Unit test No. 1

Online unit test contains 30 questions randomly chosen from previous tests.

Written and oral examination

This part contains four questions on topics 1–4.

Topic 1. Solutions and concentration. Colligative properties of solutions

Example 1:

200 mL of a solution contains 0.02 mol of ribose ($C_5H_{10}O_5$) and 0.01 mol of KCl.

Variants of problems

a) Calculate the molar concentrations of both solutes and osmolarity of the solution.

b) Calculate the osmotic pressure of the solution at 25 °C.

c) Is this solution hypo-, hyper- or isotonic with respect to 0.05 M Na_2SO_4 solution?

d) Calculate the molar concentration of NaCl in its solution that is isotonic to the given solution.

e) What will happen to red blood cells if they are placed in the given solution? (p_{osm} of blood plasma is 740–780 kPa)?

Topic 2. Chemical thermodynamics

Example 1:

Consider the following glucose fermentation reaction:

$$C_6H_{12}O_{6(s)} \rightarrow 2C_2H_5OH_{(aq)} + 2CO_{2(g)}$$

$\Delta H_f^\circ{}_{298}$ (kJ/mol)	–1260	–278	–393.5
$\Delta G_f^\circ{}_{298}$ (kJ/mol)	–919	–175	–394.4

a) Calculate ΔH°_{298} of the reaction (in kJ).

b) Calculate the mass of glucose reacted if 249 kJ of heat was released.

c) Write a thermochemical equation that represent the standard enthalpy of formation (ΔH°_f) for glucose.

d) Estimate (do not calculate precisely) the sign of the entropy change for this process. Can this reaction occur spontaneously, and if yes, at which temperatures (high, low, any)? Explain your answer.

e) For this reaction $\Delta S_r^\circ{}_{298} = 299.2$ J/K. Calculate $\Delta G_r^\circ{}_{298}$ for the reaction (kJ). Will this reaction occur spontaneously under standard conditions? Do enthalpy and entropy factors favour the spontaneity of this reaction?

f) Calculate $\Delta G_r^\circ{}_{298}$ for the reaction (kJ). Can this reaction occur spontaneously under standard conditions?

Example 2:

Consider the following reaction: $CO_{(g)} + 3H_{2(g)} \rightarrow CH_{4(g)} + H_2O_{(l)}$

$\Delta H^\circ{}_{f\,298}$(kJ/mol)	–110		–75	–286

a) Calculate ΔH°_{298} of the reaction (in kJ).

b) Estimate (do not calculate precisely) the sign of the entropy change for this process. Can this reaction occur spontaneously, and if yes, at which temperatures (high, low, any)? Explain your answer.
c) What amount of energy will be released or consumed if 4.5 g of water forms?
d) For this reaction, occurring under standard conditions, it was found that $\Delta H°/T = \Delta S°$. Which process (direct or reverse reaction, equilibrium) will be observed in this case? Explain your answer.

Example 3:
The $\Delta G°'$ values for the hydrolysis of ATP and phosphorylation of fructose are –30.5 and 15.9 kJ/mol, respectively.
$ATP + H_2O \rightarrow ADP + P$ $\Delta G°' = –30.5$ kJ/mol
$fructose + P \rightarrow fructose\text{-}6\text{-}P + H_2O$ $\Delta G°' = 15.9$ kJ/mol
a) Write the equation for the coupled reaction and explain the term "thermodynamic coupling (conjugation)".
b) Calculate the $\Delta G°'$ values for the coupled reaction.

Topic 3. Chemical equilibrium

Example 1:
In the system $2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)}$ the equilibrium concentrations of NO, O_2 and NO_2 are 0.2, 0.3 and 0.4 mol/L, respectively, and the initial concentration of NO_2 is 0.
a) Write the K_c expression. What does the K_c value depend on?
b) Calculate the K_c value. Which substances (products or reactants) will predominate at equilibrium?
c) Calculate the $\Delta G°_{298}$ value for this reaction.
d) Calculate the initial concentrations of NO and oxygen.
e) How will the position of equilibrium and the value of the equilibrium constant be affected by: decrease in the concentration of NO; decrease in pressure; decrease in temperature (the forward reaction is exothermic).

Example 2:
In the system: $C_2H_5OH + CH_3COOH \rightleftarrows CH_3COOC_2H_5 + H_2O$ the initial concentrations are (mol/L): $c(CH_3COOC_2H_5) = 2.0$, $c(H_2O) = 2.0$, $c(C_2H_5OH) = 0.2$, $c(CH_3COOH) = 0.5$.
a) Determine the direction of the spontaneous process if $K_c = 4$ (at 25 °C).
b) For this reaction, $\Delta H° > 0$. How does the value of the equilibrium constant change with increasing temperature?
c) With increasing temperature, K_c of this process decreases. What is the sign of the $\Delta H°$ for this reaction?
d) Calculate $\Delta G°_{298}$ for this reaction if $K_c = 4$ (at 25 °C).

Topic 4. Chemical kinetics

Example 1:
For the reaction $2A + B \rightarrow C + D$
a) Write the kinetic equation for this reaction if it is a second order process with respect to A and zero order with respect to B.

b) Calculate the initial rate of the reaction if the concentrations of A and B are 2 and 2.5 mol/L, respectively, and the reaction rate constant is 0.6 L/mol · s.
c) Calculate the reaction rate at the moment when 50% of A has reacted.
d) Define the term "activation energy". How will the addition of a catalyst affect the rate and activation energy (E_a) of this reaction? Draw an energy diagram.
e) How will the rate and activation energy of this reaction change if the concentration of B decreases 4 times?
f) How will the rate and activation energy of this reaction change if temperature increases by 20° ($\gamma = 3$).

Example 2:
The elimination of a drug from a patient's body is a first-order reaction
a) Write the kinetic equation for this reaction and draw a graph of c versus t and v versus c.
b) Calculate the half-life of the drug if the elimination rate constant $k = 2 \cdot 10^{-3}$ s^{-1}.
c) How long will it take to eliminate 87.5% of the drug if $\tau_{½} = 4$ h? (similar tasks for other first order reactions: decomposition of a drug, decay of isotopes, etc.).
d) For a first order reaction, $\tau_{½} = 40$ min. Calculate the reaction rate constant and the reaction rate given that a reactant concentration is 0.01 mol/L.

Sample examination paper

1. 500 mL of a solution contains 0.02 mol of glucose ($C_6H_{12}O_6$) and 0.02 mol of K_2SO_4
   a) Calculate the osmolarity of the solution.
   b) Calculate the osmotic pressure of the solution at 25 °C.
   c) What will happen to red blood cells if they are placed in this solution? (p_{osm} of blood plasma is 740–780 kPa)

2. For the reaction $C_6H_{12}O_{6(aq)} \rightarrow 2C_2H_5OH_{(aq)} + 2CO_{2(g)}$

$\Delta H_f°_{298}$ (kJ/mol)	–1264	–278	–393.5

   a) Calculate $\Delta H°_{298}$ of the reaction.
   b) For this reaction $\Delta S°_{298} = 299.2$ J/K. Calculate $\Delta G°_{298}$ for this reaction (kJ). Is the reaction spontaneous under given conditions?
   c) Do enthalpy and entropy factors favour the spontaneity of this reaction?
3. In the system $2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)}$, the equilibrium concentrations of NO, O_2 and NO_2 are 0.2, 0.3 and 0.4 mol/L, respectively, and the initial concentration of NO_2 is 0.
   a) Write the K_c expression and calculate the K_c value.
   b) Calculate the initial concentrations of NO and oxygen.
   e) What will happen to the position of equilibrium and the value of the equilibrium constant if temperature decreases (the forward reaction is exothermic)?
4. The elimination of a drug is a first-order reaction.

a) What percentage of the drug will remain in the patient's body after 12 hours if $\tau_{½} = 4$ h?
b) Calculate the reaction rate constant for the reaction.
c) Write the kinetic equation for this reaction and draw a graph of c versus t and v versus c.