TEACHER NOTES – ASTRONOMY IN THE NEWS #46

ORIGIN OF WATER ON EARTH

Slide 2 – Background Science: Origin of Water on Earth

Water covers about 70% of the surface of the Earth and is essential to life on Earth. However, the origin of the water is not well understood with three prevailing theories.

The first is that carbonaceous chondrites and other icy planetesimals accumulated on Earth about 4.5 billion years ago as the Earth grew from 60%-90% of its current mass to now. These objects would have brought water to Earth, and a significant number of collisions would have eventually built the abundances of water. The strengths of this argument are that the deuterium/hydrogen isotope ratio found on these objects is similar to that found in ocean water, and the fact that rock samples from the Apollo missions show chemical compositions similar to the Earth. The fact that this occurs indicates water must have been present on Earth at the time of the formation of the Moon.

The second is that water was delivered much later in the process, after the formation of the Moon. The reason for the requirement of this is that the noble gas isotope ratios are different in the mantle compared to the atmosphere, indicating that they formed from different sources. However, since the amount of mass accreted after the Theia collision is very low, these objects must have been very water-rich, which could be possible if icy asteroids were impacting the Earth due to Jupiter migrating closer to the Sun.

The final hypothesis is that it was, in fact, the collision with Theia that created the Moon that brought water to the Earth. If this object formed in the outer Solar System rather than in the inner Solar System, it would have been water and carbon rich, and this collision would have provided a lot of water to the Earth.

IMAGES:

1. (Left) Image of Earth showing the water on the surface that we all know exists!
2. (Right) Cartoon depiction of the collision between the Earth and Theia, the planet the size of Mars that is hypothesised to have collided with Earth to form the Moon 4.5 billion years ago.

Slide 3: Winchcombe Meteorite

A meteorite fell to the ground on February 28th, 2021, landing in Winchcombe, Gloucestershire. The fireball it created was picked up by many cameras, from dash cameras and CCTV, all the way to those dedicated to detecting these events.

There are two major results from this study. The first is about the origin of water, as was discussed in bulletin #43, and the second is where it originated from.

The meteorite was determined to be a carbonaceous chrondite due to the chemical analysis of the object. Chemical and isotopic analysis has found that the hydrogen content of the meteorite was consistent with that of oceanic water and the hydrosphere of Earth. The comparisons were made by looking at the deuterium fraction (deuterium is the isotope of hydrogen).

The origin of the meteoroid was determined in two manners. The first was from plotting the trajectory. The many detections with cameras allowed it to be determined, and it was tracked to the outer edge of asteroid belt, on the Jupiter side. This journey has taken between 200,000 and 300,000 years. The second method used further isotopes, namely of chromium and titanium, and the detected values are consistent with other objects detected in the Outer Solar System.

The articles that this resource is built on can be found here:

https://www.bbc.co.uk/news/science-environment-63631563

https://www.theguardian.com/science/2022/nov/16/meteorite-that-landed-in-cotswolds-may-solve-mystery-of-earths-water

A free version of the research article can be found here (although I caution I don't know how long it will remain free):

https://www.science.org/doi/10.1126/sciadv.abq3925

IMAGES:

1. (Left) Plot of titanium isotopic ratio vs. titanium ratio for the Winchcombe meteorite, along with the values for other meteorites and the inner planets (and the moon). The values determined here are consistent with objects known to have originated in the Outer Solar System.
2. (Top right) Photograph of the impact site of the largest segment of the Winchcombe meteorite. Quite a bit of damage for only 300g!
3. (Bottom right) The Winchcombe meteorite.

Slide 4 – Activity: Relative atomic mass

This week's activity is to calculate the relative atomic mass of oxygen, emphasising to the students what isotopes are. The slide gives the equation and the relative abundances and should allow the students to calculate the relative mass on Earth. The value that should be determined is 16.0041, as opposed to 16.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	9.5, 11.10, 11.13, 11.27
Pearson Edexcel Physics	6.3, 6.4
Pearson Edexcel Chemistry	1.9, 1.12
Pearson Edexcel Combined Science	C1.9, C1.12, P6.3, P6.4
OCR Physics B	5.1.5, 5.1.6
OCR Chemistry B	2.1.7
OCR Combined Science B	C2.1.7, P5.1.5, P5.1.6
AQA Physics	4.4.1.2
AQA Chemistry	4.1.1.5, 4.1.1.6
AQA Combined: Trilogy	5.1.1.5, 5.1.1.6, 6.4.1.2
WJEC Chemistry	1.2(e,g)
WJEC Double Award	2.2(e,g)
SQA National 5 Chemistry	Isotopes, Acids and Bases
CCEA Physics	1.5.7
CCEA Chemistry	1.1.10, 1.1.11, 1.1.12
CCEA Double Award	C1.1.10, C1.1.11, C1.1.12, P1.5.7

A-Level Physics Specifications:

Specification	Knowledge Point
OCR Physics A	6.4.1(d)
AQA Physics	3.2.1.1