Planets in a bottle

Background Information

The possibility of life on other planets intrigues and fascinates us all. However, looking at the planets in our Solar System, we can see that the very special environment needed to support life as we know it is not easy to come by. Our Earth is just the right distance from the Sun, so it's not too hot or cold and it has the right mixture of chemicals. For life to be able to exist on other planets, conditions need to be just right.

In this experiment, students will mix yeast with a nutrient broth consisting of water and sugar. This represents the 'life' that we are testing. The conditions for the life form can be altered by adding substances to the broth or exposing the yeast to different environments. The simplest planet to simulate in a bottle is Earth.

The basic mixture is prepared as follows:

1. Mix 3 teaspoons of sugar in a cup of luke-warm water, and add this to a clean, empty 500ml or 600ml used soft drink bottle. Shake this so that the sugar dissolves completely.
2. Add 2 teaspoons of dried yeast powder and carefully swirl the bottle around to mix the yeast into the sugar solution.
3. Cover the mouth of the bottle with a party balloon. Stretch the mouth of the balloon so that it covers the thread of the bottle's mouth.
4. Wait, watch and measure the circumference of the balloon every 15 minutes.

As the yeast cells digest the sugar, they produce carbon dioxide gas and inflate the balloon. A healthy sample of yeast can inflate the party balloon to a 30cm circumference in less than 30 minutes. The rate at which the balloon grows is proportional to the growth rate of the yeast colony. After the yeast cells are added to the nutrient solution, they begin to divide and increase in number. As the colony size increases, so does the rate of production of carbon dioxide, so long as there is an ample supply of nutrients. If the environment inside the bottle is conducive to yeast growth, the maximum rate of carbon dioxide production will be high. Conversely, if the environment is hostile to yeast, the maximum rate of carbon dioxide production will be low.

Simple variations of this 'Earth in a bottle' can be used to discover environmental factors that inhibit or promote the health of the yeast colony. Students can compare these factors to conditions on other planets or moons. Variations include adding an acid like vinegar to simulate acid environments like that found on Venus, and adding boiling water to simulate the intense heat found on this planet. Placing the yeast in a freezer simulates the environment of Neptune and experimenting with radiations such as microwaves and UV light will simulate planets with little atmosphere. Other variations that either you or the students can think of to simulate planets could also be considered and should be encouraged.

Suggestion
The students should be broken up into groups of four (depending on how many students are in the class and how many variations are included in the practical exercise). One pair of students in each group should simulate Earth in a bottle and record observations. This will be their control. The other pair in the group should be allocated one of the variations to simulate another planet. The students can then share results with the rest of the class and discuss them as a group.

Introduction

Our Earth is just the right distance from the Sun and has the right mixture of chemicals to support life.

In this experiment, you will be representing life on Earth by mixing yeast with a nutrient broth consisting of water and sugar. As the yeast cells digest the sugar, they begin to divide, increase in number and produce carbon dioxide. As the colony size increases, more carbon dioxide is produced so long as there is a good supply of nutrients. A healthy sample of yeast can inflate a party balloon to a 30cm circumference in less than 30 minutes.

If other substances are added to the solution to represent conditions on other planets, you can observe what happens to the rate of the production of carbon dioxide and life under these conditions.

What you need

- 1 cup of luke-warm water
- 3 teaspoons of sugar
- 2 teaspoons of yeast
- 1 empty but clean 500ml or 600ml plastic soft drink bottle
- 1 party balloon
- 1 elastic band
- 1 cloth measuring tape
- Acid (vinegar, orange juice or lemon juice)
- Freezer
- Boiling water
- Microwave oven
- UV light (if available)

What to do

This is your basic ‘Earth in a bottle’:

1. Add the warm water and the sugar to the bottle and shake the bottle until the sugar is dissolved.
2. Add the yeast to the sugar solution and gently swirl the mixture.
3. Stretch the balloon right over the mouth of the bottle.
4. Secure this with an elastic band.
5. Use the cloth measuring tape to measure the circumference of the balloon every 15 minutes.

Each group should choose or be allocated one other option below:

- Add 2 or 3 teaspoons of an acid like orange juice, lemon juice or vinegar to the nutrient to simulate acid environments like we see on Venus. You could also use boiling water instead of warm water, to simulate the immense heat on Venus.
- Irradiate the yeast in a microwave oven for a minute to simulate high radiation from the Sun on planets with no atmosphere.
- Place the yeast in a freezer for a few days before adding to the nutrient to simulate the cold environment of Pluto.
- If you have access to UV light, place the yeast under the light for a few hours to simulate high levels of UV from the Sun.
- Suggest your own experiment.

Class Results

Simulated planet	How simulated	Measured circumference (cm)
Earth		
Venus		
Neptune		

Questions

1. What effect did the acid have on the production of carbon dioxide?
2. What effect did the radiation have on the production of carbon dioxide?
3. Why was radiation used to represent a planet with no atmosphere?
4. Find out which planet has no atmosphere.
5. Which planet is likely to be exposed to a high level of UV light radiation from the Sun? Why?
6. According to your results and the conditions simulated to represent Neptune, could life exist on Neptune? Discuss.

Venus Credit: Magellan Project, JPL, NASA