

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 The ratio of the power radiated per unit area by a surface to that of an ideal black surface at the same temperature.

2.2 Total scattered power $\div$ total incident power; cloud formations and latitude.

2.3 The planet absorbs over its projected disc (πR^2) but the power spreads over the whole sphere ($4\pi R^2$), so the average over the surface is $S/4$.

2.4 Methane CH_4 , water vapour H_2O , carbon dioxide CO_2 , nitrous oxide N_2O .

2.5 The augmentation of the greenhouse effect due to human activities.

3.1 Absorbed: $0.60 \times 2200/4 = 330 \text{ W/m}^2$; balance $\sigma T^4 = 330$; $T = (330/5.7 \times 10^{-8})^{1/4} = 276 \text{ K}$.

3.2 Infrared photons match gaps between CO_2 molecular energy levels, so the molecules absorb them and gain energy; the excited molecules re-emit radiation in all directions, including back towards the surface; this returned energy adds to the surface energy budget, so the surface settles warmer than the no-atmosphere balance temperature.

3.3 Black body: $\sigma T^4 = 5.7 \times 10^{-8} \times 300^4 = 462 \text{ W/m}^2$ (461.7); emissivity = $300/462 = 0.65$. A black body of the same area radiates 462 W per unit area – $1.54\times$ more.