Atomic Structure and Bonding

Chapter 1

1. *(2005:01)*

An element Y has the electron configuration $1s^2\ 2s^2\ 2p^5$ and forms a compound XY_2 with element X. Which one of the following could be the electron configuration of X?

(a) $1s^2\ 2s^2$ (b) $1s^2\ 2s^2\ 2p^1$ (c) $1s^2\ 2s^2\ 2p^2$ (d) $1s^2\ 2s^2\ 2p^6\ 3s^1$

2. *(2005:02)*

Which one of the following species has a different number of electrons from all the others?

(a) $A\ell^{3+}$ (b) Ar (c) Ca^{2+} (d) $C\ell^-$

3. *(2005:04)*

Which one of the following compounds contains **only** ionic bonds?

(a) CH_3OH (b) $HC\ell$ (c) NaH (d) $NaNO_3$

4. *(2005:05)*

Which one of the properties of ammonia is **not** related to the hydrogen bonding between the molecules?

(a) freezing point

(b) molar mass

(c) solubility in water

(d) vapour pressure

5. *(2005:06)*

Which of the following 1.00 mol L^{-1} aqueous solutions will conduct electricity?

I	hydrogen chloride
II	ethanol
III	ammonia
IV	sodium nitrate

(a) IV only

(b) I and IV only

(c) I, II and IV only

(d) I, III and IV only

6. *(2005:07)*

Which one of the following may have 19 protons, 21 neutrons and 19 electrons?

(a) Ar (b) K (c) K^+ (d) Sc

7. *(2005:08)*

Which best describes the bonding between Mg and Cℓ?

(a) The atoms readily form ions which are attracted to each other.

(b) Polyatomic ions exhibit covalent bonding between the atoms within the ion.

(c) Mg and Cℓ form covalent bonds by sharing of electron pairs.

(d) There is a lattice of positive ions in a sea of delocalised electrons.

8. *(2006:01)*

Which one of the following species has the same electron configuration as Cℓ- ?

(a) Ar (b) S^{2-} (c) K^{+} (d) All of the above

9. *(2006:02)*

Which one of the following is a correct ground state electron configuration of a neutral atom?

(a) $1s^2 2s^2 2p^6 3s^2 3p^3$

(b) $1s^2 2s^2 2p^3 3s^2$

(c) $1s^2 2s^2 2p^6 3s^2 3d^{10} 3p^6$

(d) $1s^2 2s^2 2p^6 3s^3 3d^5$

10. *(2006:03)*

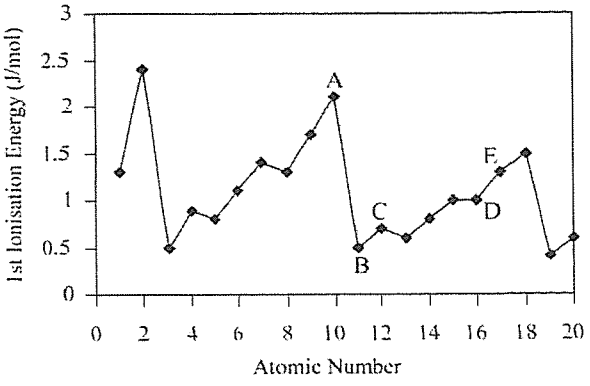
Two elements have the following electron configurations

X: $1s^2 2s^2 2p^6 3s^2 3p^2$
Y: $1s^2 2s^2 2p^4$

Which one of the following represents the most likely formula of a compound formed between X and Y?

(a) XY (b) X_2Y (c) XY_2 (d) X_2Y_3

Questions *(2006:06)* and *(2006:07)* refer to the following graph of first ionisation energies.



11. *(2006:06)*

Which of the above elements is most likely a noble gas?

(a) A (b) B (c) C (d) D (e) E

12. *(2006:07)*

Which pair of elements is most likely to form a covalent bond?

(a) A and B (b) A and D (c) C and D (d) D and E

13. *(2006:09)*

Which one of the following lists the substances in order of increasing strength of intermolecular forces?

(a) $N_2 < C_2H_6 < NH_3 < CH_3CH_2OH < H_2O$

(b) $C_2H_6 < CH_3CH_2OH < N_2 < NH_3 < H_2O$

(c) $N_2 < NH_3 < C_2H_6 < H_2O < CH_3CH_2OH$

(d) $NH_3 < N_2 < CH_3CH_2OH < C_2H_6 < H_2O$

14. *(2006:10)*

Which of the following will conduct electricity?

I molten sulfur
II ammonia solution
III mercury
IV sodium hydroxide solution

(a) IV only

(b) I and IV only

(c) I, II and III only

(d) II, III and IV only

15. *(2007:01)*

Which of the following statements concerning intermolecular forces is/are correct?

I Dispersion forces exist in all molecular solids.
II All molecules that contain polar bonds are polar molecules.
III Hydrogen bonding only occurs for molecules containing O-H bonds.

(a) I only

(b) II only

(c) III only

(d) I and II only

16. *(2007:02)*

Which one of the following will show hydrogen bonding between neighbouring molecules?

(a) Ethane

(b) Ethanol

(c) Ethene

(d) Ethanal

17. *(2007:03)*

Why is the bond between a sulfur atom and an oxygen atom polar?

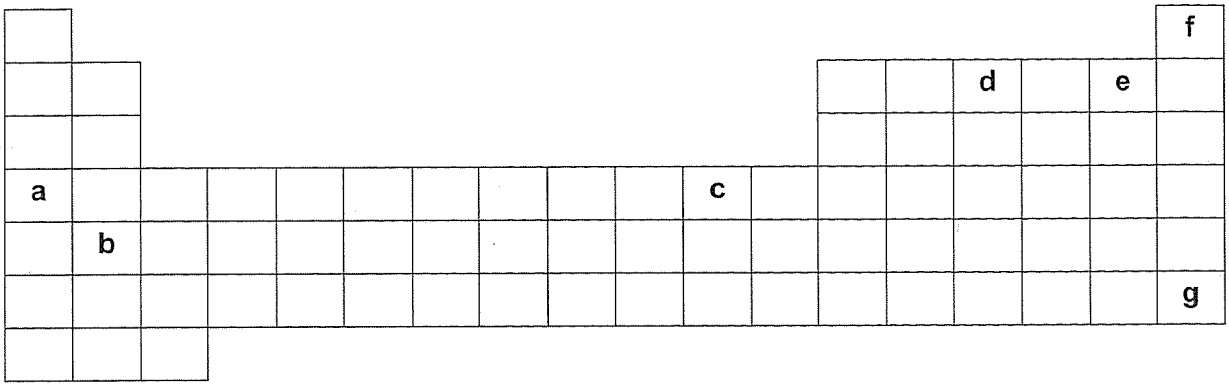
(a) The O atom is more electronegative than the S atom.

(b) The S atom has a higher positive charge in the nucleus than the O atom.

(c) The S atom is larger than the O atom.

(d) The S atom has more electrons than the O atom, so will be negative relative to the O atom.

Question *(2007:05)* refers to the periodic table shown below.



18. *(2007:05)*

Which one of the following correctly identifies the major type of bonding between the pairs of atoms?

	ae	de	cc
(a)	Ionic	Covalent	Metallic
(b)	Ionic	Dispersive	Ionic
(c)	Covalent	Ionic	Covalent
(d)	Covalent	Covalent	Metallic

19. *(2007:06)*

An element "X" has the following successive ionisation energies, in MJ mol^{-1}.

First	Second	Third	Fourth	Fifth
0.7	1.5	7.7	10.5	13.6

Which one of the following statements concerning this element is correct?

(a) The element can only belong to period 2 of the Periodic Table.

(b) The element will form a stable divalent cation X^{2+}.

(c) The element will form an oxide of formula X_2O.

(d) The element will have 5 valence electrons.

20. *(2007:07)*

Which of the following species does **NOT** have the same electronic configuration as the chloride ion, $C\ell^-$?

(a) sulfide ion S^{2-}

(b) potassium ion K^+

(c) oxide ion O^{2-}

(d) argon atom

21. *(2007:28)*

Which one of the following shows the atoms in increasing order of first ionisation energy?

(a)	Rb	K	Na	S	$C\ell$
(b)	Ca	K	Na	P	Br
(c)	I	Br	$C\ell$	Mg	Na
(d)	Br	$C\ell$	F	S	Mg

22. *(2008:P1:02)*

Which of the following is the electron configuration of a group II element?

(a) $1s^2$

(b) $1s^2 2s^2 2p^3$

(c) $1s^2 2s^2 2p^6 3s^2$

(d) $1s^2 2s^2 2p^6 3s^2 3p^2$

23. *(2008:P1:03)*

An element was found to have the following electron configuration:

$$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$$

Which of the following statements about the place of the element in the Periodic Table is correct?

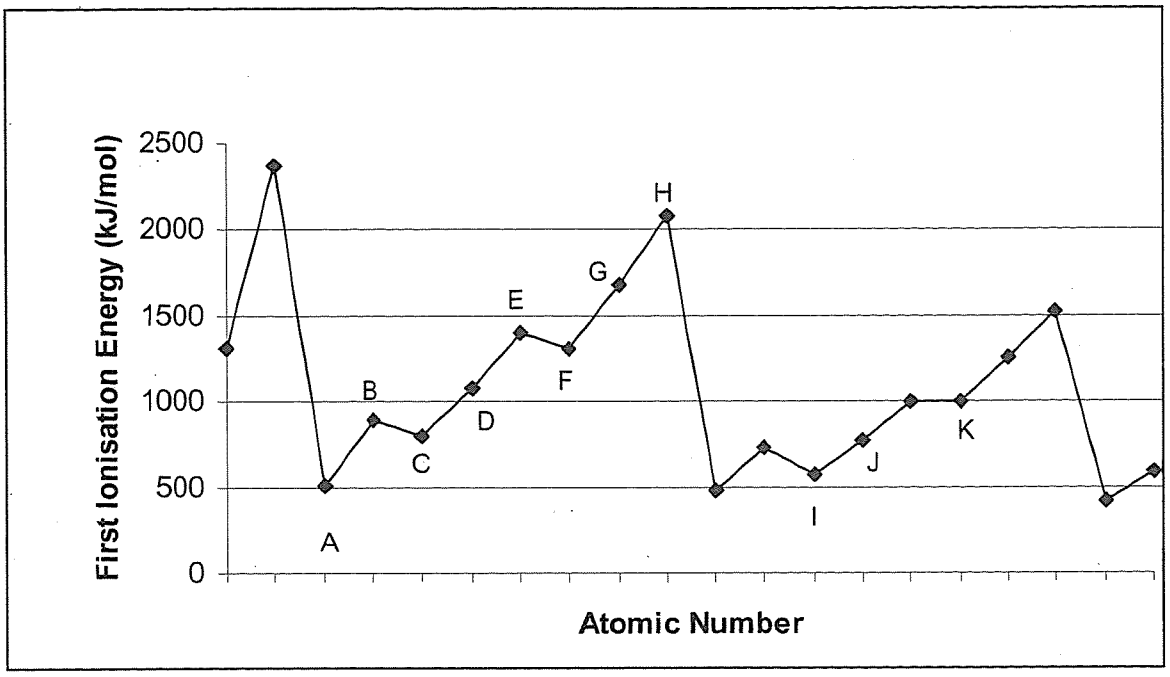
(a) The element belongs in the s-block.

(b) The element belongs in the p-block.

(c) The element belongs in the d-block.

(d) This electron configuration does not represent a ground-state configuration and so the element's position cannot be determined.

The next three questions refer to this graph, which shows the trend of first ionisation energies for the first 20 elements below.



24. *(2008:P1:04)*

Which of the following statements best explains the trend in first ionisation energies for the elements labelled A through to H?

(a) There is an increasing number of electrons in the atoms going from element A to element H.

(b) The atomic radii increase from element A to element H.

(c) There is an increasing number of protons in the nuclei going from element A to element H.

(d) Electrons are being added to the second energy level for elements A to H.

25. *(2008:P1:05)*

Which of the following combinations of atoms is most likely to result in a covalent molecular compound?

(a) B with F

(b) C with J

(c) F with K

(d) B with C

26. *(2008:P1:06)*

Which of the following elements, when combined with oxygen, would give the compound with the highest melting point?

(a) A

(b) H

(c) E

(d) K

27. *(2008:P1:07)*

Consider the following 1.00 mol L^{-1} aqueous solutions.

I Sodium chloride
II Ethanol
III Acetic acid
IV Sulfuric acid

Which of the following options lists these solutions from greatest conductivity to lowest conductivity?

(a) $NaC\ell > H_2SO_4 > CH_3COOH > CH_3CH_2OH$

(b) $CH_3CH_2OH > CH_3COOH > H_2SO_4 > NaC\ell$

(c) $H_2SO_4 > NaC\ell > CH_3COOH > CH_3CH_2OH$

(d) $CH_3COOH > NaC\ell > H_2SO_4 > CH_3CH_2OH$

28. *(2008:P1:08)*

Which of the following statements about chemical bonding is/are correct?

I All bonds involve electrostatic attractions between oppositely-charged particles.
II Polar covalent bonds arise due to the unequal sharing of the bonding electrons between the atoms involved in the bond.
III Molten sodium hydroxide conducts electricity due to the presence of delocalised valence electrons.

(a) I only

(b) II only

(c) II and III only

(d) I and II only

29. *(2008:P1:09)*

Which of the following gives the correct molecular shape around the central atom for each of the species below?

	SO_2	SO_3	SO_3^{2-}
(a)	Linear	Triangular planar	Tetrahedral
(b)	Linear	Pyramidal	Triangular planar
(c)	Bent	Pyramidal	Pyramidal
(d)	Bent	Triangular planar	Pyramidal

30. *(2009:01)*

The electron configuration of a neutral atom X is $1s^2 2s^2 2p^6 3s^2 3p^4$. Which one of the following would be the most likely ion formed by X?

(a) X^{2+}

(b) X^{2-}

(c) X^{4+}

(d) X^{4-}

The next two questions refer to electron configurations for elements I, II, III, and IV shown below.

I $1s^2 2s^1$
II $1s^2 2s^2 2p^1$
III $1s^2 2s^2 2p^6 3s^1$
IV $1s^2 2s^2 2p^6 3s^2 3p^2$

31. *(2009:02)*

Which of these elements belong to the same group of the periodic table?

(a) I and II only

(b) I and III only

(c) I, II and III only

(d) II and III only

32. *(2009:03)*

Which of these elements will have the lowest first ionisation energy?

(a) I

(b) II

(c) III

(d) IV

33. *(2009:04)*

Which one of the following best describes an atomic orbital?

(a) two electrons within an atom

(b) the path an electron makes as it moves around the nucleus of an atom

(c) a subshell within the electronic structure of an atom

(d) a region of space where an electron could be located

34. *(2009:05)*

Which one of the following is the number of valence electrons in the NO_3^- ion?

(a) 8

(b) 16

(c) 24

(d) 32

35. *(2009:06)*

Which one of the following molecules is likely to be polar?

(a) C_2H_2

(b) CO_2

(c) CF_4

(d) NF_3

36. *(2009:07)*

Which of the following properties of metals is explained by the presence of delocalised electrons in their structure?

I	electrical conductivity
II	high thermal conductivity
III	malleability
IV	ductility

(a) I only

(b) I and II only

(c) I, III and IV only

(d) I, II, III and IV

37. *(2010:01)*

Which one of the following best explains why fluorine and chlorine are chemically similar to each other?

(a) They each have seven valence electrons.

(b) They are both in Group 17 of the Periodic Table.

(c) Their nuclei have the same number of protons.

(d) They are both very powerful oxidising agents.

38. *(2010:02)*

In which one of the following sets do all species have the electron configuration of a noble gas?

(a) S^{2-}, O^{2-}, He^{2+}

(b) $H^{+}, Mg^{2+}, C\ell^{-}$

(c) P^{2-}, O^{2-}, Na^{+}

(d) S^{2-}, K^{+}, Mg^{2+}

39. *(2010:04)*

Which one of the following observations can be explained in terms of hydrogen bonding?

(a) The boiling point of H_2S is greater than that of PH_3.

(b) The melting point of CH_4 is less than that of PH_3.

(c) The boiling point of H_2O is greater than that of H_2S.

(d) The melting point of HI is greater than that of NH_3.

40. *(2010:19)*

An element X has the following five successive ionisation energies (in kJ mol^{-1}):

584, 1823, 2751, 11584, 14837

What is the formula of the compound formed when X reacts with nitrogen?

(a) X_3N

(b) XN

(c) XN_2

(d) XN_3

Chapter 1: Atomic Structure & Bonding

1.(2005:01-a) Element 'Y' is in Group 7 of the Periodic Table and has a valency of –1. Element 'X' should have a valency of +2 because it forms XY_2. Therefore 'X' should be in Group 2 and should have a terminal electron configuration of s^2.

2.(2005:02-a) The ion $A\ell^{3+}$ has ten electrons, whereas Ar has 18, Ca^{2+} has 18 and $C\ell^-$ has 18 electrons. Therefore $A\ell^{3+}$ has a different number of electrons to others.

3.(2005:04-c) NaH is the only compound that has ionic bond. All the others have covalent bonding in them.

4.(2005:05-b) Molar mass is unrelated to H–bonding.

5.(2005:06-d) Aqueous ammonia, $HC\ell$ and $NaNO_3$ are ionic to varying extents and hence conduct electricity. Aqueous ammonia is a weak electrolyte whereas the others are strong electrolytes. Ethanol is a non-electrolyte.

6.(2005:07-b) The species with 19 protons, 19 electrons and 21 neutrons should be an isotope of potassium.

7.(2005:08-a) The bonding is ionic as it is between Mg^{2+} (a metallic ion) and $C\ell^-$ (which is a non-metallic ion).

8.(2006:01-d) Ar, S^{2-} and Cl^- – all have the same configuration of $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$.

9.(2006:02-a) The key words to note are 'correct ground state'. Remember the order of filling energy levels in an atom in ground state (e.g. the 'arrow' diagram). The order of filling is $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $4s^2$, $3d^{10}$ etc. Only alternative 'a' follows the correct sequence.

10.(2006:03-c) 'X' should be in group IV of the Periodic Table with valency '±4'. 'Y' should be in group VI of the Periodic Table with valency '–2'. Therefore, the formula should be XY_2.

11.(2006:06-a) Noble gases have the highest first ionisation energy in a period since the outer shells of their atoms are saturated. Hence it is 'A'.

12.(2006:07-d) Both 'D' and 'E' are likely to be non-metals and hence are most likely to form a covalent bond.

13.(2006:09-a) 'a' is the correct alternative as it lists the substances in terms of increasing bond strength. In 'N_2', only dispersion forces exist. In 'C_2H_6', dispersion forces of a greater magnitude exist due to its larger molecular mass. In'NH_3', the predominant intermolecular force is a relatively weaker form of hydrogen 'bonding' which is stronger than dispersion forces. In CH_3CH_2OH, the predominant intermolecular force is a relatively stronger 'hydrogen bonding' plus dispersion forces which are significant. The strongest 'hydrogen bonding' exists between water molecules along with dispersion forces.

14.(2006:10-d) Apart from molten sulfur, which has covalent bonding within the molecules and dispersion forces between them, all the others conduct electricity. Ammonia and NaOH solutions contain ions and mercury has delocalised electrons to conduct electricity.

15.(2007:01-a) Statement 1 is correct because dispersion forces exist in all molecular solids though these forces are not the dominant ones in many solids. Molecules that contain polar bonds can also be non-polar molecules such as CH_4 and CO_2. Hydrogen bonding occurs also in molecules containing H-F and H-N bonds.

16.(2007:02-b) Ethanol (CH_3CH_2OH) has O-H bonds and hence contributes to hydrogen bonding between neighbouring molecules.

17.(2007:03-a) A polar bond exists if the two combining atoms have a difference in electronegativity. An oxygen atom has an electronegativity of 3.4, and sulfur an electronegativity of 2.6. The type of charge does not affect the nature of bonding.

18.(2007:05-a) 'ae' should be ionic (metal with a non-metal). 'de' is covalent (both are non-metals). 'cc' is metallic (metals).

19.(2007:06-b) The biggest increase in ionisation energy occurs when the third electron is removed. This indicates that this third electron is from the next inner shell. Thus, this atom has two valence electrons, and can form X^{2+} ions by losing these two.

20.(2007:07-c) $C\ell^-$ ion has the configuration of $1s^2$, $2s^2$ $2p^6$, $3s^2$ $3p^6$. This is that of Ar.
S^{2-} and K^+ both have also the same configuration of Ar.
But, O^{2-} has the configuration of $1s^2$, $2s^2$ $2p^6$ (same as Ne).

21.(2007:28-a) Since the ionisation energy increases from left to right across a period and bottom to top in a group (in the Periodic Table), the sequence of Rb, K, Na (Gp. 1), S and $C\ell$ (Period 3) fits the trend of increasing ionisation energy.

22.(2008:P1:02-b) Group 2 elements have an outer shell configuration of s^2. Though helium has the same configuration but it is not in Group 2.

23.(2008:P1:03-c) Following the sequence of electron filling in the ground state, and rearranging the configuration according to this sequence,
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^5$
it can be seen that this element is in the 'd' block.

24.(2008:P1:04-c) An increase in the number of electrons should go hand in hand with an increase in the protons in the nuclei which increases the ionisation energy of the elements. The atomic radii also, as a consequence, actually decrease from A to H.

25.(2008:P1:05-c) 'B' (Gr. 2) and 'F' (Gr. 6) will form an ionic compound.
'C' (Gr. 3) and 'J' (Gr. 4) cannot form a covalent molecular compound.
'F' and 'K' (both from Gr. 6) can form a covalent molecular compound.
'B' (Gr. 2) and 'K' (Group 6) will form an ionic compound.

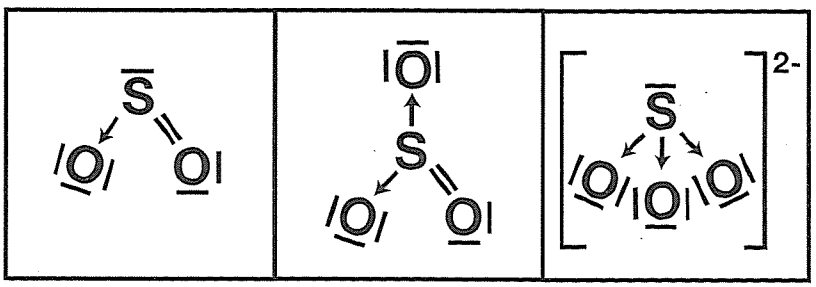
26.(2008:P1:06-a) 'A' (Gr. 1 metal) can combine with oxygen to form an ionic compound with a high melting and boiling point. 'H' (a Gr. 8 element) can combine with oxygen only under special conditions and will form an unstable compound. 'E' (Gr. 5 element) can combine with oxygen to form a gaseous compound with a low melting point. 'K' (Gr. 6 element) can combine with oxygen and form a covalent molecular solid with a low melting point.

27.(2008:P1:07-c) Alternative 'c' lists the solutions from the greatest to the lowest electrical conductivity:
H_2SO_4: Ionises fully. Total ionic concentration is 3 M. Has the greatest conductivity.
$NaC\ell$: Ionises fully. Total ionic concentration is 2 M. Has a lower conductivity.
CH_3COOH: Ionises partially. Total ionic concentration less than 1 M. Has a much lower conductivity.
CH_3CH_2OH: Least ionic of the lot. Has the lowest conductivity.

28.(2008:P1:08-d) Statement III is the only incorrect one of the three. Molten NaOH conducts electricity due to the presence of positive Na^+ and negative OH^- ions. There are no delocalised electrons here, only charged particles.

29.(2008:P1:09-d) The molecular structure and shape for each species is shown below.

SO_2 – bent SO_3 – Δr planar SO_3^{2-} – Δr pyramidal



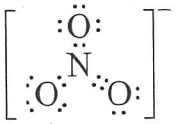
30.(2009:1-b) Based on the (ground state) electron configuration, this element is in Group VI, and hence has a valence of –2. The answer is 'b'.

31.(2009:2-b) Elements I and III are in Groups I with a Valance of +1. Hence, they both belong to Group I in the Periodic Table. The answer is 'b'.

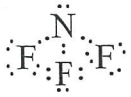
32.(2009:3-c) Ionisation energy increases from left to right across a period and decreases from top to bottom in a group. Elements III and IV are both in Period 3, but the element III is to the left of element IV in the same period. It has the lowest ionisation energy. Answer is 'c'.

33.(2009:4-c) A region or volume of space within which there is a high probability of finding an electron is known as orbital. The term orbital should not be confused with the term 'orbit' used in Bohr's theory. An orbit in Bohr's theory is the path of an electron around a nucleus. The answer is 'd'.

34.(2009:5-c) The electron dot diagram for the NO_3^- ion shown here indicates that it has 24 valence electrons including the one it has received from the other atom. (Note: The question is not about lone pairs of electrons. The question is about the total number of outer shell electrons.) The answer is 'c'.



35.(2009:6-d) NF_3 molecule has a pyramidal shape with one lone pair of electrons on the central nitrogen atom. Based on the VSEPR principle, this distorts the symmetry of the molecule and makes is polar. The answer is 'd'.



36.(2009:7-d) All the four properties listed here are due to the delocalised electrons in the crystal structure of the metals. The answer is 'd'.

37.(2010:1-a) It is the number of valence electrons in the atoms of an element that determines its chemical properties. Fluorine and chlorine are in the same group and hence have the same number of valence electrons and therefore are chemically similar. The other statements are irrelevant to the question. The answer is alternative 'a'.

38.(2010:2-d) Only S^{2-} and K^+ have the electron configuration of Argon, an inert gas. Mg^{2+} has the electron configuration of Helium, another inert gas. Only the combination in alternative, 'd' meets this criterion.

39.(2010:4-c) H_2S, PH_3, CH_4 and HI do not have hydrogen bonding capacity. H_2O and NH_3 have this capacity. However the hydrogen bonding between water molecules is much stronger than the dipole-dipole forces between H_2S molecules. The answer is alternative 'c'.

40.(2010:19-b) The biggest jump in ionisation energy occurs after the third electron. Therefore, the element should have three valence electrons and should be in Group 3 with a valency of +3. Nitrogen is in Group 5 with five valence electrons with a valency of –3. This combination of X^{+3} and N^{-3} gives the correct formula, 'XN'. The answer is 'b'.

Chapter 2: Chemical Reactions...

1.(2005:19-d) Since H^+ ions have been neutralised to water, $H_2O(\ell)$, OH^- ions have been added to H^+ ions. Obviously $Zn(OH)_4^{2-}$ ions have supplied the OH^- ions. This makes $Zn(OH)_4^{2-}$ a base.

2.(2005:23-c) A low equilibrium constant indicates that the concentrations (or the partial pressures) of the products are very low. This indicates that Ag_2S has a low solubility.

3.(2005:24-b) Addition of $HC\ell$ increases the $[C\ell^-]$ and hence the equilibrium shifts to the right. This produces $CoC\ell_4^{2-}$ (aq) ions and a deep blue solution. Catalysts have no effect once equilibrium is established. Adding Ag^+ ions will remove $C\ell^-$ ions from the mixture (forming $AgC\ell$) and making the solution red. Adding water simply dilutes the entire mixture, and does not affect equilibrium.