

"The Planets"

Astro/EPS C12 (CCN 17045 or 32505)

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LEC: 2 LeConte TWTh, 2:40–5:00pm
Office Hours: 419 Campbell Hall,
Mon 3–4 and Tue 5–6

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CORRECTIONS =(

- PS2: $F = F_0 (r_0/r)^2$, and $r_0 = 1 \text{ AU}$.

TECHNICAL SUPPLEMENT

- page 12: change π to π^2
- page 13: destroy v_{esc} formula, replace with this one:

$$v_{\text{esc.}} = \sqrt{2 g r} = \sqrt{\frac{2 G m_{\text{planet}}}{r}}$$

- page 16: change m_H (mass of hydrogen) to m_U (atomic mass unit = $1.66 \times 10^{-27} \text{ kg}$)

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PS1: question 2C

- $F = mg$, what is g if F and m are both in pounds?



"I Was Too Busy to Be Scared"

Were you scared?

No. I was too busy to be scared. I knew what was happening was not strictly normal, but we

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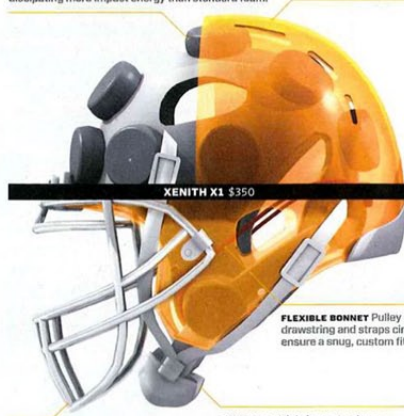
PS1: question 2C

SHOCK ABSORBERS Eighteen 2-inch-diameter hollow thermoplastic pucks, each with a small hole for airflow. On contact, they flatten like saucers and reinflate in 0.003 seconds, compressing farther and dissipating more impact energy than standard foam.

SHELL Polycarbonate, with vents running up the back to provide a natural exhaust system.

SHELL Polycarbonate that flexes to dissipate energy.

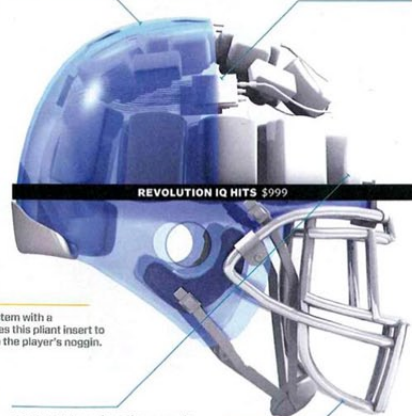
ACCELEROMETERS Six sensors send real-time data to a sideline laptop (or store it for later review), measuring the severity of a hit in g forces. Concussions become more likely at 98 gs and up.



FACE GUARD "We left it the same," Ferrara says. "We didn't want to change everything at once."

CHIN PIECE High-impact polycarbonate on the outside, soft silicone layer inside. Houses the pulley for the bonnet's drawstring and straps.

FLEXIBLE BONNET Pulley system with a drawstring and straps cinches this pliant insert to ensure a snug, custom fit on the player's noggin.



PADDING Polyurethane foam panels. The majority of hits land in front, but most concussion-inflicting knocks make contact at the sides.

FACE GUARD Helmet button disconnects the cage, enabling easy access to a player in distress.

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ORIGIN OF SOLID PLANET ATMOSPHERES

PRIMARY ATMOSPHERE

- composed of whatever gases available at time of formation
 - hydrogen
 - helium
 - methane (CH_4)
 - ammonia (NH_3)
 - water (H_2O)
- light gases (H & He) would have rapidly escaped

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ORIGIN OF SOLID PLANET ATMOSPHERES

SECONDARY ATMOSPHERE

- produced by outgassing
 - gases released from melts in the interior
 - volcanically introduced
 - water (H_2O)
 - sulfur dioxide (SO_2)
 - carbon dioxide (CO_2)
 - nitrogen compounds
- also delivered by impacts of asteroids and comets
 - mainly water
 - impacts also REMOVE atmosphere
- interactions with surface

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ORIGIN OF GIANT PLANET ATMOSPHERES

- core formed first
- direct gas capture, so giant planets are mostly hydrogen and helium
- further enrichment by accreting solid planetesimals

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MAINTAINING AN ATMOSPHERE

- gases gravitationally bound to a planet make up the atmosphere
- massive planets have stronger gravity and can maintain an atmosphere
- individual molecules in a gas are moving fast and colliding
- hot molecules move faster than cold ones (if all are equally massive)
- light molecules move faster than heavy ones (if all are at the same temperature)

$$E = 1/2 m v^2$$

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MAINTAINING AN ATMOSPHERE

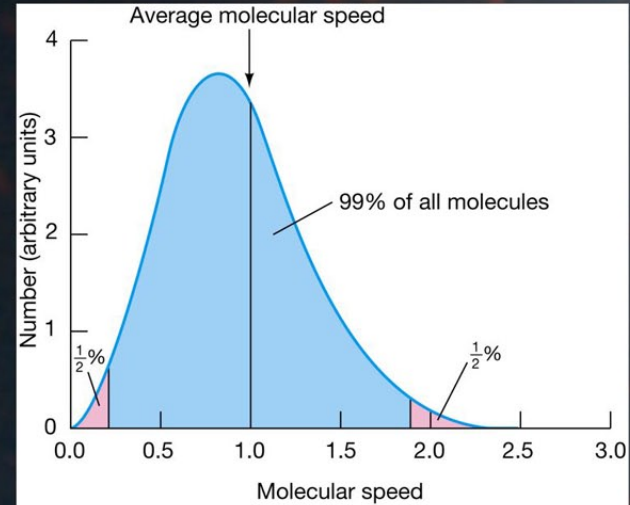
$$v_{\text{esc.}} = \sqrt{2 g r} = \sqrt{\frac{2 G m_{\text{planet}}}{r}}$$

$$\bar{v} = \sqrt{\frac{8 R T}{\pi M}} = \sqrt{\frac{8 R T}{\pi \mu M_u}}$$

- v_{esc} = escape velocity from planet
- \bar{v} = average thermal velocity of a molecule
- if $6 \bar{v} > v_{\text{esc}}$ then the atmosphere is escaping the planet !!

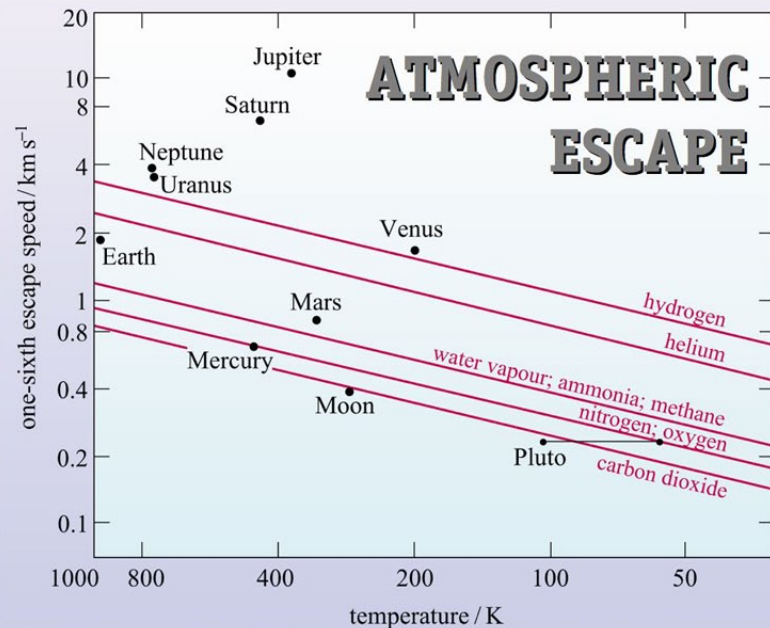
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MOLECULAR SPEEDS

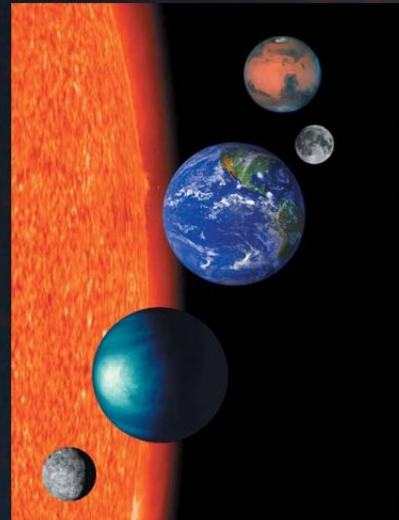


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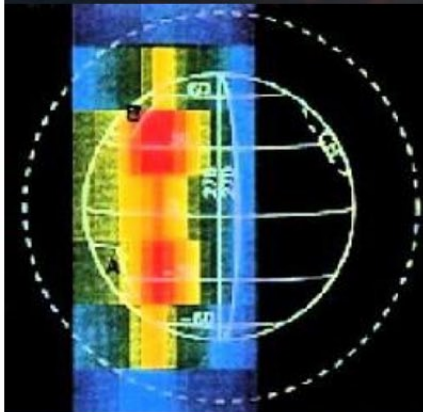
THIN ATMOSPHERES



- Mercury and the Moon, the smallest of the terrestrial planets, have only trace atmospheres
- gas atoms rarely collide with each other but can interact with surface

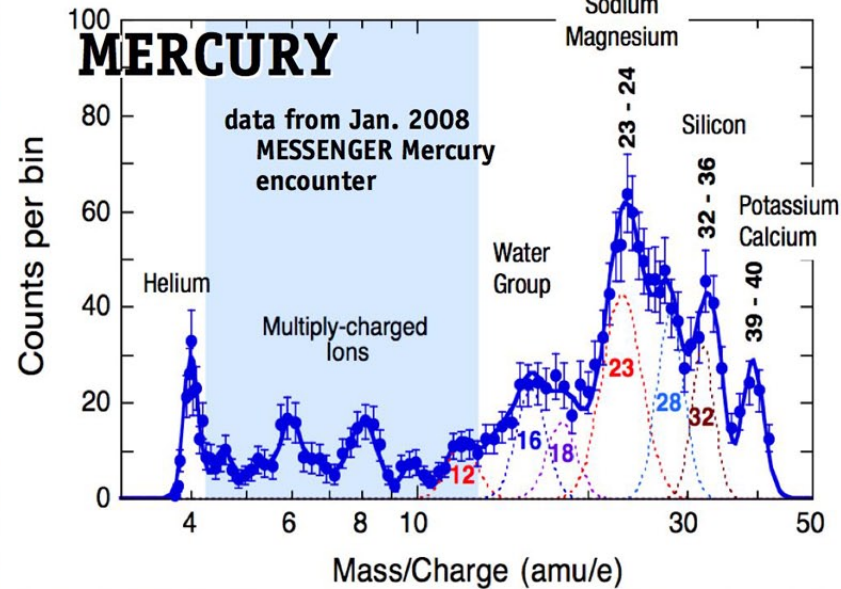
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MERCURY

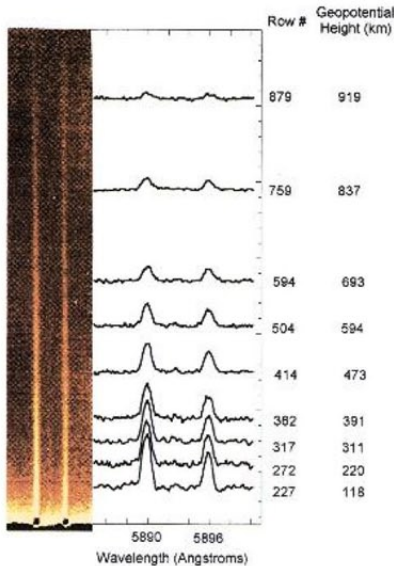


- image shows sodium emission
- potassium, H, He, oxygen and more observed
- since Mercury is not massive enough to hold an atmosphere, gases must be replenished
- solar wind implantation
- micrometeorite impacts
- outgassing?

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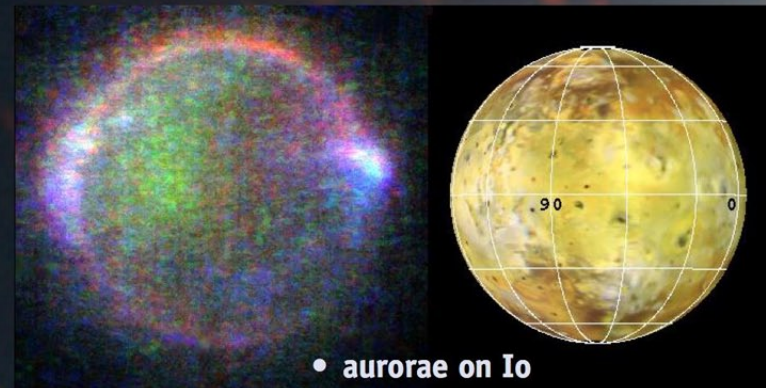
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THE MOON

- sodium emission shown here, observed using a coronagraph
- Moon's atmosphere must be continually replenished:
 - solar wind implantation
 - micrometeorite impacts
 - outgassing

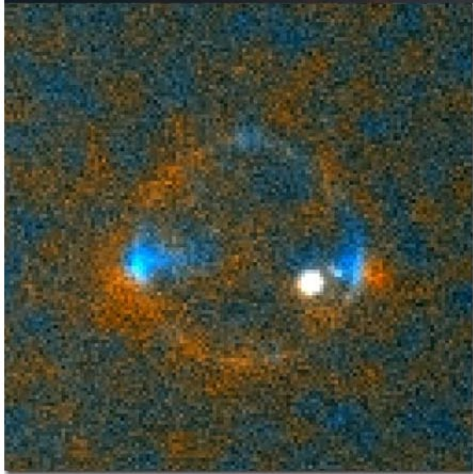
IO



- aurorae on Io (Galileo)

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IO



- red: oxygen emission
- blue: SO_2 emission
- source of Io's tenuous atmosphere: volcanoes

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IO



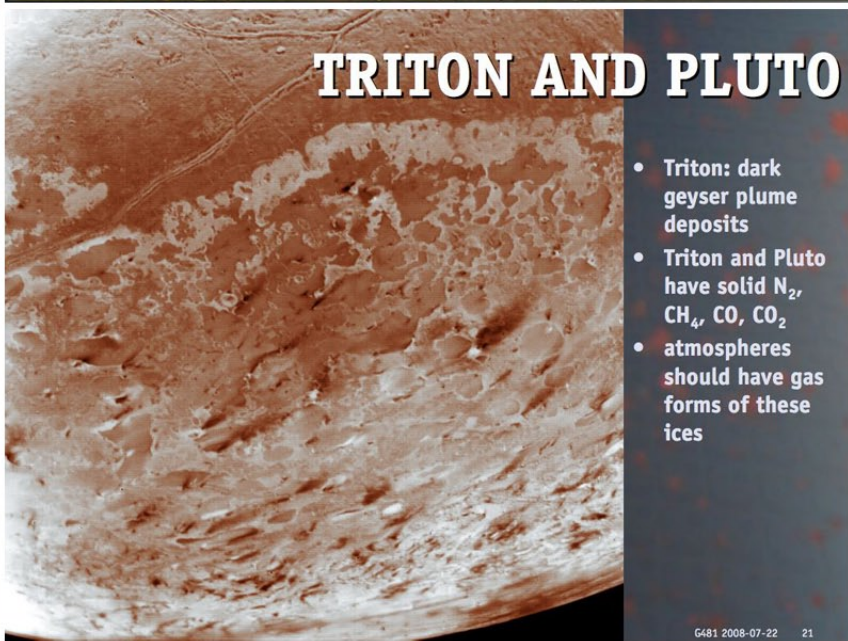
- crescent illuminated by Jupitershine
- bright spot: scattering off volcanic plume
- gases from Io escape into space around Jupiter
- yellow glow: sunlight scattered by sodium atoms

JUPITER'S ICY MOONS

- trace gases (including sodium, CO_2) have been found at the other Galilean satellites
- source: sputtering
- sputtering is when atoms/molecules get ejected from impacts by high-speed ions

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TRITON AND PLUTO



- Triton: dark geyser plume deposits
- Triton and Pluto have solid N_2 , CH_4 , CO , CO_2
- atmospheres should have gas forms of these ices

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TRITON

- clouds on horizon
- surface pressure: 15 microbars (1 bar = 1 Earth atmosphere)



Triton • Tenuous Clouds

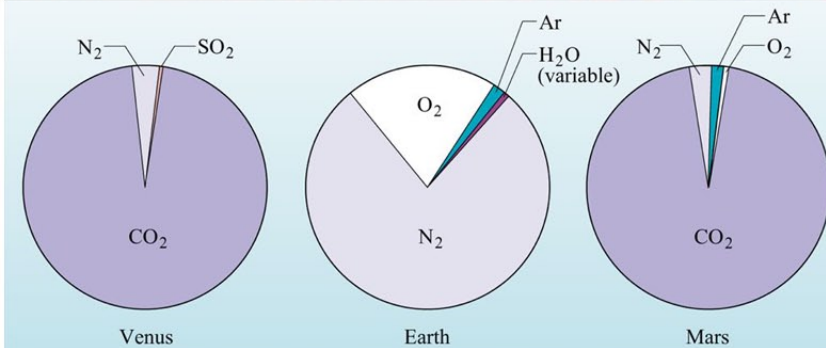
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THICK ATMOSPHERES

	Earth	Venus	Mars	Titan
CO ₂	0.03%	96%	95%	~0
N ₂	78%	4%	3%	95-99%
O ₂	21%	<1%	<1%	~0
H ₂ O	yes	no	yes	(solid)
CH ₄	<1%	<1%	~0	1-5%
Total Pressure:	1 bar	90 bar	7 mbar	1.6 bar

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ATMOSPHERIC COMPOSITION



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TERRESTRIAL PLANET ATMOSPHERIC COMPOSITIONS

Table 5.2 The major components of the atmospheres at the surfaces of the terrestrial planets.

Mercury		Venus ^a		Earth		Mars	
Gas	Volume ratio ^b	Gas	Volume ratio ^b	Gas	Volume ratio ^b	Gas	Volume ratio ^b
O ₂	0.42	CO ₂	0.965	N ₂	0.781	CO ₂	0.953
Na	0.29	N ₂	3.5 × 10 ⁻²	O ₂	0.209	N ₂	2.7 × 10 ⁻²
H ₂	0.22	SO ₂	1.5 × 10 ⁻⁴	H ₂ O ^c	<0.04	Ar	1.6 × 10 ⁻²
He	0.06	H ₂ O	1 × 10 ⁻⁴	Ar	9.3 × 10 ⁻³	O ₂	1.3 × 10 ⁻³
K	5 × 10 ⁻³	Ar	7 × 10 ⁻⁵	CO ₂	3.4 × 10 ⁻⁴	CO	7 × 10 ⁻⁴
		H ₂	<2.5 × 10 ⁻⁵	Ne	1.8 × 10 ⁻⁵	H ₂ O	3 × 10 ⁻⁴
		CO	2 × 10 ⁻⁵				

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PHASES OF MATTER

- **SOLID** -- resists forces against it (like compression); atoms/molecules fixed with respect to each other
- **LIQUID** -- has no independent shape; not very compressible; atoms/molecules can move, but are packed tightly just like in solids
- **GAS or VAPOR** -- can compress or expand; atoms/molecules can move

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PHASE TRANSITIONS

These transitions consume heat:

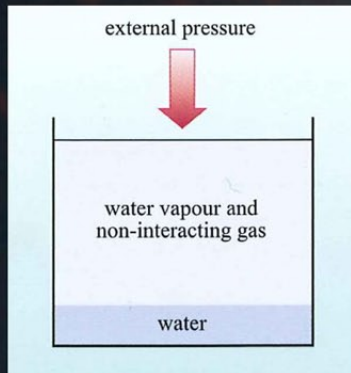
- **VAPORIZE, BOIL** -- go from liquid to gas
- **SUBLIMATE** -- go from solid to gas
- **MELT** -- go from solid to liquid

These transitions release heat:

- **FREEZE** -- go from liquid to solid
- **CONDENSE** -- go from gas to liquid
- **DEPOSIT** -- go from gas to solid

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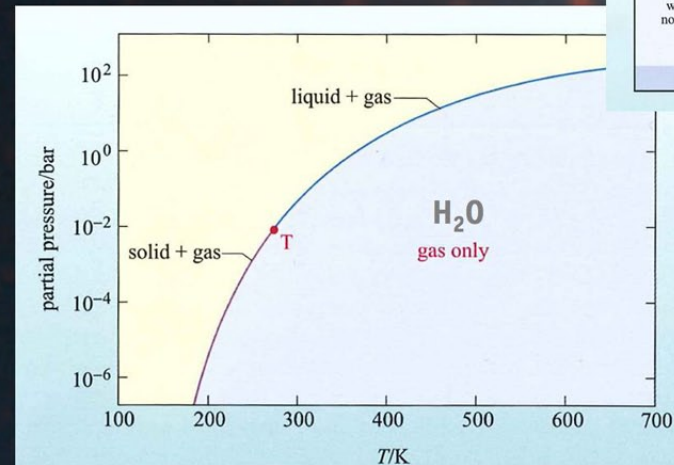
AN EXPERIMENTAL BOX



- amount of gas-phase H_2O (A.K.A. water vapor) depends on temperature and pressure in the box
- “partial pressure” is the amount of the total pressure due to just water vapor

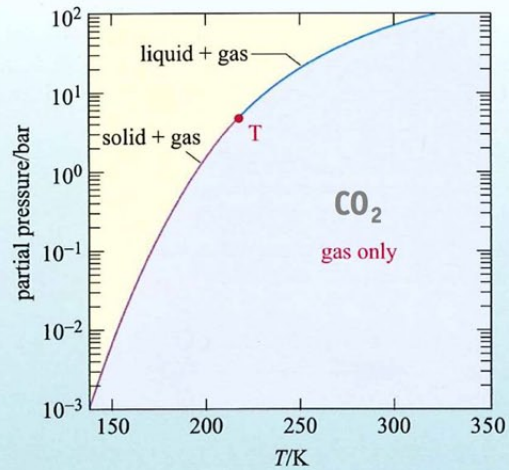
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SATURATION VAPOR PRESSURE CURVE

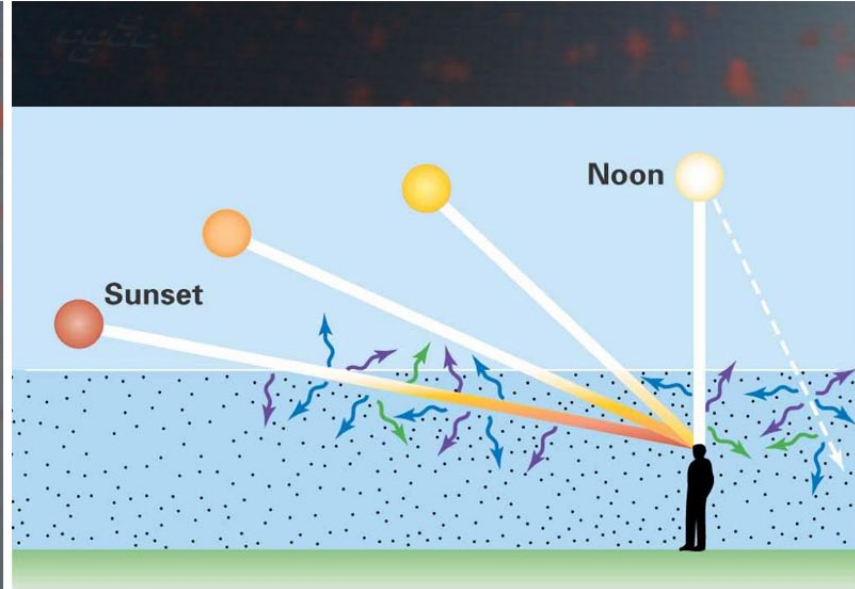


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SATURATION VAPOR PRESSURE CURVE



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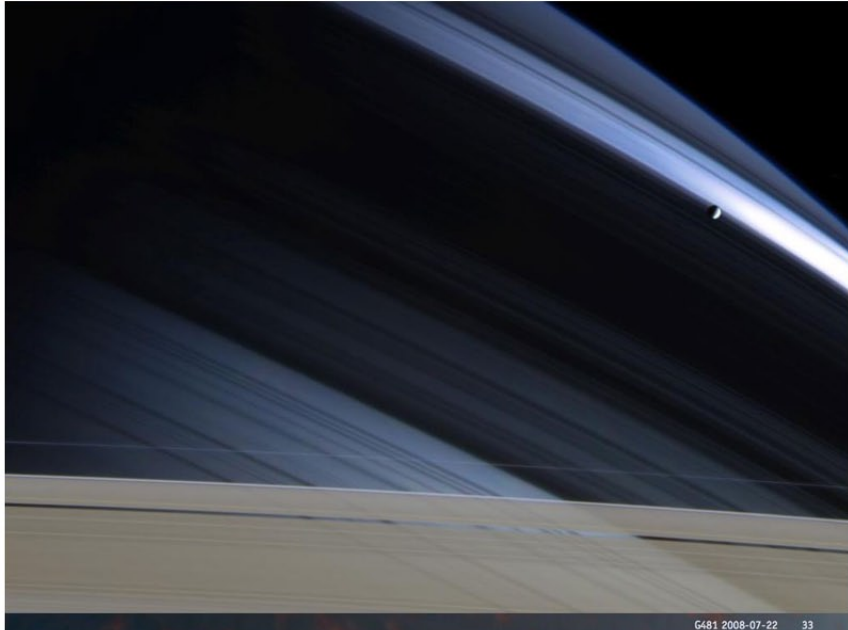
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SCATTERING

- light changes direction, but is not absorbed, in scattering events
 - Martian sunset
 - our blue sky
 - interstellar dust



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SATURN AND MIIMAS

- Cassini image
- Atmosphere looks blue
 - shading from rings means cooler temps
 - cooler temperatures means lower clouds
 - so the light we see is mainly scattered instead of cloud-reflected light
 - blue is scattered more than red

SATURN AND MIIMAS

- Cassini image

SATURN

- Cassini image

SATURN

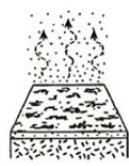
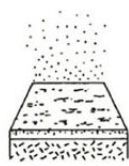
- Cassini image
- Northern hemisphere is clearly bluer than southern hemisphere

maximum
atmosphere
(methane vapor
and nitrogen)

atmosphere
condenses

minimum
atmosphere

atmosphere
forms



old surface layer
of frost and dark
deposits from
last orbit

virtually clean
frost layer
forms

new frost darkens
due to radiation
damage and
sunlight

as frost sublimates,
dark deposits
are left behind

1

2

3

4

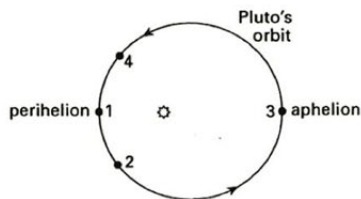
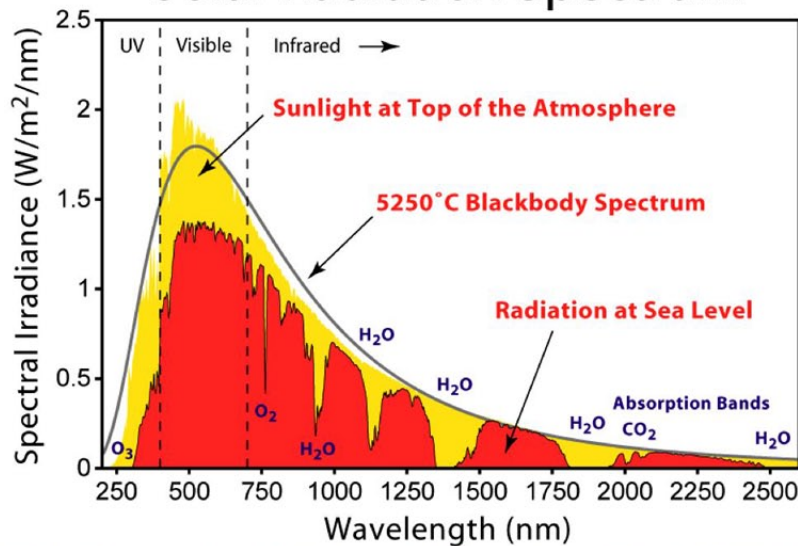


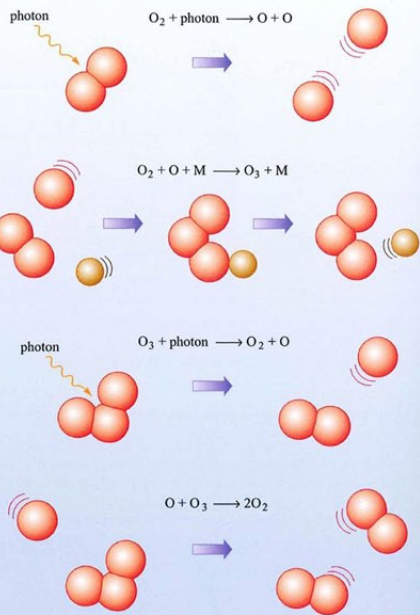
Fig. 4.1: The cycle of seasonal change and frost deposition affecting Pluto's surface.

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Solar Radiation Spectrum



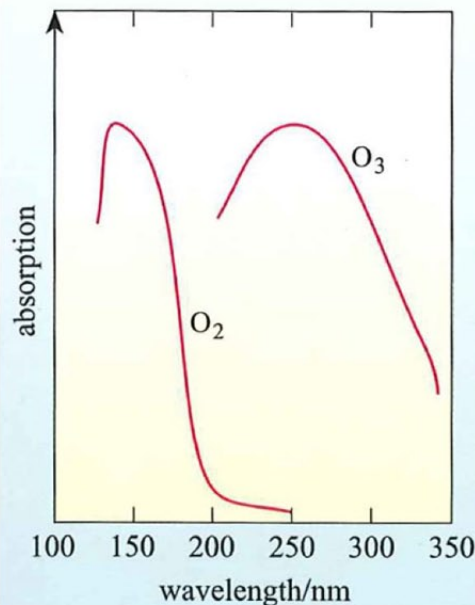
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THE "CHAPMAN SCHEME"

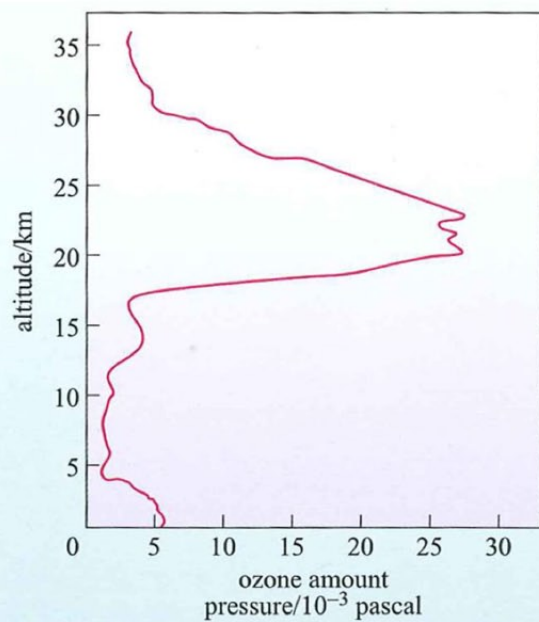
- production of ozone (O_3) from oxygen (O_2) is balanced in the normal ozone layer

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OXYGEN
AND
OZONE
ABSORB
UV LIGHT

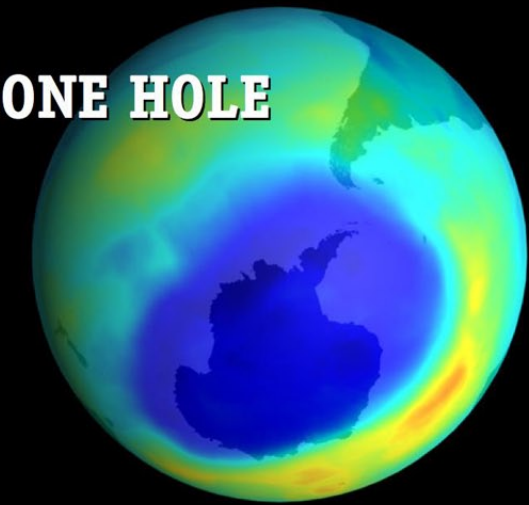
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OZONE LAYER

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OZONE HOLE



Antarctic ozone hole at its record size,
September 10, 2000. Image credit: NASA

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