THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

CHEMISTRY B (SALTERS) F332/ADVANCE NOTICE

Chemistry of Natural Resources: Advance Notice article

For issue on or after:
13 MARCH 2010

Monday 7 June 2010
Morning

Duration: 1 hour 45 minutes

OCE/13716

NOTES FOR GUIDANCE (CANDIDATES)

1 This leaflet contains an article which is needed in preparation for a question in the externally assessed examination F332.

2 You will need to read the article carefully and also have covered the learning outcomes for Unit F332 (*Chemistry of Natural Resources*). The examination paper will contain questions on the article. You will be expected to apply your knowledge and understanding of the work covered in Unit F332 to answer these questions. There are 20 marks available on the paper for these questions.

3 You can seek advice from your teacher about the content of the article and you can discuss it with others in your class. You may also investigate the topic yourself using any resources available to you.

4 You will **not** be able to bring your copy of the article, or other materials, into the examination. The examination paper will contain a fresh copy of the article as an insert.

5 You will not have time to read this article for the first time in the examination if you are to complete the examination paper within the specified time. However, you should refer to the article when answering the questions.

This document consists of **8** pages. Any blank pages are indicated.

Instruction to Exams Officer / Invigilator:
Do not send this Insert for marking; it should be retained in the centre or destroyed.

Earth-Venus-Mars

adapted from www.astronomynotes.com

Introduction

Venus, Earth and Mars are all at similar distances from the Sun. It is believed that they formed out of the same material and had approximately the same initial temperatures 4.5 billion years ago. Long ago these three planets probably had moderate enough temperatures suitable for life. However, Venus is now much too hot for life and Mars is too cold for life. What happened to these two planets and why are they so different from the comparative paradise here on Earth? This article explores these three planets in more detail in order to answer this important question and what the answer to this question might say for the future of the Earth.

Venus

Venus is about 95% the size of the Earth and has 82% of the Earth's mass. Like Earth, Venus has a rocky crust and an iron-nickel core. But the similarities stop there. Venus has a thick atmosphere made of 96% carbon dioxide (CO_2), 3.5% nitrogen (N_2) and 0.5% other gases. At Venus' surface, the atmospheric pressure is 91 times the Earth's surface atmospheric pressure. Anyone exploring Venus would need a very powerful cooling system: the surface temperature is above 700 K. This is hot enough to melt lead and is over twice as hot as it would be if Venus did not have an atmosphere. Why does Venus have such a thick atmosphere and why is it so hot on its surface?

Greenhouse Effect

Venus is so hot because of a greenhouse effect that prevents heat from escaping into space. On a planet, certain gases like carbon dioxide or water vapour in the atmosphere prevent heat energy in the form of infrared radiation from leaking out into space. These so-called greenhouse gases allow *visible* light from the Sun to pass through and heat up the surface of the planet. The surface gets warm enough to emit *infrared* light. Some of the infrared radiation is absorbed by the greenhouse gases and some is radiated back towards the surface, keeping the surface warm. On Venus, the super-abundance of CO_2 in its atmosphere is responsible for the huge greenhouse effect. Venus' greenhouse effect probably started from the presence of a lot of water vapour, but Venus is now a very dry place.

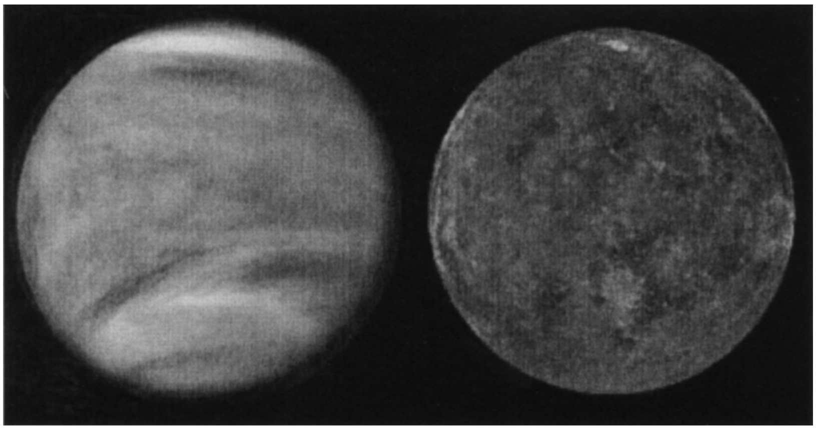


Fig. 1 Venus' cloud tops in UV (left) and Venus' surface imaged with radar (right)

Runaway Greenhouse

Venus was originally cooler than it is now and it had a greater abundance of water several billion years ago. Also, most of its carbon dioxide was locked up in the rocks. Through a process called a runaway greenhouse, Venus heated up to its present blistering hot level. Because Venus is slightly closer to the Sun than the Earth is, its water never liquefied and remained in the atmosphere to start the greenhouse heating. As Venus heated up, some of the carbon dioxide in the rocks was 'baked out'. The increase of atmospheric carbon dioxide enhanced the greenhouse heating. That baked more carbon dioxide out of the rocks (as well as any water) and a runaway feedback loop occurred. This feedback loop occurred several billion years ago, so Venus has been very hot for several billion years. The loss of water from the rocks means that Venus' rocks are harder than the rocks of Earth and its lithosphere is now probably too thick and hard for plate tectonics to occur. The water Venus originally had is now gone because of a process called ultraviolet dissociation.

Ultraviolet Dissociation of Water

Venus' early water was hot enough to remain in a gaseous form and thus (without an ozone layer) was dissociated by ultraviolet radiation from the Sun. The oxygen atoms produced combined with other atoms and the low-mass hydrogen escaped into space. Eventually the water disappeared. On Earth, however, the ozone layer protected the water vapour from the high-energy UV radiation that would cause dissociation.

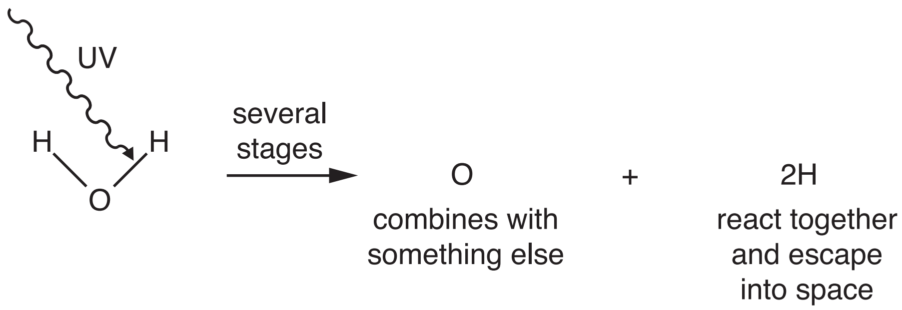
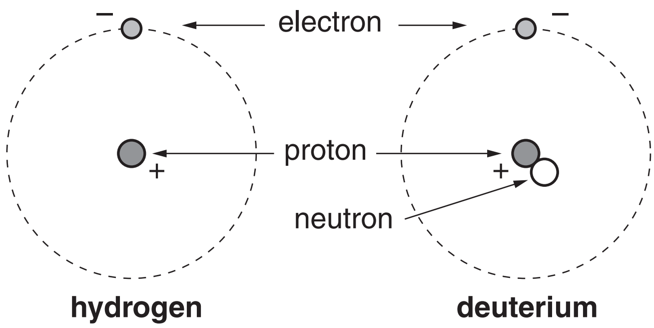


Fig. 2 Ultraviolet dissociation of water

Hydrogen/Deuterium Ratio

How is it known that Venus originally had more water? Clues come from comparing the relative abundances of hydrogen isotopes on Venus and Earth. An isotope of a given element will have the same number of protons in the atomic nucleus as another isotope of that element but not the same number of neutrons. An isotope with more particles in the atomic nucleus will be more massive (heavier) than one with fewer particles in the nucleus.



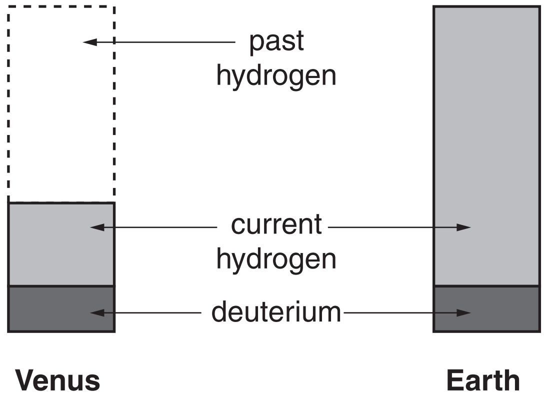
Two isotopes of hydrogen. The deuterium isotope has an extra neutron in the nucleus.

Fig. 3 Hydrogen isotopes

Ordinary hydrogen has only one proton in the nucleus, while the isotope *deuterium* has one proton plus one neutron. Therefore, deuterium is about twice as heavy as ordinary hydrogen and will thus be less likely to escape.

On Earth the ratio of ordinary hydrogen to deuterium (H/D) is 1000 to 1, while on Venus the proportion of deuterium is about ten times greater – the H/D ratio is 100 to 1. The H/D ratios on Venus and Earth are assumed to have been originally the same, so something caused the very light hydrogen isotopes on Venus to preferentially disappear. An easy explanation for it is the ultraviolet dissociation of water.

Water vapour started the greenhouse heating. Carbon dioxide was baked out of the rocks, further aggravating the greenhouse effect. A runaway greenhouse started. The end result was all of the carbon dioxide in the atmosphere and the water dissociated away. The flowchart on page 5, up to the last arrow, occurred several billion years ago. The diamond at the end describes the current state: CO_2 maintains the extremely hot temperature.



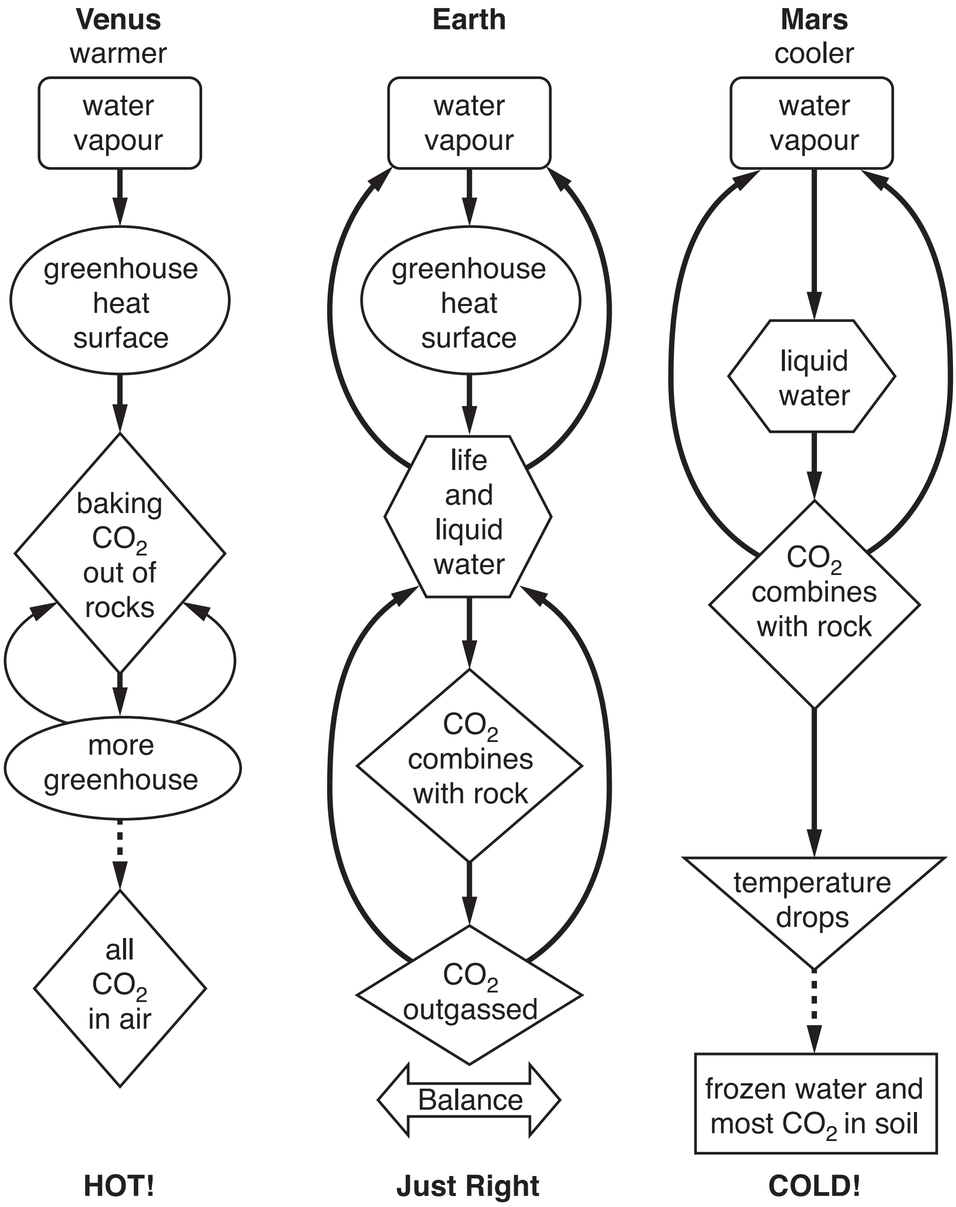
Proportions of hydrogen to deuterium on Venus and Earth are very different – ordinary hydrogen isotope was preferentially removed on Venus.

Fig. 4 Comparison of hydrogen isotopes on Earth and Venus

Earth-Venus-Mars Comparison

This is a flowchart summary of the histories of the terrestrial planet atmospheres of Venus, Earth and Mars. It shows the histories side-by-side so it is easier to compare the planet histories.

The chart for Venus, up to the dashed arrow, describes the runaway greenhouse process that happened a few billion years ago. The bottom diamond describes the current condition. The chart for Mars, up to the dashed arrow, describes the runaway refrigerator process that happened a couple of billion or more years ago, due to Mars' greater distance from the Sun than either of the other two planets. The bottom rectangle describes the current condition. The chart for Earth describes the carbon dioxide cycle as it currently operates. The Earth exists balanced between the two extremes of Venus and Mars.



Venus has a runaway greenhouse effect and no water left. Earth has life and liquid water keeping temperature balanced and most of its CO_2 in the rocks. Mars has a runaway refrigerator with water frozen in permafrost layer and most of its CO_2 in the rocks or frozen on the surface.

Fig. 5 Comparing the atmospheres of Venus, Earth and Mars

END OF ADVANCE NOTICE ARTICLE

BLANK PAGE

BLANK PAGE

BLANK PAGE