Exercise 3

In this exercise, you will read a passage and then answer the questions that follow. The suggested time for reading the passage and answering the questions is 15 minutes.

Elemental Clues to a Galaxy's Past

Clues to how a galaxy has evolved may lie in its supply of oxygen and iron, according to two astronomers. For many years, scientists have known that different galaxies evolve in different ways. In our Milky Way, for example, stars have formed at a fairly constant rate since its birth. But in our two nearest neighbours — the Large and Small Magellanic Clouds — stars seem to arise in bursts of star formation, with long periods of quiescence in between (*New Scientist, Science*, 18 August). Researchers know this because they have painstakingly measured the ages of different stars in the Magellanic Clouds, and found that stars of a certain age are more common.

Now there may be an easier way. Gerard Gilmore of the Institute of Astronomy in Cambridge, England, and Rosemary Wyse of Johns Hopkins University in Baltimore, Maryland, claim that the ratio of oxygen to iron in a galaxy's stars can reveal whether a galaxy has created stars at a steady rate (as is the case in the Milky Way) or in bursts (as is the case in the Magellanic Clouds). Their work will be reported early next year in the journal *Astrophysical Journal Letters*.

Galaxies are thought to have formed from clouds of hydrogen and helium gas that lacked heavy elements, such as oxygen and iron. Later, some of the stars born from this gas created heavier elements deep in their cores. If these stars explode, they eject the heavy elements into a galaxy. When new stars form from this ejected materials, they acquire more of these heavy elements. In this way, a galaxy's supply of heavy elements increases in time: old stars have fewer heavy elements, whereas younger stars — such as the Sun — have more.

But it turns out that oxygen and iron arise from two different types of exploding stars, or supernovae. Oxygen gets ejected into a galaxy from massive stars — those born with more than eight times the Sun's mass. Such a high-mass star burns its fuel quickly and dies quickly, exploding as a so-called Type II supernova and forming a compact neutron star or a black hole.

Before it explodes, the high-mass star creates both oxygen and iron. But oxygen is lighter than iron and floats up outside the core of the star, whereas the iron remains at the star's centre. When the star explodes, the oxygen is set free, while the iron gets sucked into the newly formed neutron star or black hole. So high-mass stars contribute a lot of oxygen to a galaxy, but little iron.

In contrast, less massive stars can eject lots of iron into a galaxy. Stars born with masses less than eight times that of the Sun's eventually form white dwarfs, stars that are dim, small and hot. If material from another star falls onto the white dwarf, the white dwarf can eventually explode, producing a so-called Type I supernova. Astronomers know that this type of explosion creates large amounts of the element iron.

High-mass stars, which eject oxygen, are short-lived, whereas lower-mass stars, which can produce iron, live longer. Therefore, the two types of stars explode at different rates during the life of a galaxy, and oxygen and iron are produced at different rates at different times.

Shortly after its formation, the Milky Way gave birth to stars with a wide variety of masses. The short-lived, high-mass stars quickly exploded and showered the Galaxy with oxygen. Only much later did white dwarfs form and explode, producing iron. The Galaxy's oldest stars — those born as the oxygen-producing stars exploded but before the iron-producing stars did so — should, therefore, have high ratios of oxygen-to-iron. This is exactly what astronomers find.

Gilmore and Wyse have modelled a galaxy that produces stars in bursts, unlike the Milky Way. They predict that such a "bursting" galaxy can have an oxygen-to-iron ratio that is lower than the Sun's.

To see why, imagine a galaxy that creates a lot of stars of different masses, then stops making stars. In the early years, the high-mass stars explode and produce oxygen. After the high-mass stars die out, however, only the lower-mass stars are left. These lower-mass stars eventually form white dwarfs, some of which explode and produce iron.

The amount of iron in this galaxy increases and the oxygen-to-iron ratio falls, because no more oxygen-producing high-mass stars are born any more. So, although the galaxy's oxygen-to-iron ratio starts high, it soon falls until it is less than the Sun's. Even if a new burst of star formation happens, the resulting high-mass stars will not produce enough oxygen to raise the oxygen-to-iron ratio above what it would have been if the galaxy had formed stars continuously. In contrast, a galaxy that keeps forming stars — such as the Milky Way — keeps producing high-mass, oxygen-producing stars all along and keeps its oxygen-to-iron ratio higher than a galaxy that forms stars in a series of bursts.

Gilmore and Wyse apply their results to the Large Magellanic Cloud, where young stars have ratios of oxygen-to-iron that are only half that of the Sun's. This low oxygen-to-iron ratio arises, Gilmore and Wyse say, because the Large Magellanic Cloud produces stars spasmodically rather than continuously.

There have been other explanations for the Large Magellanic Cloud's low oxygen-to-iron ratio. In particular, the Large Magellanic Cloud may simply produce fewer high-mass stars (which create oxygen) relative to lower-mass stars (some of which eventually create iron). But other evidence reveals starbursts in the cloud.

Questions 1-11

Decide whether, according to the passage, the following statements are true or false. Select A if a statement is true, B if it is false, and C if the information is not given. The first has been done as an example.

Example:	Answer:		
Stars in the Milky Way have formed at a fairly constant rate since its birth.	A ✓	B	C

1. Galaxies are thought to have formed from clouds of hydrogen and helium gas with heavy elements, such as oxygen and iron.	A	B	C
2. The stars in the Magellanic Clouds seem to have formed in bursts.	A	B	C
3. Old stars have more heavy elements whereas young stars have fewer.	A	B	C
4. White dwarfs are short-lived.	A	B	C
5. High-mass stars contribute a lot of iron to the galaxy.	A	B	C
6. A compact neutron star is large and bright.	A	B	C
7. Lower-mass stars will eventually form white dwarfs and high-mass stars will eventually form compact neutron stars or black holes.	A	B	C
8. The Milky Way keeps forming stars and having a higher oxygen-to-iron ratio.	A	B	C
9. There are more lower-mass stars in the Magellanic Cloud than in the Milky Way.	A	B	C
10. Young stars in the Large Magellanic Cloud have ratios of oxygen-to-iron that are twice that of the Sun's.	A	B	C
11. The Large Magellanic Cloud may produce fewer lower-mass stars relative to high-mass stars.	A	B	C