PLANETARY ATMOSPHERES

SOURCE:

1) ORIGINAL GAS IN THE COLD CLOUD OF INTERSTELLAR MATERIAL (74% H, 24% He) — SO-CALLED PRIMARY ATMOSPHERE;

2) VOLCANIC GASES: CARBON DIOXIDE (CO_2)
SULFUR DIOXIDE (SO_2)
WATER VAPOR (H_2O)
NITROGEN (N_2)

ONLY THE JOVIAN PLANETS STILL HAVE THE PRIMARY ATMOSPHERE.

JUPITER

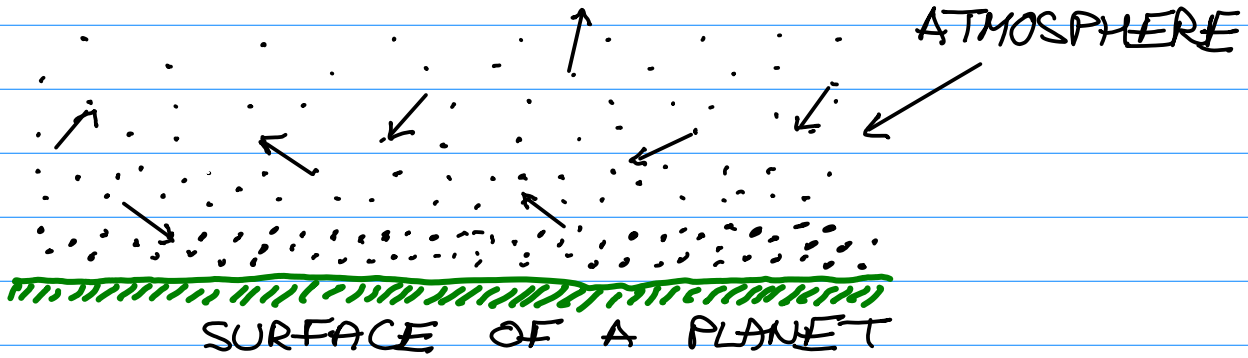
THE HIGH CLOUDS ARE COMPOSED OF AMMONIA (NH_3) CRYSTALS

TERRESTIAL PLANETS HAVE LOST THE PRIMARY ATMOSPHERE.

A PLANET CAN LOSE ITS ATMOSPHERE IF

1) IT HAS A HOT SURFACE;

2) IT IS SMALL SO THAT THE ESCAPE VELOCITY FROM IT IS LOW.



THE MOLECULES OF THE ATMOSPHERE MOVE IN A CHAOTIC WAY WITH SOME AVERAGE SPEED V WHICH IS RELATED TO THE TEMPERATURE T BY

$$T = \frac{1}{3} m V^2$$

m: MASS OF A MOLECULE

THE ESCAPE VELOCITY V_{esc} FROM A PLANET IS DETERMINED BY ITS MASS M

AND RADIUS R:

GRAVITATIONAL CONSTANT

$$V_{esc}^2 = \frac{2GM}{R}$$

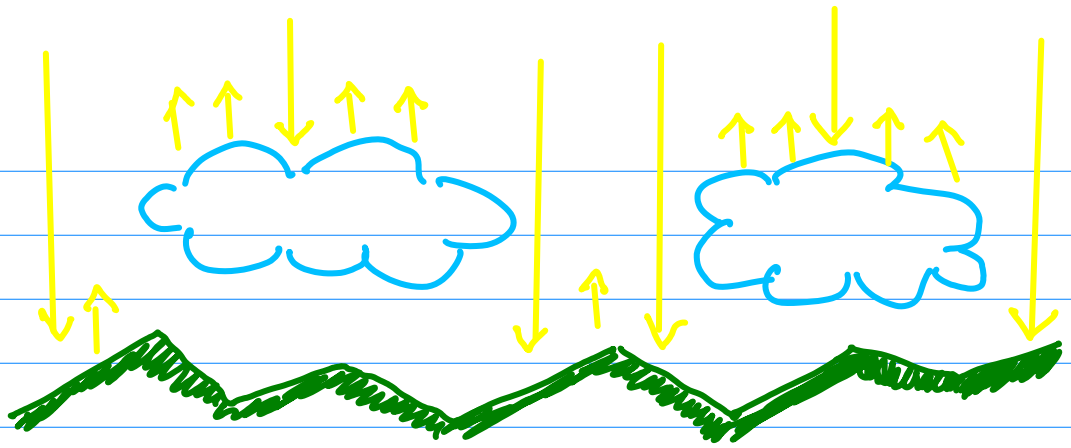
HIGH T IMPLIES HIGH V, IN PARTICULAR IF m IS SMALL (E.G. HYDROGEN AND HELIUM) AND SMALL M IMPLIES A SMALL V_{esc}. IF $V > V_{esc}$ THE MOLECULE IN THE ATMOSPHERE WILL ESCAPE.

WHICH FACTORS DETERMINE THE SURFACE TEMPERATURE T?

1) THE DISTANCE FROM THE SUN.

2) HOW MUCH OF THE RECEIVED SOLAR ENERGY IS REFLECTED BACK (REFLECTIVITY OR ALBEDO)

ALBEDO/REFLECTIVITY = PERCENTAGE OF INCOMING LIGHT THAT IS REFLECTED BACK



PURE ROCKY SURFACE: LOW ALBIDO (THE SURFACE ABSORBS MOST OF THE SOLAR ENERGY)

SOME CLOUDS: MEDIUM ALBEDO

ALL CLOUDS: HIGH ALBEDO

PLANET	ALBEDO
MERCURY	11%
VENUS	72%
EARTH	36%
(MOON	7%)
MARS	25%

JUPITER	34%
SATURN	34%
URANUS	34%
NEPTUNE	29%

MERCURY:

- CLOSE TO THE SUN
- LOW REFLECTIVITY (NO CLOUDS)

} ⇒ HIGH SURFACE TEMPERATURE

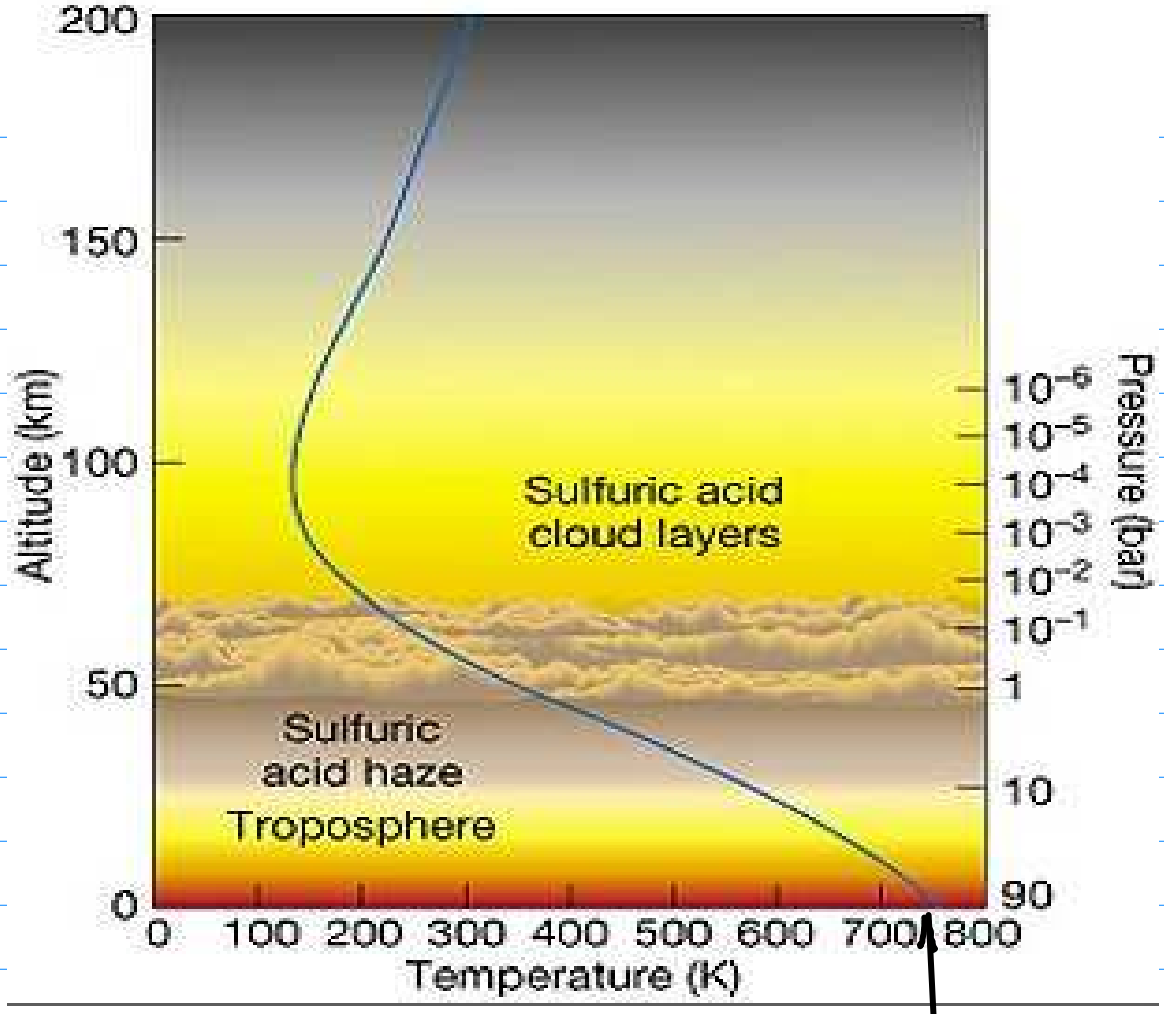
- SMALL PLANET ⇒ LOW GRAVITY / ESCAPE VELOCITY

MERCURY'S ATMOSPHERE IS EXTREMELY THIN (THE PRESSURE IS LESS THAN 10^{-12} atm).

VENUS:

VENUS HAS A SUBSTANTIAL ATMOSPHERE.

COMPOSITION: CO_2 (96%), N_2 (3.5%), SMALL AMOUNTS OF SO_2, H_2O, SULFURIC ACID, HYDROCHLORIC ACID



462°C

SURFACE TEMPERATURE : 462°C

SURFACE PRESSURE : 92 atm

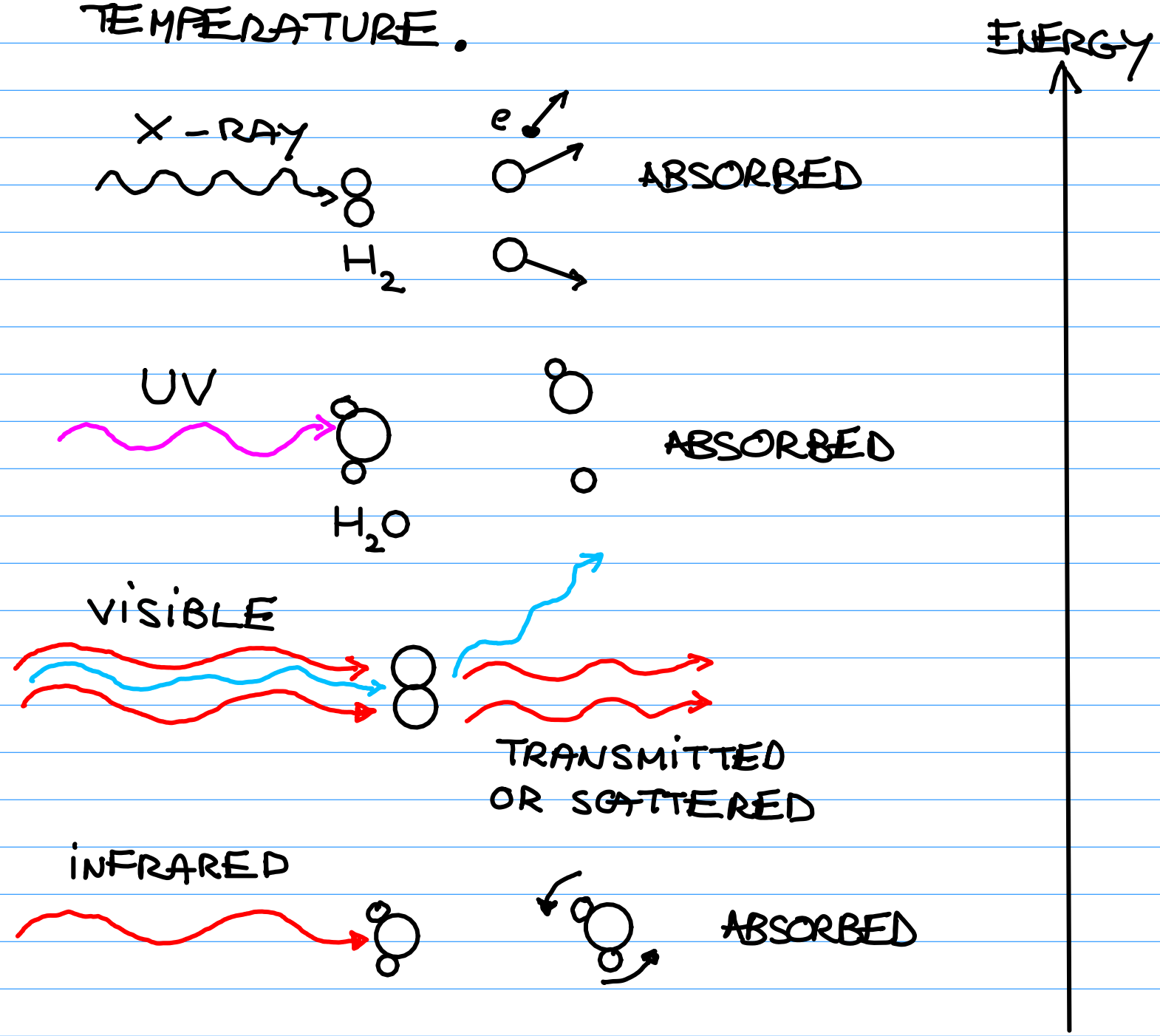
CLOUDS : DROPLETS OF SULFURIC ACID

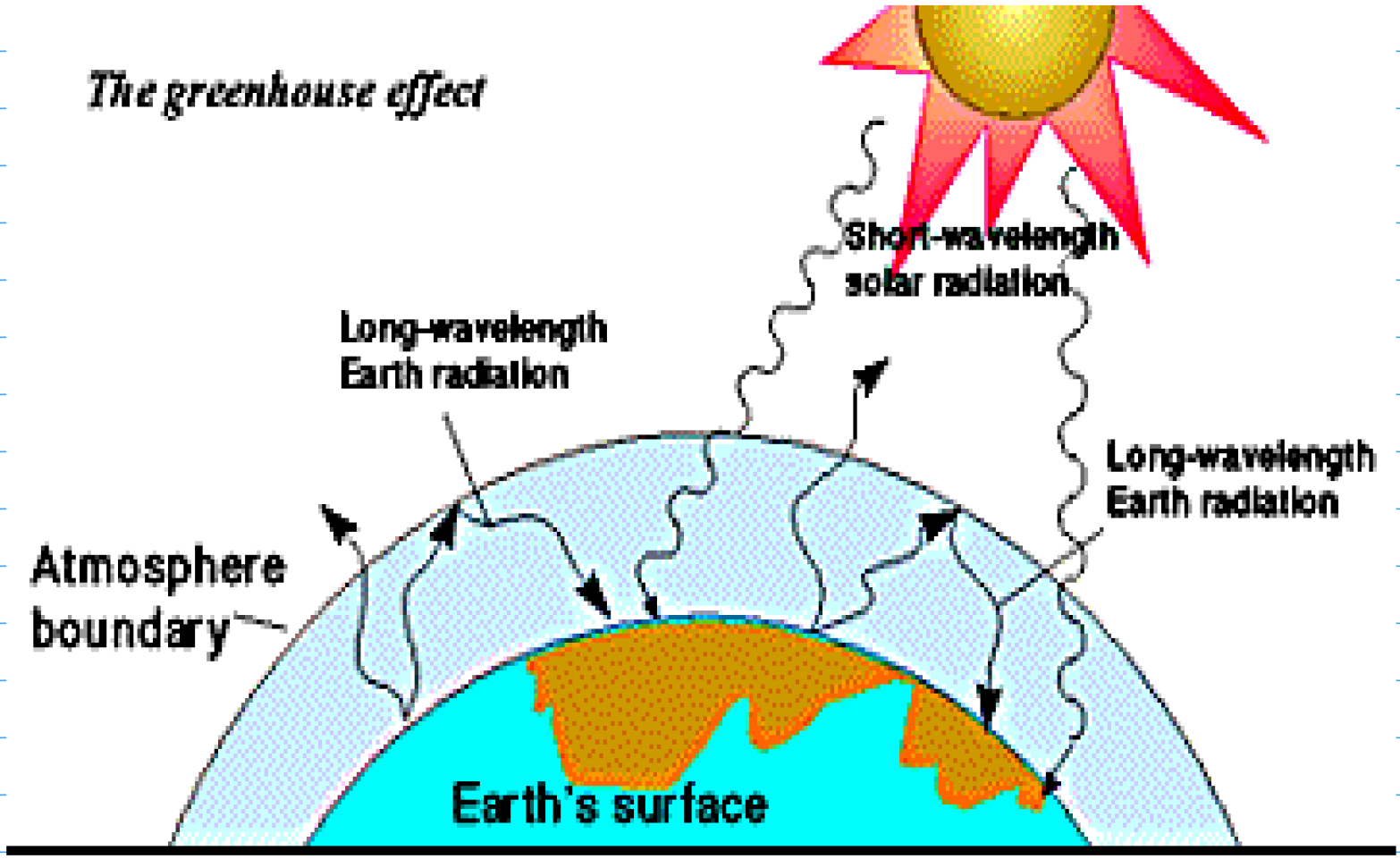
WHY IS VENUS SO HOT?

IT IS NOT THAT CLOSE TO THE SUN AND HIGH CLOUDS GIVE RISE TO

HIGH REFLECTIVITY (LESS SOLAR HEATING).

A RUNAWAY GREENHOUSE EFFECT IS RESPONSIBLE FOR A HIGH SURFACE TEMPERATURE.

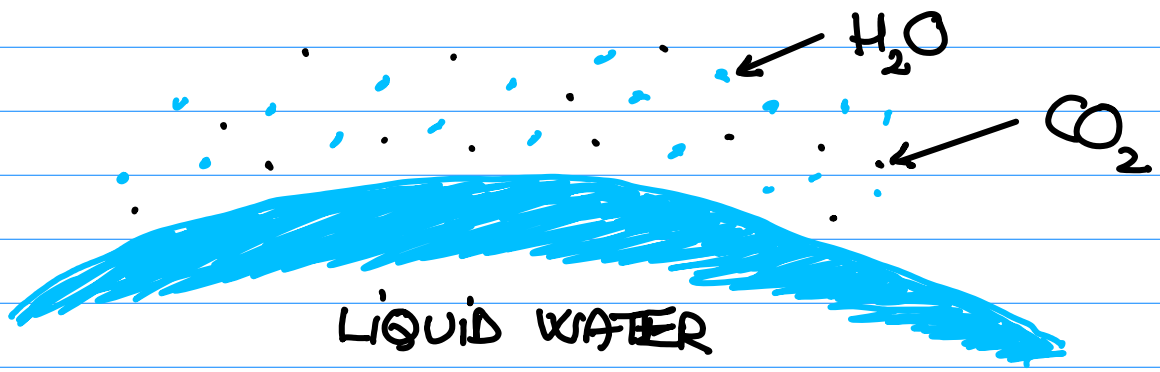




THE MOLECULES OF H_2O, CH_4 AND CO_2 (THE GREENHOUSE GASES) TRAP THE INFRARED RADIATION AND THE ATMOSPHERE HEATS UP.

WHY IS THE ATMOSPHERE OF EARTH SO DIFFERENT FROM THE ATMOSPHERE OF VENUS?

OUR DISTANCE FROM THE SUN IS JUST RIGHT SO THAT OUR H_2O IS MAINLY LIQUID WATER (THE TEMPERATURE IS BETWEEN 0 °C AND 100 °C)



- LIQUID WATER ABSORBS CO_2 FROM THE ATMOSPHERE PRODUCING CARBONIC ACID
- CARBONIC ACID + ROCK ⟶ LIMESTONE

AS A RESULT, MAINLY NITROGEN (N_2) WAS LEFT.

OXYGEN PRODUCTION IN THE ATMOSPHERE:

UV-RADIATION

$2H_2O$

O_2 LEFT BEHIND

$2H_2$ ESCAPES (SMALL MASS)

UP UNTIL 2-2.5 BILLION YEARS AGO THIS WAS THE ONLY SOURCE OF OXYGEN IN THE EARTH'S ATMOSPHERE.

BY THAT TIME THE CYANOBACTERIA (BLUE-GREEN ALGAE) EVOLVED. THEY CONSUME CO_2 AND H_2O AND THROUGH THE PROCESS OF PHOTOSYNTHESIS PRODUCE CARBOHYDRATE MOLECULES (E.G. SUGARS) AND RELEASE O_2. AS A RESULT THE OXYGEN CONTENT IN EARTH'S ATMOSPHERE INCREASED MORE RAPIDLY.

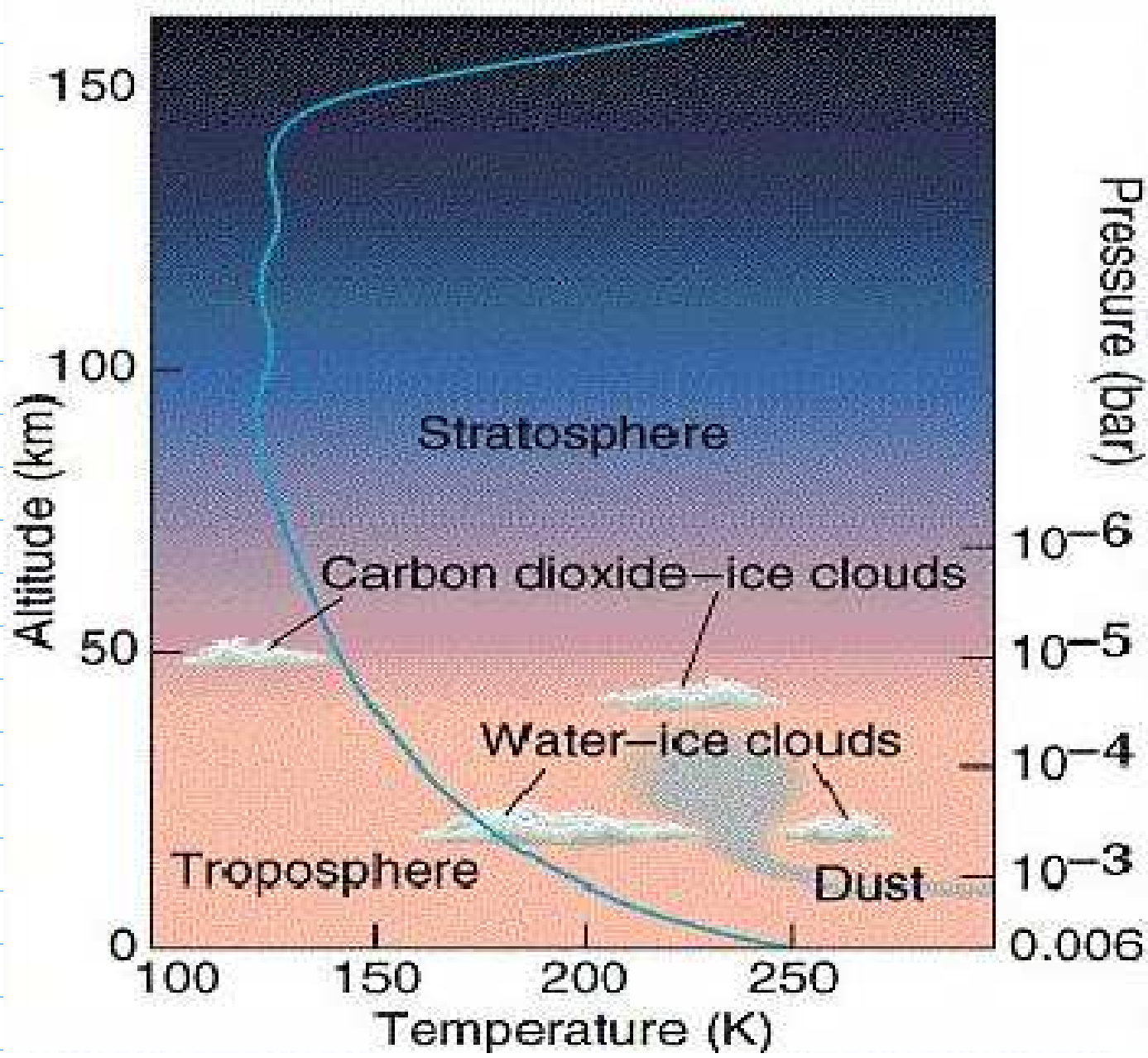
PRESENT COMPOSITION: N_2, 78%

O_2, 21%

H_2O, Ar, CO_2 } LESS THAN 1%

NOTE: N_2 AND O_2 ARE NOT GREENHOUSE GASES.

MARS:



MARS HAS A VERY THIN ATMOSPHERE

PRESSURE : 0.005 atm

TEMPERATURE: −140 °C — +20°C

COMPOSITION: CO_2, 95%

N_2, 2.7%

Ar, 1.6%

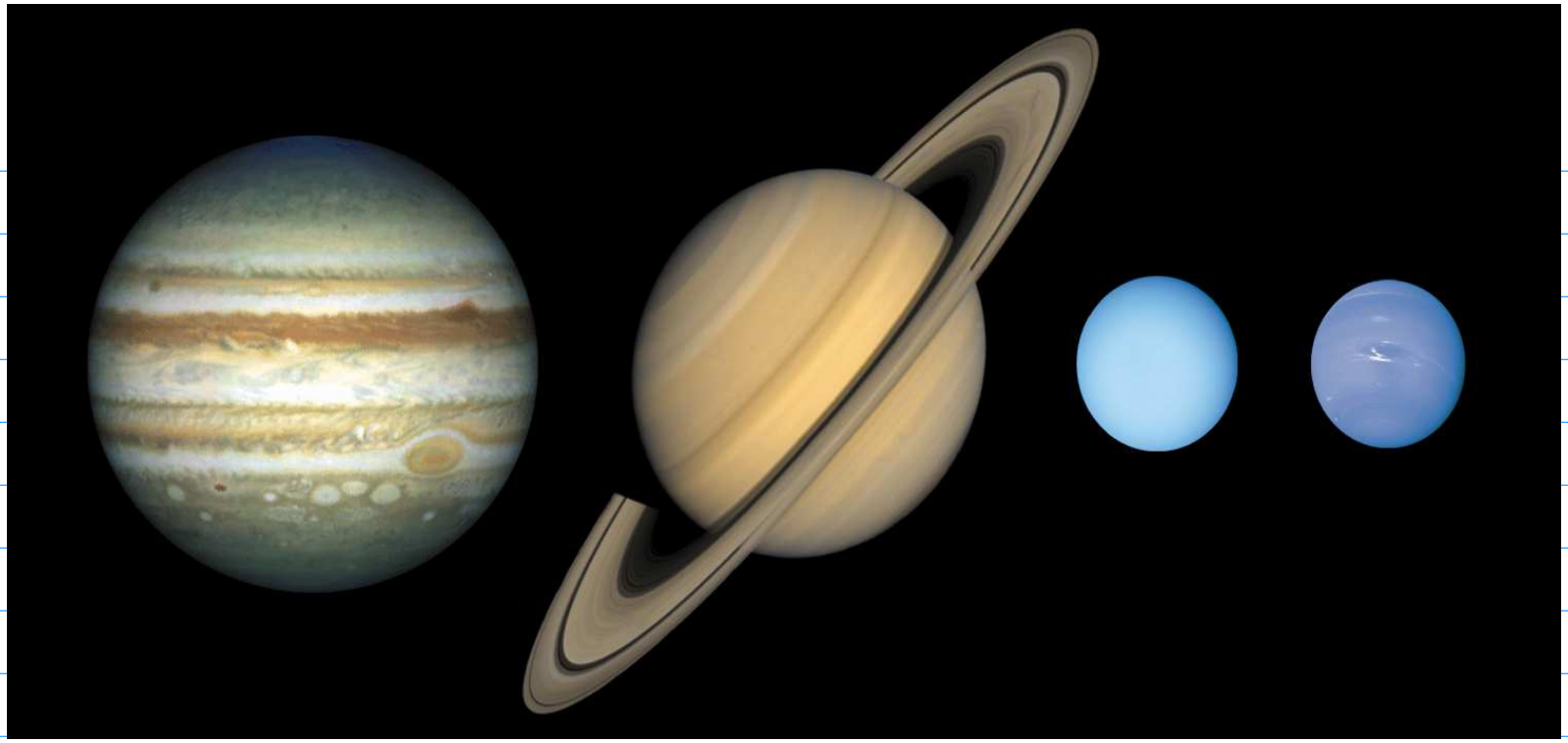
CO, 0.6%

O_2, 0.15%

H_2O, 0.03%

NOTE: MARS HAS NO MAGNETIC FIELD TO SHIELD IT FROM THE SOLAR WIND WHICH ERODED ITS ATMOSPHERE.

THE JOVIAN PLANETS ARE LARGE ENOUGH AND FAR ENOUGH FROM THE SUN (BEYOND THE FROST LINE) THAT THEY WERE ABLE TO RETAIN THE PRIMARY ATMOSPHERE (HYDROGEN AND HELIUM)



JUPITER'S ATMOSPHERE: H_2 (90%), He (10%), Ne (< 1%), AMMONIA, ARGONE, METHANE

SATURN'S ATMOSPHERE: H_2 (88%), He (11%), Ne (1%), AMMONIA, METHANE

URANUS: H_2 (76%), He (23%), METHANE (GIVES A BLUE COLOUR)

NEPTUNE: MOSTLY H_2 AND THE REST IS He WITH SOME METHANE (BLUE COLOUR)