Cosmic Chemistry: Planetary Diversity

Infrared Spectroscopy: Here Comes the Heat

STUDENT ACTIVITY

NASA/JPL, California Institute of Technology

Sir William Herschel

Your goal is to "discover" infrared radiation by reproducing the classical experiment conducted by William Herschel in 1800. Herschel passed sunlight through a prism to produce a solar spectrum in the usual way. He then arranged thermometers so that the bulbs were placed in the different colors of the solar spectrum. He recorded the temperature readings after a few minutes when equilibrium had been reached. Your team is to design an experiment in which you collect data that convincingly demonstrates that there is electromagnetic radiation lying beyond the visible spectrum that manifests itself in the form of heat instead of visible light.

PART 1

a) After reading and/or reviewing Herschel's experiment, answer questions 1 and 2 on the student reporting/data sheet.

b) Discuss among yourselves the design of an experimental procedure that will employ a prism, several thermometers, and any other materials that you feel are necessary.

c) As a team, write a description of the procedure that your team will employ, including diagrams of any apparatus that you will construct and any materials that you will need to acquire. Submit your description to the teacher.

d) After your teacher gives you directions to proceed, acquire the materials that you need and conduct the experiment that you have designed.

e) Submit a written report to your teacher in which you include a table showing the temperature of each color of light and the temperature just outside of the red portion of the spectrum. Discuss whether your observations confirm the existence of the presence of electromagnetic radiation outside of the visible region.

PART 2

Your instructor in the Herschel School of Infrared Studies, Dr. Sweets Herschey, will provide hints and materials as needed and will evaluate your work as you progress toward becoming a certified graduate of the school.

As a trainee in the Herschel School of Infrared Studies, you understand that infrared radiation is often quantified by using units that are different from those used for other parts of the electromagnetic spectrum. Before you can proceed to apply infrared measurements for practical purposes, it is necessary to demonstrate that you have a good understanding of the units used in discussions of infrared radiation.

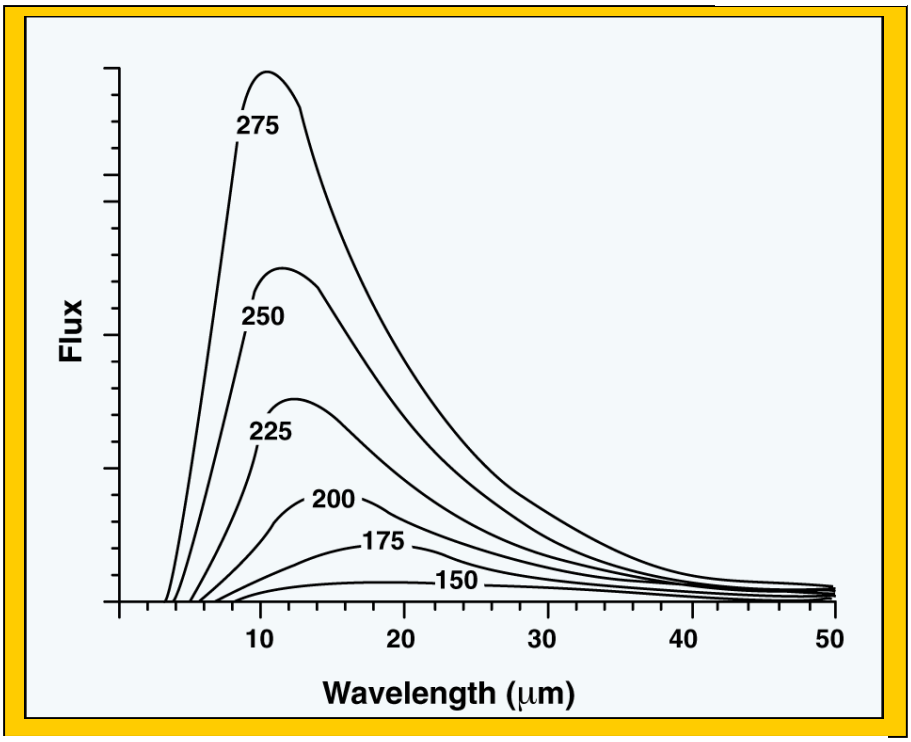
Complete Table 1 on the reportingd/data sheet to demonstrate that you have acquired sufficient knowledge of infrared wavelength units to satisfy Dr. Herschey. Once you have received Dr. Herschey's approval, proceed to Part 3.

PART 3

In order to help you understand how our view of the world depends on the wavelengths of electromagnetic radiation to which our eyes respond, Dr. Herschey will issue you imaginary glasses. These glasses allow you only to "see" radiation having a wavelength in a narrow range centered around 10 μm. Your assignment is to think about what your world would look like while wearing these glasses.

Answer the questions on the reportingd/data sheet. The figure below showing some black body emission curves may be helpful as you consider your answers. Once Dr. Herschey has approved your answers, proceed to the next part of this activity.

Figure 1



Note. Numbers on curve are temperatures in Kelvins.

PART 4

Since you are now well aware that the temperature of an object determines the wavelengths of its infrared emissions, it should be clear that the temperature of a distant object might be estimated by studying its thermal infrared emissions. The temperatures of solar system and other celestial objects often are almost impossible to measure in any other way—so infrared comes to the rescue. As a trainee, you need to demonstrate your awareness of this technique as it might apply to the solar system, where planetary diversity clearly is found in planetary temperatures. Dr. Herschey will give you a copy of a graph of thermal infrared Flux *vs.* Wavelength for several of the planets. Your first task is to decide which curve (A through F) belongs to each of the following planets: Jupiter, Saturn, Uranus, Neptune, Earth, Mars, and Pluto. Enter your conclusions on the reporting/data sheet.

Your second task is to use the curve for Earth to estimate the value of the constant in the equation: $\lambda_{\mu}T$ = constant.

Enter your answer on the reporting/data sheet.

Your third task is to decide what a curve, similar to those in the reporting/data sheet, for Mercury would look like. Sketch your proposed curve for Mercury on the graph. After Dr. Herschey has approved of your work, proceed to Part 5.

PART 5

The successful completion of this part of the activity will certify you as a graduate of the Herschel School of Infrared Studies.

As you read the student text for this activity, you learned that high-resolution infrared spectroscopy may be used to identify molecules, such as water. In principle, all molecules have a unique infrared spectrum. You also learned that vibrations within a molecule give rise to infrared absorptions and that, as a rule, the heavier the atoms involved in the vibration, the lower will be the vibrational energy. In this part of the activity, you will use your knowledge to "analyze" a major constituent of a planetary atmosphere and then identify the planet that might be associated with the infrared spectrum.

Shown on the reporting/data sheet are two simulated infrared absorption spectra. Assume that each of these spectra is characteristic of the atmosphere of one of the planets, and further assume that the spectrum shows only the planet's major atmospheric component. Your assignment is to use your knowledge of the major components of planetary atmospheres (see data tables in Student Activity, "Are We Related?") and decide which of the nine planets might give an actual spectrum corresponding to each of the graphs.

Enter your answers in the spaces provided on the reporting/data sheet and turn in your results to Dr. Herschey. Congratulations! You now are a certified graduate of the Herschel School of Infrared Studies.