ATMOSPHERIC AND SURFACE PROPERTIES OF MARS, VENUS AND THE MOON

The attached summaries on the atmospheric and surface properties of some of the planets were compiled by Dr. W.W. Kellogg, Head, Planetary Sciences Department, The Rand Corporation, Santa Monica, California at the request of Dr. C.G. Hedén. In an accompanying letter to Dr. Hedén, Dr. Kellogg makes the following comments which should be of interest to those using the tables.

At last, here are the summaries that you requested of the atmospheric and surface characteristics of Mars, Venus, and the Moon, for the use of the scientists who may be discussing the implications of contaminating these bodies. This is intended to assist you in your efforts on behalf of our Consultative Group on Potentially Harmful Effects of Space Experiments of COSPAR to organize such discussions.

I hope that it will be apparent to all who use these summaries that much of the material is quite uncertain (I have tried to indicate ranges of uncertainty where possible), and that some of the statements are based on my own biases, or "guesses". I can explain the reasoning behind all of these guesses, but realize that some scientists might still not entirely agree with me. Therefore, the summaries should be used with due caution. Just to emphasize this point, I have included the Earth as one of the planets under consideration, and it is significant that, even here, some of the characteristics that you called for are difficult to specify.

Those who may wish a more complete review of the situations on Mars and Venus can see the 1961 review by Carl Sagan and myself, published by the U.S. National Academy of Sciences, Washington, D.C.; or they may await the forthcoming issue of Annual Review in Astronomy and Astrophysics, containing an updated review of the same subject (plus Mercury) by the same authors.

As for the planet Jupiter, I left it out of my summary, in spite of the vague possibility that it might support life of some sort. We know virtually nothing about the conditions at its "surface", if it has one at all in the usual sense. Astronomers are not even sure about the conditions above its cloud tops, where they can make some observations. A recent review by E.J. Opik (Icarus, 1(3), pp. 200-257, 1962) attributes to the "observable atmosphere" the following percentage composition: He 97.2, H_2 2.3, Ne 0.39, CH_4 0.063, A 0.042, and NH_3 0.0029. Presumably there could be more NH_3 and H_2O lower in the atmosphere, but both of these tend to "snow out" at the very cold cloud level (156°K at the top) and so are not as abundant in the higher atmosphere.

SUMMARY OF LUNAR AND PLANETARY SURFACE ENVIRONMENTS FOR USE IN DISCUSSION OF IMPLICATIONS OF CONTAMINATION

	EARTH	MOON	MARS	VENUS
LOWER ATMOSPHERE				
Chemical composition	N_2~78%, O_2~21%, Ar~1%, CO_2~.03% or 2.4 m STP, H_2O 0-2.5% or 1-10 gm/cm^2 (variable)	Ar, CO_2 (?)	N_2~95%, Ar~2.5%, CO_2~2% or 30-40 m STP (1), H_2O 2-8x10^{-3} gm/cm^2 (all uncertain by at least a factor of two.)(1)	N_2 80-95%, CO_2 5-20%, H_2O~.001% or less (?)
Pressure at surface	1013 mb at sea level	$<10^{-10}$ mb	80 ~~to 120~~ mb within a factor of two (1)	5-50 atmospheres
Movement	Extremely variable, with mean speed about 1-5 m/sec. Cyclonic storms at mid-latitudes at all seasons. Most intense in winter. Occasional very strong winds in tropical storms (hurricanes) and highly localized vortices (tornados).	Free molecular diffusion	Probably light winds at equinox, cyclonic storm systems of considerable intensity around solstice. Dust storms observed; also, moving as well as stationary white or yellow clouds observed.	Probably very light winds at surface (a guess)
TEMPERATURE AT SURFACE				
Maximum	320°K (50°C)	375°K (100°C)	300°K (25°C) (equatorial noon)	700°-800°K (subsolar)
Mean	288°K (15°C)	(Rapid change day-to-nite)	210-220°K (-50 to -60°C)	
Minimum	230°K(-45°C)	120°K (-150°C)	180°K (-90°C) (winter pole)	600°-700°K (antisolar)
Length of cycle at equator (day)	24 hrs	27 days	24.6 hrs	~120 days (uncertain)
Length of cycle at poles (year)	1 year	1 year	687 days	~225 days (uncertain)

RADIATION AT SURFACE				
Ultraviolet cutoff	3000Å (due to ozone)	no cutoff	Not certain. Probably enough O_3 to give <u>some</u> attenuation at around 2500Å; also, considerable attenuation by Rayleigh scattering combined with absorption by haze particles. CO_2 will cause complete cutoff below about 1800Å in any case.	Not certain. Probably no penetration to surface below 3000A due to some ozone and multiple scattering in deep atmosphere.
Visible light intensity (relative to earth)	Same	Same	2/3 ~~Same~~ on the average	Less. May be fairly dark at surface due to deep atmosphere; blue more attenuated than near IR.
Ionizing radiation (flux of <1000Å radiation)	None	No cutoff, same as in space	None	None
CHEMISTRY OF SURFACE				
Water	4/5 surface covered with liquid or solid water.	None	Hoar frost on winter polar area. May be frozen water in permafrost layer (a guess).	None
Salt	Water-soluble salts largely unavailable at surface due to leaching by rain, except in special areas of low rainfall.	?	Common water soluble salts probably generally available (a guess)	?
Carbon sources	Widespread, due to past and present organic processes.	?	Some spectroscopic evidence for organic material in dark areas only, where seasonal reflectivity ~~color~~ changes also occur.	?
Nitrogen sources	Ibid.	?	?	?

CHARACTER OF SURFACE

Surface physical structure	Variable (sand, clay, rock, water, snow, ice, etc.)	Variable	Red areas - probably sandy or dusty, limonite suggested by color and polarization ~~on~~ observations. Dark areas - ? Hoar frost observed covering winter pole, more extensive than on Earth. Polar cap may disappear~~s~~ in summer from South Pole, persists all year near North Pole.	Probably very hot, dry dusty surface (a guess) Some radar evidence for large irregularity like a mountain range.
Temperature distribution below surface	Level of uniform temp. from 0 to 3m below surface.	Average thermal conductivity much lower than terrestrial surface. Presumably very porous material over most of surface, but evidence for localized regions with higher conductivity.	Variable. Probably like terrestrial desert (a guess).	
Depth of probe penetration in hard landing (max.)	~0.1 m in hard rock, ~5 m in sand and loose soil, up to 10 km in ocean.	Possibly very porous and easily penetrated in places, certainly some hard rock.	~0.1 m in hard rock, ~5 m in sand or loose soil (a guess).	?
TERMINAL VELOCITY OF FALL of solid dust particles (ρ= 2.5 gm/cm³) near the surface for a given particle radius (2) (cm/sec)	1μ: Insignificant relative to turbulent transport. *; 10μ: 3.1; 100μ: 139; 1000μ: 1247	∞	1μ: *; 10μ: 1.16; 100μ: 104; 1000μ: 1840	1μ: *; 10μ: 1.6; 100μ: 9.25; 1000μ: 75

Notat bene:

(1) A recent announcement by L. Kaplan and H. Spinrad (Jet Propulsion Laboratory, Pasadena, Calif.) presented verbally at the Astrophyiscal Symposium in Liege in July, 1963 (but still unpublished) gives evidence for an increase in the CO_2 content of the Martian atmosphere to about 100 m STP and a reduction in the surface pressure to less than 20 mb. This is still unconfirmed by any other workers.

(2) The fall rates presented here were calculated especially for this chart by R. R. Rapp (RAND Corporation, Santa Monica, Calif.). Details of these calculations can be made available later for those wishing them. Note that the smaller particles (1 and 10μ) obey Stokes' law, except for 1μ particles on Mars which are in the free molecular flow regime. Particles of 100μ and over obey aerodynamic drag laws on all three planets. Values for the pertinent atmospheric parameters used in these estimates are as follows: (all in c.g.s. units)

	Gravity g	Density ρ_t	Viscosity η	Mean Free Path λ
Earth	981	1.22×10^{-3}	1.79×10^{4}	6.6×10^{-6}
Mars	333	1×10^{-4}	1.6×10^{-4}	8×10^{-5}
Venus	862	3×10^{-2}	3.0×10^{-4}	2.6×10^{-7}

* The fall rates for 1μ particles on Earth, Mars, and Venus are 0.016, 0.031, and 0.024 cm/sec respectively, so it is quite certain that turbulence near the ground will determine their trajectories in the air rather than their theoretical rates of fall.