GUIDE FOR TEACHERS

Water extraction on the Moon

How do you extract water on the Moon?

Short description

In this worksheet, students learn about the different states of water and interpret a p-T diagram. This will help them understand the differences in the properties of water under different conditions and give them an idea of the difficulties of obtaining water on the Moon compared to on Earth. In the second part, the students will compare two methods of water extraction - filtration and distillation - and should decide at the end which method is the most effective or efficient on Earth and on the Moon.

Short info

Subjects: *Chemistry, Physics*
Age group: *12-16 years*
Type of tasks: *Laboratory task*
Difficulty: *medium*
Time needed: *30 minutes preparation, 1h and 20 minutes for the lesson.*
Costs: *low, all experimental material should be available in a school laboratory*
Place: *Laboratory*
Materials needed: *prepared blocks of sand-ice mixture*

Keywords: *Lunar exploration, filtration, distillation, states of aggregation, phase transitions*

Germany esero

Learning objectives

Students learn on this worksheet:

- Distinguish changes in the state of aggregation depending on pressure and temperature
- Using the particle model to understand the changes in states of matter.
- Learn the use of the distillation material for the separation of mixtures
- Use filtration to separate mixtures
- Conduct experiments correctly, giving due consideration to the proper handling of equipment, measurement accuracy, and health and safety measures.
- Evaluation of methods and suggestions for possible improvements and further investigations.
- Interpret percentages and percentage changes as a fraction or decimal

Summary of activities

Activity	Title	Description	Result	Requirements	Time
1	Is the water on the moon different?	*Identify water phases, analyze p-T- diagram for water in relation to the moon.*	*Learning how water extrusion could be done on the moon*	*none*	*Approx. 20 minutes*
2	Filtering or distilling?	*Comparison of filtering & distilling processes for "moon ice cores".*	*Plan and carry out experiment on filtration and distillation*	*Completion of the first task*	*Approx. 1 hour*

Basics

The moon

The moon is a satellite of our earth. It is easily visible from Earth in the night sky and appears very large compared to the planets of our solar system. This is due to the proximity of the moon to our earth and because of this proximity, the moon is also very well suited as the first celestial body for the establishment of a station.

Just like the earth, the moon also revolves around itself. It also revolves around the earth. One revolution lasts one month.

On the moon itself it looks like a stone desert. There is debris and dust everywhere. In contrast to the earth, the moon has a lot of craters, which were created by the impact of meteorites. The dark spots, which can also be made on the moon from the earth, are especially large craters, which are also called "seas".

The atmosphere on our Earth, that is, a shell of gas around our planet, protects us from meteorites because they burn in it. In addition, the Earth's atmosphere allows us to breathe. The moon does not have such an atmosphere, so meteorites can strike undisturbed and humans cannot breathe on the moon.

In addition, the temperature differences on the moon are enormous. If it is nighttime on the moon, it can get as cold as - 160 °C, while during the day temperatures can rise to 130 °C. Accordingly, there is no liquid water on the moon. Among other things, this is also due to the low pressure on the moon, which is the reason why water can only exist in solid or gaseous form.

The gravitational pull on the moon is also different from that on Earth. It is only about one sixth as large as that on our Earth.

During the manned moon missions between 1969 and 1972, people always stayed only a few days on the moon or in the rocket on the moon. It has not yet been possible to build a lunar station on the moon, partly because of the high costs involved, but also because questions about the supply of water for the astronauts have to be clarified. On this worksheet, students will now learn about water harvesting on the moon, which is a big part of the supply.

Size of the Moon: 3.475 km
The earth is about 4 times the size of the moon

Distance from Earth: 400.000 km

Temperature on the surface : - 160 up to + 130 °C

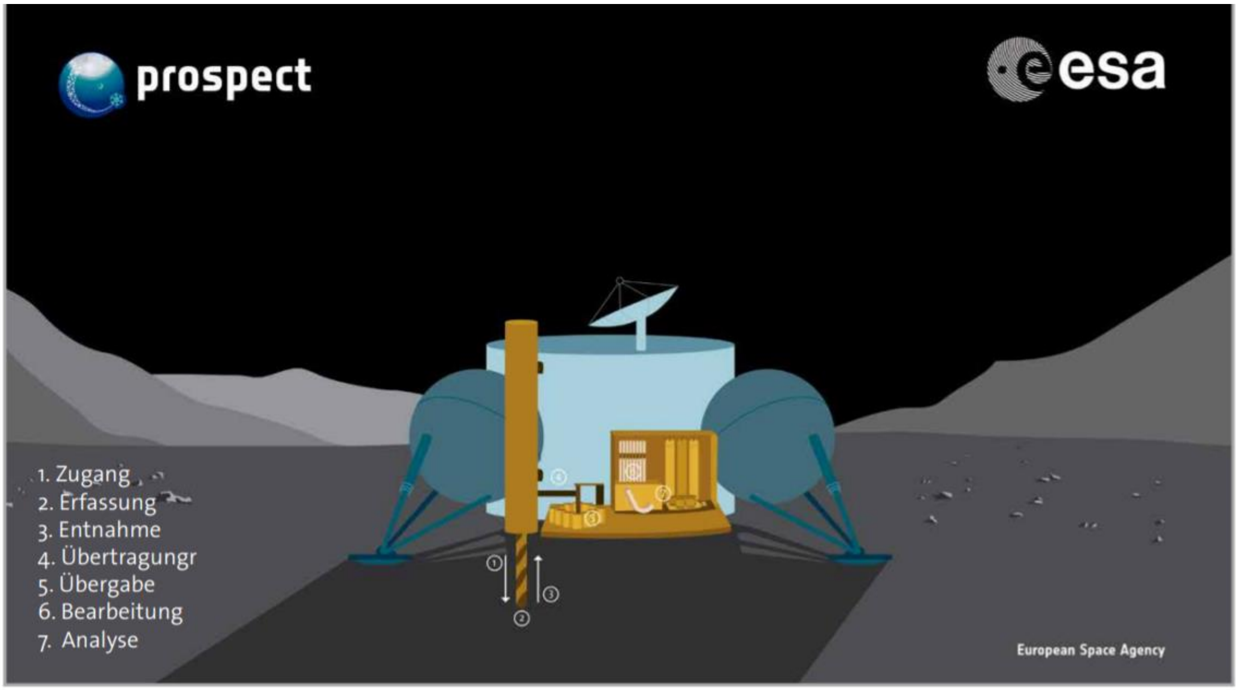
Surface finish : stony with many craters

Attraction: $\frac{1}{6}$ the size of the Earth

Atmosphere : nonexistent
No protection from meteorites, no breathing possible

Introduction to filtration and distillation

Liquid water is a substance that is abundant on Earth, covering 71% of the Earth's surface, but water is indeed extraordinary. It is the only commonly known substance that exists as a solid, liquid and gas under normal earthly conditions and has the ability to dissolve more solid substances than any other liquid. Water is also vital to all known forms of life! Water has been discovered on the Moon in the form of ice. In the future, water ice could be excavated to provide liquid water on the Moon for astronauts to drink and grow plants. The water could also be split into hydrogen and oxygen to provide breathable oxygen and rocket fuel. ESA is currently developing the PROSPECT system, which is part of the Luna 27 mission. It is drilling holes in the lunar surface to extract valuable resources, including water, to support future exploration missions.

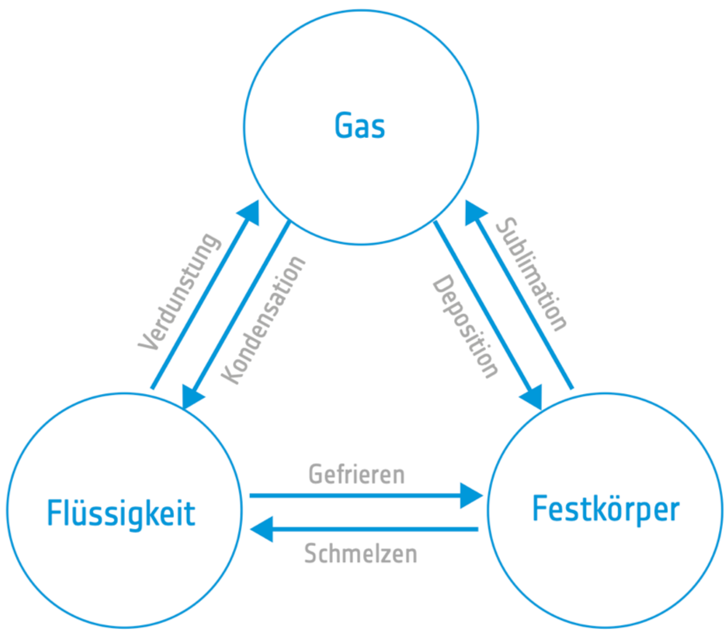


↑ Konzept des Systems PROSPECT und dessen Funktionen.

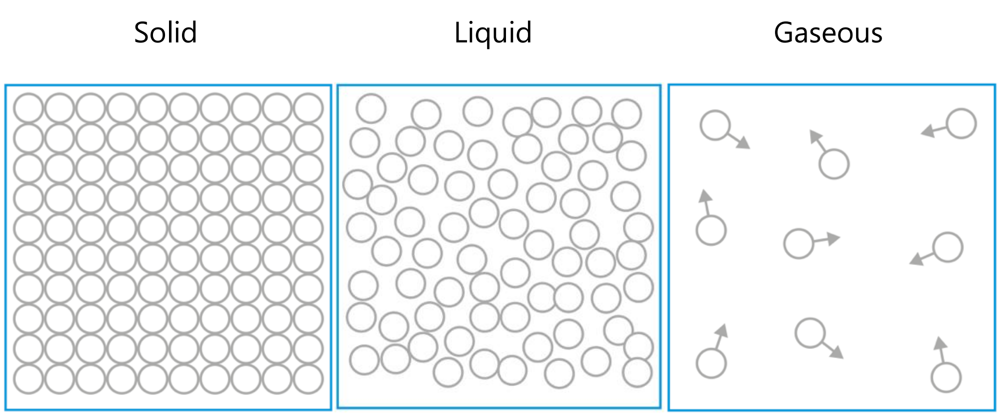
Task 1 - Is water different on the moon?

In this assignment, the students investigate the different states of water. This should give them an idea of what needs to be taken into account when extracting water on the Moon (different temperature and pressure than on Earth).

1. Complete the empty boxes with the different phase transitions:



2. Draw the structure of the particles in each of the three states of matter in the boxes below. The particle model for the gaseous state of matter has already been given to you.



3. Phase transitions depend not only on temperature, but also on pressure. The phase diagram below (Figure A3) shows the state of aggregation of water as a function of temperature and pressure. It is divided into three sections: Solid, Liquid, and Vapor (gas). Complete the table below using Figure A3:

Aggregat-zustand des Wassers	Temperatur-bereich (K)	Druck (atm)
Festkörper	< 273	1
Flüssigkeit	273-373	1
Gas	>373	1

4. What happens to the boiling point of water as pressure decreases? Explain this.

   At very low pressure, water can no longer exist in a liquid state of aggregation, as the boiling point of water continues to drop.

5. Since the moon has no atmosphere, the pressure on its surface is about 0 atm. Temperatures on the Moon are extreme, ranging from -248°C to 123°C, depending on where you are on its surface and whether it is day or night.
   a. Using Figure A4, explain why water cannot be found in the liquid state on the lunar surface.

      As can be seen in Fig 3, at very low pressure water has no liquid phase, which means it passes directly from a solid to a gaseous state.
   b. Imagine that you have extracted water from a permanently shadowed crater that has a temperature of 100 K. The water in this crater would have the same physical state as the water in the crater. What state of matter would the water in this crater have?

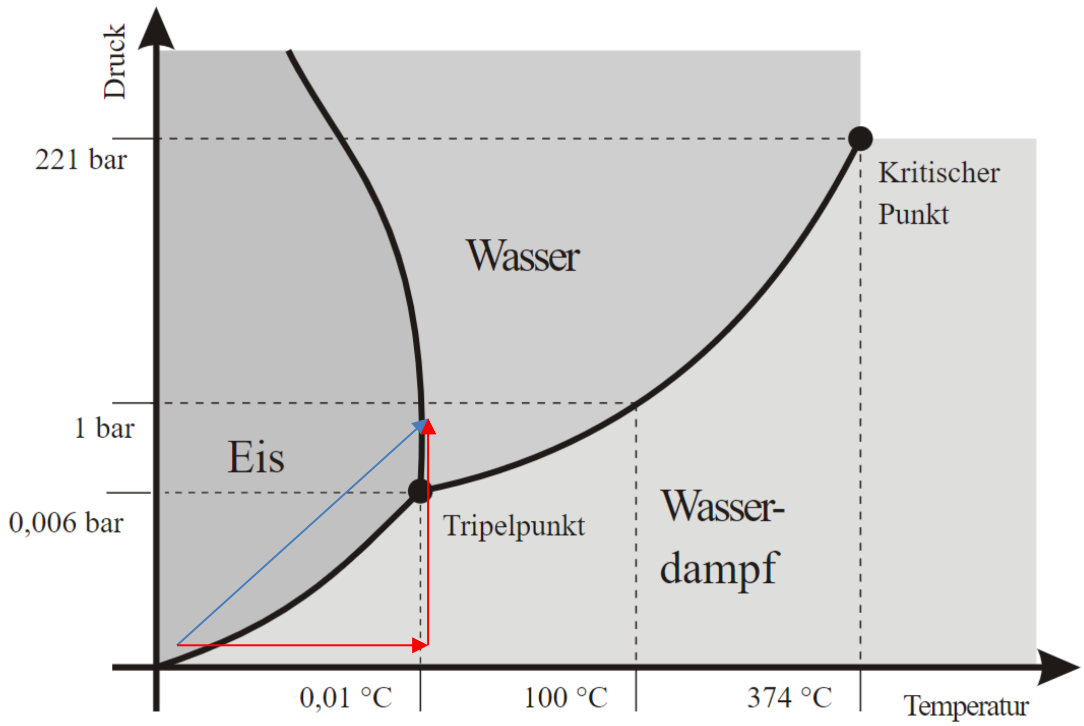
      It has a solid state of aggregation (ice).
   c. What would happen to your water sample from question 5 b if you tried to transport it out of the crater?

When ice is removed from the crater, the temperature rises. As the water ice warms, it begins to sublime. If a closed container is not used for storage, it dissipates into a gas and all the water would be lost.

d. How could you obtain liquid water from ice on the moon?

Temperature and pressure would have to be increased.

e. Draw arrows on the phase diagram (Figure A3) to show your solution to question 5 d.



Arrow blue: simultaneous pressure & temperature rise, for example, by samples entering directly into pressurized environment

Arrows red: First warming (by sunlight), then temperature rise (in the lunar base).

Task 2: Filtering or distilling?

In this task, the students perform an experiment in which they learn how water can be extracted by different methods, in this case by filtration and distillation. To do this, they are given previously prepared sand-ice cubes from which they are then to extract the water.

Materials

- *Prepared water sand ice*
- *Several measuring cylinders*
- *2x line (one from graduated cylinder through the ice, other from can with ice to Erlenmeyer flask).*
- *Can*
- *Ice cube*
- *2x Erlenmeyer flask*
- *Bung*
- *Bunsen burner*
- *Tripod*
- *Filter*
- *Funnel*

2. What safety precautions do you need to consider?

   More than the usual safety precautions in the laboratory (protective goggles, do not drink, etc.) is not necessary for this experiment.

3. What do you think are the advantages and disadvantages of filtering and distilling?

	Vorteile	Nachteile
Filtrieren	• Energieeffizient • Kostengünstig • Einfache Vorrichtung • Skalierbar	• Langsam • Versuchsmaterial hängt von dem Gemisch ab • Ein Teil der Flüssigkeit verbleibt im Rückstand
Destillieren	• Tötet schädliche Bakterien ab • Durch Temperaturänderung an verschiedene Gemische anpassbar • Skalierbar	• Erfordert mehr Energie für die Erwärmung • Kompliziertere Anordnung

4. What do you need to measure before performing the procedure?

   Before carrying out the mass of the ice cores must be determined.

5. What do you need to measure after performing the procedure?

After the performance, the mass of the extracted water must be determined.

6. Enter your results in the table.

Example comparison: $\frac{Wassermasse}{Masse\ der\ Eiskerne} \times 100$

Masse der Eiskerne (g)	Filtrieren Wassermasse (g)	% aufgefangen
100	19	19

Masse der Eiskerne (g)	Distillation Wassermasse (g)	% aufgefangen
100	36	36

7. Which method yields the highest amount of water? Why do you think that is?

Distilling results in the higher amount of water. This could be due to the fact that the water also evaporates during filtration.

8. Which method do you think gives the cleanest water?

Distilling kills harmful bacteria through heating, this is not the case with filtration.

9. a. Which method do you think is the most energy intensive on Earth? Explain.

Distillation has a higher energy requirement than filtration due to the heating process.

b. And on the moon? Explain.

On the Moon, both methods have about the same energy requirement because, as discussed earlier, an increase in temperature and pressure is required to obtain liquid water on the Moon.

10. What problems would you encounter if you tried to conduct this investigation on the moon?

    No liquid water exists on the moon due to the lack of pressure. When heating the ice cores, the ice would sublimate, the gas would escape and finally no water would remain. One would have to use therefore a pressure vessel, in order to accomplish the investigation.

11. Can you think of other ways to extract water from regolith?

12. How many liters of water per kilogram of moon ice do you obtain using the most efficient method? (To help you with your analysis, assume that 1 liter of water has a mass of 1 kg).

    Distillation is the most efficient, as it allows 36% of the water to be captured:

$$\frac{36}{100} \times 1\,kg = 0.36\,kg = 0.36l = 360\,ml$$

13. Assume that 6 liters of water are needed per day and per astronaut on the moon. How many kilograms of moon ice would you have to extract to supply a crew of 6 astronauts every day?

    For an astronaut applies: $\frac{6}{0.36kg} = 16.7kg$

    So that for 6 astronauts: $6 \times 16.7\,kg = 100.2\,kg$

WORKSHEET FOR STUDENTS

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The Moon

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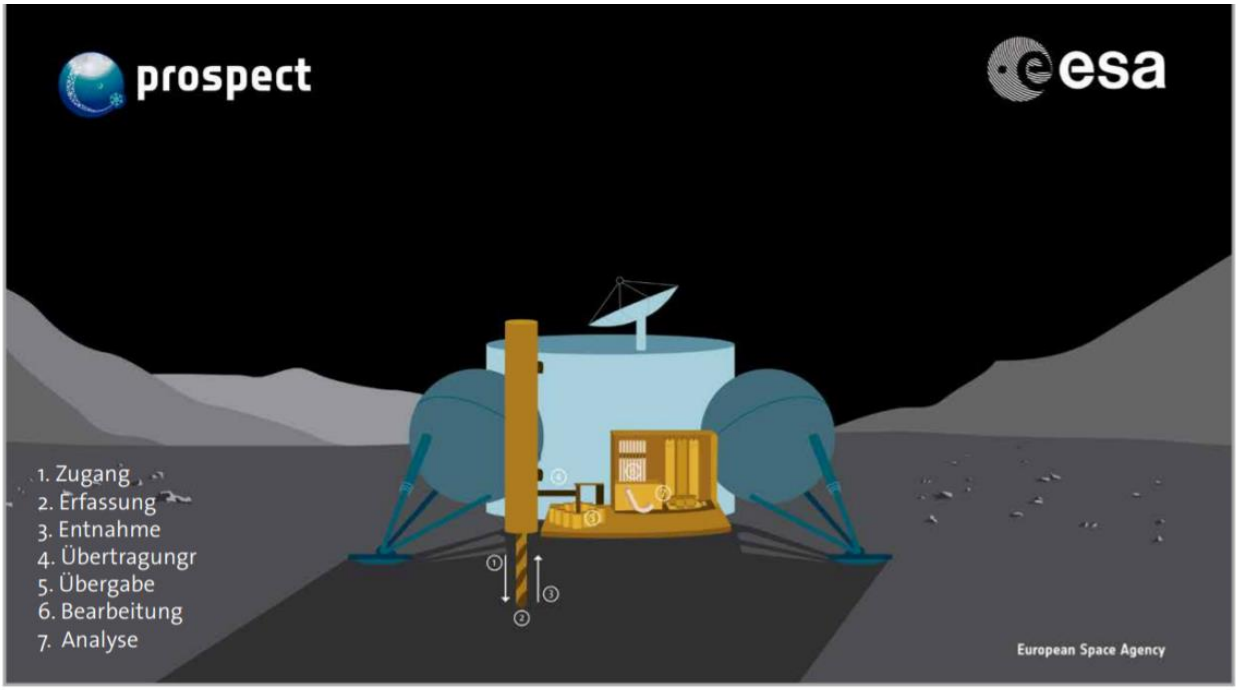

↑ Konzept des Systems PROSPECT und dessen Funktionen.

Task 1: Is water different on the moon?

In order to extract water on the Moon, we need to know something about states of matter and phase transitions.

1. Complete the empty boxes with the different phase transitions:

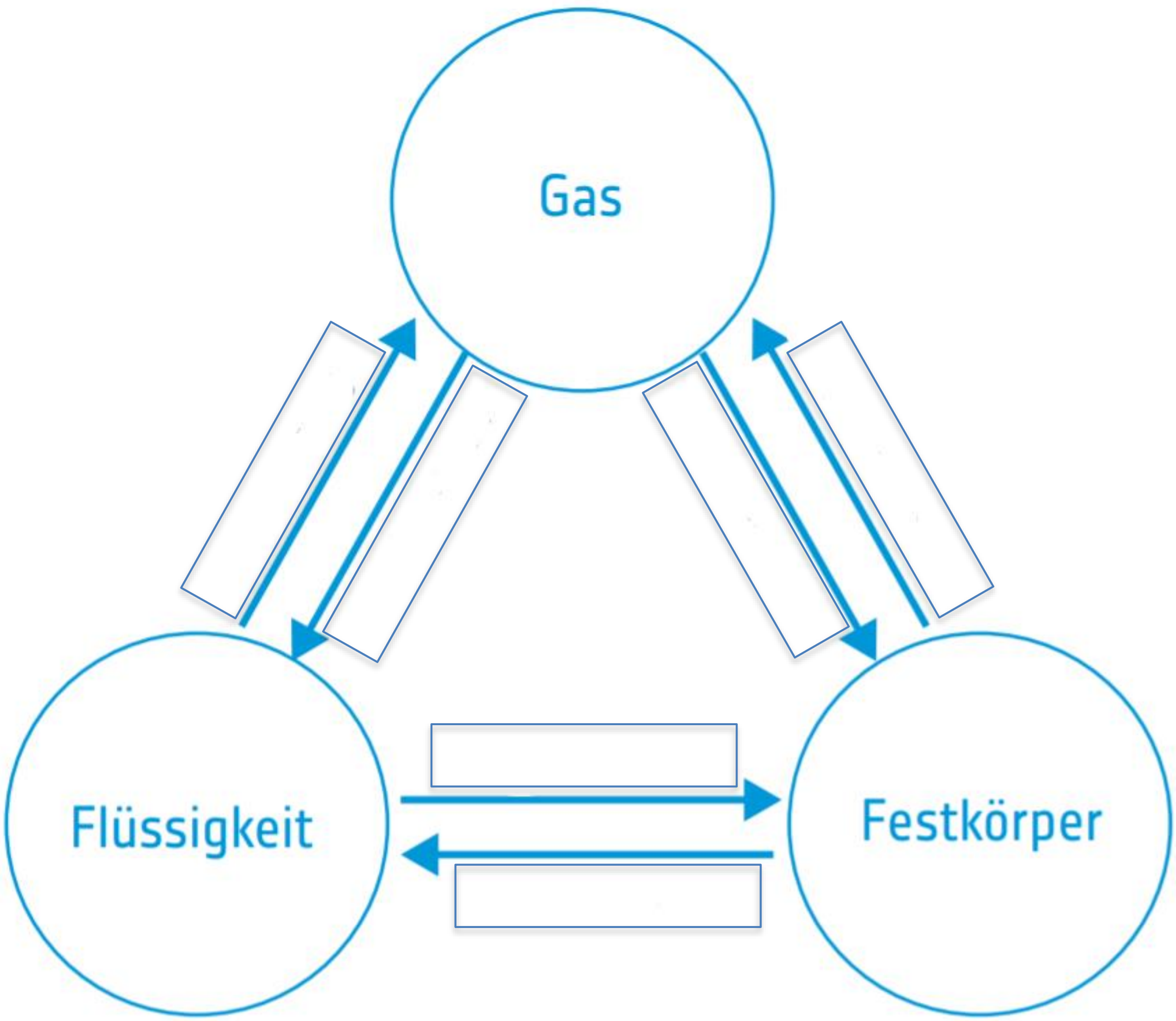

Figure A1

2. Draw the structure of the particles in each of the three states of matter in the boxes below. The particle model for the gaseous state of matter has already been given to you.

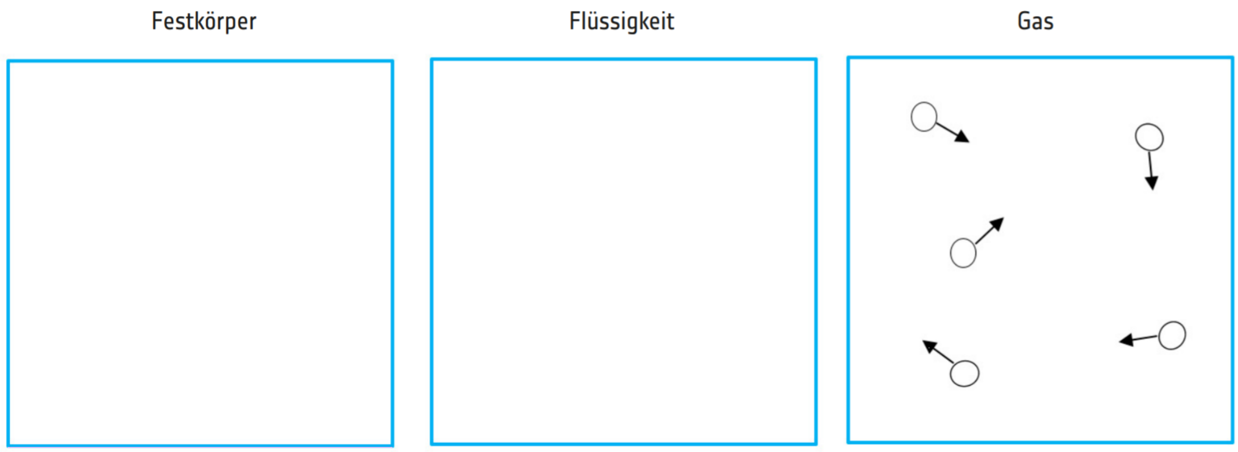

Figure A2

3. Phase transitions depend not only on temperature, but also on pressure. The phase diagram below (Figure A3) shows the state of aggregation of water as a function of temperature and pressure. It is divided into three sections: Solid, Liquid, and Vapor (gas). Complete the table below using Figure A3:

Aggregat-zustand des Wassers	Temperatur-bereich (K)	Druck (atm)
Festkörper		1
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Gas		1

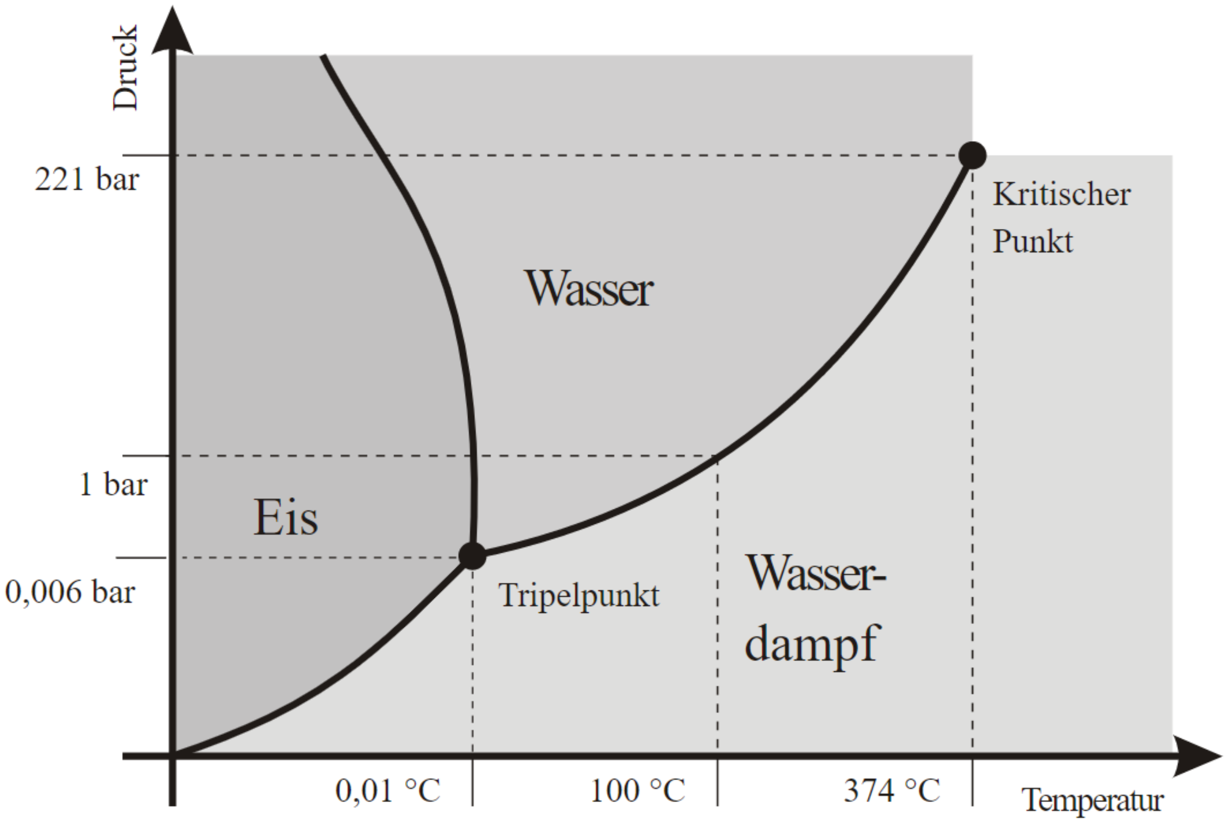

Figure A3

4. What happens to the boiling point of water as pressure decreases? Explain this.

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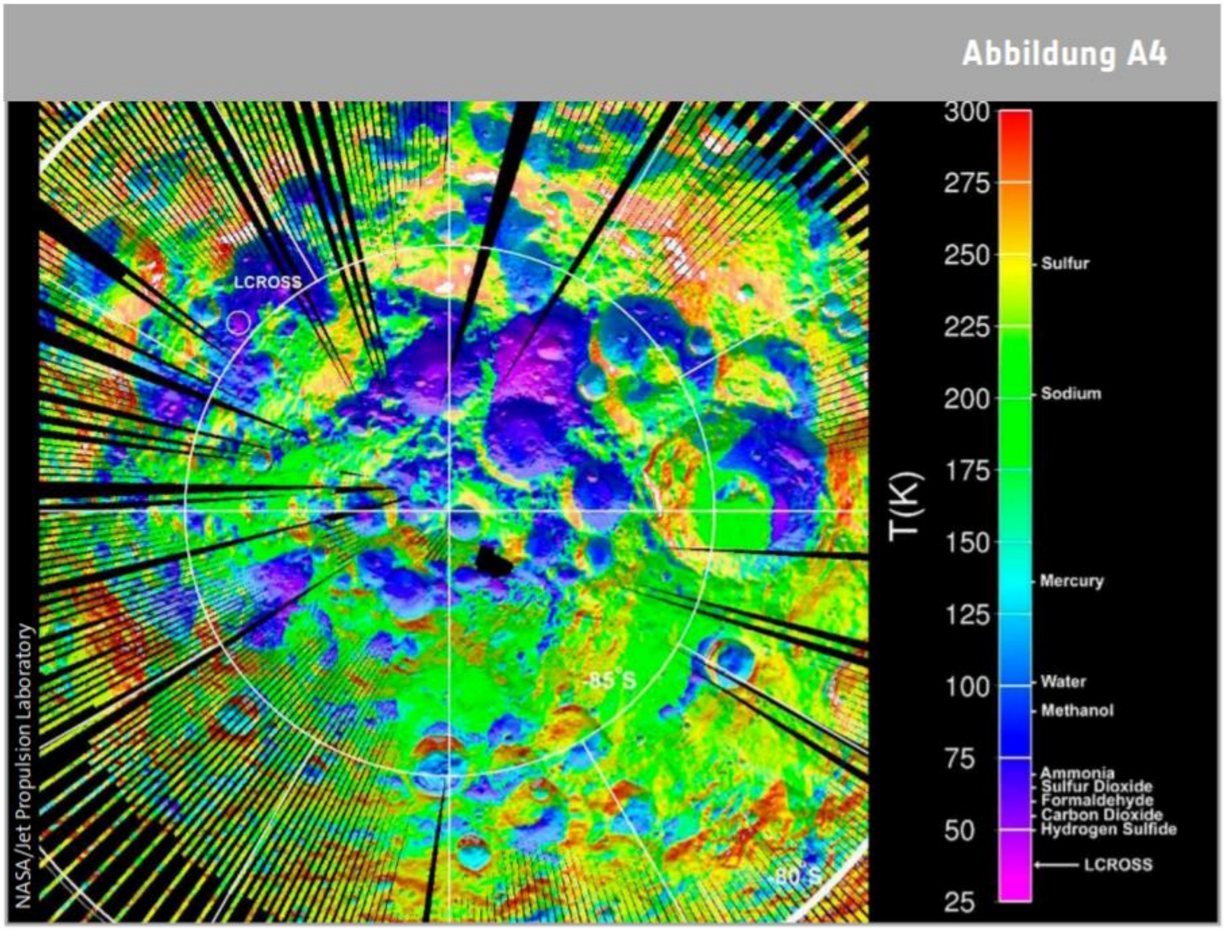
5. Since the moon has no atmosphere, the pressure on its surface is about 0 atm. Temperatures on the Moon are extreme, ranging from -248 °C to 123 °C, depending on where you are on its surface and whether it is day or night.



↑ Karte der Oberflächentemperatur der Südpolregion des Mondes bei Tage von LRO Diviner. Die Karte zeigt die Orte einiger ständig beschatteter Krater, die potenzielle Standorte für Wassereis darstellen.

a. Using Figure A4, explain why water cannot be found in the liquid state on the lunar surface.

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b. Imagine that you have extracted water from a permanently shadowed crater that has a temperature of 100 K. The water in this crater would have the same physical state as the water in the crater. What state of matter would the water in this crater be in?

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c. What would happen to your water sample from question 5 b if you tried to transport it out of the crater?

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d. How could you obtain liquid water from ice on the moon?

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e. Draw arrows on the phase diagram (Figure A3) to show your solution to question 5 d.

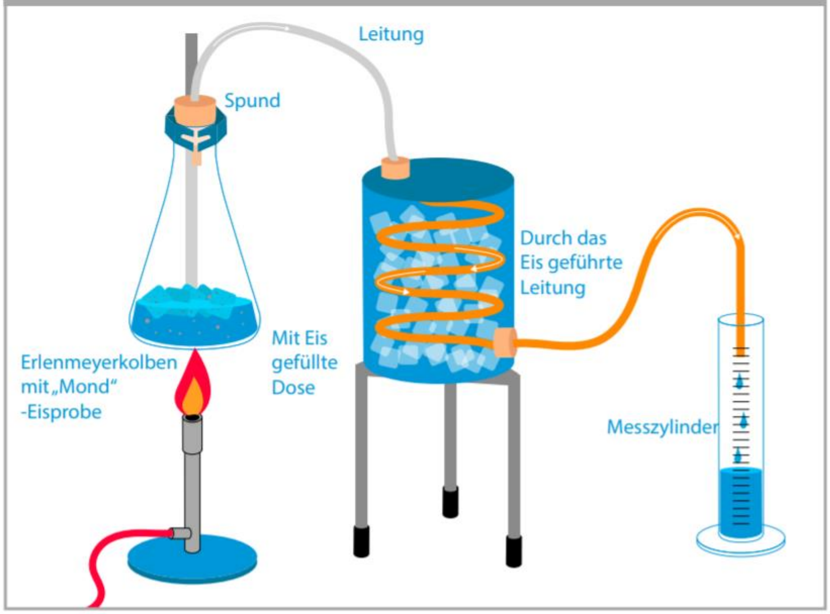
Task 2: Filtering or distilling?

The water ice extracted from the surface layers of the moon is held in the regolith (lunar soil). In this task, you must find a way to separate the water from a regolith-like material. You will be given frozen "moon" ice cores and your task is to compare two methods of extracting water from the simulated moon regolith.

Materials

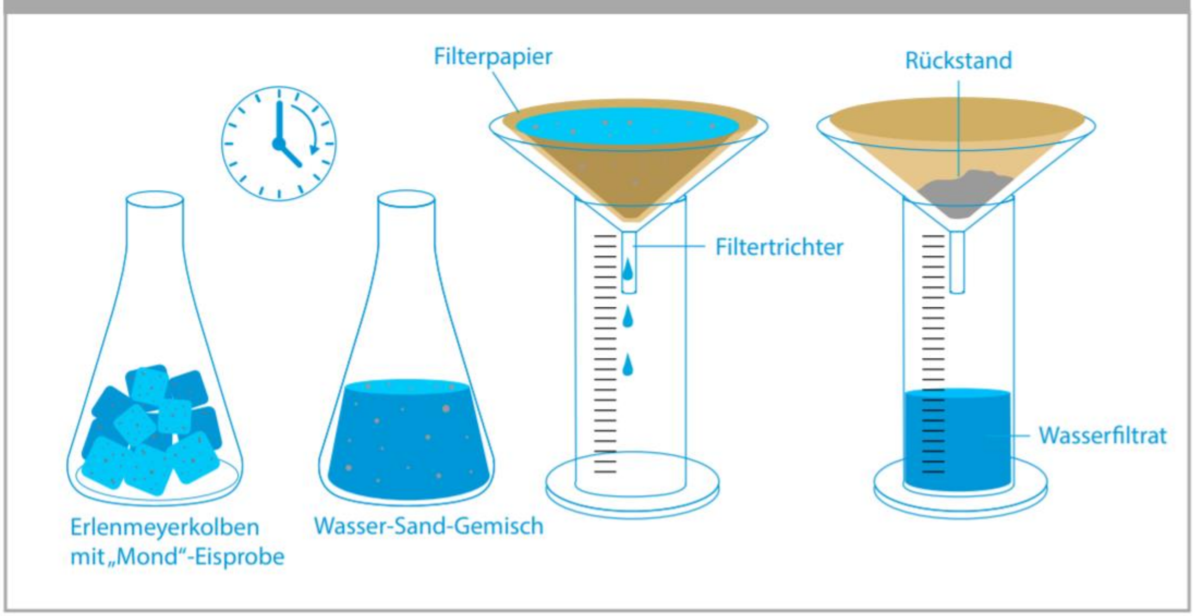
- *Prepared water sand ice*
- *Several measuring cylinders*
- *2x line (one from graduated cylinder through the ice, other from can with ice to Erlenmeyer flask).*
- *Can*
- *Ice cube*
- *2x Erlenmeyer flask*
- *Bung*
- *Bunsen burner*
- *Tripod*
- *Filter*
- *Funnel*

Abbildung A5



↑ Versuchsanordnung zum Destillieren

Abbildung A6



↑ Versuchsanordnung zum Filtrieren

Compare two methods for extracting water from lunar regolith: filtration and distillation. Distilling is the process of separating substances from a liquid mixture by boiling the liquid and cooling the vapor to form a condensate. Filtration is the process of separating solids from liquids by adding a medium that allows only the liquid to pass through.

Your task is to compare the percentage of mass of water extracted in the distillation process and in the filtration process.

1. Using the above information and the available experimental material, draw up a study plan to compare the two extraction methods.

2. What safety precautions do you have to take into account?

3. What do you think are the advantages and disadvantages of filtering and distilling?

4. What do you need to measure before performing the procedure?

5. What do you have to measure after performing the procedure?

6. Record your results in the table.

Masse der Eiskerne (g)	Filtrieren	
	Wassermasse (g)	% aufgefangen

Masse der Eiskerne (g)	Distillation	
	Wassermasse (g)	% aufgefangen

7. Which method results in the highest amount of water? Why do you think this is?

8. Which method do you think gives the cleanest water?

9. a. Which method do you think is the most energy intensive on Earth? Explain.

b. And on the moon? Explain this.

10. What problems would you encounter if you tried to do this investigation on the moon?

11. Can you think of other ways to extract water from the regolith?

Schon gewusst?

Die Astronauten auf der Internationalen Raumstation bereiten das meiste von ihnen verwendete Wasser wieder auf – etwa 75%. Das Wasser-Rückgewinnungssystem kann Wasser aus dem Urin der Astronauten und aus deren Atem wiedergewinnen. Dieses wird gefiltert und gereinigt und kann wiederverwendet werden. Im Durchschnitt verwendet ein Astronaut auf der Internationalen Raumstation 90% weniger Wasser als ein Mensch auf der Erde.

12. How many liters of water per kilogram of moon ice do you obtain using the most efficient method? (To help you with your analysis, assume that 1 liter of water has a mass of 1 kg).

Assume that 6 liters of water are needed per day and per astronaut on the moon. How many kilograms of moon ice would you have to extract to supply a crew of 6 astronauts every day?

Links

ESA Resources

ESERO Germany website: www.esero.de

ESERO Germany Worksheets: www.esero.de/materialien/arbeitsblaetter

ESA classroom resources: www.esa.int/Education/Classroom_resources

ESA Kids Homepage: www.esa.int/kids