CHEM1901/3 Answers to Problem Sheet 3

1. **As 1 eV = 1.602 × 10^{-19} J, the kinetic energy = T = 100eV = 1.602 × 10^{-17} J. Rearranging the equation for the kinetic energy in terms of the momentum and substituting in the value of the electron mass, m_e, gives:**

$$p = \sqrt{2m_e \times T}$$
$$= \sqrt{2 \times (9.109 \times 10^{-31}\text{ kg}) \times (1.602 \times 10^{-17}\text{ J})} = 5.402 \times 10^{-24}\text{ kg m s}^{-1}$$

As the momentum $p = mv$, the electron velocity is:

$$v = \frac{p}{m_e} = \frac{(5.402 \times 10^{-24}\text{ kg m s}^{-1})}{(9.109 \times 10^{-31}\text{ kg})} = 5.93 \times 10^{6}\text{ m s}^{-1}$$

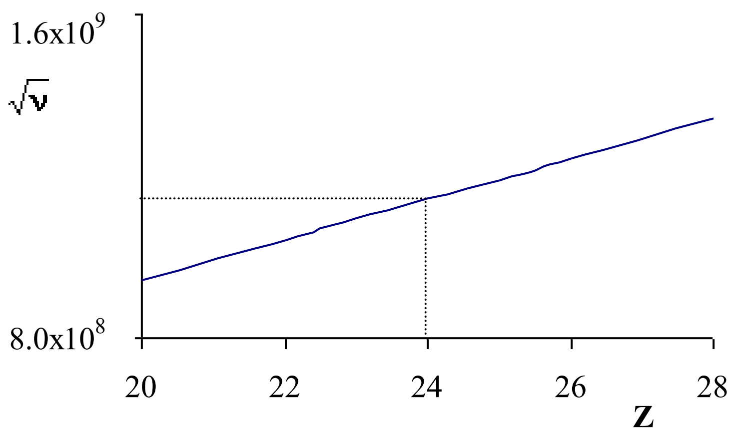
From de Broglie's relationship, the wavelength associated with a particle of momentum p is:

$$\lambda = \frac{h}{p} = \frac{(6.626 \times 10^{-34}\text{ J s})}{(5.402 \times 10^{-24}\text{ kg m s}^{-1})} = 1.23 \times 10^{-10}\text{ m} = 1.23\text{ angstroms}$$

2. **Moseley found empirically that a plot of $\sqrt{\nu}$ *vs.* atomic number Z gives a straight line. The wavelengths first need to be converted into frequencies using $\nu = c / \lambda$:**

element	$_{20}$Ca	$_{22}$Ti	$_{23}$V	$_{25}$Mn	$_{26}$Fe	$_{28}$Ni
frequency (Hz)	8.92 × 10^{17}	1.09 × 10^{18}	1.20 × 10^{18}	1.42 × 10^{18}	1.55 × 10^{18}	1.81× 10^{18}

A plot of $\sqrt{\nu}$ *vs Z* is shown below and is indeed a straight line. For *Z* = 24 (Cr), the value of $\sqrt{\nu}$ = 1.15 × 10^{9} so ν = 1.32 × 10^{18} Hz. Using $\lambda = c / \nu$ gives <u>λ = 0.227 nm</u>



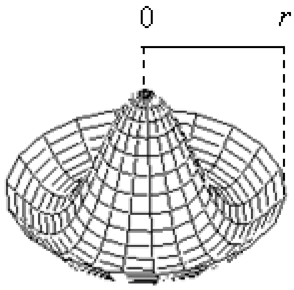
3. **The energy levels get closer and closer together as *n* increases so the *biggest* gap is between the *n* = 1 and *n* = 2 levels.**

Helium has Z = 2. The energy of the n = 1 and n =2 levels are:

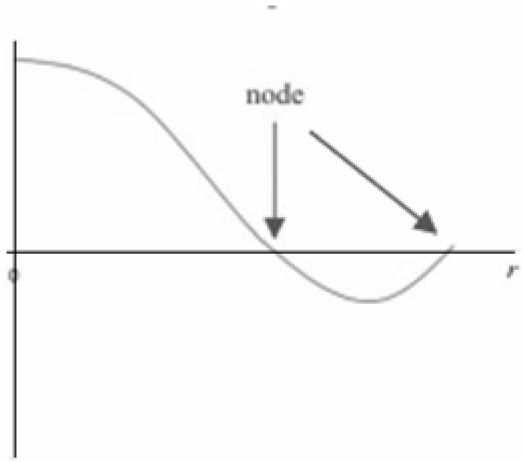
$$E_1 = \frac{-E_R(2)^2}{(1)^2} = -4E_R \text{ and } E_2 = \frac{-E_R(2)^2}{(2)^2} = -E_R$$

The energy separation is $3E_R = 3 \times (2.18 \times 10^{-18}$ J) = $\underline{6.54 \times 10^{-18} \text{ J}}$

4. .



Radial part:

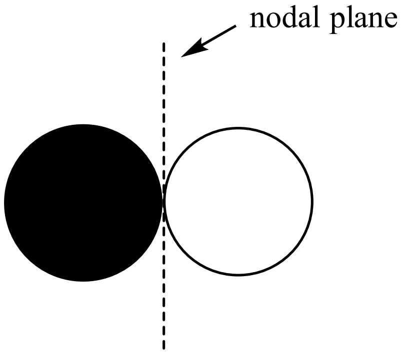


5.

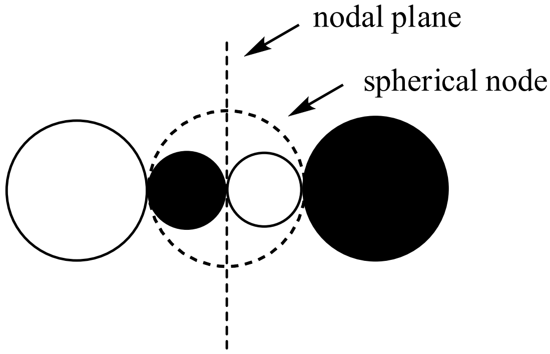
Orbital	*n*	*l*	m_l
4*d*	4	2	-2, -1, 0, 1, 2
1*s*	**1**	**0**	**0**
3*p*	**3**	**1**	**-1, 0, 1**
5*d*	**5**	**2**	**-2, -1, 0, 1, 2**

5.

2*p*:



3*p*:



6.	(a)	O	**[He]$2s^2 2p^4$**	**[He]** ↑↓ ↑↓ ↑ ↑
	(b)	Ga	**[Ar]$4s^2 3d^{10} 4p^1$**	**[Ar]** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑
	(c)	Fr	**[Rn]$7s^1$**	**[Rn]** ↑

Optional question.

The s-electrons in mercury must travel at high speeds due to their closeness to the large (Z = 80) nuclear charge. As a consequence, their masses are relativistically increased. This causes a reduction in the size of s-orbitals and this, in turn, increases the attraction to the nucleus. As a result, the $6s^2$ electrons are unexpectedly inert and reluctant to get involved in metallic type bonding. The weak interaction between Hg atoms causes it to be a liquid at room temperature.

Calculations in which relativity is ignored indicate that in a hypothetical universe in which relativistic effects are zero (i.e. one in which the speed of light is infinite), mercury would be a metallic solid like zinc and cadmim.