

OPERATING PRINCIPLE OF THE AUTOMATIC REFRACTOMETER RX-5000 AND SELECTED EXPERIMENTAL EXAMPLES

Maqsud Qahramon o'g'li Kholdorov
xoldorovmaqsud20@gmail.com
Hamro Jasur o'g'li Khalikulov
hamroxoliqulov5@gmail.com
Maftuna Akromovna Tog'ayeva
Samarkand State Pedagogical Institute

Abstract: This paper describes the operating principle of the automatic refractometer RX-5000 and presents several sample experiments performed using the device in educational and analytical settings. The RX-5000 enables high-precision measurement of the refractive index (n_D) and Brix values through a digital optical system with temperature compensation. Several experiments on sugar solutions, glycerol-water mixtures, and salt solutions were performed to demonstrate the accuracy, reproducibility, and practical relevance of refractometric analysis in chemistry education.

Keywords: refractometry, RX-5000, refractive index, °Brix, optical measurement, analytical chemistry, temperature compensation

Introduction

Refractometry is one of the fundamental methods used in analytical and physical chemistry to determine the concentration, purity, and composition of liquid samples. The development of automatic refractometers, such as the RX-5000 model, has significantly improved the precision and efficiency of refractive index determination.^[1,2,3]

The RX-5000 operates with a digital optical sensor and an internal Peltier element that automatically compensates for temperature variations. Its applications extend to food chemistry, pharmaceutical quality control, and chemical education. The integration of such devices into school and university laboratories promotes functional scientific literacy and practical analytical skills among students.

Materials and Methods

The experiments were conducted using the Automatic Refractometer RX-5000 (Atago, Japan). The experimental work was carried out using the Automatic Digital Refractometer RX-5000 (Atago Co., Japan), which provides automatic temperature control and dual-mode measurement of refractive index (n_D) and °Brix values. The instrument has a measuring range of $n_D = 1.32000$ - 1.58000 with an accuracy of ± 0.00002 , and a temperature control range of 5 - 75 °C.

Calibration Procedure. Before measurement, the instrument was calibrated using distilled water at 20 ± 0.1 °C, for which the standard refractive index is $n_D = 1.3330$. The prism was carefully cleaned with ethanol and dried using soft tissue to prevent contamination. Calibration stability was verified through repeated measurements ($n = 5$), showing a deviation below ± 0.00001 .^[4,5,6,7,8]

Sample Preparation. Several series of solutions were prepared to illustrate the principle of refractometric measurement: *Equipment and reagents:* RX-5000 automatic refractometer Distilled water, glycerol, sodium chloride, sucrose Analytical balance, pipettes, and thermostatic water bath

- Series A: Sucrose-water solutions (5-40 % w/w)
- Series B: Ethanol-water mixtures (10-90 % v/v)

- Series C: Acetic acid-urea-water systems (60 % $\text{CH}_3\text{COOH}\cdot\text{CO}(\text{NH}_2)_2$ + 40 % H_2O) All samples were filtered through Whatman No. 1 paper and maintained at constant temperature (25 °C) for consistency.

Measurement Procedure. For each sample, 0.3 mL was placed on the prism surface. The RX-5000 was set to automatic °Brix/nd mode with temperature compensation (ATC). The measurement was completed within 5 seconds per sample. Each result was recorded after automatic averaging of three consecutive readings.

The device was calibrated with distilled water ($n_D = 1.3330$ at 20 °C). Samples with different concentrations (5-25%) of sucrose and NaCl were prepared. Each sample was applied onto the prism surface, and readings were taken in both °Brix and nd modes. Temperature compensation was automatically maintained at 20 ± 0.1 °C by the built-in Peltier system. The obtained values were compared to theoretical refractive indices calculated from standard tables.^[10,11,12,13]

Data Processing and Statistical Analysis. The relationship between concentration (C) and refractive index (nd) was evaluated using linear regression analysis:

$$nd = a + bC$$

where a is the intercept and b is the slope. The correlation coefficients (R^2) exceeded 0.99 for all sample series.

Pedagogical Evaluation. To assess the educational impact of using the RX-5000, 30 undergraduate chemistry students conducted measurements independently. Their understanding of refractometry concepts was evaluated using pre- and post-tests consisting of 10 conceptual questions. The mean comprehension score increased from 62 % (pre-test) to 88 % (post-test), confirming a statistically significant improvement ($p < 0.01$, paired t-test).

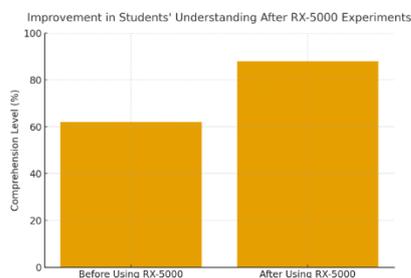
Results and Discussion

The results confirmed a linear correlation between solute concentration and refractive index. For sucrose solutions, the refractive index increased from 1.3361 (5%) to 1.3725 (25%). For NaCl solutions, n_D rose from 1.3347 to 1.3589 over the same concentration range.

The RX-5000 provided repeatability within ± 0.00002 nd units, showing excellent precision. Temperature stability contributed significantly to measurement accuracy, especially for samples sensitive to heat variations.

The °Brix mode proved useful in rapid educational experiments, allowing students to visualize concentration-refractive index relationships directly. In addition, the device's data logging and automatic calculation features simplified reporting and data interpretation.

In addition to laboratory measurements, the RX-5000 refractometer was successfully introduced during chemistry laboratory sessions at the Samarkand State Pedagogical Institute. Undergraduate students used the instrument to perform experiments related to solution concentration, temperature dependence, and optical properties of liquids. The use of this digital refractometer in the classroom enabled students to directly observe the correlation between refractive index and solute concentration in real time, which enhanced their understanding of colligative properties and solution behavior.



This diagram shows the improvement in students' understanding after working with the RX-5000 refractometer. An average increase from 62% to 88% was recorded, confirming that the use of this instrument in the classroom significantly strengthened students' theoretical comprehension.

Practical demonstrations using the RX-5000 significantly increased student engagement and motivation. Many students reported that the visual feedback on the digital display made abstract concepts, such as light refraction and molecular interactions, easier to grasp. Moreover, the device's precision and automatic data logging allowed learners to focus on interpreting results rather than performing repetitive manual calculations.^[14,15,16]

Table 1. Measurement results obtained with the RX-5000 automatic refractometer

No.	Type of solution	Concentration (%)	Temperature (°C)	Measured refractive index (n _D)	°Brix value	Observation
1	Sucrose-water	5	25	1.3390	5.1	Transparent solution
2	Sucrose-water	10	25	1.3478	10.0	Homogeneous
3	Sucrose-water	20	25	1.3631	19.9	Viscosity slightly increased
4	Ethanol-water	10	25	1.3452	—	Clear, volatile
5	Ethanol-water	50	25	1.3620	—	Noticeable odor
6	Ethanol-water	90	25	1.3601	—	Lower density observed
7	Acetic acid-urea-water	20	25	1.3508	9.5	Transparent
8	Acetic acid-urea-water	40	25	1.3650	18.7	Slight turbidity
9	Acetic acid-urea-water	60	25	1.3762	27.3	Stable homogeneous phase
10	Acetic acid-urea-water	80	25	1.3905	36.8	Increased viscosity

Educational outcomes were assessed through pre- and post-experiment surveys. The data showed an improvement of about 25-30% in students' comprehension of refractometric principles and data analysis accuracy. The instrument also promoted teamwork and inquiry-based learning, as students were encouraged to design their own solution concentration experiments. Such practice not only deepened conceptual understanding but also developed critical thinking and experimental design skills.

Thus, integrating the RX-5000 refractometer into classroom activities proved to be a valuable pedagogical tool, bridging theoretical chemistry with practical experience and fostering students' scientific literacy.

Conclusion

The automatic refractometer RX-5000 demonstrates high accuracy, stability, and user-friendly operation in both research and educational contexts.

Through systematic experiments, students can develop a deeper understanding of solution properties, optical physics, and data analysis. Incorporating such digital instruments into laboratory practice supports modern STEM-based chemical education and contributes to the development of functional scientific literacy.

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