1. CO₂ and SiO₂ are oxides of Group IV elements.
   (i) Account for the fact that CO₂ is a gas while SiO₂ is a high melting solid under room temperature and atmospheric pressure.
   (ii) Give the hybridization state of carbon in CO₂ and of silicon in SiO₂.
   
2. Explain why silicon, a metalloid, has a very high melting point.

3. Account for each of the following facts:
   (i) There is a significant difference in the melting point between silicon (m.p. 1410°C) and lead (m.p. 328°C).
   (ii) Silicon forms one oxide with formula SiO₂, while lead forms three oxides with formulae PbO, PbO₂ and Pb₃O₄.

4. Carbon, germanium and lead are elements in Group IV of the Periodic Table.
   (a) Diamond and graphite are allotropes of carbon.
      (i) Draw their three-dimensional structures.
      (ii) With reference to their structures, compare the hardness of diamond and graphite.
   (b) Germanium has the same structure as diamond. Which of these substances has a higher melting point? Explain.
   (c) Suggest why the density of lead (11.3 g cm⁻³) is much higher than that of germanium (5.3 g cm⁻³).

5. Carbon, silicon and lead are group IV elements in the Periodic Table. They form different oxides.
   (i) Suggest a chemical test to distinguish between carbon monoxide and carbon dioxide.
   (ii) At room temperature and pressure, carbon dioxide is a gas whereas silicon dioxide exists as a solid. Explain this difference.
   (iii) A reaction occurs when lead(IV) oxide is heated. State the observation and write a balanced equation for the reaction. Briefly explain why silicon(IV) oxide does not produce a similar reaction.

6. Elements in Group IV of the Periodic Table exhibit two oxidation states, namely +2 and +4, in their compounds. Illustrate, with two cases, the truth of the following statement:
   ‘For the Group IV elements, the stability of the +2 oxidation state relative to the +4 oxidation state increases with relative atomic mass.’

7. For each of the elements carbon, silicon and tin:
   (i) Choose one oxide that is stable at room temperature and state whether it is acidic, basic or amphoteric.
   (ii) Write a balanced equation(s) to illustrate this property in each case.
   (iii) Predict the formula and the acidic, basic or amphoteric nature of an oxide of germanium.

8. For each of the following statements, state whether it is true or false. If you consider the statement to be false, then you have to give an example to support your answer.
   (b) All Group I elements react with water to give hydrogen and an alkaline solution.
   (c) Any halogen can exhibit more than one oxidation state in its compounds.
   (d) All oxides of group IV elements with the formula MO are amphoteric.

9. State all observation when CO₂ is bubbled, until in excess, into EACH of the following solutions: (1) dilute HCl(aq); (2) Ca(OH)₂(aq).

10. Write a balanced equation for the reaction between MnO₂(s) and PbO₂(s) in acidic solution to give MnO₄⁻(aq) and Pb²⁺(aq).

11. Complete and balance the following equations by filling in the blanks and adding stoichiometric coefficients where necessary.

12. (a) State the expected observation when CCl₄ and SiCl₄ are treated separately with water. Write the relevant balanced equation(s).
   (b) Compare the relative stability of PbO and PbO₂ upon heating. Write the relevant balanced equation(s).
   (c) Suggest how to show experimentally that PbO is an amphoteric oxide.
13. (a) Explain why potassium exists in only one oxidation state in its compounds, whereas lead exists in two different oxidation states in its compounds.

(b) (i) State the effect of heat on lead(IV) oxide.
(ii) Lead(IV) oxide can be produced by heating a water soluble lead(II) salt with potassium chlorate(I) solution.
   (1) Name ONE water soluble lead(II) salt.
   (2) Write a balanced equation for the reaction.

14. This question concerns the chemistry of Group IV elements.

(a) (i) The first element of a group in the periodic table exhibits anomalous properties compared with the outer members. Use carbon to illustrate this statement.
(ii) Explain why there is no apparent diagonal relationship in the properties of carbon and phosphorus.

(b) (i) What is the most stable oxidation state for each of the elements carbon, silicon and lead?
(ii) For Si and Sn, name one higher and one lower oxide, and in each case indicate their relative stability.
(iii) Write equations showing the amphoteric nature of lead(II) oxide.
(iv) What two main factors determine the relative stabilities of MCl\textsubscript{4} and MCl\textsubscript{2} (M = Sn, Pb)?
(v) Compare the rate of formation of MCl\textsubscript{4} (M = Sn, Pb) from MCl\textsubscript{2} by chlorination at 25°C.

15. Describe the bonding, structure and the reactions with water of the Group IV tetrachlorides. Explain how the thermal stability of these tetrachlorides varies on descending the group.

16. Account for each of the following:
   (i) An aqueous solution of tin(II) chloride has a cloudy appearance. Upon addition of aqueous acids or alkalis, the solution becomes clear.
   (ii) Both carbon and tin are group IV elements in the Periodic Table, but tetrachloromethane behaves differently from tin(IV) chloride towards water.

17. How would you distinguish a sample of tin(II) chloride from a sample of tin(IV) chloride using a chemical test?

18. X is an element in Period 3 of the Periodic Table. The structures of X and one of its oxides are shown below.

(a) Suggest, with explanation, what element X is.
(b) Give ONE use of X and ONE use of its oxide.

(c) (i) Draw the three-dimensional structure of the chloride of X.
   (ii) The chloride of X is added to water. State the expected observation and write the chemical equation for the reaction involved.

19. (a) With reference to its structure, explain why silicon dioxide can be used as an abrasive.
(b) Dry ice can be used in packaging ice-cream. Suggest TWO advantages of using dry ice over using ice in packaging ice-cream.

20. (a) Silicon and germanium normally have the same crystal structure.
   (i) Indicate the type of crystal structure of silicon and germanium.
   (ii) Explain which of these two elements has a higher melting point.

(b) Explain why silicon(IV) oxide has a higher melting point than silicon(IV) chloride in terms of their structures.

21. Write an essay on the group of elements carbon to lead, covering the trends in their physical properties as well as the trends in properties of their hydrides and oxides.
1. (i) CO₂ exists as simple molecules and the intermolecular attraction is weak van der Waals’ forces 1
SiO₂ has a giant covalent network structure, attraction between Si and O atoms is strong covalent bond 1
(ii) C in CO₂ : sp hybridized; Si in SiO₂ : sp³ hybridized 1+1

2. Silicon has a giant covalent network structure 1
Melting of Si involves breaking a large number of covalent bonds, requiring a large amount of energy 1

3. (i) Si has a giant covalent network structure 1
melting involves breaking a large no. of strong Si-Si covalent bonds between atoms 1
Pb has a closely packed metallic structure 1
melting involves breaking a small proportion of metallic bonds between Pb²⁺ and delocalized electrons 1
(ii) Si forms compounds with O.S. = +4 1
whereas Pb cpds exist in +2 and +4 (Pb₃O₄ = 2 PbO-PbO₂) 1

4. (a) diamond is harder than graphite 1
in graphite, hexagonal layers of C atoms are held by weak van der Waals’ forces 1
⇒ the layers can easily slip over each other 1
in diamond, each C atom is bonded strongly to other C atoms by strong covalent bonds 1
⇒ relative motion of atoms is restricted 1
(b) Diamond. C-C bond is stronger/shorter than Ge-Ge bond 1
(c) relative atomic mass of Pb is much higher than that of Ge 1
atoms in lead is more closely packed 1

5. (i) Treat the two gases with citrated chicken blood: CO turns blood colour to cherry red; CO₂ no observable change 1+1
or, Burn each of the gases: CO burns with a blue flame; CO₂ does not burn 1
or, Pass each gas into NaOH/KOH: CO₂ dissolves (‘: acidic); CO does not 1
or, Pass each gas into limewater: CO₂ gives a milky solution; CO gives no observable change 1
(ii) CO₂: exists as discrete molecules. Intermolecular attraction is weak van der Waals’ force 1½
SiO₂: exists as giant covalent network with strong covalent C-C bonds between C atoms 1½
(iii) (brown) PbO₂ decomposes to give a solid PbO which is brown/orange when hot and yellow when cold 1
2 PbO₂(s) → 2 PbO(s) + O₂(g) 1
descending group IV, the +2 O.S. becomes more stable ⇒ SiO₂ is thermally more stable than SiO 1

6. Any TWO of the following: 2+2
the thermal stability of XO increases as the group is descended:
PbO₂ decomposes upon gentle heating to give PbO and O₂ ; 1
SnO₂ decomposes at higher temperatures; SiO₂ does not decompose 1
or, the oxidizing power of XO₂ increases as the group is descended:
PbO₂ can oxidize conc. HCl to Cl₂ but SnO₂ & SiO₂ cannot 1
or, only Pb and Sn can form XCl₂ ; Si and Ge cannot 1

7. (i) CO₂ and SiO₂ are acidic; SnO is amphoteric 1
(ii) CO₂ + H₂O = 2H⁺ + CO₃²⁻ 1
SiO₂ + 2 NaOH → Na₂SiO₃ + H₂O 1
SnO + 2 OH⁻ + H₂O → [Sn(OH)₃]²⁻ 1
SnO + 2 HCl → SnCl₂ + H₂O 1
(iii) GeO; amphoteric 1

8. (b) True 1
(c) False. F, the most electronegative element, can exhibit only one O.S. of -1 1
(d) False. CO is a neutral oxide 1

9. (1) no observable change 1
(2) turns milky, then becomes clear again 1
CO₂ + Ca(OH)₂ = CaCO₃ + H₂O 1
CaCO₃ + CO₂ + H₂O = Ca(HCO₃)₂ 1

10. 2 MnO₂ + 3 PbO₂ + 4 H⁺ → 2 MnO₄⁻ + 3 Pb²⁺ + 2 H₂O 1

11. 5 C₂O₄²⁻(aq) + 2 MnO₄⁻(aq) + 16 H⁺(aq) → 10 CO₂ + 2 Mn²⁺ + 8 H₂O 1
Sn²⁺(aq) + H₂O₂(aq) + 2 H⁺(aq) → Sn⁴⁺ + 2 H₂O 1
12. (a) CCl₄: no observable change / two layers of liquids
SiCl₄: hydrolyses to give misty white fumes of HCl
SiCl₄ + 4 H₂O → Si(OH)₄ + 4 HCl
or, SiCl₄ + 2 H₂O → SiO₂ + 4 HCl
(b) PbO₂ decomposes on heating to give PbO, while PbO does not
2 PbO₂(s) → 2 PbO(s) + O₂(g)
(c) add excess/conc. NaOH(aq) to PbO ⇒ it dissolves to give a colorless solution
add excess HNO₃(aq) to PbO ⇒ it dissolves to give a colorless solution
(do not accept H₂SO₄ / HCl; no mark for observation if reagent is wrong or not given)

13. (a) K has electronic configuration of [Ar] 4s¹ ⇒ formation of K⁺ leads to a stable octet electronic structure
Pb has outermost electronic configuration of 6s² 6p²
⇒ formation of Pb²⁺ and Pb⁴⁺ gives the relatively stable 6s² and 5d¹⁰ outermost electronic structures respectively
(also accept the explanation of +2 O.S. in terms of inert-pair effect)
(b) (i) PbO₂ decomposes to give PbO and O₂
(ii) (1) lead(II) nitrate(V)
(2) Pb²⁺ + ClO⁻ + H₂O → PbO₂ + Cl⁻ + 2 H⁺

14. (a) C atoms can form compounds by bonding with other C atoms ⇒ catenation occurs
or, C atoms can form multiple bonds to form unsaturated compounds
or, C forms gaseous dioxide whereas others do not
or, CH₄ does not hydrolyse in water whereas others do
(ii) there is a large difference between the electronegativity of C and P
P has vacant, low-lying d-orbitals whereas C does not
(b) (i) C: +4; Si: +4; Pb: +2
(ii) SiO₂ is more stable than SiO
SnO₂ is less stable than SnO
(iii) PbO + 2 H⁺ → Pb²⁺ + H₂O
PbO + 2 OH⁻ + H₂O → [Pb(OH)₄]²⁻
(v) (1) magnitude of bond enthalpy M-Cl ⇒ Pb-Cl bond is weaker than Sn-Cl
(2) inert-pair effect ⇒ increasing stability of the n s² electrons to remain un-removed down the group
(vi) SnCl₂ + Cl₂ → SnCl₄ (slow)
PbCl₂ + Cl₂ → PbCl₄ (very slow)

15. covalent bond is present between group IV elements and Cl atoms
compounds adopt simple molecular structure with molecules being held together by weak van der Waals’ force
molecules are tetrahedral in shape
all group(IV) tetrachlorides except CCl₄ undergo hydrolysis to form HCl
SiCl₄ + 4 H₂O → Si(OH)₄ + 4 HCl
thermal stability of tetrachlorides decreases down the group (larger atomic size will weaken the M-Cl bond
+4 O.S. becomes less stable because of the inert-pair effect)

16. (i) tin(II) chloride hydrolyzes in water to form an insoluble SnO which turns the solution to cloudy
SnCl₂(aq) + H₂O(l) = SnO(s) + 2HCl(aq)
adding H⁺ shifts the eqm to LHS which turns the solution to clear
adding OH⁻ leads to the formation of [Sn(OH)₄]²⁻ complex
SnO + 2 OH⁻ + H₂O → [Sn(OH)₄]²⁻
(ii) hydrolysis involves nucleophilic attack of H₂O molecules on the central atom of SnCl₄
Sn has vacant and low-lying d-orbitals to accept lone-pair electrons from O atom in H₂O
there is no vacant & low-lying d-orbitals in C for H₂O molecules to attack

17. react with acidified KMnO₄
SnCl₂ will decolorize the purple colour of MnO₄⁻
whereas SnCl₄ gives no observable change

18. (a) silicon
co-ordination number = 4 / tetrahedral arrangement ⇒ group IV
(b) Si: semi-conductor; SiO₂: manufacture of glass / quartz
(c) (ii) white fumes of HCl produced
SiCl₄ + 4 H₂O → Si(OH)₄ + 4 HCl
19. (a) \( \text{SiO}_2 \) is hard and strong
strong Si-O covalent bonds restricts the relative motion between atoms

(b) dry ice produces a very low temperature (-78°C)
dry ice sublimes without producing messy liquid form (as in the case of ice)

20. (a) (i) giant covalent structure
(ii) Si would have a higher melting point than Ge
Si-Si bond is stronger than Ge-Ge bond

(b) \( \text{SiO}_2 \) has a giant covalent structure: large amount of energy required to break down numerous Si-O covalent bonds
\( \text{SiCl}_4 \) has simple molecular structure: small amount of energy is sufficient to overcome weak van der Waals’ forces between molecules

21. Introduction

- elements in Group IV: carbon, silicon, germanium, tin, lead
  (Full name, allow only 1 spelling mistake)
- outermost electronic configuration of elements \( ns^2np^2 \)

Trends in physical properties (should include 5 properties with elaboration/4 properties with elaboration + 2 properties stated/3 properties with elaboration + 4 properties stated)

- effective nuclear charge on outermost electron increases down the group
- atomic radius increases down the group
- first ionization energy decreases down the group
- metallic character increases down the group
- hardness decreases down the group [reduced bond strength as size of atom (atomic volume) increases down the group]
- discussion of the trend in electronegativity/electropositivity
- discussion of the trend in boiling point and/or melting point
- discussion of the trend in enthalpies of fusion and/or atomization
- discussion of the trend in density of element
- discussion of the electrical conductivity of element [graphite:good, diamond:insulator; Si: Ge:semi-conducting; Sn:grey semi-conducting, white good; Pb:good.]
- effect of d-block and f-block contraction on the properties of Ge and Pb

(Answers should include at least TWO cases of similarity and TWO cases of dissimilarity of the Group IV elements. Award \( \frac{1}{2} \) marks for each property mentioned and \( \frac{1}{2} \) marks for an explanation/elaboration/appropriate illustration.)

Oxides (should include 2 properties with elaboration/1 property with elaboration + 2 properties stated)

- C can form \( \text{CO}, \text{CO}_2, \text{C}_2\text{O}_3 \) (carbon suboxide); Si forms only \( \text{SiO}_2 \); Ge, Sn, Pb can form both \( \text{MO} \) and \( \text{MO}_2 \) (GeO is very unstable)
- oxides of carbon are molecular (\( \cdot \cdot \) has low m.p. and b.p.;) \( \text{SiO}_2 \) exists as covalent network,
  (4:2 coordination) \( \text{GeO}_2 \) can exist in both as covalent network (4:2 coordination) or ionic
  structure (6:3 coordination); \( \text{SnO}_2 \) and \( \text{PbO}_2 \) are ionic (6:3 coordination)
  (i.e. ionic character of oxide increases)
- stability of tetravalent oxides decreases down the group (\( \text{PbO}_2 \) is a strong oxidizing agent;
  \( \text{SnO}_2 \) a mild oxidizing agent; \( \text{GeO}_2, \text{SiO}_2 \) do not exhibit any oxidizing properties)
  
  heat
  \[ \text{PbO}_2 \text{ \text{\xrightarrow{heat}} \text{ PbO}} + \frac{1}{2} \text{O}_2 \]
- Descending the group, the basic property of the oxides increases
  e.g. \( \text{CO}_2, \text{SiO}_2, \text{GeO}_2 \) are acidic
  \( \text{SnO}_2, \text{PbO}_2 \) are amphoteric
- The ionic and basic properties of the divalent oxides are more significant than those of the tetravalent oxides
  e.g. \( \text{PbO} \) and \( \text{PbO}_2 \)

(\( \frac{1}{2} \) marks for each property mentioned; \( \frac{1}{2} \) marks for an explanation/elaboration/appropriate examples)