Atmospheric Chemistry I

Knowledge "explosion"

Space probes, remote sensing
Growing awareness that Man can interfere
ozone hole, acid rain, smog formation
CO_2 as greenhouse gas (return later to greenhouse effect)

Nature of atmospheric chemistry

Atmospheric concentrations; sources, sinks
e.g. COW → CH_4 →[chemistry in atmosphere] → CO_2 + H_2O
⇑ ⇐ photosynthesis ⇐ deposition
Laboratory studies of reaction paths and rates
Models linking lab. and field data

Need for CHEMISTS with understanding of problems

Nature and structure of course

In pursuit of knowledge, good vehicle for illustration both of fundamental physico-chemical principles and of experimental studies

Overview and principles
Atmospheric ozone in stratosphere; Man's influence on stratospheric ozone
Troposphere; heterogeneous processes and droplet chemistry; pollution
Mesosphere; airglow

Nature of course – limitations; handouts; books

Variety of atmospheres

Mercury

Venus, Mars .. to .. Jupiter, Saturn ..Uranus, Neptune

The moons of Jupiter, Saturn, and Neptune: Callisto, Io, Titan, Triton

Earth: H_2O liquid (temperature stability over geological time);
Major constituents: O_2/N_2; CO_2 in carbonate rocks

Other minor gases: CH_4, CO, H_2, H_2S, NH_3: "combustible mixture"

Biological processes have effected the disequilibrium: entropy reduction, driven by Solar energy

Cycles

Almost closed, but some escape, and some input from outside

On Earth, importance of biota: biogeochemical cycles

Atmospheres as giant photochemical reactors
Penetration of UV, and energetics of chemistry
UV progressively filtered out by atmospheric constituents: by the ground, just about enough to give you a suntan.

Origin of solar system, planets and atmospheres

Primordial (outer planets – solar abundances) and secondary (Venus, Earth, Mars) atmospheres

Big bang → H, He; Fusion → heavier elements; > Fe from supernova explosions that scatter C, H_2O, silicates of Mg, Fe. Accretion, galaxies, formation of stars, etc.

Composition of Earth's atmosphere

Major constituents: already presented in handout 1.1
Noble gases:
^{36}Ar about 10^6 too low, ^{20}Ne 55 x 10^6 too low
Ar and He from radioactive decay
RMM of Ar means almost all is ^{40}Ar (^{36}Ar/^{40}Ar ≈ 1/300)
In natural gases, [Ar]/[He] roughly 1, but in atmosphere nearly 2000: evidence that He has escaped
Main point: all original (primordial) gas has escaped, that which remains has degassed from the interior of the planet

Comparison of Venus, Mars, and Earth

Compositions of atmospheres: pie charts
Carbon dioxide on the three planets

The Greenhouse effect
λ_{peak} for 5780K just less than 1μm
λ_{peak} for 256K just more than 10μm

Runaway Greenhouse Effect
Venus - all CO_2 in atmosphere: no H_2O

Mars - almost all CO_2 condensed

Life on Earth
CO_2 in rocks (biological and abiological weathering) and oceans. Liquid H_2O; ? Temp control.

EARTH

Pressures

Hydrostatic Equation: effectively single mass 28.8 to 100km (reason)
P drops by factor of 10 in ca. 18km: 90% mass of atmosphere in first 17km.
Mean Free Paths: mixing, separation, and escape

Temperatures

Division into regions: expect to drop with z, but note inversions (reasons soon): stability of inversion regions
adiabatic lapse rate (dry) ~ 6K km^{-1}

Chemosphere

Minor neutral constituents
Altitude profile: note O atom dominance at high z
O_3 in the atmosphere: rôle in stratosphere and troposphere

Atmospheric Chemistry I : Slides

1.	YG 60	Growth of carbon dioxide levels
2.	B 50	Mercury mosaic
3.	B 3	Clouds of Venus
4.	YG 6	Mars and Phobos: n.b. Polar caps (N = water; S = carbon dioxide)
5.	YG 7	Mars: Plume of water ice
6.	YG 8	Mars: Clouds of water ice
7.	B 75	Voyager trajectory
8.	B 16	Jupiter: General view
9.	B 61	Saturn: General view (Voyager 2; 21Mkm)
10.	B 52	Jupiter with Io and Europa
11.	B 14	Jupiter and moons (closer in)
12.	B 55	Callisto
13.	B 56	Io: General
14.	B 58	Io: Volcanic activity
15.	B 59	Io: Volcanic lava flow
16.	B 65	Titan (Voyager 1)
17.	B 73	Titan Haze (more detail)
18.	B 76	Neptune (Voyager 2)
19.	B 77	Neptune (methane enhanced)
20.	B 78	Triton (geysers)
21.	YG 9	Earthrise
22.	YG 10	Earth (USA)
23.	YG 4	Cyclic processes: Sources & sinks of atmospheric gases
24.	YG 61	Cyclic processes with biota (from C of A)
25.	YG 1	Origin of atmospheres: Nebula M42
26.	BG 10B	Noble Gases: Graph of abundances
27.	YG 63	Volcano eruption
28.	YG 11	Abundance of Gases: Pie chart for Venus
29.	YG 12	Abundance of Gases: Pie chart for Mars
30.	YG 13	Abundance of Gases: Pie chart for Earth
31.	BG 50	Greenhouse effect
32.	BG 16	Runaway greenhouse effect for Venus: phase diagram
33.	R 1	Regions of Earth's atmosphere
34.	R 2	Concentration of neutral species in Earth's atmosphere

Atmospheric Chemistry I : Viewgraphs

1. Nature of atmospheric chemistry
2. Tropospheric gases
3. Methane from enteric fermentation
4. Cyclic processes of biogeochemistry (from C of A): see also slide 24
5. Pressure and mean free path as a function of altitude; hydrostatic equation
6. Regions of Earth's atmosphere: troposphere, stratosphere, mesosphere