Year 13 Science: Water, carbon, volcanoes and climate trends

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. 25 mm of rain falls on 1.0 km². How much latent heat was released when it condensed? Use $L = 2.26 \times 10^6$ J kg^{-1}.

2. Using the CO_2 table, find the average rate of rise from 2010 to 2020.

3. New Zealand's mean temperature in 2021 was 13.56 °C. How far above the 1981 to 2010 average of 12.61 °C was it?

4. Why does SO_2 that reaches the stratosphere affect climate for longer than SO_2 that stays in the troposphere?

5. Why does the CO_2 record rise and fall a little every year?

Exam-style question: the Pinatubo eruption

In June 1991, Mt Pinatubo in the Philippines erupted, sending a column of ash and gas about 35 km high and putting around 15 million tonnes of SO_2 into the stratosphere. In 1992, average global surface temperature was about 0.5 °C lower than before the eruption.

6. Describe what happened in the troposphere close to the volcano.

7. Explain how the SO_2 in the stratosphere cooled the Earth's surface.

8. Explain why the cooling was felt around the world, including in New Zealand.

9. Explain why the cooling lasted only about two years.

Fix the mistake

10. Correct this statement: "Volcanic ash in the stratosphere is what cools the climate for years."

11. Correct this statement: "Last winter was cold, so the climate is not warming."

12. Correct this statement: "Evaporation cools the air because the water takes heat from it."

13. Correct this statement: "The yearly wiggle in CO_2 is caused by people burning more fuel in winter."

Answer key (for parents and tutors)

1. 25 mm of rain falls on 1.0 km². How much latent heat was released when it condensed? Use $L = 2.26 \times 10^6$ J kg^{-1}.
   Mass = 0.025 m × 1.0 × 10^6 m² × 1000 kg m^{-3} = 2.5 × 10^7 kg; Q = 2.5 × 10^7 × 2.26 × 10^6 = 5.7 × 10^{13} J.

2. Using the CO_2 table, find the average rate of rise from 2010 to 2020.
   (414.2 − 390.1) ÷ 10 = 24.1 ÷ 10 = 2.4 ppm a year.

3. New Zealand's mean temperature in 2021 was 13.56 °C. How far above the 1981 to 2010 average of 12.61 °C was it?
   13.56 − 12.61 = 0.95 °C.

4. Why does SO_2 that reaches the stratosphere affect climate for longer than SO_2 that stays in the troposphere?
   There is no rain in the stratosphere to wash the sulfate aerosol out, so it stays for one to three years and spreads worldwide; in the troposphere rain removes it within about a week or two.

5. Why does the CO_2 record rise and fall a little every year?
   Plants in the Northern Hemisphere, which has most of the land, take in CO_2 during the northern summer and release it as they decay in winter.

6. Describe what happened in the troposphere close to the volcano.
   Ash and gas fell out of the troposphere near the volcano within days, darkening the sky and cooling it locally; SO_2 there formed sulfate that rain washed out as acid rain (Achieved).

7. Explain how the SO_2 in the stratosphere cooled the Earth's surface.
   In the stratosphere the SO_2 reacted with water vapour to form tiny sulfuric acid droplets. These reflect and scatter incoming short-wave sunlight back to space, so less reaches the surface and it cools; they also absorb some radiation, warming the stratosphere (Merit).

8. Explain why the cooling was felt around the world, including in New Zealand.
   The stratosphere has no weather to remove the droplets, and stratospheric winds carried the aerosol around the globe within months and spread it into both hemispheres, so the reduction in sunlight was global, reaching New Zealand's skies with vivid sunsets (Merit).

9. Explain why the cooling lasted only about two years.
   The droplets slowly grow and settle out of the stratosphere over one to three years, so as the aerosol layer thinned, sunlight returned to normal; meanwhile the greenhouse gases that drive the long-term warming were unchanged, so warming resumed (Excellence links injection height, aerosol formation, global spread, residence time and the long-term trend).

10. Correct this statement: "Volcanic ash in the stratosphere is what cools the climate for years."
    Ash falls out within weeks; the long cooling comes from sulfate aerosol droplets made from SO_2.

11. Correct this statement: "Last winter was cold, so the climate is not warming."
    Climate is a 30-year average; one season is weather, and trends need long records.

12. Correct this statement: "Evaporation cools the air because the water takes heat from it."
    Evaporation cools the surface it leaves; the latent heat is released into the air when the vapour condenses.

13. Correct this statement: "The yearly wiggle in CO_2 is caused by people burning more fuel in winter."
    It comes from Northern Hemisphere plants taking in CO_2 in their summer and releasing it in winter.