Entropy and Enthalpy Guided Notes

1) Define

a) Entropy_____

b) Enthalpy_____

c) Spontaneous_____

d) Non-spontaneous_____

2) There is a natural tendency for reaction to move to the side with **minimum** enthalpy

Minimum enthalpy is the side **with** the heat term

On a PE diagram, the tendency of minimum enthalpy favours the side that is **Higher or lower** on the graph.

In an endothermic reaction (forward), min. enthalpy favours the _____**reactants**_____.

In an exothermic reaction (forward), min. enthalpy favours the ___**products**_____.

Problems

Tell whether each of the following is *endothermic* or *exothermic* and state which has ***minimum enthalpy,*** the *reactants* or the *products*:

a. $PCl_{5(g)} \rightleftarrows Cl_{2(g)} + PCl_{3(g)} \quad \Delta H = 92.5\ kJ$

___**endo**___thermic and the ____**reactants**_____ have *minimum enthalpy.*

b $2NH_{3(g)} + 92.4\ kJ \rightleftarrows N_{2(g)} + 3H_{2(g)}$

____**endo**__thermic and the ____**reactants**_____ have *minimum enthalpy.*

c $CO_{(g)} + 3H_{2(g)} \rightleftarrows CH_{4(g)} + H_2O_{(g)} + 49.3\ kJ$

___**exo**____thermic and the ____**products**_____ have *minimum enthalpy.*

d. $Cl_{2(g)} \rightleftarrows Cl_{2(aq)} \quad \Delta H = -25\ kJ$

___**exo**____thermic and the ____**products**_____ have *minimum enthalpy.*

3) There is a natural tendency for reaction to move to the side with _____maximum_____ entropy

There is a natural tendency towards the side of the reaction with **more or less** order

List the phases by increasing entropy (lowest to highest)

_____**solids < liquids < solutions < gases**_____

The side of the reaction with **more or less** moles of gas has maximum entropy

In the following examples, the ***entropy is increasing*** (or the ***products*** have ***greater entropy***):

1. There is a *gas* (or gases) on the *right*, when there are *no gases* on the *left* of the equation:

   $CaCO_{3(s)} + 2\,HCl_{(aq)} \rightleftharpoons CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

   a gas is formed on the right.

2. When there are *gases on both sides*, the ***products*** have ***greater entropy*** when there are ***more moles of gas on the right*** (add up coefficients of gases on left and right.):

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

   There are (4 + 5) = 9 moles of gas on the left

   There are (4 + 6) = 10 moles of gas on the right.

Problems

For each of the following, decide whether the ***reactants*** or the ***products*** have ***greater entropy***:

a) $I_{2(s)} \rightleftharpoons I_{2(aq)}$ The _____**products**_____ have greater entropy.

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

The _____**products**_____have greater entropy.

c) $NH_{3(g)} \rightleftharpoons NH_{3(aq)}$

The _____**reactants**_____have greater entropy.

d) $CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$

The _____ **reactants** _____have greater entropy.

e) $MgCO_{3(s)} + 2HCl_{(aq)} \rightleftarrows MgCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$

The _____**products**_____have greater entropy.

4) In nature there is a natural tendency for a reaction to favour the side with

___minimum____ enthalpy and _____maximum___ entropy.

5) Choose one of the following
does not occur-non-spontaneous or goes to completion- spontaneous or goes to equilibrium

a) If min. enthalpy and maximum entropy both favour the products

- the forward reaction will ____**go to completion**_____

-the reverse reaction will _____**not occur**_____

b) If min. enthalpy and maximum entropy both favour the reactants

- the forward reaction will _____**not occur**_____

-the reverse reaction will _____**go to completion**_____

c) If min. enthalpy and maximum entropy both favour the opposite directions

- the forward reaction will _____**go to equilibrium**_____

-the reverse reaction will _____**go to equilibrium**_____

Problems
For each of the following reactions decide which has ***minimum enthalpy*** (reactants or products), which has ***maximum entropy*** (reactants or products), and if the reactants are mixed, what will happen? (go to completion/ reach a state of equilibrium/not occur at all).

a) $PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$; $\Delta H = -92.5$ kJ

The _____**products**_____ has/have minimum enthalpy.

The _____**reactants**_____ has/have maximum entropy.

If PCl_3 and Cl_2 are put together, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

_____**reach a state of equilibrium**_____

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

The _____**products**_____ has/have minimum enthalpy.

The _____**reactants**_____ has/have maximum entropy.

If NO_2 was put in a flask, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

_____**reach a state of equilibrium**_____

c) $P_{4(s)} + 6H_{2(g)} + 37\ kJ \rightleftarrows 4PH_{3(g)}$

The _____**reactants**_____ has/have minimum enthalpy.

The _____**reactants**_____ has/have maximum entropy.

If $P_{4(s)}$ and $6H_{2(g)}$ was put in a flask, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

_____**not occur at all**_____

d) $2PbO_{(s)} + 4NO_{2(g)} + O_{2(g)} \rightleftarrows 2Pb(NO_3)_{2(s)}$; $\Delta H = -597\ kJ$

The _____**products**_____ has/have minimum enthalpy.

The _____**reactants**_____ has/have maximum entropy.

If $PbO_{(s)}$ and $NO_{2(g)}$ were put in a flask, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

_____**reach a state of equilibrium**_____

Self Test

1. What is meant by ***enthalpy?*** _____

   _____

2. What is meant by ***entropy?*** _____

3. In an ***endothermic reaction***, the _____**reactants**_____ have ***minimum enthalpy***.

4. In an ***exothermic reaction***, the _____**products**_____ have ***minimum enthalpy***.

5. Arrange the following in order from ***least entropy*** to ***greatest entropy***:
   a) liquids b) gases c) aqueous solutions d) solids

   solids < liquids < aqueous solutions < gases

6. There is a natural tendency toward _____**minimum**_____ ***enthalpy***

   and _____**maximum**_____ ***entropy***.

7. A ~~process~~ in which ***entropy increases*** and ***enthalpy decreases*** will
   (go to completion/ reach a state of equilibrium/not occur at all) _____

8. A process in which ~~***entropy increases***~~ and ***enthalpy increases*** will
   (go to completion/ reach a state of equilibrium/not occur at all) _____

9. A process in which ~~***entropy decreases***~~ and ***enthalpy decreases*** will
   (go to completion/ reach a state of equilibrium/not occur at all) _____

10. A process in which ***entropy decreases*** ~~and ***enthalpy increases***~~ will
    (go to completion/ reach a state of equilibrium/not occur at all) _____

11. A process in which ***both the enthalpy and entropy trends favour reactants*** will

    (go to completion/ reach a state of equilibrium/not occur at all) _____

12. A process in which ***both the enthalpy and entropy trends favour products*** will

    (go to completion/ reach a state of equilibrium/not occur at all) _____

13. A process in which ~~***the enthalpy and entropy trends oppose each other***~~ will
    (go to completion/ reach a state of equilibrium/not occur at all) _____

14. In each of the following, state which has the ***maximum entropy***, (reactants or products)

a) $C_{(s)} + O_{2(g)} \rightleftarrows CO_{2(g)}$ _____**products**_____

b) $2Al(s) + 6HCl_{(aq)} \rightleftarrows 3H_{2(g)} + 2AlCl_{3(aq)}$ _____**products**_____

c) $2SO_{3(g)} \rightleftarrows 2SO_{2(g)} + O_{2(g)}$ _____**products**_____

d) $HCl_{(g)} \rightleftarrows H^+_{(aq)} + Cl^-_{(aq)}$ _____**reactants**_____

e) $KOH_{(s)} \rightleftarrows K^+_{(aq)} + OH^-_{(aq)}$ _____**products**_____

15. For each of the following reactions decide which has ***minimum enthalpy*** (reactants or products), which has ***maximum entropy*** (reactants or products), and if the reactants are mixed, what will happen? (go to completion/ reach a state of equilibrium/not occur at all).
Assume there is sufficient activation energy to initiate any spontaneous reaction.

a) $PCl_{5(g)} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$; $\Delta H = +92.5$ kJ

The _____**reactants**_____ has/have minimum enthalpy.

The _____**products**_____ has/havemaximum entropy.

If PCl_5 is put in a flask what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

b) $2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)} +$ energy

The _____**products**_____ has/have minimum enthalpy.

The _____**reactants**_____ has/have maximum entropy.

If NO and O_2 were put in a flask, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

c) $Na_2CO_{3(s)} + 2HCl_{(aq)} \rightleftarrows 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)} +$ 27.7 kJ

The _____**products**_____ has/have minimum enthalpy.

The _____**products**_____ has/have maximum entropy.

If $Na_2CO_{3(s)} + 2HCl_{(aq)}$ were put in a flask, what should happen?
(go to completion/ reach a state of equilibrium/not occur at all)

d) $2Pb(NO_3)_{2(s)} + 597\ kJ \rightleftharpoons 2PbO_{(s)} + 4NO_{2(g)} + O_{2(g)}$;

The _____**reactants**_____ has/have minimum enthalpy.

The _____**products**_____ has/have maximum entropy.

If $Pb(NO_3)_2$ was put in a flask, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

16. Reactions which result in a/an _____**decrease**_____ in enthalpy and a/an _____**increase**_____ in entropy will ***always*** be **spontaneous**.

17. Reactions which result in a/an _____**increase**_____ in enthalpy and a/an ____**decrease**_____ in entropy will ***always*** be **non-spontaneous**.