***We Are Aliens* – A Guide for Educators**

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About the Planetarium Show

We Are Aliens invites your students to explore how our understanding of life on Earth guides the hunt for alien life elsewhere in the universe. We visit Mars, Europa and distant exoplanets to help answer the ultimate question… are we alone? Explore what life needs to thrive and how astronomers use clever techniques to find planets around distant stars in this immersive program that perfectly balances science, education, and entertainment.

Next Generation Science Standards

We Are Aliens explores topics in each of the four disciplinary core ideas as outlined in the Next Generation Science Standards: physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science. From a thorough investigation of the incredible diversity of lifeforms found on Earth, to imagining space missions that can hunt for alien life in our solar system and beyond, there are many ways to connect this planetarium program to your current science lessons. Some relevant standards are listed below:

K-LS1-1 Use observations to describe patterns of what plants and animals need to survive.

1-ESS1-1 Use observations of the sun, moon, and stars to describe patterns that can be predicted.

2-LS4-1 Make observations of planets and animals to compare the diversity of life in different habitats.

2-ESS2-3 Obtain information to identify where water is found on Earth and that it can be solid or liquid.

3-LS4-3 Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.

3-LS3-2 Use evidence to support the explanation that traits can be influenced by the environment.

4-PS4-1 Develop a model of waves to describe patterns in terms of amplitude and wavelength.

5-PS3-1 Use models to describe that energy in animals' food was once energy from the sun.

5-ESS2-1 Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

MS-PS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

MS-LS4-2 Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

For more information on Oregon's Science Standards, visit
http://www.ode.state.or.us/search/page/?id=1577

Before Your Visit

- Begin by assessing what your students already know about the search for life beyond Earth. Specifically, invite them to share what they have heard on their own. For example:
    - What does Earth have that makes it such a haven for life?
    - Where else in our solar system could we look for life? How are these places similar to and/or different from the Earth.
    - Is the Sun the only star that has planets? Are planets common in the universe?
    - Poll your students to see how many of them believe in alien life.

Remind your students that some of these may be open-ended questions, like many great questions in science! While scientists are looking for signs of life beyond Earth, we haven't found any yet.

Activities For Before or After Your Visit

- In any astronomy unit, one of the most challenging concepts to convey is just how big and empty space truly is. This activity will allow your students to work together to create a scale model of the Earth, Earth's moon, and Mars using balloons. Students will first make their models based on what they think is the correct scale before you show them the accurate model. Use this activity to explore as a group why it is so challenging to travel to Mars and beyond.
  Full activity description:
  https://marsed.asu.edu/sites/default/files/stem_resources/Earth_Moon_Mars_Balloons_K-4_Lesson_8_2013.pdf
- In space exploration, robotic rovers are sent to destinations like Mars to test landing procedures and explore these locations before humans can safely travel there. But studying the Martian environment through the "eyes" of a robotic rover is no easy task. In this activity, students will bring an item from home in a paper bag. Then, these bags of items will be randomly distributed to students and they will have to use their senses to make inferences about the nature of the hidden item based on their indirect observations.
  Full activity description:
  http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Whats_Hidden_Inside_Activity.html
- This activity will demonstrate that when scientists look for life on Mars, or elsewhere in the universe, the signs of life are not always easy to determine. Begin by discussing with your students how they think life is defined and then conduct a simple experiment looking for signs of life in three different "soil" samples. Following the experiment, you may need to reassess how living things vs. non-living things are defined.
  Full activity description:
  www.lpi.usra.edu/education/explore/LifeOnMars/activities/searchingForLife/
- When scientists discover exoplanets – planets orbiting stars other than our sun – the first thing they will do is try to determine if that exoplanet is orbiting in its stars' "habitable" zone where it is not too hot and not too cold, but just the right temperature for liquid water. This video is an example of a demonstration you can do in class with your students exploring what the habitable zone is using the innermost planets or our solar system as an example.
  Full activity description: https://nightsky.jpl.nasa.gov/download-view.cfm?Doc_ID=311

Useful Websites

- NASA's exoplanet site: https://exoplanets.nasa.gov/
    - New exoplanet discoveries are announced all the time. While this is exciting from a scientist's perspective, as an educator it can be frustrating to have out-of-date information. NASA's exoplanet archive is the go-to resource for the current number of confirmed exoplanets in our galaxy.
- NASA's Mars exploration site: http://mars.nasa.gov/
    - This is a great collection of all things Mars. Highlights include a history of Mars missions, the latest press releases of new discoveries made about the red planet, and a wonderful collection of multimedia resources to share with your students.
- NASA's Space Place: http://spaceplace.nasa.gov/
    - NASA's Space Place website is a wonderful resource for general space information. This site includes kid-friendly educational games, hands-on activities, and lots of beautiful space images to help visualize the cosmos.

We Are Aliens! – Classroom activity 1 (Biology)

Is there life in there?

Background:

All life forms on Earth are based on organic biochemistry. This activity requires students to analyse an unknown soil sample (just recovered from a space mission to another planet!) and look for signs of carbohydrates, lipids and proteins as possible indicators for life. The results from the practical investigation mirror those of the Viking missions that first analysed the surface of Mars in the 1970's.

The activity covers a variety of curriculum areas and can be used across KS3, KS4, and KS5 with modification and differentiation.

Curriculum areas covered:

- Cell biology
- Food tests – biochemical tests for protein, fat and carbohydrates (starch and reducing sugar)
- Practical skills – handling laboratory glassware and reagents, making observations, preparing slides, using a light microscope
- How Science Works – formulation of a theory, need for reliability, peer review

Equipment list:

- Three containers labelled A, B and C (size optional)
- Soil samples in each container. Each sample to vary in terms of its content – example below:

	Soil A	Soil B	Soil C
Contents of soil	Sand & salt	Sand, alka seltzer,	Sand, yeast, glucose, protein, fat, starch

The exact quantities of each substance in the containers are not crucial – the tests are sensitive enough to pick up small amounts of each organic molecule. As a rough guide, about 4 parts sand to 1 part 'extra ingredients' is usually sufficient.

- Test tubes
- Spatulas
- Water baths
- Pipettes
- Hand lenses

- Sildes & cover slips
- Microscopes

Reagents:

- Benedict's solution
- Biuret A & Biuret B solutions
- Ethanol
- Potassium Iodide solution

Method:

Visual inspection:

1. Ask students to take a small amount of each 'soil' type and place on separate pieces of paper
2. Students observe with the naked eye and record any obvious differences between each soil type on the results sheet
3. A small quantity of each soil sample is then placed into a dimple tile. Add a few drops of warm water (enough to cover the soil) to each sample. Observe carefully over the next five minutes and record observations on the results sheet

Looking for cells (yeast):

Place a small amount of each hydrated soil sample (use a pipette) on separate slides and observe at low, medium and high power magnification. Record your observations on the results sheet

Starch test:

1. Take a small amount of each 'soil' type and place in separate test tubes
2. Add approx 5 cm^3 of water to the test tube and shake
3. Allow time for the soil to form a sediment at the bottom of the tube
4. Add a few drops of iodine solution to the test tube and observe any colour change. A black colour indicates the presence of starch
5. Record results on the results sheet

Reducing sugar test:

1. Take a small amount of each 'soil' type and place in separate test tubes
2. Add approx 5 cm^3 of water to the test tube and shake
3. Allow time for the soil to form a sediment at the bottom of the tube

4. Add approx 5 cm^3 of Benedict's solution to the test tube and place in a hot water bath for five minutes. A brick red colour indicates the presence of large quantities of reducing sugars. Yellow/Green/Orange colours indicate smaller quantities.

5. Record results on the results sheet

Protein test:

1. Take a small amount of each 'soil' type and place in separate test tubes

2. Add approx 5 cm^3 of water to the test tube and shake

3. Allow time for the soil to form a sediment at the bottom of the tube

4. Add a few drops of Biuret A solution to the test tube and then add a few drops of Biuret B solution. Observe any colour change. A purple colour indicates the presence of protein

Lipid test:

1. Add approx 5 cm^3 of ethanol to the test tube and shake

2. Allow time for the soil to form a sediment at the bottom of the tube

3. Add a few drops of water to the test tube. Observe any colour change. A milky white colour indicates the presence of a lipid.

The rapid effervescence seen in B is typical of a short but unsustained chemical reaction – reminiscent of the labelled release experiment performed by the Viking probes on Mars (see below). The continual release of gas in C illustrates an important feature of life – that of sustainability.

Discussion:

After students have completed the practical and filled in their results sheets, two students should act as a 'peer review panel' and collate results from different groups and display on the board. Discussion follows on the overall results of the class, reasons for any disagreement, contamination, anomalies, etc. Discussion leads into the Viking Lander missions and the parallels between this investigation and those carried out on the surface of Mars. The main link is the idea of sand sample B giving off a great deal of gas – but it being entirely due to chemical, and not biological, reactions.

	Soil A	Soil B	Soil C
Visual inspection			
Response to hydration			
Test for starch			
Test for sugar			
Test for protein			
Test for fat			

Background information - Mars

Mars is by far the most studied planet in our solar system. It has notable surface similarities with Earth including volcanoes, mountains, valleys, deserts and polar ice caps, although it is approximately only half the size of the Earth. Mars currently hosts three active space probes in orbit (***Mars Odyssey*** (NASA), ***Mars Express*** (ESA) and the ***Mars Reconnaissance Orbiter*** (NASA)). It also has two exploration rovers on the surface (***Spirit*** and ***Opportunity*** (NASA)) plus a host of inert probes from the past – including the British Beagle 2 probe and NASA's ***Phoenix*** probe, which recently completed its mission to research the history of water on the planet.

The data gathered thus far has shown that:

- The surface is composed of fine iron (III) oxide – giving Mars its rust red colouration
- There is evidence of geological activity and plate tectonics (as evidenced by Valles Marineris, Olympus Mons and paleomagnetism of minerals), but this seems to have stopped a long time ago. This is possibly due to the fact that Mars is much smaller than Earth and so lost heat more rapidly, leading to cooling and solidification of the core.
- Mars appears to have lost its magnetic field early on in its history, meaning that the Solar Wind has stripped away much of its atmosphere. What atmosphere remains is very thin and is comprised mainly of carbon dioxide (95%) with smaller quantities of nitrogen (3%), argon (1.6%) and trace amounts of oxygen.
- A lack of ozone in the atmosphere means that the surface is irradiated with large quantities of UV radiation – meaning that organic molecules on the surface would be quickly broken down
- The thin atmosphere means that air pressure is very low ranging from 0.03 KPa (summit of Olympus Mons) to 1.155 KPa (depths of Hellas Planitia).
- Methane has been found in the Martian atmosphere with a concentration of about 30 ppb by volume. Since methane is an unstable gas that is broken down by ultraviolet radiation, typically lasting about 340 years in the Martian atmosphere, its presence would indicate a current or recent source of the gas on the planet.
- Significant amounts of water ice have been found at the poles of Mars and have also be found under the surface in other locations. NASA has estimated that there is sufficient water ice at the poles alone to flood the planet to a depth of 11 metres if melted. Surface features of Mars indicate that in the past water may have existed in liquid form.

Viking Invaders…

Fig 01 (above)

It is now more than 30 years since the first search for life took place on another planet – Mars. In the mid 1970's NASA's two ***Viking*** landers conducted biology experiments looking for **biosignatures**. These experiments included:

Gas Chromatograph — Mass Spectrometer

Designed to separate, identify and quantify a large number of different chemicals. Particular interest was centered around the identifying any organic molecules that could indicate life.

Gas Exchange

Designed to look for gases given off by an incubated soil sample. Metabolism by living organisms should result in changing concentrations of several gases including oxygen, carbon dioxide, methane, nitrogen and hydrogen

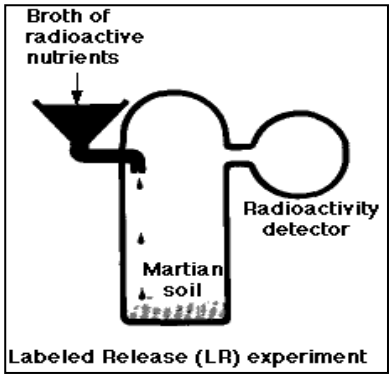


Fig 02 (above)

Labeled Release

Designed to test a sample of Martian soil inoculated with a drop of very dilute aqueous nutrient solution. The nutrients were tagged with radioactive ^{14}C and the air above the soil was then monitored for the evolution of radioactive $^{14}CO_2$ gas (possibly indicating respiration). This experiment was then repeated, but this time the soil was first heated to a very high temperature rendering it completely sterile (acting as a control).

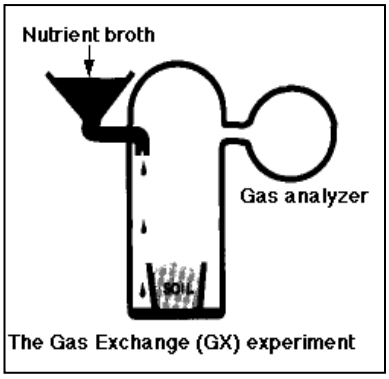


Fig 03 (above)

Pyrolytic Release

This involved providing a soil sample with light, water, carbon dioxide and carbon monoxide. The carbon was labelled with ^{14}C – the idea being that this would be incorporated into the biomass of a photosynthetic organism. After removing the gases, the soil was then baked at high temperatures to vaporise any biomass in the soil. If ^{14}C was detected, it would provide some evidence for a biological life form.

The results initially caused a great deal of excitement when a steady stream of radioactive gases (including carbon dioxide) were released in the labelled release experiment. However, this was not sustained – subsequent injections of nutrients did not result in any reaction. The findings from the other investigations failed to find any evidence for organic molecules on the surface, aside from traces that were due to contamination of the spacecraft from Earth. The experiments carried out by Viking therefore remain inconclusive – it is possible that Martian soil has built up a thin layer of an oxidant chemical which reacts strongly with nutrients to produce CO_2.

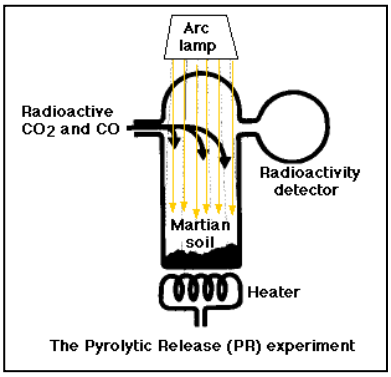


Fig 04 (above)

From Viking to ExoMars

Fig 05 (below)

ESA's Mars Rover - a drill will be used to penetrate Martian soil to a depth of 2 metres

Since Viking, missions to Mars have focused mainly on geological or atmospheric analysis. However, this is about to change with the launch of the ESA **ExoMars** mission (currently scheduled for 2016). The aim of the mission will be to further characterise the biological environment of Mars in preparation for robotic missions and then human exploration. Data that is gathered during the mission should provide us with a clearer picture of whether life has ever evolved on the planet.

The mission will carry a rover (designed and tested in the UK) which is intended to act as a 'field biologist' on the surface of Mars. Unusually, this rover will carry a drill that is designed to take samples from two metres below the surface – where scientists think that there may be water and hence life.

The rover will then deliver soil and rock samples to an instrument (called the 'Urey' instrument) which will grind the samples and expose them to a fluorescent dye that attaches to molecules containing an **amine (NH2)** group. The dye is called flourescamine, and is a highly **specific** reagent.

A laser inside the instrument will illuminate the sample, causing amine-containing compounds labeled with flourescamine to appear in a detector even if they are present only in minute amounts. The detector is estimated to be one million times more sensitive than Viking. If amino acids or DNA is present, there is therefore a very good chance that they will be detected.

All life on Earth assembles chains of amino acids to make proteins during the process of **translation** at **ribosomes** in a cell**.** However, amino acids can be made either by a living organism or by non-biological means. This means it is possible that Mars has amino acids and other chemical precursors of life but has never had life. To distinguish between that situation and evidence for past or present life on Mars, the Urey instrument team will make use of the knowledge that most types of amino acids can exist in two different forms called **stereoisomers**. One form is referred to as "left-handed" and the other as "right-handed." Just as the right hand on a human mirrors the left, these two forms of an amino acid mirror each other.

Amino acids from a non-biological source come in a roughly 50-50 mix of right-handed and left-handed forms. Life on Earth, from the simplest microbes to the largest plants and animals, makes and uses only left-handed amino acids, with rare exceptions. Comparable uniformity -- either all left or all right -- is expected in any extraterrestrial life using building blocks that have mirror-image versions because a mixture would complicate biochemistry.

A Urey component called the micro-capillary **electrophoresis unit** has the critical job of separating different types of organic compounds from one another for identification, including separation of mirror-image amino acids from each other. The device for sending to Mars will be a small version incorporating this detection technology, which is already in use for biomedical procedures such as law-enforcement DNA tests and checking for hazardous microbes.

Source of information: NASA Jet Propulsion Laborator

RISK ASSESSMENT	Overall risk (provided safety procedures are followed) = LOW

Substance	**Hazard**	**Comment**
Food	b BIOHAZARD	Uncooked samples of food may be contaminated with microbes.) Some people are allergic to some foods, especially peanuts.
Benedict's solution Used to test for reducing sugars.	LOW HAZARD	Contains slightly-alkaline copper sulfate solution, but at concentrations which present only a LOW HAZARD. Some risk of spitting if heating test tubes.
Ethanol Used to test for fats (lipids).	F HIGHLY FLAMMABLE	If Bunsen burners are being used nearby for other food tests, there is a serious fire risk.
Iodine solution Used to test for starch.	LOW HAZARD	Wear eye protection, though the solution in water is dilute and only presents a LOW HAZARD.
Biuret test Used to test for proteins.	I IRRITANT	Uses very dilute copper sulfate solution (LOW HAZARD) and sodium hydroxide solution which is IRRITANT (not CORROSIVE) if kept dilute (below 0.5 M).

Additional comments:

- Do not taste foods in laboratories; avoid using products containing peanuts etc if there is a known allergy. Wear eye protection and use the smallest possible amounts of chemicals. Heat with a water bath. Do **not** use ethanol if there are naked flames nearby.
- Provided that concentrations of reagents are kept as recommended above and that a water bath is used for heating, the risk for these tests is low. The main hazard comes from ethanol which is highly flammable – naked flames should not be allowed anywhere near ethanol for this reason.
- Eye protection should be worn throughout all of the practical procedures and latex gloves are also desirable to prevent skin irritation from the reagents used.

In case of accident/incident:

• **In the eye**	Flood the eye with gently-running tap water for 10 minutes. See a doctor.
• **Swallowed**	Do no more than wash out the mouth with water. Do **not** induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor.
• **Spilt on skin or clothing**	Remove contaminated clothing. Drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor.
• **Clothing catches fire**	Smother flames on clothing or skin with a fire blanket or other material. Cool any burnt skin with gently-running tap water for 10 minutes. Allow fires in sinks, etc to burn out.
• **Other ethanol fires Spilt on floor, bench, etc**	Fires at the top of test tubes, beakers, etc should be smoth-ered with a damp cloth or heat-proof mat if this can be done safely. For small amounts, use a damp cloth. Rinse well. For larger amounts, cover with mineral abs-orbent (eg, cat litter) and scoop into a bucket. Neutralise alkali with citric acid. Rinse with water.

Image References:

Figure 01 - ASTROBIOLOGY Magazine (2012) *Alien Safari; Alien vs Predator* [WWW] Credit: *NASA / JPL / Malin Space Sciences System* Available from: http://www.astrobio.net/debate/3062/alien-vs-predator [03/12/2012]

Figure 02 - THE ENCYCLOPEDIA OF SCIENCE; ASTROBIOLOGY (date unknown) *Viking Labeled Release (LR) experiment* [WWW] http://www.daviddarling.info/encyclopedia/V/VikingLR.html [03/12/2012]

Figure 03 - KIMBALL, J (May 2012) *Is (Was?) There Life on Mars?* [WWW] http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/M/Mars.html [03/12/2012]

Figure 04 - KIMBALL, J (May 2012) *Is (Was?) There Life on Mars?* [WWW] http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/M/Mars.html [03/12/2012]

Figure 05 - DLR; PRESS RELEASES (2009) *Press Releases 2009* [WWW] Credit: ESA - AOES Medialab http://www.dlr.de/en/desktopdefault.aspx/tabid-5105/8598_read-20530/gallery-1/gallery_read-Image.1.11546/ [03/12/2012]

We Are Aliens! – Classroom activity 2 (Biology)

Martian Death Rays ...

Background:

Could there be life on Mars? Perhaps so, although the high intensity of UV light means that it is unlikely to be found on the surface. The following experiment will demonstrate why this is the case.

Bacterial cells contain DNA just as plant and animal cells do, and the DNA in cells is damaged by UV radiation. On Earth we have our atmosphere, particularly the ozone to protect our DNA from harmful UV radiation. Mars however has no ozone layer and so its surface is not protected from this radiation. Follow the method below to see the effect of UV light on cellular life forms (bacteria).The experiment is mainly aimed at KS5, but can be adapted to lower key stages as required.

Curriculum areas covered:

- Microbiology
- Cell biology
- Aseptic technique
- How Science Works – collecting, analysing (via statistical tests) and interpreting data

Equipment list:

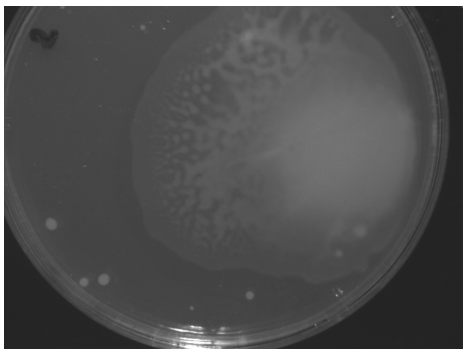
- UV cleaning device
- 4 nutrient agar plates per group
- 4 sterile swabs per group
- 1 dirty place – computer keyboards are ideal as they are difficult to clean
- Tape
- Marker pen
- Access to an incubator

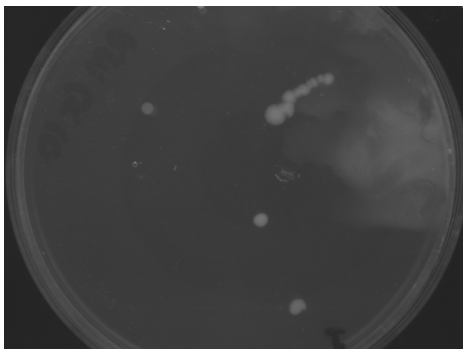
Method:

1. Take a sterile swab of an area on the keyboard that is often used.
2. Wipe the swab carefully across the agar plate being careful not to disrupt the surface of the agar.
3. Replace the lid, tape at two points and label at the edge with a marker pen.
4. Repeat steps 1-3 for another area on the key board.
5. Using the UV cleaning device, clean the keyboard by holding it about 2cm away from the surface for 10-20 seconds in each area.
6. Repeat steps 1-4 for the same two areas on the keyboard.
7. Incubate the agar plates at 20^{o}C for 48 hours.

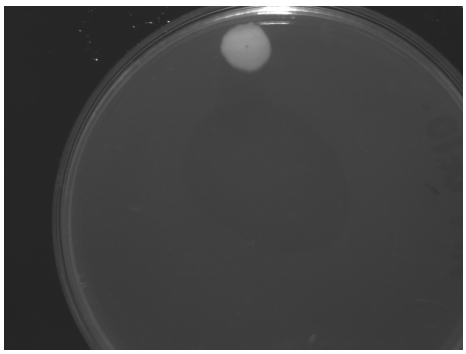
Discussion:

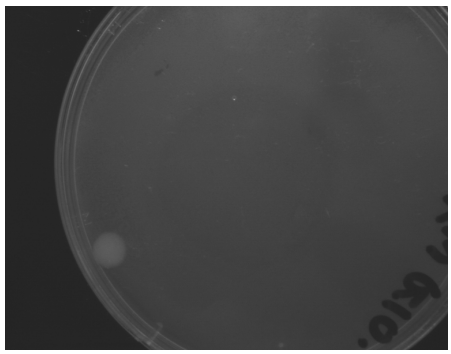
The pictures below show the samples taken before the keyboard was cleaned.





The pictures below show the samples taken after the keyboard was cleaned.





Figures 1-4 – above

UV light has sufficient energy to break apart organic molecules, including DNA. Because DNA is damaged by UV light, cells are prevented from reproducing and this reduces the colony count for areas that have received UV treatment.

You can count the number of colonies on each plate by dividing it into sectors using a marker pen. A hand lens can then be used to scrutinise each sector for bacterial colonies and the marker pen used to strike through each colony as it is counted. Count the number of colonies visible before and after UV exposure.

Once you have obtained some numerical data, you should then consider repeating the investigation several times (pooling classroom data) and analysing the results using an appropriate statistical test (e.g. 95% confidence limits and 2 x standard error) – this will determine whether there is any significant difference in the number of bacterial colonies before and after UV exposure.

Background information - Mars

LIFE ON MARS? THE VIKING LABELED RELEASE EXPERIMENT*

GILBERT V. LEVIN and PATRICIA ANN STRAAT

***Biospherics Incorporated, Rockville, MD 20852, U.S.A.* 1977**

Viking radiorespirometry ("Labeled Release" [LR]) experiments conducted on surface material obtained at two sites on Mars have produced results which on Earth would clearly establish the presence of microbial activity in the soil. However, two factors on Mars keep the question open. First, the intense UV flux striking Mars has given rise to several theories postulating the production of highly oxidative compounds. Such compounds might be responsible for the observed results. Second, the molecular analysis experiment has not found organic matter in the Mars surface material, and therefore, does not support the presence of organisms. However, sensitivity limitations of the organic analysis instrument could permit as many as one million terrestrial type bacteria to go undetected.

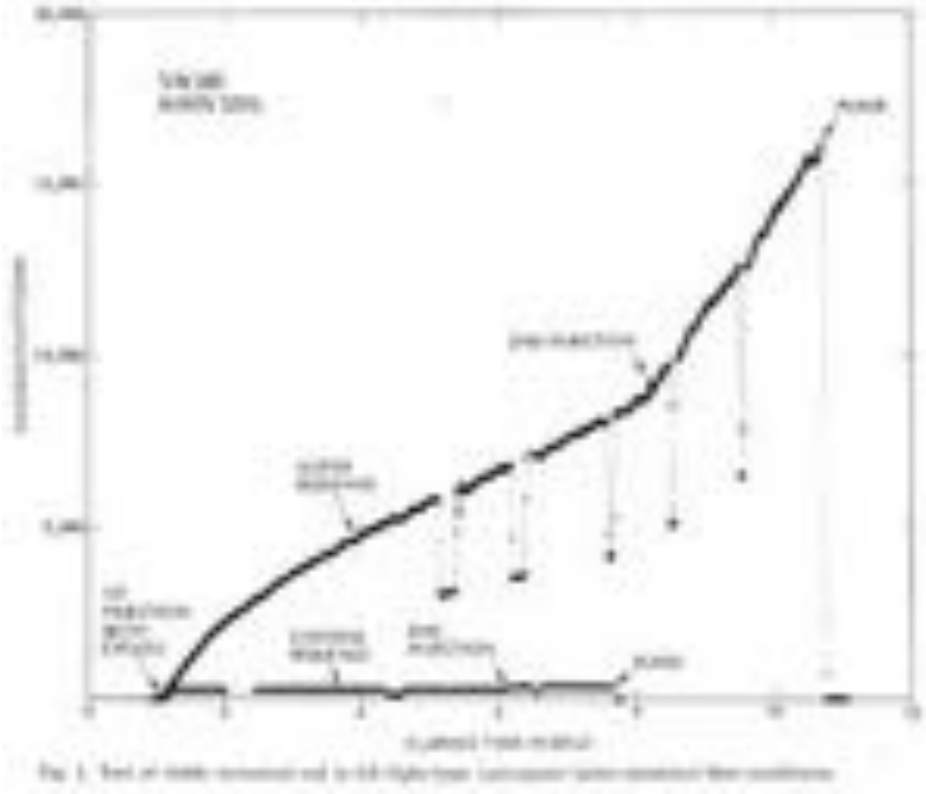
Terrestrial experiments with UV irradiation of Mars Analog Soil did not produce Mars type LR results. Gamma irradiation of silica gel did produce positive results, but not mimicking those on Mars. The life question remains open.

The Viking Labeled Release (LR) Experiment (Levin and Straat, 1976) has obtained results consistent with the presence of microbial life on Mars. In the LR experiment, a dilute aqueous solution of simple, uniformly labeled carbon compounds is applied to a sample of soil in a sealed test cell. The headspace atmosphere in the chamber is monitored for the appearance of radioactive gas. A positive response is tested for biological lability by repeating the experiment after heating a duplicate portion of the sample to 160°C to sterilize it. Tests conducted with terrestrial soils containing viable microorganisms invariably produce positive responses and, under favorable environmental conditions, gas evolution plotted as a function of time reveals the classic microbial growth curve with lag, exponential and stationary phases clearly defined.

Prior to Viking launch, a carefully controlled LR experiment was conducted in a sister instrument to those flown to Mars. The atmospheric composition and pressure, the water vapor content and the temperature of the test cell containing a California soil with a rich microbial population were controlled to simulate conditions anticipated within the test cell on Mars. The results of the active and

control cycles are presented in Fig. 1 as the cumulative evolution of radioactive gas over Martian sols (1 sol = 24.6 h). At the point indicated in Fig. 1, a second aliquot of the radioactive nutrient was injected onto the soil which immediately produced a fresh radiorespirometric response. In the control sequence, a duplicate portion of this soil was heated to 160°C for 3 h and permitted to cool prior to nutrient injection. As seen in Fig. 1, essentially no gas evolved.

Figure 5 – below



*Presented at the Fifth International Conference on the Origin of Life, Kyoto, Japan, April 5-10, 1977.

As of this writing, two active cycles of the LR experiment have been performed at each of the two Mars lander sites some 4000 miles apart. All four active cycles have yielded positive, and surprisingly similar, results upon their first injections. However, rather than producing additional gas, subsequent injections in each cycle have all produced diminutions in the accumulated quantity of radioactive gas already evolved. Typical results, those for VL-1, Cycle 3, are presented in Fig. 2. During this long incubation, a total of three nutrient injections were made. The first produced a strong positive response, but the second and third were followed by a decline in the amount of radioactive gas evolved by the first, indicating a drastic change or loss of the active agent in the soil sometime prior to the second injection.

Figure 6 – below

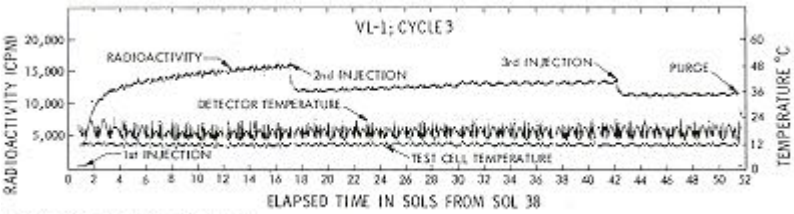
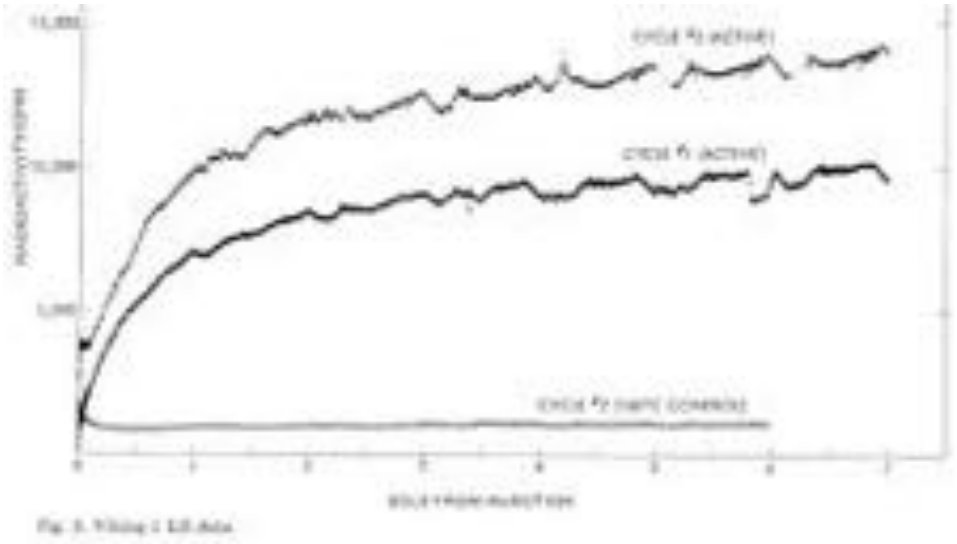


Fig. 2. Labeled release Mars data.

Fig. 3 summarizes the current first injection data at Viking Lander 1. Two active cycles and one control cycle are presented on a scale comparable to that used in Fig. 1 to permit ready comparison of the Mars and Earth results. Similarly, the current first injection results at Viking Lander 2 are summarized in Fig. 4 to the same scale.

Figure 7 – below



Comparison of the results from all four Mars active cycles to the results obtained from terrestrial soil under simulated Mars conditions, Fig. 1, shows that, with respect to the first injection, the responses are similar in magnitude over the time span measured. The shapes of the first injection portions of the active cycle curves on Mars and on Earth differ in that the Mars responses approach plateau earlier in the time course. Nonetheless, the similarity among all four active tests on Mars is striking. This is despite the fact that one of the experiments, VL-1, Cycle 3, was conducted on a sample obtained by moving a rock which had protected it from UV radiation for many thousands of years. It is interesting to note that, while the Mars data fail to show evidence of exponential gas evolution, from which growth might be inferred, neither do the terrestrial microorganisms under the imposed Martian conditions. The 160°C preheated control samples produced similar, low level results on Earth and Mars.

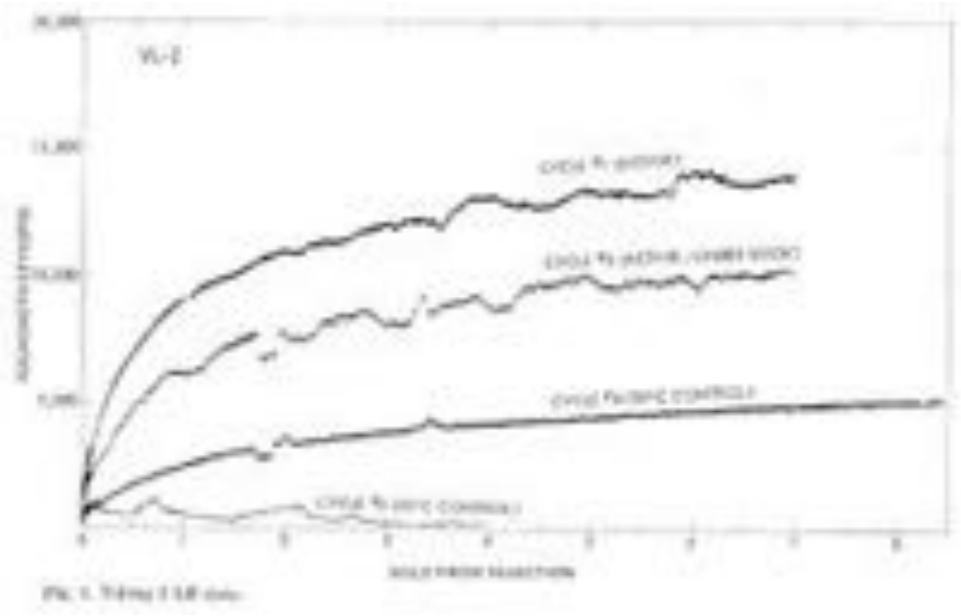
Although the LR results are consistent with the presence of life on Mars, other factors prevent the indicated conclusion at this time. Experimenters for the other two Viking life detection experiments, Pyrolytic Release and Gas Exchange, have stated (Horowitz, 1977) that their experiments have produced no confirming

evidence. Also, the Molecular Analysis Experiment (Biemann, 1977) has found no evidence of organic matter in the Martian surface material. However, the sensitivity threshold for this experiment could permit 10^6 terrestrial type bacteria to go undetected provided they were not accompanied by organic debris many times their own mass as is generally, if not always, the case in terrestrial soils (Biemann, 1977).

Various hypotheses that exotic Martian conditions, principally the high UV flux, could produce active states or highly oxidative compounds in the Mars surface material led to speculations (Levin and Straat, 1976) that physical or chemical processes might falsely indicate the presence of life. The early receipt of a positive active cycle and a negative control from the LR experiment on Mars intensified speculation on these hypotheses.

Within the severe limitations of the spacecraft instrument, the authors attempted variations in the LR experiment soon after the positive results on Mars in an attempt to resolve the dilemma. The control pretreatment temperature was dropped to 50°C (actually approx. 51.5°C) (Levin and Straat, in press) on the theory that microorganisms on Mars would be severely damaged even at 50°C, a temperature beyond their experience, but that physical or chemical phenomenon causing the breakdown of the nutrient was far less likely to be degraded by this relatively mild treatment. The results shown in Fig. 4 for VL-2, Cycle 2, indicate severe attenuation of the LR reaction. However, the strange kinetics aroused suspicion that the LR instrument had malfunctioned. A series of engineering tests remotely conducted on the instrument failed to detect any malfunction and a subsequent active cycle, Cycle 3, Fig. 4, produced a "normal" active LR curve for Mars. Nonetheless, the significance of the reduced response following heating to 50°C required that the effect be confirmed. Accordingly, Cycle 4, in which a fresh sample was preheated to only 46°C (Levin and Straat, in press), was conducted. The results confirmed the major reduction in the LR response achieved by mild heating although, this time, the strange kinetics were not evident. (The relatively minor fluctuations in the radioactivity curves correlate with temperature changes imposed on the test cell by the lander's temperature control mechanism as it reacts to the diurnal temperature swing on Mars.)

Figure 8 – below



Simultaneous with the attempts to resolve the life issue on Mars, the authors undertook a series of laboratory simulation experiments. The experiments reported herein were complementary to the "under the rock" experiment conducted on Mars in that they sought to determine whether exposure of soil to radiation might mimic the LR results. A "worst case" test of the theories that ionizing radiation of oxygen-rich minerals might activate sites capable of degrading one or more of the organic substrates (Levin and Straat, 1976) comprising the LR medium was effected through the irradiation of pure silica gel with gamma rays emitted from a cobalt-60 source. Silica gel was selected because it was almost pure SiO_2 for which considerable evidence has been cited (Zeller et al., 1970; Zeller, 1976) concerning its activation by solar flux protons or harder, ionizing radiation. Moreover, SiO_2, in the form of silica gel, would provide enormous surface area to contact the LR medium. Davison silica gel, grade 950* was selected for use. Its typical chemical analysis on a percent dry weight basis is: 99.85% SiO_2; iron as Fe_2O_3, 0.005%; sodium as Na_2O, 0.004%; calcium as CaO, 0.018%; titanium as TiO_2, 0.058%; and zirconium as ZrO_2, 0.030%. Surface area is given as 700 m^2/g. Maximum total volatile content at 1750°F (954.4°C) is 6.5%.

Samples were prepared in the following manner. Samples (0.5 g) of the silica gel were placed into either 7 ml glass ampoules or 1.5 ml quartz ampoules. All ampoules were then heat treated at 160°C for three or more hours under continuously maintained vacuum. One atmosphere of $C0_2$ was introduced upon cooling and the ampoules were sealed. The ampoules were then heat sterilized at 160°C for a minimum of 2.5 h. The glass ampoules were then packed in dry ice and received 0.83 Mrad of cobalt-60 gamma irradiation. They were maintained in dry ice during shipment to the Biospherics laboratory where they were immediately placed in a cold room maintained at 4°C. The purpose of the cold treatment was to minimize hypothesized (Danielli and Plumb) temperature induced annealings of any disjunctions or defects in the silica gel produced by the irradiation.

The silica gel in quartz ampoules was treated in the same manner as just described for the glass ampoules. These samples were then Subjected to UV irradiation. The UV source consisted of 10 Rayonett, 2,537 Å lamps (15 watts per lamp) arranged in a 10 inch diameter circle. The ampoules were placed on their sides for maximum surface exposure of the silica gel and were stationed at the bottom center of the circle of lamps. They were irradiated continuously for 14 days at approx. 25°C. The physical constraints made it impossible to maintain these samples in dry ice during irradiation. However, immediately after irradiation, they were packed in dry ice where they were maintained during shipment to Biospherics and introduction into the 4°C cold room.

*Davison Silica Gel Selective Adsorption Grades, Technical Bulletin, Adsorbents Department, Davison Chemical Grade Co.

Prior to conducting LR experiments, one set each of duplicate ampoules exposed to gamma and UV radiation were given the following respective heat treatments for 3 h: 4°C, 50°C, and 160°C. All heated samples were then returned to the cold room where Labeled Release experiments were conducted. Each ampoule was broken and the silica gel contents transferred aseptically to sterilized glass vials of 25 cc capacity. 0.1 ml of VMl flight-type Labeled Release medium was pipetted onto each portion of silica gel. Absorbent pads (20 mm diameter, No. 470, Schleicher and Schuell) placed inside the glass vial screw cap, were quickly moistened with two drops of a freshly prepared, saturated solution of $Ba(OH)_2$. These caps were immediately screwed on to collect evolved $^{14}CO_2$. Incubation was maintained at the 4°C temperature of the room. As a control against contamination and a check on the noise level of the medium, duplicate portions of the sterile VMl alone were incubated. At intervals ranging from 15 min initially to a maximum of once per day toward the end of the experiment, the glass vial caps were removed and immediately replaced with fresh ones containing $Ba(OH)_2$ moistened pads. All pads exposed for the collection of radioactive $^{14}CO_2$ were transferred to planchets, dried and counted for radioactivity in a gas flow counter.

The results, adjusted for instrument sensitivity and scaled to permit direct comparison of the Mars and Earth results, are presented in Fig. 5. Fig. 5A presents the data on evolved radioactivity from non-irradiated silica gel subjected to the various heat treatments. All samples of silica gel evolved an amount of gas within the typical sterile control range for the Labeled Release experiment. No significant differences are attributed to the heat treatments. The results of the gamma irradiated samples, however, Fig. 5B, show that gamma irradiation has a pronounced effect on the non-biological activity of the silica gel. The samples approach the activity levels seen for terrestrial organisms under Martian conditions in Fig. 1 and for the Mars data presented in Figs. 3 and 4. All figures have been drawn to approximately the same scale to facilitate visual comparison. The 160°C heating of the silica gel significantly attenuated its response. However, the magnitude of the effect does not approach that on Mars where the 160°C preheat treatment virtually eradicated the response. Although the duplicates for the non-heated samples and the samples heated to 50°C overlap, there may be a slight (approx. 10%) reduction in silica gel reactivity following heating at 50°C. Again, however, the effect does not approach the magnitude of the response

attenuation caused by heating the Mars sample to 50°C.

Figure 9 – below

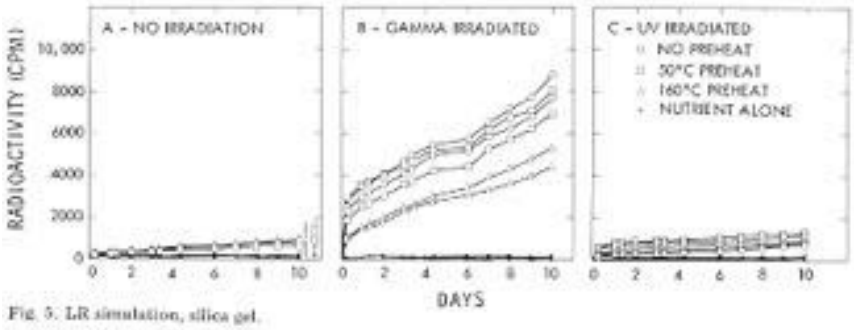


Fig. 5. LR simulation, silica gel.

Responses from the UV irradiated samples are presented in Fig. 5C. All are essentially within the range of control responses characterizing heat sterilized soils tested in the LR experiment.

Figure 10 – below

TABLE 1

pH of UV and gamma irradiated and non-irradiated silica gel after heat treatment and LR incubation.

Pretreatment temp. (°C)	pH		
	UV	Gamma	Non-irradiated
4	5.55	5.75	5.70
4	6.05	5.75	—
50	5.90	5.45	6.00
50	6.10	5.50	—
160	5.90	5.65	5.90
160	—	5.90	—

pH VM1 alone after incubation: 8.30, 7.55.

Upon the conclusion of the experiment, 0.5 ml of distilled water (pH 6.3, unbuffered) was then added to each remaining portion of the sample and its pH determined. The results are presented in Table 1. The remaining half of each sample was plated on trypticase-soy agar to check for sterility. The material was shaken out of the glass vial in which it had been incubated and dispersed on the agar plate by agitating the plate. After incubating at room temperature for four days, all plates were negative for colonies.

Figure 11 – Please see below

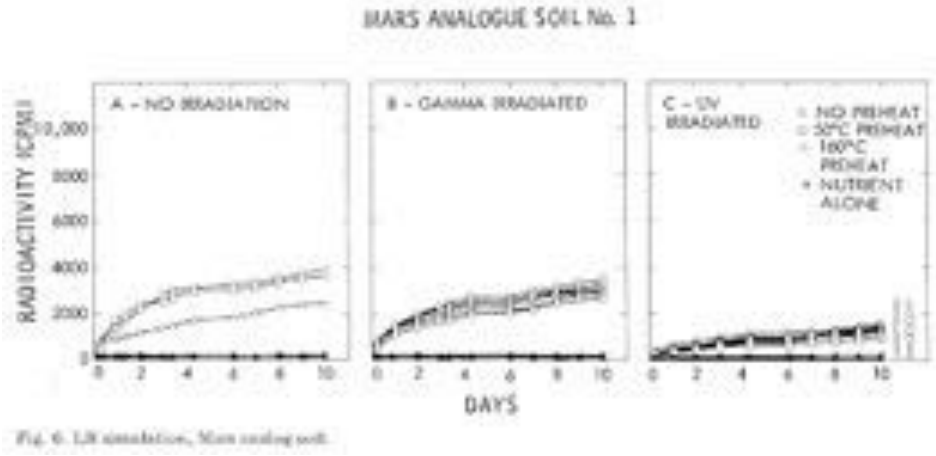
TABLE 2

Mars analog soil composition: wt %

Minerals		Elements	
Montmorillonite	51.3	Na	0.33
Montmorillonite	33.3	Mg	2.65
Kaserite	9.4	Al	3.94
Calcite	6.0	Si	16.15
Hematite	1.0	P	0.01
Magnetite	2.0	S	1.28
		Cl	0.02
	100.0	Ar	0.00
		K	0.15
		Ca	5.17
		Ti	0.19
		Fe	15.71
		C	0.73
		O	48.79
			100.0

An identical set of experiments was simultaneously performed on a portion of the Mars analog soil (Clark et al.) prepared by the Viking Inorganic Analysis Team in accordance with X-ray fluorescence analyses performed on Mars. The composition of the Mars analog soil is presented in Table 2. The results of this experiment are presented in Fig. 6. In its non-irradiated condition, the Mars analog soil, Fig. 6, produced gas evolution in significantly greater quantities than did non-irradiated silica gel. There is essentially no difference between the non-heated Mars analog soil sample and the sample preheated to 50°C. The magnitude of the responses approach 50% of those obtained from Mars. The apparent diminution in response of the sample preheated to 160°C may be an artifact in that the very early portion of the curve shows this response exceeding the others prior to a sharp break in the slope which may reflect a gas leak or other loss of that day's collection. Fig. 6B shows that exposure of the Mars analog soil to gamma irradiation did not increase its reactivity with VM1. Nor is any significant attenuation in response attributable to the heat treatment indicated. However, all responses are above normal control levels for typical sterilized soils examined in the LR experiment. UV irradiation of the Mars analog soil, as shown in Fig. 6C, resulted in a diminution in all responses producing results at, or near, the normal sterilized soil control levels.

Figure 12 – Please see below



The pH of each portion of the Mars analog soil was determined in the same manner as for the silica gel samples. The results are shown in Table 3. Sterility tests were performed on all portions of Mars analog soil at the termination of the LR experiment identically as described for the silica gel. All plates were negative.

Figure 13 – Please see below

TABLE 3

pH of UV and gamma irradiated mars analog soil after heat treatment and LR incubation.

Pretreatment temp. (°C)	pH		
	UV	Gamma	Non-irradiated
4	8.38	8.23	8.37
4	8.06	8.27	—
50	8.07	8.30	8.20
50	8.07	8.23	—
160	8.23	8.23	8.20
160	8.17	8.26	—

pH VM1 alone after incubation: 8.30, 7.55.

Discussion

The gamma radiation levels in the vicinities of the Viking spacecraft on Mars have not yet been measured. However, they must be low in that the background levels monitored by the LR radioactivity detectors correspond extremely closely to the gamma levels anticipated from the radioisotopic thermoelectric generators (RTGs) carried out by the Viking landers. Any external gamma contribution to the background readings must, therefore, be minor. The background level for the flight Labeled Release instrument on Earth, without the influence of the RTGs, is approx. 10 cpm. Thus, the 0.83 Mrad gamma dose administered to the silica gel and Mars analog soil samples represents an accumulated dose over a long period of time on Mars. This combination of a severe gamma dose administered to a substance highly susceptible to sustaining defects did cause a significant release of radioactive gas from the VMl approximating that of the LR Mars response in magnitude, but not in kinetics. Pretreatment of the irradiated silica gel at elevated temperatures resulted in decreased Labeled Release activity following

nutrient injection. This is evocative of the LR Mars data, but the temperature effect on silica gel is greatly muted with respect to that on Mars.

The UV flux incident to the surface of Mars has been estimated (Glasston, 1968) at 2 X 10^{-4} W cm^{-2}. Current estimates (Shorthill, pers. comm.) indicate that only 50% of this UV flux reaches the Martian surface, yielding a flux at the surface of 10^{-4} watts or 10^{3} ergs sec^{-1}. Based on an estimated UV dose of 10,000 μW cm^{-2}, or 10^{5} ergs sec^{-1}, incident to the samples from the irradiation array, the UV irradiation given the samples exceeds that on Mars, by approximately two orders of magnitude. The LR response produced by UV irradiated Mars analog soil is even less than that produced by non-irradiated Mars analog soil. Thus, the results of these two tests of the Mars analog soil make it unlikely, if the Mars analog soil is a faithful representation, that ultraviolet irradiation is responsible for the results obtained on Mars in the LR instrument. While the positive response of the non-irradiated Mars analog soil and its possible pretreatment temperature dependency are of interest, the fact that its capability to produce gas from VMl is UV-labile makes it an unlikely explanation of the Mars results. The analog soil tested contained alpha-Fe_2O_3. Recently, it has been suggested (Oyama, Viking Biology Team) that epsilon-Fe_2O_3 might be the form on Mars and that it might react with organic compounds. Accordingly, the Viking Inorganic Analysis Team is presently preparing another Mars analog soil, similar to the first, but containing epsilon-Fe_2O_3. The authors plan to test this material for possible activity in the LR experiment.

Conclusions

1. The Viking Labeled Release Experiment has produced evidence for life on Mars. However, non-terrestrial soil chemistry may be mimicking a biological response. All hypotheses require further study before a conclusion can be reached.
2. Intense gamma irradiation of silica gel causes evolution of gas when the LR VMl medium is applied to it. The amount of gas evolved approaches that observed in the LR experiment on Mars. However, while some pretreatment temperature dependency was observed in the silica gel, the effects are not as great as those observed in the Mars experiments. This "worst case" test is extreme in that the gamma levels on Mars do not approach the dosage applied in the test. However, the reaction is of sufficient interest that it will be explored further and its possible relevancy, to the LR Mars results studied, perhaps as an analog of long-term exposure to the solar wind.
3. No significant effect was observed in the LR experiment when silica gel was irradiated by UV light.
4. Non-irradiated Mars analog soil produces a response in the LR experiment. The response may show some slight pretreatment temperature dependency, but not of the magnitude observed on Mars.
5. Gamma irradiation of the Mars analog soil had no apparent effect in the LR experiment.
6. UV irradiation of the Mars analog soil reduced the LR response to well within those normally observed from sterilized soils. It is thus unlikely that the Mars

results can be attributed to a factor in the Mars analog soil.

Conclusions 3 and 6 in conjunction with the LR Mars data obtained from the "under the rock" sample tend to eliminate UV radiation as causative of the Labeled Release response.

Updated versions of the Mars analog soil (including epsilon-Fe_2O_3) will be tested with and without gamma irradiation in the Labeled Release Test Standards Module (TSM) (Levin and Straat, 1976) where they can be maintained under simulated Mars conditions throughout the incubation period. The effect of additional injections of nutrient can be studied in the TSM for comparison with the Mars results.

RISK ASSESSMENT	Overall risk (provided safety procedures are followed) = LOW

Substance	**Hazard**	**Comment**
Bacterial colonies	**BIOHAZARD**	Agar plates will contain numerous bacterial colonies at high concentrations. They must remain closed at all times, and sealed via two strips of sellotape either side of the dish – incubate at a temperature no higher than 20°C. Cotton swabs used to sample different areas should be disposed of in the disinfectant solution provided. Agar plates should be disposed of in an autoclave after use.
UV light	**HAZARD**	UV light is damaging to skin cells and also cells of the retina. Exposure to UV light from the sterilising probe should be prevented at all times
Cotton swab	**LOW HAZRAD**	Possibly harbours pathogenic microbes after being used for sampling. However, the concentrations of microbes will likely be at a low level prior to incubation on agar. Cotton swab should be disposed of using the sterile solution provided.

Additional comments:

- Wash hands thoroughly before and after procedure and wear latex gloves if available
- Agar plates should be sealed with only two strips of sellotape at either side of the plate, to prevent anaerobic conditions developing and pathogenic bacteria being grown.
- Under no circumstances should the agar plates be opened once incubation has begun.
- Agar plates must be disposed of using an autoclave at the end of the investigation
- Ensure that the UV probe is switched off when not in use to prevent accidental exposure to UV light

In case of accident/incident:

• Exposure to UV light	Depending on the length of time that the exposure was for, seek medical advice.
• Exposure to bacterial colonies	If skin contact, immediately wash affected area with soap and warm water. Antiseptic solutions or wipes may also be used to clean affected area. Re-seal any agar plate that has become exposed and arrange for disposal via autoclave. Seek medical advice.

Image References:

Figures 1-4 - Owned by Christopher Carr – Author of Classroom Activity #2

Figure 5 - GILBERT V. LEVIN and PATRICIA ANN STRAAT (1977) *LIFE ON MARS? THE VIKING LABELED RELEASE EXPERIMENT** [WWW] Copyright: Elsevier/North-Holland Scientific Publishers, Ltd. http://mars.spherix.com/lifemars/lifemars.htm [03/12/2012]

Figure 6 - GILBERT V. LEVIN and PATRICIA ANN STRAAT (1977) *LIFE ON MARS? THE VIKING LABELED RELEASE EXPERIMENT** [WWW] Copyright: Elsevier/North-Holland Scientific Publishers, Ltd. http://mars.spherix.com/lifemars/lifemars.htm [03/12/2012]

Figure 7 - GILBERT V. LEVIN and PATRICIA ANN STRAAT (1977) *LIFE ON MARS? THE VIKING LABELED RELEASE EXPERIMENT** [WWW] Copyright: Elsevier/North-Holland Scientific Publishers, Ltd. http://mars.spherix.com/lifemars/lifemars.htm [03/12/2012]

Figure 8 - GILBERT V. LEVIN and PATRICIA ANN STRAAT (1977) *LIFE ON MARS? THE VIKING LABELED RELEASE EXPERIMENT** [WWW] Copyright: Elsevier/North-Holland Scientific Publishers, Ltd. http://mars.spherix.com/lifemars/lifemars.htm [03/12/2012]

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We Are Aliens! – Classroom activity 3 (Biology)

What's your limit?

Background:

Physical conditions on other planets and moons are unlikely to be within the same ranges as that experienced by Earth. However, a significant degree of variance from 'ideal' ranges may be tolerable for a small number of organisms known as *extremophiles*. These are organisms which can withstand (and even thrive) in extreme environments on Earth, including those of temperature, pH and salinity. This investigation looks at the effects of subjecting a living organism (yeast) to some extreme conditions and observing changes to rates of reaction – indicating the ranges at which it can survive. The investigation is aimed mainly at the upper end of KS3 or KS4. However, it is possible to adapt the investigation into a form more suitable for KS5 if required.

Curriculum areas covered:

- Respiration
- Cell biology
- Enzymes & rates of reaction
- How Science Works – collecting, analysing (via statistical tests) and interpreting data

Equipment list:

- Empty water bottles (250ml)
- Balloons
- Dried yeast granules
- Glucose
- White vinegar
- Water at different temperatures – hot, warm and cold
- Marker pen
- Andrews Salts (dissolve in water to create an alkaline solution)
- Salt (to create solutions of different salinities)

Method:

The investigation involves subjecting some pre-prepared yeast samples to different conditions of temperature, pH and salinity. A mixture of yeast and glucose is hydrated with water inside a bottle, with a balloon placed on the top to gauge the amount of carbon dioxide produced, and hence activity of the yeast. **The task sheets that follow give full details of the main investigations** but it is important to note the following details regarding the initial setup of apparatus:

- You will need to first set up several bottles each containing two teaspoons of glucose and four teaspoons of yeast. Each group in the class will need three bottles.
- The bottles can be pre-marked with lines that show approximate volumes of water or other solutions required.
- The yeast, glucose and water must be firmly shaken for about 30 seconds before the investigation commences.

- The results of the investigation are not instantaneous – you will need to plan for at least 30 minutes while balloons become inflated by carbon dioxide produced from the yeast. This would be a good time for students to answer questions on the task sheets and feedback their predictions to the whole class.
- The investigation has plenty of scope for developments, refinements and improvements – students should be encouraged to carry out an evaluation after the investigation is over.

Discussion:

After about 30 minutes has elapsed, ask each group to come to the front of the class and hold their bottles up (with partially inflated balloons). Ask each group to describe the differences between the relative amounts of balloon inflation and then explain using their knowledge of enzymes, cells, rates of reaction and/or osmosis:

Temperature – warm temperature will show greatest rate of inflation, due to enzymes in yeast being closest to their optimum temperature. Cold temperatures will show little inflation due to reduced kinetic energy and hence rates of reaction. Hot temperatures will show little inflation due to denaturation of some enzymes.

pH – the enzymes in yeast generally have optimum values close to pH 7. There will be little inflation in acidic or alkaline conditions due to the denaturation of these enzymes.

Salinity – the addition of salt lowers the water potential of the solution in the bottle. The more salt added, the lower the water potential becomes resulting in water loss from yeast cells (and their subsequent death). Inflation of the balloons will likely diminish as more and more salt is added.

Meet the record breakers...

Finish the lesson with a discussion on the extreme conditions that life has been known to withstand:

Hottest	121°C	Strain 121, an Archaeon, in the Pyrodictiaceae family. Isolated from a hydrothermal vent.
Coldest	-15°C	Cryptoendoliths (Antarctica)
Deepest	4 km	Bacteria that live along fractures in rock under the Earth's crust and are exposed to high levels of pressure, heat, and radiation.
Most acidic	pH 0.0	Bacteria that grow in caves.
Most alkaline	pH 11	Alkaliphilic bacteria are found in areas where large bodies of water have evaporated and left behind layers of alkaline (i.e., basic) minerals.
Radiation Dose	5 million rads	Deinococcus radiodurans is a common soil organism. A radiation dose rads dose of 1000 rads will kill a person.
Longest period in space	6 years	Bacillus subtilis survived in a NASA satellite that exposed in space test organisms to the extreme conditions of outer space.

Note that all these organisms are *bacterial* – more complex life forms are simply *too complicated* to withstand these environments (the more complex something is, the more there is to go wrong!). Finding life existing in extreme environments may be possible, but it is unlikely to anything other than simple micro-organisms.

Further examples of Earthly extremophiles

Cold – The McMurdo Dry Valleys in Antarctica are some of the coldest, driest deserts on Earth, with average annual temperatures of -20°C (-4°F) and less than 10 centimetres (4 inches) of precipitation a year. Scientists have found bacteria in liquid water pockets embedded about twelve feet deep in "solid" lake ice. Some of these bacteria use chemical nutrients from particles of dirt in the ice and use energy from sunlight for photosynthesis.

Hot – Large concentrations of microbes thrive in Yellowstone National Park's Grand Prismatic Springs, a hot spring with water temperatures up to 90°C (188°F). Other hot springs in Yellowstone are extremely acidic, yet are home to many different kinds of bacteria and microbes. Many of these microbes use chemical nutrients in the waters and energy from sunlight for photosynthesis.

Deep underground – Scientists have discovered bacteria living in groundwater 5 kilometres below the surface in deep gold mines of the Witwatersrand Basin in South Africa. These microbes thrive in cavities and cracks in rocks. Scientists are also are investigating life within and below permafrost in northern Canada.

Bottom of the sea – Scientists have found abundant life clustered around hydrothermal vents on the ocean floor, including bacteria, mussels, clams, shrimp, and giant tubeworms that can reach ten feet in length. Water pouring out of the vents in the complete darkness thousands of feet under the surface of the sea can reach temperatures of 113-120°C (235-248°F). The high pressures keep the water from boiling. Bacteria use chemicals in the vent's water, primarily hydrogen sulfide, as their energy source instead of sunlight. Other creatures survive by eating the bacteria or each other.

High Acidity – The water in the Rio Tinto in southwestern Spain is very acidic, a result of chemical reactions between the water, and iron and sulfur minerals in the ground. The river has a deep red color, like wine, because of iron dissolved in the water. Microbes living in the water use chemical reactions with iron and sulfur minerals to generate the energy they need. Products from these metabolic reactions contribute to the low pH in the environment. Many algae and fungi also live in the acidic waters.

Source: NASA

Task sheet

You are investigating the effect of pH on the rate of respiration in yeast.

You will need to work together as a team to ensure that each experiment takes place at the same time, so that your results can be compared

Collect three of the bottles that have been pre-prepared with yeast and sugar and collect three balloons

You will now need to vary a key variable depending on your group:

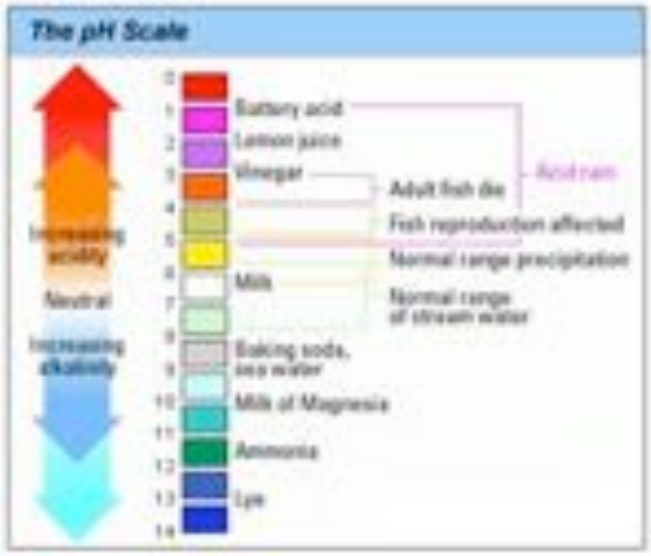


Figure 1 – above

Varying pH

Collect some warm water from a water bath and add this to your bottles until it reaches the first black line on the side of the bottle. Shake the bottle well to mix the contents.

- Add a small volume of vinegar to your first bottle until the water level reaches the second black line. Shake again and **when you are ready to start, immediately attach the balloon to the end of the bottle**.

- Add a small volume of sodium bicarbonate solution to your second bottle until the water level reaches the second black line. Shake again and **when you are ready to start, immediately attach the balloon to the end of the bottle**.

- Add a small volume of warm water from a water bath to your third bottle until the water level reaches the second black line. Shake again and **when you are ready to start, immediately attach the balloon to the end of the bottle**.

Once you have set the bottles up, you will need to leave them to stand for at least 20 minutes. You should then be able to make some comparisons between the different bottles

Think about it.....

1. Which bottles showed the greatest rate of respiration and which showed the least?
2. What sort of pH conditions do you think yeast is adapted to live in?
3. Do you have enough data to establish the range of pH values to which yeast is tolerant? How could you improve the investigation to give a more accurate estimate of the range of tolerances?
4. Explain why changes in pH would affect the rate of respiration in yeast
5. What was the purpose of adding more water to your third bottle?

Fig. 2 – above

Task sheet

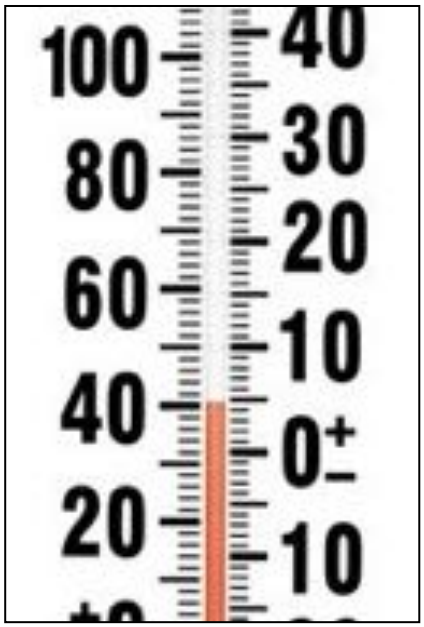


Figure 3 – above

You are investigating the effect of temperature on the rate of respiration in yeast.

You will need to work together as a team to ensure that each experiment takes place at the same time, so that your results can be compared

Collect three of the bottles that have been pre-prepared with yeast and sugar and collect three balloons

You will now need to vary a key variable depending on your group:

Varying temperature

You are provided with cold, warm and hot water in three different water baths. You should note the temperatures of the water using the thermometers provided.

- Add a small volume of cold water from the cold water bath to your first bottle until the water level reaches the second black line on the bottle. Shake the bottle well and **when you are ready to start, immediately attach the balloon to the end of the bottle**.

- Add a small volume of warm water to your second bottle until the water level reaches the second black line. Shake again and **when you are ready to start, immediately attach the balloon to the end of the bottle**.

- Add a small volume of hot water (CARE!) from a water bath to your third bottle until the water level reaches the second black line. Shake again and **when you are ready to start, immediately attach the balloon to the end of the bottle**.

Once you have set the bottles up, you will need to leave them to stand for at least 20 minutes. You should then be able to make some comparisons between the different bottles

Think about it.....

1. Which bottles showed the greatest rate of respiration and which showed the least?
2. What sort of temperature conditions do you think yeast is adapted to live in?
3. Do you have enough data to establish the range of temperature values to which yeast is tolerant? How could you improve the investigation to give a more accurate estimate of the range of tolerances?
4. Explain why changes in temperature would affect the rate of respiration in yeast
5. Do you think that the surface temperature of a planet would have any implications about the likelihood of finding life there? Explain your answer

Fig. 2 – above

Task sheet

You are investigating the effect of salinity on the rate of respiration in yeast.

You will need to work together as a team to ensure that each experiment takes place at the same time, so that your results can be compared

Collect three of the bottles that have been pre-prepared with yeast and sugar and collect three balloons

You will now need to vary a key variable depending on your group:

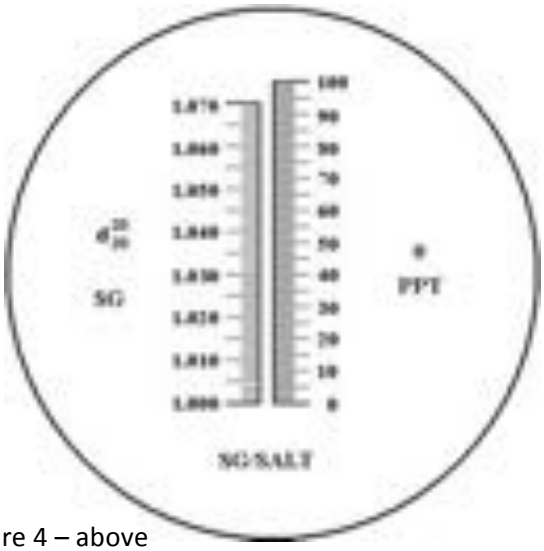


Figure 4 – above

Varying salinity

Collect some warm water from a water bath and add this to your bottles until it reaches the second black line on the side of the bottle. Shake the bottle well to mix the contents.

- Add two teaspoons of salt to your first bottle. Shake well so that the salt dissolves and **when you are ready to start, immediately attach the balloon to the end of the bottle**.
- Add six teaspoons of salt to your second bottle. Shake well so that the salt dissolves and **when you are ready to start, immediately attach the balloon to the end of the bottle**.
- Do not add any salt to your third bottle. Shake well and **when you are ready to start, immediately attach the balloon to the end of the bottle**.

Once you have set the bottles up, you will need to leave them to stand for at least 20 minutes. You should then be able to make some comparisons between the different bottles

Think about it.....

1. Which bottles showed the greatest rate of respiration and which showed the least?
2. What sort of salinity conditions do you think yeast is adapted to live in?
3. Do you have enough data to establish the range of salinity values to which yeast is tolerant? How could you improve the investigation to give a more accurate estimate of the range of tolerances?
4. Explain why changes in salinity would affect the rate of respiration in yeast

Fig. 2 – above

RISK ASSESSMENT	Overall risk (provided safety procedures are followed) = LOW

Substance	**Hazard**	**Comment**
Yeast	**BIOHAZARD**	Yeast is a micro-organism that should not be ingested or allowed to enter cuts or abrasions on skin surfaces. Thorough washing of hands before and after use is generally the only precaution required.
Vinegar	**LOW HAZARD**	Weak acid, requiring eye protection to be worn. Main danger comes from squirting out of the bottle as pressure builds due to carbon dioxide production
Sodium bicarbonate solution	**LOW HAZARD**	Weak alkali, requiring eye protection to be worn. Main danger comes from squirting out of the bottle as pressure builds due to carbon dioxide production
Hot water > 70 °C	HAZARD	Danger of scalding. Eye protection must be worn while handling. Teacher to arrange for hot water to be poured into separate beakers which students can then use

Additional comments:

- Care should be taken when bottles are shaken to hydrate yeast – make sure bottle caps are fully screwed on to prevent any possible ejection of the contents
- Eye protection must be worn throughout the practical, particularly when removing, inspecting or adding balloons as pressure can be released suddenly causing the contents of the bottle to be ejected

In case of accident/incident:

• **In the eye**	Flood the eye with gently-running tap water for 10 minutes. See a doctor.
• **Swallowed**	Do no more than wash out the mouth with water. Do **not** induce vomiting. Sips of water may help cool the throat and help keep the airway open. See a doctor.
• **Scalds**	Run affected area under cold water for at least ten minutes and possibly longer depending on extent on the injury. Apply a sterile dressing and see a doctor if blistering occurs.
• **Spilt on skin or clothing**	Remove contaminated clothing. Drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor.

Image References:

Figure 01 - LUX Innovate Ltd (2009) *Assessment of erosion susceptibility* [WWW] LUX DS Available from: http://luxds.com/web/index.php?option=com_content&task=view&id=31 [04/12/2012]

Figure 01 - ELMHURST (date unknown) *pH Scale – Introduction and Definitions* [WWW] Available from: http://www.elmhurst.edu/~chm/vchembook/184ph.html [04/12/2012]

Figure 02 - TOON, MARK (2012) *Stickman hands on hips look puzzled clipart* [WWW] Mark Toon Available from: http://www.marktoon.co.uk/cartoons/stickmen/stickman-hands-on-hips-looks-puzzled-clipart.gif [04/12/2012]

Figure 03 - REIGN OVER US (09-07-2010) *The sights of summer* [WWW] Available from: http://reignover.us/2010/07/ [04/12/2012]

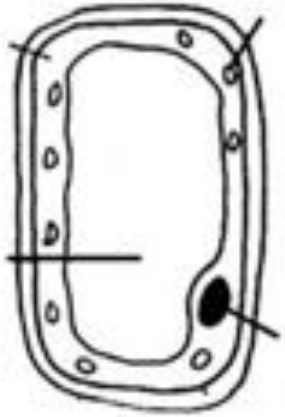
Figure 04 - Land_Fish (04-10-2004) *Re: Refractometer @ swingarm SG testers* [WWW] Post by – Land_Fish Available from: http://www.3reef.com/forums/water-chemistry/refractometer-swingarm-sg-testers-32759.html [04/12/2012]

We Are Aliens! – Classroom activity 4 (Biology)

Cells

1. First label the two cells below as plant or animal
2. Now add these labels

nucleus cytoplasm chloroplast cell wall cell membrane vacuole



3. Fill in the table below by listing the parts found in plant and animal cells.

Plant cell	Animal cell

4. Use colours to match the part with its job

Part
Nucleus
Cytoplasm
Membrane
Cell wall
Vacuole
Chloroplast

Job
Helps to provide support and contains cell sap
Absorbs light energy for photosynthesis
Carries genetic information
Provides support
Many chemical reactions occur here
Controls the movement of substances in and out of the cell

5. Here are two student models of cells

a) Are they plant or animal cells?
b) Add as many labels as you can

We Are Aliens! – Classroom activity 5 (Biology)

Making Model Cells

The cell is the smallest unit of life and although we don't know exactly when they first appeared on Earth we know that life arrived a remarkably short time after the birth of the planet. For many millennia single celled organisms were the only form of life on Earth and it's this type of life that astrobiologists are looking for elsewhere in the solar system. In this fun activity, wallpaper paste is used to build model cells. It's very good for helping students to appreciate what cells are like and is very memorable.

Equipment

- Wallpaper paste (ensure it's the almost colourless sort rather than the type based on starch)
- Small sealable plastic bags (sandwich bags are OK but rather big. Smaller bags are readily available on line. For example you can get 1000 3" bags here for £6 amazon link)
- Waterproof pen(s)

To make microbes

- Cotton
- String
- lengths of wool

To make plant cells

- Green tiddlywinks/counters (chloroplasts)
- {Red tiddlywinks/counters (mitochondria)}
- Cling film (vacuole)
- Marbles (nucleus)

Practical tips

The wallpaper paste needs making up before the lesson and should only be dispensed by the teacher unless you want a lot of mess. Follow the instructions on the packet but make it up using the smallest amount of water specified (ie as if hanging heavy paper).

If you want to identify the cells later, ensure student write their names on the bags before they are filled. Use the water proof pens for this.

To make a model microbe:

1. Add some lengths of cotton to the plastic bag to represent the DNA strands. You could also add some cotton loops to represent plasmids.
2. The teacher adds a good dollop of wallpaper paste
3. Squeeze out the air and seal the bag. When the outside of the bag is dry, you may want to ensure it stays sealed by adding sellotape
4. Using sellotape, fix a length of wool to the outside of the bag to represent flagella
5. Add several short length of this string to represent pillli
6. You can even use a layer of wall paper paste on the outside of the bag to represent a bacterial capsule.

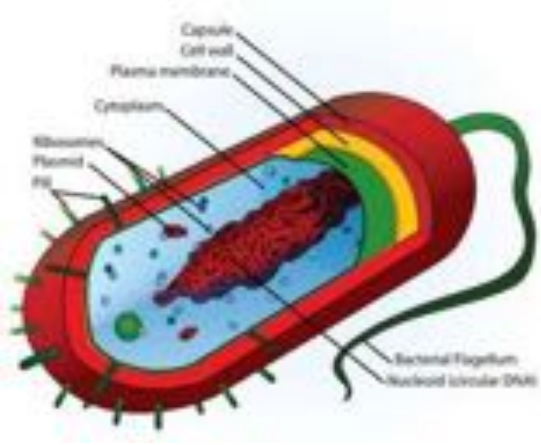


Figure 1 – above

To make a model plant cell:

1. Carefully run some water into a “saggy” piece of cling film and then twist the corners together to make a “bubble” of water. You may want to add sellotape to help seal it.
2. Place the cling film bubble, marble and several green tiddlywinks, into a plastic bag. If appropriate to your specification you can also add red tiddlywinks
3. Teacher adds a good dollop of wallpaper paste, then seal the bag to finish the model cell

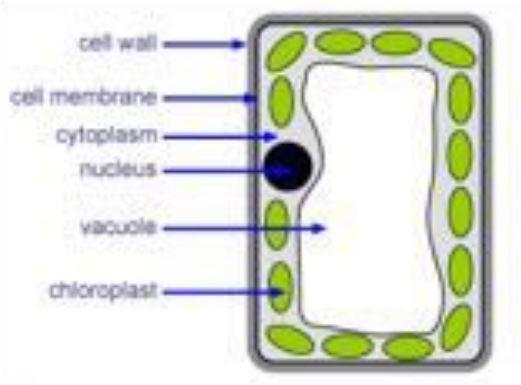


Figure 2 – above

Follow up work

Match the part of the model to what it represents in a real microbe

Plastic bag	cytoplasm
Cotton thread	cell membrane
Wall paper paste	flagellum
Wool	pilli
String	chromosome

Match the part of the model to what it represents in a real plant cell

Marble	vacuole
Green tiddlywinks	cytoplasm
Wallpaper paste	membrane
Plastic bag cell	chloroplasts
Cling film	nucleus

The one part of the cell that was missing was the _____(cell wall)

There is also a simple reinforcement worksheet on cells for students to complete

Taking it further *(taken from the University of Utah's learn genetics website)*
Some of the oldest cells on Earth are single-cell organisms called bacteria. Fossil records indicate that mounds of bacteria once covered young Earth. Some began making their own food using carbon dioxide in the atmosphere and energy they harvested from the sun. This process (called photosynthesis) produced enough oxygen to change Earth's atmosphere. Soon afterward, new oxygen-breathing life forms came onto the scene. With a population of increasingly diverse bacterial life, the stage was set for some amazing things to happen

There is compelling evidence that mitochondria and chloroplasts were once primitive bacterial cells. This evidence is described in the endosymbiotic theory. How did this theory get its name? Symbiosis occurs when two different species benefit from living and working together. When one organism actually lives inside the other it's called endosymbiosis. The endosymbiotic theory describes how a large host cell and ingested bacteria could easily become dependent on one another for survival, resulting in a permanent relationship. Over millions of years of evolution, mitochondria and chloroplasts have become more specialized and today they cannot live outside the cell.

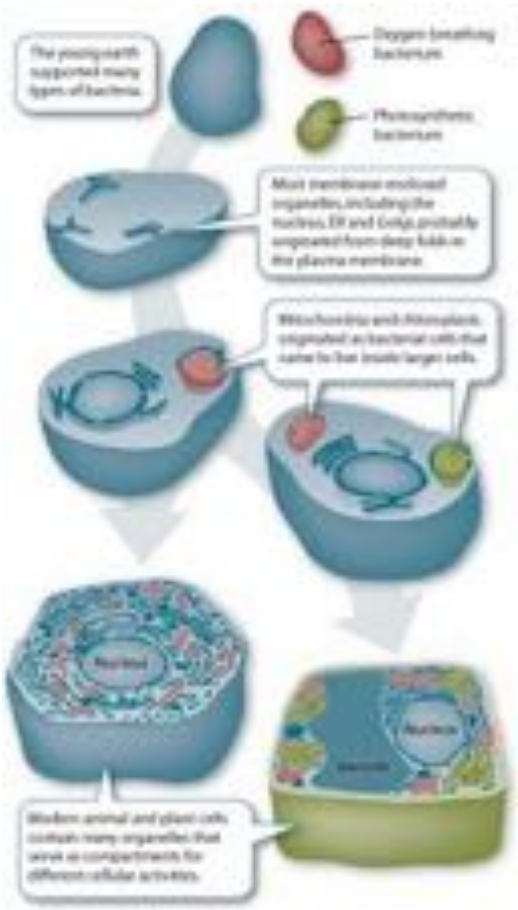


Figure 3 – above

Image References:

Figure 01 - RUIZ, MARIANA (date unknown) Gram Stain and Bacterial Cell Wall Structure [WWW] Available from: http://tamiport.hubpages.com/hub/Gram-Stain-and-Bacterial-Cell-Wall-Structure#slide2149066 [06/12/2012]

Figure 02 - 9A REVISION (date unknown) *These are the things that plants need for photosynthesis* [WWW] Available from: http://9arevision.wikispaces.com/plants [04/12/2012]

Figure 03 - UTAH LEARN GENETICS (date unknown) *Endosymbiotic Origin of Chloroplasts and Mitochondria* [WWW] Utah Learn Genetics – Education Available from: http://www.uic.edu/classes/bios/bios100/lectures/cells.htm [04/12/2012]

We Are Aliens! – Classroom activity 1 (Chemistry)

Living in the Freezer

The cells of plants, animals and bacteria living in low temperature environments on Earth often contain antifreeze proteins to prevent their body fluids from freezing.

If there's life anywhere else in our solar system, it's likely that it too will have to cope with cold conditions and need some sort of antifreeze.

You can demonstrate the effect that freezing water has on cells by displaying strawberries (and other fruit and veg) after they have been in the freezer. The ice crystals that form have a larger volume than liquid water they're made from and the resulting expansion breaks open cell walls resulting in "soggy" strawberries

In this activity, students plan and carry out an experiment to find out the effect of an antifreeze on the melting point of water. The aim of the experiment is conceptually simple, allowing students to develop their planning and practical skills.

They may already know that "grit" containing rock salt (impure sodium chloride) is spread on roads in the winter to stop ice forming. Liquid antifreezes are also added to the water in the coolant system and screen wash bottles of cars to prevent water from freezing over the winter.

There are two different methods that could be used. Depending on the time you have available, you might like to steer students towards one or the other.

1. Finding the concentration needed to stop water from freezing in a domestic freezer. Different concentrations of antifreeze and used to fill an ice cube tray and then placed in a freezer. The next lesson, students can view the ice cubes and see which concentrations remain liquid.
2. Finding out how long ice cubes made with different concentrations of antifreeze take to melt. The longer they take to melt, the less effective the antifreeze. Students should devise their own method for determining the melt time but suitable methods include, placing the cube in a beaker of water and timing how long it takes to disappear and placing the ice cube in a funnel held over 10cm^3 measuring cylinder and measuring the volume of water produced in a certain time. To save time, he ice cubes could be made up ready by technicians

Using either of the methods above, an alternative investigation is to determine which antifreeze is most effective.

Antifreezes to try include:

- Rock salt
- Pure sodium chloride
- Calcium chloride irritant
- Potassium chloride
- Ethan-1,2-diol (ethylene glycol) (this is the active ingredient in commercial antifreezes) harmful
- Commercial antifreeze
- IMS/IDA/ethanol highly flammable and harmful
- Windscreen washer fluid (often contains ethanol)

Risk Assessment- refer to CLEAPS hazchem cards and carry out your own risk assessment.

Equipment List will vary depending up on the exact method students choose but it likely to include

- One or more antifreezes (see above)
- Ice cube trays
- Access to a freezer
- Food colourings
- Measuring cylinders
- Distilled water
- Balance
- Funnels
- Beakers
- (thermometers – for measuring water temperature if melting ice cubes)

Practical Hints

When making up solutions of liquid antifreezes, students could use $10cm^3$ measuring cylinders.

$10cm^3$ water = 0% antifreeze

$9.5cm^3$ water + $0.5cm^3$ antifreeze = 5% antifreeze

$9cm^3$ water + $1cm^3$ antifreeze = 10% antifreeze

$8cm^3$ water + $2cm^3$ antifreeze = 20% antifreeze

And so on

When making up solutions of solid antifreezes then % concentrations are worked out most easily w/v (weight for volume)

$100cm^3$ water = 0% antifreeze

$100cm^3$ water + 5g salt = 5% antifreeze

$100cm^3$ water + 10g salt = 10% antifreeze

And so on

Commercial antifreeze solutions are often coloured and concentrations can be seen by judging the depth of colour. If students make up their own ice cubes, it is recommended that they use a row of the tray for successive concentrations. Indelible pens can be used to mark the trays with names etc.

If making up ice cubes with different salt concentrations, it can save a lot of confusion if food colouring is also added to the water. So, for example, 5% cubes are yellow, 10% cubes are green etc.

Domestic freezers usually operate at about -20^oC but you may be able to get them colder if they have an adjustable thermostat. If you have the option of "fast freeze" you may be able to get down to about -26^oC

Follow up work

A data analysis worksheet is included that requires students to draw a bar graph that includes negative numbers and interpret the data it shows.

Extension

You could go on to investigate the effect of an antifreeze on the boiling point of water. Students may be surprised to find that salt raises the boiling point of water.

We Are Aliens! – Classroom activity 1 (Chemistry)

Antifreezes

Name _____

(graph paper required)

	Anti-freeze liquid			
	A	B	C	D
Freezing Point (°C)	10	-6	0	-15

Draw a bar graph (on graph paper) to show this data.
Before you start, think about where the horizontal axis should be.

Use your graph or the table to complete this work.

1. Liquid _____ has the lowest freezing point.
2. Liquid _____ has the highest freezing point.
3. Liquid _____ could be water.
4. Liquid _____ would be useless as an antifreeze.
5. Liquid _____ would make the best antifreeze.
6. Liquid C will melt at _____ °C
7. If liquids B and C were mixed, the freezing point would be about _____ °C
8. If liquids A and D were mixed, the freezing point would be about _____ °C
9. One winter day the temperature is -2°C.

   Liquids _____ and _____ would actually be solids on this day.
10. The average temperature on Mars is -55°C.

    Explain why none of these liquids would be any good as an antifreeze on Mars

11. Enceladus is a moon of Saturn. This picture shows a plume of ice and water gushing into space. Scientists have discovered that the water contains salt. Explain why this might help keep the water a liquid.

_____

_____

_____

_____

_____

_____

We Are Aliens! – Classroom activity 6 (Chemistry)

Using UV beads to investigate reaction rates

Overview

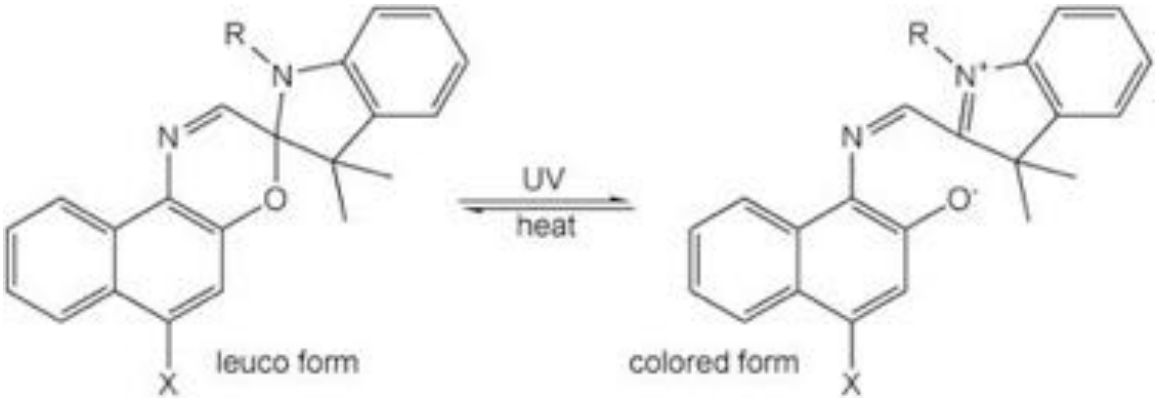
The rate of a chemical reaction is highly dependent on temperature; often a 10^{o} rise in temperature will double a reaction rate. The chemical reactions that take place in living cells are now exception, indeed many organism regulate their temperature very accurately for this reason. In this experiment students will explore how rate depends on temperature in a very direct manner without the complication of measuring chemical reactants of their products.

Photochromic beads contain a UV sensitive pigment. When placed under UV light or sunlight they change from colourless to coloured. Once the light source is removed their colour gradually fades until they are colourless again. The reaction is reversible and repeatable. The return to the colourless form provides a reaction which can be safely investigated experimentally. The beads can also be used as a simple UV radiation detector. Many schools will already have a supply of these beads but if not they are available from mindsetsonline.co.uk for around £6.50 for 100 either in single colours or mixed.

Figure 1 – Please see above

Scientific Concepts

The dye molecules in UV reactive beads consist of two large flat conjugated systems or chromophores that are at right angles to one another. They absorb radiation only in the UV part of the spectrum and the dye remains colourless. When UV light excites the central carbon atom, the two smaller chromophores form one large conjugated system. This chromophore is large enough to shift the absorption into the visible part of the spectrum and the dye becomes coloured. By changing the size of the two conjugated sections of the molecule, different wavelengths are absorbed and different dye colours can be produced. Heat from the surroundings provides the activation energy needed to return the coloured form of the molecule back to its lower energy colourless form.



It is the reaction that produces the colourless form that is most easily investigated in this scenario. However, there is scope for further space related work. Stars emit a wide range of electromagnetic radiation including ultra violet. On Earth we are protected from much of this radiation by our atmosphere, however in space or on other worlds there may be no such protection. Complex organic molecules will absorb and hence be effected by this radiation. In many space environments molecules are exposed to short wavelength radiation and low temperatures and this reaction provides a model for the type of reactions that can lead to the formation of life precursor molecules such as the amino acids found in meteorites and comets.

Description of Activity

A number of beads are exposed to UV light, either from a UV lamp or sunlight. It helps to keep the beads cool while being exposed to the UV. Placing them in a beaker with some crushed ice will achieve this. Once fully coloured they are quickly removed from the light source and immediately placed in a beaker of water at a pre-set temperature. The time for the beads to fade to the same shade as some reference beads not exposed to UV is recorded. This is done over a range of temperatures. The beaker should be placed on a white tile or paper to facilitate judging when the colour has completely faded. A temperature range from 20°C to 50°C provides a suitable range so the water could come from hot and cold taps. If a UV source is unavailable then the beads can be stored in their coloured state for several days in a freezer.

At Key Stage 4 the activity could be used to investigate the effect of temperature on rate of reaction with students plotting graphs of 1/time against temperature. Students could use Excel to try and fit a line to the data and to link the findings to collision theory and the concept of activation enthalpy. Alternatively the provided results sheet could be used to speed things up.

Teaching Resources

UV beads, stopwatches, beakers, thermometers (0-50°C are ideal but any will do), white tiles and a source of hot and cold water e.g. kettle or hot tap. A UV lamp may be needed on a dull winters day.

UV torch £9.99 from Amazon

UV Beads from mindsetsonline.co.uk

Figure 2 – Please see to the left

Health and Safety

The beads may represent a choking hazard for very small children. Care should be taken with hot water and glassware.

Associated Digital Resources

WAL_Chemistry_06_Results.docx

Extra Resources

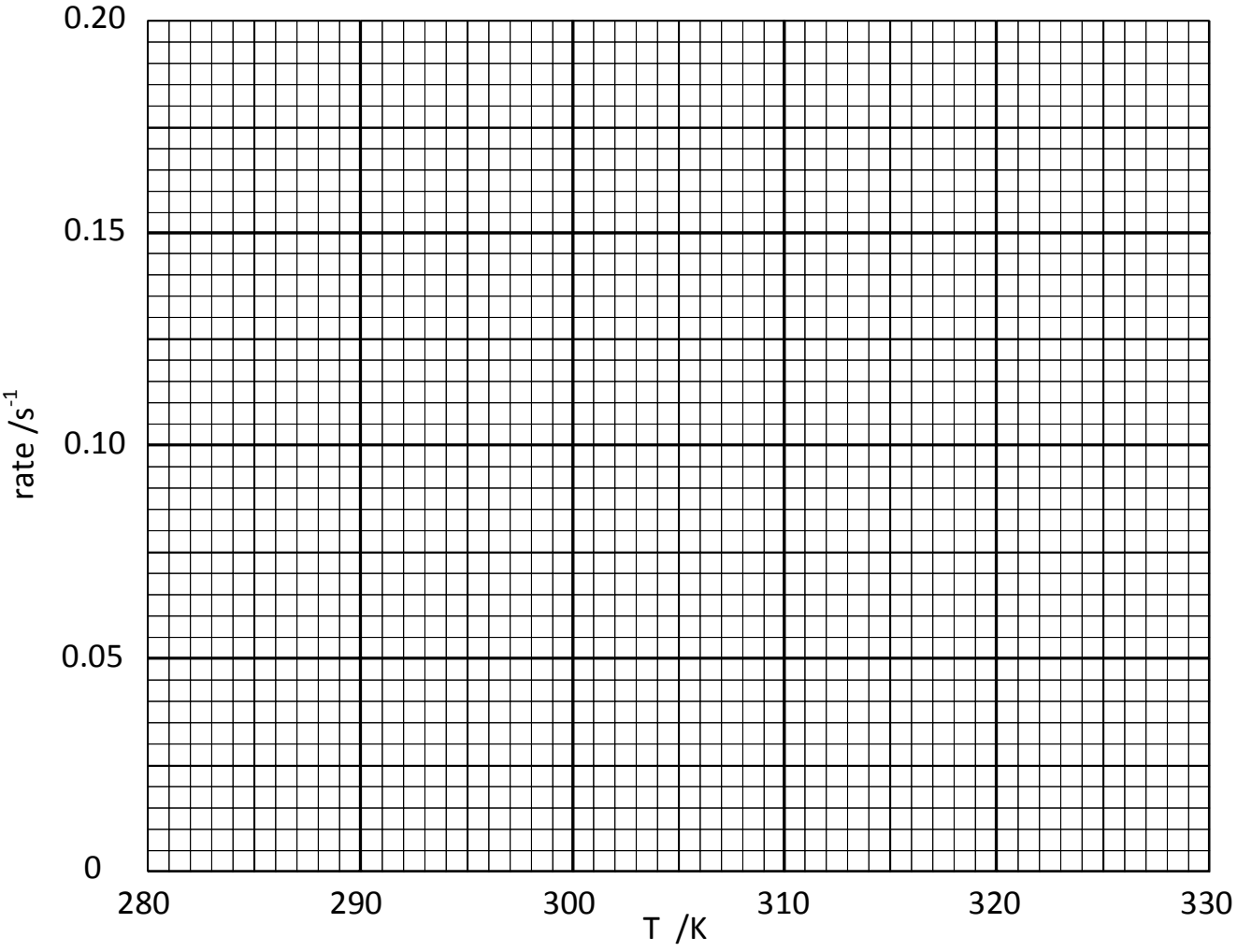
WAL_Chemistry_06_VennDiagram_Worksheet.docx

The Venn diagram activity works well at KS4 alongside this activity. It is a useful diagnostic tool revealing misconceptions in students (and teachers) understanding of collision theory. It can be scaled up so each student has an A5 print out a statement and the Venn Diagram is chalked on the ground. Through discussion the students must arrange themselves in the correct locations on the diagram.

Investigating the Effect of Temperature on the Rate of a Chemical Reaction

For temperature between 7°C and 57°C and times over 5s.

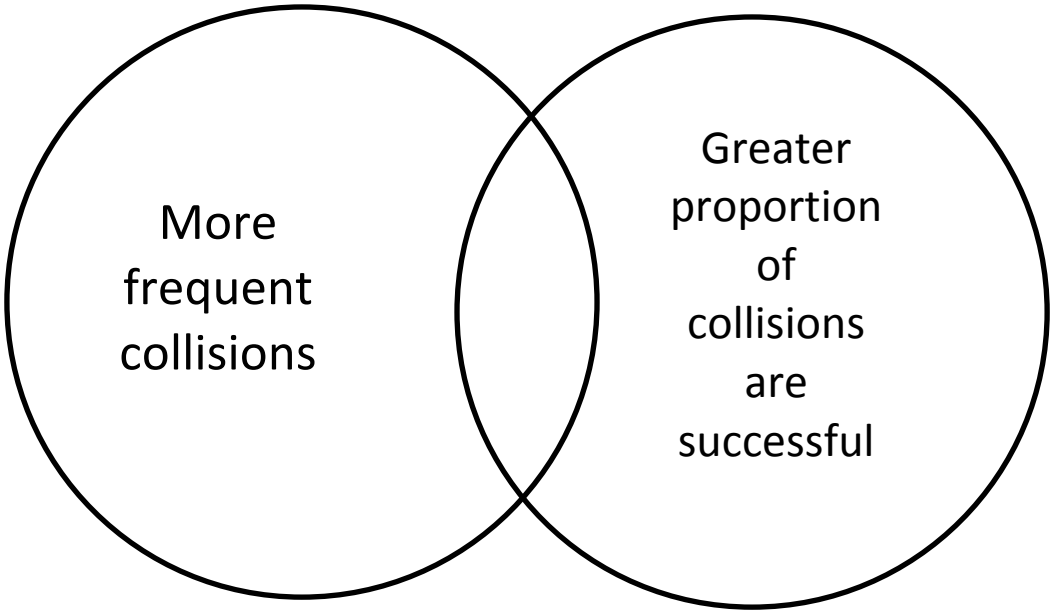
temp /°C	temp /K	time/s	rate = 1/time /s^{-1}



Conclusion
Q When does Temp/°C = time/s ?

increased concentration of dissolved reactant	increased concentration of dissolved product
increased surface area of solid catalyst	increased temperature of reactants
demand the chemicals react faster or else….	giving the reaction verbal encouragement
greater volume of reacting solution	use freshly made up solutions
smaller particles (lumps) of solid reactant	increased surface area of solid reactant
presence of suitable enzyme	increase concentration of dissolved catalyst
stir well	add a catalyst
use a powder instead of a lump	buy more expensive chemicals
shake	write to your MP and demand action

increased pressure of gaseous reactants	increase size of reaction vessel
add a catalyst and increase the concentration of the reactants	addition of substance that reduces activation energy
increased surface area of solid reactant	carry out the experiment at a higher temperature
use more concentrated reactants	stare at the reaction in a menacing fashion
larger surface area and a higher temperature	Shine light on the reaction mixture



We Are Aliens! – Classroom activity 7 (Chemistry)

Using UV Reactive Beads to find Activation Enthalpy

Overview

The rate of a chemical reaction is highly dependent on temperature; often a 10^{o} rise in temperature will double a reaction rate. The chemical reactions that take place in living cells are now exception, indeed many organism regulate their temperature very accurately for this reason. In this experiment students will explore how rate depends on temperature in a very direct manner without the complication of measuring chemical reactants of their products and use their results to calculate the activation enthalpy for the reaction

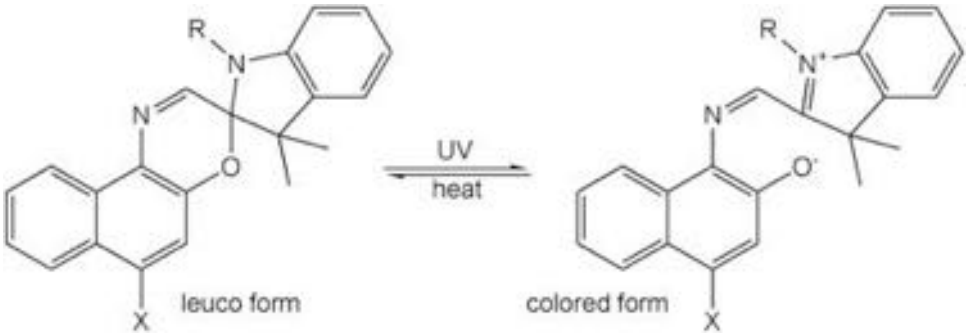
Photochromic beads contain a UV sensitive pigment. When placed under UV light or sunlight they change from colourless to coloured. Once the light source is removed their colour gradually fades until they are colourless again. The reaction is reversible and repeatable. The return to the colourless form provides a reaction which can be safely investigated experimentally. The beads can also be used as a simple UV radiation detector. They are available from mindsetsonline.co.uk for around £6.50 for 100 either in single colours or mixed.

Figure 01

At Key Stage 5 the activity could be used to establish the activation energy/enthalpy for the reaction using the Arrhenius equation. The reaction is also a nice example of a reversible reaction where the position of equilibrium can be shifted. The beads could be used to introduce the idea of equilibrium constant and Le Chatelier's principle. Investigating whether different coloured beads have different activation energies could form the basis of an A2 chemistry investigation. The results sheet can be used as is or modified to provide differentiation.

Scientific Concepts

The dye molecules in UV reactive beads consist of two large flat conjugated systems or chromophores that are at right angles to one another. They absorb radiation only in the UV part of the spectrum and the dye remains colourless. When UV light excites the central carbon atom, the two smaller chromophores form one large conjugated system. This chromophore is large enough to shift the absorption into the visible part of the spectrum and the dye becomes coloured. By changing the size of the two conjugated sections of the molecule, different wavelengths are absorbed and different dye colours can be produced. Heat from the surroundings provides the activation energy needed to return the coloured form of the molecule back to its lower energy colourless form.



Stars emit a wide range of electromagnetic radiation including ultra violet. On Earth we are protected from much of this radiation by our atmosphere, however in space or on other worlds there may be no such protection. Complex organic molecules will absorb and hence be effected by this radiation.

This provides a space based context for the reaction. For example the pigment molecules in the beads could be used in an astronaut's eye protection visor (as in photochromic sun glasses) with the students investigating how the visor would be are effected by temperature.

In many space environments molecules are exposed to short wavelength radiation and low temperatures and this reaction provides a model for the type of reactions that can lead to the formation of life precursor molecules such as the amino acids found in meteorites and comets.

The beads provide a experimentally simple way to establish the activation enthalpy for a reaction. The theory behind this is briefly outlined below starting with the Boltzmann distribution of energy states.

For a chemical reaction to occur reactant particles must collide with a certain minimum kinetic energy in order for a reaction to occur, that is, the activation energy. In a collection of molecules at temperature, T the fraction of molecules, N having an energy greater than E is given by, $\mathbf{N = e^{-E/kT}}$ where k is the Boltzmann constant.

If E_a is the activation energy per mole of molecules (i.e. in $kJmol^{-1}$) the Avogadro constant, L must be introduced to compensate giving $\mathbf{N = e^{-Ea/LkT}}$. Since Lk = R, where R is the gas constant, $\mathbf{N = e^{-Ea/RT}}$

The rate of the reaction will depend on the collision rate (combined with steric factors) and on the fraction of molecules with enough energy to react i.e. **rate = collision rate × fraction.** Substituting the expression for N gives the Arrhenius equation, **rate = collision rate** $\times \mathbf{e^{-Ea/RT}}$ and taking natural logs of both sides gives, **ln(rate) = ln (collision rate) – Ea/RT** which can be written as

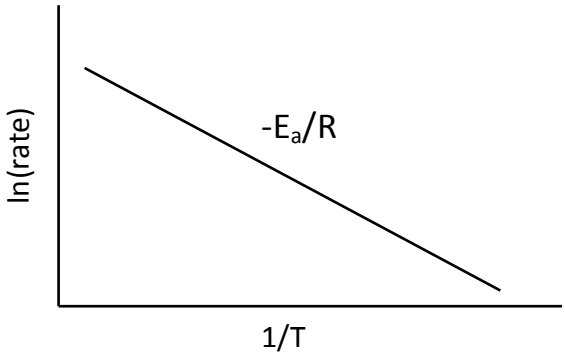
$$\mathbf{\ln(rate) = -(Ea/R) \times (1/T) + \ln(collision\ rate)}$$

This in the form of an equation of a straight line (y= mx+c) where y is ln(rate) and x is 1/T. The gradient is –Ea/R and the intercept is ln(collision rate). So a graph of ln(rate) vs 1/T will have a gradient of –Ea/R. (R= 8.31 $JK^{-1}mol^{-1}$)

Description of Activity

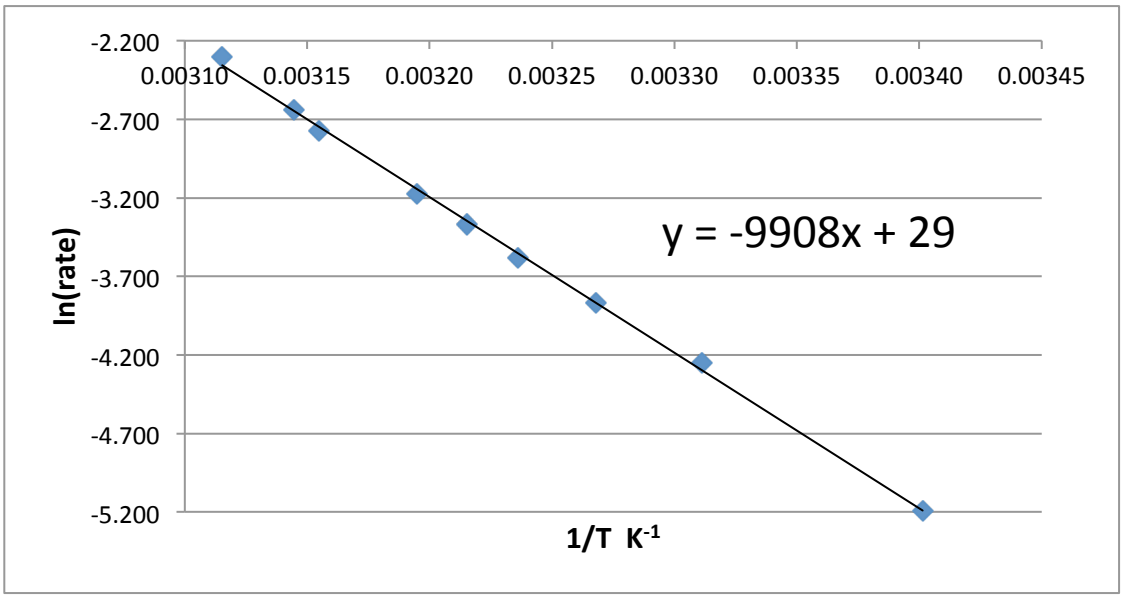
A number of beads are exposed to UV light, either from a UV lamp or sunlight. It helps to keep the beads cool while being exposed to the UV. Placing them in a beaker with some crushed ice will achieve this. Once fully coloured they are quickly removed from the light source and immediately placed in a beaker of water at a pre-set temperature. The time for the beads to fade to the same shade as some reference beads not exposed to UV is recorded. This is done over a range of temperatures. The beaker should be placed on a white tile or paper to facilitate judging when the colour has completely faded. A temperature range from 20°C to 50°C provides a suitable range so the water could come from hot and cold taps. If a UV source is unavailable then the beads can be stored in their coloured state for several days in a freezer.

From the temperatures and times it is possible to calculate the activation energy for the reaction from the gradient of a graph of ln(rate) against 1/temperature. The rate is just given by 1/time and T is the temperature in K.



The table and graph below give typical times. A graph of ln(rate) against 1/T for this data has a gradient of -9908K. Since the gradient = $-E_a/R$ it follows that E_a = gradient x R (8.31 $JK^{-1}mol^{-1}$) which gives a value for E_a of 82.3$kJmol^{-1}$.

Sample Data for Purple Beads			
Temp/°C	time/s	1/T K^{-1}	ln(rate)
21	180	0.00340	-5.193
29	70	0.00331	-4.248
33	48	0.00327	-3.871
36	36	0.00324	-3.584
38	29	0.00322	-3.367
40	24	0.00319	-3.178
44	16	0.00315	-2.773
45	14	0.00314	-2.639
48	10	0.00312	-2.303



Ea in $kJmol^{-1}$ can also be established from just two times, t_1 and t_2 recorded at temperatures, T_1 and T_2 using the equation.

$$Ea = \frac{8.31 \times ln\left(\frac{t_2}{t_1}\right)}{1000 \times \left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$$

Based on the data from the trial experiment above it is possible to generate a mathematical model for the relationship between temperature and time. Time in seconds = 1/(EXP((-9908/(Temperature in °C +273))+28.51))
An extension activity might be to investigate deviations from such a model.

Teaching Resources

UV beads, stopwatches, beakers, thermometers (0-50°C are ideal but any will do), white tiles and a source of hot and cold water e.g. kettle or hot tap. A UV lamp may be needed on a dull winters day.

UV torch £9.99 from Amazon

UV Beads from mindsetsonline.co.uk

Health and Safety

The beads may represent a choking hazard for very small children. Care should be taken with hot water and glassware.

Associated Digital Resources

WAL_Chemistry_07_ChemistryOfUVReactiveBeads_Information.xlsx

Excel file with sample data

WAL_Chemistry_07_ChemistryOfUVReactiveBeads_Information.pptx

PowerPoint Slide

Extra Resources

WAL_Chemistry_07_VennDiagram_Worksheet.docx

The Venn diagram activity works well at KS4 and KS5 alongside this activity. It is a useful diagnostic tool revealing misconceptions in students (and teachers) understanding of collision theory. It can be scaled up so each student has an A5 print out a statement and the Venn Diagram is chalked on the ground. Through discussion the students must arrange themselves in the correct locations on the diagram.

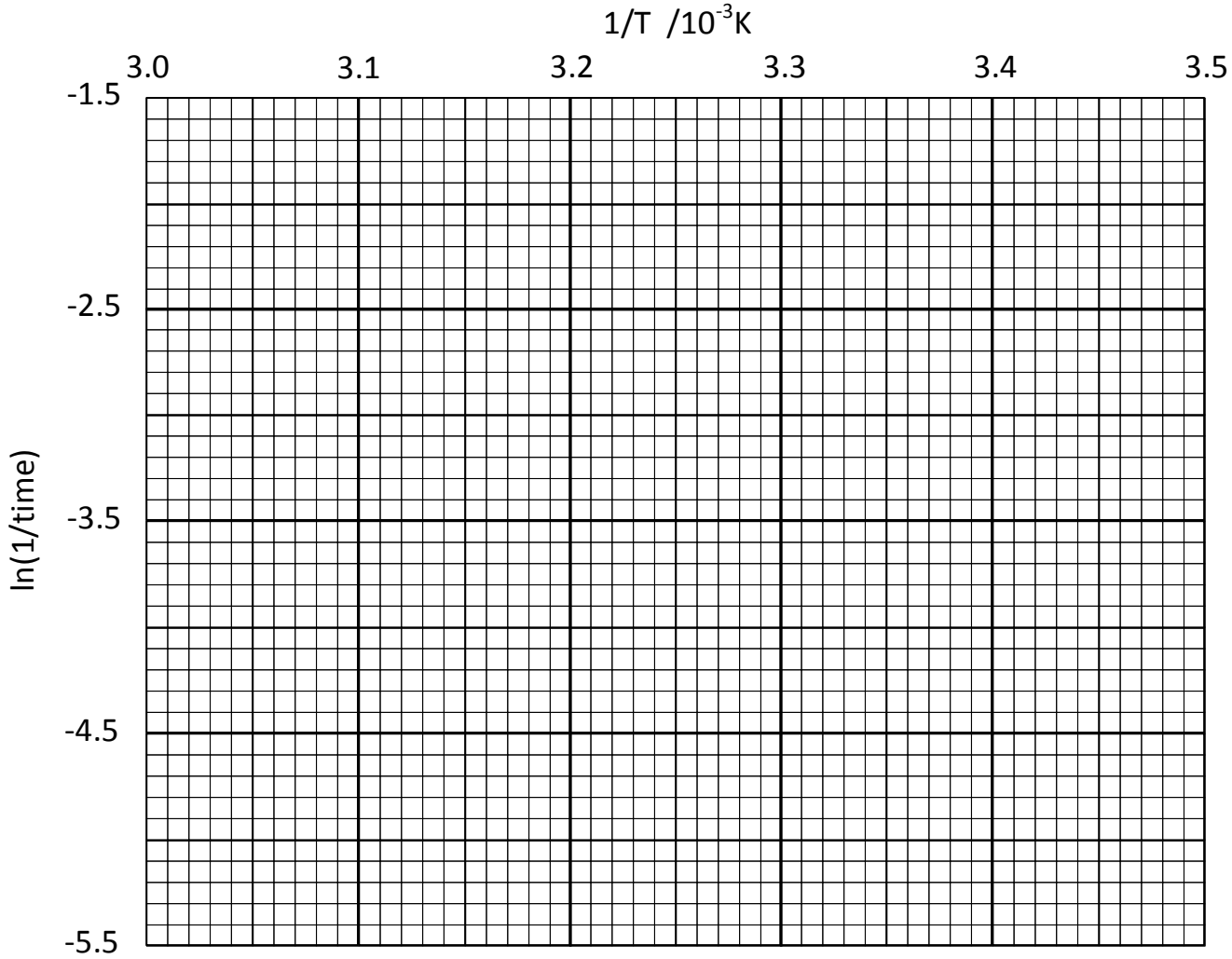
Also see

Photochromism Amino Acids in Meteorites Complex Molecules in Space

Calculating the Activation Enthalpy for a Chemical Reaction

For temperature between 20°C and 50°C and times between 5s and 240s

temp /°C	temp /K	1/temp /K^{-1}	time/s	1/time /s^{-1}	ln(1/time)



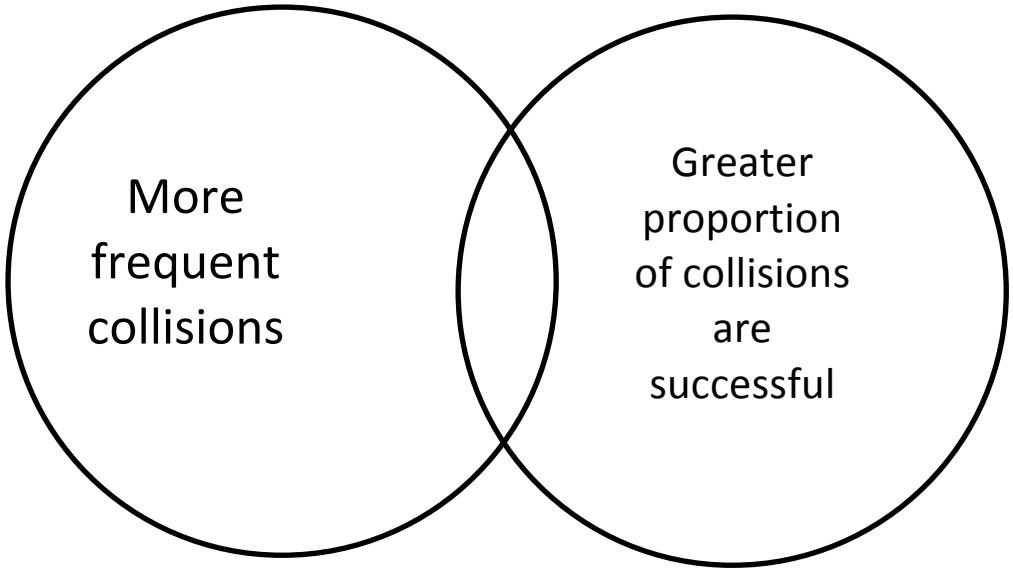
gradient = $\frac{\Delta y}{\Delta x}$ = _____ = _____ K

E_a = gradient x - 8.31 $Jmol^{-1}K^{-1}$ = _____ $kJmol^{-1}$

Q When does Temp/°C = time/s ?

increased concentration of dissolved reactant	increased concentration of dissolved product
increased surface area of solid catalyst	increased temperature of reactants
demand the chemicals react faster or else….	giving the reaction verbal encouragement
greater volume of reacting solution	use freshly made up solutions
smaller particles (lumps) of solid reactant	increased surface area of solid reactant
presence of suitable enzyme	increase concentration of dissolved catalyst
stir well	add a catalyst
use a powder instead of a lump	buy more expensive chemicals
shake	write to your MP and demand action

increased pressure of gaseous reactants	increase size of reaction vessel
add a catalyst and increase the concentration of the reactants	addition of substance that reduces activation energy
increased surface area of solid reactant	carry out the experiment at a higher temperature
use more concentrated reactants	stare at the reaction in a menacing fashion
larger surface area and a higher temperature	Shine light on the reaction mixture

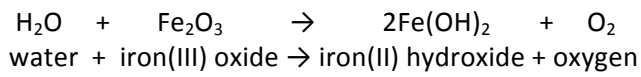


We Are Aliens! – Classroom activity 8 (Chemistry)

Could life exist in this ice core? Answer sheet

Not all life on Earth respires aerobically using glucose as an energy source. There are many types of bacteria that respire using inorganic molecules either with or without oxygen. Here are some examples.

1. The equation below shows a respiration (redox) reaction carried out by so called iron bacteria.



a. Give the oxidation state of the iron in Fe_2O_3 +3
and $Fe(OH)_2$ +2

b. Give the oxidation state of the oxygen in H_2O -2
and O_2 0

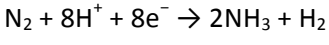
c. What is acting as the reducing agent? water

2. The purple sulfur bacteria are often found in hot springs or stagnant water. Unlike plants they do not use water as their reducing agent, and so do not produce oxygen. Instead they use hydrogen sulfide, which is oxidized to produce granules of elemental sulfur. This in turn may be oxidized to form sulfuric acid. These bacteria thrive is sulphuric acid lakes.

a. By balancing hydrogen with hydrogen ions, write an electrically balanced equation for the oxidation of hydrogen sulphide (H_2S) to elemental sulphur

b. Explain why this reaction is oxidation
Hydrogen has been removed, oxidation state of sulphur has increased from -2 to 0

3. Biological nitrogen fixation occurs when atmospheric nitrogen is converted to ammonia by an enzyme called nitrogenase The reaction is:



a. Explain why this is a redox reaction and name the oxidising agent
Nitrogen is oxidised from 0 to +3, hydrogen is reduced from +1 to 0 so both reduction and oxidation have taken place. The oxidising agent is hydrogen.

So what do you think, could life exist on Europa or Enceladus?
How much would you be prepared for governments to spend in order to find out?

We Are Aliens! – Classroom activity 8 (Chemistry)

Ice Core Analysis

On Earth, wherever there's water there's life, even if much of that water is frozen. Our own solar system contains a number of such environments, which astrobiologists are keen to explore. In this activity students will analyse ice cores that have come from frozen worlds such as Europa, one of Jupiter's moons and Enceladus, a moon of Saturn. The accompanying PowerPoint with pictures of these moons could be used to further set the scene.

The composition of the ice core can be modified to match particular specifications or to match the resources available in different schools. The details provided in this activity are speculative and are not intended to accurately represent the composition of particular moons!

Chemistry Covered

An introduction to inorganic compounds including the formulae of naturally occurring compounds.
Acids, bases and neutralisation reactions including acid-base titrations.
Oxidation states and redox reactions including a redox titration.

Outline of Practical Activity

Students are given samples of ice purported to be from Enceladus/Europa on which they carry out the following activities over a sequence of lessons:

- Melt the sample, record the volume and filter it.
- Examine the solids recovered using a low power microscopy and identify minerals present.
- Perform qualitative tests on the melt water to discover the identity of dissolved ions.
- Titrate a known volume of the melt water against sodium hydroxide to calculate the concentration of the acid present.
- Titrate a known volume of the melt water against manganate (VII) ions to determine the concentration of iron(II)

Making the Ice Cores

Make up a solution of approximately 0.05moldm^{-3} iron (II) sulphate in approximately 1 moldm^{-3} sulphuric acid. To this base add a selection of mineral fragments, produced by smashing up cheap mineral samples with a hammer. To make the cores, use the cylindrical ice trays now readily available for cooling drinks bottles. (suitable tray here at Amazon for £3.50) Ensure that each core contains some of the mineral fragments. Alternatively, make up a large block of ice using a large ice-cream container or similar and provide students with samples of ice obtained by smashing the large block with a hammer. It is possible to get the mineral fragments distributed throughout the ice cores by making up the cores from crushed frozen solution and ice cold solution. This will prevent the mineral grains from sinking.

If desired, add other salt solutions for students to perform qualitative analysis on.
Only very small amounts of mineral samples are required as they will be viewed using a microscope. You may wish to mix the fragments you obtain with fine sand (a mineral itself) to make them easier to handle.
Mineral samples suitable for this can be obtained cheaply (95p each) from ukge.co.uk/uk/small-minerals.asp
It is recommended that you obtain a range of 5 or 6 minerals, ideally all different colours to aid identification.

Suitable minerals include:

- Pyrite
- Malachite
- Quartz
- Galena
- Amethyst
- Chrysocolla

Students will need about 30-40 cm^3 of solution (about 4 standard ice cubes)

NSC creative · National Space Centre · Science & Technology Facilities Council

Risk Assessment

When working with ice cubes previously students may have tried to drop them down the necks of other students. They should be warned that these are "acid" cubes and should be not be handled.

1 moldm^{-3} sulphuric acid	irritant
0.05 moldm^{-3} iron (II) sulphate	low hazard
Mineral samples	low hazard when handled in this form but galena is toxic and, as a precaution, students should wash their hands before leaving the lab.
0.1 moldm^{-3} sodium hydroxide solution	irritant
1 moldm^{-3} hydrochloric acid	irritant
0.2 moldm^{-3} silver nitrate	irritant
0.5 moldm^{-3} barium chloride	harmful
Universal indicator	flammable
Phenolphthalein indicator	flammable
0.001 moldm^{-3} potassium manganate (VII)	low hazard

Equipment List

Recording and Mineral Identification

- Beakers
- Cylindrical ice cube trays OR and container to make a large block of ice
- Access to freezer
- Iron(II) sulphate
- 1 moldm^{-3} sulphuric acid
- Crushed mineral samples (see below)
- Low power microscopes (often those used at KS3/4 are most suitable)
- Filter paper and funnels

Qualitative Analysis

- Melted ice sample from previous work
- Qualitative analysis information sheet
- Universal indicator
- Range of chemicals with which to carry out qualitative analysis
    - 0.1 moldm^{-3} sodium hydroxide solution
    - 0.5 moldm^{-3} hydrochloric acid
    - 0.2 moldm^{-3} silver nitrate solution
    - 0.5 moldm^{-3} barium chloride solution
    - spills

Acid-Base Titration

- melted ice sample from previous work
- 100cm^3 volumetric flask
- Distilled water
- 10cm^3 pipette
- 25 cm^3 pipette
- Burette, burette stand and clamp
- Phenolphthalein indicator
- White tile
- Funnel
- 0.10 moldm^{-3} sodium hydroxide solution (made up accurately)

Redox Titration

As above but without indicator and potassium manganate replaces sodium hydroxide

- 0.001 moldm^{-3} potassium manganate (VII) solution (made up accurately)

Student Practical Work

1. Recording and Mineral Identification

This is a lovely activity that students often really enjoy. Using a microscope to view small mineral samples is comparable to viewing large mineral samples with the naked eye. Most will find the samples they view beautiful and will be keen to identify them.

a. Place the ice sample in a clean, dry beaker and use a Bunsen burner to melt the ice.
b. Filter your melted sample collecting the filtrate in a measuring cylinder (choose the most appropriate size available). Make sure that all the solid ends up being transferred to the filter paper.
c. Record the volume of solution you obtain. Transfer your solution to the container it will be stored in and label it clearly. You will need it again later.
d. Examine the contents of the filter paper with a microscope using a low power lens.
e. Use the mineral identification sheet to try and identify the mineral samples you find.

2. Qualitative Analysis

You may wish to adapt this part of the analysis to match your own specification or not to carry out this part of the practical at all.

Students are provided with an information sheet that details a range of qualitative analytical tests. Their task is to carry out the tests, decide which ions are present and suggest the formulae of some dissolved salts which may be present.

They should also use universal indicator to find the pH of the solution.
Warn students to only use small amounts of their solution. They should leave at least 20cm^3 for further analytical work.

3. Acid –Base Titration

This is a standard acid-base titration set in a novel context. The end point of the titration is the first permanent appearance of pink.

a. Using a 10cm^3 pipette, transfer 10.00cm^3 of your sample into a 100cm^3 volumetric flask.
b. Using distilled water, make the solution up to the mark and shake well. You now have a 1 in 10 dilution of your original sample.
c. Using a pipette transfer 20/25cm^3 of your sample into a conical flask and add a few drops of phenolphthalein indicator.
d. Set up a burette and fill it with 0.10 $moldm^{-3}$ sodium hydroxide solution.
e. Carry out the titration until you have at least two concordant results.

4. Redox Titration

Manganate (VII) ions are used here to determine the concentration of iron (II) ions present in the ice core. Manganate (VII) is added to the sample from a burette and is decolourised immediately. As soon as all the reducing agent (Fe^{2+} ions) is used up, the solution in the conical flask goes pale pink due to the presence of MnO_4^- ions. The end point of the titration is the first permanent appearance of this pale pink colour. No indicator is required as the manganate (VII) is self-indicating.

a. Using a 10cm^3 pipette, transfer 10.00cm^3 of your sample into a 100cm^3 volumetric flask.
b. Using distilled water, make the solution up to the mark and shake well.
You now have a 1 in 10 dilution of your original sample.
c. Using a pipette transfer 20/25cm^3 of your sample into a conical flask.
d. Set up a burette and fill it with 0.001$moldm^{-3}$ potassium manganate (VII) solution.
e. Carry out the titration until you have at least two concordant results.

We Are Aliens! – Classroom activity 8 (Chemistry)

Ice Core Analysis

1. Mineral Identification

a. Place the ice sample in a clean, dry beaker and use a Bunsen burner to melt the ice.
b. Filter your melted sample collecting the filtrate in a measuring cylinder (choose the most appropriate size available). Make sure that all the solid ends up being transferred to the filter paper.
c. Record the volume of solution you obtain. Transfer your solution to the container it will be stored in and label it clearly. You will need it again later.
d. Examine the contents of the filter paper with a microscope using a low power lens
e. Use the mineral identification sheet to try and identify the mineral samples you find.

Volume of solution	cm^3

Brief description including colour	Possible name	Possible formula

2. Qualitative Analysis

Use the information sheets to carry out tests on you sample of melt water. Make sure you keep **at least** 20cm^3 of sample for the next two experiments.

Use these tables to record your positive results

Colour with Universal Indicator	Estimated pH

Cations Present	Anions Present

Using your qualitative analysis results:

Suggest what acid could be present	Suggest the formula of some possible dissolved salts

3. Acid –Base Titration

You are using sodium hydroxide of known concentration (in the burette) to find out the concentration of acid in your ice sample. The end point of the titration is the first permanent appearance of pink.

a. Using a 10cm^3 pipette, transfer 10.00cm^3 of your sample into a 100cm^3 volumetric flask.
b. Using distilled water, make the solution up to the mark and shake well. You now have a 1 in 10 dilution of your original sample
c. Using a pipette transfer 20/25cm^3 of your sample into a conical flask and add a few drops of phenolphthalein indicator
d. Set up a burette and fill it with 0.10 moldm^{-3} sodium hydroxide solution
e. Carry out the titration until you have at least two concordant results

Titre/cm^3				
Rough	1	2	3	mean

Your melt water sample contains sulphuric acid (H_2SO_4). In this titration, it was neutralised by sodium hydroxide solution.

i. Write a balanced equation for the neutralisation

ii. You used 0.10moldm^{-3} sodium hydroxide solution. Use your titre mean to calculate the number of moles of sodium hydroxide you added.

iii. Use your equation from i to work out the number of moles of sulphuric acid that must have been present in the conical flask.

iv. You had either 20 or 25cm^3 of acid in your conical flask at the start of the titration. Use your answer from iii. to calculate the concentration of the sulphuric acid present

v. The solution in the conical flask was a 1 in 10 dilution of your melt water. Calculate the concentration of sulphuric acid in the original ice.

4. Redox Titration

In this titration purple manganate (VII) ions are used to determine the concentration of iron (II) ions present in the ice core. Manganate (VII) is added to the sample from a burette and is decolourised immediately. As soon as all the reducing agent (Fe^{2+} ions) is used up, the solution in the conical flask goes pale pink due to the presence of MnO_4^- ions. The end point of the titration is the first permanent appearance of this pale pink colour. No indicator is required as the manganite (VII) is self-indicating.

a. Using a $10cm^3$ pipette, transfer $10.00cm^3$ of your sample into a $100cm^3$ volumetric flask.
b. Using distilled water, make the solution up to the mark and shake well. You now have a 1 in 10 dilution of your original sample.
c. Using a pipette transfer $20/25cm^3$ of your sample into a conical flask.
d. Set up a burette and fill it with $0.001moldm^{-3}$ potassium manganate (VII) solution.
e. Carry out the titration until you have at least two concordant results.

Titre/cm^3				
Rough	1	2	3	mean

Your melt water sample contained Fe^{2+} ions which reacted with MnO_4^- ions. The equation for the reaction is below.

$$8H^+ + 5Fe^{2+} + MnO_4^- \rightarrow 4H_2O + 5Fe^{3+} + Mn^{2+}$$

i. Use the equation to tell you which element was oxidised.
Give the before and after oxidation states for this element.

ii. Which element was reduced? Give the before and after oxidation states for this element.

iii. You added $0.001moldm^{-3}$ potassium manganate (VII) ($KMnO_4$) solution to the flask.
Use your titre to calculate the mean number of moles of manganate ions added.

iv. Use the equation given above to work out the number of moles of iron (II) that the manganite reacted with.

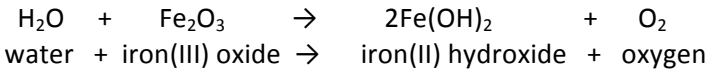
v. You had either 20 or $25cm^3$ of iron solution in your conical flask at the start of the titration.
Use your answer from iv to calculate the concentration of the Fe^{2+} present.

vi. The solution in your conical flask was a 1 in 10 dilution from your melt water.
Calculate the concentration of iron in the original ice.

Could life exist in this ice core?

Not all life on Earth respires aerobically using glucose as an energy source. There are many types of bacteria that respire using inorganic molecules either with or without oxygen. Here are some examples.

1. The equation below shows a respiration (redox) reaction carried out by so called iron bacteria.



a. Give the oxidation state of the iron in Fe_2O_3 and $Fe(OH)_2$

b. Give the oxidation state of the oxygen in H_2O and O_2

c. What is acting as the reducing agent?

2. Purple sulphur bacteria are often found in hot springs or stagnant water. Unlike plants they do not use water as their reducing agent, and so do not produce oxygen. Instead they use hydrogen sulphide, which is oxidized to produce granules of elemental sulphur. This in turn may be oxidized to form sulphuric acid. These bacteria thrive is sulphuric acid lakes.

a. By balancing hydrogen with hydrogen ions, write an electrically balanced equation for the oxidation of hydrogen sulphide (H_2S) to elemental sulphur.

b. Explain why this reaction is oxidation.

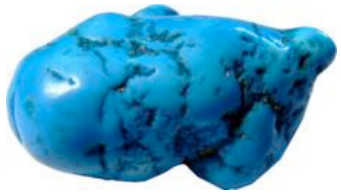
3. Biological nitrogen fixation occurs when atmospheric nitrogen is converted to ammonia by an enzyme called nitrogenase. The reaction is:

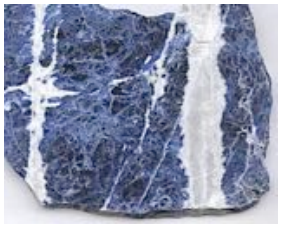
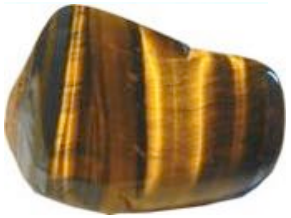
$$N_2 + 8H^+ + 8e^- \rightarrow 2NH_3 + H_2$$

Explain why this is a redox reaction and name the oxidising agent.

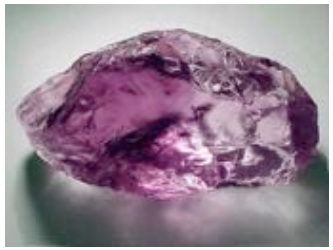
So what do you think, could life exist on Europa or Enceladus?
How much would you be prepared for governments to spend in order to find out?

We Are Aliens! – Classroom activity 8 (Chemistry) - Mineral Information



Turquenite	Black tourmaline	Pyrite	Sodalite	Tiger eye	Galena	Malachite
calcium borosilicate hydroxide	a complex silicate	iron sulphide	sodium aluminium silicate	silicon dioxide with traces of iron	lead sulphide	copper carbonate hydroxide
$Ca_2B_5SiO_9(OH)_5$	$(Ca,K,Na,)(Al,Fe,Li,Mg,Mn)_3(Al,Cr,Fe,V)_6(BO_3)_3(Si,Al,B)_6O_{18}(OH,F)_4$	FeS_2	$(Na_4Al_3(SiO_4)_3Cl)$	SiO_2	PbS	$Cu_2CO_3(OH)_2$






Amethyst	Calcite	Rose quartz	Quartz	Rhodonite	Chrysocolla
silicon dioxide with traces of titanium or manganese	calcium carbonate	silicon dioxide with traces of titanium or manganese	silicon dioxide	manganese silicate	copper and aluminium silicate
SiO_2	$CaCO_3$	SiO_2	SiO_2	$MnSiO_3$	$(Cu,Al)_2H_2Si_2O_5(OH)_4{\cdot}nH_2O$

Tests for Anions

Anion	Symbol	Test	Positive result
Bromide	Br^-	Add silver nitrate solution	Pale yellow precipitate forms which dissolves slightly in ammonia solution.
Carbonate	CO_3^{2-}	Add dilute hydrochloric acid	Effervescence (fizzing) is seen and carbon dioxide is given off
Chloride	Cl^-	Add silver nitrate solution	Thick white precipitate forms which dissolves in ammonia solution.
Iodide	I^-	Add silver nitrate solution	Pale yellow precipitate forms which does not dissolve in ammonia solution.
Sulphate	SO_4^{2-}	Add barium chloride solution.	White precipitate forms.

Tests for Cations

Sodium hydroxide test

Cation	Formula	Observations
Aluminium	Al^{3+}	White precipitate which dissolves when more sodium hydroxide is added
Calcium	Ca^{2+}	White precipitate which does not dissolve when more sodium hydroxide is added
Magnesium	Mg^{2+}	White precipitate which does not dissolve when more sodium hydroxide is added
Copper	Cu^{2+}	Blue precipitate
Iron (II)	Fe^{2+}	Green precipitate
Iron (III)	Fe^{3+}	Brown (rust) precipitate
Lithium	Li^+	No precipitate
Sodium	Na^+	No precipitate
Potassium	K^+	No precipitate
Ammonium	NH_4^+	No precipitate

Flame test: Soak a spill in the solution to be tested and place the spill in the blue flame of a Bunsen burner

Cation	Formula	Flame colour
Lithium	Li^+	Red
Sodium	Na^+	Orange
Potassium	K^+	Lilac
Calcium	Ca^{2+}	Brick red
Barium	Ba^{2+}	Light green
Copper	Cu^{2+}	Blue-green

Tests for Anions

Anion	Symbol	Test	Positive result
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Barium	Ba^{2+}	Light green
Copper	Cu^{2+}	Blue-green

We Are Aliens! – Classroom activity 1 (Physics)

The “boiling water in a syringe without heating it” experiment and why oceans can’t exist on Mars now – but once upon a time, they did!

Boiling is the large-scale evaporation of a liquid into the gaseous state and, for pure water, occurs at 100^{o}C at 1 atmospheric pressure (1013.25 mb or 101325 Pa).

As atmospheric pressure decreases, the temperature at which boiling occurs also reduces:

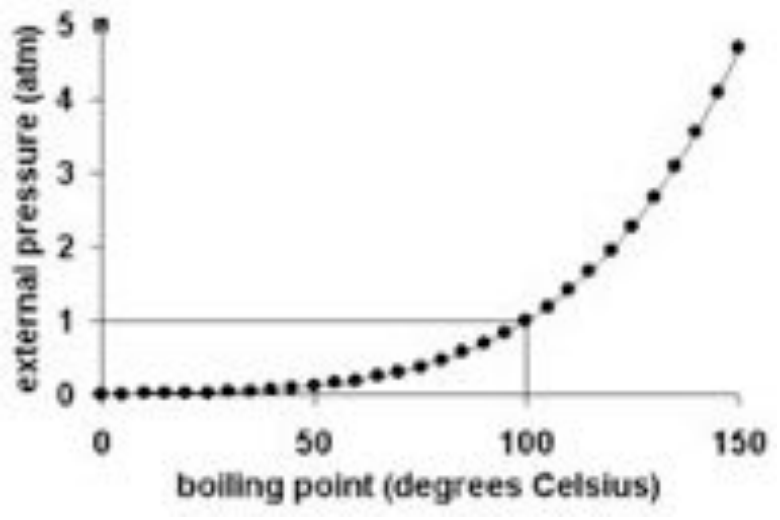


Figure 01

As we ascend in the atmosphere the decreasing air pressure means that water boils at progressively lower temperatures.

On the summit of Mount Everest, which is 8,848m (29,028ft) above sea level - only slightly lower than the altitude commercial airliners fly at - this figure has reduced from our familiar 100 Centigrade to around 70 degrees Centigrade.

Higher still, the consequences for unprotected humans become even more insidious. At 20,000m (63,000 ft) the boiling point of water equals a human's body temperature: 37 degrees Centigrade. If we consider the main constituent of the human body, the relevance of this particular pressure to human physiology and survival is clear. In fact, the aero medical boundary of space is taken as being at this altitude (63 000ft), since a full pressure suit would be needed for survival. The pressure is so low (6% of sea-level) that the boiling point of water is below the average human blood temperature. The outside pressure is less than the partial pressure of water in the body.

A common misconception is that an unprotected human's blood would start boiling in the arteries and veins, but since the skin is a reasonably good pressure vessel this would not be the case.

However, the dramatic outgassing of nitrogen dissolved in the bloodstream (similar to, but far more rapid than the experiences of divers who ascend too quickly from depth) coupled with the effects of explosive decompression and lack of oxygen would result in unconsciousness in seconds, and death within a minute or two.

From an aeromedical, or human physiology and survival perspective, this is the boundary of space

Martian mean datum pressure is well below the pressure equivalent at this altitude, and thus a full-pressure suit like those currently in use for spacewalks (EVAs) on the International Space Station would be needed.

Current surface conditions on Mars and liquid water

Left: a frozen Martian lake?

Below: Sedimentary rocks photographed by Opportunity

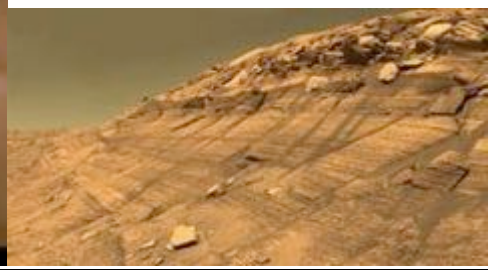


Figure 2 (above left) Figure 3 (above right)
At present, ambient pressures are so low that liquid water poured out onto the Martian surface would simultaneously freeze and evaporate away. There are no long-lying areas of liquid water anywhere on the current surface.

Yet we see much evidence of a warmer, wetter past – what looks like an ancient river system below spans several hundred kilometres:

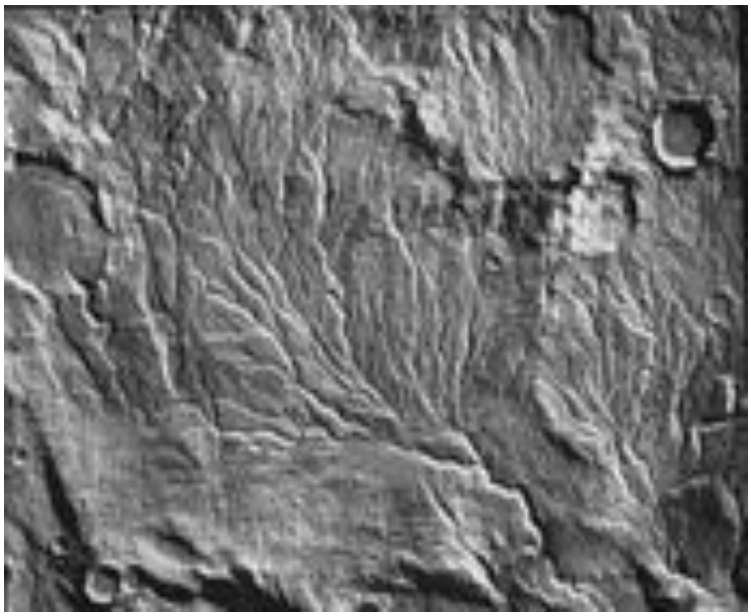


Figure 4

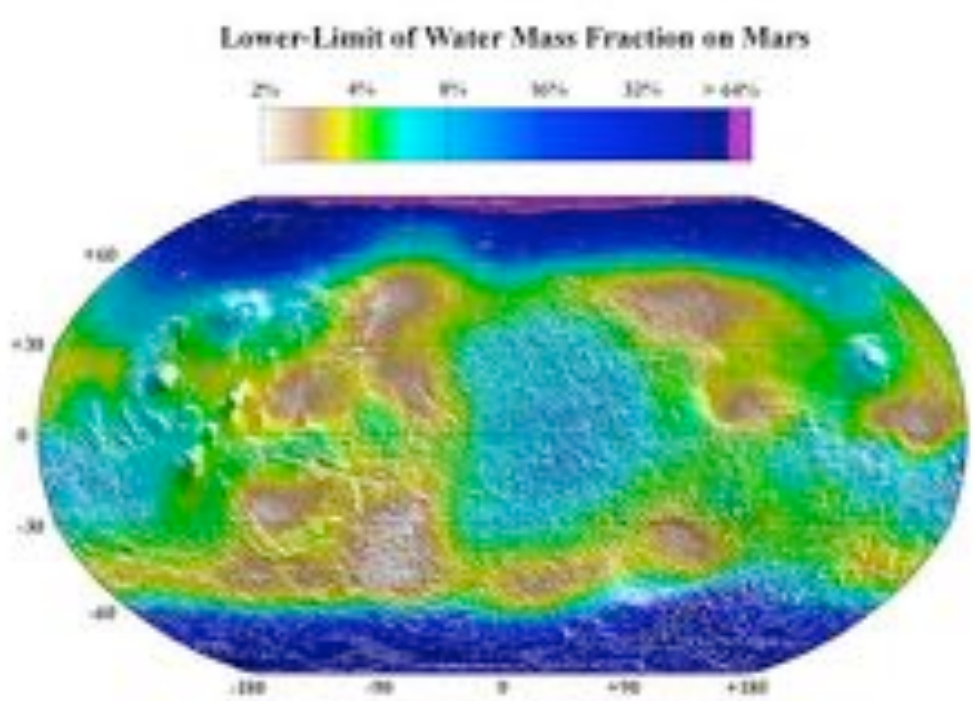
Mars – a buried ocean?

Mars Odyssey, which has been orbiting Mars since October 2001 carried a **neutron spectrometer** to measure the neutron flux produced due to the following:

- High-energy galactic cosmic radiation (GCR) slams into the Martian surface – neutrons are ejected from surface atomic nuclei
- Some of the ejected neutron flux is upwards towards the orbiting spacecraft which detects them
- Each chemical element creates its own unique distribution of neutron energies
- The measured neutron flux "signatures" allow determination of the top surface material's chemical composition
- Hydrogen in the soil (assumed to be in subsurface ice) will effectively absorb neutron energy and reduce the neutron flux that escapes from the surface to be detected on orbit.
- Addition gamma fluxes caused by nuclear de-excitation after GCR interactions with surface nuclei were also measured by the spacecraft

The following map shows the inferred distribution of subsurface ice from orbital data:

Figure 5 (below)



This dataset is valid for surface depths of only 1m or thereabouts – yet the amount of water indicated is staggering.

More recent results from NASA's Mars Phoenix lander have confirmed the presence of subsurface ice which slowly sublimates on exposure to surface conditions.

Conclusion

At present the conditions on the surface of Mars are such that complex Earth organisms such as ourselves would find it impossible to survive without significant protection from the extreme environmental parameters highlighted in the demonstration films.

Yet all the geological and observational evidence points to a planet that was once significantly wetter and warmer. All over the Martian surface we see evidence of features associated with long-standing extensive bodies of liquid water…..dendritic river systems, evidence of catastrophic flood events and rocks that require the presence of liquid water to form. These imply the planet once had a much denser atmosphere, one that would as a consequence have had significantly higher temperatures than those currently extant. What happened?

Mars today. This MGS composite image is centred on Vallis Marineris, the giant tectonic crack in Mars' crust. At left can be seen the Tharsis bulge with the "supervolcanoes" Arsia, Pavonis and Ascraeus Mons.

Figure 6 (above)

This artistic impression shows what Mars may have looked like 3.8-3.5 billion years ago (Noachian epoch). The Northern hemisphere lowlands are covered by a shallow ocean that fills Vallis Marineris.

Figure 7 (above)

Image Referencing:

Figure 01 - CHEM.PURDUE.EDU (date unknown) *Boiling; Factors that affect boiling point* [WWW] Purdue edu Available from: http://www.chem.purdue.edu/gchelp/liquids/boil.html [06/12/2012]

Figure 02 - VIRGINIA.EDU (2012) *Water on Mars: Frozen Lake in Crater* [WWW] Credit: ESA/DLR/FU Berlin (G.Neukum) http://www.astro.virginia.edu/class/oconnell/astr121/im/ice-in-crater-Mexpress-lg.jpg [06/12/2012]

Figure 03 - NASA (2012) *Mars Exploration Program Analysis Group (MEPAG)* [WWW] Pancam photo mosaic, approximately true color: NASA/JPL/Cornell Available from: http://mepag.nasa.gov/science/1_ancient_persistent_liquid_water/index.html [06/12/2012]

Figure 04 - ABOVE TOP SECRET (2011) *The Search For Life. Part 2 – Are they here?* [WWW] Available from: http://www.abovetopsecret.com/forum/thread669103/pg1 [06/12/2012]

Figure 05 - NASA (2012) *Mars Exploration Program Analysis Group (MEPAG)* [WWW] Graphic: NASA/JPL/University of Arizona Available from: http://mepag.nasa.gov/science/3_Modern_Water/index.html [06/12/2012]

Figure 06 - NRAO (2012) *Mars* [WWW] Available from: http://www.gb.nrao.edu/epo/sol_sys/mars.html [06/12/2012]

Figure 07 - CARROLL, MICHAEL (2012) *Liquid Water on Mars (artistic impression)* [WWW] Painting by Michael Carroll Available from: http://www.lpi.usra.edu/publications/slidesets/redplanet2/slide_28.html [06/12/2012]

We Are Aliens! – Classroom activity 2 (Physics)

COMET RECIPE

Comet Ingredients

Water in a jug (about half the amount of dry ice)
Bin liners
Dry Ice (about 2-3 x 600ml container fulls)
1 Spoonful of sand 1 Spoonful of carbon dust
Few dashes of worcester sauce (organic component)
Few dashes of whisky/red wine (optional – the methanol/ethanol component)
Bowl Disposal Bucket
Rubber Gloves Wooden Spoon
Clear screen Polysterene container for dry ice

Method

1. Take a bin liner and use it to line the bowl.
2. Add the ingredients of your comet – water, sand, carbon dust, worcester sauce. These replicate the compounds that real comets are composed of. Volunteers of the audience can add some of these. Mix well with wooden spoon.

A note on the significance of the ingredients:

- WATER - how comets have large amounts of H_2O, and in the past it is believed comets could have brought water to Earth through impacts with our planet billions of years ago.
- The SAND, The CARBON, ALCOHOL, and the WORCESTER SAUCE for the organic component. Comets have all the right ingredients for life, but the mixture is not under the correct conditions for life to exist.
- THE DRY ICE – frozen CO2, the frozen gas that holds together our comet and sublimates when it interacts with the solar wind and solar radiation to form the coma and gas tail.

3. Finally add the dry ice. Wearing gloves feel around the bin liner and mould the comet into one lump. Don't compress it too hard as the comet may break, allow steam gas to escape.

4. When the demonstration is completed place the comets inside the bin liner in a bucket.

Safety Precautions

- When handling the dry ice wear gloves and goggles. Do not touch, swallow or taste the dry ice. Do not allow students too near the dry ice. Give the audience clear instructions on the hazard and the distance they should be seated form the dry ice as the comet may 'spit'
- Do not seal the dry ice into a container as explosive outgassing may result!
- Transport dry ice in a plastic bag inside a box.
- Dispose of comet outside in a well-ventilated area where students can't access it.

The Science

Dry ice is frozen Carbon Dioxide (-78.5^{o}C, or -109.3^{o}F), or CO_2, which is a gas under standard temperature and pressure conditions. The atmosphere contains about 0.035% of this gas. CO_2 is a greenhouse gas, which means it absorbs light at infrared wavelengths. An increase in the concentration of this gas may cause an increase in the atmosphere's average temperature. The high concentration of CO_2 (>96%)in the atmosphere of the planet Venus contributes to that planet's high average temperature.

At normal atmospheric pressure on this planet, frozen CO_2 doesn't melt into a liquid, but rather evaporates directly into its gaseous form -hence the name 'dry ice'. This process is called sublimation and is responsible for the formation of a comet's coma. We can see CO_2 gas subliming away from our comet from where water vapour in the air condenses around it.

We Are Aliens! – Classroom activity 3 (Physics)

Pressure and what it's really like on Earth, Venus and Mars!

What do we Mean by Pressure?

Put simply, pressure is the measure of a force spread over a surface area. The unit of pressure, the Pascal, is the force of 1N acting over an area of 1 square metre.

The Origin of Atmospheric Pressure

Atmospheric pressure, which we take for granted, can have unusual effects, as we see in the glass of water and card experiment. Its cause is simply the weight of atmosphere above us which extends to an altitude of well over 100km - the internationally accepted boundary of space (although nearly 90% of the total mass of the atmosphere is within 10 km of the Earth's surface).

Figure 01

We tend to forget that we are living at the bottom of an "ocean" of air.

Atmospheric pressure varies at a given location with the passage of weather systems, and decreases exponentially with altitude. The standard value is 101.325 Pa (1013.25 mb), also known as 1 atmosphere (atm). This means that every square meter of the Earth's surface is sitting under 10 tonnes of atmospheric mass!

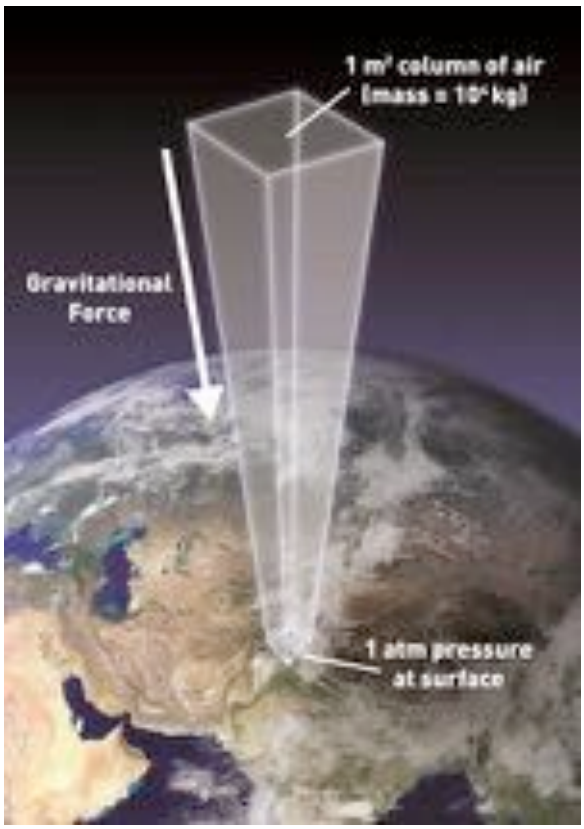


Figure 02 – Shown above

The Effects of Atmospheric Pressure

Gas pressure is caused by momentum changes during the collisions between the molecules or atoms that compose the gas, and anything that happens to be in the way! We often model the behaviour of gases by considering them to be "ideal" gases. These are monatomic gases with a total particle volume which is negligible in comparison to the total volume occupied by the gas and with no interparticle interactions apart from during collisions.

The Ideal Gas Equation – GCSE+ level

This is derived by putting together the familiar equations from three Laws

pV = constant, p/T = constant and V/T = constant

for a constant mass of ideal gas;

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

which leads to (A Level)

$$pV = nRT$$

n= number of MOLES of the gas (one MOLE is defined as being Avogadro's number of something. If you ever get stressed about what a mole is, just think of it as being 6.02 x 10^{23} of something – be it gas molecules or people!)

R = MOLAR GAS CONSTANT – a measure of the kinetic energy/ temperature link for one mole's worth of molecules/particles.

T = Absolute temperature in Kelvin

For a MICROSCOPIC rather than MACROSCOPIC model (i.e. considering the small nature of particles rather than masses of them at once), the ideal gas equation is often written as Boltzmann's constant gives us a direct link between translational kinetic energy and

$$pV = NkT$$

N = total absolute number of particles (rather than grouping them into moles)
T = temperature in K
k = BOLTZMANN's CONSTANT
= $1.38*10^{-23}$ J/K

temperature for a single particle. The mean translational kinetic energy of a particle in a

system at temperature T is 3/2 kT. (If we start considering other "degrees of freedom" such as molecular ROTATION or VIBRATION, then we add a factor of kT/2 for each extra degree and mode that's included.)

Pressure and Altitude (GCSE and A Level)

As we ascend in the atmosphere, the air pressure diminishes, as there is less weight of air above.

A Level modelling

If we assume an ideal gas is behaving HYDROSTATICALLY, then for a particular layer of gas at a given altitude the downward force of its weight and the downward force exerted by pressure in the layer above is equal to the upward force exerted by pressure in the layer below.

It's possible to show that the following relation holds

$$P = P_0 e^{-(mgh/kT)}$$

P = pressure at altitude h metres
P_0 = sea level pressure
m = mean mass of a particle in the atmosphere

For Earth, with an approximate atmospheric composition of 80% N_2 and 20% O_2, we find a mean molar mass of 28.8g (N_2 =28, O_2=32) which needs to be expressed in kg. The Earth value translates to a mean molecular MASS of 28.8 times that of a hydrogen atom = 4.8 x 10^{-26} kg.

Using this equation is as straightforward as the more familiar uses of exponentials with regards to

Radioactivity	$N = N_0 e^{-\lambda t}$
Capacitance	$V = V_0 e^{-(t/CR)}$

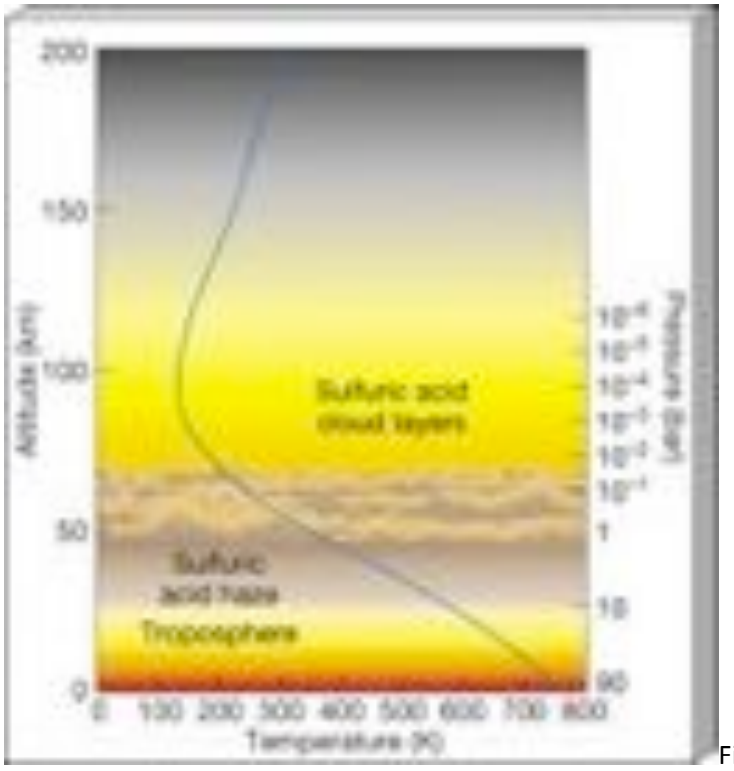
Taking the sea-level value for pressure given above, a mean atmospheric temperature of 0 ^{o}C and the height of Mount Everest as 8850 m , we can show that the pressure on its summit is about one-third of the sea-level value, and calculate it in Pascals.

Of course the model is inaccurate in that it assumes the atmosphere is ISOTHERMAL; at the same temperature throughout. In fact, as we ascend in the atmosphere, temperature drops at the LAPSE RATE of 6.5^{o}C per 1000m until we reach the coldest part of the atmosphere – the tropopause (boundary between troposphere and stratosphere). Above this altitude, in the STRATOSPHERE, temperature increases with altitude due to incident uV absorption and re-emission at longer wavelengths causing atmospheric heating.

Venus – Earth's "evil twin"

Venus, named after the Roman goddess of love, probably wins the prize for the astronomical object that fails to live up to its label! It is probably the closest approximation to Hell that we could envisage anywhere in the Solar System. With surface temperatures of the order of 480 C (and little variation in day and night) and a surface pressure of 90+ Earth atmospheres (equivalent to nearly 1000Newtons on every square centimetre) even the most robust planetary landers have only survived to return data for a matter of minutes or, at best, a few hours.

Step out on Venus's surface without a tungsten armoured hard-shell pressure suit and you'd be crushed and baked within seconds!



This cross-sectional pressure and temperature profile through the Venusian atmosphere highlights the exponential pressure increase with depth in the atmosphere

1 bar = 100 000N/m^2
1 standard Earth atm = 1013.25mb

Figure 03

Our images of the surface date back to the 1970s and 1980s. The Soviet Venera series of landers survived to return surface data, with Veneras 9,10, 13 and 14 each returning one panoramic fish-eye view before succumbing to the harsh environment:

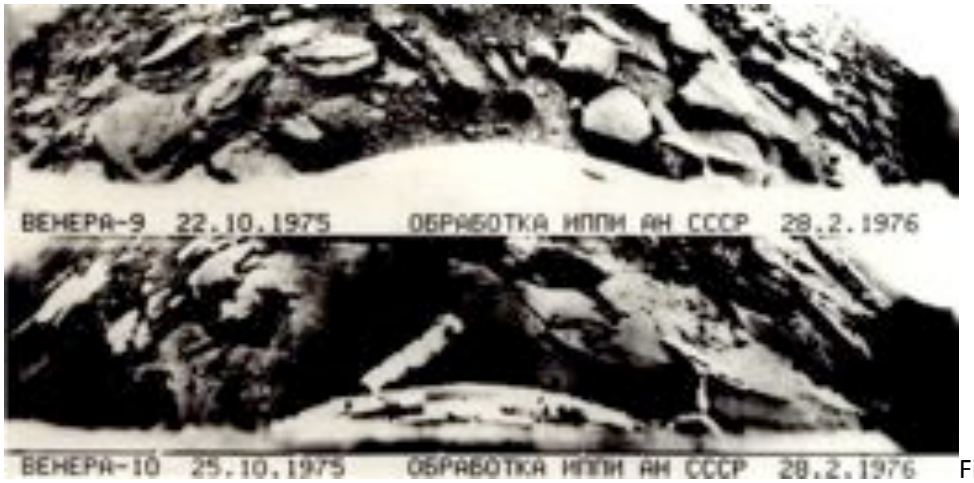


Figure 04

This Venera 13 raw image (1982) at top has been enhanced to bring out further details:

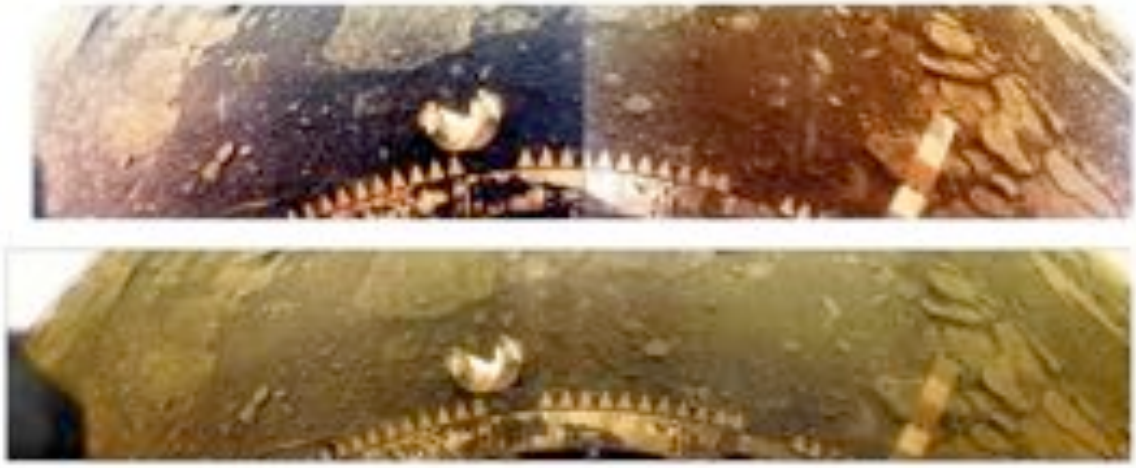


Figure 05 – Shown above

The atmosphere of Mars

On Mars, the atmosphere has less than 1% of the sea-level pressure on Earth. Martian pressures are given with reference to a Martian imaginary sea-level called the mean datum because Mars has no oceans at present!

Mars' atmosphere is so insubstantial compared to Earth's that even in Martian summer where occasionally the surface temperature in a few low-lying locales might reach 20^{o}C, the lapse rate in the immediate vicinity of the surface is much larger than on Earth. The Martian atmosphere's heat retention capacity is so low that even two or three metres above our surface in midsummer, it would be below 0^{o}C.

Misunderstandings about pressure differentials and the human body

The human body, if exposed to the Martian or vacuum environment unprotected, would NOT explode! In vacuum chamber accidents, humans have survived exposure to vacuum of up to one minute without the explosion of the internal organs or skin or eyeballs. The human skin is stronger than expected and would function to some degree as a pressure suit for a short period of time. Blood would not boil through the skin but dissolved gases in the

bloodstream would start cascading out of solution – resulting in lethal ebullism in a short period of time.

- Explosive outgassing of air from the lungs at overpressures corresponding to $10N/cm^2$ (normal atmospheric pressure) would be enough to blast out weaker human front teeth

- A lot of misconceptions confuse diving decompression accidents with spacesuit failures. In the early 1980s a decompression accident (the Byford Dolphin incident) resulted in a number of divers being explosively decompressed from a pressure of 9 atm (900 000Pa) to 1atm in less than a second. This resulted in the explosive disintegration of one of the diver's bodies. However, a spacesuit decompression would result in a pressure gradient far less steep and hence the humnan body would most likely retain integrity.

- In 1966 Johnson Space Center engineer James LeBlanc was testing a spacesuit in a vacuum chamber when his suit decompressed at an equivalent altitude of 250 000 ft (to all intents an d purposes a vacuum). His last memory was of the saliva boiling off his tongue as he lost consciousness. The chamber was flooded with air within 14 seconds and LeBlanc made a full recovery within days.

Landing on Mars…….is challenging, to say the least!

There is enough of an atmosphere to cause ram-air heating on atmospheric entry, but not enough to be able to rely on the terminal velocity of aerodynamic decelerators (i.e. parachutes) delivering the spacecraft safely to the surface.

The success rate for Martian landing missions is still only just over 50% - after nearly four decades of landing attempts, notable failures have included:

- Mars 2 (1971) Crashed on Mars (Soviet Union)
- Mars 3 (1971) 15 seconds of data and partial image (SU)
- Mars 6 (1973) Transmissions ceased just before landing (SU)
- Mars Polar Lander (1999) Engine cutoff whilst 40m above surface(US)
- Deep Space 2 (1999) Unknown (US)
- Beagle 2 (2003) Unknown (UK 2003)

Successes have included the Viking landers of the 1970s, Pathfinder and the Sojourner mini-rover (1997) and the spectacular US Mars Exploration Rovers (MER) – Spirit and Opportunity. Launched in 2003 with an operational expectancy of 90 Martian days (sols), Opportunity has now been returning data for eight years (Spirit finally stopped transmitting in 2010) and both rovers have transformed our understanding of the Martian environment and given us tantalising clues as to the planet's past history.

Most recently Phoenix (US) successfully landed in the Martian Arctic in 2008 and Curiosity (NASA's Mars Science Laboratory) is currently exploring Gale crater, having successfully landed in the summer of 2012.

Mars currently hosts three active space probes in orbit (***Mars Odyssey*** (NASA), ***Mars Express*** (ESA) and the ***Mars Reconnaissance Orbiter*** (NASA)).

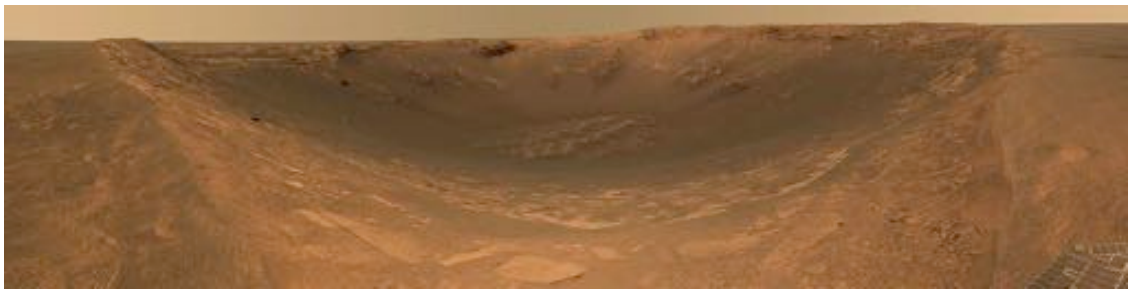


Figure 06 – Shown above

The above image shows a true-colour panorama of the Endurance crater as explored by MER-B (Opportunity)

Surface pressure data from NASA's Pathfinder mission (1997)

For reference, Earth's mean pressure is 1013.25mb.

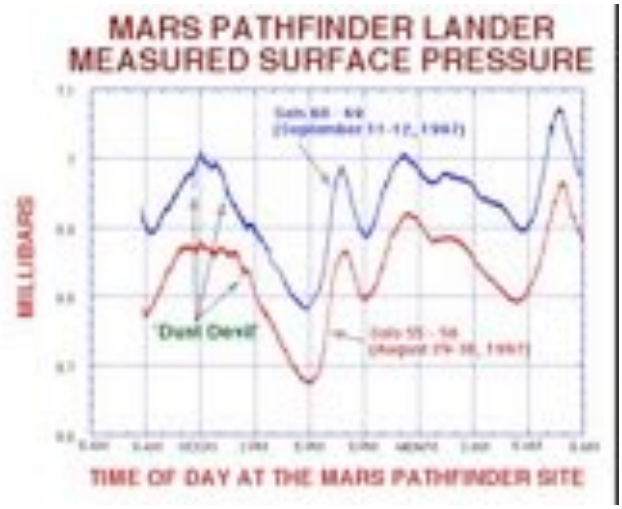


Figure 07

Mars Global Surveyor's thermal emission spectrometer obtained the following data about surface temperatures in the southern hemisphere from Martian orbit:

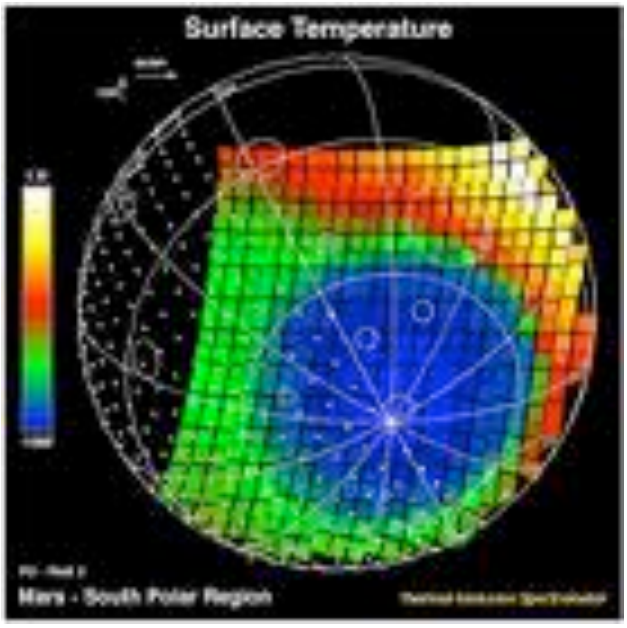


Figure 08

From orbital and ground measurements we can combine datasets to give the following overall approximate picture of the Martian surface environment:

- Temp (Mean): -46C
- Temp (Max): -5 to +20C (very transient)
- Temp (Min): -90C
- Mean surface pressure = 8mb
- (Earth = 1013.25mb = 101325Pa)
- Composition: 96% CO_2

The "frost" in this 1978 Viking 2 image is not water ice but rather solid CO_2 that has sublimed out of the Martian atmosphere as winter draws closer.

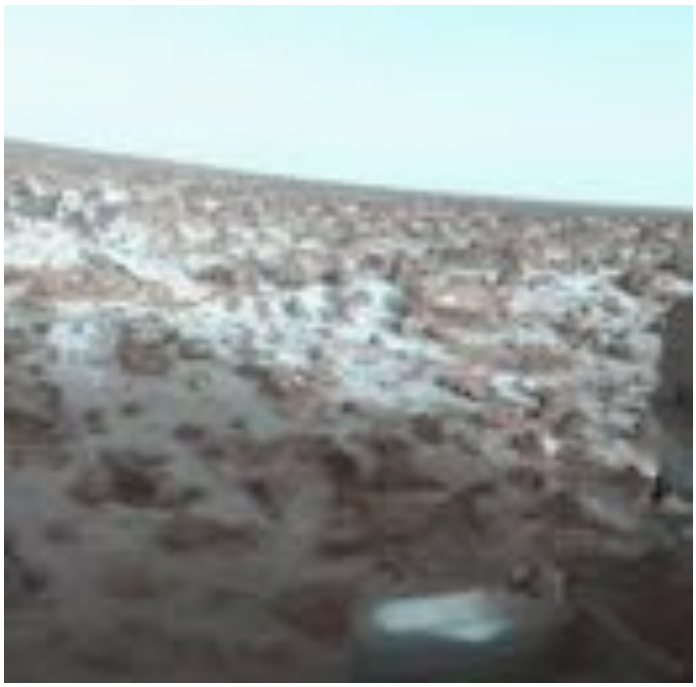


Figure 09

The blue sky is a false-colour artefact from image processing.

Image References:

Figure 01 - Image from We Are Aliens! teaching resource video (2012) ©NSCCreative 2012

Figure 02 - (2012) ©NSCCreative 2012

Figure 03 - DAILYKOS.COM (2011) *Getting to know yourSolar System (3): Venus* [WWW] Available from: http://www.dailykos.com/story/2011/08/28/1008141/-Getting-to-Know-Your-Solar-System-3-Venus [06/12/2012]

Figure 04 - UOREGON.EDU (date unknown) *Venera* [WWW] Available from: http://abyss.uoregon.edu/~js/space/lectures/lec11.html [06/12/2012]

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We Are Aliens! – Classroom activity 4 (Physics)

Using TVs and magnets to explain why Mars is the schizophrenic world of the Solar System!

We often think of space as a vacuum – but the Sun is continually emitting a stream of charged particles – the solar wind – in all directions.

This torrent of high-energy electrons and protons has the capability, over millions of years, to strip away a planetary atmosphere. The reason it doesn't, in the case of Earth, is because of our global planetary magnetic field. **(CRT TV and magnet demo)**

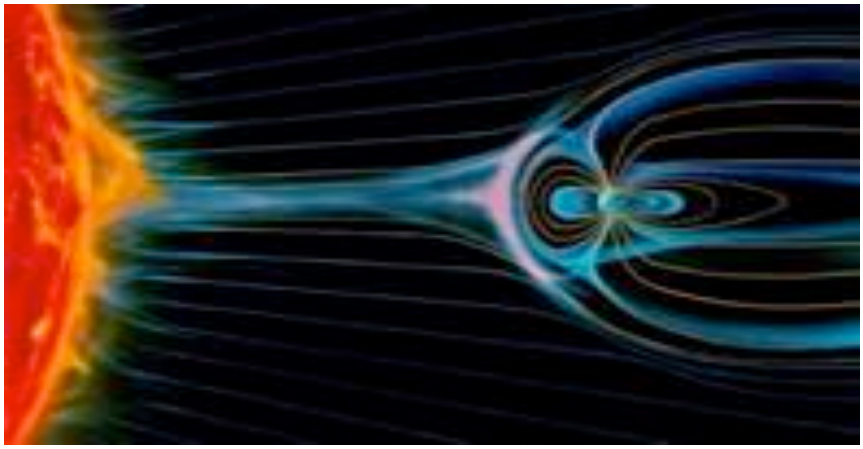
Figure 01

If we heat a permanent iron magnet to above its CURIE temperature (about 1000K) then thermal agitation means that individual atomic dipole moments are randomly aligned – i.e. the material will lose its permanent magnetic moment. The interior of the Earth is well above this temperature – there can't be a solid iron magnet buried there that creates the Earth's magnetic field!

Current modelling suggests that liquid currents in the Earth's outer core generate a planetary magnetic field – a mechanism called the geomagnetic dynamo.

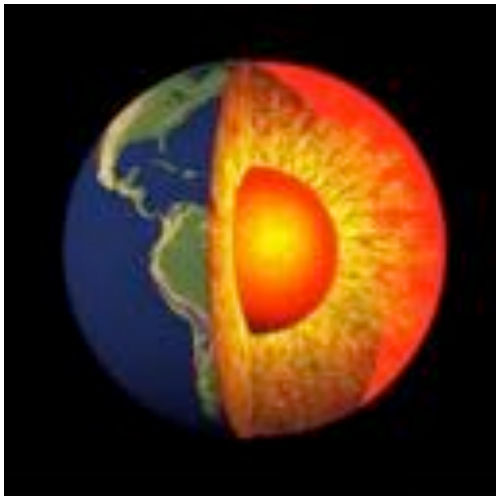
Figure 02

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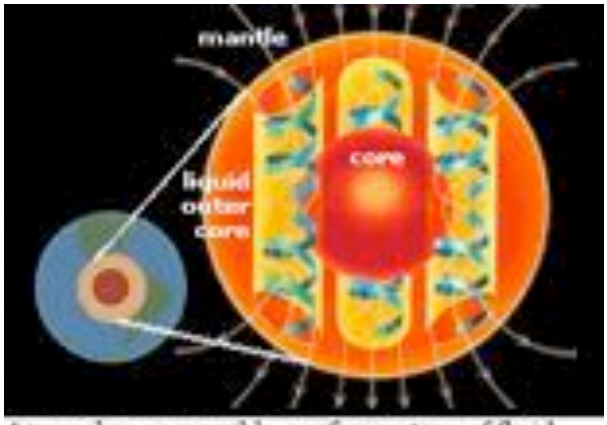
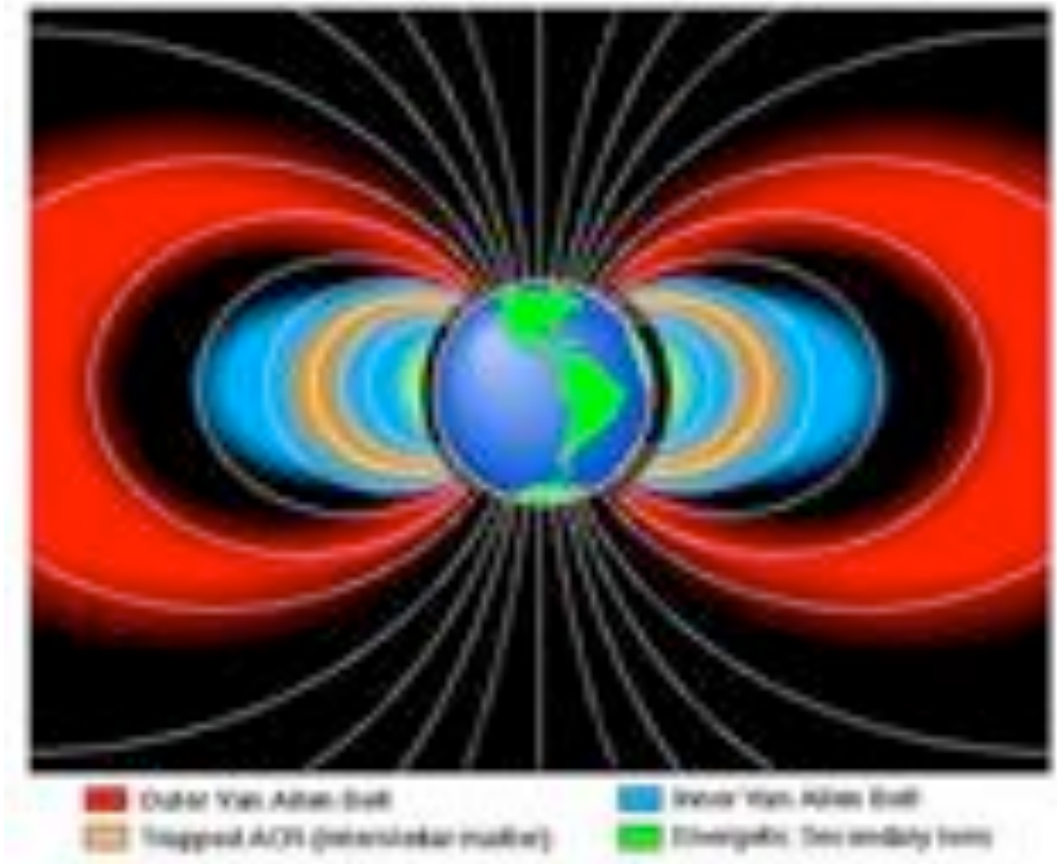


Lines show a possible configuration of fluid flow and magnetic field in the liquid outer core

Figure 03

The interaction between the Earth's magnetic field and the charged particles of the solar wind (trillions of electric currents, in effect – each thus creating their own magnetic field) causes the particles to be deflected away from stripping away the atmosphere. Some get funnelled to the polar regions, causing the upper atmospheric aurorae whilst others get trapped in the Earth's magnetic field oscillating back and forth in the famed Van Allen radiation belts.

Figure 04 – Shown below



Currently Mars has no global magnetic field of comparable strength to Earth's.

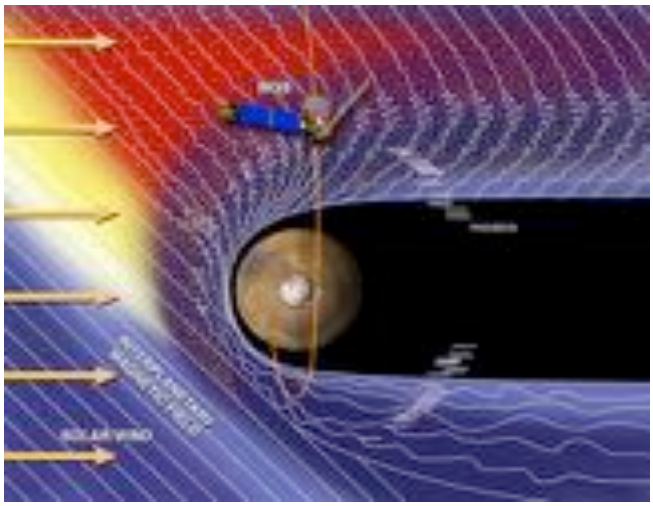
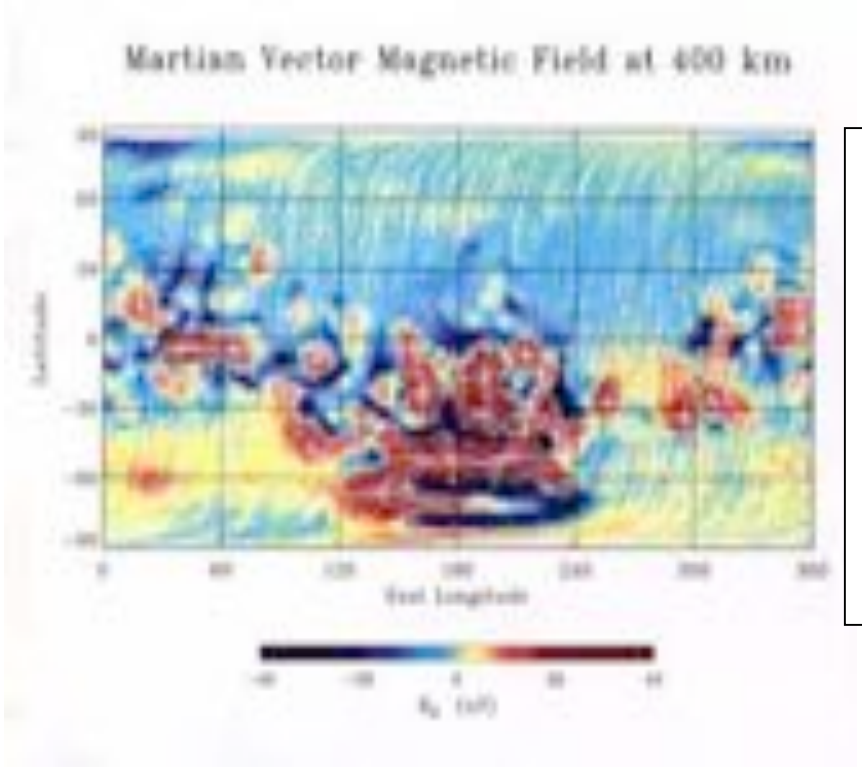


Figure 05 – Shown above

However, we see geological evidence for a “fossil” field in the past from MGS (Mars Global Surveyor) data:



For reference, Earth’s magnetic field strength at the surface (away from the geomagnetic poles) is approximately 5 *10^{-4} Tesla.

The figures for Mars are 4 to 5 orders of magnitude smaller.

Figure 06 – Shown above

As a smaller planet than Earth, Mars has a larger surface area to volume ratio and so lost internal heat quicker. It also had less gravitational self-accretion energy to start with and a lower inventory of radioactive materials in its core which provides extra “internal heating”.

Perhaps Mars’ core was once warm enough to enable the liquid motion necessary within the core to create a planetary magnetic field. A side effect of this increased core heat would have been partial surface tectonic activity – as evidenced by the enormous shield volcano Olympus Mons and the giant tectonic crack of Vallis Marineris.

It is as if the tectonic engine on Mars was stuttering but never became globally operational.

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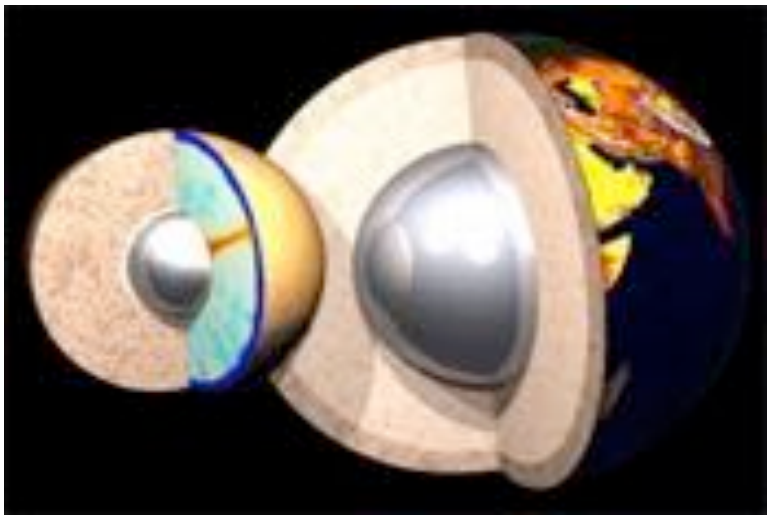

Figure 07 – Shown above

Here we see that with the lack of tectonic plate movement of the Martian crust, the magmatic plume responsible for the creation of the Olympus Mons supervolcano created a massive, 550 km wide peak reaching over 20km above mean datum.

The largest volcanoes on Earth – the Hawaiian island chain, formed an arc due to relative motion of the oceanic plate over the mantle plume.

As time went on and the planet's interior cooled, tectonism died away and the liquid currents necessary in the core to produce a powerful global magnetic field ceased as the core cooled and solidified.

It is also possible that a sequence of giant asteroid impacts destroyed the planetary magnetic field. Whichever mechanism was responsible, the end result was the same: the tenuous solar wind was now able to start directly interacting with Mars' atmosphere, stripping it away in a relentless process over billions of years with the final result being the barren, dead(?) world we observe today.

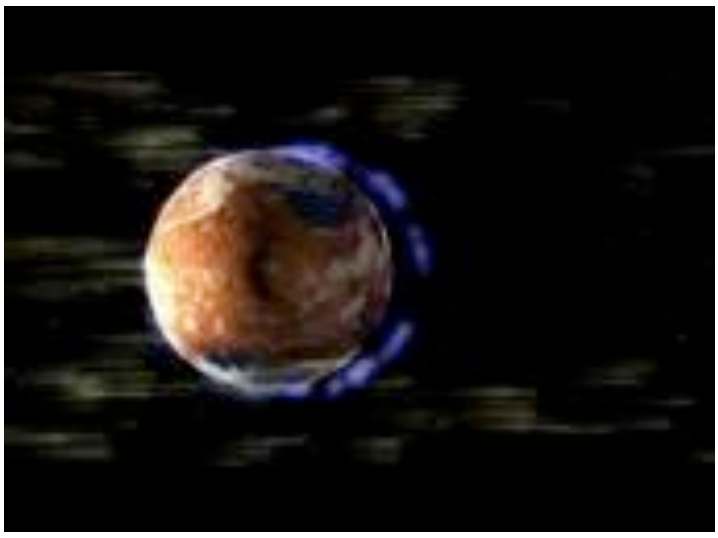

Figure 08

Observations have shown that Martian aurora are not confined to regions coincident with planetary geomagnetic poles but are evident at all latitudes.

Could this be the fate of our planet? It's certainly a possibility but current estimates give us at least 1.5 billion years before the effects would be so dramatic on our home world. Nevertheless, this highlights one of the benefits of planetary exploration – unlocking the secrets of other worlds gives us better insights into our own.

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