Volumetric analysis

Volumetric or titrimetric analysis is based on an accurate measurement of the volume of titrant spent in the reaction with the substance under investigation.
Titrated solution is called with exactly known concentration.
The initial call substances that can prepare a solution of accurate weigh.
Indicators – are weak organic acids or bases that change their color depending on the pH of the solution.
The interval transition color indicator – this pH range in which the indicator changes its color.

Indicator	color in the acidic environment	transition interval color (pH)	color in the alkaline environment
Methyl orange	Pink	3,1 – 4,4	yellow
Phenolphthalein	Colourless	8,2 – 10,5	raspberry
Methyl red	Red	4,2 – 6,2	yellow
Litmus	Red	5 – 8	blue

The method of neutralization

Neutralization method - a method of volumetric analysis, which uses volumetric solution of acids and alkalis.
The method is based on neutralization reaction: $H^+ + OH^- \rightarrow H_2O$.
Depending on the method of neutralization of the titrant, is divided into alkalimetry and acidimetry.

Alkalimetry – a method for determination of acids and salts, which give the hydrolysis of an acid reaction, using volumetric solution of alkali.
Titrant bases NaOH and KOH are preparing for a rough hitch, and then establish their title, the exact concentration of precursor – oxalate (oxalic acid) $N_2S_2O_4 \cdot 2H_2O$ and succinate (succinic acid) NOOS – – CH_2CH_2COOH – alkaline solutions are prepared at about the same concentration as the starting material, a sample of alkali calculated, knowing the concentration of the original substance.

Challenges for the preparation of solutions in alkalimetry

1) Calculate the sample of the solution for preparation 2 l NaOH, if the title will be set to 0.1 N solution of oxalate (oxalic acid).

V = 2 L
$C_N(H_2S_2O_4)$ = 0,1 mol/l
m(NaOH) =?

1) As the title of alkali will establish by 0.1 N solution $H_2S_2O_4$, the alkaline solution should be also 0.1N.
2) To calculate the mass of alkali, use the formula C_N:

$$C_N = \frac{m_X}{M_X \cdot f_{\text{eqv.}} \cdot V}.$$

hence $m_x = C_N \cdot m_x \cdot f_{eqv} \cdot V = 0,1 \cdot 40 \cdot 1 \cdot 2 = 8$g.

<u>Answer:</u> The weight of alkali 8g.

2) Calculate the hitch for the preparation of 1 liter of 0.15 N KOH solution.

V = 1 L C_N = 0.15 mol/l	1) For the calculation we write the formula, C_N $C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$
m(KOH) =?	hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V$ = 0,15· 56 · 1· 1 = 8,4 g

Answer: The weight of 8.4g, the alkali

3) Calculate the sample of the solution for preparation 2 L KOH, if the title will be set at 0.1 N solution of succinic acid.

V = 2 L C_N ($S_4N_6O_4$) = 0,1 mol/l	1) As the title of alkali is established by 0.1 N solution $S_4N_6O_4$, the solution by 0.1 N solution $S_4N_6O_4$, the solution should be also 0.1 N
m (KOH) =?	2) To calculate the mass use of alkali formula C_N:

$$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V$ = 0,1 · 56 · 1 · 2 = 11.2g

Answer: The weight of alkali is 11.2 g

4) What volume of 30% solution H_2SO_4 (ρ = 1,18) is necessary for preparation 2 l working solution with C_N = 0.1 mol/L, if acid reacts completely?

ω_1 = 30% = 1,18 V_2 = 2 L C_{N2} = 0,1 mol/l	Denote the parameters of the original 30% solution ; numeral 1, and the ρ_1 ρ solution which we must prepare –0,1 N - the numeral 2. 1) data from the first solution is insufficient to calculate formula of mass fraction, so use the formula for molar concentration C_N equivalent to finding the mass of material in the second solution:
V_1 =?	$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V$ = 0,1 · 98 · 1/2 · 2 = 9.8g

(As sulphuric acid reacts completely, ie all two hydrogen atoms are replaced by metal, then the equivalence factor is 1/2).

2) The mass of the solute is the same in both solutions

$$mx_1 = mx_2.$$

3) Using the mass fraction, we find the mass of the first solution:

$$\varpi = \frac{m(x)}{m(sol.)} 100\%, \quad \text{hence} \quad m_{sol.} = \frac{m_X}{\varpi} \cdot 100\% = \frac{9,8}{30} \cdot 100\% = 32,7.$$

4) Find the volume of the 30% solution:

$$V = \frac{m_{sol.}}{\rho} = \frac{32,7}{1,18} = 27,68 ml.$$

Answer: We need to take 27.68 ml 30% of the solution and pour water to 2 l.

Problems:

1) How many ml of 50% solution H_2SO_4 (ρ = 1,7) is necessary for cooking 3L desktop solution with C_N = 0.1 mol/L, if acid reacts completely? (16.66 g)
2) Calculate the sample of the KOH cooking 3L solution if its titer is set to 0.1 N solution of oxalate. (16,8 g)
3) Compute C_N hydrochloric acid, if the titration of 5 ml of solution spent 5.1 ml of 0.1 N KOH

solution. (0.1 mol/L)
4) Calculate the sample of the oxalate to prepare 4L 0.1 N solution.
5) Calculate the sample of the phosphate acid for the preparation of 2 L 0.1 N solution, if it reacts completely. (6.53 g)

Acidimetric- a method of determining the bases and salts, which give the hydrolysis of alkaline reaction, with the help of titrant acid.

Titrant acid HCI and H_2SO_4 are preparing for a rough hitch, and then establish their titre, the exact concentration of precursor – sodium carbonate Na_2CO_3, sodium tetra borate (borax)$Na_2B_4O_7 \cdot 10H_2O$ and sodium oxalate $Na_2S_2O_4$. Acid solutions are prepared about the same concentration as the starting material, sample of the acid is calculated knowing the concentration of the substance.

Challenges for the preparation of solutions in acidimetric

1) Calculate the mass of hydrochloric acid necessary for the preparation of 3 l of the solution, if the titre will be installed on the 0.1 N solution of sodium carbonate.

V = 3L
(Na_2SO_3) = 0,1 mol/l

m (HCl) =?

1) As the title of hydrochloric acid will set to 0.1 N solution C_N of Na_2SO_3, then the acid solution should be too 0.1 N
2) To calculate the mass of the acid we use the formula C_N:

$$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0.1 \cdot 36.5 \cdot 1 \cdot 3 = 10.5g.$

Answer: The mass of acid was 10.5g

2) Calculate the molar concentration of H_2SO_4, if in 400 ml of solution containing 49g acid.

V = 400ml
m (H_2SO_4) = 49g

C_X =?

1) Write the formula for molar concentration:

$$C_X = \frac{m_X}{M_X \cdot V} = \frac{49}{98 \cdot 0,4} = 1,25 mol/l.$$

Answer: C_X (H_2SO_4) = 1,25 mol/liter.

3) Calculate a sample of Na_2SO_3 to prepare 1 l titrated solution with C_N = 0.1 mol/liter.

V = 1L
$C_N(Na_2SO_3)$ = 0,1 mol / l

(Na_2SO_3) =?

1) To calculate the mass of Na_2SO_3 use the formula C_N:

$$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0,1 \cdot 106 \cdot 1/2 \cdot 1 = 5.3$ g

Answer: The mass of carbonate 5.3 g

4. Calculate the mass of a phosphate acid necessary for the preparation of 2 l of the solution, if the titre will be installed on the 0.1 N solution of borax.

V = 2 L
C_N $(Na_2V_4O_7)$ = 0,1 mol/l

m (H_3PO_4) =?

1) Since the titer of the phosphate acid will set to 0.1 N solution of borax, then the acid solution should be too 0.1 N.

2) To calculate the mass of the acid we use the formula C_N:
hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0,1 \cdot 202 \cdot 1 / 2 \cdot 2 = 20.2g$

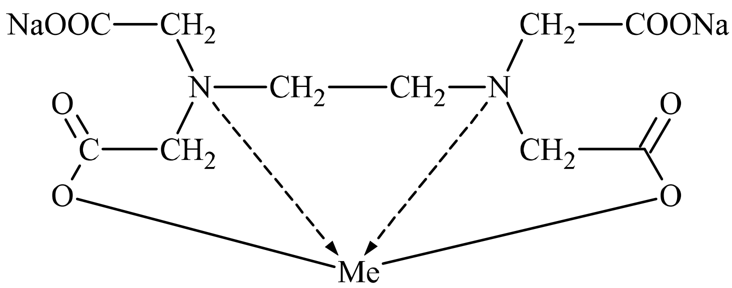
Answer: The mass of acid was 20.2g

Problems:

1) Calculate the sample of the drills for the preparation of 0,5 l titrant with C_N = 0.1 mol / liter. (Answer: 4,55 g)
2) Calculate the C_N acid phosphate solution, if it contains 1,5 l 7.5 g of the acid. (Answer: 0,15 mol / l)
3) Calculate the molar concentration of hydrochloric acid, if in 700ml solution contains 3.5 g of it. (Answer: 0.13 mol / L)
4) Calculate the molar concentration of sulphuric acid equivalent, if 600ml of solution containing 5.5 g of it .. (Answer: 0,18 mol / l)
5) Calculate the HF solution of hydrochloric acid, if in 200ml of solution contained 15g acid. (Answer: 0.2 mol / L)

Chelatometry

Chelatometry is a method of volumetric analysis, which uses titrant complexing.
Complexones – amino polycarbonic acids and their derivatives.
Increasingly using ethylenediaminetetr -acetic acid (**Trilon B)**, which is to give chelates metal cations:



To determine the end of the titration using indicators - Black T, blue chromogen, murexid.

The chemistry of the method:

Ind + Me → Me-Ind;
blue cherry

Me-Ind + TrB → Me-TrB + Ind
cherry red

The starting materials of the method: MgO; $CaCO_3$, Zn.

Examples

1) How many grams of Trilon B is necessary for the preparation of 250ml solution with C_N = 0.05 mol / L?

V = 250ml
C_N= 0.05mol/l

1) Since the problem is given by the molar concentration equivalent of C_N, the solution begins with the formula C_N:

M_X =?

$$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0,05 \cdot 372 \cdot 1/2 \cdot 0,25 = 2.3$ g

Answer: The weight of TrB was 2.3 g

2) On titration 10ml $MgCl_2$ solution with C_N = 0.1 mol/l spent 11.9 ml of working solution of Trilon B. Calculate the concentration of solution of Trilon B.

V ($MgCl_2$) = 10ml
C_N ($MgCl_2$) = 0,1mol/l
V (Tr B) = 11.9ml

C_N (Tr B) =?

1) to solve using the law equivalence:

$C_N(MgCl_2) \cdot V(MgCl_2) = C_N(Tr\ B) \cdot V(Tr\ B)$;

hence $C_N(Tr.\ B) = \frac{C_N(MgCl_2) \cdot V(MgCl_2)}{V(Tr.B)}$

$$= \frac{0,1 \cdot 10}{11,9} = 0.084 mol/l.$$

Answer: C_N (Tr B) = 0.084 mol/liter.

3) Calculate the total hardness of water, if the titration of 30ml of it spent 2.7 ml of 0.1 N Trilon B.

V (H_2O) = 30 ml
V (Tr B) = 2.7 ml
C (Tr B) = 0,1 mol/l

C (H_2O)=?

1) To solve using the law equivalence:

$C_N(H_2O) \cdot V(H_2O) = C_N(v) \cdot V(Tr\ B)$

hence $C_N(H_2O) = \frac{C_N(Tr\ B) \cdot V(Tr\ B)}{V(H_2O)}$

$$= \frac{0,1 \cdot 2,7}{30} = 0,009 = 9 mol/l.$$

Answer: The total water hardness 9mol/liter.

4) Calculate a sample of Trilon B to prepare 1 liter of solution if the titer (the exact concentration) will be set as 0.1 N solution of the starting material MgO.

V (Tr B) = 1 ml
C (MgO) = 0,1 mol/l

m (MgO) =?

1) Since the titre will be set by Tr B 0.1 N solution of starting material MgO, a sample of the Tr B is also counting on the basis of concentration of 0.1 mol / litre. Since the problem given molar concentration equivalent C_N, the solution begins with the formula C_N:

$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$ hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0,1 \cdot 372 \cdot 1/2 \cdot 1 = 18.6$g

Answer: The weight of Tr B was 18.6 g

5) Calculate a sample of zinc sulphate for the preparation of 200g of a solution with mass fraction of salt 1,5%.

$m_{sol\text{-}n}$ = 200g
ω ($ZnSO_4$) = 1,5%

m ($ZnSO_4$) =?

1) Since the problem is given by the mass fraction, then use the formula:

$\varpi = \frac{m(x)}{m(sol.)} 100\%$, hence $m_X = \frac{\varpi \cdot m_{sol.}}{100\%} = \frac{1,5\% \cdot 200}{100} = 3g.$

Answer: Response; linkage $ZnSO_4$ – 3g.

Problems

1) Compute a sample of Trilons B to prepare 0.5 litres of solution if the titer (the exact concentration) will be set as 0.1 N solution of the starting material $CaCO_3$. (Answer: 9.3 g)
2) Compute a sample of nickel sulphate for the preparation of 400 g solution with mass fraction of salt 1,5%. (Answer: 6g)
3) How many grams of Trilon B is necessary for the preparation of 250ml solution with C_N = =0.05 mol /l? (Answer: 2.325 g)
4) Calculate a sample of mercury (II) nitrate for the preparation of 500ml 0.1 N solution. (Answer: 6.575 g)

METHOD OF PERMAGANATION

Permanganation- a method of volumetric analysis, which uses potassium permanganate titrant $KMnO_4$. The main reaction is the method:

$$MnO_4^- + 8H^+ + 5\bar{e} \rightarrow Mn^{+2} + 4H_2O$$

$KMnO_4$ titrant is prepared for a rough hitch, and then set the title of the original substance - $H_2C_2O_4$ or $Na_2C_2O_4$.
Titration is carried out in an acidic medium. End of titration set for the appearance of pink color when adding one extra drop of solution $KMnO_4$.

Examples of solving problems
1) Compute a sample of 400 ml to prepare solution $KMnO_4$. If the title will be set to 0.1 N solution of starting material $H_2C_2O_4$

V (sol-n) = 400 ml
C ($H_2C_2O_4$) = 0,1 mol/l
m ($KMnO_4$) =?

1) Since the titer of $KMnO_4$ solution will set on 0.1 N solution $H_2C_2O_4$, then $KMnO_4$ solution concentration must also be 0.1 mol/liter. Use the formula of the molar concentration of equivalent: $C_N = \dfrac{m_X}{M_X \cdot f_{eqv.} \cdot V}$.

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0{,}1 \cdot 158 \cdot 1/5 = 0.4 \cdot 12.64g$

Answer: The mass of $KMnO_4$ is 12.64g

2) The laboratory has 10% solution of $KMnO_4$ (ρ = 1,4). Calculate C_N.

ω ($KMnO_4$) = 10%
ρ = 1,4
C_N =?

1) Using a formula that relates the C_N and ω:

$$C_N = \frac{\varpi\% \cdot \rho \cdot 10}{M_X \cdot f_{eqv.}} .= \frac{10\% \cdot 1{,}4 \cdot 10}{158 \cdot 1/5} = 4{,}43 mol/l.$$

Answer: C_N ($KMnO_4$) = 4.43 mol/liter.

3) Compute a sample of $Na_2C_2O_4$ for the preparation of 500 ml 0.1 N solution.

V (sol-n) = 500 ml

1) Use the formula of the molar concentration equivalent:

$C_N = 0.1$ N	$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$.
m ($Na_2C_2O_4$) -?	hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0,1 \cdot 134 \cdot 1/2 \cdot 0,5 = 3.35g$

Answer: The mass was $Na_2C_2O_4$ 3.35 g

4) How many grams of iron (II) sulphate is necessary for the preparation of 100ml of solution, if there is a volumetric solution $KMnO_4$ with $C_N = 0.08$ mol/litre.

V (sol-n) = 100 ml ($KMnO_4$) = 0.08 mol/l	1) Since titration carried 0.08 N $KMnO_4$ solution, the solution of C_N $FeSO_4$ necessary to prepare the same concentration.
Use the ($FeSO_4$) =?	Formula of molar concentration equivalent of C_N

$$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V},$$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0,08 \cdot 152 \cdot 1 \cdot 0,1 = 1.216g$,

Answer: The mass of $FeSO_4$ 1,216g

5) Calculate the volume of 30% solution of H_2O_2 (ρ = 1,27) for the preparation of 2 l of the solution, if the titration is carried out 0.09 N solution $KMnO_4$ in acidic medium.

ω_1 (H_2O_2) = 30% $\rho_1 = 1.27$ $V_{sol\text{-}n\ 2}$ (H_2O_2) = 2 l C_N ($KMnO_4$) = 0.09 mol/l	1) Since the titration is carried 0.09N $KMnO_4$ solution, the solution of H_2O_2 necessary to prepare the same concentration. Using the formula molar concentration equivalent C_N find the mass of H_2O_2 in 200 ml of 0.09 N solution:
$V_{sol\text{-}n\ 1}$ (H_2O_2) =?	$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V = 0,09 \cdot 34 \cdot 1 / 2 \cdot 2 = 3.06$ g;

2) The mass of hydrogen peroxide is the same in solutions 1 and 2:

$$m_{X1} = m_{X2};$$

3) Using the mass fraction, we find the mass of a 1:

$$\varpi = \frac{m(x)}{m(sol.)} 100\% \ ; \quad \text{hence } m_{sol.1} = \frac{m_{x1}}{\varpi_1} \cdot 100\% = \frac{3,06 \cdot 100}{30} = 10,2g$$

4) Find the volume of solution 1:

$$V = \frac{m_{sol.}}{\rho} = \frac{10,2}{1,27} = 8,03ml.$$

Answer: The volume of 30% solution of hydrogen peroxide, 8.03 ml.

Problems

1) Compute a sample of 400 ml to prepare solution $KMnO_4$. If the title will be set to 0.1 N solution of starting material $H_2C_2O_4$. (Answer: 1.26 g)
2) Calculate the HF solution of H_2O_2, if the titration of 5 ml of it spent 4.8 ml of 0.09 N solution of $KMnO_4$ (titration carried out in acidic medium). (Answer: 0.086)
3) In the laboratory, there is a 5% solution of potassium permanganate (ρ = 1,15).

How many ml of this solution is necessary for the preparation of 1 litre of 0.1 N solution of potassium permangate? (Answer: 54.96 g)
4) How many ml of 5% solution of $Na_2C_2O_4$ (ρ = 1,1) is necessary for preparation of 200ml 0.1N solution? (Answer: 24.36 ml)

METHOD IODOMETRY

Iodometry - a method of volume analysis, which uses titrant I_2 or I^-.
The basic equation of the method:

$$I_2 + 2\bar{e} \leftrightarrow 2I^-$$

Since the titration of iodine is slow, then to the test solution was added an excess of iodine, and the residue titrated sodium thiosulphate $Na_2S_2O_3$:

$$2\,Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6.$$

The precursor method – I_2.
Titration is carried out in acidic or neutral media. Indicator is starch. End of titration is set by the disappearance of blue color of iodine with starch.

Examples

1) Compute a sample of iodine for the preparation of 500 ml 0.1 N solution.

V(sol-n) = 500 ml
C_N = 0.1 N

m(I_2) =?

1) As the problem is given by the molar concentration equivalent of C_N, then use the formula:

$$C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}.$$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V$ = 0,1 · 254 · 1 / 2 · 0,5 = 6.35 g;
Answer: The linkage of iodine was 6.35 g

2) Compute a sample of $Na_2S_2O_3 \cdot 5H_2O$ for preparing 200ml of solution, if the titre is set at 0.1 N solution of I_2.

V (sol-n) = 200 ml
$C_N(I_2)$ = 0,2 mol/l
m($Na_2S_2O_3 \cdot 5H_2O$) -?

1) Since the titre is set to $Na_2S_2O_3$ 0.1 N iodine solution, the concentration thiosulphate should be about the same concentration Since the problem is given by thiosulphate should be about the same concentration. Since the problem is given by the molar concentration equivalent to C_N, then use the formula: $C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$

hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V$ = 0,1 · 248 · 1 · 0,2 = 4.96 g;
Answer: The linkage $Na_2S_2O_3 \cdot 5H_2O$ 4,96 g

3) To determine the titer of the solution $Na_2S_2O_3 \cdot 5H_2O$ use as potassium dichromate $K_2Cr_2O_7$. Calculate the C_N solution if it took titration 5ml 4.8 ml of 0,1 N solution potassium dichromate.

Vsol-n ($Na_2S_2O_3$) = 5 ml
$C_N(K_2Cr_2O_7)$ = 0,1 mol/l
Vsol-n($K_2Cr_2O_7$) = 4,8 m

1) Using the equation of the law equivalence:
$C_N(Na_2S_2O_3) \cdot V(Na_2S_2O_3) = C_N(K_2Cr_2O_7) \cdot V(K_2Cr_2O_7)$,
hence $C_N(Na_2S_2O_3) = \frac{C_N(K_2Cr_2O_7) \cdot V(K_2Cr_2O_7)}{V(Na_2S_2O_3)}$

$C_N(Na_2S_2O_3)$ =?	$= \frac{0{,}1 \cdot 4{,}8}{5} = 0{,}096 mol/l.$

Answer: $C_N(Na_2S_2O_3)$ = 0,096 mol/liter.

4) In the laboratory, there is a 5% solution of iodine (ρ = 1,15). How many ml of this solution is necessary for the preparation of 1 liter of 0.1 N iodine solution?

ω_1 = 5%	1) Data for the calculation of V_1 on the mass fraction is not enough, so we use the formula molar concentration equivalent to C_N finding the mass of the
ρ_1 = 1,15	
V_2 = 1L	substance in solution: $C_N = \frac{m_X}{M_X \cdot f_{eqv.} \cdot V}$.
C_N = 0,1 mol/l	hence $m_X = C_N \cdot M_X \cdot f_{eqv.} \cdot V$ = 0,1 · 254 · 1/2 · 1 = 12.7g
V_1 =?	2) The mass of iodine in both solutions is the same:

$$m_{X1} = m_{X2};$$

3) Using the mass fraction, we find the mass of a 1:

$$\varpi = \frac{m(x)}{m(sol.)} 100\% \;;\quad \text{hence } m_{sol.1} = \frac{m_{x1}}{\varpi_1} \cdot 100\% = \frac{12{,}7 \cdot 100}{5} = 254g$$

4) Find the volume of solution 1:

$$V = \frac{m_{sol.}}{\rho} = \frac{254}{1{,}15} = 220{,}87 ml.$$

Answer: The amount of 5% iodine solution was 220.87 ml.

Problems

1) Compute a sample of $Na_2S_2O_3 \cdot 5H_2O$ for preparing 400ml of solution, with C_N = 0.05 mol/ liter. (Answer: 4.96 g)
2) Compute a sample of iodine to prepare 1,000 ml 0.1 N solution. (Answer: 12,7 g)
3) How many ml of 10% iodine solution (ρ = 1,32) is necessary for preparation 500ml 0.1 N iodine solution?
4) Calculate a sample of $K_2Cr_2O_7$, to determine the exact concentration of $Na_2S_2O_3$ (approximate concentration was 0.1 mol/l). Volume of solution $K_2Cr_2O_7$ - 200ml. Titration is carried out in an acidic medium. (Answer: 1.96 g)

REACTION MEDIUM WATER SOLUTIONS - pH

Water - a weak electrolyte - dissociates by the equation:

$$H_2O \leftrightarrow H^+ + OH^-$$

Ionic product of water - a product of the concentration of hydrogen ions (protons) on the concentration of hydroxide ions:

$$[H^+] + [OH^-] = 10^{-14}$$

It is a constant at a given temperature.
Dissociation of acids follows the scheme:

$$CH_3COOH \leftrightarrow H^+ + CH_3COO^-$$

Active acidity - is a concentration drowned.
Potential acidity - is a concentration dissociating acid molecules.
Total acidity - is the total concentration of acid in the mole eq.
The amount of active and potential acidity equal to the total acidity.
When the titration is determined by the total acidity.
Total alkalinity - is the concentration of hydroxide - anions.

Potential alkalinity - is the concentration of un dissociated molecules of the base.
Total alkalinity - is the total concentration of alkali in the mole eq.
The amount of active and potential alkalinity equal total alkalinity.
When the titration is determined by the total alkalinity.
The reaction medium is determined by the concentration of protons.

$$\underbrace{10^{-1}\ldots\ldots\ldots\ldots}_{\text{acid condition}}\ \underbrace{10^{-7}}_{\text{neut. condition}}\ \underbrace{\ldots\ldots\ldots\ldots 10^{-14}}_{\text{alkaline condition}}$$

Concentration of protons in an acid solution is calculated by the formula:

$$[H^+] = \alpha \cdot [acid]$$

strong acid	strong acid
$\alpha = 1$	$\alpha = 1$
$[H^+] = \alpha \cdot [acid]$	$[H^+] = \sqrt{Cd \cdot [acid]}$

α – acid degree of dissociation

The dissociation of the base form of hydroxide anions, whose concentration is calculated as follows:

$$[OH^-] = \alpha \cdot [base]$$

strong base	strong base
$\alpha = 1$	$\alpha = 1$
$[OH^-] = \alpha \cdot [base]$	$[OH^-] = \sqrt{Cd \cdot [base]}$

α – base degree of dissociation

The reaction medium is more convenient to express the solution via the pH.
pH - is the negative logarithm of hydrogen ion concentration:

$$pH = -\lg [H^+].$$

Similarly, we can calculate the pOH:

$$pOH = -\lg [OH^-].$$

Based on the negative logarithm of the ion product of water is:

$$pOH + pH = 14.$$

blood pH = 7.36;
gastric juice pH = 0,9 - 1,5.

Examples

A. Calculating the pH of solutions of strong and weak acids and bases.
1) Calculate the pH, if $[H^+] = 10^{-2}$.

$pH = -\lg [H^+] = -\lg 10^{-2} = 2.$

2) Calculate the pOH if $[OH^-] = 10^{-5}$.

$pOH = -\lg [OH^-] = -\lg 10^{-5} = 5.$

3) Calculate the pH if [OH⁻] = 10^{-4}.

pOH = -lg [OH⁻] = -lg 10^{-4} = 4.

pH = 14 - pOH = 14 - 4 = 10.5

4) Calculate the pH of the solution with the concentration of H^+ -ion $3,7·10^{-5}$ mol / liter.

[H^+] = $3,7·10^{-5}$ | pH = - lg [H^+] = -lg 3,7 · 10-5 = -lg 3,7 - lg10^{-5} = 5 - 0.57 = 4.43.

pH -?

Answer: pH = 4.43.

5) Calculate the pH of HCl C_N = 0.1 mol/liter.

C_N (HCl) = 0,1 mol/l

pH -?

1)To calculate the pH of the solution, one must know [H^+]. Since the strong acid HCl. Then [H^+] = [acid] = 0.1 mol/L = 10^{-1};

2) Find the pH of the solution:

pH = - lg [H^+] =-lg 10^{-1} = 1.

Answer: pH = 1.

6) Calculate the pH of 0.0001 N HCl solution.

pH = - lg [HCl] - lg [H^+] =-lg · 10^{-4} = 4.

7) Calculate the pH of the NaOH with CH = 0.2 mol/liter.

C_N (NaOH) = 0.2 mol/liter

pH =?

1) Because of the condition given by the foundation, then first find [OH^-]. In a solution of strong base

[OH^-] = [base] = 0,2 = 2 · 10^{-1};

2) Find the pOH: pOH =-lg[OH^-]= -lg 2 · 10^{-1} = - lg2 -lg 10^{-1} = 1 - 0.3 = 0.7.

3) Find the pH: pH = 14 - pOH = 14 - 0,7 = 13,3. Answer: pH = 13.3.

8) Calculate the pH of 0.001 N solution of NaOH.

pOH =-lg [NaOH] =-lg [OH^-] = -lg 10^{-3} = 3.

pH = 14 - pOH = 14 - 3 = 11.

9) Calculate the pH of the solution of HCOOH with C_N = 0.1 mol/l (Kd = 1,8 · 10^{-5})

C_N (HCOOH) = 0.1 mol/L

Cd = 1,8 · 10^{-5}

pH =?

1) To calculate the pH of the solution, one must know [H^+]. Since HCOOH weak acid, then use the formula:

$$[H^+] = \sqrt{Cd \cdot [\text{acid}]} = \sqrt{1.8 \cdot 10^{-4} \cdot 0.1} = 4.24 \cdot 10^{-3}$$

2) Find the pH: pH =-lg 4,24 · 10^{-3} = -lg 4,24-lg 10^{-3} = 3 -0.63 = 2.37.

Answer: pH = 2,37.10

10) Calculate the pH of the solution NH_4OH with C_N = 0.15 mol/l (Kd = 1,85 · 10^{-5}).

C_N (NH_4OH) = 015 mol/L

Kd = 1,85 · 10^{-5}

pH -?

1) Because of the condition given by the foundation, then first find [OH^-]. In the solution of a weak base:

$$[OH^-] = \sqrt{Cd \cdot [\text{base}]} = \sqrt{1.8 \cdot 10^{-5} \cdot 0.15} = 1.64 \cdot 10^{-3}$$

2) Find the pOH

pOH =-lg 1,64 · 10^{-3} = - lg 1.64 -lg 10 · 10^{-3} = 3 - 0.21 = 2.79.

3) Find the pH: pH = 14 - pOH = 14 - 2.79 = 11.21.

Answer: pH = 11.21.

11) Calculate the pH of the solution H_2SO_4 w = 3% (ρ = 1,1; $F_{ekv.}$ = 1/2).

ω = 3%

ρ = 1,1

1) Transfer IARF share in the normal concentration equivalents using a formula which connects the C_N and ω:

$f_{ekv.} = 1/2$ $\qquad C_N = \dfrac{\varpi\% \cdot \rho \cdot 10}{M_X \cdot f_{eqv.}} = \dfrac{3 \cdot 1{,}22 \cdot 10}{98 \cdot 1/2} = 0{,}73 mol/l.;$

pH =? $\qquad$ 2) Find the $[H^+]$ and pH:

$[H^+] = [acid] = 0{,}73 = 7{,}3 \cdot 10^{-1}$;

$pH = -\lg [H^+] = -\lg 7{,}3 \cdot 10^{-1} = -\lg 7{,}3 - \lg 10^{-1} = 1 - 0{,}86 = 0{,}14$

Answer: 0,14

B. Determination of pH of solutions after dilution with water.

12) How to change the pH of the solution HNO_3, if a 40ml solution of 0.1N add 20ml of water?

$V_1(HNO_3) = 40$ ml
$C_{N1} = 0{,}1$ mol/l
$V(H_2O) = 20$ ml
$\Delta pH (HNO_3) =?$

1) $\Delta pH = pH_1 - pH_2$,
where pH_1 - pH solution HNO_3 before adding water
pH_2 is the pH of the solution after the addition of HNO_3 water;
2) Find the pH_1: to calculate the pH of the solution you need to know
. $[H^+]$. Since the strong acid HNO_3, then
$[H^+] = [acid] = 0.1$ mol/L $= 10^{-1}$;

3) Find the solution pH_1: $pH_1 = -\lg [H^+] = -\lg 10^{-1} = 1$;

4) Upon dilution with water the acid concentration decreases. Find it using the law of equivalents: $C_{N1} \cdot V_1 = C_{N2} \cdot V_2$; where V_2 - volume of the solution after adding water,
$V_2 = 40 + 20 = 60$ml;

Hence: $C_{N2} = \dfrac{C_{N1} \cdot V_{N1}}{V_2} = \dfrac{0.1 \cdot 40}{60} = 0.067 = 6.7 \cdot 10^{-2}$;

5) Find pH_2: $[H^+]_2 = [acid] = 6.7 \cdot 10^{-2}$;

$pH_2 = -\lg [H^+] = -\lg 6{,}7 \cdot 10^{-2} = -\lg 6{,}7 - \lg 10^{-2} = 2 - 0{,}83 = 1.17$;

6) $\Delta pH = 1.17 - 1 = 0.17$.

Answer: 0.83.

13) How to change the pH of the solution NH_4OH, if a 50 ml 0.1 N solution of its add 30ml of water? ($Kd = 1{,}85 \cdot 10^{-5}$).

$V(NH_4OH) = 50$ml
$C_N(NH_4OH) = 01$mol/l
$Kd = 1{,}85 \cdot 10^{-5}$
$V(H_2O) = 30$ ml
ΔpH -?

1) $\Delta pH = pH_1 - pH_2$,
where pH_1 - is the solution pH before adding NH_4OH water;
pH_2 is the pH of the solution after the addition of NH_4OH water;
Since by the condition given by the foundation, then first find $[OH^-]$
In the solution of a weak base:

$$[OH^-] = \sqrt{Cd \cdot [base]} = \sqrt{1.8 \cdot 10^{-5} \cdot 10^{-1}} = 1.64 \cdot 10^{-3}$$

2) Find the $pOH_1 = -\lg 1{,}34 \cdot 10^{-3} = -\lg 1{,}34 - \lg 10^{-3} = 3 - 0.127 = 2.87$;
$pH_1 = 14 - 2.87 = 11.13$.

3) Upon dilution with water the concentration of base decreases. Find it using the law of equivalents: $C_{N1} \cdot V_1 = C_{N2} \cdot V_2$; where V_2 - volume of the solution after adding water,
$V_2 = 50 + 30 = 80$ ml;

$$C_{N2} = \frac{C_{N1} \cdot V_{N1}}{V_2} = \frac{0{,}1 \cdot 50}{80} = 0{,}0625 = 6.25 \cdot 10^{-2};$$

4) Find the pOH_2: $[OH^-] = \sqrt{Cd \cdot [base]} = \sqrt{1.8 \cdot 10^{-5} \cdot 6.25 \cdot 10^{-2}} = 1.06 \cdot 10^{-3}$

$pOH_2 = -\lg 1{,}06 \cdot 10^{-3} = -\lg 1{,}06 - \lg 10^{-3} = 3 - 0.025 = 2.975$.;
$pH_2 = 14 - 2.975 = 11.025$.

5) Find the ΔpH: $\Delta pH = 11.13 - 11.025 = 0.105$.

Answer: 0.105.

14) How to change the pH of water if the 80 ml add 20 ml of solution NaOH with C_N = 0.1 mol/L, (α = 1)

V (H_2O) = 80 ml C_N(NaOH) = 0,1 mol/l (NaOH)=20 ml ΔpH(H_2O) =?	1) H_2O pH = 7; 2) After you have added to the water solution of NaOH obtained by V solution of the base, the concentration which we find in law equivalents: $C_{N1} \cdot V_1 = C_{N2} \cdot V_2$; V_2 = 80 ml + 20 ml = 100 ml.

3) Find the concentration of alkali solution, C_{N2}, [OH^-], pOH and pH:

$$C_{N2} = \frac{V_1 \cdot C_{N1}}{V_2} = \frac{20 \cdot 0{,}1}{100} = 0{,}02 = 2 \cdot 10^{-2}$$ – concentration of NaOH in the solution.

[OH^-] = [base] = $2{\cdot}10^{-2}$.

pOH = -lg [OH^-] = - lg 2 · 10^{-2} = -lg 2 - lg 10^{-2} = 2 - 0.3 = 1,7.
pH = 14 - 1.7 = 12.3
4) Find the change in pH of water: Δ pH = 12.3 - 7 = 5,3.
Answer: 5.3.

B) Determination of pH after pouring acid solutions and base.

15) Determine the pH of the solution obtained after mixing equal volumes of HCl and C_N = 0.3 mol/l NaOH

C_N = 0.1 mol/liter C_N(HCl) = 0,3 mol/l C_N(NaOH) = 0,1 mol/l V(HCl) = V(NaOH) pH =?	1) When mixing acid and alkali react according to the equation: HCl + NaOH → NaCl + H_2O; From the equation it is clear that the acid and alkali react in a ratio of 1: 1. Since from the acid was taken 0.3 mol after reaction in solution remained acid: 0,3 - 0,1 = 0,2 mol. Since the volume of the mixture

increased 2 times, the concentration of acid in solution: 0,2/2 = 0.1 mol/l;
2) Find the pH of the resulting solution:
[H^+] = [acid] = 0,1 = 10^{-1}.
pH = - lg [H^+] = - lg 10^{-1} = 1.
Answer: pH = 1.

16) Determine the pH of the solution obtained after mixing equal volumes of solutions of H_2SO_4 and C_N = 0.2 mol/l NaOH with C_N = 0.6 mol/liter.

C_N (H_2SO_4) = 0,2 mol/l C_N (NaOH) = 0,6 mol/l V(H_2SO_4) = V(NaOH) pH =?	1) When mixing acid and alkali react according to the equation: H_2SO_4 + 2NaOH → Na_2SO_4 + $2H_2O$; From the equation it is clear that the acid and alkali react in the ratio 1: 2. Since acid was taken 0.2 mole, then:

1 mol H_2SO_4 — 2 mol NaOH
0.2 mol H_2SO_4 — x mol NaOH

x = 0.4 mol NaOH.

By the condition of the problem given 0.6 mol NaOH, then left after the reaction 0.6 - 0.4 = 0.2 mol NaOH. Since the volume of the mixture increased 2 times, the concentration of NaOH solution: 0,2/2 = 0.1 mol/l;
2) Find the [OH^-], pOH, pH, the resulting solution:
[OH^-] = [base] = 0,1 = 10^{-1}.

$pOH = - lg [OH^-] = - lg 10^{-1} = 1.$
$pH = 14 - pOH = 14 - 1 = 13.$

Answer: pH = 13.

G. Calculation of [H^+] for a given value of pH and pOH.

17) Calculate the [H^+] in the blood if the pH = 7.36.

pH = 7,36	$[H^+]$ = ant lg pH = ant lg 7,36 = ant lg [8 – 0.64] = $4,36 \cdot 10^{-8}$ mol/l
$[H^+]$ =?	

Answer: $4,36 \cdot 10^{-8}$ mol/l

18) Calculate the [H^+] solution if pOH = 4.29.

pOH = 4.29	1) Find the pH:
	pH = 14 - pOH = 14 - 4,29 = 9.71;
$[H^+]$ =?	$[H^+]$= ant lg pH = ant lg 9,71 = ant lg [10 – 0.29] = $1,95 \cdot 10^{-10}$mol/l.

Answer: $1,95 \cdot 10^{-10}$mol/l

Problems

1. Calculate the pH of the solution of HC1 with a mass fraction of 2%. (Answer: 0.26)
2. Calculate the pH of the solution NN_4ON with C_N = 0.3 mol/l (Kd = $1,8 \cdot 10^{-5}$) (Answer: 11.37)
3. How to change the pH of the solution of HNO_3 with C_N = 0.3 mol/L, if a 20ml solution pour 80 ml of water? (Answer: 0,7)
4. How to change the pH of the solution obtained after mixing equal volumes of solutions H_2SO_4 with C_N = 0.8 mol/l NaOH with C_N = 0.2 mol/l? (Answer: 0.46)
5. Calculate the pH of 4% KOH solution. (Answer: 13.75)
6. How will the pH of the water, when added 50ml of 20 ml of 0.1 N solution NaOH. (Answer: 5.45)
7. Calculate $[H^+]$, if pOH solution 3.58.