Q1.

3 **(a)** **(i)** simple/discrete covalent/molecular [1]

(ii) giant/macro covalent/molecular (NOT atomic) [1]

(iii) (giant) ionic [1]

a general statement that strong attraction means high m.pt. and weak means low [1]

4

(b) **(i)** $CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$
or $CO_2 + NaOH \rightarrow NaHCO_3$ [1]
(this mark is negated if candidate states that SiO_2 dissolves/reacts)

$SnO_2 + 2NaOH \rightarrow Na_2SnO_3 + H_2O$
or $SnO_2 + 2NaOH + H_2O \rightarrow Na_2Sn(OH)_4$ etc [1]

(if neither of the above marks can be awarded, allow CO_2 **and** SnO_2 dissolve/react but SiO_2 *does not, for [1])*

(ii) CO_2 **and** SiO_2 - no reaction [1]

$SnO_2 + 4HCl \rightarrow SnCl_4$ (*or* $Sn^{4+} + 4Cl^-$) $+ 2H_2O$ [1]

4

(c) $PbO_2 + 4HCl \rightarrow PbCl_2 + 2H_2O + Cl_2$ [1]

E_{cell} = 1.47 – 1.36
= **0.11** (V) [for 1 M HCl] [1]

or

$Pb^{4+} + 2Cl^- \rightarrow Pb^{2+} + Cl_2$ [1]

E_{cell} = 1.69 – 1.36
= **0.33** (V) [for 1 M HCl] [1]

2

Q2.

2 (a) covalent (*giant* or *macro*) negates, as also does any reference to ionic bonding) [1]
(*simple molecular is not enough – look for covalent*)

tetrahedral [1]

(b) (i) plotting (allow ±1°) [1]
138 – 151°C (stated in numbers, or read from the graph) [1]

(ii) (b. pt. increases due to) larger intermolecular / van der Waals / induced dipole (NOT permanent dipole) / attractions [1]

due to the larger no. **of electrons** *or* more shells **of electrons** (in MX_4) [1]

(c) (i) Si has empty low-lying orbitals *or* empty d-orbitals (C does not) [1]

(ii) $SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$ [1]

[*or* $SiCl_4 + 4H_2O \longrightarrow Si(OH)_4 + 4HCl$ etc.]

(iii) (yes), because Ge also has empty (low lying d-) orbitals [1]

(d) (i) $SiCl_4 + 2Zn \longrightarrow Si + 2ZnCl_2$ [NOT ionic equation] [1]

(ii) mass = 250 x 2 x 65.4/28.1

= **1164** (g) (actually 1163.7 – but allow 1160) [2]

*allow e.c.f from the stoichiometry of the candidate's equation e.g. allow **582**g for [2] marks if the equation shows the stoichiometry to be 1:1. But if 582g is obtained because the candidate forgot to apply the stoichiometry as given in the equation, award only [1] mark.*

correct answer = [2], with – [1] for one error. OR marks as follows:
use of 2:1 ration [1]
correct use of A_r data for Si and Zn [1]

Total = [12]

Q3.

3 (a) (i) $2CO + O_2 \longrightarrow 2CO_2$
$2PbO_2 \longrightarrow 2PbO + O_2$ } *(or x ½)* [1]

(ii) +4 state becomes less stable down the group [1]
or +2 state becomes more stable down the group **[2]**

(b) (i) $Pb^{II} : Pb^{IV} = 2:1$ [1]

(ii) $Pb_3O_4 \longrightarrow 3PbO + ½O_2$ [1]

(iii) $Pb_3O_4 + 4HNO_3 \longrightarrow 2Pb(NO_3)_2 + PbO_2 + 2H_2O$ [1]

(iv) PbO/Pb(II) is more basic than PbO_2/Pb(IV) [1]
as PbO_2 does not react /form a salt with HNO_3 [1]
or PbO **does** react etc. **[5]**

(c) $SnO + 2NaOH \longrightarrow Na_2SnO_2 + H_2O$ *(or $Na_2Sn(OH)_4$ etc.)* [1]
(NOT SnO_2 or PbO) **[1]**

[Total: 8]

Q4.

3 **(a)** tetrahedral diagram (either dashed+wedge, or similar representation) [1]
angles (all) 109° – 110° [1]
(award [0] for part **(a)** if an angle of 90° or 180° is mentioned) **[2]**

(b) volatility decreases *or* boiling points increase
(allow b.pt. CCl_4 > $SiCl_4$ but b.pt. increases thereafter) [1]
due to greater van der Waals'/intermolecular forces *or* due to more electrons [1]
(mention of "ions" negates this mark) **[2]**

(c) (i) Pb^{4+}/Pb^{2+}: $E^{\ominus}$ = +1.69V, Sn^{4+}/Sn^{2+}: $E^{\ominus}$ = +0.15V, [both] [1]
a valid comment about relative redox power *or* stability, e.g.:
(hence) Sn^{2+} easily oxidised *or* Sn^{4+} is more stable than Sn^{2+} *or*
Pb^{4+} is easily reduced *or* Pb^{2+} is more stable than Pb^{4+} *or*
+2 oxidation state more stable down the group [1]

(ii) $Sn^{2+} + I_2 \longrightarrow Sn^{4+} + 2I^-$ [1]
$Pb^{4+} + SO_2 + 2H_2O \longrightarrow 4H^+ + SO_4^{2-} + Pb^{2+}$ [1]
(N.B. no marks in **(ii)** for $E^{\ominus}$ values) **[4]**

(d) (i) for Si: $\Delta H = 244 - 2(359) =$ **–474** (kJ mol^{-1}) [1]
for Sn: $\Delta H = 244 - 2(315) =$ **–386** (kJ mol^{-1}) [1]
(allow [1] out of [2] salvage mark for 474 & 386; 962 & 874; *or* –962 & –874)

(ii) Yes: the +4 state becomes decreasingly stable – the ΔH is less exothermic [1]
(mark is for relating ΔHs to stability: allow ecf from **d(i)** and also from **c(i)**) **[3]**

[Total: 11]

Q5.

3 **(a)** PbO_2 decomposed into PbO (and O_2). (SnO_2 is stable) [1]

(b) **(i)** $PbCl_4$ dissociates into Cl_2 and $PbCl_2$ (white solid)
or $PbCl_4 \longrightarrow PbCl_2 + Cl_2$ or in words
(1) (1)
$Cl_2 + 2KI \longrightarrow 2KCl + I_2$ (1)

$E^o(Cl_2/Cl^-)$ is more positive than $E^o(I_2/I^-)$ (1)

(ii) $SnCl_4$ is more stable than $PbCl_4$ / answers using E^o accepted (1)
(5 max 4) [4]

(c) **(i)** $Cl\overset{+}{C}:\overset{-}{C}l$ *or* $Cl=\overset{..}{C}-Cl$ (1)

bent *or* non-linear *or* angle = 100–140° (1)

(ii) $CCl_2 + H_2O \longrightarrow CO + 2HCl$ (1) [3]

[Total: 8]

Q6.

3 **(a)** SiF_4 is symmetrical *or* tetrahedral *or* bonds are at 109° *or* has no lone pair *or* 4 electron pairs shared equally *or* all Si-F dipoles cancel out, ***or*** SF_4 has a lone pair (on S). (1) [1]

(b)

compound	molecule has an overall dipole	molecule does not have an overall dipole
BCl_3		✓
PCl_3	✓	
CCl_4		✓
SF_6		✓

mark row-by-row, (2) [2]

(c) **(i)** Si **and** B have empty / available / low-lying orbitals *or* C does not have available orbitals (allow "B is electron deficient" but not mention or implication of d-orbital on B) (1)

(ii) $BCl_3 + 3H_2O \rightarrow H_3BO_3 + 3HCl$ *or* $2BCl_3 + 3H_2O \rightarrow B_2O_3 + 6HCl$ (1)

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ etc., e.g. $\rightarrow Si(OH)_4$, H_2SiO_3 (1) [3]

(d) (i) $Si_3Cl_8O_2$ (this has $M_r = 84 + 280 + 32 = 396$) *or* $Si4Cl_4O_9$ *or* $Si_8Cl_4O_2$ (1)

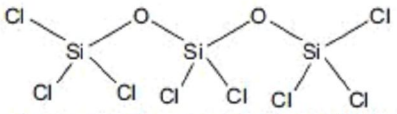
(ii)

mass number	structure
133	Cl_3Si
247	$Cl_3Si\text{-}O\text{-}SiCl_2$
263	$Cl_3Si\text{-}O\text{-}SiCl_2\text{-}O$

(3)

(if correct structures are **not** given for last 2 rows, you can award (1) mark for ***two*** correct molecular formulae:
either $Si_2Cl_5O + Si_2Cl_5O_2$ *or* $Si_3ClO_8 + Si_3ClO_9$ *or* $Si_7ClO + Si_7ClO_2$)

(iii)

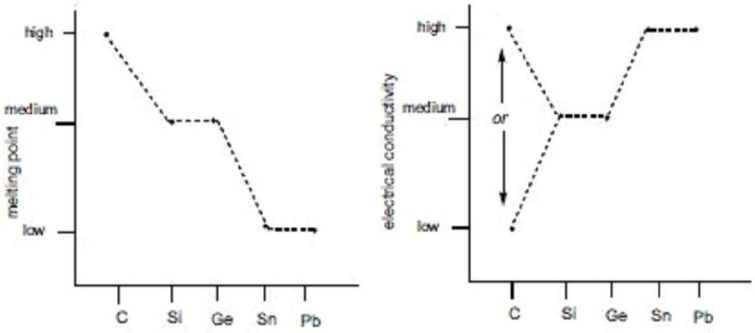


allow ecf on the structure drawn in the third row of the table in **(ii)**
but any credited structure must show correct valencies for Si, Cl and O. (1) [5]

[Total: 11]

Q7.

2 (a) (i)



[2] + [2]

(ii) m. pt. trend: (from) giant/macro molecular/covalent to metallic bonding
(or implied from at least two specific examples, e.g. diamond and tin) [1]
(mention of *simple* covalent anywhere negates this mark)

conductivity trend: increasing delocalisation of electrons (down the group) [1]
or e^- are more free-moving
(or implied from at least two examples, e.g. Si is semiconductor, lead has delocalised e^-)
[6]

(b) (i) heat PbO_2, or T > 200°C *or* Δ on arrow: $PbO_2 \rightarrow PbO + ½O_2$ (N.B. $½O_2$ NOT [O]) [1]

(ii) (burning CO in air produces CO_2): $CO + ½O_2 \rightarrow CO_2$ [1]
blue flame (ignore ref to limewater test) [1]

(iii) e.g. $SnCl_2$(aq) will turn $KMnO_4$ from purple to colourless [1]
$5Sn^{2+} + 2MnO_4^- + 16H^+ \rightarrow 5Sn^{4+} + 2Mn^{2+} + 8H_2O$ [1]

or $SnCl_2$(aq) will turn $K_2Cr_2O_7$ from orange to green [1]
$3Sn^{2+} + Cr_2O_7^{2-} + 14H^+ \rightarrow 3Sn^{4+} + 2Cr^{3+} + 7H_2O$ [1]

or $SnCl_2$(aq) will turn Fe^{3+} from orange/brown/yellow to green/colourless [1]
$Sn^{2+} + 2Fe^{3+} \rightarrow Sn^{4+} + 2Fe^{2+}$ [1]

or $SnCl_2$(aq) will turn Cu^{2+}(aq) from blue to colourless *or* give a pink/brown/copper-coloured ppt. [1]
$Sn^{2+} + Cu^{2+} \rightarrow Sn^{4+} + Cu$ [1]

Other possible oxidants ($E^{\ominus}$ must be > +0.2V) include: $S_2O_8^{2-}$, H_2O_2, Cl_2, Br_2, I_2 and Ag^+. No observations with the first three of these, but this should be stated explicitly, e.g. "no colour change".

[5]

[Total: 11 max 10]

Q8.

4 (a) (i) volatilities decrease down the group [1]

due to greater van der Waals (VDW) forces (*intermolecular is not sufficient*) [1]

due to larger no of electrons [1]

(ii) CCl_4 does not react with water [1]

CCl_4 unreactive due to no **d**-orbitals [1]

$GeCl_4$ **and** $PbCl_4$ hydrolyse/react [1]

$MCl_4 + 2H_2O \longrightarrow MO_2 + 4HCl$ (M = Ge *or* Pb) [1]
[7]

(b) (i) **B** is $PbSO_4$ **and** **C** is $PbCl_2$ [1]

(ii) $SnO_2 + 2H_2SO_4 \longrightarrow Sn(SO_4)_2 + 2H_2O$ [1]

$PbO_2 + H_2SO_4 \longrightarrow PbSO_4 + H_2O + ½\ O_2$ [1]

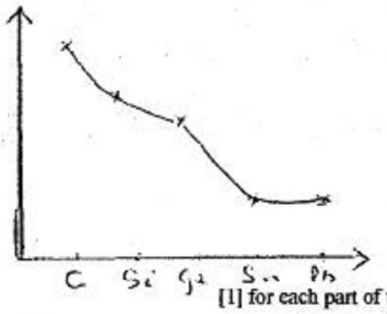
$PbO_2 + 6HCl \longrightarrow H_2PbCl_6 + 2H_2O$ [1]

$H_2PbCl_6 \longrightarrow PbCl_2 + 2HCl + Cl_2$ [1]
[5 max 4]

[Total: 11]

Q9.

3 (a) (i) diag:



[1] for each part of the curve – concave upwards [2]

If [2] cannot be awarded, look at the following alternative marking schemes:
either split the curve into two parts: C to Ge and Ge to Pb. Give [1] for each part if it's correct
or award [1] for a general downward trend in the whole curve

(ii) any two of C, Si, Ge: giant/macro covalent/molecular/atomic [1]
(if only two are stated as giant etc, the other one must NOT contradict, e.g. van der Waals or ionic)
weaker/longer bonds in Si *or* Ge than C [1]
Sn *or* Pb *or* "the last two": metallic bonding [1]
5

(b) (i) no reaction/hydrolysis *or* insoluble *or* immiscible [1]

(ii) gives (HCl) fumes/gas *or* ppt/white solid/gel (of SiO_2) [1]

(iii) $SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$ [1]
[allow balanced equations giving H_2SiO_3 or $Si(OH)_4$, but not partial hydrolysis to $SiOCl_2$ etc]
[penalise other equations, e.g. $CCl_4 + H_2O$, **only** if mark in (i) HAS been awarded]

(iv) Si has (available) d-orbitals (so attack by nucleophiles is easier) [1]
4

Total: 9 max 8

Q10.

3 (a) (i) melting point: graph showing (Si (+ Ge): medium)
and C: higher than Si/Ge [1]
Sn + Pb: lower than Si/Ge [1]

conductivity: graph showing (Si (+ Ge): medium)
and C: lower (or higher!) than Si/Ge [1]
Sn + Pb: higher than Si/Ge [1]
[for your information, the actual figures are shown below]

(ii) Sn, Pb (and C(graphite)) have delocalised electrons/metallic bonds [1]
Si, Ge (and C(diamond)) have localised electrons/covalent bonds [1]
[for [2] marks carbon has to be mentioned once, and the allotrope mentioned must fit in with the conductivity shown]

6

(b) (i) e.g. CO burns to give CO_2 [$2CO + O_2 \longrightarrow 2CO_2$]
or CO reduces Fe_2O_3 [$3CO + Fe_2O_3 \longrightarrow 3CO_2 + 2Fe$]

(ii) e.g. PbO_2 decomposes on heating [$2PbO_2 \longrightarrow 2PbO + O_2$]
two valid examples [1]
two balanced equations [1] + [1]
[two valid and balanced equations warrants [3] marks]

3

(c) use: pottery/china/porcelain etc + property: hardness, high melting point, insulator etc.
(any one use + one relevant property) [1]

1

(d) (i) amphoteric [1]

(ii) e.g. $SnO + 2HCl \longrightarrow SnCl_2 + H_2O$ [1]

e.g. $SnO + 2NaOH \longrightarrow Na_2SnO_2 + H_2O$ [1]

3

total: 13

(Actual figures for (a) (i):)

element	m.pt./°C	conductivity
C(graph)	3652	2×10^{-3}
C(dia)	3550	1×10^{-15}
Si	1410	2×10^{-2}
Ge	937	2×10^{-2}
Sn	232	9×10^{4}
Pb	328	5×10^{4}

Q11.

1 **(a)** boiling points increase down the group (because of...) (1)

...larger van der Waals/intermolecular attractions *or* bigger induced dipoles (1)

due to more electrons per molecule (1) **[3]**

(b) tetrahedral - clear from diagram (1)
angles = 109°-110° (1) **[2]**

(c) **(i)** four bonded pairs + 2 lone pairs around Xe (1)
three lone pairs on at least one F atom (1)

(ii) square planar (can be read into **very clear** diagram in **(i)**) (1)
angles = 90° (1) **[4]**

(d) CCl_4 does not react *or* $SiCl_4$ does (*or* read into an equation) (1)

due to presence of available/low-lying/d-orbitals on Si (1)

$SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$
(*or* $SiCl_4 + 4H_2O \longrightarrow Si(OH)_4 + 4HCl$ etc: also allow partial hydrolysis) (1) **[3]**

(e) $PbCl_4 + \_\_\mathbf{8}\_\_Na + \_\_\mathbf{4}\_\_C_2H_5Cl \longrightarrow Pb(C_2H_5)_4 + \_\_\mathbf{8}\_\_NaCl$ (1)

$Pb(C_2H_5)_4 = 207 + 4x29 = 323$ (1)

323g needs 8 x 23 = 184g Na

$\therefore$ 1000g needs 1000 x 184/323 = **569 or 570**g ecf from equn (1)
(correct ans = (2) marks)

(alternative method:
1.0kg of $Pb(C_2H_5)_4$ is 3.096 moles (1)
*$\therefore$ we need 8 x 3.096 = 24.77 moles of Na, which is **569 or 570**g)* (1) **[3]**

[Total: 15]

Q12.

4 **(a)** CCl_4 is unreactive. (The rest react (with increasing vigour)) [1]
no d-orbitals *or* available/low-lying empty orbitals in carbon *or* unable to expand octet [1]
e.g. $SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$
(*or* $GeCl_4$ etc) *or* $Si(OH)_2Cl_2$
or $Si(OH)_4$
(allow balanced equations for partial hydrolysis) [1]
[3]

(b) **(i)** E(C*l*-C*l*) = 244 kJ mol^{-1}; 2 E(C-C*l*) = 2 x 340 = 680 kJ mol^{-1}
$\therefore \Delta H =$ **–436** (kJ mol^{-1}) [1]

(ii) $\Delta H = 359 - 329 =$ **+30** (kJ mol^{-1}) [1]

(iii) since reaction **(ii)** is endothermic, the +4 oxidation state is less stable
or the +2 oxidation state is more stable (down the group) [1]
[3]
[Total: 6]

Q13.

4 **(a)** **(i)** SnO_2 Can be read into equation (1)
$2NaOH + SnO_2 \rightarrow Na_2SnO_3 + H_2O$ (1)

(ii) PbO Can be read into equation (1)
$PbO + 2HCl \rightarrow PbCl_2 + H_2O$ (1)

[4]

(b) moles of oxygen = 9.3/16 = 0.581 mol
moles of lead = 90.7/207 = 0.438 mol (both 3 s.f.) (1)

so formula is Pb_3O_4 (1) **[2]**

(c) **(i)** $K_{sp} = [Pb^{2+}][Cl^-]^2$ (1) units = $mol^3\ dm^{-9}$ (1)

(ii) if $[Pb^{2+}] = x$, $K_{sp} = 4x^3$, so $x = \sqrt[3]{\{K_{sp}/4\}}$
$[Pb^{2+}] = \sqrt[3]{\{2 \times 10^{-5}/4\}} = \mathbf{1.71 \times 10^{-2}}$ mol dm^{-3} (1)

(iii) $[Pb^{2+}] = 2 \times 10^{-5}/(0.5)^2 = \mathbf{8.0 \times 10^{-5}}$ mol dm^{-3} (1)

(iv) common ion effect, or increased $[Cl^-]$ forces solubility equilibrium over to the left (1)

[Max 4]

[Total: 10]

Q14.

8 **(a)** **(i)** diagram to show tetrahedral arrangement (3D or bond angle marked) (1)

(ii) 4 covalent bonds/bond pairs (with Cl) **only** or **no lone pairs**. (1) **[2]**

(b) **(i)** steamy/white fumes/gas *or* heat evolved (1)
(fumes are) HCl (from hydrolysis of Sn-Cl bonds) *or* exothermic reaction/bond breaking (1)
(can award second mark for HCl (g) in eqn.)

(ii) $SnCl_4 + 2H_2O \rightarrow SnO_2 + 4HCl$ etc. (allow partial hydrolysis and with OHs) (1) **[3]**

[Total: 5]

Q15.

2 (a) (i) Si-Si bonds are weaker (than C-C bonds) [1]

(ii) metallic (Sn) is weaker than (giant) covalent (Ge) [1]

[2]

(b) (i) $SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$
or $SiCl_4 + 4H_20 \longrightarrow Si(OH)_4 + 4HCl$
or $SiCl_4 + 3H_20 \longrightarrow H_2SiO_3 + 4HCl$
(partial hydrolysis is *not sufficient* e.g. to $SiCl_3OH + HCl$) [1]

(ii) $PbCl_4 \longrightarrow PbCl_2 + Cl_2$ [1]

(iii) $SnCl_2 + 2FeCl_3 \longrightarrow SnCl_4 + 2FeCl_2$ [1]

(iv) $SnO_2 + 2NaOH \longrightarrow Na_2SnO_3 + H_2O$
or $SnO_2 + 2NaOH + 2H_2O \longrightarrow Na_2Sn(OH)_6$
or ionic equation $SnO_2 + 2OH^- \longrightarrow SnO_3^{2-} + H_2O$ [1]

[4]

[Total: 6]

Q16.

4 (a) (i) Carbon (graphite) has delocalised electrons whereas silicon's electrons are localised. [1]

(ii) Tin has metallic structure *or* delocalised/mobile electrons whereas germanium has localised electrons *or* giant covalent structure [1]
[2]

(b) (i) $2PbO_2 \longrightarrow 2PbO + O_2$ [1]

(ii) $PbO_2 + 4HCl \longrightarrow PbCl_2 + Cl_2 + 2H_2O$ [1]

(iii) $SnO + 2NaOH \longrightarrow Na_2SnO_2 + H_2O$ [1]

(iv) $GeCl_4 + 2H_2O \longrightarrow GeO_2 + 4HCl$ [1]
[4]

[Total: 6]