Tips: Circle key terms, results, main ideas
-Use the information given - all you need to know is in front of you!

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PASSAGE IV

The *photoelectric effect* is the emission of electrons from matter upon the absorption of electromagnetic radiation, such as ultraviolet radiation or X-rays. Electromagnetic radiation is made up of *photons*, which can be considered finite packets of energy at various levels. Photons have properties attributed to both particles and waves. This phenomenon is known as the *wave-particle duality*.

The photoelectric effect is especially noticeable when dealing with metals. When a metallic surface is exposed to electromagnetic radiation that is above the minimum energy threshold (which is specific to the type of surface and material), photons are absorbed and electrons are emitted. No electrons are emitted for radiation with energy frequencies below that of the threshold, as the electrons are unable to gain sufficient energy to overcome the attractive forces within the metal. A scientist wishing to measure the photoelectric effect so as to further understand the nature of photons conducted the following experiments.

Experiment 1

Wishing to measure the energy required to produce the photoelectric effect on a surface of a sheet of copper, the scientist directed a beam of radiation at different frequencies (energies)—measured in Hertz (Hz)—onto the surface. After 5 minutes, the charge—measured in volts (V)—of the sheet of metal was recorded. This was done because if electrons were emitted from the surface, the metal would take on a positive charge. The results were recorded in Table 1.

Table 1

Frequency of radiation (Hertz)	Charge on the sheet of copper (volts)
10^{14}	0
10^{15}	+0.001
10^{16}	+0.224
10^{17}	+0.239

Experiment 2

Solar cells used to generate electricity are based on the concept of the photoelectric effect; however, the goal of the cell is to capture the emitted electron and create an electric current. The scientist measured the effects of different frequencies (in Hz) of radiation on the current (in V) generated by a certain solar cell. The results were recorded in Table 2.

Table 2

Frequency of radiation (Hertz)	Voltage of electric current (volts)
10^{14}	0.02
10^{15}	0.15
10^{16}	0.95
10^{17}	1.25

EMI

19. A scientist predicts that in years to come the earth's atmosphere will become much less effective at shielding the surface from radiation of higher frequencies. If this prediction is correct, which of the following is most likely to happen based on results of the experiments?

A. The photoelectric effect on metals exposed to the sun will be less evident.
B. The photoelectric effect on metals exposed to the sun will be more evident.
C. Solar cells will gradually become less effective at producing electricity.
D. Fewer photons will be emitted by particular metals.

EMI

20. Suppose that the rate of the photoelectric effect is directly proportional to the surface area of the metal exposed. Using a larger sheet of copper metal in Experiment 1 would most likely have affected the results in what way?

F. The frequency of radiation would have increased.
G. The charge on the sheet would have decreased.
H. The charge on the sheet would have increased.
J. The charge on the sheet would have stayed the same.

SIN

21. Which of the following procedures would result in the most accurate values for the effect of frequency of radiation on the photoelectric effect (Experiment 1)?

A. Test a variety of metals once each and record the trends.
B. Test a single metal many times and record the trends.
C. Test a variety of metals each at different frequencies of radiation and record the trends.
D. Test different sized samples of a variety of metals many times each, systematically varying the frequency, and record the trends.

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22. Suppose a scientist wanted to measure the effect of the atmosphere on the photoelectric effect. The scientist could learn most by doing which of the following?
    F. Setting up on the earth's surface a sheet of metal and a detector to measure the metal's charge.
    G. Setting up in orbit around the earth a sheet of metal and a detector to measure the metal's charge
    H. Placing radioactive materials close to a sheet of metal and a detector to measure the metal's charge.
    J. Setting up on the earth's surface and in space in orbit around the earth sheets of metal and detectors to measure the metal's charge.

23. Which of the following assumptions did the scientist probably make in choosing these experiments to test the nature of photons?
    A. The photoelectric effect will occur regardless of the energy of the radiation present.
    B. Radiation will not have an effect on inanimate objects.
    C. Because photons are finite quantities of energy, only photons with high enough frequency will emit electrons.
    D. Doubling the frequency of radiation will result in doubling the emission of electrons by various metals.

24. Do the results of the experiments help to explain the nature of photons as finite packets of energy at various levels?
    F. Yes, because the experiments illustrate how solar panels can produce more electricity when exposed to higher frequencies of radiation.
    G. Yes, because the experiments illustrate how higher frequency radiation (photons with higher energy levels) causes emission of electrons, which require a minimum energy to escape the surface of the metal.
    H. No, because the experiments illustrate how higher frequency radiation (photons with higher energy levels) does not cause increased emission of electrons.
    J. No, because there is no relation between the energy level of photons and the rate of photoelectric emission of electrons.