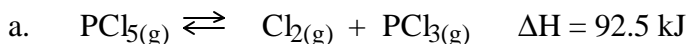


## Tutorial 2 - Solutions Enthalpy and Entropy

### 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*:



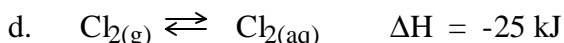
\_\_\_ **endothermic** and the \_\_\_ **reactants** \_\_\_ have *minimum enthalpy*.



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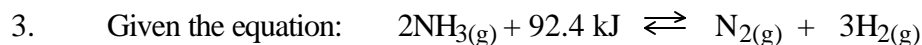


\_\_\_ **exothermic** and the \_\_\_ **products** \_\_\_ have *minimum enthalpy*.

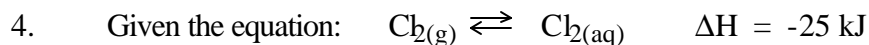


\_\_\_ **exothermic** and the \_\_\_ **products** \_\_\_ have *minimum enthalpy*.

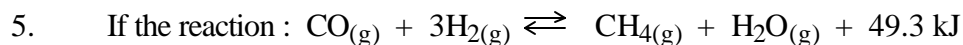
2. When no other factors are considered, a reaction will move in such a way (left or right) in order to achieve a state of \_\_\_\_\_ **minimum** \_\_\_ enthalpy.



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



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



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

6. If the reaction:  $\text{PCl}_5(\text{g}) \rightleftharpoons \text{Cl}_2(\text{g}) + \text{PCl}_3(\text{g}) \quad \Delta H = 92.5 \text{ kJ}$   
was proceeding to the *right*, the enthalpy would be \_\_\_\_\_ **increasing**. Is this a *favourable* change? no.
7. If the reaction:  $\text{Cl}_2(\text{g}) \rightleftharpoons \text{Cl}_2(\text{aq}) \quad \Delta H = -25 \text{ kJ}$   
was proceeding to the *right*, the enthalpy would be \_\_\_\_\_ **decreasing**. Is this a *favourable* change? yes.
8. If the reaction:  $2\text{NH}_3(\text{g}) + 92.4 \text{ kJ} \rightleftharpoons \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$   
was proceeding to the *right*, the enthalpy would be \_\_\_\_\_ **increasing**. Is this a *favourable* change? no.

\*\*\*\*\*

**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)  $\text{I}_2(\text{s}) \rightleftharpoons \text{I}_2(\text{aq})$  The product has greater entropy. ((aq) > (s))
- b)  $2\text{NH}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3\text{H}_2(\text{g})$   
The products have greater entropy.  
(Reactants have 2 moles of gas, products have 1 + 3 = 4 moles of gas.)
- c)  $\text{NH}_3(\text{g}) \rightleftharpoons \text{NH}_3(\text{aq})$   
The reactant has greater entropy.  
(A gas has more disorder than an aqueous solution. The particles are much farther apart in a gas!)
- d)  $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{COCl}_2(\text{g})$   
The reactants have greater entropy.

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



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.)

\*\*\*\*\*

### 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).

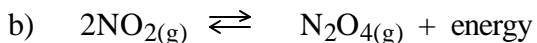


The \_\_\_\_\_ **product** \_\_\_\_\_ have minimum enthalpy.

The \_\_\_\_\_ **reactants** \_\_\_\_\_ have maximum entropy.

If  $\text{PCl}_3$  and  $\text{Cl}_2$  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.)

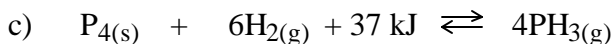


The \_\_\_\_\_ **product** \_\_\_\_\_ has minimum enthalpy.

The \_\_\_\_\_ **reactants** \_\_\_\_\_ have maximum entropy.

If  $\text{NO}_2$  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.)

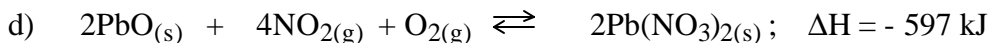


The \_\_\_\_\_ **reactants** \_\_\_\_\_ have minimum enthalpy.

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 (both enthalpy and entropy favour reactants.)



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)

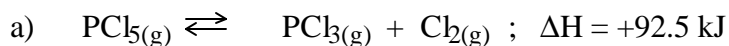
reach a state of equilibrium (the enthalpy and entropy oppose each other.)

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

- What is meant by *enthalpy*? \_\_\_\_\_ **heat content or chemical potential energy** \_\_\_\_\_
- What is meant by *entropy*? \_\_\_\_\_ **disorder** \_\_\_\_\_
- In an *endothermic reaction*, the \_\_\_\_\_ **reactants** \_\_\_\_\_ have *minimum enthalpy*.
- In an *exothermic reaction*, the \_\_\_\_\_ **products** \_\_\_\_\_ have *minimum enthalpy*.
- 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** \_\_\_\_\_
- There is a natural tendency toward \_\_\_\_\_ **minimum** \_\_\_\_\_ *enthalpy*  
and \_\_\_\_\_ **maximum** \_\_\_\_\_ *entropy*.
- 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.

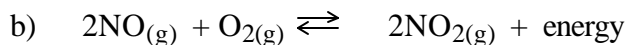


The reactant has/have minimum enthalpy.

The products has/have maximum entropy.

If  $\text{PCl}_5$  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

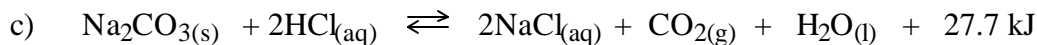


The products has/have minimum enthalpy.

The reactants has/have maximum entropy.

If  $\text{NO}$  and  $\text{O}_2$  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

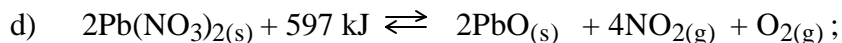


The products has/have minimum enthalpy.

The products has/have maximum entropy.

If  $\text{Na}_2\text{CO}_3(\text{s}) + 2\text{HCl}(\text{aq})$  were put in a flask, what should happen?(go to completion/ reach a state of equilibrium/not occur at all)

go to completion



The \_\_\_\_\_ **reactant** \_\_\_\_\_ has/have minimum enthalpy.

The \_\_\_\_\_ **products** \_\_\_\_\_ has/have maximum entropy.

If  $\text{Pb}(\text{NO}_3)_2$  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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