

### Question 1

(1) **B**

The correct electronic configurations for the other species given are:

$\text{Cu}^{2+}$ :  $[\text{Ar}]3d^9$

Cr:  $[\text{Ar}]4s^13d^5$

Pb:  $[\text{Xe}]4f^{14}5d^{10}6s^26p^2$

(2) **B**

The head-on overlap of wavefunctions with different signs gives  $\sigma^*$

(3) **C**

Simply plug all the values into the  $E_n$  equation given in the formula page, with  $n=1$ . Do take note resultant answer is in cgs-esu, be familiar with the conversion to J!

(4) **B, C and D**

Option A: The order of ionisation energy should be  $\text{Cs} < \text{Al} < \text{Mg} < \text{Si} < \text{N}$

Option B: N has a **lower** electron affinity than O, due to the disruption of its stable  $2p^3$  configuration with the addition of a new electron.

(5) **A and B**

Option A: The node is the region where the wavefunction *passes through* zero. The semantics here is more mathematical than anything else.

Option B: The energy equation cannot be used with a two-electron system.

Option C: CORRECT, All orbitals of hydrogen with the same principal quantum number are degenerate at the ground state.

Option D: CORRECT, All one-electron systems can have their Schrodinger equation solved with exact solutions.

(6) **C and D**

$l$  has a maximum value of  $n-1$ , and  $m$  cannot take absolute values larger than  $l$ .

(7) **A and C**

The diagram shows 2 radial nodes. This corresponds to any orbital whose  $n$  and  $l$  values differ by 3 e.g. 3s, 4p, 5d, 6f etc.

(8) **A**

Option A: The angular component of a s-orbital wavefunction is a constant and does not depend on  $n$ .

Option B: CORRECT, At a given  $n$ , the orbital corresponding to an  $l$  value of  $n-1$  has its radial distribution function's maxima occur at  $n^2 a_0$ .

Option C: CORRECT, The Bohr model assumes a fixed orbit around the nucleus, thus the electron cannot be found anywhere else but within that orbit.

Option D: CORRECT, There is literally no atom whose second ionisation energy is lower than the first.

**Question 2**

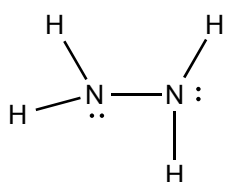
(1) We first group the orbitals in the sequence: (1s), (2s, 2p), (3s, 3p), (3d), (4s, 4p)...

For calcium, there are 2 4s electrons and no 3d electrons. For each 4s electron, the other affords a shielding of 0.35; the next lower quantum number electrons (3s, 3p) afford a shielding of  $8 \times 0.85$ , and the remaining 10 inner electrons gives a shielding of 10. The total shielding  $S$  is thus 17.15.  $Z_{\text{eff}}$  is thus  $20 - 17.15 = 2.85$

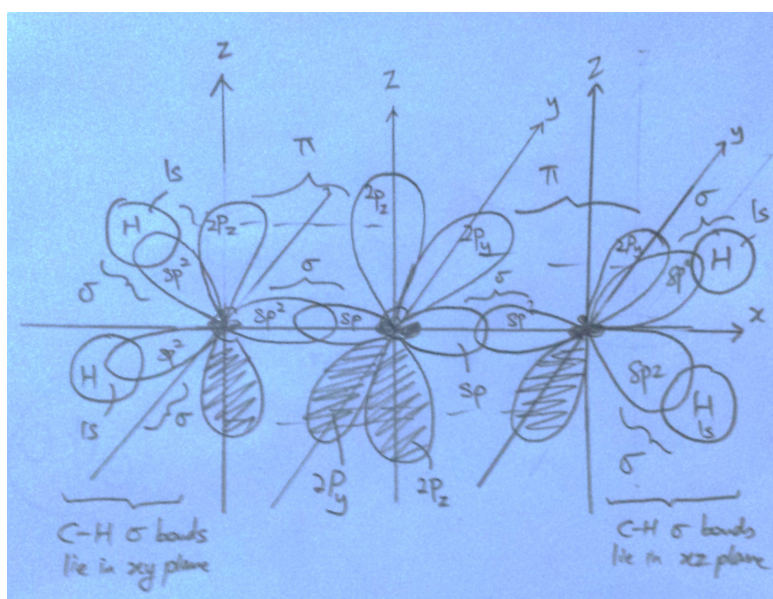
For titanium, there are 2 4s electrons and 2 3d electrons. For each 4s electron, the other affords a shielding of 0.35 and the next lower quantum number electrons (3s, 3p) and (3d) afford a shielding of  $10 \times 0.85$ , and the remaining 10 inner electrons gives a shielding of 10.

The total shielding  $S$  is thus 18.85.  $Z_{\text{eff}}$  is thus  $22 - 18.85 = 3.15$

(2)



(3)



(4)

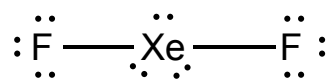
(i)  $\text{He}_2$ ,  $\text{Be}_2$ ,  $\text{Ne}_2$

(ii)  $\text{B}_2$ ,  $\text{O}_2$

(iii)  $\text{N}_2$

(5)

(i)



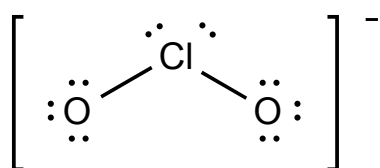
5 electron regions around Xe, basic shape is trigonal bipyramidal

2 bonding electron pairs; shape is linear.

F—Xe—F bond angle is  $180^\circ$

Hybridisation is  $sp^3d_{z^2}$

(ii)



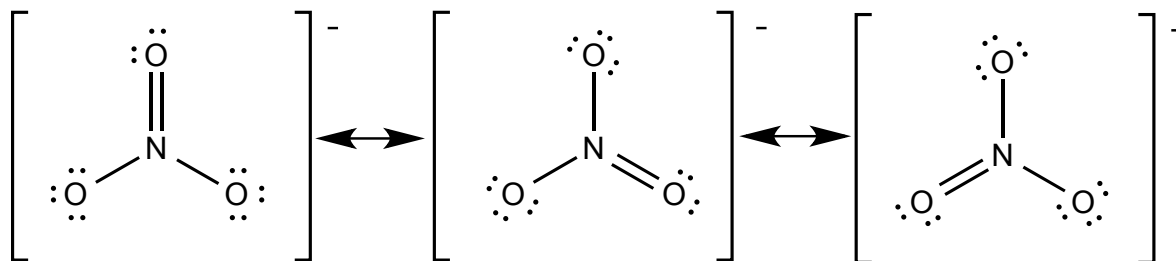
4 electron regions around Cl, basic shape is tetrahedral

2 bonding electron pairs; shape is bent

O—Cl—O bond angle is  $<109.5^\circ$

Hybridisation of Cl is  $sp^3$

(iii)



3 electron regions around N, basic shape is trigonal planar

3 bonding electron pairs; shape is trigonal planar

O—N—O bond angle is  $120^\circ$

Hybridisation of N is  $sp^2$