Tutorial 2 - Solutions
Enthalpy and Entropy

Answers to questions 1-8 on page 6 & 7 of Tutorial 2:

1. 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.*

2. When no other factors are considered, a reaction will move in such a way (left or right) in order to achieve a state of _____**minimum**__ enthalpy.

3. Given the equation: $2NH_{3(g)} + 92.4\ kJ \rightleftarrows N_{2(g)} + 3H_{2(g)}$

   If only the *enthalpy* is considered, the (reactant / products) _____**reactants**__ will be favoured at equilibrium.

4. Given the equation: $Cl_{2(g)} \rightleftarrows Cl_{2(aq)} \quad \Delta H = -25\ kJ$

   If only the *enthalpy* is considered, the (reactant / products) _____**products**__ will be favoured at equilibrium.

5. If the reaction : $CO_{(g)} + 3H_{2(g)} \rightleftarrows CH_{4(g)} + H_2O_{(g)} + 49.3\ kJ$

   was proceeding to the *right*, the enthalpy would be _____**decreasing**. Is this a *favourable* change? __**yes**_____.

6. If the reaction: $PCl_{5(g)} \rightleftarrows Cl_{2(g)} + PCl_{3(g)}$ $\Delta H = 92.5$ kJ

was proceeding to the *right*, the enthalpy would be _____**increasing**. Is this a *favourable* change? ___**no**_____.

7. If the reaction: $Cl_{2(g)} \rightleftarrows Cl_{2(aq)}$ $\Delta H = -25$ kJ

was proceeding to the *right*, the enthalpy would be _____**decreasing**. Is this a *favourable* change? ___**yes**____.

8. If the reaction: $2NH_{3(g)} + 92.4$ kJ $\rightleftarrows N_{2(g)} + 3H_{2(g)}$

was proceeding to the *right*, the enthalpy would be _____**increasing**. Is this a *favourable* change? ___**no**___.

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Answer to question 9 a-e on p. 10 of Tutorial 2.

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

a) $I_{2(s)} \rightleftarrows I_{2(aq)}$ The ___**product**_____ has greater entropy.((aq) > (s))

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

The _____**products**_____have greater entropy.

(Reactants have 2 moles of gas, products have 1 + 3 = 4 moles of gas.)

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

The _____**reactant**_____has greater entropy.

(A gas has more disorder than an aqueous solution. The particles are much farther apart in a gas!)

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

The _____**reactants**_____have greater entropy.

(The reactants have 2 moles of gas, while the product has only 1 moles of gas.)

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

The _____**products**_____have greater entropy.

(There is a gas in the products and no gases in the reactants. This means the products have greater entropy.)

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Answer to question 10 on page 15 of Tutorial 2

10. 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 _____**product**_____ have minimum enthalpy.

The _____**reactants**_____ 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 (the enthalpy and entropy oppose each other.)

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

The _____**product**_____ has minimum enthalpy.

The _____**reactants**_____ 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 (the enthalpy and entropy oppose each other.)

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

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

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

If $P_{?\ (s)}$ and $6H_{2(g)}$ was put in a flask, what should happen?(go to completion/ reach a state of equilibrium/

__not occur at all (both enthalpy and entropy favour reactants.)

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

The _____**product**_____ has minimum enthalpy.

The _____**reactants**_____ 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)

_reach a state of equilibrium (the enthalpy and entropy oppose each other.)

Answers to Self Test on Tutorial 2 - pages 16-18

1. What is meant by ***enthalpy?*** **__heat content or chemical potential energy _____**

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

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) **___go to completion_____**

8. A process in which ***entropy increases*** and ***enthalpy increases*** will

(go to completion/ reach a state of equilibrium/not occur at all) **___reach a state of equilibrium____**

9. A process in which ***entropy decreases*** and ***enthalpy decreases*** will

(go to completion/ reach a state of equilibrium/not occur at all) **___reach a state of equilibrium___**

10. A process in which ***entropy decreases*** and ***enthalpy increases*** will

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

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) **__reach a state of equilibrium __**

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

a) $C_{(s)} ? O_{2(g)} \rightleftharpoons CO_{2(g)}$ **_____product_____**

b) $2Al(s) + 6HCl_{(aq)} \rightleftharpoons 3H_{2(g)} + 2AlCl_{3(aq)}$ **_____products___**

c) $2SO_{3(g)} \rightleftharpoons 2SO_{2(g)} + O_{2(g)}$ **_____products_____**

d) $HCl_{(g)} \rightleftharpoons H^+_{(aq)} + Cl^-_{(aq)}$ **_____reactant_____**

e) $KOH_{(s)} \rightleftharpoons K^+_{(aq)} + OH^-_{(aq)}$ **_____product_____**

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 _____**reactant**_____ has/have minimum enthalpy.

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

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

_____**reach a state of equilibrium** _____

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)

_____**reach a state of equilibrium** _____

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)

_____**go to completion**_____

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

The _____**reactant**_____ 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)

_____**reach a state of equilibrium**_____

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**.

You have now finished Tutorial 2
Get clarification on anything you don't understand - as soon as possible!

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