3.4 Atomic, molecular and ionic properties 2005 Answers

ONE: ATOMIC PROPERTIES

a Trend in radius: It increases
Trend in 1st IE: It decreases

Reason: Going down the group, electrons are added and valence electrons are in energy levels further from the nucleus, resulting in an increased radius. Despite the increased nuclear charge (and more inner levels of electrons providing shielding), there is a decrease in electrostatic attraction. This means the energy required to remove an electron decreases.

A = BOTH trends correct. OR links ONE trend to number of electron shells / levels NOT orbitals
M = Answer links increased radius and decreased IE to electron arrangement and also decreased electrostatic attraction / ease of removal of electron.

b **i**

F	$1s^2\ 2s^2\ 2p^5$
F^-	$1s^2\ 2s^2\ 2p^6$
Na^+	$1s^2\ 2s^2\ 2p^6$

A = Correct answer

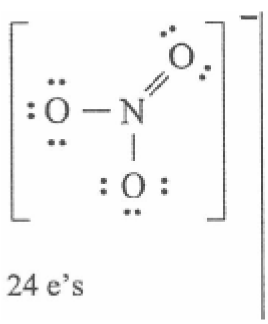
ii F^- ion and F atom both have **the same nuclear charge** but the additional valence electron in the F^- ion results in **an increased electrostatic repulsion between the valence electrons** and hence an increased radius.

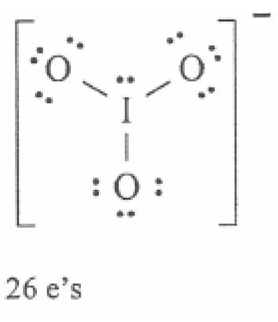
iii F^- and Na^+ have same electron configuration but Na^+ has more protons in the nucleus. This results in an increased electrostatic attraction between the nucleus and the valence electrons, so the radius of Na^+ is smaller than F^-.

A = Correctly describes the relative sizes of F^- and F AND relative sizes of F^- and Na^+.
M = Correctly describes relative sizes of both AND discussion shows clear understanding of how relative sizes are linked to electron configuration and charge on nucleus for ONE of the pairs.
E = As for merit but discussion for BOTH pairs.

QUESTION TWO: STRUCTURE AND PROPERTIES OF COMPOUNDS

a **i**





A = Correct number of valence electrons in both structures AND one structure correct. (Do not need brackets around Lewis diagram or charge. Iodate ion may have expanded octet on central atom.)
M = Both Lewis structures correct. Must include brackets around each Lewis diagram and must show charge.

Ii Nitrate ion is trigonal planar while iodate ion is a trigonal pyramid. This is because the nitrate ion has only 3 regions of electron density around the central N atom and repulsion between these 3 results in a l20° bond angle. The iodate has 4 regions of negative charge around the central I atom and these point towards the corner of a tetrahedron. With only 3 of these regions being bonded pairs of electrons, the shape of the molecule is a trigonal pyramid with bond angles of approximately 109°.

A = Correct identification of BOTH shapes – must be consistent with Lewis diagram drawn.
M = Correct identification of both shapes and explanation in terms of regions of electron density (not bonds) around the central atom.

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b The Cl atom is more electronegative than the P atom so each of the P-Cl bonds is polar. In PCl_5, these P – Cl bonds are symmetrically arranged around the central P atom so that the sum of their dipoles is zero and overall the molecule is non-polar. In comparison the presence of the nonbonding pair of electrons on the P atom of PCl_3 means that there is not a symmetrical arrangement of charge around the P atom and the molecule is polar.

A = Refers to relative electronegativity of the atoms OR Correctly identifies the polarity of BOTH PCl_3 and PCl_5.
M = Relates correct shape of molecule to polarity AND description correctly refers to the relative electronegativities of the atoms.
E = Full discussion in relation to BOTH polar nature of PCl_3 and non-polar nature of PCl_5.

QUESTION THREE: COLOURFUL CHEMICALS

a $Mn^{2+}(aq)$ colourless/pale pink
$MnO_4^{2-}(aq)$ green
$Cr^{3+}(aq)$ green or blue

A = 2 correct

b Transition metal ions have partially-filled *d* orbitals. Electrons are able to jump between one *d* sub-orbital and another. The energy required to make such a transition is equal to that carried by photons (or light) in the visible region of the electromagnetic spectrum. When white light falls on the solution, these frequencies of light are absorbed and the transmitted light is coloured.
A = Incomplete *d* orbitals.
M = A plus transition between *d* suborbitals uses energy in visible region of spectrum
E = M plus explanation of why solution is coloured.

QUESTION FOUR: EXTRACTION OF HYDROGEN

a $\Delta_f H$ = 111 kJ mol^{-1} (or kJ)

A = Correct answer (no units required)

b i $\Delta_f H = \Sigma E_{\text{bonds broken}} - \Sigma E_{\text{bonds made}}$

$-41.2 = E_{\text{CO}} + (2 \times 463) - (2 \times 743) - 436$

$E\text{co} = -41.2 - 926 + 436 + 1486$

$= 954.8$ or 955 kJ mol^{-1}

A = Correct process for calculation OR evidence of correct usage of three ratios in calculation. e.g. 2x463 − 743x2 − 436.
M = Correct mathematical calculation with one mathematical error.
E = Answer calculated correctly with correct unit. (Accept answer with 3 significant figures AND any valid process which uses bond energies to obtain correct answer).

ii Bond breaking requires the input of energy, so it's endothermic.

A = Correct answer.

iii The double bond is stronger than the single bond as it involves the sharing of two electron pairs rather than one as occurs in the single C − O bond.

A = More (less) energy is required to break double (single) bonds.
M = Explanation links higher bond enthalpy to nature of bond and energy required to break bonds (one electron pair : C–O OR two electron pairs : C=O).

QUESTION FIVE: FIREWORKS

a $Ba(s) + N_2(g) + 3O_2(g) \rightarrow Ba(NO_3)_2(s)$

.A = Correct equation including states.

b $\Delta_r H° = \Sigma \Delta_f H_{\text{products}} - \Sigma \Delta_f H_{\text{reactants}}$

$= (5 \times -1676 + 3 \times -554) - 3 \times (-992)$

$= -7066$ kJ mol^{-1} or -7070 kJ mol^{-1}

A = Correct process for calculation OR evidence of correct usage of three ratios in calculation. e.g. (5 x −1676 + 3 x −554) − 3 × (−992).
M = Answer correct with either 3 or 4 significant figures and units.

c i $n(\text{jelly-baby}) = \dfrac{4.56 \text{ g}}{342 \text{ g mol}^{-1}}$

$= 0.0133$ mol

E released = 0.0133 x 2192 kJ

$= 29.2$ kJ

OR $\Delta_r H = -29.2$ kJ

ii $n(SrCl_2)$ vaporised

$$= \frac{29.2\text{ kJ}}{343\text{ kJ mol}^{-1}}$$

= 0.0851 mol

$m(SrCl_2)$ = 0.0851 mol x 159 g mol^{-1}

= 13.5 g (Allow follow-on if answer used from **i** is not 29.2 kJ)

(Accept 0.0132 mol jelly-baby 28.8 kJ

0.0841 mol $SrCl_2$ 13.4 g $SrCl_2$)

A = Moles and energy (for the moles stated) calculated correctly. (Sign can be positive or negative.)
M = Three correct steps with one error.
E = Four correct steps with correct answers, correct sign and units.

QUESTION SIX: BONDING

a Hydrogen bonds involve the attraction between the H bonded to an O, N or F atom in one molecule and the non-bonding electrons on O, N or F in another molecule.

A = Mention of H bonded to highly electronegative element and Intermolecular force.
(Diagram may be included, but must indicate the Hydrogen bond with correct indication of polarity.)

b Propanoic acid has lower melting point than butanoic acid because it has the same intermolecular forces (both have an acid group), but propanoic acid has a smaller mass and fewer electrons than butanoic acid hence its temporary dipoles are weaker.

Ethyl ethanoate has a lower melting point because it cannot form hydrogen bonds between molecules, so the intermolecular forces are weaker than for the two acids.

A = Differences in melting point linked to differences in nature or strength of intermolecular forces. e.g. butanoic acid has a higher melting point as it has stronger intermolecular forces than ethyl ethanoate AND the forces are named.
M = Discussion of intermolecular forces and relationship to melting point, mostly correct.
E = Comprehensive discussion of the different intermolecular forces correctly linked to the variation in melting point for all 3 substances with the forces correctly named.

Judgement Statement

Achievement

NINE opportunities answered at Achievement level or higher.
9 × A

Achievement with Merit

TWELVE opportunities answered with at least SIX at Merit level or higher.
6 × M *plus* 6 × A

Achievement with Excellence

FOURTEEN opportunities answered with at least FOUR at Excellence level and FOUR at Merit level.
4 × E *plus* 4 × M *plus* 6 × A