Year 13 Science: Composition, layers and energy balance of the atmosphere

Name: _____ Date: _____

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

Practice

1. Use p = 1013 e^(−h ÷ 8.0) to find the pressure at 5.5 km.

2. On a day when it is 15 °C at the ground, estimate the temperature 4.0 km up, using 6.5 °C per kilometre.

3. In which layer does temperature rise with height because ozone absorbs ultraviolet light?

4. Why is nitrogen not a greenhouse gas?

5. If Earth's albedo rose from 0.30 to 0.32, how much energy per square metre would be absorbed, taking 340 W m^{-2} arriving?

Exam-style question: summer UV in Aotearoa

Measurements at Lauder in Central Otago show that summer UV levels in New Zealand are much higher than at similar latitudes in Europe and North America.

6. Describe how ozone forms in the stratosphere and how it absorbs ultraviolet light.

7. Explain why temperature increases with height in the stratosphere.

8. Explain why New Zealand's summer UV is higher than at the same latitude in the Northern Hemisphere.

9. Explain how clouds and aerosols change the amount of UV reaching the ground.

Fix the mistake

10. Correct this statement: "The thermosphere is 1500 °C, so it would burn a spacecraft."

11. Correct this statement: "The greenhouse effect is caused by the ozone hole letting heat in."

12. Correct this statement: "Nitrogen is the main greenhouse gas because there is most of it."

13. Correct this statement: "Pressure falls by the same amount for every kilometre you climb."

Answer key (for parents and tutors)

1. Use p = 1013 e^(−h ÷ 8.0) to find the pressure at 5.5 km.
   p = 1013 × e^(−0.6875) = 1013 × 0.503 = 509 hPa, about half.
2. On a day when it is 15 °C at the ground, estimate the temperature 4.0 km up, using 6.5 °C per kilometre.
   15 − 6.5 × 4.0 = 15 − 26 = −11 °C.
3. In which layer does temperature rise with height because ozone absorbs ultraviolet light?
   The stratosphere.
4. Why is nitrogen not a greenhouse gas?
   N_2 is two identical atoms; its vibration does not change how charge is spread across it, so it cannot absorb infrared.
5. If Earth's albedo rose from 0.30 to 0.32, how much energy per square metre would be absorbed, taking 340 W m^{-2} arriving?
   340 × (1 − 0.32) = 340 × 0.68 = 231 W m^{-2}, down from 238 W m^{-2}.
6. Describe how ozone forms in the stratosphere and how it absorbs ultraviolet light.
   Ultraviolet light splits O_2 into oxygen atoms, which join other O_2 molecules to make O_3. Ozone absorbs UV and splits into O_2 and O, which recombine, so the cycle repeats and the UV energy becomes heat (Achieved).
7. Explain why temperature increases with height in the stratosphere.
   UV arrives from above and is absorbed as it passes down through the ozone, so most heating happens high in the stratosphere; with heat added at the top and none from below, temperature rises with height (Merit).
8. Explain why New Zealand's summer UV is higher than at the same latitude in the Northern Hemisphere.
   The Earth is closest to the Sun in early January, during the southern summer, so about 7% more sunlight arrives than in the northern summer; the air over New Zealand has fewer pollution aerosols to scatter and absorb UV; and southern summer ozone is slightly lower (Merit for two linked reasons).
9. Explain how clouds and aerosols change the amount of UV reaching the ground.
   Thick cloud reflects and absorbs much of the UV, cutting it sharply, while broken cloud can reflect extra UV onto the ground near cloud edges; aerosols such as smoke and sulfate scatter and absorb UV, so clean air lets more through. Combining Earth's orbit, clean air and the ozone layer explains New Zealand's high UV, and why the UV Index can be high even on a cool or partly cloudy day (Excellence).
10. Correct this statement: "The thermosphere is 1500 °C, so it would burn a spacecraft."
    Its particles are fast but so few that little heat is transferred; spacecraft orbit in it without burning.
11. Correct this statement: "The greenhouse effect is caused by the ozone hole letting heat in."
    Greenhouse gases absorb outgoing infrared; the ozone hole lets more UV reach the ground, a separate problem.
12. Correct this statement: "Nitrogen is the main greenhouse gas because there is most of it."
    N_2 and O_2 do not absorb infrared; water vapour and CO_2 do, despite their small amounts.
13. Correct this statement: "Pressure falls by the same amount for every kilometre you climb."
    Pressure falls exponentially, halving about every 5.5 km, so the drop per kilometre gets smaller with height.