Fingerprints in Starlight: Spectroscopy of Stars
Inquiry Questions with Answers

1. What type of reaction fuels the Sun? Write the equation(s) for the reaction.

Fusion reaction in four steps:
1) two protons fuse to form deuterium, emitting a positron and a neutrino
   (positron annihilates quickly with an electron from the plasma, emitting two gamma rays)
2) deuterium fuses with a proton to form helium-3, emitting a gamma ray
3) two helium-3 atoms fuse to create beryllium-6, which is unstable
4) beryllium-6 disintegrates into helium-4 (alpha particle) plus two protons

net photon release: 6 gamma rays
(neutrinos interact so weakly that they fly out of the sun immediately)

The mass of one helium nucleus is less than the total mass of the four hydrogen nuclei that fuse to form it. The mass difference is converted into the tremendous amount of energy that fuels the sun ($e = mc^2$).

2. What happens to the photons released by this reaction?

High energy gamma rays are absorbed and re-emitted many times on their journey from the core out of the sun as they collide with atoms in their path. They transmit energy to an atom with each collision, reducing their energy and generating additional lower-energy photons as the excited atom decays. Each high-energy gamma ray will eventually become a thousand low-energy photons!

3. What color is the Sun? Why is it this color?

The Sun is white because sunlight is composed of electromagnetic radiation of all wavelengths and frequencies. Even to human eyes which can "see" only wavelengths in the visible spectrum, it appears white due to the blending of these colors.

Why then are we taught in elementary school to color the Sun yellow?

4. Why do we care so much about the Balmer series in atomic spectra? What is H□?

The Balmer series is the visible wavelength portion of the hydrogen emission or absorption spectrum. Since all stars contain hydrogen, we expect to see these bands in any spectra obtained from a star. H□ is the red band in the hydrogen spectrum that represents an electron transition between level 3 and level 2. It corresponds to a wavelength of 656 nm.

5. Why do electrons need to be in the second energy level in order to be able to absorb photons with Balmer wavelengths?

Only electrons in the second energy level of a hydrogen atom will absorb the exact quantum of energy required to produce a photon with a wavelength corresponding to a Balmer spectral line. Hydrogen atoms in cool stars only have electrons in the ground state. Very hot stars contain hydrogen that that is either ionized or with electrons excited to higher energy levels. In both cases the stars will have weak Balmer absorption lines.

6. Why is information about many stars contained in absorption rather than emission spectra?

If there is a cloud of gas at a cooler temperature directly between a denser source producing a continuous spectrum (i.e. a star) and a telescope, the gas will absorb light at specific wavelengths that are characteristic of the chemical composition of the cooler gas. The excited atoms will relax back to ground state and re-emit light of the same wavelengths but in random directions, resulting in fewer photons of those wavelengths reaching the telescope. This will produce an absorption spectrum.

7. What information can be obtained from emission and absorption spectra?

Spectral class, distance, temperature, age, chemical composition, mass, radial velocity, rotational velocity, expansion or contraction, ionization level, luminosity, magnetic fields, spectroscopic binary systems, emission nebulae, interstellar absorption lines and more.

8. Are all elements found in every star? If not, why?

No, not all elements are found in every star. In our Sun, 67 chemical elements have been detected from solar spectra and there may be more in small enough quantities to prevent detection. Most stars, like our Sun, are about 70% hydrogen and 28% helium by mass. The mass fraction of all the other "heavy elements" varies from 2-3% for stars like our Sun (population I stars) to 0.1 to 0.01% in stars found in globular clusters (population II stars). Population I stars are older stars thought to have formed from interstellar clouds previously enriched in heavier elements from other stars. Younger, metal-poor population II stars originated from hydrogen and helium gas clouds and require time to start producing heavier elements.

9. Which elements are found in all stars? Why do you think this is the case?

Hydrogen and helium are found in all stars. Ninety percent of all atoms in the universe are hydrogen atoms and fusion reactions fuel stars, resulting in the formation of helium and higher atomic number elements. This is the case because of the Big Bang, when temperatures were so high that only energy could exist. As the universe expanded, it cooled and some of the energy converted into matter in the form of electrons, protons and neutrons. As the universe continued to expand and cool, these particles formed the nuclei of the simplest elements, hydrogen and helium. Fusion reactions in star cores first form helium from hydrogen, and as core temperatures increase helium is fused into carbon. Such repeated fusion reactions can form atoms as massive as iron.

Very massive stars are the source of heavier elements. When such a star fuses all its hydrogen into helium and helium into heavier elements up to iron, the star collapses and blows apart in a supernova. All elements heavier than iron are formed in supernova explosions. The star's contents are blown into space where they can become part of a newly forming star system.

10. Why do we find the same elements in the stars as we find on Earth?

During the formation of our solar system, the initial solar nebula consisted of mixtures of rock grains and ices. Located in the inner part of the solar system where it was sufficiently hot that only solids could exist, Earth was formed from accretion of the solid grains. We and the Earth are thus made of the same "star stuff" as our Sun. "We are stardust, we are golden….."

Of all the elements listed on the periodic table, 93 are found in nature. Three of these elements, Technetium (Te), Promethium (Pm), and Neptunium (Np), are not found on Earth but have been detected in the spectra of stars.

Source: http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/961112a.html