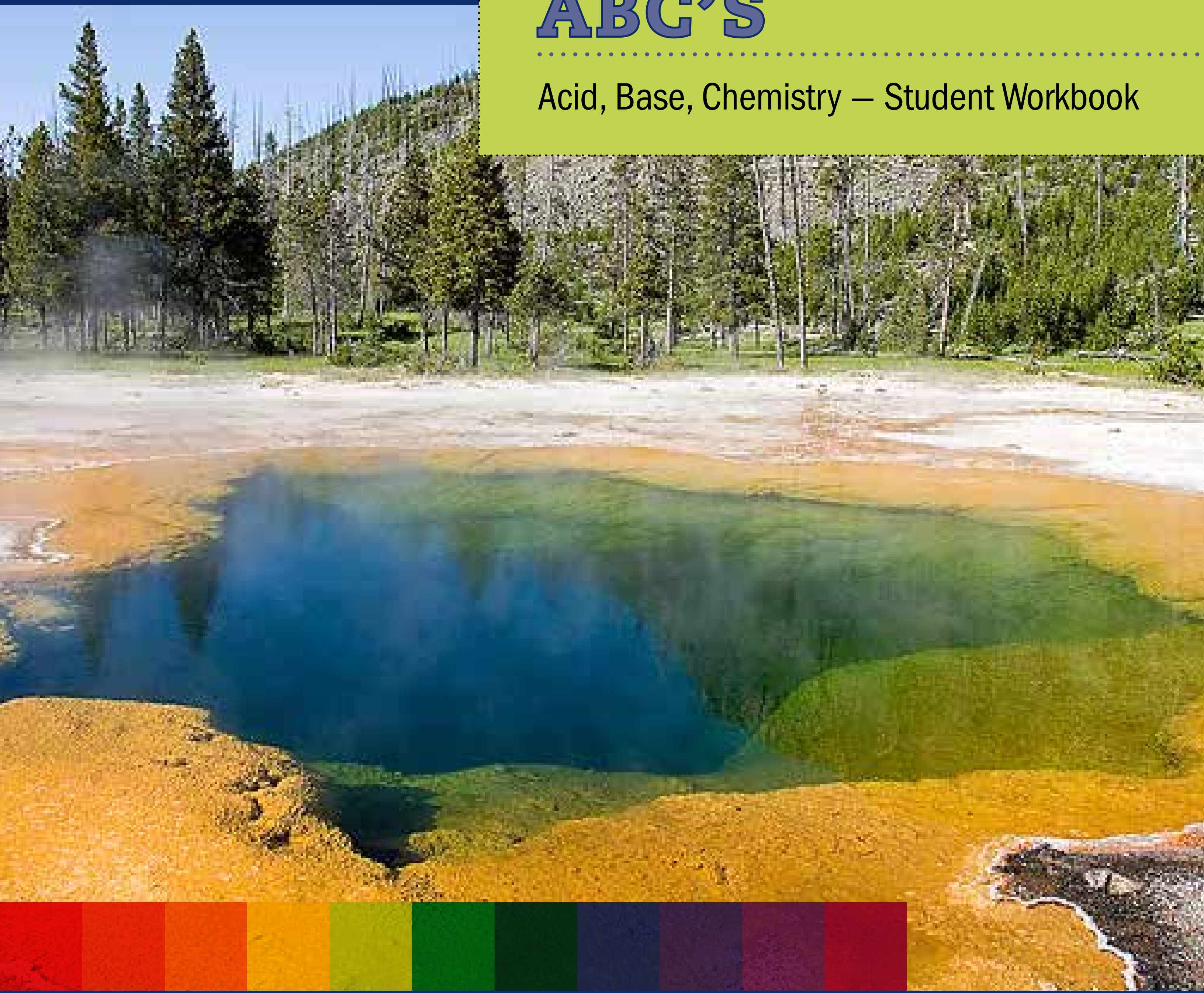
YELLOWSTONE ABC'S

Acid, Base, Chemistry — Student Workbook



MONTANA STATE UNIVERSITY
Astrobiology Biogeocatalysis Research Center

The Astrobiology Biogeocatalysis Research Center at Montana State University

Our team supports the work of the NASA Astrobiology Institute (NAI), a multidisciplinary umbrella for conducting research on the origin and evolution of life on Earth and elsewhere in the universe.

The origin of life, sustainable energy, and global climate change are intimately linked, and the answers we seek to solve our energy needs of the future are etched into Earth's history. ABRC's work supports NASA's missions, such as Mars exploration and possibilities of habitation of other worlds. Our research also focuses on the future of life on Earth. These efforts support the fundamental groundwork for Goal 3 (Origins of Life) of the NASA Astrobiology Roadmap.

ABRC involves investigators with expertise in geochemistry, experimental and theoretical physical chemistry, materials science, nanoscience, and iron-sulfur cluster biochemistry who work to define and conduct integrated research and education in astrobiology.

We are proud of our interdisciplinary research and teaching, and are committed to communicating and educating the public about our science and helping to train and inspire the next generation of scientists.

The nearby natural laboratory of Yellowstone National Park provides ABRC with unique field research opportunities. Life in the extreme environments of Yellowstone's thermal features is thought to resemble conditions of early Earth. Yellowstone's abundant and unique thermal features give researchers insights into the origin, evolution and future of life.

Whether you are a potential MSU student, a research investigator, a teacher or a citizen, we welcome you to the world of astrobiology. ABRC is committed to sharing our work and its impact with the people of Montana and beyond, through formal and informal education; public outreach; and communications to many different audiences.

Our outreach and education activities are strengthened by many factors, including MSU's proximity to Yellowstone National Park, the expertise and experience of our faculty and close partners, the outstanding commitment from our MSU students to share their work with the public, and a rich network of partners, including the Montana Library Association, Museum of the Rockies, Space Public Outreach Team and Hopa Mountain. We also work closely with the other teams from the NASA Astrobiology Institute.

Please feel free to contact us with any questions, and enjoy exploring our website: **http://abrc.montana.edu**

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This learning module was developed by Montana State University Extended University in collaboration with the Astrobiology Biogeocatalysis Research Center at Montana State University. For additional astrobiology education resources, visit http://abrc.montana.edu/outreach/ and for even more research-based educational resources for community and schools, visit http://eu.montana.edu/outreach/resources/

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Part 1.1 | Determining pH of common solutions

1. List the name of the solutions you are testing in the "solution" column on the table below.
2. Follow the instructions on your pH test strips or pH meter to test the pH of each solution you have been given. ***Follow all safety procedures and wear eye protection, gloves, and clothing protection (as directed by your teacher).***
3. Fill in the pH column with your test result for each solution.
4. Based on the pH of the solution, list whether the solution is acidic, basic, or neutral.
5. Write the solution names and pH values on the appropriate area of the pH scale on the next page.

Solution	pH	Acidic, Basic, or Neutral

Student pH scale

Increasing
Acidity

Neutral

Increasing
Akalinity

0

1

2

3

4

5

6

7

8

9

10

11

12

13

14

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PART 2

Part 2.0 | Ask yourself

What do you think pH, water temperature and living organisms have to do with Yellowstone?

Part 2.1 | Yellowstone pH and temperature

The table below contains the names, pH and temperature of several of Yellowstone's thermal features.

1. Look at the pH listed for each of the thermal features in the table below. Write whether it is acidic or basic, based on its pH, in the space provided.
2. Are there any solutions you tested in the lab that are similar to the pH of the thermal feature? If so, then write the name of the solution in the space provided.
3. Write the name of the thermal feature on the pH meter that you constructed for the lab activity on page 2.
4. Using the table, answer the questions below.

Thermal feature	pH	Water temperature	Acidic or basic	Similar solution?
Amethyst Geyser	1.4	35.9° C/96.6° F		
Black Dragon's Caldron	2	51.4° C/ 124.5° F		
Arrowhead Spring	8.5	75.5° C/ 167.9° F		
Palette Spring and Terrace	6.5	68° C/ 154.4° F		
Mud Geyser	2.5	43.5° C/ 110.3° F		
Mud Volcano	3	86° C/ 186.8° F		
Blue Mud Steam Vent	4.9	91° C/ 195.8° F		
Blood Geyser	8.5	90° C/ 194° F		
Deluge Geyser	9.1	86° C/ 186.8° F		
Grand Prismatic Spring	8.3	23.3° C / 73.9° F		
Crested Pool	9.4	93° C / 199.4° F		

Which Yellowstone thermal feature is the most acidic? ________________________________

Which thermal feature is the most basic?________________________________

Which thermal feature is closest to neutral?________________________________

Which thermal feature is closest to the boiling point of water? ________________________________
(Hint: water boils at 100° C/ 212° F)

   

Part 2.2 | Life in the extreme!

What is an extremophile?____.

Match the extremophile to its extreme environment. Ask your classmates or teacher for help if you get stuck.

Extremophiles:

____ **Thermophile**

____ **Hyperthermophile**

____ **Acidophile**

____ **Alkaliphile**

____ **Endolith**

____ **Halophile**

____ **Psychrophile**

____ **Metallotolerant**

____ **Thermoacidophile**

____ **Xerophile**

Extreme environments:

a. These microbes are happiest at pH levels between 0 and 3.

b. An organism that lives in the microscopic spaces in rocks.

c. These microbes grow best at pH levels of 9 or above.

d. These organisms live in boiling and near boiling water; they thrive in temperatures between 80–122° C (176-251° F).

e. An organism that can grow in extremely dry conditions.

f. These guys like it hot! Preferably between 60–80° C (140-176° F)

g. These organisms can live in water with high levels of heavy metals such as cadmium, arsenic, copper, and zinc.

h. An organism capable of survival, growth or reproduction at temperatures of -15° C or lower.

i. An organism that likes water that is both hot and acidic.

j. A microbe that requires extremely salty conditions in order to grow.

What types of extremophiles do you think are found in Yellowstone's thermal features?

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PART 3

Yellowstone, Hot Springs, and Extraterrestrial Life

When you look at the microbiology of Yellowstone, you see creatures making a living in ways very different from what we would expect. The thermal features of Yellowstone National Park are home to many extremophiles including thermophiles, hyperthermophiles, acidophiles, thermoacidophiles, alkaliphiles, and metallotolerant organisms. In the Park, scientists have found different microbes and even microbial communities that can thrive without light or oxygen, in temperatures near boiling, and with pH levels that would destroy most of Earth's life forms. Some use the sun for energy, others use sulfur, and still others use hydrogen. Yellowstone's extreme microbes have adapted to use the resources available in their environments—resources that most plants and animal can't use. The microbes of Yellowstone's thermal areas have a truly unique ecosystem on the modern Earth, but what about in Earth's past?

Aside from how interesting and unique extremophiles are, scientists study them because they may give us the best idea about early life on Earth. Scientists think that extremophiles were some of the first forms of life on the planet, because they thrive in conditions that are similar to what early Earth was like. The conditions on Earth's surface when life first started to evolve, 3.5 to 4 billion years ago, were very different than they are now. Earth was probably a lot hotter. Scientists estimate it had an average surface temperature of 55-85° C (131-185° F). They also think that the conditions in Yellowstone's sulfuric pools may resemble what Earth's early surface waters were like. These types of conditions would make early Earth a horrible place for humans to live, but extremophiles would feel right at home.

The microscopic life in Yellowstone is as rich, diverse, and interesting as all the large animals you see in the park. Yellowstone's microbes are so unique and fascinating that even NASA is interested in them. Why is NASA studying the extremophiles in Yellowstone? The NASA Astrobiology Institute is a group of scientists and researchers from around the world. They work together to understand what the limits of life are so that they can look for life elsewhere in our solar system and the universe. After decades of exploring with probes and satellites, we have found that no other object in our solar system is quite like Earth. The conditions on the surface of our neighbors in space are very different than our cozy corner of the universe. Our neighbors are bigger or smaller, hotter or colder, shrouded in toxic clouds or lacking an atmosphere, covered in volcanoes or frozen in ice, and very unlike Earth. If scientists want to find life elsewhere in the solar system, that life will have to be able to deal with some extreme conditions. Therefore, many scientists think that if we find life elsewhere in the universe, it may resemble the organisms living in Earth's most extreme environments.

Where else might there be life in our solar system? Two candidates in Earth's neighborhood are promising places to look for extremophilic life.

Mars

Our neighbor Mars is a promising place to look for life because it is similar to Earth in many ways. Mars is similar in size and also is about the same distance from the sun. This means it is in the *habitable zone* of the solar system: not too hot and not too cold. Mars has a thin atmosphere and its surface is made up of rocks and soil like the Earth's. There is even evidence that Mars had some plate tectonics and perhaps even water flowing on its surface sometime in its past. Modern

Mars has water in the form of polar ice caps, and some scientists think that there may be liquid water deep below the surface. But there's a reason people don't live on Mars: it is cold and dry, and its puny atmosphere doesn't provide much protection from blasts of solar radiation from space. Mars isn't such a nice place for humans, but what about microbes? Could they deal with Martian conditions?

On Earth we have extremophiles called xerophiles that can live with very little water. They have been found in the cold deserts of the Chilean Atacama Desert, a place that gets less than .004 inches of rain a year, and in the dry valleys of Antarctica. Perhaps water in the form of ice isn't such a big problem for life either. Earth's icy poles, glaciers, and snowfields support cold-loving psychrophiles and other forms of life.

What about the thin Martian atmosphere? Because Mars has a thin atmosphere, its surface gets blasted by a lot of solar radiation and that's hard on living things. Life forms on Mars would probably have to live below the surface where the radiation can't penetrate. On Earth we have many different microbes capable of living in conditions the might exist below Mars' surface. There are the endoliths that can live inside rocks, piezophiles that can withstand great pressure, and hypoliths that live under rocks in cold deserts. A group of NASA researchers recently identified large plumes of methane being released from Mars, a hint that methane-producing microbes may be present and active. Who knows what life forms may be lurking in the Martian soil?

Europa

Europa is one of Jupiter's moons and is covered in ice. Scientists believe that below Europa's frozen surface lies a liquid ocean of water that is kept relatively warm by volcanic activity within the moon. Although it's possible that Europa has some form of psychrophile living on its frozen surface, what astrobiologists are really curious about is what's going on under the ice. They think that the volcanic activity could create conditions like we find in Yellowstone, a place where extremophiles thrive. Or, it may create conditions similar to the hydrothermal vents found deep in Earth's oceans, places where sunlight never reaches and yet are teeming with life, including extremophiles. A place with warm water oceans supplied with chemicals by volcanic activity sounds like the perfect place for extremophiles!

Reading Questions

1. Why does NASA's Astrobiology Institute study Yellowstone's extremophiles?

2. Based on what scientists have discovered about extremophiles in Yellowstone, could life exist on a planet that has liquid water that is near boiling? What about water that is highly acidic or basic?

3. What environments on Mars may be home to life?

4. What two characteristics of Europa make it a good candidate for life?

Part 3.1 | Exit Quiz | What do you know?

In the list below, write an A **in front of substances that are acidic and a** B **in front of substances that are basic.**

______ Bleach
______ Lemon juice
______ Cola
______ Vinegar
______ Ammonia
______ Baking soda
______ Toothpaste
______ Black coffee

Which of the following types of extremophiles are found in Yellowstone's thermal features?

Thermophile Halophile Hyperthermophile

Acidophile Alkaliphile Psychrophile

True or False?

______ pH is a measure of the number of hydrogen ions in a solution.

______ Acids have pH values higher than 7 and bases have pH values lower than 7.

______ Extremophiles are only found in Yellowstone.

______ Astrobiology seeks to find the limits of where life can exist.

______ You can get chemical burns from strong acids but not from strong bases.

______ Acids taste bitter; bases taste sour.

______ Mars has a thick atmosphere that shields it from solar radiation.

______ Europa may have warm oceans under its icy surface.