(b) *Fused glasses.* Glasses, apparently formed by fusion of primary minerals and rocks, occur in soil and breccias as (1) bodies of regular spheroidal, ellipsoidal, dumbbell or teardrop shapes, (2) irregular fragments, and (3) vesicular coatings on pieces of breccias and crystalline rocks.

Regularly shaped glass bodies form about 10 per cent of all glasses in the soil. Their sizes range from 2 mm to 0·3 μm. Light colored (green to colorless) glass bodies can be distinguished from a darker colored group containing yellow-brown, red-brown and violet-brown glasses. The darker colored glass bodies of regular shape occur about twice as frequently as the green and colorless ones.

Most of the regularly shaped glass bodies consist of very homogeneous glass with or without vesicles. The spherical vesicles are either distributed at random or concentrated near the periphery. Some of the homogeneous spheres include one single vesicle at the very center. Some glass bodies contain minute spherules of metallic iron which are very often accumulated in the surface of the bodies. These glasses originated from the rapid solidification of a silicate melt containing small droplets of liquid iron. The accumulation of iron spherules in the surface may have been caused by centrifugal forces acting in the rotating fluid body and/or by surface forces which held the iron droplets within the surface if their wettability by the silicate melt was low (contact angle, measured in the silicate melt, exceeding 90°).

There are at least two possible mechanisms for the formation of the iron spherules: (1) Admixture of meteoritic iron condensing from the vapor phase produced by the impact of iron-bearing meteorites. (2) Segregation of free iron during melting of iron rich silicates under vacuum conditions, as was observed from a synthetic ferrobasalt glass by ANDERSON *et al.* (1970). A choice between these possibilities should be based on the level of Ni-concentration.

Instead of spheres some glass bodies contain small opaque cubes, probably of iron. Apparently, the cooling of these glasses proceeded in such a way that the temperature remained long enough close to the crystallization temperature of iron to allow the growth of one single crystal out of each liquid iron droplet.

In general, the cooling rate of the homogeneous glass bodies was so rapid that they were quenched without crystallization of silicates. However, devitrified glass bodies occur, which cooled more slowly. Most conspicuous are parallel or radiating crystals, probably pyroxene. Some of them resemble orthopyroxene chondrules of chondrites.

Some regularly shaped glass bodies are inhomogeneous. Besides vesicles, they contain inclusions of mineral grains (pyroxene, plagioclase, ilmenite) and/or a flow pattern of schlieren of different color and refractive index. The mineral grains are sometimes partially fused, showing a crystalline core surrounded by melt. Because all transitions occur between inhomogeneous and homogeneous glass bodies, it is probable that these glasses have been formed by fusion of small rock particles or mineral aggregates. The homogeneous glasses represent heating to very high temperatures. However, very homogeneous spherules, free of vesicles, may have been formed by condensing from silicate vapor.

As yet, the shapes of the regular glass bodies have not been studied systematically. A preliminary inspection has shown that they are either spheres or elongated bodies the longest axis of which is always an axis of rotational symmetry. We assume that these forms were produced by the interaction of two forces upon drops of liquid melt which were propelled at high speeds and fell freely through the lunar vacuum. The one force was surface tension, the other resulted from the moments of inertia of the rotating bodies. If the liquid was very homogeneous or there was no or weak rotation, the surface tension prevailed and produced a perfect sphere. If the liquid drop contained inhomogeneities, such as vesicles or mineral grains, rotation raised inertia forces which distorted the sphere into an elongated body of rotational symmetry. The symmetry axis was the main axis of rotation and the axis of the lowest moment of inertia. If the viscosity was low enough, depending on initial temperature and cooling rate, rotation around the axis of highest moment of inertia led to dumbbell forms and

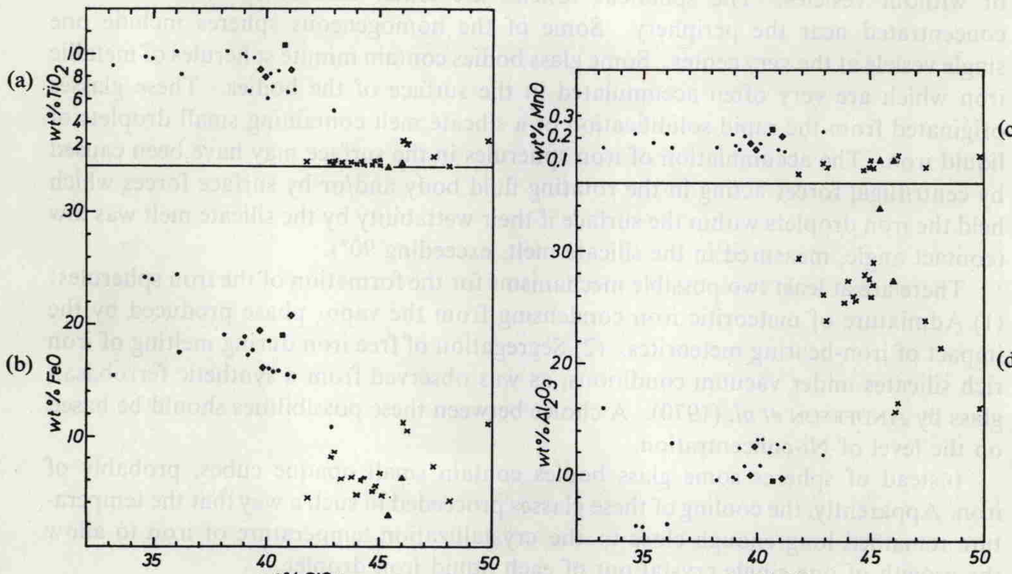

Fig. 9. Chemical composition of fused glasses (wt. %).
(a) TiO_2 vs. SiO_2; (b) FeO vs. SiO_2; (c) MnO vs. SiO_2; (d) Al_2O_3 vs. SiO_2. ● Yellow-brown, red-brown and violet-brown glasses; × Colorless and green glasses; ◊ Vesicular glass coatings; ■ Lunar basalt, average; △ Lunar anorthositic rocks.

finally to separation into two teardrop bodies. Tektites and glass bodies in terrestrial pyroclastics and impact breccias do not show comparable regular shapes because liquid drops propelled through the atmosphere must adjust their shapes to aerodynamic forces. As no plastic distortions have been observed it is assumed that the regular glass bodies were cooled to a brittle state before they hit the ground and became embedded in the lunar soil. In the soil and breccias the glass bodies are often broken, especially the elongated dumbbells. This fracturing may have occurred when the bodies first hit the ground or during later reworkings of the soil, due to repeated meteorite impacts.

The majority of glass pieces in the soil and the breccias are irregular fragments. As with the regular glass bodies the same two groups of light colored (colorless to