



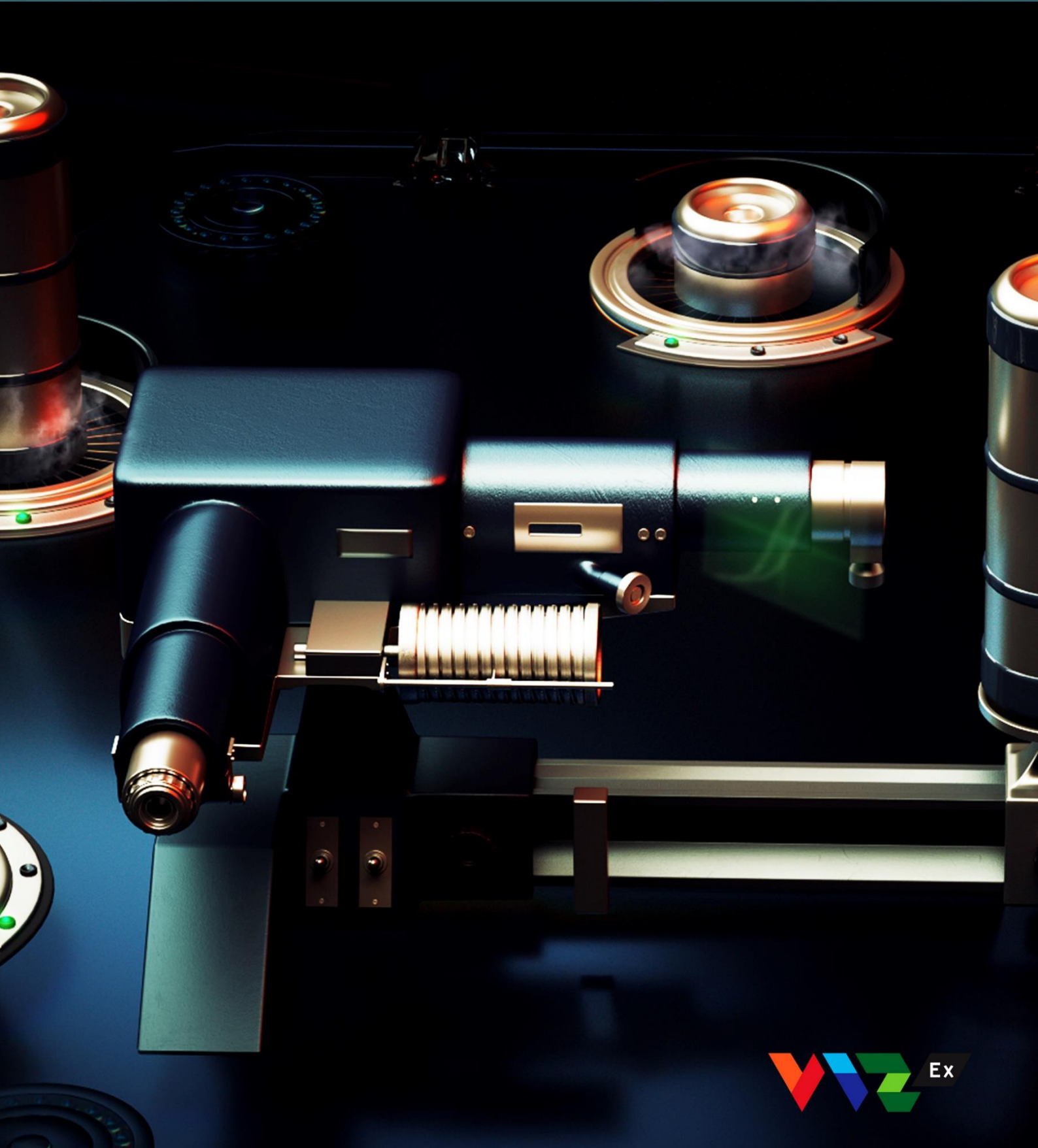
Virtual laboratory



SCIENCE

Study of atomic spectra

User
manual



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Terms and Definitions

The following general terms are used in the User Guide:

Virtual laboratory	Virtual laboratory "Science", "Study of the atomic spectra" section
Scene	A virtual three-dimensional space within which the user can interact with the Virtual Laboratory objects. The concept of "scene" also includes the data of the current research (positions of objects, their parameters, etc.)
Process simulation	The process of interaction between objects in a scene modeled in the Virtual Laboratory.
Camera	A scene tool with which the user observes everything that happens in the Virtual Laboratory.
Click	To make a click: — When using a mouse, move the mouse pointer to the object, press and release the left mouse button without moving the pointer; — When using a touchscreen, press the object with a finger and release it without moving the finger along the screen.
Toggle-button	A button that changes its state from inactive to active and vice versa after being pressed. The state is retained until the next interaction.

1 System requirements

Minimum system requirements for the Virtual laboratory "Science", "Study of the atomic spectra" section are:

- **Processor:** Intel Ivy Bridge series / AMD Bulldozer series.
- **RAM:** 4 GB.
- Graphics Card:
 - Integrated: Intel HD Graphics 5000 / Intel Iris;
 - Discrete: GeForce 400 series or newer / Radeon HD 7000 series.
- **Screen Resolution:** 1920x1080 / 1920x1200 and higher (4K and Retina displays require a more powerful graphics card for comfortable operation).
- **Supported Browsers:** Chrome, Yandex.Browser, Opera 44+, Firefox 51+, Edge 79+, Safari 15+.
- **Supported Operating Systems:**
 - Microsoft Windows 7 (x64 versions) with WebGL 2.0 driver support;
 - MacOS X "Snow Leopard" 10.6 with WebGL 2.0 driver support;
 - Linux or Debian with WebGL 2.0 driver support.

2 Virtual laboratory interface

The virtual laboratory is a three-dimensional virtual environment for conducting experiments to study the atomic spectra.

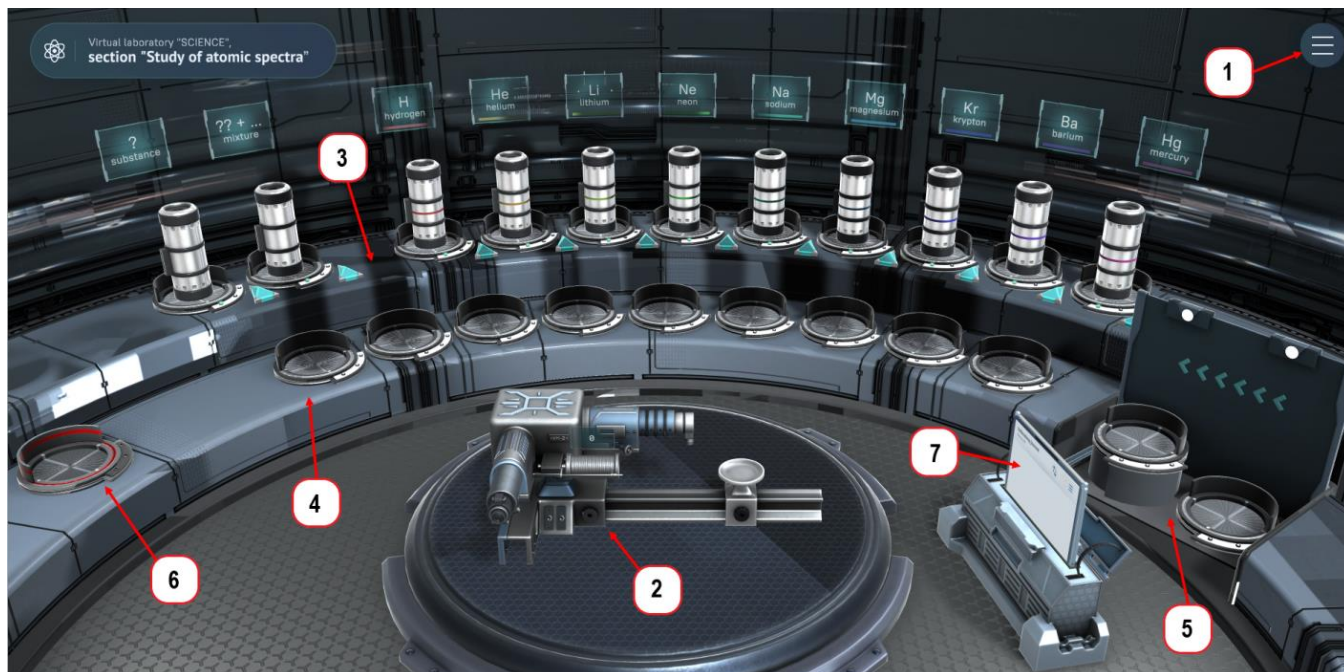


Figure 1 – Interface of the Virtual Laboratory

The Virtual Laboratory interface (Figure 1) includes the following elements:

- 1) **Main menu** (see [4 Main menu](#)).
- 2) **Universal monochromator UM-2** is a three-dimensional model that imitates the structure and external properties of a real device and repeats the logic of its behavior (see [5.1 Universal monochromator UM-2](#)).
- 3) **Generator gallery with gas lamps** (see [5.2 Gas lamps](#)).
- 4) **Storage gallery with stands for gas lamps** (see [5.3 Storage gallery](#)).
- 5) **Device for mixing substances** (see [5.4 Mixing device](#)).
- 6) **Deletion slot** (see [5.2 Gas lamps](#)).
- 7) **Laboratory journal** (see [5.5 Laboratory journal](#)).

3 Camera control

The camera is controlled using the mouse or your fingers (when working with a touch screen).

While the application is loading, the camera is in default position — focused at the center of the table (Figure 2).

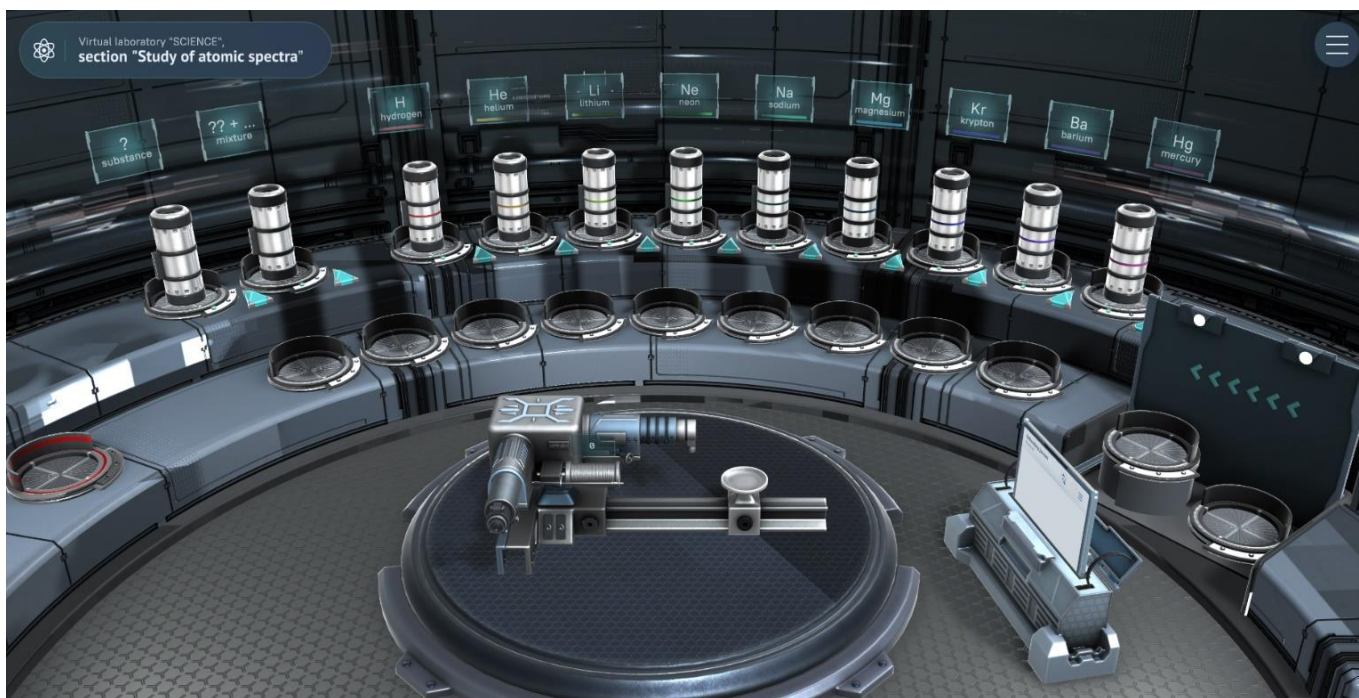


Figure 2 – Camera in default position

To **zoom in/out**, rotate the mouse wheel. When using the touch screen, touch the screen with two fingers, then spread them apart or press them together.

To **return** the camera to the default position, click anywhere in the scene around the installation.

To **move** the camera, hold down the right mouse button anywhere in the scene; drag the pointer in the desired direction and then release it. The camera moves no more than 10° .

To **focus the camera on the monochromator ocular** and observe the spectral lines, click on the device or rotate the mouse wheel (pinch your fingers when using the touch screen) until the camera moves to focus on the installation (Figure 3).



Figure 3 – Focusing the camera on the device's ocular

To switch to a **cross-sectional view of the device** and observe how the beam passes through the Abbe prism, focus the camera on the monochromator ocular and click on the device or rotate the mouse wheel (pinch your fingers when using the touch screen) until the camera switches to a top view of the device (Figure 4).

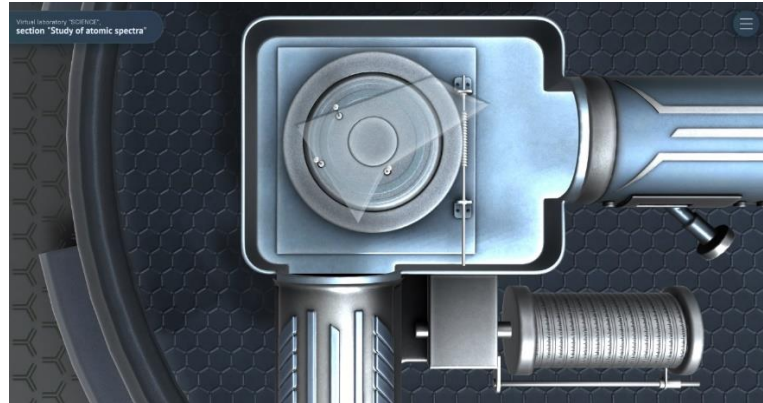


Figure 4 – Top view of the monochromator

4 Main menu

To open the **Main menu**, press the  button in the upper right corner of the application (1 in Figure 1). The **Main menu** consists of the following elements (Figure 5):

- 1) Set of functional buttons:
 - **Instructions** button  (see [4.1 Instructions](#));
 - **Tips mode** button  (see [4.2 Tips mode](#));
 - **Virtual keyboard** button  (see [4.3 Virtual keyboard](#));
 - **Fullscreen mode** button  (see [4.4 Fullscreen mode](#)).
- 2) Username display field.
- 3) **Scene menu** (see [4.5 Scene menu](#)).

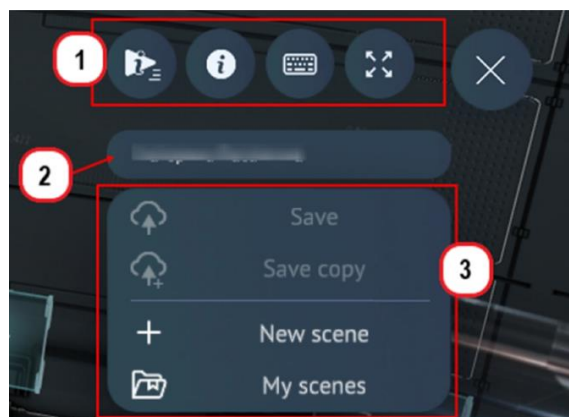


Figure 5 – Main menu

To close the **Main menu**, press the  button or click anywhere in the scene outside the menu.

4.1 Instructions

To select an instruction to view, click the **Instructions**  toggle-button in the **Main menu** (Figure 5). A video instruction selection menu will open (Figure 6). Read **User Manual** or watch video instructions to learn:

- how to work with the scene and equipment — "Introduction video";
- how to save created scenes and load saved scenes — "Saving and loading".

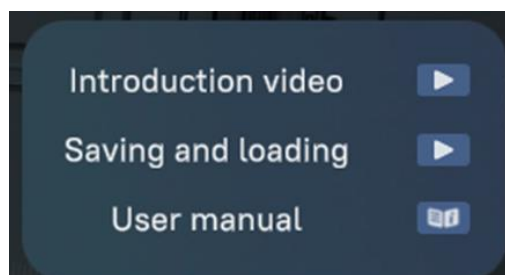


Figure 6 – Menu for selecting instructions

Click on the video title to start watching. The video will play on the screen over the scene. Control playback using the built-in player (Figure 7).



Figure 7 – Player control elements

To close the playback screen, click the **Close** button  in the top right corner of the screen.

To close the video instructions selection menu, press the  button.

4.2 Tips mode

To switch to the interactive tips mode, click the **Tips Mode** toggle-button  in the **Main menu** (Figure 5). Tips points will appear next to the objects in the scene, and a description of the installation will open on the left side of the screen (Figure 8).



Figure 8 – Tips mode

To view a tip, press the point. To close the tip panel, press the tip point again or click on the cross in the upper right corner of the panel.

Tip points change their outline color depending on whether the user has viewed the tip or not (Figure 9):

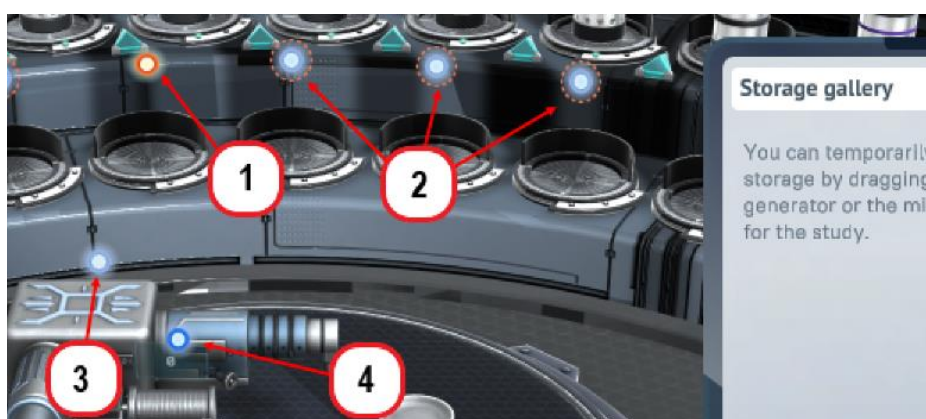


Figure 9 – Point outline color options

- 1) Point with orange outline  — the tip is open on the screen (as in Figure 9).
- 2) If several objects have the same tooltips and one of these tooltips is currently open, then the tooltip points of other objects with the same tooltip will have a double outline: dotted gray and orange  .
- 3) Point with gray outline  — the user previously viewed and closed the tooltip.
- 4) Point with blue outline  — the user has not yet viewed this tip.

To exit the **Tips mode**, press the  button in the **Main menu**.

4.3 Virtual keyboard

To switch to the **Virtual Keyboard mode**, press the toggle-button  in the **Main menu** (Figure 5). In this mode, a virtual keyboard will appear on the screen automatically when you start to type in any text field (Figure 10).



Figure 10 – Virtual keyboard

The virtual keyboard has two layouts: Latin and symbolic. The layout is changed using the button  on the virtual keyboard.

To exit the **Virtual Keyboard Mode**, press the button  in the **Main menu**.

4.4 Fullscreen mode

To enable full screen mode, press the **Fullscreen Mode** button  in the **Main menu** (Figure 5). The application will expand to full screen, hiding the browser frame and the OS taskbar. To exit full screen mode, press the  button or the **Esc** button on your keyboard.

4.5 Scene menu

Working in the Virtual laboratory, you can:

- save the current scene (see [4.5.1 Saving a scene](#));
- save a copy of the current scene (see [4.5.2 Saving a copy of a scene](#));
- create a new scene (see [4.5.3 Creating a new scene](#));
- open the **My scenes** library (see [4.5.4 Viewing and loading user scenes](#)).

To go to one of the actions, select the desired item in the **Scene menu** (Figure 11).

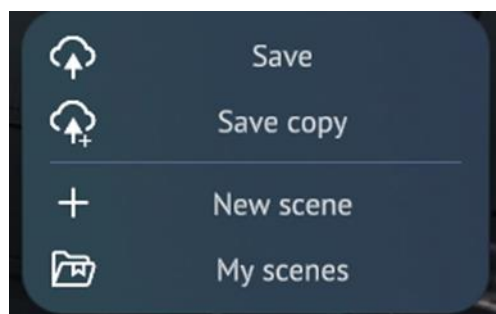


Figure 11 – Scene menu

To close the **Scene menu** and the **Main menu**, press the  button or click anywhere in the scene outside the menu.

4.5.1 Saving a scene

To save the created scene in the **My scenes** library, select **Save** in the **Scene menu** (Figure 11). The scene state and laboratory journal's entries will be saved.

If the scene has already been saved, the application will overwrite the contents of the scene file. If the scene is being saved for the first time, the save scene form will open (Figure 12).

Figure 12 – Scene saving form

Enter the **name** of the scene to be saved (no more than 36 characters) and its **description** (no more than 1000 characters) in the appropriate fields of the form and click the  button.

You can use the virtual keyboard if necessary. To do so, use the  button, located to the left of the saving form. This button duplicates the  button on the **Main menu** (see [4.3 Virtual keyboard](#)): if the **Main menu** had the virtual keyboard mode enabled , then the button next to the scene saving form will also be in the active state  and vice versa.

If you want to cancel the saving of the scene, press the  button.

4.5.2 Saving a copy of a scene

To save a copy of the scene in the **My Scenes** library, select **Save copy** in the **Scene menu** (Figure 11). This will open the form for saving a copy of the scene, which is similar to the scene saving form (Figure 12).

If the scene is being saved for the first time, you must fill in the **Scene name** (no more than 36 characters) and **Scene description** (no more than 1000 characters) fields.

If the scene has already been saved, the previously saved scene name with the copy number in brackets will be displayed in the **Scene name** field — **Scene 1(3)**. The scene name and copy number can be adjusted or left unchanged.

Click the **Save** button to save a copy of the scene.

After you have saved a copy, you will continue to work with it, and the copy of the scene you worked with before will remain in the state of its last save.

If you do not need to save the scene copy, press the **Cancel** button.

4.5.3 Creating a new scene

To create a new scene, select **New scene** in the **Scene menu** (Figure 11). If there are unsaved data, a window with a warning about possible data loss (Figure 13) will open.

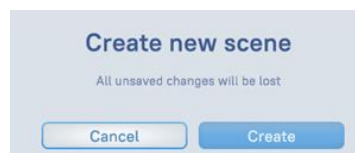


Figure 13 – Create new scene window

To avoid losing the current data, click the **Cancel** button and continue working with the scene. If you do not need to save the data, click the **Create** button, and all unsaved data will be lost and a new empty scene will open.

4.5.4 Viewing and loading user scenes

To view a list of scenes, select **My scenes** in the **Scene menu** (Figure 11). **My Scenes** library page (Figure 14) will open.

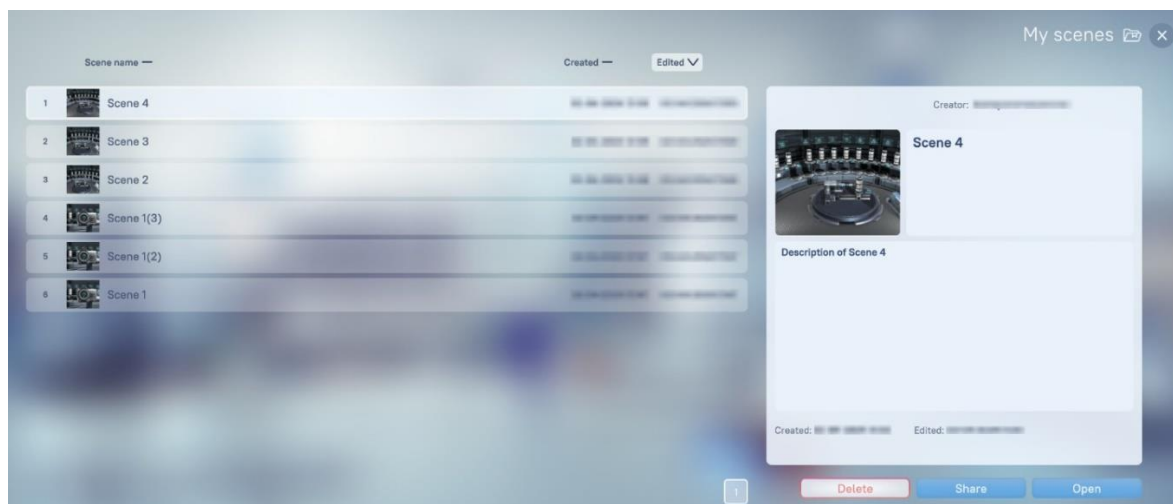


Figure 14 – My scenes library

On the left side of the screen, a list of all saved scenes will be displayed. You can sort the data by scene name, creation date, and modification date. To sort, click on the name of the corresponding table column (Name, Created or Modified). The "-" icon next to the name will change to a check mark, indicating the sorting direction .

If the list of scenes does not fit on one screen, it will be split into pages. Navigation through the pages is done using a series of buttons with page numbers, located to the right under the table.

The information about the selected scene is in the scene card to the right of the table. If necessary, you can open, delete, or share the selected scene using the buttons located under the scene card.

5 Objects description

5.1 Universal monochromator UM-2

The universal monochromator UM-2 is a three-dimensional model that imitates the structure of a real device and repeats the logic of its behavior. A light beam from a gas lamp enters the device, then splits into spectral lines, refracts in the Abbe prism and enters the monochromator ocular. The prism is located inside the device on the table. The prism table can be rotated using a reel. Depending on the angle of rotation of the prism, different spectral lines may enter the ocular. To observe the passage of a beam through an Abbe prism, go to the cross-sectional view of the device (see [3 Camera control](#)).

During research, you can select substances (see [5.2 Gas lamps](#)), create mixtures for your study (see [5.4 Mixing device](#)) and record the observation results in the laboratory journal (see [5.5 Laboratory journal](#)).

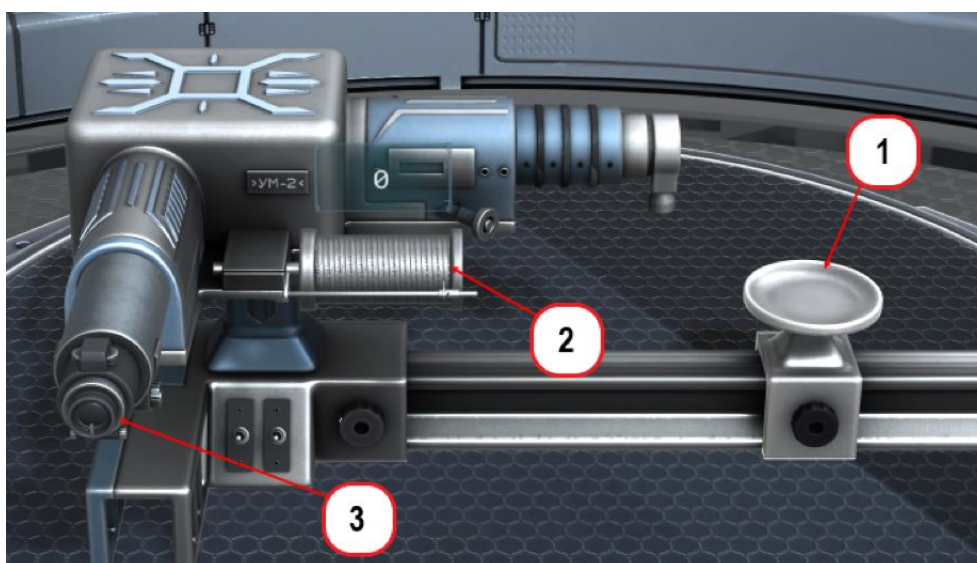


Figure 15 – Appearance of the universal monochromator UM-2

The monochromator consists of the following elements (Figure 15):

- 1) **Stand** for the gas lamp;
- 2) **Reel** with a screen for the Abbe prism rotation;
- 3) **Ocular** with a needle-pointer for the spectral lines observation.

To start a study, place the gas lamp (see [5.2 Gas lamps](#)) on the monochromator stand (1 in Figure 15). To do this, hold down the gas lamp with the desired substance with the left mouse button, drag the mouse pointer onto the stand and then release it. A card of its contents will be displayed to the right of the lamp (Figure 16).

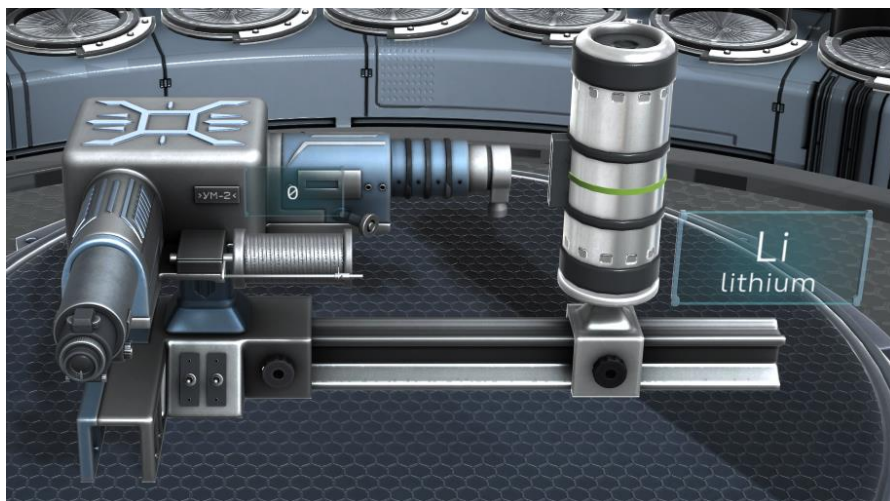


Figure 16 – Monochromator with installed gas lamp

To select a fragment of the spectrum to be displayed in the ocular (1 in Figure 17), hold down the reel pointer (2) with the left mouse button and drag it to the right or left until the desired position is reached. For precise adjustments, hold the left reel wheel (3) and drag it up/down, or hover it over the reel and roll the mouse wheel. The set value will be displayed on the reel screen (4).



Figure 17 – Displaying and adjusting a spectrum fragment

5.2 Gas lamps

A gas lamp contains a substance or mixture of substances to be examined (Figure 18). Lamps with the following substances (1) are available in the Virtual Laboratory: hydrogen, helium, lithium, neon, sodium, magnesium, krypton, barium, mercury. Two lamps with unknown contents are also available: with a substance (2) and with a mixture of substances (3).

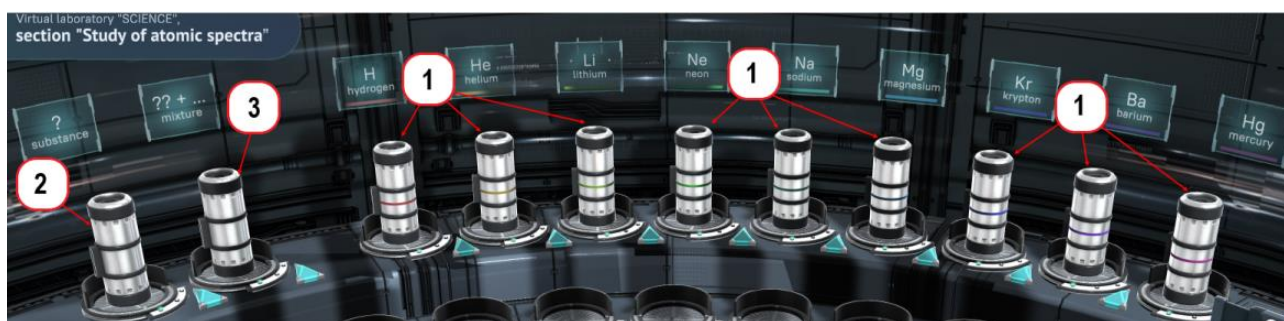


Figure 19 – Gas lamps

Gas lamps are located in the stands of the generator gallery (3 in Figure 1). When a lamp is removed from the generator gallery, a lamp with the same content is generated in its place. When a lamp with unknown content is removed from the gallery, a lamp with new unknown content is generated.

Above the lamps in the generator gallery there are cards with formulas and names of the substances in the lamps and their color coding (Figure 20). The color of the markings on the card matches the color of the markings on the lamp (1).

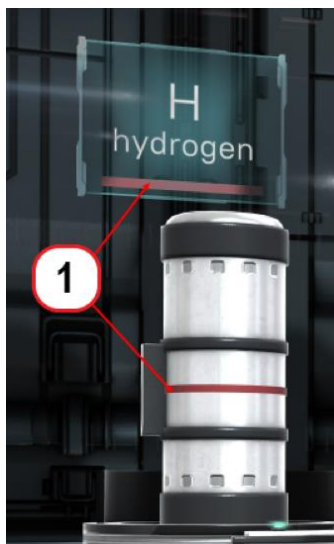


Figure 20 – Color coding of the gas lamp and its card



Figure 21 – Color coding of a gas lamp with a mixture of substances

If the lamp contains a mixture of substances, then the markings on it will indicate each of them (see [5.4 Mixing device](#)).

To move a gas lamp, hold down the left mouse button, drag the pointer to the desired stand and release it. When the pressed pointer is in the correct position, the indicator on the stand will light up yellow and the lamp will be automatically installed on the stand (Figure 22). Once the lamp is placed on the stand, the green stand indicator will light up (Figure 23). If the stand is already occupied by a lamp, then if you try to install another lamp on it, the indicator will light up in red (Figure 24).



Figure 22 – Yellow indicator on the stand



Figure 23 – Green indicator on the stand



Figure 24 – Red indicator on the stand

Lamps can be placed:

- in the storage gallery stands (see [5.3 Storage gallery](#));

- in the stands of the mixing device (see [5.4 Mixing device](#));
- in the monochromator stand (see [5.1 Universal monochromator UM-2](#)). There are no color indicators on the monochromator stand.

To remove a gas lamp from the scene, hold it with the left mouse button, move it to the deletion slot (6 in Figure 1) and then release it.



Figure 25 – Removing a gas lamp

5.3 Storage gallery

Storage gallery stands are used for the temporary storage of gas lamps (4 in Figure 1). Lamps with identical substances cannot be stored in the storage gallery: a lamp with a duplicate substance will be removed immediately after such placement. In this case, the lamp with this substance already placed in the storage gallery will be illuminated (Figure 26).

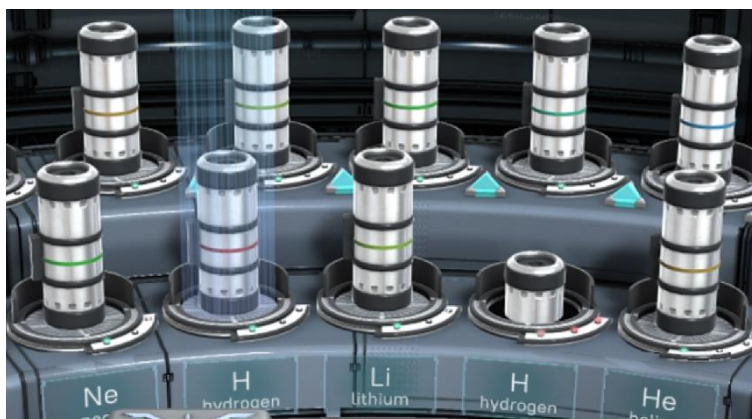


Figure 26 – Removing a lamp with a duplicating substance from the storage gallery



Figure 27 – Cards of lamp contents on a storage gallery stand

Cards with their contents are displayed under the lamps in the storage gallery: chemical formula and name of the substance (Figure 27). For mixtures, the amount of constituent substances is also displayed. To reveal the composition of a mixture, click on its card.

5.4 Mixing device



Figure 28 – Mixing device

Mixing device (5 in Figure 1) consists of two lamp stands. There are color indicators above the stands. Before you start working with the device, they glow white (Figure 28).

To mix substances from two gas lamps, place them on the supports of the mixing device. The substance or mixture from the lamp on the right stand will be added to the lamp on the left one.

When the gas lamps are placed correctly, the device indicators will light up green and the mixing process will begin (Figure 30). During mixing, both lamps are hidden in the device and the indicator of the left stand of the device lights up in blue (Figure 31). After mixing is completed, a lamp with the resulting mixture appears on the stand on the left, with a green indicator above it (Figure 29). The marking of the gas lamp with the mixture corresponds to the composition of the mixture.



Figure 30 – Correct placement of the lamps



Figure 31 – Beginning of the mixing process



Figure 32 – Completing the mixing process



Figure 33 – Removing a gas lamp duplicate

It is impossible to mix substances from lamps with identical contents. When a lamp with a duplicating substance is placed in the device, the red indicator above it will light up and the lamp will be automatically removed from the device (Figure 33).



The starting substances are mixed in the device in equal quantities. When a substance that is already in the mixture is added to it, its amount remains unchanged.

5.5 Laboratory journal

Laboratory journal (7 in Figure 1) is used to record the results of observing the spectrum of the substance under study. While working with the journal, you can:

- open the journal (see [5.5.1 Opening a journal](#));
- view the list of studies and delete unnecessary ones (see [5.5.2 Viewing the list of studies](#));
- create a new study (see [5.5.3 Creating a new study](#)).

5.5.1 Opening a journal

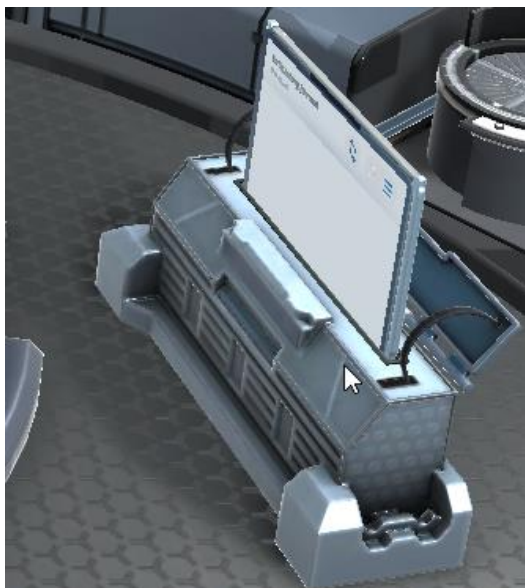


Figure 34 – Opening a journal

To open a laboratory journal, click on the journal or on its stand (Figure 34).

The journal will open on the left side of the screen (Figure 35). If journal entries have already been made in the current scene, they will be displayed in the open journal. If there were no entries, an empty journal will open.

To collapse an open journal, click on its stand or hold down the journal with the left mouse button and drag it off the screen border on the left.

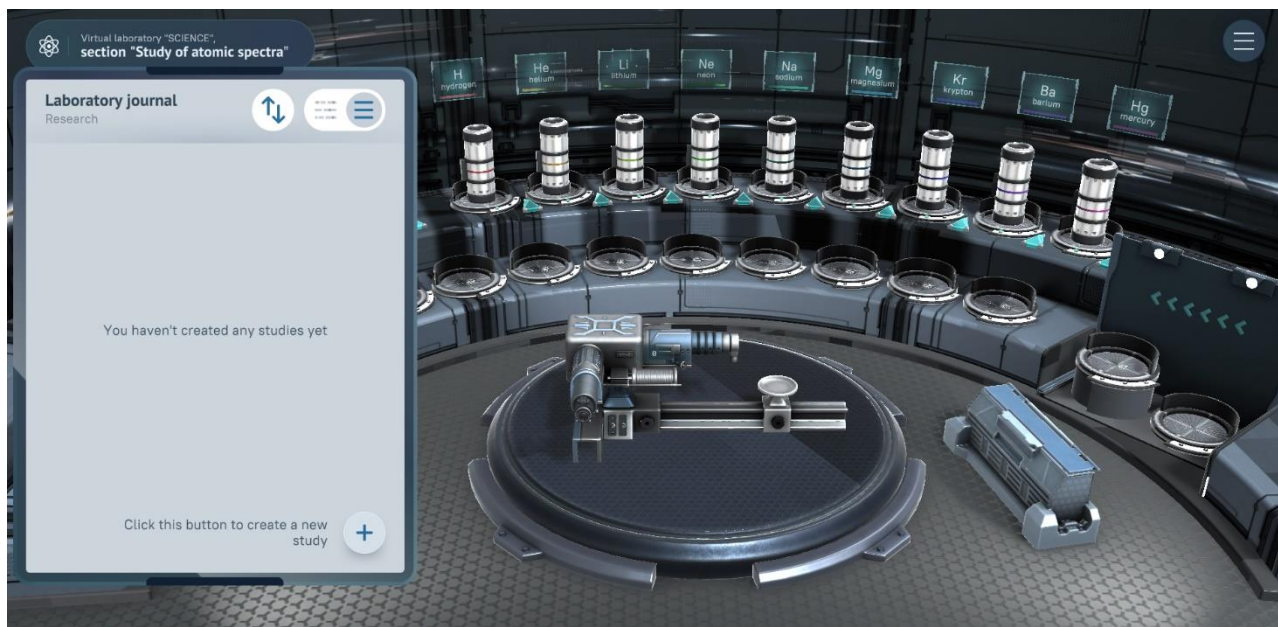


Figure 35 – Lab journal

5.5.2 Viewing the list of studies

The list of studies is a set of cards (Figure 36), each of which contains data about the study: number, time and date of creation, name of the study, test substance or mixture used and the number of records about the results of the study.

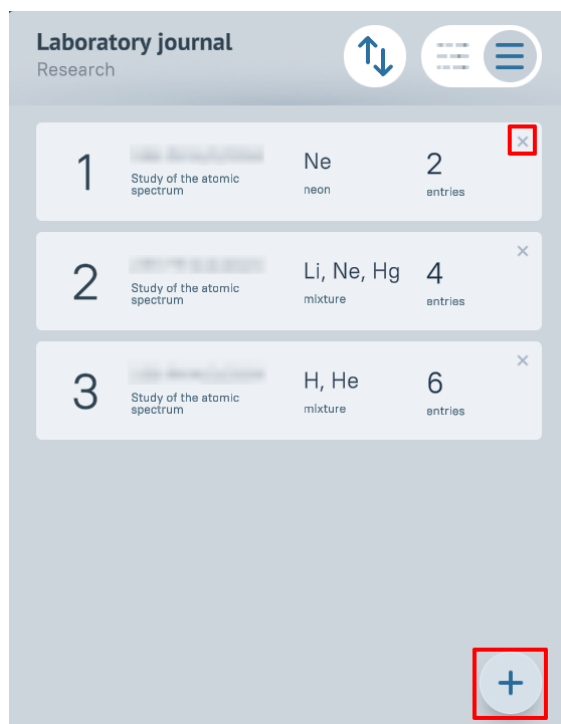


Figure 36 – The list of studies

To open a study card, left-click on it.

To create a new study, press the  button in the lower right corner of the journal (Figure 36).

To delete a study, press the  button in the upper right corner of the study card.

If the list of studies does not fit on the screen, a scroll bar will appear to the right of the list. To view the list, hover your mouse over the journal and roll the mouse wheel or drag the scroll bar up or down. When using the touch screen, scroll through the list with your finger.

To change the order of the cards in the list, click the  button. Arrows will appear to the left of each card (Figure 37). Click the arrows to move a card up or down in the list. To disable the ability to move cards, click the  button on the top panel of the journal.



Figure 37 – Buttons for moving the cards in the list

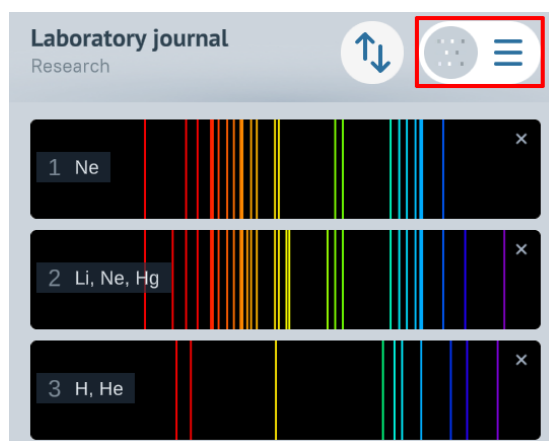


Figure 38 – List of studied spectra

To view all atomic spectra recorded in the journal, click the  switch on the top panel of the journal. Instead of study cards, the journal will display bands of spectra drawn in the studies (Figure 38). Click on the spectrum band to open the research card. To return to card viewing, press the switch again.

5.5.3 Creating a new study

To create a new study, place the gas lamp on the monochromator stand and click the  button in the lower right corner of the journal (Figure 36) — the recording page will open.



Figure 39 – Creating a new study

Press the  button to start recording the results of the study (Figure 39).



Figure 40 – Entry page

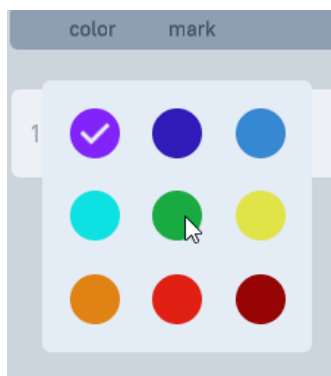


Figure 41 – Spectral line color selection

To add a line for more entries, press the button  in the lower right corner of the page (Figure 40).

To select the color of the observed spectral line, click on the circle in the **Color** column (1 in Figure 40) — the color choice menu will open (Figure 41). In the menu, click on the color corresponding to the color of the observed spectral line. By default, the first line observed is purple.

To enter data obtained as a result of the study, click on the corresponding input field (2 in Figure 40) and enter the value using the keyboard of your device or the virtual keyboard (see [4.3 Virtual keyboard](#)).

To delete a line of entries, press the  button in the upper right corner of the line. To return to the list of studies in the journal, press the  button in the upper left corner of the page.

6 Procedure for studying the atomic spectrum

To begin studying the atomic spectrum of a substance or mixture, place a gas lamp with the substance in the UM-2 monochromator stand (Figure 42). A contents card will appear next to the lamp (more about working with gas lamps see [5.2 Gas lamps](#)).

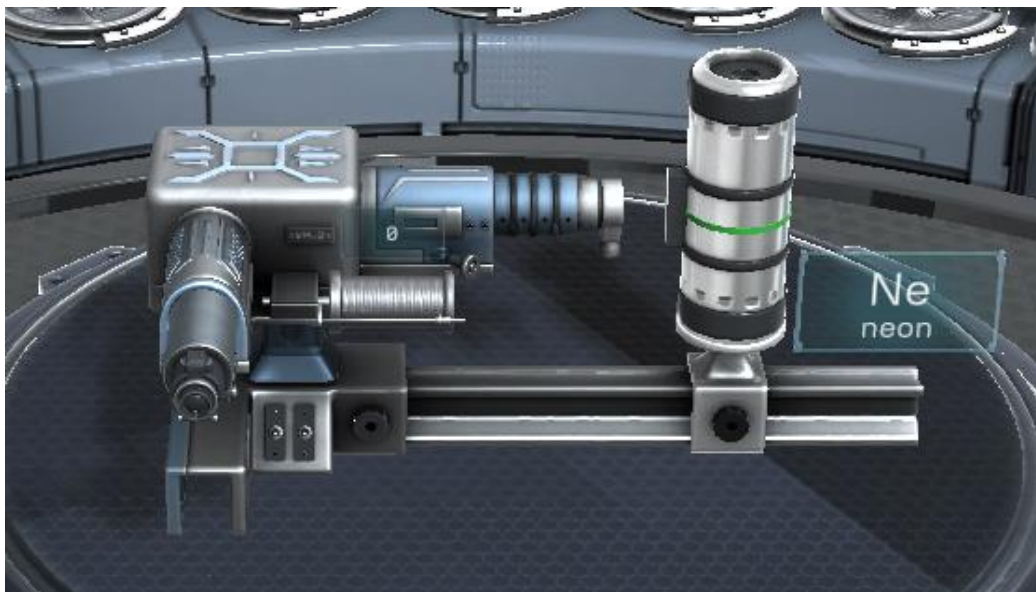


Figure 42 – Monochromator with installed gas lamp

To study the atomic spectrum of a substance or mixture, focus the camera on the ocular of the monochromator (see [3 Camera control](#)).



Figure 43 – Focusing the camera on the device ocular

By default, the monochromator reel indicator is set to "0" and this is its extreme right position (Figure 44). Rotate the reel of the device to observe the lines of the atomic spectrum of the substance (more about working with the reel see [5.1 Universal monochromator UM-2](#)). Movement along the spectrum occurs from right to left and from the violet lines to the red ones.

Align the ocular needle with the spectral line (1 in Figure 45) and, if necessary, record the line color and the value of the current reel mark (2) in the laboratory journal (see [5.5 Laboratory journal](#)). For a complete study, record the marks for each line of the spectrum.

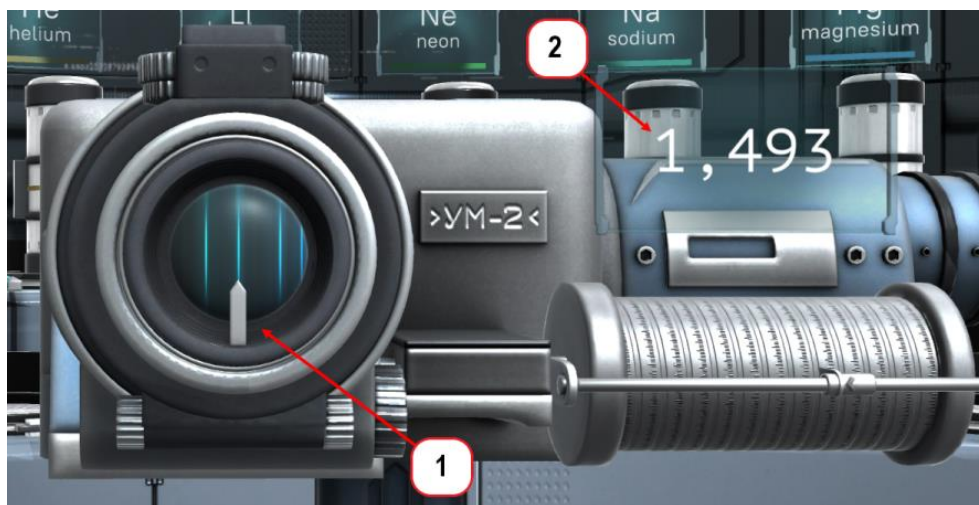


Figure 45 – Aligning the pointer angles with the spectral line

To view the entire spectrum, go to the top view of the device (see [3 Camera control](#)).

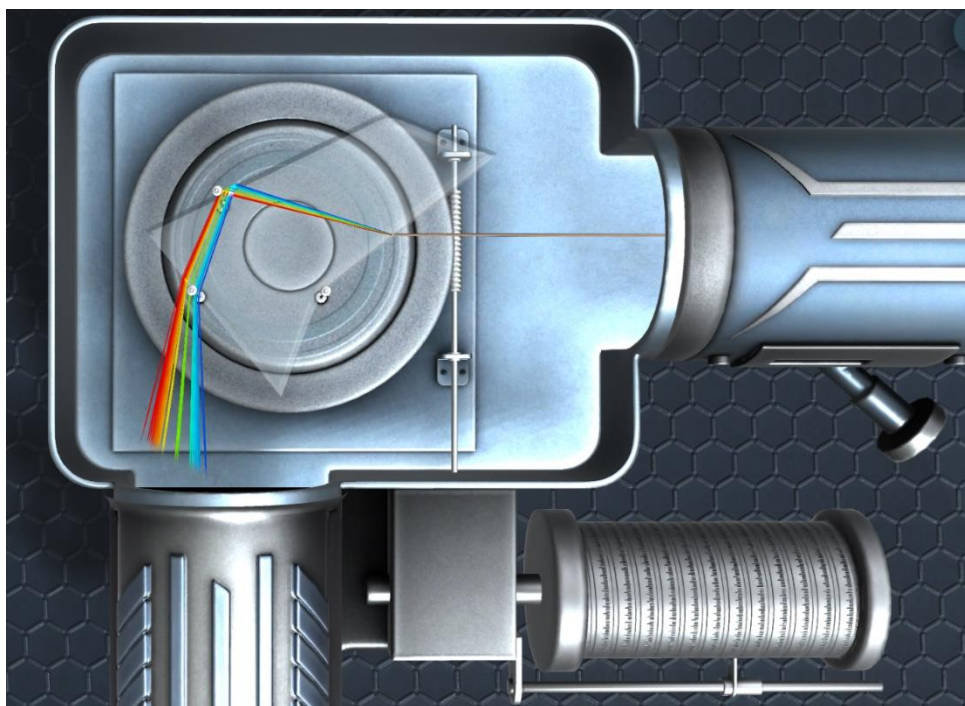


Figure 46 – Cross-sectional top view of the monochromator