ATOMIC HYDROGEN SPECTRUM

1. A hydrogen discharge tube contains hydrogen gas at low pressure with an electrode at each end. If you put a high voltage across this (say, 5000 volts), the tube lights up with a bright pink glow. If the light is passed through a prism or diffraction grating, it is split into its various colours.

2. a) UV

   b) When a hydrogen atom is excited, its electron jumps into a higher energy level. As the electron falls back to a lower energy level, losing energy, that energy is released as light. The energy levels are fixed, and an electron can only have the particular energy of whatever level it happens to be on.

   As the electron falls from one fixed level to another fixed level, it gives out light of a fixed energy. That means that only certain energies can be produced – which means that only certain frequencies can be produced.

   c) The one furthest to the left on the diagram, with the lowest frequency. The energy of a particular frequency, ν, is given by $E = h\nu$, where h is a constant – so the lower the frequency, the lower the energy.

   d) All electron jumps in the Lyman series in the emission spectrum of hydrogen end up in the 1 level.

   A: A has the lowest frequency, and so is the jump with the smallest energy gap – from 2 to 1.
   B: B has the next lowest frequency, and so the next lowest energy gap - from 3 to 1.
   C: From 5 to 1, by the same sort of argument.

   e) From the infinity level to 1.

   f) From the infinity level to 2.

   g) From 3 to 2. All the jumps in the Balmer series end up at the 2-level.

3. a) Substitute values in the Rydberg equation. n_1 is 1 for the Lyman series, so the first term in the brackets is $1/1^2$, which is just 1. The other term is 1/infinity^2, which is zero. That means that the whole contents of the bracket just comes out as 1.

   So $\nu = 2.998 \times 10^8 \times 1.097 \times 10^7 = 3.289 \times 10^{15}\ s^{-1}$

   (Don't forget the units. You are multiplying a number with the units m s^{-1} by one with units m^{-1}. You just multiply the units as well. The m and the m^{-1} cancel out, leaving you with just the s^{-1}. You could also use the unit Hz (cycles per second) which means the same thing in this context, but that makes it much more difficult to work out the units for the next stage.)

b) $\Delta E = h\nu$

c) $\Delta E = 6.626 \times 10^{-34} \times 3.289 \times 10^{15} = 2.179 \times 10^{-18}$ J

(Again, don't forget the units. Work them out as in part (a).)

You are making the perfectly logical assumption that the amount of energy needed to promote an electron from the 1-level to the infinity level is the same as you get out when it falls back to the 1-level.

d) The ionisation energy is the energy needed to remove a moles-worth of electrons, not just a single electron. All you need to do is to multiply your last answer by the number of electrons in a mole of electrons – the Avogadro constant.

$$IE = 2.179 \times 10^{-18} \times 6.022 \times 10^{23} = 1312000 \text{ J mol}^{-1}$$

(You can't quote your answer to more than 4 significant figures. That is the accuracy of the figures you are working with. Don't forget the units.)

Ionisation energies are quoted in kJ mol^{-1}, not J mol^{-1}. You need to divide the last answer by 1000.

$$IE = 1312 \text{ kJ mol}^{-1}$$