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### PART A

In 1913, Niels Bohr proposed a model for the hydrogen atom. He succeeded in calculating accurately the wavelengths of the four emission lines that lie in the visible region of the electromagnetic spectrum. Bohr's model also works for ions that have a single electron. For the helium ion,  $\text{He}^+$ , Bohr's model gives for the energies of the stationary states with quantum number  $n$ :

$$E_n = -2.18 \times 10^{-18} \text{ J} / n^2, \text{ where } n = 1, 2, 3, 4, \dots$$

The negative sign appears because the state in which the electron is completely separated from the nucleus is arbitrarily assigned an energy of zero and all other states have a lower energy.

Use your scientific calculator or a computer spreadsheet to calculate the energies of three states of the electron in the helium ion and list them in Table 1. Express the results in scientific notation, retaining **six** digits after the decimal point, as in the examples for  $n = 6$  and  $n = 8$ .

Table 1	
$n$	$E_n$ (J per ion)
2	_____
3	_____
5	_____
<b>Examples:</b>	
6	$-2.420770 \times 10^{-19}$
8	$-1.361683 \times 10^{-19}$

Next, calculate the differences in energy between the pairs of states listed in Table 2. **DO NOT ROUND.**

Convert these  $\Delta E$  values to the frequencies (Hz, where 1 Hz = 1 per second) of the photons emitted in each transition using

Use  $h = 6.62606876 \times 10^{-34} \text{ J}\cdot\text{s}$  as the value of Planck's constant. Report the frequencies in scientific notation, retaining **six digits** after the decimal point, as in the example in Table 2.

Finally, calculate the wavelength, in nanometers, corresponding to each frequency using

Use  $c = 2.99792458 \times 10^8$  meters per second as the speed of light. The factor  $10^9$  is needed to convert meters to nanometers. Report the wavelengths to **two decimal places**, as in the example.

In the last column, state whether the wavelength lies in the infra-red (IR), visible (VIS), or ultraviolet (UV) region of the electromagnetic spectrum. If  $\lambda$  is in the VIS, also state the **color** of the light.

Table 2

Transition $n_{\text{HIGH}} \rightarrow n_{\text{LOW}}$	$\hat{E}$ (J per ion)	$\hat{\nu}$ (Hz)	$\hat{\lambda}$ (nm)	Region (IR, VIS, or UV)
5 $\rightarrow$ 3	_____	_____	_____	_____
5 $\rightarrow$ 2	_____	_____	_____	_____
3 $\rightarrow$ 2	_____	_____	_____	_____
<b>Example:</b> 8 $\rightarrow$ 6	1.059087 x 10 <sup>-19</sup>	1.598364 x 10 <sup>14</sup>	1875.62	IR

**PART B**

The half-life of carbon-14 is approximately 5730 years, but, for the purposes of this exercise, assume it is 6000 years. Fill in Table 3.

1. If a carbon-containing artifact contains enough C-14 to undergo decay of 800 atoms per minute when created, how many decays per minute will occur after one, two, three, and four half-lives have elapsed thereafter?
2. You now have decay rates for zero, one, two, three, and four half-lives.
3. Find the logarithm of each decay rate. On the graph paper, plot the **logarithm of the decay rate (y-axis) versus years elapsed (x-axis)**. ATTACH THE GRAPH WITH A PAPER CLIP OR STAPLE.
4. Assume that the measured decay rate may be uncertain by  $\pm 10$  decays per minute. What is the age range for the artifact that has a measured rate of 310 decays per minute? **USE THE NUMBERS IN TABLE 3A TO HELP YOU MAKE THIS ESTIMATE BY READING FROM THE STRAIGHT-LINE GRAPH .**

No. of half-lives elapsed	No. of years elapsed	Decay Rate(decays/minute)	Log of Decay Rate
0	0	800	2.903
1	6000	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____

\*\*\*\*\*

No. of years elapsed	Decay Rate(decays/minute)	Log of Decay Rate
_____	300	2.477
_____	310	2.491
_____	320	2.505