PYRITE STABILITY ON THE SURFACE OF VENUS. M. Yu. Zolotov, Vernadsky Institute USSR Academy of Sciences, Moscow, USSR

Pyrite FeS_2 existence on the surface of Venus is much under discussion especially in context of high radar reflectivity of the highlands [e.g.1]. Some authors excluded the stable existence of the mineral on the surface [2-4], in [5,6,7] pyrite was predicted as a stable phase predominantely at the highlands, in [8-11] it was expected as an important phase in buffering mineral assemblages for the lowland conditions. These investigations showed that the results of an estimation of pyrite stability are critically depended on an adopted model of the atmospheric chemistry. Taking into account the possible disequilibrium between gases near the mean planetary radius as well as for the highlands [e.g. 3,12] the stability of pyrite was estimated relatively to contents of measured atmospheric gases (CO_2, CO, H_2O, SO_2, H_2S, COS, and S_2). The fields of pyrite stability were calculated in Fe-S-O-C-H system for the temperatures 740 K and 705 K (95.2 bar, 6051.4 km; and 71.4 bar, 6055.95 km respectively [13]). The stability of magnetite, hematite and pyrrhotite $Fe0.877S$ were also estimated in this system.

The calculations show that pyrite could be formed as a result of chemical interaction of H_2S with ferromagnesian silicates as well as magnetite and hematite (Fig. 1 and also [14]). Highlands seem to be more favorable for the pyrite formation. In contrast the hypsometric level near to the mean planetary radius, providing the lowest H_2S mixing ratio (1 ppm) and highest H_2O mixing ratio (100 ppm) are found to be near the pyrite-magnetite equilibrium line. It was shown that pyrite should not be subjected to oxidation by water vapor at any hypsometric level.

Pyrite is found to be stable also relatively to CO_2, as well as CO and SO_2 at the temperatures lower than 740 K (temperature of the magnetite-pyrite equilibrium [11]) i.e. at the level above the mean planetary radius (Fig. 2). At the high temperature lowland conditions pyrite could be oxidized to magnetite. The possibility of pyrite oxidation by CO_2 at high temperatures have been recently shown experimentally [4]. The pyrite oxidation rate on the surface of Venus have been estimated as using of these kinetic data [4]. Our data show that Fegley's substantial extrapolations of the oxidation rate to the temperatures of the Venus surface could be thoroughly corroborated as not enough accurate.

The possibility of pyrite formation as a result of S_2 interaction with some Fe-bearing mineral (e.g. magnetite) is under the question due to uncertainty of S_2 content (Fig. 3). At the 740 K pyrite should be formed if S_2 mixing ratio is higher than 0.3ppm. The calculations show that if the COS mixing ratio is lower than (2-3 ppm) (i.e. Pioneer Venus measurements) an interaction of that gas with Fe-bearing minerals should not result in pyrite formation at any hypsometric level. On the other hand pyrite could be formed if COS content is in accord with the Venera-13,14 measurements [15] above 29 km (Fig. 4).

These calculations of pyrite stability show that the highland atmospheric conditions are more favorable for the pyrite formation. That conclusion is in agreement with the previous [5,6] and recent estimations [7] of pyrite stability. Pyrrhotite if found to be unstable on the surface of Venus (see also [11]). But it is necessary to bear in mind that the real stability of pyrite is governed by the absolute and relative rates of the suggested weathering reactions with various atmospheric gases.

REFERENCES: 1. Pettengill G.H., et al. (1988) J. Geophys. Res. 93, p. 14881. 2. Lewis J.S. (1970) LPSL 10. p.73. 3. Fegley B.J. (1990) subm. to Proc. First Int. Conf. Lab. Res. for Planet. Atm. 4.Fegley B.J.,Treiman A.H. (1990) subm. to Bull. Amer. Astr. Soc. 5. Khodakovsky I.L. et al. (1979) Geokhimiya No 12. p.1821. 6. Nozette S., Lewis J.S. (1982) Science 216, p.181. 7. Wood J.A., Hashimoto A. (1990) subm. to EPSL. 8.Mueller R.(1965) Icarus 4. p.506. 9. Lewis J.S., Kreimendahl F. (1980) Icarus 42, p.330. 10. Barsukov V.L. et al.(1982) J.Geoph. Res. Suppl., p.A3. 11. Zolotov M.Yu. (1991) Pyrite-magnetite... this vol. 12. - Redox conditions... this vol. 13. Seiff A. et al. (1985) Adv. Space Res. 5, No 11, p.3. 14. Zolotov M.Yu.(1991) Chemical weathering... this vol. 15. Moroz V.I. (1983) in Venus, ed. D.Hunten et al., Ariz. Univ. Press., p.45.

FIG. 1. Pyrite and magnetite stability fields as a function of H_2S and H_2O partial pressures at the temperatures 740 and 705 K. The lines show the equilibrium conditions for the reaction $3FeS_2 + 4H_2O = Fe_3O_4 + 4H_2S + S_2$. 1 - for S_2 mixing ratio (x) - 0.02ppm (see [12] for ref.); 2 - for x(S_2) = 0.39 ppm (S_2 mixing ratio for CO_2-CO equilibrium conditions at 740K (see [12])). The arrows show the error bars for uncertainties of thermodynamic properties of the substances. The Venus' atmospheric conditions (x(H_2S) = 1-5 ppm, x(H_2O) = 20-100 ppm, (see [12] for ref.)) are shown as quadrangles.

FIG. 2. Pyrite and magnetite stability fields as a function of CO and SO_2 partial pressures at 740, 720 and 705 K. The lines show equilibrium conditions for the reaction $3FeS_2 + 16CO_2 = Fe_3O_4 + 6SO_2 + 16CO$ for x(CO_2) = 0.965. The Venus'atmospheric conditions (x(CO) = 17-20ppm. x(SO_2) = 130-185ppm are shown as quadrangles.

PYRITE STABILITY
M. Yu. Zolotov

FIG 3. Pyrite and magnetite stability fields as a function of S2 and SO2 partial pressures at 740 and 705 K. The lines show the equilibrium conditions for the reaction 3FeS2 + 2SO2 = Fe3O4 + 4S2. The Venus atmospheric conditions (x(S2) = 0.003-0.02 ppm, x(SO2) = 130-185 ppm (see [12] for ref.)) are shown as quadrangles.

FIG.4. Pyrite and magnetite stability fields as a function of CO and COS partial pressures at 740 and 705 K. The lines show the equilibrium conditions for the reaction 3FeS2 + 2CO + 4CO2 = 6COS + Fe3O4 for x(CO2) = 0.965. The Venus' atmospheric conditions: 1 - (x(CO) = 1.7-20 ppm, x(COS) < 3 pmm (see [12] for ref.)) are shown on the left part of the plot; 2 - x(CO) = 17-20 ppm, x(COS) = 20-60 ppm [15] are shown as quadrangles.
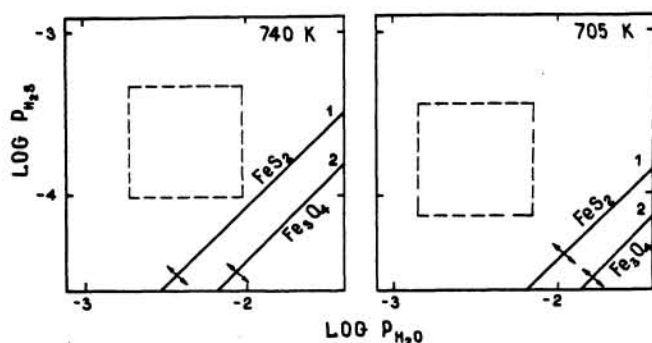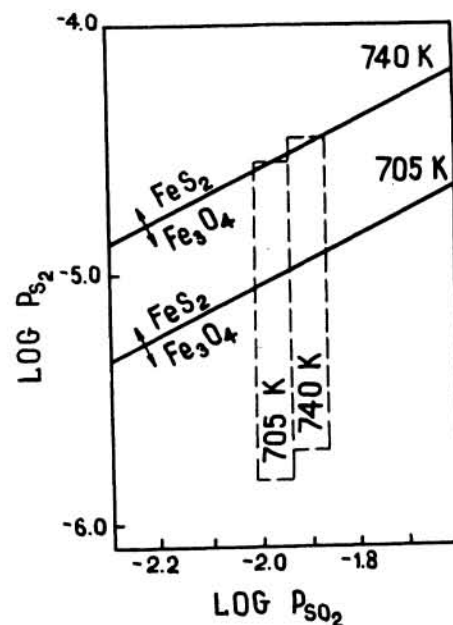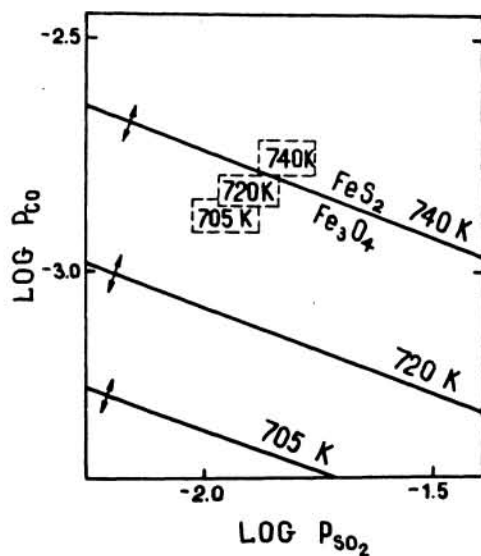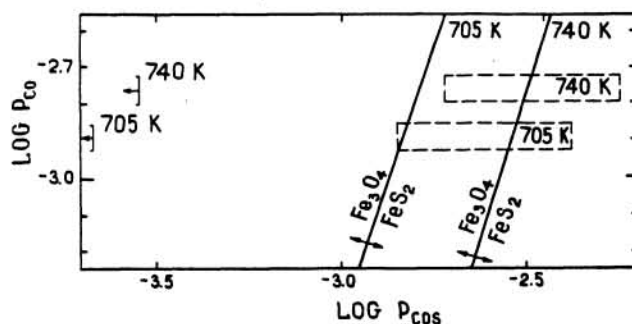

FIG. 1

FIG. 2

FIG. 3

FIG. 4