#80143 Chemistry, Other

Calculate the ionization energy of hydrogen atom using Bohr's theory.

Answer:
(1) Accoring to Rydberg expression:
The wavelength λ of the emission line in the hydrogen spectrum is given by:
$1/\lambda = R[1/(n1)^2 - 1/(n^2)^2]$
R is the Rydberg Constant and has the value 1.097×10^7 m^{-1}
n^1 is the principle quantum number of the lower energy level
n^2 is the principle quantum number of the higher energy level.

Since the electron is in the n^1=1 ground state we need to consider series 1. These transitions occur in the u.v part of the spectrum and is known as The Lyman Series.

As the value of n^2 increases then the value of $1/(n^2)^2$ decreases. At higher and higher values the expression tends to zero until at n = ∞ we can consider the electron to have left the atom resulting in an ion.
The Rydberg expression now becomes:
$1/\lambda = R[1/(n1)^2 - 0] = R(n1)^2$
Since n^1 = 1 this becomes:
$1/\lambda = R$
$1/\lambda = 1.097 \times 10^7$
$\lambda = 9.116 \times 10^{-8}$ m

We can now find the frequency and hence the corresponding energy:
$c=\nu\lambda$
$\nu=c\lambda=3 \times 1089.116 \times 10^{-8} = 3.291 \times 10^{15}$ s^{-1}

Now we can use the Planck expression:
$E=h\nu$
$E=6.626 \times 10^{-34} \times 3.291 \times 10^{15} = 2.18 \times 10^{-18}$ J

This is the energy needed to remove 1 electron from 1 hydrogen atom. To find the energy required to ionize 1 mole of H atoms we multiply by the Avogadro Constant:
$E=2.18 \times 10^{-18} \times 6.02 \times 10^{23}=13.123 \times 10^5$ J/mol
E=1312 kJ/mol

(2) Now it in necessary to use the convergence limit of the UV spectrum in an experimental method.
From the diagram the energy levels converge and coalesce to a continuum. This means that the emission lines will converge also.
The frequency at which this happens can give us the ionization energy.
The 1st column shows the frequency of the line.
The second column gives the difference in frequency which is getting less and less.

Now we can actually get 2 lines using upper and lower values. The important point is that they converge to the same point where Δν tends to zero.

We can the read the convergence limit off the x axis.
This gives $\nu=3.28 \times 10^{15}$ s^{-1} which is very close to the value from method (1).
As in method (1) we can convert to Joules using the Planck expression:
$E = h\nu$
$E=6.626 \times 10-34 \times 3.28 \times 10^{15} = 2.173 \times 10^{-18}$ J
So for 1 mole:
$E=2.173 \times 10^{-18} \times 6.02 \times 10^{23} = 13.08 \times 10^5$ J/mol = 1308 kJ/mol