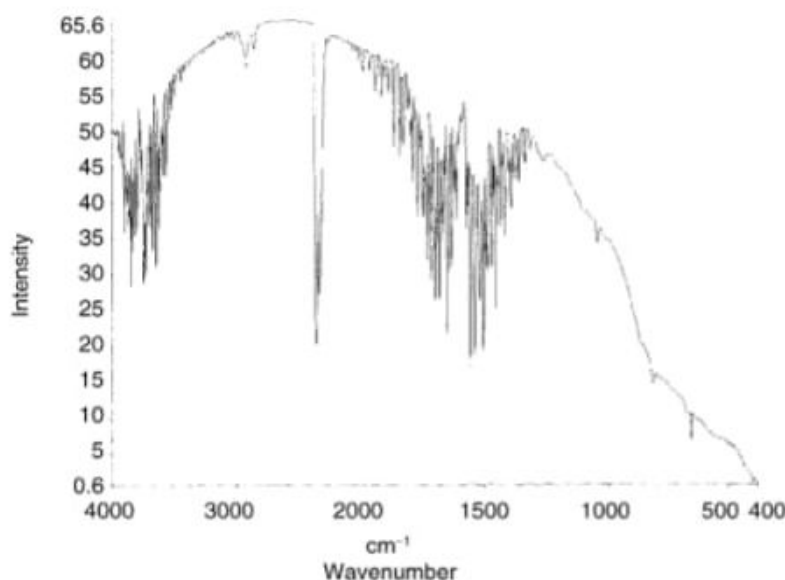


### 4.2.3. Detectors

Detectors for IR radiation fall into two classes: thermal detectors and photon-sensitive detectors. Thermal detectors include *thermocouples*, *bolometers*, *thermistors*, and

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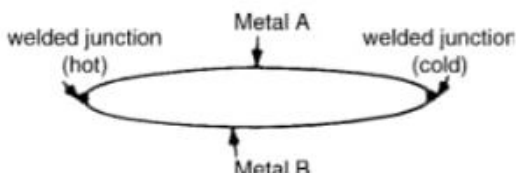
**Figure 4.14** A background spectrum of air, showing the absorption bands due to water vapor and carbon dioxide. Collected on a Paragon 1000 FTIR spectrometer, PerkinElmer Instruments, Shelton, CT ([www.perkinelmer.com](http://www.perkinelmer.com)).

*pyroelectric* devices. Thermal detectors tend to be slower in response than photon-sensitive semiconductors. The most common types of detectors used in dispersive IR spectroscopy were bolometers, thermocouples, and thermistors, but faster detectors are required for FTIR. FTIR relies on pyroelectric and photon-sensitive semiconducting detectors. Table 4.5 summarizes the wavenumber ranges covered by commonly used detectors.

#### 4.2.3.1. Bolometer

A bolometer is a very sensitive electrical resistance thermometer that is used to detect and measure weak thermal radiation. Consequently, it is especially well suited as an IR detector. The bolometer used in older instruments consisted of a thin metal conductor, such as platinum wire. Incident IR radiation heats up this conductor, which causes its electrical resistance to change. The degree of change of the conductor's resistance is a measure of the amount of radiation that has fallen on the detector. In the case of platinum, the resistance change is 0.4% per °C. The change in temperature depends on the intensity of incident radiation and on the thermal capacity of the detector. It is important to use a small detector and to focus the radiation on it. The *rate* at which the detector heats up or cools down determines how fast the detector responds to a change in radiation intensity as experienced when an absorption band is recorded. This constitutes the *response time* of the detector. For these older types of bolometers, the response time is long, on the order of seconds. Consequently, a complete mid-IR scan using a dispersive instrument and bolometer could take 20 min.

Modern bolometers are micro-machined from silicon. This type of bolometer is only a few micrometers in diameter and is usually placed in one arm of a Wheatstone bridge for measurements. The modern micro-bolometer has a fast response time and is particularly useful for detecting far-IR radiation ( $600\text{--}20\text{ cm}^{-1}$ ).



**Figure 4.15** Schematic diagram of a thermocouple.

#### 4.2.3.2. Thermocouples

A thermocouple is made by welding together at each end two wires made from different metals (Fig. 4.15). If one welded joint (called the *hot junction*) becomes hotter than the other joint (the *cold junction*), a small electrical potential develops between the joints. In IR spectroscopy, the cold junction is carefully screened in a protective box and kept at a constant temperature. The hot junction is exposed to the IR radiation, which increases the temperature of the junction. The potential difference generated in the wires is a function of the temperature difference between the junctions and, therefore, of the intensity of IR radiation falling on the hot junction. The response time of the thermocouple detector is slow; thermocouples cannot be used as detectors for FTIR due to their slow response.

#### 4.2.3.3. Thermistors

A thermistor is made of a fused mixture of metal oxides. As the temperature of the thermistor increases, its electrical resistance decreases (as opposed to the bolometer). This relationship between temperature and electrical resistance allows thermistors to be used as IR detectors in the same way as bolometers. The thermistor typically changes resistance by about 5% per °C. Its response time is also slow.

#### 4.2.3.4. Golay Detector

The Golay detector was a pneumatic detector, a small hollow cell filled with a nonabsorbing gas such as xenon. In the center of the cell was a blackened film. Radiation was absorbed by the blackened film, causing an increase in temperature. In turn, the film heated the enclosed gas. Thermal expansion of the gas caused the internal pressure of the cell to increase. One wall of the cell was a thin convex mirror that was part of the optical system. As the pressure inside the cell increased, the mirror bulged. A change in radiation intensity falling on the Golay detector caused a change in the readout from the detector. An important advantage of this detector was that its useful wavelength range was very wide. The response was linear over the entire range from the UV through the visible and IR into the microwave range to wavelengths about as long as 7.0 mm. The Golay detector's response time was about  $10^{-2}$  s, much faster than that of the bolometer, thermistor, or thermocouple. The detector was very fragile and subject to mechanical failure. While this detector is no longer in use as an IR detector, a variation of the Golay detector, the photoacoustic detector, is used in photoacoustic spectroscopy, discussed later in this chapter.

#### 4.2.3.5. Pyroelectric Detectors

*Pyroelectric materials* change their electric polarization as a function of temperature.