The lowest four energy levels of the $\text{He}^+$ ion are given.

<table>
<thead>
<tr>
<th>Principal quantum number ($n$)</th>
<th>Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$-8.720 \times 10^{-18}$</td>
</tr>
<tr>
<td>2</td>
<td>$-2.180 \times 10^{-18}$</td>
</tr>
<tr>
<td>3</td>
<td>$-0.969 \times 10^{-18}$</td>
</tr>
<tr>
<td>4</td>
<td>$-0.545 \times 10^{-18}$</td>
</tr>
</tbody>
</table>

An electronic transition is identified by specifying the value of $n$ of the initial state and the value of $n$ of the final state. Identify the electronic transition responsible for the emission of radiation from $\text{He}^+$ with a wavelength of 30.4 nm?

The wavelength of light is related to its energy through Planck’s equation:

$$E = \frac{hc}{\lambda}$$

Substituting the values for Planck’s constant ($h$), the speed of light ($c$) and the wavelength gives:

$$E = \frac{(6.626 \times 10^{-34} \text{ J s})(2.998 \times 10^8 \text{ m s}^{-1})}{(30.4 \times 10^{-19} \text{ m})} = 6.534 \times 10^{-18} \text{ J}$$

This corresponds to the energy difference between the $n = 2$ and $n = 1$ levels:

$$\Delta E = E_{n=2} - E_{n=1} = (-2.180 \times 10^{-18} \text{ J}) - (-8.720 \times 10^{-18} \text{ J}) = 6.534 \times 10^{-18} \text{ J}.$$ For the emission of light, the transition is from $n = 2$ to $n = 1$. 
Identify one property used by Mendeleev to organise elements in his periodic table.

One from: atomic volume, stoichiometry of oxides, hydroxides, chloride and other compounds, melting points of elements and compounds, chemical reactivity and atomic mass

Provide a brief explanation of the origin of the periodicity of this property in terms of the quantum theory of atomic structure.

For atomic volume: atomic volume increases going down the groups of the table as new valence shells are filled.

For stoichiometry of compounds: compounds of elements in the same group show the same stoichiometry because they have the same configuration of valence electrons and therefore combine with the same number of atoms of another element to form a stable electronic configuration. Moving across a period, the stoichiometry changes as the number of valence electrons changes.

For melting points of elements and compounds: the type of bonding found in an element (metallic, covalent, dispersion) and in compounds (ionic, covalent, intermolecular) depends on the number of electrons in the outer shell. Elements on the left hand side of the periodic table have few valence electrons and relatively low nuclear charges favouring formation of metallic bonds in the element and ionic bonds in compounds. Elements on the right hand side have configurations just short of stable ones and tend to form covalent bonds with each other and ionic bonds with the metals.
- Explain why electrons in atoms occupy discrete energy levels rather than being able to possess any possible energy below that required for ionisation.

Electrons, with insufficient energy to escape, are confined in atoms by the electrostatic attraction of the nucleus and have wave-like properties. The electron wave must fit into this confined space but this is only possible with certain wavelengths. As the wavelength is related to the momentum and hence the kinetic energy, through the de Broglie relationship, this means that only certain discrete energies are possible.

- A certain pigment is found to have an electronic excitation energy of $4.97 \times 10^{-19}$ J. What is the wavelength at which this molecule will absorb radiation?

The wavelength of light is related to its energy through Planck’s equation:

$$E = \frac{hc}{\lambda}$$

or

$$\lambda = \frac{hc}{E}$$

Substituting the values for Planck’s constant ($h$), the speed of light ($c$) and the value of excitation energy gives:

$$\lambda = \frac{(6.626 \times 10^{-34} \text{ J s}) (2.998 \times 10^8 \text{ m s}^{-1})}{(4.97 \times 10^{-18} \text{ J})} = 4.00 \times 10^{-7} \text{ m} = 400. \text{ nm}$$

ANSWER: $4.00 \times 10^{-7}$ m or 400. nm

What colour do you expect this pigment to be? Explain your answer.

Absorption at 400. nm corresponds to blue light. The colour of the pigment will be white light with the blue removed – the complementary colour.

From Newton’s wheel, the complementary colour of blue is orange.