MINISTRY OF HEALTH OF UKRAINE

BOGOMOLETS NATIONAL MEDICAL UNIVERSITY

STUDENT'S WORKBOOK

(auditory and extra-auditory independent work)

Academic discipline	Fundamentals of chemical metrology
Branch of knowledge	22 "Health care"
Specialty	226 "Pharmacy, industrial pharmacy"
Specialization	226.01 "Pharmacy"
Department	Analytical, physical and colloid chemistry

Approved by methodological counsel of Analytical, Physical and Colloid Chemistry Department
Proceedings N 1 dated 29 August 2024

Considered and approved by cyclical methodological commission of specialty 226 "Pharmacy, industrial pharmacy"
Proceedings N 2 dated 07 October 2024

Authors:
Yaroslava Pushkarova – Associate Professor of Analytical, Physical and Colloid Chemistry Department, PhD in Chemistry, Associate Professor;
Galina Zaitseva – Head of Analytical, Physical and Colloid Chemistry Department, PhD in Chemistry, Associate Professor.

CONTENTS

INTRODUCTION

The workbook for independent auditory and extra-auditory work of students of specialty 226 “Pharmacy, industrial pharmacy” for discipline “Fundamentals of chemical metrology” is a structured methodical development that contains basic information for the successful assimilation of the educational material of each topic of the discipline and preparation for practical classes.

The main purpose of using the workbook is to optimize and increase the effectiveness of the educational and cognitive activity of students by mastering the methods of independent acquisition, active assimilation and application of knowledge regarding the statistical processing of the results of a chemical (pharmaceutical) experiment, the interpretation and evaluation of the results of the analysis of medicinal products.

Features of the proposed tasks

The proposed tasks for auditory and extra-auditory work are aimed at the development of abstract thinking, analysis and synthesis, the ability to work in a team and the formation of the ability to apply knowledge in practical situations.

The order of tasks for independent work

Tasks of independent extra-auditory work should be completed till practical lesson on this topic.

Tasks of auditory independent work are completed during a practical lesson.

During performance the independent work, the student should write down his answers to the assigned tasks in the workbook.

Evaluation criteria

When evaluating the performance of independent work, preference is given to standardized control methods: test questions and structured written tasks.

The grade **“5 − Perfectly”** – student gives at least 90% correct answers to standardized test questions, answers written tasks without mistakes.

The grade **“4 − Good”** – student gives at least 75% correct answers to standardized test questions, answers written tasks with minor errors.

The grade **“3 − Satisfactory”** – student gives at least 60% correct answers to standardized test questions, answers written tasks with significant errors.

The grade **“2 − Unsatisfactory”** – student gives less than 60% correct answers to standardized test questions, answers written tasks with gross errors or does not give answers to them.

Rules for keeping a workbook

Adherence to academic integrity by students involves:

− independent performance of all types of work, tasks, forms of control provided for by the work program of this educational discipline;

− references to sources of information in the case of using ideas, developments, statements, information;

− compliance with the legislation on copyright and related rights;

− providing reliable information about the results of one’s own educational (scientific, creative) activities, used research methods and sources of information.

Course ID: 7412

For your attention on the platform are presented:

– academic curriculum
– syllabus
– guidelines to lectures
– guidelines to practical lectures
– presentations of lectures
– recommended literature
– workbook for auditory and extra-auditory work

The authors of the workbook hope that the proposed elective course will be interesting and useful for future masters of pharmacy!

We wish you success!

Topic 1. Significant figures. Rounding of the measurement results

Purpose: ability to present the results of a chemical (pharmaceutical) experiment with the required accuracy.

Student should:

- ✓ to know rules for determining the number of significant figures;
- ✓ to know scientific notation of very large or very small numbers;
- ✓ to know rules for rounding of data in a computation;
- ✓ to be able to determine the significance of the result of various mathematical operations.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Metrology	science of the measurements.
Data	defined as things known, or assumed facts and figures, from which conclusions can be inferred.
Significant figures in a measurement	include all certain digits plus the first uncertain digit.

Recommended literature:

Basic

1. Taylor, J. K., Cihon, C. Statistical techniques for data analysis (second edition). Chapman and Hall/CRC, 2004, P. 66-73. https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. Statistics and Chemometrics for Analytical Chemistry (seventh edition) / J. N. Miller, J.C. Miller and R. D. Miller : Pearson, 2018, P. 29-31. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

2. Ellison S. L. R., Williams A. Eurachem/Citac Quide: Quantifying Uncertainty in Analytical Measurements (third ed, 2012). URL: https://www.eurachem.org/images/stories/Guides/pdf/QUAM2012_P1.pdf (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Significant figures.
2. Rounding of data in a computation.

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. How many significant figures does the number 0.0702 contain?

A. 4
B. 2
C. 3
D. 5

2. How many significant figures does the number $0.01300 \cdot 10^{-2}$ contain?

A. 2
B. 4
C. 3
D. 5

3. Calculate the expression and give the answer with required number of significant figures: 12.3 + 4.25.

A. 17.0
B. 16.55
C. 16.5
D. 16.6

4. Calculate the expression and give the answer with required number of significant figures: 1.1·1.25.

A. 1.4
B. 1.37
C. 1,375
D. 1.38

5. Round the number 3.245, taking into account that the third significant figure is uncertain.

A. 3.20
B. 3.25
C. 3.24
D. 3.2

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. How many significant figures does the number contain?

1) 128.3; 2) 0.015; 3) 709;
4) 3·10-3; 5) $5.71 \cdot 10^{4}$ 6) $0.01300 \cdot 10^{-2}$

Answer and explanation

Task 2. Round numbers, taking into account that the third significant figure is uncertain:

1) 40.23; 2) 3.245; 3) 0.8450; 4) 0.3235.

Answer and explanation

Tasks for auditory work:

Task 1. Sum following numbers and give the answer with required number of significant figures: $0.120 \cdot 10^{-3}$; $5.00 \cdot 10^{-2}$; $2.1 \cdot 10^{-4}$; $4 \cdot 10^{-5}$.

Answer and explanation

Task 2. Calculate pH of the solution if the molar concentration of Hydrogen ions is $4.3 \cdot 10^{-11}$ mol/dm^3. Give the answer with required number of significant figures.

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. pH of the solution is 4.73. Calculate the molar concentration of hydrogen ions in the solution. Give the answer with required number of significant figures.

Answer and explanation

Example of problem with solution:

Equal volumes of solutions of sodium chloride with a molar concentration of $2 \cdot 10^{-5}$ mol/dm^3, potassium chloride with a molar concentration of $0.33 \cdot 10^{-4}$ mol/dm^3, and hydrochloric acid with a molar concentration of $5.0 \cdot 10^{-5}$ mol/dm^3 were mixed. What is the concentration of chloride ions in the resulting solution? Give the answer with required number of significant figures.

Answer

Convert the numbers by bringing exponents to the largest.

$$2 \cdot 10^{-5} = 0.2 \cdot 10^{-4}$$

$$0.33 \cdot 10^{-4} = 0.33 \cdot 10^{-4} \text{ (without changes)}$$

$$5.0 \cdot 10^{-5} = 0.50 \cdot 10^{-4}$$

Calculate the concentration of chloride ions in the resulting solution:

$$\frac{0{,}2 \cdot 10^{-4} + 0{,}33 \cdot 10^{-4} + 0{,}50 \cdot 10^{-4}}{3} = 0{,}343 \cdot 10^{-4} \text{ mol/dm}^3$$

The number $0.2 \cdot 10^{-4}$ has the smallest number of significant figures after the decimal point, so the result of $0.343 \cdot 10^{-4}$ should be rounded to $0.3 \cdot 10^{-4}$ mol/dm^3.

Answer: $0.3 \cdot 10^{-4}$ mol/dm^3.

Topic 2. Estimation of the presence of outliers in results

Purpose: ability to classify measurement errors and estimate the presence of outliers in results.

Student should:

- ✓ to know basic knowledge about measurement errors and their classification;
- ✓ be able to estimate the presence of outliers using the Q-test (Dixon's test), Grubb's test and rule of the huge error;
- ✓ to be able to interpret the results of calculations.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Measurement error	measured quantity value minus a reference quantity value.
Outlier	observation that lies an abnormal distance from other values in a random sample from a population. In a sense, this definition leaves it up to the analyst to decide what will be considered abnormal.
Sample size	number of total observations / measurements.

Recommended literature:

Basic

1. Taylor, J. K., Cihon, C. Statistical techniques for data analysis (second edition). Chapman and Hall/CRC, 2004, P. 100-107. https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. Statistics and Chemometrics for Analytical Chemistry (seventh edition) / J. N. Miller, J.C. Miller and R. D. Miller : Pearson, 2018, P. 49-52. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Classification of errors.
2. Exclusion of outliers using the Q-test (Dixon's test).
3. Exclusion of outliers using the Grubb's test.
4. Exclusion of outliers using the rule of the huge error.

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. In pharmaceutical analysis during quality control of medicinal products, the confidence level is most often taken equal to:

A. 90%
B. 99%
C. 95%
D. 80%

2. Results of the determination of antipyrine in the blood by the chromatographic method (μg/g) are: 0.01: 0.06; 0.03; 0.04: 0.02; 0.05. Determine the sample size and the number of degrees of freedom for the given experimental data.

A. 6 and 4
B. 5 and 5
C. 6 and 6
D. 6 and 5

3. Sample is considered homogeneous if it does not contain:

A. systematic error
B. outlier
C. instrumental error
D. methodical error

4. Results of determining the hardness of natural water by the method of complexonometry (mmol/dm^3) are: 8.55; 8.80; 8.75; 8.65; 8.55; 8.50. What is the control value of the Q-criterion for this case at a confidence level 95%?

A. 0.51
B. 0.64
C. 0.56
D. 0.48

5. What is the range of dataset?

A. product of the maximum and minimum values
B. sum of the maximum and minimum values
C. difference between the maximum and minimum values
D. ratio of the maximum value to the minimum value

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. Results of the titration of hydrochloric acid with sodium hydroxide are (cm^3): 3.1; 3.3; 3.2; 3.0; 3.6. For the specified experimental data:

1) sort results in ascending order,
2) calculate the range,

3) calculate the mean value,
4) calculate the standard deviation.

Answer and explanation

Tasks for auditory work:

Task 1. Screen the data set for outliers using Dixon's test (Q-test) at confidence level 95%. Results of succinic acid titration with sodium hydroxide (cm^3) are: 40.12; 40.15; 40.25; 40.05; 40.10.

Answer and explanation

Task 2. Screen the data set for outliers using Grubb's test at confidence level 95%. Results of pH determining of the solution are: 8.29; 8.30; 8.39; 8.28; 8.31; 8.29.

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. A set of data was taken to calibrate a measuring instrument. In the course of a preliminary manual plot of the data (eye estimate), it was noticed that one point appeared to be much farther from the line than the others, so it was ignored for the moment. The analyst was tempted to reject it because he feared (and rightly so) that its inclusion (if it were an outlier) would falsify his least squares fit. The average deviation of the plotted points from the line (observed – curve) was 0.012. The deviation of the suspected point from the line was 0.06. Use the Huge Error Rule for statistically supported decision with respect to rejection or retention of a suspected outlier.

Answer and explanation

Example of problem with solution:

Consider the following example to illustrate the Grubb's test. Dataset:

9, 12, 12, 13, 13, 14, 15

Measurement 9 is the suspected point.

Answer

Calculation of the standard deviation gives

$$\bar{x} = \frac{9+12+12+13+13+14+15}{7} = 12.57,$$

$$s^2 = \frac{(9-12.57)^2+2\times(12-12.57)^2+2\times(13-12.57)^2+(14-12.57)^2+(15-12.57)^2}{7-1} =$$

$$= \frac{12.7449+4\times0.3249+2.0449+5.9049}{6} = 3.6657,$$

$$s = \sqrt{3.6657} = 1.91,$$

$$G = \frac{|9-12.57|}{1.91} = 1.869.$$

For 95% confidence of rejection, G = 1.938 from Table in Supplement. The decision is to retain the data point.

Answer: retain the data point.

Topic 3. Basics of statistical analysis of the results of chemical experiment

Purpose: ability to correctly carry out statistical processing of the results of chemical analysis and interpret their calculations.

Student should:

- ✓ to know the specifics of chemical analysis as a metrological discipline;
- ✓ to be able to calculate basic metrological characteristics.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Chemical analysis as a metrological discipline	methods and means of measuring the chemical properties of substances and the composition of samples.
Main metrological parameters	mean, variance, standard deviation, coefficient of variation, relative standard deviation, standard deviation of the mean or standard error of mean, confidence limits of the mean.
Variance	square of the standard deviation.

Recommended literature:

Basic

1. Statistics and Chemometrics for Analytical Chemistry (seventh edition) / J. N. Miller, J.C. Miller and R. D. Miller : Pearson, 2018, P. 16-25. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. European Pharmacopoeia / European Directorate for the Quality of Medicines & HealthCare of the Council of Europe. – tenth edition, volume 1. Strasbourg : Council of Europe, 2019. Section 5.3. Statistical analysis of results of biological assays and tests. P. 683-713. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Specificity of chemical analysis as a metrological discipline.
2. Calculation of basic metrological characteristics.

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. Results of determining the content of hydrogen peroxide in the solution by permanganatometry (%) are: 7.30; 7.28; 7.38; 7.28; 7.25. Calculate the mean value of the obtained experimental data.

A. 7.30
B. 7,20
C. 7.40
D. 7.25

2. Square of the standard deviation is:

A. variance
B. confidence limits
C. mean value
D. relative standard deviation

3. Results of the titration of ascorbic acid with iodine in potassium iodide (cm^3) are: 10.2; 10.5; 10.4; 10.2. Standard deviation is $15 \cdot 10^{-2}$. Calculate the standard deviation of the mean.

A. 0.075
B. 0.30
C. 0.0375
D. 0.60

4. In the case of determination of NaOH by the acidimetry method, 6.7, 6.8 and 6.9 ml of titrant were used for the titration of a 15 ml aliquot in three parallel measurements. Determine the standard deviation of the obtained results.

A. $1.0 \cdot 10^{-1}$
B. $1.0 \cdot 10^{-2}$
C. $2.0 \cdot 10^{-1}$
D. $5.0 \cdot 10^{-2}$

5. Why is the value of the relative standard deviation most often used to characterize the reproducibility of results?

A dimensionless quantity
B. expressed in the same units as the measured value
C. does not require any calculations
D. reference value

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. Analyze and write down formulas for calculating the main metrological characteristics.

Metrological characteristic	*Formula for calculation*
Mean	
Standard deviation	
Variance	
Coefficient of variation	
Relative standard deviation	
Standard deviation of the mean	

Tasks for auditory work:

Task 1. Results of determining the molar concentration of the hydrochloric acid solution (mol/dm^3) are: 0.1113; 0.1112; 0.1109; 0.1111; 0.1110. For the presented data, calculate the following metrological characteristics: mean, variance, standard deviation, coefficient of variation, relative standard deviation, standard deviation of the mean.

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. Assess the reproducibility of the titration results given in the previous example.

Answer and explanation

Example of problem with solution:

When determining the Nickel content in the standard steel sample, the following results were obtained (%): 5.1; 5.5; 5.4; 5.8; 5.2. Calculate the basic metrological (statistical) characteristics.

Answer

Calculation of mean: $\bar{x} = \frac{5.1+5.5+5.4+5.8+5.2}{5} = 5.4$

Calculation of standard deviation:

$$s = \sqrt{\frac{(5.1-5.4)^2+(5.5-5.4)^2+(5.4-5.4)^2+(5.8-5.4)^2+(5.2-5.4)^2}{5-1}} =$$

$$= \sqrt{\frac{0.09+0.01+0+0.16+0.04}{4}} = \sqrt{\frac{0.3}{4}} = \sqrt{0.075} = 0.2739 \text{ rounded to } 0.27$$

Calculation of variance: $s^2 = 0.2739^2 = 0.075$

Calculation of standard deviation of the mean: $s_{\bar{x}} = \frac{0.2739}{\sqrt{5}} = \frac{0.2739}{2.236} = 0.1225$ rounded to 0.12.

Calculation of coefficient of variation: $CV = \frac{0.2739}{5.4} = 0.0507$ rounded to 0.051.

Calculation of relative standard deviation: $RSD = 0.0507 \cdot 100 = 5.07\%$ rounded to 5.1%.

Answer: $\bar{x} = 5.4$, $s = 0{,}27$, $s^2 = 0.075$, $s_{\bar{x}} = 0.12$, $CV = 0.051$, $RSD = 5.1\%$.

Topic 4. Confidence limits and estimation of their value

Purpose: ability to correctly calculate the confidence limits and interpret their calculations.

Student should:

- ✓ to know the practical value of confidence limits;
- ✓ to be able to calculate confidence limits;
- ✓ to be able to present the results of quantitative analysis.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Degrees of freedom	number of independent deviations which are used in calculating.
Confidence limits of the mean value	range which we may reasonably assume includes the true value.

Recommended literature:

Basic

1. Statistics and Chemometrics for Analytical Chemistry (seventh edition) / J. N. Miller, J.C. Miller and R. D. Miller : Pearson, 2018, P. 26-30. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

2. Introduction to Statistics in Metrology / S. Crowder et al. Cham : Springer International Publishing, 2020, P. 166-169. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. European Pharmacopoeia / European Directorate for the Quality of Medicines & HealthCare of the Council of Europe. – tenth edition, volume 1. Strasbourg : Council of Europe, 2019. Section 5.3. Statistical analysis of results of biological assays and tests. P. 683-713. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Calculation of the confidence limits of the mean value.
2. Presentation of the results of quantitative analysis.

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. What criterion is used for calculating confidence limits?
   A. Cochrane's criterion
   B. Fisher's criterion (F-test)
   C. Student's criterion (t-test)
   D. Pearson's criterion
2. Confidence limits is an interval of values which includes:
   A. true value of the analytical signal
   B. average value of the analytical signal
   C. largest value of the analytical signal
   D. smallest value of the analytical signal
3. Results of determining the content of acetic acid in the solution by the method of acid-base titration (%) are: 6.82; 6,12; 6.32; 6.22; 6.02. What is the control value of the t-criterion (Student's criterion) for this case at a confidence level 95%?
   A. 3.7469
   B. 2.5706
   C. 3.1824
   D. 2.7764
4. The first step of statistical processing of chemical analysis is:
   A. calculation of confidence interval
   B. estimation of systematic error
   C. calculation of standard deviation
   D. checking the presents of outliers in results
5. For finding the control value of the t-criterion (Student's criterion) you need to know:
   A. standard deviation and number of degrees of freedom
   B. confidence level and sample size
   C. confidence level and the number of degrees of freedom
   D. variance and sample size

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. Analyze and write down the formula for calculating the confidence limits of the mean value. What metrological characteristics do you need to know for calculating the confidence limits?

Answer and explanation

Tasks for auditory work:

Task 1. Results of titration of oxalic acid with potassium permanganate (cm^3) are: 25.20; 25.35; 25.30; 25.25; 25.32. Calculate the confidence limits of the mean value at confidence level 0.95 for the presented data.

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. Describe the main steps of statistical processing of chemical (pharmaceutical) analysis results.

Answer and explanation

Example of problem with solution:

The sodium ion content of a urine specimen was determined by using an ion-selective electrode. The following values were obtained: 102, 97, 99, 98, 101, 106 mM. What are the 95% and 99% confidence limits for the sodium ion concentration?

Answer

The mean and standard deviation of these values are 100.5 mM and 3.27 mM respectively. There are six measurements and therefore 5 degrees of freedom. From Table 1 in Appendix the value of t_5 for calculating the 95% confidence limits is 2.57 and the 95% confidence limits of the mean are given by:

$$100.5 \pm 2.57 \times \frac{3.27}{\sqrt{6}} = 100.5 \pm 3.4\ mM$$

Similarly the 99% confidence limits are given by:

$$100.5 \pm 4.03 \times \frac{3.27}{\sqrt{6}} = 100.5 \pm 5.4\ mM$$

Answer: $100.5 \pm 5.4\ mM$

Topic 5. Comparison of two methods of analysis by reproducibility

Purpose: ability to compare two methods of analysis by reproducibility and to interpret their calculations.

Student should:

✓ to know the algorithm for comparing two methods of analysis by reproducibility;

✓ to be able to calculate F-test;

✓ to be able to interpret the results of their calculations.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Test for statistical significance	indicate whether observed differences between assessment results occur because of sampling error or chance.
F-test	considers the ratio of the two sample variances, i.e. the ratio of the squares of the standard deviations.

Recommended literature:

Basic

1. Statistics and Chemometrics for Analytical Chemistry (seventh edition) / J. N. Miller, J.C. Miller and R. D. Miller : Pearson, 2018, P. 45-48. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

2. Taylor, J. K., Cihon, C. Statistical techniques for data analysis (second edition). Chapman and Hall/CRC, 2004, P. 91-93. https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. European Pharmacopoeia / European Directorate for the Quality of Medicines & HealthCare of the Council of Europe. – tenth edition, volume 1. Strasbourg : Council of Europe, 2019. Section 5.3. Statistical analysis of results of biological assays and tests. P. 683-713. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Definition of the term “reproducibility”.
2. Algorithm for comparison of two methods of analysis by reproducibility (comparison of variances).

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. Comparison of two methods of analysis by reproducibility involves:
   A. comparison of sample sizes
   B. comparison of confidence intervals
   C. comparison of standard deviations
   D. comparison of variances

2. When comparing the reproducibility of two methods of analysis, calculate:
   A. t-test
   B. F-test
   C. Q-test
   D. G-test

3. Determination of antipyrine in blood (μg/g of plasma) was carried out by chromatographic (I) and kinetic (II) methods.

   I – 0.022; 0.042; 0.037; 0.028; 0.050 s^2= 0.000123
   II – 0.030; 0.075; 0.050; 0.066; 0.045 s^2= 0.000314

Calculate F-test.
   A. 2.55
   B. 0.39
   C. 1.78
   D. 0.029

4. Determination of antipyrine in blood (μg/g of plasma) was carried out by chromatographic (I) and kinetic (II) methods.

   I – 0.022; 0.042; 0.037; 0.028 $s^2 = 8.02 \cdot 10^{-5}$
   II – 0.030; 0.075; 0.050; 0.066; 0.045 $s^2 = 3.14 \cdot 10^{-4}$

What is the control value of the F-criterion for this case at confidence level 95%?
   A. 6.26
   B. 6.59
   C. 9,12
   D. 5,19

5. Choose the correct statement. F-criterion cannot be:
   A. more than one
   B. less than one
   S. positive value
   D. equal to one

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. Analyze the algorithm of comparison of two methods by reproducibility analysis, write down its main principles and formulas.

Answer and explanation

Tasks for auditory work:

Task 1. Determination of antipyrine in blood (μg/g of plasma) was carried out by chromatographic (I) and kinetic (II) methods.

I – 0.022; 0.042; 0.037; 0.028; 0.050

II – 0.030; 0.075; 0.050; 0.066; 0.045

Calculate F-test.

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. Use the data of the previous example and the corresponding calculations to it. Answer the following questions:

1) is it possible to combine the results of two methods into one general population?

2) are the variances homogeneous?

3) is statistically significant difference between the values of the two variances?

Answer and explanation

Example of problem with solution:

Assume that an analyst used a certain method to determine the amount of lead in a water sample and estimated s = 2.5 μg/L based on 7 measurements. At a later date, she analyzed another water sample for its lead content, using the same method, and obtained s = 3.3 μg/L based on 10 measurements. Were both sets of measurements equally precise with 95% confidence?

Answer

Calculate

$$F = \frac{3.3^2}{2.5^2} = 1.74,$$

ν_1 = 9 for numerator, ν_2 = 6 for denominator; for 95% confidence, F_c = 4.099 (by interpolation).

Since F does not exceed F_c, conclude that, at the 95% level of confidence, there is no reason to believe that the precisions differ.

Suppose someone asked how large would to have been on the second occasion, before it would have been significantly different from the first measurement? The answer could be based on the following calculation:

$$F_c = 5.52 = \frac{s^2}{2.5^2},\ s^2 = 34.5,\ s = 5.9.$$

Answer: there is no reason to believe that the precisions differ, F = 1.74.

Topic 6. Comparison of the mean values of two samples

Purpose: ability to compare the mean values of experimental data obtained by two different methods or for two different objects, and to interpret their calculations.

Student should:

✓ to know the algorithm for comparison of two experimental means if the standard deviations differ significantly;

✓ to know the algorithm for comparison of two experimental means if the standard deviations do not differ significantly;

✓ to be able to interpret the results of their calculations.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Measurement precision	closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions.

Recommended literature:

Basic

1. Statistics and Chemometrics for Analytical Chemistry (seventh edition) / J. N. Miller, J.C. Miller and R. D. Miller : Pearson, 2018, P. 37-44. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

2. Taylor, J. K., Cihon, C. Statistical techniques for data analysis (second edition). Chapman and Hall/CRC, 2004, P. 87-90. https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. European Pharmacopoeia / European Directorate for the Quality of Medicines & HealthCare of the Council of Europe. – tenth edition, volume 1. Strasbourg : Council of Europe, 2019. Section 5.3. Statistical analysis of results of biological assays and tests. P. 683-713. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Comparison of the mean values of two samples for cases:
1.1. Standard deviations differ significantly.
1.2. Standard deviations do not differ significantly.

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. When comparing the mean values of two samples, calculate:

A. Q-criterion
B. Pearson's criterion
C. t-criterion
D. Gauss's criterion

2. When comparing the mean values of two samples at the first stage, it is necessary to establish whether there is a statistically significant difference between:

A. standard deviations
B. sample sizes
C. confidence intervals
D. relative standard deviations

3. When comparing the mean values of two samples in the case that standard deviations do not differ significantly, there is a need to calculate:

A. pooled mean value
B. pooled confidence interval
C. pooled standard deviation
D. pooled relative standard deviations

4. Mean values of two samples are compared, and the sample sizes are the following values: $n_1 = 5$, $n_2 = 6$. It is established that standard deviations do not differ significantly. What number of degrees of freedom will you use to find the control value of the t-criterion in the table?

A. 11
B. 9
C. 10
D. 8

5. Mean values of two samples are compared, and the sample sizes are the following values: $n_1 = 4$, $n_2 = 5$. It is established that standard deviations do not differ significantly. What is the control value of the t-criterion for this case at confidence level 95%?

A. 2.3060
B. 2.2622
C. 2.3646
D. 2.9980

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. Analyze algorithms for comparison of mean values of two samples, write down their main principles and formulas.

Standard deviations differ significantly	Standard deviations do not differ significantly

Tasks for auditory work:

Task 1. Determination of antipyrine in blood (μg/g of plasma) was carried out by chromatographic (I) and kinetic (II) methods.

I – 0.022; 0.042; 0.037; 0.028; 0.050

II – 0.030; 0.075; 0.050; 0.066; 0.045

Compare the mean values of two samples, given that standard deviations do not differ significantly.

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. Use the data of the previous example and the corresponding calculations to it. Answer the following questions:

1) is it statistically significant difference between mean values?

2) it is known that the chromatographic method is certified and does not contain a systematic error. Based on the calculations, conclude whether the kinetic method contains a systematic error.

Answer and explanation

Example of problem with solution:

Consider Case I. The standard deviations do not differ significantly.

The two sets of data are the following:

$\bar{x}_A = 50$ mg/L, $s_A = 2$ mg/L, $n_A = 5$

$\bar{x}_B = 45$ mg/L, $s_B = 1.5$ mg/L, $n_B = 6$

$\Delta = 5$ mg/L

Step 1. $s_p = \sqrt{\frac{2^2 \times 4 + 1.5^2 \times 5}{4+5}} = \sqrt{3.028} = 1.74$, df = 9

Step 2. $V_A = \frac{3.028}{5} = 0.6056$, $V_B = \frac{3.028}{6} = 0.5047$

Step 3. Decision to be made with 95% confidence level

Step 4. $U_\Delta = 2.26 \times \sqrt{0.6056 + 0.5047} = 2.38$

From Table 2 in Appendix, the critical value is $t_9 = 2.26$ ($P = 0.05$)

Step 5. Since Δ exceeds U_Δ, conclude that the means differ significantly at the 95% level of confidence.

Consider Case II. The standard deviations differ significantly.

The two sets of data are the following:

$\bar{x}_A = 50$ mg/L, $s_A = 2$ mg/L, $n_A = 5$

$\bar{x}_B = 45$ mg/L, $s_B = 1.5$ mg/L, $n_B = 6$

$\Delta = 5$ mg/L

Step 1. $V_A = \frac{2^2}{5} = 0.800$, $V_B = \frac{1.5^2}{6} = 0.375$

Step 2. Decision to be made with 95% confidence level

Step 3. $f = \frac{(0.800+0.375)^2}{\frac{0.800^2}{4}+\frac{0.375^2}{5}} = 7.34 = 7$

Step 4. $U_\Delta = 2.365 \times \sqrt{0.800 + 0.375} = 2.6$

Step 5. Since Δ exceeds UΔ, conclude that the means differ at the 95% level of confidence.

Topic 7. Estimation of the accuracy of measurements

Purpose: ability to estimate the accuracy of measurements obtained experimentally and to interpret their calculations.

Student should:

✓ to know the algorithm for estimation of the accuracy of measurements using confidence limits;

✓ to know the algorithm for estimation of the accuracy of measurements using the t-criterion;

✓ to be able to interpret the results of their calculations.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Bias	overall deviation of a result from the true value even when random errors are very small.
Measurement accuracy	closeness of agreement between a test result and the accepted reference value of the analyte.

Recommended literature:

Basic

1. Introduction to Statistics in Metrology / S. Crowder et al. Cham : Springer International Publishing, 2020, P. 19-28. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

2. Taylor, J. K., Cihon, C. Statistical techniques for data analysis (second edition). Chapman and Hall/CRC, 2004, P. 112-115. https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. European Pharmacopoeia / European Directorate for the Quality of Medicines & HealthCare of the Council of Europe. – tenth edition, volume 1. Strasbourg : Council of Europe, 2019. Section 5.3. Statistical analysis of results of biological assays and tests. P. 683-713. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Algorithm for estimation of the accuracy of measurements using confidence limits.
2. Algorithm for estimation of the accuracy of measurements using the t-criterion.

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. Indicator of the accuracy of the method is usually the value:
   A. methodical error
   B. random error
   C. systematic error
   D. outlier
2. You can estimate the accuracy of measurements using:
   A. Pearson's test
   B. Student's test
   C. Fisher's test
   D. Gauss’s test
3. You can estimate the accuracy of measurements using:
   A. confidence intervals
   B. variances
   C. average values
   D. standard deviations
4. It is impossible to estimate the presence of a systematic error without:
   A true value of the analytical signal
   B. average value of the analytical signal
   C. largest value of the analytical signal
   D. smallest value of the analytical signal
5. For estimation of the accuracy of the method using the Student's criterion (t-criterion), the following parameters must be calculated:
   A. variance and standard deviation
   B. mean value and standard deviation
   C. mean value and confidence interval
   D. standard deviation and confidence interval

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. Analyze algorithms for estimation of the accuracy of measurements using confidence limits and Student's criterion (t-test), write down their main principles and formulas.

Estimation of the accuracy of measurements using confidence limits	Estimation of the accuracy of measurements using the t-criterion

Tasks for auditory work:

Task 1. Using the Student's criterion (t-criterion), determine whether there is a systematic error in the presented results and make conclusion about the accuracy of the results (P = 0.95).

Results of determining the content of bromide ions in a standard sample of mineral water by the potentiometric method (g/l) are: 0.008; 0.01; 0.019; 0.007; 0.016; 0.007 (the true value of the content of bromide ions, according to the passport, is 0.019 g/l).

Answer and explanation

Task 2. Using the confidence limits, determine whether there is a systematic error in the presented results and make conclusion about the accuracy of the results (P = 0.95).

Results of determining the content of bromide ions in a standard sample of mineral water by the potentiometric method (g/l) are: 0.008; 0.01; 0.019; 0.007; 0.016; 0.007 (the true value of the content of bromide ions, according to the passport, is 0.019 g/l).

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. Evaluate the value of the relative systematic error for the results given in previous task.

Answer and explanation

Example of problem with solution:

The absorbance scale of a spectrometer is tested at a particular wavelength with a standard solution which has an absorbance given as 0.470. Ten measurements of the absorbance with the spectrometer give = 0.461, and s = 0.003. Find the 95% confidence interval for the mean absorbance as measured by the spectrometer, and hence decide whether a systematic error is present. Make conclusion about accuracy of results.

Answer

The 95% confidence limits for the absorbance as measured by the spectrometer are:

$$\bar{x} \pm t_{n-1} \times \frac{s}{\sqrt{n}} = 0.461 \pm 2.26 \times \frac{0.003}{\sqrt{10}} = 0.461 \pm 0.002.$$

Since the confidence interval does not include the known absorbance of 0.470, it is likely that a systematic error has occurred. The results are not accurate.

Answer: the results are not accurate.

Topic 8. Estimation of the repeatability of results

Purpose: ability to estimate the repeatability of results and interpret their calculations.

Student should:

- ✓ to know the algorithm for estimatation the repeatability of results;
- ✓ to be able to interpret the results of their calculations.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Repeatability	characterizes the precision of the technique when it is performed under the same conditions (in particular, by the same analyst or group of analysts) over a short period of time.
Validation	verification, where the specified requirements are adequate for an intended use.

Recommended literature:

Basic

1. Introduction to Statistics in Metrology / S. Crowder et al. Cham : Springer International Publishing, 2020, P. 19-28. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

2. Statistics and Chemometrics for Analytical Chemistry (seventh edition) / J. N. Miller, J.C. Miller and R. D. Miller : Pearson, 2018, P. 6-12. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. B. Magnusson and U. Örnemark (eds.). Eurachem Guide: The Fitness for Purpose of Analytical Methods – A Laboratory Guide to Method Validation and Related Topics, (2nd ed. 2014). URL: www.eurachem.org/images/stories/Guides/pdf/MV_guide_2nd_ed_EN.pdf (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Estimatation of the repeatability of results.
2. Validation of analytical methods and tests: basic terms and concepts.

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. For estimatation the repeatability of results is used a factor calculated according to:
   A. Fisher
   B. Student
   C. Pearson
   D. Gauss
2. For estimatation the repeatability of results is used the product of two values:
   A. standard deviation per factor calculated by Pearson
   B. standard deviation per factor calculated by Student
   C. variance per factor calculated by Pearson
   D. mean value per factor calculated by Pearson
3. Issues of validation of analytical methods are not considered for the following type:
   A. identification test
   B. fatigue test
   C. quantitative tests to determine impurities
   D. limit test for impurity control
4. What does not belong to the typical validation characteristics?
   A. limit of detection
   B. precision
   C. linearity
   D. flexibility
5. The purpose of analytical methodology validation is to demonstrate that it:
   A. suitable for inclusion in the working curriculum
   B. suitable for storage
   C. suitable for its intended use
   D. suitable for description on the Internet

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. List typical validation characteristics

Answer and explanation

Task 2. Analyze the algorithm for estimatation the repeatability of results, write down its main principles and formulas

Answer and explanation

Tasks for auditory work:

Task 1. Results of determining the content of calcium oxide in calcite (%) are: 55.95; 56.00; 56.04; 56,23. Estimate the repeatability of results (P = 0.95).

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. Compare the validation characteristics "repeatability" and "reproducibility", note the common and different features.

Characteristic	Common features	Different features
Repeatability		
Reproducibility		

Example of problem with solution:

The following values (expressed as percentages) give the antibody concentration in human blood serum for a sample of eight healthy adults. 1.13, 1.45, 1.35, 1.09.

Estimate the repeatability of results using relative standard deviation.

Answer

Calculation of mean: $\bar{x} = \frac{1.13+1.45+1.35+1.09}{4} = 1.255$ rounded to 1.26

Calculation of standard deviation: $s = \sqrt{\frac{(1.13-1.255)^2+(1.45-1.255)^2+(1.35-1.255)^2+(1.09-1.255)^2}{4-1}}=$

$= \sqrt{\frac{0.015625+0.038025+0.009025+0.027225}{3}} = \sqrt{0.0299666} = 0.17311$ rounded to 0.17

Calculation of relative standard deviation: $RSD = \frac{0.17311}{1.255} \times 100 = 13.7935\%$ rounded to 13.8%.

The results are not characterized by the repeatability.

Answer: RSD = 13.8%, the results are not characterized by the repeatability.

Topic 9. Calculation of linear dependence parameters. Estimation of the limit of detection

Purpose: ability to calculate parameters of linear dependence and estimate the limit of detection.

Student should:

- ✓ to know the basics of regression analysis and correlation analysis;
- ✓ to be able to calculate parameters of linear regression;
- ✓ to be able to determine the detection limit of the analytical technique.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Product–moment correlation coefficient	common method of estimating how well the experimental points fit a straight line.
Limit of detection	lowest concentration of an analyte in a sample that can be consistently detected with a stated probability (typically at 95% certainty).

Recommended literature:

Basic

1. Statistics and Chemometrics for Analytical Chemistry (seventh edition) / J. N. Miller, J.C. Miller and R. D. Miller : Pearson, 2018, P. 120-137. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. Introduction to Statistics in Metrology / S. Crowder et al. Cham : Springer International Publishing, 2020, P. 227-240. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Linear and non-linear regressions.
2. Statistical estimation of the limit of detection.

Tasks for extra-auditory independent work:

Test questions

Choose and justify the correct answer.

1. Indicator of the strength of the linear relationship between two variables is:

A. power factor
B. similarity coefficient
C. correlation coefficient
D. strength coefficient

2. When using many chemical and physico-chemical methods of quantitative analysis, the following dependence between a certain value (parameter) and the desired concentration (amount) of the determined substance is most often found:

A. linear
B. polynomial
C. logistic
D. exponential

3. To determine the regression coefficients, the following is used:

A. method of largest squares
B. method of least squares
C. method of least triangles
D. method of largest triangles

4. Calculation of the limit of detection is impossible without:

A. standard deviation for the mean value of the analytical signal of the "full" experiment
B. standard deviation for the mean value of the analytical signal of the "random" experiment
C. standard deviation for the mean value of the analytical signal of the "best" experiment
D. standard deviation for the mean value of the analytical signal of the "blank" experiment

5. Calculation of the limit of detection is impossible without:

A. instrumental precision coefficient
B. instrumental specificity coefficient
C. instrumental sensitivity coefficient
D. instrumental correlation coefficient

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. Spectrophotometric determination of the concentration of copper in the studied sample was carried out using the gradient dependence described by the equation y = – 0.0002875 + 0.1578·x. The optical density value is 0.517. Calculate the concentration of copper in the test solution.

Answer and explanation

Tasks for auditory work:

Task 1. Calculate parameters a and b of linear regression $y = a + bx$ in the determination of phenol by the spectrophotometric method, if the following data are obtained for the construction of a graduation graph:

with, μg/cm^3	0	1.0	2.0	4.0	8.0
A	0.050	0.148	0.241	0.452	0.820

The mean value of the optical density at c=0 was obtained from the following values: 0.055; 0.047; 0.053; 0.045; 0.048; 0.050; 0.052.

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. Calculate the limit of detection (P = 0.999) determination of phenol by spectrophotometric method (see previous task).

Answer and explanation

Example of problem with solution:

Standard aqueous solutions of fluorescein are examined in a fluorescence spectrometer, and yield the following fluorescence intensities (in arbitrary units):

Fluorescence intensities:	2.1	5.0	9.0	12.6	17.3	21.0	24.7
Concentration, pg ml^{-1}		0	2	4	6	8	10	12

Determine the correlation coefficient, *r*.

Answer

In practice, such calculations will almost certainly be performed on a calculator or computer, alongside other calculations covered below, but it is important and instructive to examine a manually calculated result. The data are presented in a table, as follows:

	x_i	y_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	$y_i - \bar{y}$	$(y_i - \bar{y})^2$	$(x_i - \bar{x}) \times (y_i - \bar{y})$
	0	2.1	-6	36	-11.0	121.00	66.0
	2	5.0	-4	16	-8.1	65.61	32.4
	4	9.0	-2	4	-4.1	16.81	8.2
	6	12.6	0	0	-0.5	0.25	0
	8	17.3	2	4	4.2	17.64	8.4
	10	21.0	4	16	7.9	62.41	31.6
	12	24.7	6	36	11.6	134.56	69.6
Sums	42	91.7	0	112	0	418.28	216.2

$$r = \frac{216.2}{\sqrt{112 \times 418.28}} = \frac{216.2}{216.44} = 0.9989$$

Answer: 0.9989.

Topic 10. Probability theory in pharmacy

Purpose: ability correctly apply the main theorems of probability theory, estimate the probability of a random event and calculate the probability of consecutive independent events according to Bernoulli's formula.

Student should:

- ✓ to know the basic theorems of probability theory;
- ✓ to be able to estimate the probability of a random events;
- ✓ to be able to calculate the probability of successive independent events according to the Bernoulli's formula.

Basic concepts of the topic:

Term, parameter, characteristic	*Definition*
Probability theory	science of random events; a branch of mathematics in which mathematical models of random (stochastic) phenomena are studied.
Stochastic experiment	certain test, observation or experiment, the result of which cannot be predicted unequivocally.
Event	everything that may or may not happen under certain conditions.

Recommended literature:

Basic

1. Riffenburg R. H., Gillen D. L. Statistical in Medicine (fourth edition). Academic press, 2020, P. 51-64. URL: https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Additional

1. Taylor, J. K., Cihon, C. Statistical techniques for data analysis (second edition). Chapman and Hall/CRC, 2004, P. 185-187. https://likar.nmu.kiev.ua/md/course/view.php?id=7412 (date of access: 25.07.2024).

Information resources

1. https://nmuofficial.com/en/zagalni-vidomosti/kafedri/department-medical-general-chemistry/
2. https://likar.nmu.kiev.ua/md/course/view.php?id=7412

Questions for theoretical study:

1. Basic theorems of probability theory.
2. Consecutive independent events. Bernoulli's formula.

Tasks for extra-auditory independent work:

Test guestions

Choose and justify the correct answer.

1. Probability theory is science of:
   A. all events
   B. systematic events
   C. random events
   D. pleasant events
2. Probability characterizes:
   A. strength of dependence between two quantities
   B. chance of a certain event occurring
   C. suitability of the analytical technique
   D. presence of random error
3. Three blue, five black and eight red balls were placed in the urn. Find the probability of drawing a white ball.
   A. 0.8
   B. 0.2
   C. 0.5
   D. 0.0
4. Three blue, five black and eight red balls were placed in the urn. Find the probability of drawing a red ball.
   A. 0.5
   B. 0.1
   C. 0.9
   D 0.4
5. The Bernoulli's formula allows you to calculate the probability of success in a series:
   A. dependent tests
   B. independent tests
   C. best trials
   D. reliable tests

Write down below the letters that indicate the correct answers to the test questions:

1-☐ 2-☐ 3-☐ 4-☐ 5-☐

Written tasks

Task 1. There are 30 test tubes in a closed rack: 10 with red solution, 5 with blue solution and 15 with colorless solution. Find the probability of drawing a colored test tube.

Answer and explanation

Task 2. We have three boxes in which there are 10 glasses with solutions. There are 8 standard solutions in the first box, 7 standard solutions in the second, and 9 standard solutions in the third. One glass is taken out at random from each box. Find the probability that the solutions in all three removed glasses will be standard.

Answer and explanation

Tasks for auditory work:

Task 1. A student came to the analytical chemistry exam having studied only 40 questions out of 50. There are three questions in the exam card. Calculate the probability that the student answers the first question of the card, the second question, and the third question.

Answer and explanation

Task 2. There are 100 packages of one medicine in the pharmacy. The shelf life of 20 packages is 90% of the shelf life, 50 packages – 70%, 24 packages – 50%. 6 packs have expired. What is the probability that a randomly taken package of the medicine can be accepted for sale?

Answer and explanation

Task 3. The pharmacy has 40 different analeptics, 40 analgesics and 20 anesthetics. What is the probability that the pharmacist will answer the customer about the properties and dosage of a particular medicine, if he knows well only 30 analeptics, 10 analgesics and 8 anesthetics?

Answer and explanation

Tasks for auditory independent work (under the supervision of a teacher):

Task 1. The coin has been tossed 6 times. Find the probability that the coat of arms will fall 4 times.

Answer and explanation

Example of problem with solution:

The cook prepared 160 muffins from 10 kg of dough and 300 raisins. What is the probability that one randomly selected cupcake will not contain any raisins?

Answer

Use Bernoulli's formula: n = 300 (total number of raisins), k = 0 (because we are looking for the probability that one randomly selected cupcake will not have a single raisin), p = 1/160 (because we choose 1 cupcake out of 160):

$$P = \frac{300!}{0! \cdot (300-0)!} \cdot \frac{1}{160}^{0} \cdot (1-\frac{1}{160})^{300-0} = 0.15 = 15\%$$

Answer: 15%.

SUPPLEMENT

Table D1. Values for use in the Dixon Test (Q-test) for Outliers

n	*P* = 0,90	*P* = 0,95	*P* = 0,99
3	0,89	0,94	0,99
4	0,68	0,77	0,89
5	0,56	0,64	0,76
6	0,48	0,56	0,70
7	0,43	0,51	0,64
8	0,40	0,48	0,58
9	0,38	0,46	0,55

Table D2. Values for Use in the Grubbs Test for Outliers

n	*P* = 0,90	*P* = 0,95	*P* = 0,99
3	1.148	1.153	1.155
4	1.425	1.463	1.492
5	1.602	1.672	1.749
6	1.729	1.822	1.944
7	1.828	1.938	2.097
8	1.909	2.032	2.221
9	1.977	2.110	2.323

Table D3. The t-distribution

υ	P = 0,90	P = 0,95	P = 0,98	P = 0,99
1	6,3138	12,7062	31,8205	63,6567
2	2,9200	4,3027	6,9646	9,9248
3	2,3534	3,1824	4,5407	5,8409
4	2,1318	2,7764	3,7469	4,6041
5	2,0150	2,5706	3,3649	4,0321
6	1,9432	2,4469	3,1427	3,7074
7	1,8946	2,3646	2,9980	3,4995
8	1,8595	2,3060	2,8965	3,3554
9	1,8331	2,2622	2,8214	3,2498
10	1,8125	2,2281	2,7638	3,1693
11	1,7956	2,2010	2,7181	3,1058
12	1,7823	2,1788	2,6810	3,0545
13	1,7709	2,1604	2,6503	3,0123
14	1,7613	2,1448	2,6245	2,9768
15	1,7530	2,1314	2,6025	2,9467
16	1,7459	2,1199	2,5835	2,9208
17	1,7396	2,1098	2,5669	2,8982
18	1,7341	2,1009	2,5524	2,8784
19	1,7291	2,0930	2,5395	2,8609
20	1,7247	2,0860	2,5280	2,8453
25	1,7081	2,0595	2,4851	2,7874
30	1,6973	2,0423	2,4573	2,7564
40	1,6839	2,0211	2,4233	2,7045
50	1,6759	2,0086	2,4033	2,6778
100	1,6602	1,9840	2,3642	2,6259

Table D4. Critical values for the F-test, P=0.05, ν_1 is the number of degrees of freedom of the numerator, ν_2 is the number of degrees of freedom of the denominator

υ_1 / υ_2	**1**	**2**	**3**	**4**	**5**	**6**	**8**	**12**	**24**	∞
1	161,5	199,5	215,7	224,6	230,2	233,9	238,9	243,9	249,0	254,3
2	18,51	19,00	19,16	19,25	19,30	19,33	19,37	19,41	19,45	19,50
3	10,13	9,55	9,28	9,12	9,01	8,94	8,84	8,74	8,64	8,53
4	7,71	6,94	6,59	6,39	6,26	6,16	6,04	5,91	5,77	5,63
5	6,61	5,79	5,41	5,19	5,05	4,95	4,82	4,68	4,53	4,36
6	5,99	5,14	4,76	4,53	4,39	4,28	4,15	4,00	3,84	3,67
7	5,59	4,74	4,35	4,12	3,97	3,87	3,73	3,57	3,41	3,23
8	5,32	4,46	4,07	3,84	3,69	3,58	3,44	3,28	3,12	2,93
9	5,12	4,26	3,86	3,63	3,48	3,37	3,23	3,07	2,90	2,71
10	4,96	4,10	3,71	3,48	3,33	3,22	3,07	2,91	2,74	2,54
11	4,84	3,98	3,59	3,36	3,20	3,09	2,95	2,79	2,61	2,40
12	4,75	3,88	3,49	3,26	3,11	3,00	2,85	2,69	2,50	2,30
13	4,67	3,80	3,41	3,18	3,02	2,92	2,77	2,60	2,42	2,21
14	4,60	3,74	3,34	3,11	2,96	2,85	2,70	2,53	2,35	2,13
15	4,54	3,68	3,29	3,06	2,90	2,79	2,64	2,48	2,29	2,07
16	4,49	3,63	3,24	3,01	2,85	2,74	2,59	2,42	2,24	2,01
17	4,45	3,59	3,20	2,96	2,81	2,70	2,55	2,38	2,19	1,96
18	4,41	3,55	3,16	2,93	2,77	2,66	2,51	2,34	2,15	1,92
19	4,38	3,52	3,13	2,90	2,74	2,63	2,48	2,31	2,11	1,88
20	4,35	3,49	3,10	2,87	2,71	2,60	2,45	2,28	2,08	1,84
21	4,32	3,47	3,07	2,84	2,68	2,57	2,42	2,25	2,05	1,81
22	4,30	3,44	3,05	2,82	2,66	2,55	2,40	2,23	2,03	1,78
23	4,28	3,42	3,03	2,80	2,64	2,53	2,38	2,20	2,00	1,76
24	4,26	3,40	3,01	2,78	2,62	2,51	2,36	2,18	1,98	1,73
25	4,24	3,38	2,99	2,76	2,60	2,49	2,34	2,16	1,96	1,71
26	4,22	3,37	2,98	2,74	2,59	2,47	2,32	2,15	1,95	1,69
27	4,21	3,35	2,96	2,73	2,57	2,46	2,30	2,13	1,93	1,67
28	4,20	3,34	2,95	2,71	2,56	2,44	2,29	2,12	1,91	1,65
29	4,18	3,33	2,93	2,70	2,54	2,43	2,28	2,10	1,90	1,64
30	4,17	3,32	2,92	2,69	2,53	2,42	2,27	2,09	1,89	1,62
35	4,12	3,26	2,87	2,64	2,48	2,37	2,22	2,04	1,83	1,57
40	4,08	3,23	2,84	2,61	2,45	2,34	2,18	2,00	1,79	1,51

45	4,06	3,21	2,81	2,58	2,42	2,31	2,15	1,97	1,76	1,48
50	4,03	3,18	2,79	2,56	2,40	2,29	2,13	1,95	1,74	1,44
60	4,00	3,15	2,76	2,52	2,37	2,25	2,10	1,92	1,70	1,39
70	3,98	3,13	2,74	2,50	2,35	2,23	2,07	1,89	1,67	1,35