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Measurements of Neutron-absorbing Elements on Mercury's Surface with the MESSENGER Neutron Spectrometer

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The Neutron Spectrometer (NS) on the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission has made measurements of cosmic-ray-generated thermal neutrons during each of MESSENGER's three Mercury flybys. These thermal neutron data have allowed us to make the first direct measurements of Mercury's surface elemental composition. Specifically, we show that Mercury's surface is enriched in neutron-absorbing elements and has a measured macroscopic neutron absorption cross section of (70–130) $\times$ 10^(-4) cm^2/g, which is similar to the neutron absorption of lunar basalts from Mare Fecunditatis. The expected neutron-absorbing elements are Fe and Ti, with possible trace amounts of Gd and Sm. Fe and Ti, in particular, are important for understanding Mercury's formation and how its surface may have changed over time through magmatic processes. With the neutron Doppler filter technique – a neutron energy separation technique based on spacecraft velocity – we demonstrate that Mercury's surface composition cannot be matched by prior models having characteristically low abundances of Fe, Ti, Gd, and Sm. While neutron spectroscopy alone cannot separate the relative contributions of individual neutron-absorbing elements, these results provide strong new constraints on the nature of Mercury's surface materials. For example, if all the measured neutron absorption were due to the presence of a Fe-Ti oxide and that oxide were ilmenite, then Mercury's surface would have an ilmenite content of 14 to 31 wt.%. This result is in agreement with the inference from color imaging and visible–near-infrared spectroscopy that Mercury's overall low reflectance is consistent with a surface composition that is enriched in Fe-Ti oxides. The incorporation of substantial Fe and Ti in oxides would imply that the oxygen fugacity of basalts on Mercury is at the upper range of oxygen fugacity inferred for basalts on the Moon.