occur at all* or *reach a state of equilibrium*?

____

9. For the reaction:

$$2NaHCO_{3(s)} + \text{heat} \rightleftarrows Na_2SO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$$

As this reaction proceeds right, enthalpy is _______creasing and entropy is ______creasing.

If the reactants are combined will the reaction *go to completion*, *not occur at all* or *reach a state of equilibrium*?

____

10. For the reaction:

$$Cl_{2(aq)} + 25\ kJ \rightleftarrows Cl_{2(g)}$$

The tendency toward *minimum enthalpy* favours the ____________________ . The tendency toward *maximum entropy* favours the __________________________________

If the reactants are combined will the reaction *go to completion*, *not occur at all* or *reach a state of equilibrium*?

____

11. For the reaction:

$$Na_{(s)} + H_2O_{(l)} \rightleftarrows Na^+_{(aq)} + OH^-_{(aq)} + \frac{1}{2} H_{2(g)} \qquad \Delta H = -184\ kJ$$

Which way will the equilibrium shift when the following changes are made:

a) $NaCl_{(aq)}$ is added .... ____________________________

b) The pressure is increased .... ____________________________

c) The $[OH^-]$ is decreased .... ____________________________

d) The temperature is decreased .... ____________________________

e) The volume of the container is decreased .... ____________________________

f) The solid sodium is chopped into smaller pieces.. ____________________________

g) A catalyst is added .... ____________________________

12. For the following reaction:

$$4NH_{3(g)} + 5O_{2(g)} + heat \rightleftarrows 4NO_{(g)} + 6H_2O_{(g)}$$

Which way will the equilibrium shift (if any) when the following changes are made:

a) [NO] is decreased .... ______________________________

b) $[O_2]$ is increased .... ______________________________

c) $[NH_3]$ is increased .... ______________________________

$$4NH_{3(g)} + 5O_{2(g)} + \text{heat} \rightleftarrows 4NO_{(g)} + 6H_2O_{(g)}$$

d) The temperature is decreased .... ________________________________

e) The volume of the container is increased .... ________________________________

f) The total pressure is increased .... ________________________________

g) Helium gas is added to increase the total pressure ________________________________

h) The temperature is increased .... ________________________________

i) A catalyst is added .... ________________________________

13. Discuss the ideal pressure and temperature conditions for achieving maximum yield of ammonia at a reasonable rate in the *Haber Process*:

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

Pressure should be (*high/low*) _______________________ and temperature should be

(*high/low*)______________, but still high enough to maintain a ________________________

Give reasons for your answer. ____

____

14. In an experiment at 423°C, the following concentrations were measured for the ***equilibrium*** system:

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

$[HI] = 17.7 \times 10^{-3}$ M, $[H_2] = 1.83 \times 10^{-3}$ M and $[I_2] = 3.13 \times 10^{-3}$ M.

Calculate the *value* for the equilibrium constant (Keq) at 423°C .

15. If, at 423°C , the $[H_2]$ and $[I_2] = 4.8 \times 10^{-3}$ M, calculate the [HI]. Use Keq from question 14.

16. Given the equilibrium equation:

$$X_{2(g)} \quad + \quad 3Y_{2(g)} \quad \rightleftarrows \quad 2XY_{3(g)}$$

If 2.0 moles of X_2 and 2.0 moles of Y_2 are added to a 1.0 L container, an equilibrium is established in which the $[Y_2] = 0.80$ M. Find the following at equilibrium. (*Use a table.*)

$[X_2]$ = ______________ $[XY_3]$ = ________________ Keq = ______________

17. The equation: $A_{(g)} + B_{(g)} \rightleftarrows C_{(g)} + D_{(g)}$ has a Keq = ***49*** at 25°C.

If 1.0 mole of C and 1.0 mole of D are added to a 0.50 L container at 25°C, calculate the following *at equilibrium*: (*Use a table.*)

[A] = ______________ [B] = _____________ [C] = ____________ [D] = ____________

18. In the equilibrium in question 17, what, if anything, would happen to the *value* of the equilibrium constant if the *temperature is increased* and the reaction is exothermic?

Answer _______________________________

Explain your answer. ____

____

19. Write the *Keq expression* for the following reaction: (*Be careful of phases!*)

$$2NaHCO_{3(s)} + heat \rightleftarrows Na_2SO_{3(s)} + CO_{2(g)} + H_2O_{(g)}$$

20. The Keq for the reaction:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$$ is ***85.0*** at 25°C.

Using this information, calculate the Keq for the reaction :

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

21. Consider the following equilibrium:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$$ Keq = ***6.5*** at a certain temperature

What will occur when 1.0 mol of SO_2, 1.0 mol of O_2, and 1.0 mol of SO_3 are placed in a 1.0 L container and allowed to reach equilibrium? Include in your answer a description of what will happen to the concentration of each of the chemicals.

22. Given the equilibrium:

$$CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)} \qquad \Delta H = -41 \text{ kJ}$$

Give 5 actions which could cause this equilibrium to shift to the ***left***:

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

23. How does the addition of a *catalyst* affect the Keq for a system? ______________________

24. Choose the equilibrium which most *favours the reactants*.
 a) $NO + 1/2O_2 \rightleftarrows NO_2$ Keq = 4.4×10^7
 b) $CO + 1/2O_2 \rightleftarrows CO_2$ Keq = 4.0×10^{-3}
 c) $C + H_2O \rightleftarrows CO + H_2$ Keq = 3.1×10^3
 d) $NO + H_2O \rightleftarrows NO_2\ H_2$ Keq = 1.0×10^{-22}

25. Consider the following system: $2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$ $\Delta H = -99$ kJ/mol
What are *four* things which could be done in order to increase the yield of SO_3?

 1. ____

 2. ____

 3. ____

 4. ____

26. Given the equilibrium equation: $\boldsymbol{XY_{(g)} + heat \rightleftarrows X_{(g)} + Y_{(g)}}$

If initially, at equilibrium, the [XY] = 3.0 M, the [X] = 5.0 M and the [Y] = 6.0 M, draw a graph showing qualitatively what happens to the concentrations of each species as the following changes are made to the system:
 Time I - The *temperature is decreased*.
 Time II - Some $X_{(g)}$ is *removed from* the system
 Time III - Some $XY_{(g)}$ is *added to* the system
 Time IV - The *total pressure is increased*.