Section I: Life & Habitability

1.

1)

A = Bond albedo (**0.3**)
L⋆ = Star's luminosity (Sun) = **3.827×1026** W
σ = Stefan-Boltzmann constant = **5.670×10−8** W m^{-2} K^{-4}
a = orbital distance from the star (in meters or AU).
I AU = **1.496×1011** m
Due to:

$$T_{eq} = \left(\frac{L_\star (1 - A)}{16 \pi \sigma a^2} \right)^{1/4}$$

a = sqrt ((L⋆ * (1- A)) / (16*pi* *σ*pow(T,4)))*
*a = sqrt ((***3.827×1026** * (1- **0.3**)) / (16*3.14* **5.670×10−8** **pow (***273*,*4)))*
= **1.299×1011 m**
= **0.87 AU**

So:

Freezing (273 K) **->** *a* = **0.87** AU
Boiling (373 K) **->** *a* = **0.47** AU

So, the habitable zone for liquid water is from 0.47 AU to 0.87 AU for these assumptions.

2)

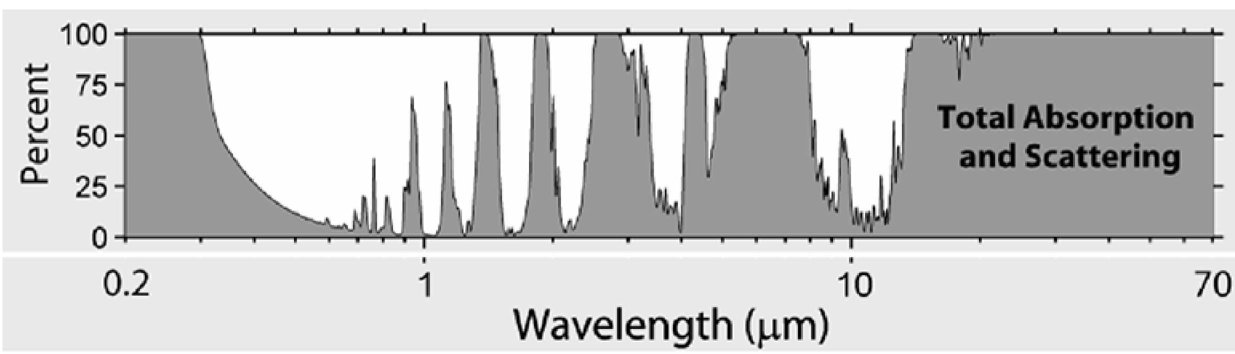
This blackbody "bare rock" model underestimates the extent of the real habitable zone. Because it does not account for greenhouse effects.
For example, Earth orbits at 1 AU, which is outside the "0.87 AU" calculated zone, but Earth is still habitable. Greenhouse gases in the atmosphere warm planets, shifting the habitable zone further out than our simple blackbody model suggests.

Section II: Interpreting Atmospheric Absorption Spectra

2.

the main absorption features are located at different parts of the infrared/visible spectrum:

- H_2O (Water vapor):
  - Strong absorption in bands near 0.95, 1.1, 1.4, 1.9, 2.6, and 6.3 μm (infrared).
- CO_2 (Carbon dioxide):
  - Strong band at 4.3 μm, 15 μm.
- O_2 (Oxygen):
  - Absorbs strongly at 0.76 μm ("A band"), and at shorter UV wavelengths.
- O_3 (Ozone):
  - Absorbs in the "Chappuis" band (0.5–0.7 μm) and very strongly in the UV (0.2–0.3 μm, "Hartley" band).
- CH_4 (Methane):
  - Absorbs near 1.7 and 2.3 μm.



Section III: Characterizing Atmospheric Loss

3.

1)

Mass = **2.389×10^{25}** kg
Radius = **1.2756×10^{7}** m
G= **6.6743×10^{-11}** $m^3\ kg^{-1}\ s^{-2}$

Due To:

$$v_{esc} = \sqrt{\frac{2GM}{R}}$$

So:

V = sqrt ((2*G*M) / (R))

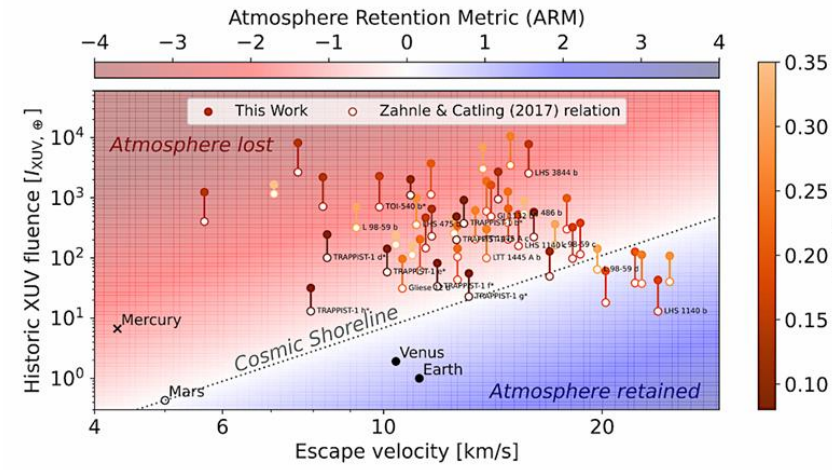
V = sqrt ((2* **6.6743×10^−11** ***.389×10^25**) / (**10^7** m))

= **1.581×10^4** m/s

=**15.8** km/s

2)

- Terra II has an escape velocity of 15.8 km/s.
- But it receives 100 times more XUV radiation than Earth.
- On the Cosmic Shoreline diagram: Planets with higher escape velocity (like Earth or above) and low XUV can retain their atmospheres. If XUV is strong, a higher escape velocity is needed to retain your atmosphere.
- For Earth-like XUV, 11.2 km/s is enough (Earth's value).
- For 100× XUV, much higher escape velocity is needed—often above 20 km/s even for rocky planets.
- Terra II at 15.8 km/s and 100× XUV likely cannot retain a thick atmosphere — it falls in the likely "atmosphere lost" area in such diagrams.



Atmosphere Retention Metric (ARM)
−4
−3
−2
−1
0
1
2
3
4
This Work
Zahnle & Catling (2017) relation
Atmosphere lost
Atmosphere retained
Cosmic Shoreline
Mercury
Mars
Venus
Earth
LHS 3844 b
TOI-540 b*
L 98-59 b
LHS 1140 b
LTT 1445 A b
TRAPPIST-1 d*
TRAPPIST-1 h*
TRAPPIST-1 f*
TRAPPIST-1 g*
Historic XUV fluence [$I_{XUV,\oplus}$]
Escape velocity [km/s]
M_* [$M_\odot$]
0.35
0.30
0.25
0.20
0.15
0.10
4
6
10
20
10^4
10^3
10^2
10^1
10^0