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Spectral geometry has connections with the field of spectroscopy where one is interested in recovering the structure and composition of a molecule or compound from various spectral data. We demonstrate that the moments of inertia of a molecule can be recovered from its rotational spectrum. Geometrically speaking this means that the isometry classes of left-invariant metrics on $SO(3)$ can be mutually distinguished via their spectra. In fact, they can be distinguished by their first four heat invariants. More generally, we demonstrate that among compact homogeneous three-manifolds a non-trivial isospectral pair must consist of spherical three-manifolds possessing non-isomorphic cyclic fundamental groups and each is equipped with a so-called Type I metric: at present, no such isospectral pairs exist in the literature. (Received February 07, 2017)