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October 12, 2010

The Atmospheres of Different Planets

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Introduction

The atmosphere in the solar system planets is the most important factor which its composition, structure, density, and thickness can affect on the planet environment. The heliocentric distance of the planet, mass of the planet, surface gravity, escape velocity, exospheric temperature, and atmospheric mass are determining crucial composition of the planet's atmosphere, such as formation temperature, present equilibrium temperature, incident UV intensity, and incident solar wind flux. In this project brief information about composition, structure, surface pressure and mean surface temperature of the planets in the solar system introduced. In addition, existence of the planetary magnetosphere has been discussed; because of its important affect on the atmosphere of each planet.

1. Mercury

Mercury's atmosphere containing oxygen (42%), sodium (29%), hydrogen (22%), helium (6%), potassium (0.5%) and water vapor. (Figure 1)

The atmosphere is extremely transitory which is due to Mercury's very weak gravitational field and low escape velocity for gaseous molecules (4.0 km sec^{-1}), in compare to the escape velocity for gaseous molecules in the earth's upper atmosphere (11.86 km sec^{-1}).

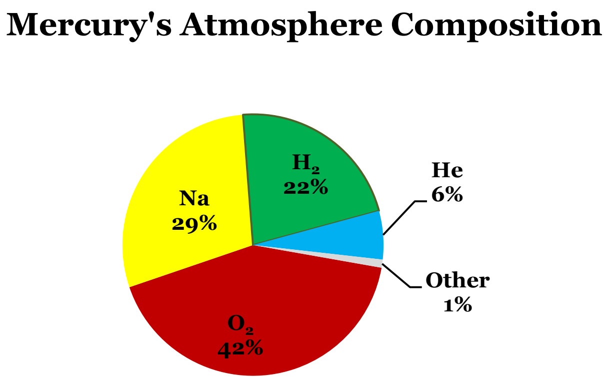

Figure 1: Mercury's approximate atmospheric composition.

The Mercury's position in the solar system is the primary problem in studying the composition of the Mercury's atmosphere. Telescopic observation of Mercury are difficult or made impossible because Mercury can rise at a maximum, almost two hours prior to earth's sunrise or set two hours after earth's sunset. Hence, present knowledge about Mercury's atmosphere provided by the Mariner 10 spacecraft (1974) and recently by the MESSENGER spacecraft (2008). Mariner 10's spectrometer confirmed the presence of argon, neon and xenon from dark side of Mercury. Mariner 10's ultraviolet spectrometer detected the helium atoms which are identified as transient atoms from the solar wind. Each of these atoms remains trapped in the atmosphere for ≈ 200 days. The oxygen may arise from sputtering, photolysis, and chemical processes involving interaction of hydrogen with surface silicaceous rocks. The Mariner 10 fluxgate magnetometer experiments, confirmed a well developed magnetosphere about Mercury, with the magnetopause standing well off from its surface and a comet-like tail exist behind the planet due to solar lights which are pushes the atmospheric gases away from the sun. The Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER) probe, discovered large amounts of water present in the Mercury's exosphere. The MESSENGER also detected evidence of volcanic activity on Mercury's surface which implies the planet has a liquid core. Moreover, MESSENGER experiments showed elements such as magnesium, calcium, sodium and potassium are also exists in the Mercury's exosphere. The Mercurian day temperature varies between 590-725 K while, in the Mercurian night's temperature decrease to 100 K. The total atmospheric pressure at Mercury has been estimated at 2×10^{-9} mb, while earth's standard sea level pressure is 1013.2 mb which shows the surface atmospheric pressure of Mercury is similar to the earth's atmosphere at 50 km altitude.

2. Venus

The atmosphere of Venus is one of the most chemically complex and dynamically active planetary atmosphere in the solar system. The Venusian atmosphere consist of carbon dioxide (95.5%), nitrogen (3.5%), sulfur dioxide (0.015%), argon (0.007%), carbon monoxide (0.002%), helium (0.001%), neon (0.001%). (Figure 2)

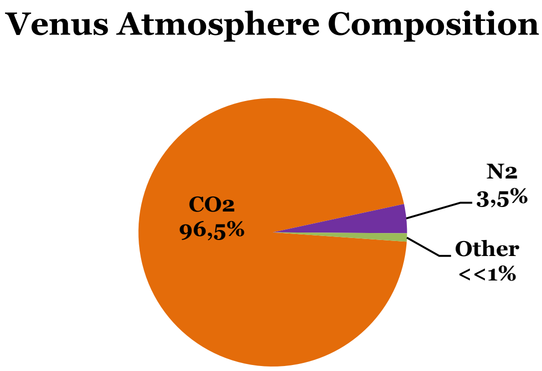

Figure 2: Venus' atmosphere approximate composition ratio.

The high concentration of carbon dioxide in the Venus's atmosphere had been detected from earth. The relatively major amount of CO_2 in the atmosphere explain Venus high surface temperature as a direct consequence of the greenhouse effect which cause a surface temperature equal to 737 K on the Venus surface. Since, infrared energy at most wavelengths absorb by carbon dioxide. The surface temperature exhibits some degree of uniformity because the CO_2 relatively uniform mixed in atmosphere. The Venus' atmospheric structure only consists of troposphere and thermosphere.

The pressure on the surface is 92 atm.press of Earth. Venus' lack of a magnetosphere revealed an ionosphere which separates the atmosphere from outer space and the solar wind. The peak ion concentration is located at an altitude ≈150 km. The weak magnetism and absence of a magnetosphere permit solar wind to penetrate farther downward into the atmosphere. Hence, the solar wind does create a magnetic field in the ionosphere by induction, which is considered as the Venus' induced magnetosphere. This induced magnetosphere produces a bow shock, magnetosheath, magnetopause and magnetotail with the current sheet.

3. The Earth

The atmosphere of Earth is mainly composed of nitrogen (78.08%) and oxygen (20.95%). The remaining part of the atmosphere divided into the permanent and the variable constituents. The permanent constituents consist of the five noble gases, argon, neon, helium, krypton and xenon also other materials such as carbon dioxide, hydrogen, methane, nitrous oxide and radon. The variable constituents of the atmosphere are water, carbon monoxide and ozone. (Figure 3)

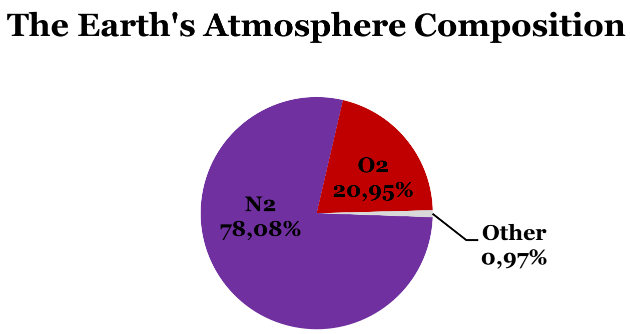

Figure 3: Earth's atmosphere approximate composition ratio.

The mean surface pressure at sea level is 1.0 atm. press of Earth (1013.2 mb). The pressure of Earth's atmosphere changes vertically at a negative constant rate of one thirtieth of its value for every 275 m in altitude. In general, the temperature varies between 283 K (night) and 293 K (day). The Earth's atmosphere vertical temperature changes as shown in figure 4 does not decrease uniformly with height.

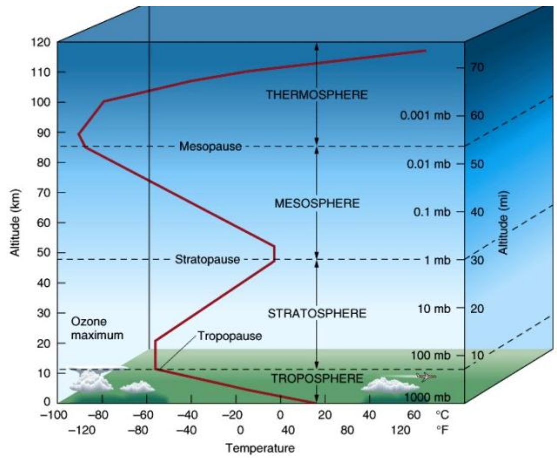

Figure 4: Earth's structure and temperature profile.

The temperature varies with four major layers of the Earth's atmosphere, the troposphere, stratosphere, mesosphere and thermosphere. Two layers, the troposphere and mesosphere, temperature decrease with height, by assuming that the earth's atmosphere is not in motion. This value would be ≈6.5 K km^{-1}. On the other hand, the temperature increases in the stratosphere and thermosphere, with height because of the ultraviolet energy absorption by molecular oxygen. The magnetic field around the earth generate by powerful electric currents which are conducting by the earth's liquid metallic core. The magnetosphere of Earth is a region in space whose shape is determined by Earth's internal magnetic field. Earth's magnetosphere provides protection for the planet against the solar winds. The life as we know it could not survive without Earth's magnetosphere.

4. Mars

Mars is a desert planet with a rarified atmosphere that is mostly carbon dioxide. The atmosphere of Mars is very different from the Earth's atmosphere. Martian atmosphere is relatively thin and the atmospheric pressure on the surface caries from 0.004 atm.pres Earth to 0.009 atm.press Earth. The atmosphere on Mars consists of carbon dioxide (95%), nitrogen (2.7%), argon (1.6%), oxygen (0.13%), carbon monoxide (0.08%), water (0.021%), and nitric oxide (0.01%). (Figure 5)

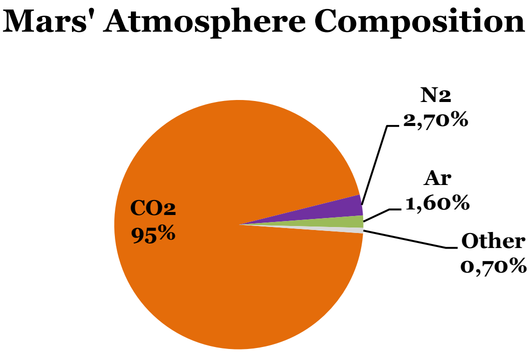

Figure 5: Mars' atmosphere approximate composition ratio.

Carbon dioxide dominates Mars' atmosphere and amounts to 13 g cm^{-2}. Studies showed that Mars may have actually outgassed 250 g cm^{-2} of carbon dioxide or approximately twenty times the present amount in the atmosphere. The difference indicates that most of the carbon dioxide has been lost. Three theories suggest the possibilities. First, Mars may have lost its excess carbon dioxide directly to space. Second, it is possible the carbon dioxide was outgassed and combined into the planet's rock materials via chemical weathering process. Or, lastly, the disappeared carbon dioxide may have been physically adsorbed onto the soil particles. Assessments propose that Mars also has outgassed between ten and thirty times the amount of nitrogen it has now has. The mean temperature at the surface varies between 184 K (night) and 242 K (day). Mars atmosphere is divided into four major layers, the lower atmosphere which is a warm region, middle atmosphere which Martian jet streams flow in this region, upper atmosphere or thermosphere which has very high temperature, caused by heating from the sun and exosphere which starts at 200 km. Mars has a weak planetary magnetic field. The Mars Pathfinder measurements showed that Mars has a large iron core which generates a magnetic field but the magnetic field is very weak because the planet core solidified. Therefore, Mars has a magnetosphere but it may be too small to protect Mars' atmosphere against the solar wind.

5. Jupiter

The planet Jupiter chemical composition is similar to sun more than any of the other planets. The atmosphere of Jupiter has relative ratios of constituents the sun. The atmosphere in this planet based on ground optical telescopes and Pioneer 10 satellite data, consist of hydrogen (89.8%), helium (10.2%), methane (0.3%), ammonia (0.026%), clouds made of ammonia ice, water ice, ammonium hydrosulfide and other materials like phosphine, sulfide, acetylene, ethane and germanium tetra hydride which are detected by the Voyager probes.

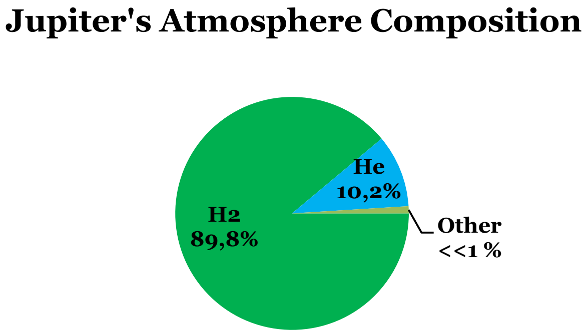

Figure 6: Jupiter's atmosphere approximate composition ratio.

Jupiter's atmospheric mass of hydrogen and helium is vigorous in upper portions and sluggish and weak in the lower regions. This behavior of the atmosphere of Jupiter compared to the earth's oceanic circulation. Jupiter's atmosphere is divided into four main layer troposphere, stratosphere, mesosphere and thermosphere. In the troposphere the temperature decreases with height. In the stratosphere the temperature increases while in the mesosphere the temperature decreases with height and finally in thermosphere of Jupiter sharp increase of temperature were detected. The atmospheric pressure in Jupiter's tropopause is approximately >> 1000 atm.press of Earth and the temperature at 1.0 atmosphere is ≈165°K. The evidence seems to suggest Jupiter has a small rocky inner core surrounded by liquid metallic hydrogen. Jupiter does have a strong magnetic field and magnetosphere.

6. Saturn

Saturn is physically smaller than Jupiter but many similarities exist between these two giant gaseous. The Saturn's atmosphere composed of hydrogen (96.3%), helium (3.25%), methane (0.45%), ammonia (0.0125%), etan (0.0007%) and clouds made of ammonia ice, water ice. (Figure 7)

Saturn's Atmosphere Composition

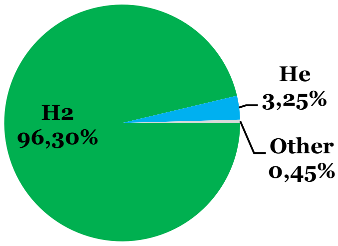

Figure 7: Saturn's atmosphere approximate composition ratio.

The Saturn's temperature at the 1 bar reference level is equal to 140°K and the atmosphere pressure approximately equal to Jupiter's atmospheric pressure. Saturn has a smaller magnetic field in comparison to Jupiter's but still its magnetic field is many times greater than the earth's magnetic field. Therefore, Saturn's has a magnetosphere.

7. Uranus

The Uranus atmosphere is consist of hydrogen (82.5%), helium (15.2%), methane (2.3%) and clouds made of ammonia ice, water ice, ammonium hydrosulfide, methane ice.(Figure 8)

Uranus' Atmosphere Composition

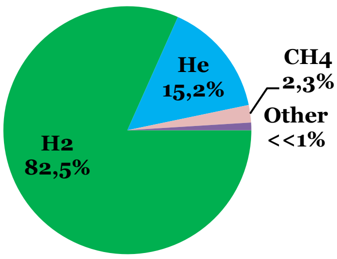

Figure 8: Uranus' atmosphere approximate composition ratio.

Infrared measurements shows at 10^2 mb pressure level, Uranus has an effective atmosphere temperature of 58°K. In the troposphere layer the temperature decrease with height but in the stratosphere and thermosphere temperature increase with height. Voyager's observation showed Uranus has a magnetosphere which is like other planet has a bow shock, a magnetopause, a fully developed magnetotail and radiation belts.

8. Neptune

Neptune's atmosphere seems to be composed of hydrogen (80%), helium (18 %), methane (1.5%), etan (0.0002%) and clouds made of ammonia ice, water ice, ammonium hydrosulfide and methane ice.(Figure 9)

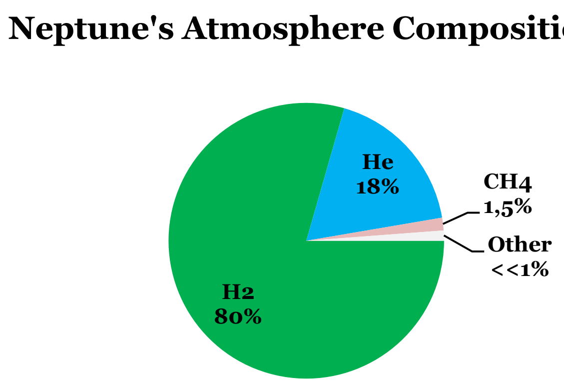

Figure 9: Neptune's atmosphere approximate composition ratio.

Neptune's atmosphere has two major regions. First region is the lower troposphere, where the temperature decreases with altitude and second region is the stratosphere where the temperature increases with altitude. The Neptune's magnetosphere is similar to Uranus magnetosphere. The infrared measurement showed the effective temperature at the 10^2 mb pressure level is 60°K.

9. Pluto

Pluto is probably composed of methane, nitrogen, water ice, carbon dioxide, ammonia. The temperature on Pluto is probably > 40°-50°K and the atmospheric pressure is around 3×10^{-6} atm.press of Earth. Pluto's orbit is very elliptical therefore in closest position of Pluto to the sun the surface of solid nitrogen heats up and changes directly from a solid to gas. Pluto doesn't have enough gravity to keep these gases and when it gets further from the sun the atmosphere freezes and solidifies back down on the surface of Pluto. It's not confirmed yet but it seems from its dual orbit with its moon Charon that Pluto may have a magnetic field.

Summery

From the point view of planetary atmospheric composition, we can divide the solar system planets into 3 major groups, first group is Mercury and Pluto which do not have normal atmosphere in compare to the other planets due to their heliocentric distance from the Sun which Mercury is too close and Pluto is so far. Second group is Venus, Earth and Mars, they all have large amount of nitrogen in their atmosphere and Venus and Mars major atmospheric element is carbon dioxide. Third group is Jupiter, Saturn, Uranus and Neptune which they have hydrogen and helium as their major atmospheric elements. In addition, Uranus and Neptune have methane in their atmospheric structure. Also in perspective of surface temperature, Venus and Mercury are hottest planets in solar system while Uranus, Neptune and Pluto are coldest one. Other planets temperature varies between 140 K and 293 K. As we mentioned magnetosphere play important role in atmosphere composition and structure. Among the solar system planets, Mercury, Earth, Jupiter, Saturn, Uranus and Neptune have magnetosphere while Pluto may have magnetosphere (still unknown!) and Venus has an induced magnetosphere.

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