Analytical Chemistry Cumulative Exam
Professor M. Trenary
November 4, 2004

On October 26 of this year the Cassini spacecraft had its first close encounter with Titan, the largest moon of Saturn. Titan is unique among the moons of the planets in our solar system in that it has a dense atmosphere consisting of 97% N_2, with the remainder largely methane and other small hydrocarbons. Many analytical instruments are carried aboard Cassini that are being used to measure the atmosphere and other properties of Titan and Saturn. This exam concerns these instruments and the measurements made with them.

The following is a list of the scientific experiments aboard the Cassini orbiter.

a) CAPS (Cassini Plasma Spectrometer)
b) CDA (Cosmic Dust Analyzer)
c) CIRS (Composite Infrared Spectrometer)
d) INMS (Ion and Neutral Mass Spectrometer)
e) ISS (Imaging Science Subsystem)
f) MAG (Magnetometer)
g) MIMI (Magnetospheric Imaging Instrument)
h) Cassini RADAR (Radio Detection and Ranging Instrument)
i) RPWS (Radio and Plasma Wave Science Instrument)
j) RSS (Radio Science Subsystem)
k) UVIS (Ultraviolet Imaging Spectrograph)
l) VIMS (Visible and Infrared Mapping Spectrometer)

1) (10 pts) The various instruments can be classified as being either direct sensing (like taste, touch, or smell) or indirect sensing (like sight or hearing). Indicate whether experiments a) through l) are direct sensing, indirect sensing, or both.

2) (30 pts) The Cassini Plasma Spectrometer (CAPS) system consists of three separate spectrometers: the electron spectrometer (ELS), the ion mass spectrometer (IMS), and the ion beam spectrometer (IBS). CAPS will measure the flux (i.e., the flow rate or density) of ions as a function of mass per charge and the flux of ions and electrons as a function of energy per charge and angle of arrival relative to the CAPS instrument.

a) The ion mass spectrometer consists of a toroidal electrostatic analyzer, carbon foils and a time of flight spectrometer. Briefly explain the purpose of these three components.

b) Whereas the ion mass spectrometer (IMS) provides species-resolved measurements of the flux of positively charged atomic and molecular ions as a function of energy/charge vs aperture entry direction, the ion beam spectrometer (IBS) measures the flux of positively charged ions of all species as a function of energy/charge and aperture entry direction. Explain what is different about the information provided by the IMS and the IBS.

c) The third major CAPS subassembly is the electron spectrometer (ELS), which measures the flux of electrons as a function of energy/charge and aperture entry direction. It consists of a spherical electrostatic analyzer and curved microchannel plate detectors. Give some

possible reasons why NASA decided to have a separate electron spectrometer, rather than simply reversing the bias on the IBS spectrometer so that negative instead of positive particles could be detected.

3. (20 pts) The major functional components of the INMS Subsystem are an open ion source, a closed ion source, a quadrupole deflector and lens system, a quadrupole mass analyzer, and a dual detector system.

a) The ability to analyze neutral species is an obvious difference between the CAPS and INMS systems. What is the main reason INMS is designed to also study positive ions since positive ions are already being analyzed with the CAPS system? In other words, what kind of information will INMS provide on positive ions that is not provided by CAPS?

b) One of the first findings from Cassini regarding the atmosphere of Titan was that the $^{15}N_2/^{14}N_2$ ratio is much higher than on earth. Which instrument was likely to have been used for this determination?

4. (10 pts) The measurements made with the magnetometer will be very important in understanding the chemical composition of Titan's atmosphere, just as the Earth's magnetic field influences atmospheric chemistry here. Briefly explain the connection between a planet's or moon's magnetic field and the chemical reactions that take place in its atmosphere.

5. (30 pts) Pick two of the other scientific instruments a) through l) other than the CAPS and INMS systems and describe the nature of the instrumentation involved and the type of information the systems are designed to provide.