SECTION 12 Patterns in the Chemical World

Multiple-Choice Questions

CE08_22

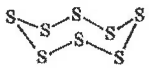
Comparing the elements in the second period of the Periodic Table, from lithium to fluorine which of the following statements is/are correct?

(1) They show a gradual change from having metallic property to having non-metallic property.
(2) They show a gradual increase in the number of electron shells in their atoms.
(3) They show a gradual decrease in melting point.

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

CE10_31

The structure of a sulphur molecule in sulphur powder is shown below:



Which of the following statements is correct?

(Relative atomic mass: S = 32.1)

A. The relative molecular mass of sulphur is 32.1.
B. The oxidation number of sulphur in the molecule is 0.
C. The attraction between sulphur molecules is covalent bond.
D. Double bonds are present between adjacent atoms in sulphur molecules.

DSE12PP_30

In which of the following reactions, is/are the transition metal species NOT acting as a catalyst?

(1) action of acidified $MnO_4^-(aq)$ on $SO_3^{2-}(aq)$ at room temperature
(2) action of Ni(s) on a mixture of $H_2C{=}CH_2(g)$ and $H_2(g)$ at high temperature
(3) action of Pt(s) on a mixture of CO(g) and $O_2(g)$ at high temperature

A. (1) only B. (2) only
C. (1) and (3) only D. (2) and (3) only

DSE12PP_35

1st statement	2nd statement
The melting point of the non-metals in Period 3 of the Periodic Table decreases from sulphur to argon.	The relative atomic mass increases from sulphur to argon in Period 3 of the Periodic Table.

DSE12_31

Which of the following oxides would form an acidic solution when added to water?

A. Carbon dioxide B. Silicon dioxide
C. Aluminium oxide D. Lithium oxide

DSE13_26

Which off the following is NOT a characteristic property of transition metals?

A. They form colored compounds.
B. They exhibit variable oxidation numbers in their compounds.
C. They react with dilute hydrochloric acid to give hydrogen gas.
D. They exhibit catalytic property in elemental sate or as compounds.

DSE13_36

1st statement	2nd statement
Both aluminum oxide and magnesium oxide exhibit similar acid-base properties.	Both aluminum oxide and magnesium oxide are ionic oxides.

DSE14_36

1st statement	2nd statement
Aluminium oxide is soluble in water.	Aluminium oxide is an amphoteric oxide.

DSE15_25

Which of the following statements concerning the Periodic Table is correct?

A. The melting point of the Group I elements increases down the group.
B. The boiling point of the Group VII elements increases down the group.
C. The elements are arranged in the order of increasing relative atomic mass.
D. The electrical conductivity of the third period elements increases from left to right.

DSE15_35

1st statement	2nd statement
The melting point of silicon is higher than that of aluminium.	The number of electrons in a silicon atom is greater than that in an aluminium atom.

DSE16_30

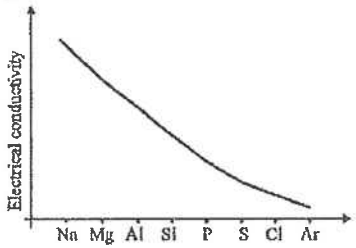
Which of the following trends involving Na, Mg and Al is INCORRECT?

A. Melting point of metal: Al > Mg > Na
B. Electronegativity of metal: Al > Mg > Na
C. Metal reactivity with water: Na > Mg > Al
D. Base strength of metal oxide: $Al_2O_3 > MgO > Na_2O$

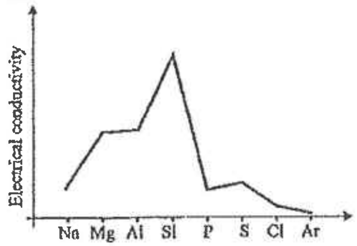
DSE14_30

Which of the following graphs (not drawn to scale) correctly shows the variation in electrical conductivity of the elements in the third period of the Periodic Table at room temperature?

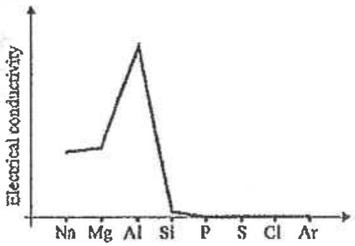
A.



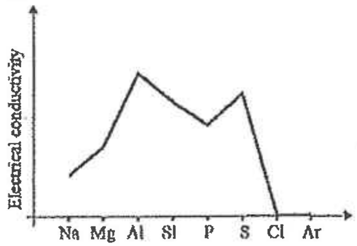
B.



C.



D.



DSE16_36

1st statement	2nd statement
P_4O_{10}(s) can react with NaOH(aq).	P_4O_{10}(s) is an acidic oxide.

DSE17_22

Which of the following statements concerning burning coal under room conditions are correct?

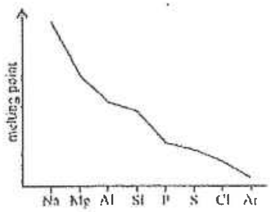
(1) Burning coal forms both acidic and non-acidic substances.
(2) Burning coal forms both gaseous and non-gaseous substances.
(3) Burning coal forms both poisonous and non-poisonous substances.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

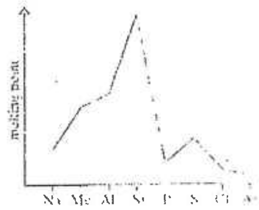
DSE17_25

Which of the following graphs (not drawn to scale) shows the variation in melting points of the elements in the third period of the Periodic Table?

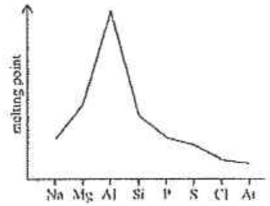
A.



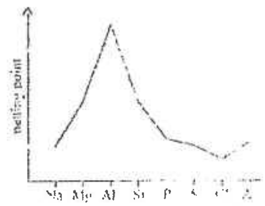
B.



C.



D.



DSE17_30

Which of the following statements concerning silicon dioxide solid is correct?

A. There are single covalent bonds between silicon atoms and oxygen atoms.
B. It is insoluble in sodium hydroxide solution.
C. It has a simple molecular structure.
D. It conducts electricity at room temperature.

DSE18_28

Which of the following statements is correct?

A. The boiling point of argon is lower than that of neon.
B. The boiling point of nitrogen is lower than that of oxygen.
C. The melting point of silicon is lower than that of sodium.
D. The melting point of aluminium is lower than that of magnesium.

DSE18_32

Which of the following processes can illustrate the characteristics of transition metals?

(1) Mixing $AgNO_3$(aq) and NaCl(aq)
(2) Mixing $FeSO_4$(aq) and Br_2(aq)
(3) Mixing $CuSO_4$(s) and H_2O(l)

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

DSE19_33

Which of the following does NOT exhibit a characteristic of iron as a transition metal ?

A. Iron corrodes readily.

B. Iron can be used as a catalyst.

C. Iron can form two chlorides.

D. Iron(II) sulphate solution is green.

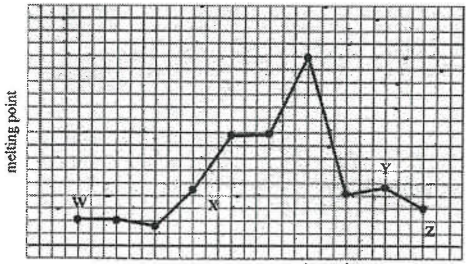
DSE20_28

28. Which of the following statements concerning the oxides of elements in the third period of the Periodic Table is correct ?

A. $SiO_2(s)$ dissolves in water to form a neutral solution.
B. $P_4O_{10}(s)$ dissolves in water to form an acidic solution.
C. $Al_2O_3(s)$ dissolves in water to form an alkaline solution.
D. $Cl_2O(g)$ dissolves in water to form $Cl_2(aq)$ and $O_2(g)$ only.

DSE20_30

30. The sketch below shows the melting points of ten consecutive elements in the second and third periods of the Periodic Table, arranged in the order of increasing atomic numbers. Sodium is one of these ten elements. Which of W, X, Y or Z may represent sodium ?



A. W
B. X
C. Y
D. Z

DSE21_28

28. Which of the following statements correctly describes the property of an amphoteric oxide ?

A. It can react as an acid or as a base.
B. It can react with water to form an acid and an alkali.
C. It can be simultaneously oxidised and reduced in a reaction.
D. It can react with water to form an oxidising agent and a reducing agent.

DSE21_33

33. Which of the following statements concerning the elements in the third period of the Periodic Table going from Na to Cl is / are correct ?

(1) The bond type of the elements changes from metallic bonding to covalent bonding.
(2) The oxide of the elements changes from acidic to basic.
(3) The electrical conductivity of the elements keeps decreasing.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

Structural Questions

AL96 (I)_04a

BaO is a basic oxide, while CO_2 is an acidic oxide.

(i) State all observations when dilute HCl(aq) is added to BaO(s).

(1.5 marks)

(ii) State all observations when CO_2 is bubbled, until in excess, into the following solutions.

(1) dilute HCl(aq)

(2) $Ca(OH)_2(aq)$

(2.5 marks)

AL96 (II)_06c (modified) [Similar to DSE14_11]

State THREE characteristic properties of transition elements, apart from complex ion formation. In each case, illustrate your answer with an example involving copper or vanadium.

(3 marks)

AL98 (I)_03b

Sketch the trends for the properties mentioned in (i) and (ii) below, and account for the trend in each case.

(i) Melting point of the alkali metals, Li, Na and K

(2 marks)

(ii) Boiling point of the Period 3 elements, Na, Mg and Al

(2 marks)

AL99 (I)_03 [Similar to DSE17_14]

When $KMnO_4(aq)$ is added dropwise to acidified $Na_2C_2O_4(aq)$, decolorization is slow at the beginning and then becomes faster.

(a) Write the balanced equation for the reaction involved.

(1 mark)

(b) Explain why the rate of decolorization increases.

(2 marks)

AL99 (I)_03

Describe how to detect the presence of water of crystallization in an inorganic salt.

(1 mark)

AL02 (I)_03

Account for the following observation:

When hydrated copper(II) hydroxide solid is shaken with deionized water, the liquid portion off the mixture is very pale blue. On the addition of an aqueous solution of ammonium chloride, the liquid portion shows no significant change in color. However, if instead, aqueous ammonia is added, an intense blue color is observed.

(3 marks)

AL02(I)_03

CO_2 and SiO_2 are oxides of Group IV elements. Account for the fact that CO_2 is a gas while SiO_2 is a high melting solid under room temperature and atmospheric pressure.

(2 marks)

ASL02(I)_04

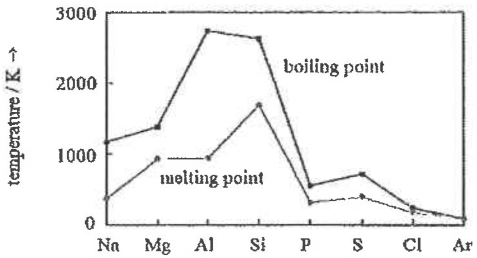
Sketch the variations of their boiling points and account for the variations.

Na, Mg and Al

(3 marks)

AL02(II)_02 [Similar to DSE19_14]

The graph below shows the variations of melting points and boiling points of the Period 3 elements.



Explain why

(a) silicon, a metalloid, has a very high melting point;

(2 marks)

(b) the boiling points of the metals are in the order:

Al > Mg > Na

(3 marks)

(c) there is generally a larger difference between the melting point and the boiling point for metals than for non-metals;

(2 marks)

(d) the melting point of sulphur is the highest among the non-metals.

(2 marks)

AL05(I)_01 [Similar to DSE16_14]

(a) Sketch the variation in electrical conductivity of the Period 3 elements from sodium to argon at room temperature and atmospheric pressure.

(2 marks)

(b) Explain the variation in (a).

(3 marks)

AL05(II)_04

Aluminium hydroxide is an active ingredient of antacid. Two paths for the production of aluminium hydroxide using $Al(s)$, $H_2SO_4(aq)$ and $NaOH(aq)$ as reactants are outlined below:

Paths I: $Al(s) \longrightarrow Al_2(SO_4)_3(aq) \longrightarrow Al(OH)_3(s)$

Paths II: $Al(s) \longrightarrow Na[Al(OH)_4](aq) \longrightarrow Al(OH)_3(s)$

(a) Use chemical equations to describe the reactions in Path I and in Path II.

(4 marks)

(b) Work out the number of moles of H_2SO_4 and $NaOH$ required for producing 2 mol of $Al(OH)_3$ via Path I and via Path II.

(1 mark)

(c) Suggest, with explanation, whether Path I or Path II is recommended for the production of aluminium hydroxide.

(2 marks)

AL05(II)_01

Each of six reagent bottles labeled **A**, **B**, **C**, **D**, **E** and **F** contained one of the following solutions:

$AgNO_3(aq)$, $BaCl_2(aq)$, $H_2SO_4(aq)$, $NH_3(aq)$, $NaOH(aq)$ and $Na_2S_2O_3(aq)$

In an attempt to identify the contents of the bottles, a series of tests were conducted by mixing two of the solutions. The table below lists the observations in these tests.

Solutions being mixed	Observations
A and C	A brown precipitate is formed
A and E	A white precipitate is formed
A and F	A brown precipitate is initially formed, and the precipitate dissolves when F is in excess.
B and C	Only heat is liberated
B and D	A pale yellow precipitate is formed slowly
B and E	A white precipitate is formed

Identify, with explanation, the contents of the six reagent bottles based on the above information.

(6 marks)

AL06(I)_03 (modified)

The table below lists the melting points of three oxides of the Period 3 elements:

Oxide	Na_2O	Al_2O_3	SO_2
Melting point / °C	920	2040	–75

Account for the large difference in the melting points of the three oxides.

(3 marks)

AL06(I)_03

Write chemical equations for the following reactions:

(a) The reaction of S(s) with concentrated HNO_3 to give SO_4^{2-}(aq) and NO_2(g).

(1 mark)

(b) The reaction of Mn^{2+}(aq) with O_2(g) under alkaline conditions to give $Mn(OH)_3$(s).

(1 mark)

(c) The disproportionation of MnO_4^{2-}(aq) in water to give MnO_4^-(aq) and MnO_2(s).

(1 mark)

ASL06(II)_11 [Similar to DSE13_13]

The symbols p, q, r, s, t, u, v and w represent eight consecutive elements in the second and third periods of the Periodic Table The table below lists their boiling points:

Element	p	q	r	s	t	u	v	w
Boiling point / K	4203	5103	77	90	85	27	1163	1383

(a) Deduce from the above information which elements q and r represent respectively.

(4 marks)

(b) Explain why the boiling point of t is higher than that of u.

(2 marks)

(c) Explain why the boiling point of v is lower than that of w.

(2 marks)

AL07(I)_03

A mixture of Fe^{3+}(aq) and Cu^{2+}(aq) is separated by paper chromatography using a mixture of propanone and 6 M HCl(aq) as the mobile phase. Suggest how you would identify chemically the Fe^{3+}(aq) and Cu^{2+}(aq) on the chromatographic paper.

(3 marks)

ASL07(II)_02 [Similar to DSE15_10]

Account for the difference in hydrolytic behavior of the following oxides of the Period 3 elements:

Na_2O, SiO_2 and SO_2

(3 marks)

ASL07(II)_03

Aluminium is commonly extracted from bauxite, which contains mainly hydrated aluminium oxide with compounds of iron and silicon as impurities. The extraction consists of two stages: (1) removal of impurities from bauxite to give aluminium oxide, and (2) electrolysis of molten aluminium oxide.

(a) In Stage (1), bauxite is treated firstly with sodium hydroxide solution and subsequently with carbon dioxide to convert it to aluminium hydroxide. The aluminium hydroxide is then strongly heated to give aluminium oxide.

Outline the chemistry involved in obtaining aluminium oxide in Stage (1) and write chemical equations for the reactions involving the aluminium-containing species.

(5 marks)

(b) In Stage (2), an electrolytic bath consisting of a molten mixture of aluminium oxide and cryolite, Na_3AlF_6, is used.

Suggest why cryolite is used in the electrolysis.

(2 marks)

(c) Knowing that aluminium is highly abundant in the earth's crust, a student remarked, 'Recycling of used aluminium objects is economically unsound.'

Do you agree with the student? Explain.

(1 mark)

AL08(II)_02

The following four substances all exist in the form of white powder:

Baking soda ($NaHCO_3$), cornstarch, finely ground sugar, and plaster of Paris ($CaSO_4 \cdot ½H_2O$)

Suggest how you would do experiments at home to distinguish the four substances from one another. (You are *not* allowed to taste the substances.)

(4 marks)

ASL09(I)_09 [Similar to DSE16_14, DSE19_14]

Write an essay to discuss the variation in physical properties of elements in period 3 of the Periodic Table.

(6 marks)

AL10 (I)_03 [Similar to DSE12PP_13]

State the expected observation in each of the following experiments, and account for the observation with the aid of chemical equation(s).

Adding NH_3(aq) dropwise to $CuSO_4$(aq) until in excess.

(3 marks)

ASL10 (II)_05 [Similar to DSE18_14]

Account for the following:

(a) The boiling point of neon is lower than that of argon. (2 marks)

(b) $Al_2O_3(s)$ is soluble in both aqueous acids and aqueous alkalis. (2 marks)

ASL11(I)_04

Although both K and Br are Period 4 elements, KOH and HOBr exhibit different acid-base behavior. (2 marks)

AL11(I)_07

For each of the following pairs of species, suggest a chemical test to distinguish between them and write the chemical equation(s) of the reaction(s) involved.

(a) $Ba^{2+}(aq)$ and $Pb^{2+}(aq)$ (2 marks)

(b) $Cl^-(aq)$ and $Br^-(aq)$ (2 marks)

AL11 (II)_06

State the expected observation(s) in each of the following experiment, and write the chemical equation(s) of the reaction(s) involved.

$NaOH(aq)$ is added dropwise to $Al(NO_3)_3(aq)$ until in excess. (3 marks)

AL12(I)_01 [Similar to DSE15_10, DSE17_14]

Apart from complex formation, state TWO properties of iron that characterize it as a transition metal. (2 marks)

ASL12(I)_11 [Similar to DSE16_14]

Write an essay on the classification of elements according to bonding and structure, and comment on the electrical conductivity property of each class. (10 marks)

ASL12(II)_05 [Similar to DSE19_14]

Sketch the variation of the melting point of the following elements: Na, Mg, Si, S and Cl. Account for the variation. (5 marks)

ASL13(II)_02 [Similar to DSE12PP_09, DSE18_14]

For the following oxides, comment on their behavior with water. Explain your answer.

$Na_2O(s)$ $Al_2O_3(s)$ $SiO_2(s)$ and $P_4O_{10}(s)$ (4 marks)

AL13(II)_02

Suggest why transition metal compounds are usually colored. (2 marks)

DSE11SP_14

Compare the acid base properties of sodium oxide (Na_2O) and sulphur dioxide (SO_2) with reference to how they interact with water molecules. (4 marks)

DSE12PP_09 [Similar to ASL13(II)_02]

(a) Using the following notations to complete the table below so as to provide information about the structure and acid-base property of the oxides of Period 3 elements.

IC: ionic crystal CN: covalent network SM: simple molecular structure

AC: acidic BA: basic AM: amphoteric

	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2
Structure					
Acid-base property					

(2 marks)

(b) By considering the trend of acid-base property and that of bonding of these oxides, state the relationship between the two trends. (1 mark)

(c) Outline chemical tests to show how these oxides can be classified into acidic, basic and amphoteric. (4 marks + 1 mark)

DSE12PP_13 [Similar to AL10(I)_03]

In an experiment, excess aqueous ammonia is added to an aqueous solution of copper(II) sulphate. The following equilibrium is established and the resulting solution is deep blue in color.

$$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$$

(c) When $H_2SO_4(aq)$ is added slowly to the equilibrium mixture until in excess, a blue precipitate is formed and the precipitate subsequently dissolves in the excess acid forming a blue solution. Account for these observations with the help of relevant chemical equation(s). (5 marks)

DSE12_16

Consider the following oxides:

Na_2O MgO Al_2O_3 SiO_2 P_4O_{10} SO_2 Cl_2O

(a) Which of the oxides listed above can conduct electricity in molten state?

(1 mark)

(b) Explain why SiO_2 has the highest melting point among the covalent oxides listed above.

(2 marks)

(c) Write a chemical equations for the reaction between $Al_2O_3(s)$ and NaOH(aq).

(1 mark)

DSE13_13 [Similar to ASL06(II)_11]

Lithium, beryllium, carbon (graphite) and nitrogen are elements of the second period of the Periodic Table. Arrange them in increasing order of melting point, and explain the order in terms of structure and bonding.

(4 marks + 1 mark)

DSE14_11 [Similar to AL09(II)06c]

Vanadium is a transition metal, its chemical symbol is V. The formulae and the colors of three aqueous vanadium-containing ions are shown below:

Formula	$VO^{2+}(aq)$	$V^{3+}(aq)$	$V^{2+}(aq)$
Color	Blue	Green	violet

(a) Based on the given information, suggest TWO properties of vanadium to characterize it as a transition metal.

(1 mark)

DSE15_10 [Similar to ASL07(II)_02, AL12(I)_01]

(a) For each of the oxides below, draw its electron diagram (showing electrons in the outermost shells only), and stat its behavior in water.

(i) Na_2O

(2 marks)

(ii) Cl_2O

(2 marks)

(b) Using iron as an example, illustrate TWO characteristics of transition metals.

(2 marks)

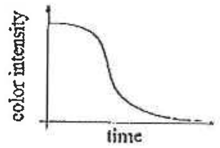
DSE16_14 [Similar to AL05(I)_01, ASL09(I)_09, ASL12(I)_11]

Arrange sodium, aluminium, silicon and sulphur in decreasing order of electrical conductivity at room conditions, and explain your answer in terms of bonding and structure.

(4 marks + 1 mark)

DSE17_14 [Similar to AL99(I)_03, AL12(I)_01]

At 60°C, $MnO_4^-(aq)$ reacts with $C_2O_4^{2-}(aq)$ in an acidic medium to give $Mn^{2+}(aq)$, $CO_2(g)$ and $H_2O(l)$. The graph below shows the variation of the color intensity of the reaction mixture with time.



Based on the information above, write the chemical equation for the reaction and illustrate THREE characteristics of transition metals exhibited by manganese.

(5 marks + 1 mark)

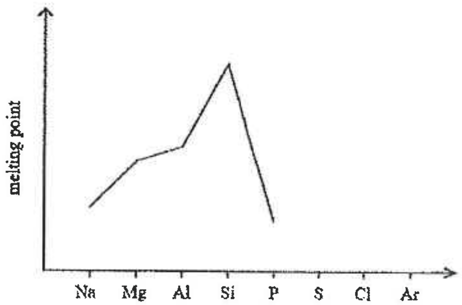
DSE18_14 [Similar to ASL10 (II)_05, ASL13(II)_02]

Using Na_2O, Al_2O_3 and SO_2 as examples, illustrate the acid-base behavior of the oxides of the third period elements with the aid of relevant reactions.

(5 marks + 1 mark)

DSE19_14 [Similar to AL02(II)_02, ASL09(I)_09, ASL12(II)_05]

The following graph shows an incomplete sketch of the variation in melting points of the elements in the third period of the Periodic Table.



(a) Complete the sketch on the graph above.

(1 mark)

(b) Explain why the melting point of Mg is higher than that of Na.

(1 mark)

(c) Explain why the melting point of Si is higher than that of P.

(2 marks)

DSE20_12

12. An experiment was performed to study the following reaction :

$$KO_2CCH(OH)CH(OH)CO_2Na(aq) + 3H_2O_2(aq) \rightarrow HCO_2K(aq) + HCO_2Na(aq) + 2CO_2(g) + 4H_2O(l)$$
(colourless)

When 10 cm^3 of 0.25 M $KO_2CCH(OH)CH(OH)CO_2Na(aq)$ and 3 cm^3 of 6% $H_2O_2(aq)$ were mixed at 60°C, it was found that only a few gas bubbles evolved. Then a small amount of pink $CoCl_2(aq)$ solution was added to the mixture. Gas bubbles formed vigorously and the mixture turned to green due to the formation of a cobalt(III) compound. When no more gas evolved, the green mixture turned back to pink.

There is a view saying that cobalt illustrates THREE characteristics of transition metals according to the observation of this experiment. Suggest reasons to support this view.

DSE21_12

12. (a) Silicon dioxide is an acidic oxide. However, the pH of a mixture of silicon dioxide and distilled water is 7.

(i) Suggest why silicon dioxide is classified as an acidic oxide.

(ii) Explain why the pH of the mixture is 7.

(b) Phosphorus(V) oxide is an acidic oxide. With the aid of a chemical equation, explain why the pH of a mixture of phosphorus(V) oxide and distilled water is smaller than 7.

(c) Refer to the following reaction :

$$Cu_2O(s) + H_2SO_4(aq) \rightarrow Cu(s) + CuSO_4(aq) + H_2O(l)$$

State how this reaction can demonstrate that copper exhibits TWO characteristics of transition metals.

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*13. Describe the acid-base properties of the products formed (if any) when the following oxides are added to water separately. Chemical equations are NOT required.

Na_2O MgO Al_2O_3 Cl_2O

(5 marks)

3. (c) The major ingredient in a certain brand of iron supplement tablets is $FeSO_4$. Several pieces of these iron supplement tablets were dissolved in deionised water to obtain an aqueous solution **S**. The concentration of Fe^{2+}(aq) ions in solution **S** was determined by using the following two methods :

(i) **Method (I) : using volumetric analysis**

The chemical equation for the reaction involved in the titration is as follows :

$$MnO_4^-(aq) + 5Fe^{2+}(aq) + 8H^+(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$$

25.00 cm^3 of solution **S** was acidified and then titrated with 0.0041 M $KMnO_4$(aq). The mean volume of the $KMnO_4$(aq) required to reach the end point was 32.35 cm^3.

(1) The colour of the reaction mixture changed from pale yellow to pale pink at the end point of the titration. Explain the colour change.

(2) Calculate the concentration of Fe^{2+}(aq) ions in solution **S**.

(4 marks)

Marking Scheme

MCQ

CE08_22	A (33%)	CE10_31	A (60%)	DSE12PP_30	A	DSE12PP_35	B
DSE12_31	A (81%)	DSE13_26	C (72%)	DSE13_36	C (62%)	DSE14_36	C (66%)
DSE15_25	B (49%)	DSE15_35	B (69%)	DSE16_30	D (68%)	DSE14_30	C (77%)
DSE16_36	A (65%)	DSE17_22	D (50%)	DSE17_25	B (75%)	DSE17_30	A (37%)
DSE18_28	B (69%)	DSE18_32	D (45%)	DSE19_33	A		
DSE20_28	B	DSE20_30	B				

Structural Questions

AL96 (I)_04a

(i) **BaO dissolves forming colorless solution.** [1]

Heat evolves [½]

(ii) (1) No change / solution remains colorless. [1]

(2) White precipitate / solution turns milky. [½]

Precipitate redissolves / solution turns clear again. [1]

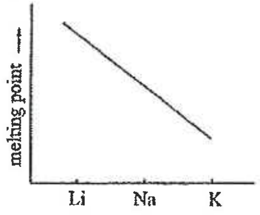
AL96 (II)_06c (modified)

Any THREE of the following: [3]

- Exhibition of **variable oxidation states**, e.g. Cu^+ & Cu^{2+} / V^{2+}, V^{3+}, VO^{2+}, VO_2^+
- Formation of **colored compounds**, e.g. $Cu^{2+}(aq)$ is blue, $VO_2^+(aq)$ is yellow
- Exhibition of **catalytic properties**, e.g. V_2O_5 in contact process, CuO in syngas formation.
- Exhibition of **paramagnetic properties**, e.g. Cu^{2+} / V^{2+} are paramagnetic

AL98 (I)_03b

(i)

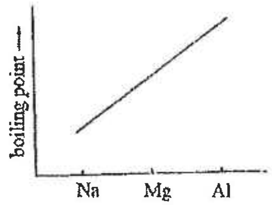


[1]

Atomic size: Li < Na < K [½]

∴ Attraction of nucleus on the delocalized electron / strength of metallic bond decreases in the order: Li > Na > K, hence m.p. decreases. [½]

(ii)



[1]

The atomic radius decreases and the no. of electron involved in metallic bond increases in the order: Na, Mg, Al [½] [½]

∴ Attraction of nucleus on the delocalized electron in the same order.

AL99 (I)_03

(a) $2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$ [1]

(b) **Mn^{2+} acts as a catalyst for the reaction** [1]

At the beginning, when $[Mn^{2+}]$ is low, rate of reaction is slow [½]

When $[Mn^{2+}]$ builds up gradually, the reaction occurs much faster [½]

AL99 (I)_03

Heat the sample [½]

Water vapor will turn anhydrous $CoCl_2$ from blue to pink / anhydrous $CuSO_4$ from white to blue. [½]

(0 mark if heating is not mentioned.)

AL02 (I)_03

Hydrated $Cu(OH)_2$ has a very low solubility in water / concentration of $Cu^{2+}(aq)$ in the liquid portion is very low. ∴ It has a very pale blue color. [1]

The extent of hydrolysis of $NH_4^+(aq)$ is very small. $[NH_3(aq)]$ in $NH_4Cl(aq)$ is very low. Thus, the concentration of $[Cu(NH_3)_4]^{2+}(aq)$ is low.

$NH_3(aq)$ reacts with $Cu(OH)_2(s)$ to give a complex ion $[Cu(NH_3)_4]^{2+}(aq)$ which has a deep blue color. [1]

$Cu(OH)_2(s) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ [1]

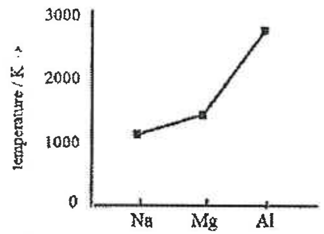
AL02(I)_03

CO_2 exists as simple molecules and the intermolecular attraction is van der Waals' forces. [1]

SiO_2 has a giant covalent network structure.

Attraction between CO_2 molecules is weak, but attraction between Si and O atoms in $SiO_2(s)$ is strong. [1]

ASL02(I)_04



Strength of metallic bond increases with number of electrons taking part in metallic bond per atom and decreases with increasing in size of atom. [1] [1]

For Na, Mg and Al,

No of valence electron : Al > Mg > Na [½]

Size of atom: Al < Mg < Na [½]

Hence, boiling point increases in the order Al > Mg > Na

AL02(II)_02

(a) Silicon has a giant covalent network structure. [1]

Melting of Si involves breaking down of the network structure, a large number of covalent bonds. Hence, a large amount of energy is required. [1]

(b) Strength of metallic bond increases with number of electrons taking part in metallic bond per atom and decreases with increasing in size of atom. [1] [1]

For Na, Mg and Al,

No of valence electron : Al > Mg > Na [½]

Size of atom: Al < Mg < Na [½]

Hence, boiling point increases in the order Al > Mg > Na

(c) For metals, metallic bonding persists in the liquid state and this strong bonding has to be overcome during vaporization. [1]

Non-metals (P, S, Cl, Ar) exis as simple molecules. The molecules are held by week van der Waals' forces. Only a small amount of energy is needed for the elements in liquid state to undergo vaporization. [1]

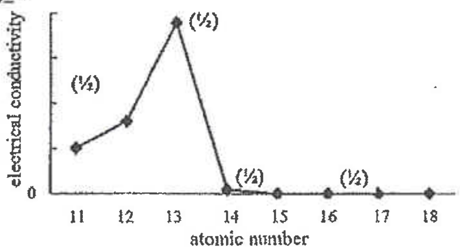
(d) Sulphur exists as S_8, phosphorus as P_4, chlorine as Cl_2 and argon as Ar. [1]

Strength of van der Waals' forces depends on the number of electrons per molecules / relative molecular mass / polarizability of molecules. [1]

S_8 has the larger molecular size. Hence, melting point of sulphur is the highest.

AL05(I)_01

(a) [2]



(b) Explanation:

Na, Mg and Al are good electrical conductors.

For Na, Mg and Al, the number of valence electrons available for delocalization increases with atomic number. ∴ electrical conductivity increases. [1]

Si is a semi-conductor. [1]

P, S, Cl and Ar exist in simple molecular structures. They do not possess delocalized electrons for electrical conductivity and are insulators. [1]

AL05(II)_04

(a) Paths I: $2Al(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2(g)$ [1]

$Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$ [1]

Path II: $2Al(s) + 2OH^-(aq) + 6H_2O(l) \longrightarrow 2Al(OH)_4^-(aq) + 3H_2(g)$ [1]

$Al(OH)_4^-(aq) + H^+(aq) \longrightarrow Al(OH)_3(s) + H_2O(l)$ [1]

(b) Path I: Production of 2 mol of $Al(OH)_3$ requires 3 mol of H_2SO_4 and 6 mol of NaOH [½]

Path II: Production of 2 mol of $Al(OH)_3$ requires 1 mol of H_2SO_4 and 2 mol of NaOH [½]

(c) Path II is better because less reactants are used [1]

and less heat is produced. [1]

AL05(II)_01

The six solutions are:

A: $AgNO_3(aq)$ B: $H_2SO_4(aq)$ C: NaOH(aq)

D: $Na_2S_2O_3(aq)$ E: $BaCl_2(aq)$ F: $NH_3(aq)$

A is $AgNO_3(aq)$ [1]

C is NaOH(aq) while F is $NH_3(aq)$ [1]

C and F are alkalis because $AgNO_3(aq)$ reacts with alkalis to give brown $Ag_2O(s)$ [1]

$$2Ag^+(aq) + 2OH^-(aq) \longrightarrow AgO_2(s) + H_2O(l)$$

$AgO_2(s)$ reacts with excess $NH_3(aq)$ to give $[Ag(NH_3)_2]^+(aq)$

$$Ag_2O(s) + H_2O(l) + 4NH_3(aq) \longrightarrow 2[Ag(NH_3)_2]^+(aq) + 2OH^-(aq)$$

B is $H_2SO_4(aq)$ as it undergoes neutralization with C. (heat is evolved)

E is $BaCl_2(aq)$ as it reacts with $SO_4^{2-}(aq)$ ions (in B) to give a white precipitate. [1]

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$$

E also reacts with $AgNO_3(aq)$ to give a white precipitate AgCl(s) [1]

D is $Na_2S_2O_3(aq)$ because it reacts with acid (B) to give a pale yellow precipitate. [1]

$$S_2O_3^{2-}(aq) + 2H^+(aq) \longrightarrow S(s) + SO_2(g) + H_2O(l)$$

AL06(I)_03 (modified)

$Na_2O(s)$ and $Al_2O_3(s)$ are ionic compounds. $SO_2(g)$ is a covalent compound and it exists as simple molecules. [1]

The attraction between SO_2 molecules is weak van der Waals' forces. ∴ $SO_2(g)$ has a very low melting point. [1]

The charge : radius ratio of Al^{3+} is greater than that of Na^+. $Al_2O_3(s)$ has a stronger ionic bond than that in $Na_2O(s)$. ∴ m.p. of $Al_2O_3(s)$ > m.p. of $Na_2O(s)$ [1]

AL06(I)_03

(a) $S(s) + 6HNO_3(aq) \longrightarrow H_2SO_4(aq) + 2H_2O(l) + 6NO_2(g)$ [1]

(b) $4Mn^{2+}(aq) + O_2(g) + 8OH^-(aq) + 2H_2O(l) \longrightarrow 4Mn(OH)_3(s)$ [1]

(c) $3MnO_4^{2-}(aq) + 2H_2O(l) \longrightarrow 2MnO_4^-(aq) + MnO_2(s) + 4OH^-(aq)$ [1]

ASL06(II)_11

(a) q has the highest b.p. and [1]

a sudden drop in b.p. occurs from q to r. [1]

q: carbon r: nitrogen [1]

(b) Both t and u have simple molecular structure.

t has more electrosn while u has less electrons. [1]

OR t exists in diatomic molecules while u in monoatomic molecules

t has stronger van der Waals' forces than that in u. [1]

(c) Both v and w have metallic bonds.

Number of electrons participated in metallic bond formation in v is less than that in w. [1]

Cationic size of v is larger than that of w. [1]

So metallic bond of v is weaker. [1]

AL07(I)_03

Place the chromatographic paper in an atmosphere of ammonia. [1]

Fe^{3+}(aq) reacts with OH^-(aq) to give brown $Fe(OH)_3$(s). [1]

Cu^{2+}(aq) reacts with NH_3(aq) to give deep blue complex $[Cu(NH_3)_4]^{2+}$(aq). [1]

ASL07(II)_02

Na_2O is an ionic oxide. O^{2-} reacts with H_2O to give an alkaline solution. [1]

$O^{2-} + H_2O \longrightarrow 2OH^-$

SiO_2 has a giant covalent network structure. It has no reaction with water. [1]

In SO_2, S carries a partial positive charge and it is susceptible to (nucleophilitic) attack by H_2O. An acid solution is formed. [1]

$H_2O + SO_2 \longrightarrow H_2SO_3$

ASL07(II)_03

(a) Aluminium oxide is amphoteric. It reacts with NaOH(aq) to give $Al(OH)_4^-$(aq).

$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \longrightarrow 2[Al(OH)_4]^-(aq)$ [1]

Compound of silicon will also react to give soluble silicates. [1]

Oxides of iron are not amphoteric. They can be removed by filtration. [1]

CO_2 is weakly acidic. Addition of CO_2 can convert $Al(OH)_4^-$(aq) to Al_2O_3(s) while the silicates remain unreacted.

$[Al(OH)_4]^-(aq) + H^+(aq) \longrightarrow Al(OH)_3(s) + H_2O(l)$ [1]

The $Al(OH)_3$(s) is removed by filtration and then heated to obtain Al_2O_3(s).

$2Al(OH)_3(s) \longrightarrow Al_2O_3(s) + 3H_2O(g)$ [1]

(b) Al_2O_3(s) has a very high melting point. [1]

Additional of cryolite can lower the temperature of the electrolytic bath. [1]

(c) No.

Open-end question. Possible answers: [1]

The extraction of Al from its ore involves electrolysis and a huge amount of energy is required.

Aluminium objects do not contain much impurities. Cost of removal of impurities is low.

AL08(II)_02

(This question has many possible answers. Marker should exercise their judgment when awarding marks. The principle for awarding marks is 1 point for giving a correct test for each of the compounds.)

For example,

Add water. Only baking soda and sugar are water soluble. [1]

To the water-soluble substance, add vinegar. Only baking soda give effervescence. [1]

Plaster of Paris gives a lot heat when added to water. [1]

For the water-insoluble substances, add tincture of iodine. Only starch will give a purple color. [1]

ASL09(I)_09

Boiling point: increases from Na to Si and then decreases to Ar. [2]

For Na, Mg and Al, the interatomic attraction is metallic bond. Its strength increases with the number of valence electrons. ∴ b.p. Na < Mg < Al

Si has a giant covalent network structure. It has the highest boiling point.

For the simple molecules, the intermolecular attraction is van der Waals' forces. The strength of which depend on relative molecular mass. Phosphorus exists as P_4, sulphur as S_8, chlorine as Cl_2 and argon as Ar. ∴ b.p. Ar < Cl_2 < P_4 < S_8

Melting point: increases from Na to Si then decreases to Ar. [2]

Melting point depends on both the strength of interatomic / intermolecular forces and degree of compactness of particles in solid state.

For Na, Mg and Al, the interatomic attraction is metallic bond. Its strength increases with the number of valence electrons. ∴ b.p. Na < Mg < Al

Si has a giant covalent network structure. It has the highest boiling point.

For the simple molecules, the intermolecular attraction is van der Waals' forces. The strength of which depend on relative molecular mass. Phosphorus exists as P_4, sulphur as S_8, chlorine as Cl_2 and argon as Ar. ∴ m.p. Ar < Cl_2 < P_4 < S_8

Electronegativity: increases from Na to Cl [2]

As the atomic decreases across the period, the effective nuclear charge experienced by the outermost electrons increases. Hence, electronegativity increases across the period.

AL10 (I)_03

A pale blue precipitate is formed. The precipitate dissolves in excess NH_3(aq) to give a deep blue solution. [1] [1]

$Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$ [½]

$Cu(OH)_2(s) + 4NH_3(l) \longrightarrow [Cu(NH_3)_4]^{2+}(aq) + 2OH^-(aq)$ [½]

ASL10 (II)_05

(a) Both neon and argon exist as monoatomic molecules. Their intermolecular attraction is van der Waals' forces. [1]

Ar has a greater number of electrons per molecule / has greater relative molecular (atomic) size / has greater polarizability. ∴ Ar has a higher boiling point. [1]

(b) $Al_2O_3(s)$ is amphoteric. [1]

$Al_2O_3(s) + 6H^+(aq) \longrightarrow 2Al^{3+}(aq) + 3H_2O(l)$ [½]

$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \longrightarrow 2[Al(OH)_4]^-(aq)$ [½]

ASL11(I)_04

K is highly electropositive while O is electronegative. In KOH, K exists as K^+ ions and O as OH^- ions. [½]

KOH is basic because it ionizes in water to give $K^+(aq)$ and $OH^-(aq)$ ions. [½]

HOBr is acidic because it ionizes in water to give $H^+(aq)$ and $OBr^-(aq)$ ions. [½]

$HOBr(aq) \rightleftharpoons H^+(aq) + OBr^-(aq)$

Br is an electronegative element. Ionization of HOBr is in water gives $H^+(aq)$ and $OBr^-(aq)$ instead of $OH^-(aq)$ and $Br^+(aq)$ as the latter system is highly unstable. / $OBr^-(aq)$ is stabilized by electronegative Br. [½]

AL11(I)_07

(a) Add HCl(aq) / KCl(aq). Only $Pb^{2+}(aq)$ gives a white precipitate. [1]

$Pb^{2+}(aq) + 2Cl^-(aq) \longrightarrow PbCl_2(s)$ [1]

OR, Add NaOH(aq). Only $Pb^{2+}(aq)$ gives a white precipitate which is soluble in excess alkali).

$Pb^{2+}(aq) + 2OH^-(aq) \longrightarrow Pb(OH)_2(s)$

$Pb(OH)_2(s) + 2OH^-(aq) \longrightarrow [Pb(OH)_4]^{2-}(aq)$

OR, Add KI(aq). Only $Pb^{2+}(aq)$ gives a yellow precipitate.

$Pb^{2+}(aq) + 2I^-(aq) \longrightarrow PbI_2(s)$

(b) Add acidified $AgNO_3(aq)$. $Cl^-(aq)$ gives a white precipitate, while $Br^-(aq)$ gives a pale yellow precipitate. [1]

$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$ [1]

OR, Add $Cl_2(aq)$. Only $Br^-(aq)$ gives a brown solution.

$Cl_2(aq) + 2Br^-(aq) \longrightarrow Br_2(aq) + 2Cl^-(aq)$

OR, Treat solution wit acidified $KMnO_4(aq)$. $Cl^-(aq)$ causes decolorization slowly; $Br^-(aq)$ gives an orange solution.

$10X^-(aq) + 2MnO_4^-(aq) + 16H^+(aq) \longrightarrow 5X_2(g/l) + 2Mn^{2+}(aq) + 8H_2O(l)$

AL11 (II)_06

White precipitate is formed and the precipitate dissolves in excess alkali to give a colorless solution. [1] [1]

$Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$ [1]

$Al(OH)_3(s) + OH^-(aq) \longrightarrow [Al(OH)_4]^-(aq)$

ASL12(I)_01

Any TWO of the following: [2]

- Fe compound are colored, e.g. $Fe^{3+}(aq)$ is yellow.
- Iron / Fe compounds can have catalytic properties.
- e.g. Fe in the Haber process / $Fe^{2+}(aq)$ catalyze the reaction of $I^-(aq)$ with $S_2O_8^{2-}(aq)$.
- Iron can exhibit variable oxidation states, e.g. Fe^{2+} and Fe^{3+}
- Many Fe compounds are paramagnetic, e.g. Fe^{3+}.
- Many Fe compounds are non-stiochiometric, eg. FeS.

ASL12(I)_11

Chemical Knowledge (10 marks)

Chemical knowledge (including bonding, structure and electrical conducting property of solids) covers four areas A, B, C and D.

Solid substance can be classified into four types, namely metals, molecular solids, giant covalent network solids and ionic solids.

A. Metal (and alloys) e.g. Na, Fe [3]
- Bonding between atoms is metallic bond which is non-directional. Metallic bond is electrostatic attraction between metallic cations and delocalized electrons.
- Metals are good electrical conductor as the delocalized electrons can move in the direction of the applied voltage.

B. Molecular solid [5]

Simple molecular, e.g. P_4, S_8, glucose, etc.
- Within a molecule, atoms are attracted by covalent bond / sharing of electrons. Attraction between molecules is mainly van der Waals' forces, sometimes hydrogen-bond or even ionic bond.
- Most simple molecular solids are insulators as molecules are electrically neutral.

Macromolecular, e.g. polymeric materials, proteins, carbohydrates
- Bonding between atoms in molecule is predominately covalent bond. Attraction between molecules is commonly van der Waals' forces, e.g. polyethene
- Most polymeric materials are insulator, e.g. polyethene

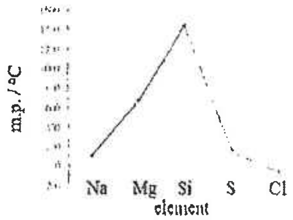
C. Covalent network solid, e.g. Si, C, SiO_2 [3]
- Bonding between atoms is covalent bond in covalent network structure (diamond / graphite / silicon)
- Electrical conducting property:
  Insulators (e.g. diamond / silica) + explanation (bonding electrons are localized)
  Conductors (e.g. graphite / carbon nanotubes)
  Semi-conductors (e.g. Si). The electrical conductivity of semi-conductors increases with temperature and is affected by the addition of doping agent (e.g. In an Sb)

D. Ionic solid, e.g. NaCl, MgO [3]
- Bonding between cations and anions is ionic bond / transfer of electrons from an electropositive atom to an electronegative atom.

- Structure: giant ionic lattice, e.g. NaCl structure, CsCl structure
- With cations and anions occupying fixed positions in the lattice, ionic solids cannot conduct electricity.

ASL12(II)_05

[2]



Both Cl & S exist as simple molecules. Their intermolecular attraction is van der Waals' forces. [½]

They have low melting point. [½]

Both Na & Mg have metallic structure. Their interparticle attraction is metallic bond.

Si has a covalent network structure. The atoms are held by covalent bond. It has the higher melting point among the five elements.

Chlorine exists as Cl_2 molecules and sulphur as S_8. [1]

The strength of van der Waals' force increases with the number of electrons in the molecule.

∴ m.p. of S > m.p. of Cl

Metallic bond strength is affected by (1) no. of valence electrons per atom participating in metallic bonding; (2) atomic radius; (3) degree of compactness. [1]

As compared with Na, (1) Mg has greater number of valence electrons, (2) Mg atoms has a smaller size, and (3) Mg atoms are more closely packed in solid state. ∴ m.p. of Mg > m.p. of Na.

(For metallic bond strength, accept any ONE of the correct explanations.)

ASL13(II)_02

Behavior with water: [2]

- $Na_2O(s)$ dissolves in water to give an alkaline solution.
- $Al_2O_3(s)$ and $SiO_2(s)$ are insoluble.
- $P_4O_{10}(s)$ dissolves in water to give an acidic solution.

Explanation: [2]

Across period 3, the structure of the oxides changes from ionic crystals to covalent network and then to simple molecules.

- $Na_2O(s)$ is an ionic oxide. The O^{2-} ions react with water to give $OH^-(aq)$ ions.
- $Al_2O_3(s)$ is an ionic solid with a very strong ionic bond. The interactions between ions and water are much weaker than the ionic bond in Al_2O_3. It is insoluble in water.
- $SiO_2(s)$ has a giant covalent network structure. Its atoms are bounded by strong covalent bonds. It is insoluble in water.
- $P_4O_{10}(s)$ hydrolyzes in / reacts with water to give an acidic solution.

AL13(II)_02

Transition metal ions usually have unoccupied 3rd (or 4th) electron shell. [1]

Transition of electrons in these electron shell involves absorption of electromagnetic radiation in the visible light region. [1]

Thus transition metal compounds are usually colored.

DSE11SP_14

Sodium oxide dissolves in water to give an alkaline solution ($NaOH(aq)$). [1]

$Na_2O(s) + H_2O(l) \longrightarrow 2Na^+(aq) + 2OH^-(aq)$ [1]

Sulphur dioxide dissolves in water to give an acidic solution ($H_2SO_3(aq)$). [1]

$SO_2(aq) + H_2O(l) \rightleftharpoons SO_3^{2-}(aq) + 2H^+(aq)$ [1]

DSE12PP_09

(a)

	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	[2]
Structure	IC	IC	CN	SM	SM	
Acid-base property	BA	AM	AC	AC	AC	

(b) Ionic oxides are basic, while covalent oxides are acidic. [1]

(c) (In this question, award 1 mark for the reagents used in each of tests for acidic, basic and amphoteric oxides, and 1 mark for a correct observation. One possible method is shown below.)

Add each oxide to HCl(aq) and measure the pH of the mixture. Only MgO(s) and $Al_2O_3(s)$ react with HCl(aq) and the pH increases. These two oxides demonstrate basic properties. [1] [1]

Add each oxide to NaOH(aq) and measure the pH of the mixture. Only $Al_2O_3(s)$, $SiO_2(s)$, $P_4O_{10}(s)$ and $SO_2(g)$ react with NaOH(aq) ($SiO_2(s)$ reacts with hot conc. NaOH(aq)), and the pH decreases. These oxides demonstrate acidic properties. [1]

$Al_2O_3(s)$ reacts both cases. It is amphoteric. [1]

Effective communications (Award 1 mark if candidates can express their ideas clearly.) [1]

DSE12PP_13

(c) $H_2SO_4(aq)$ reacts with the $NH_3(aq)$ present:

$H^+(aq) + NH_3(aq) \longrightarrow NH_4^+(aq)$ [1]

OR, $H_2SO_4(aq) + 2NH_3(aq) \longrightarrow (NH_4)_2SO_4(aq)$

Removal of $NH_3(aq)$ causes the position of the following equilibrium to shift to the left. [1]

$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$

$NH_3(aq)$ is a weak base:

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ [1]

When $[Cu^{2+}(aq)]$ builds up it will react with the $OH^-(aq)$ ions to give the blue precipitate.

$Cu^{2+}(aq) + OH^-(aq) \longrightarrow Cu(OH)_2(s)$ [1]

When excess $H_2SO_4(aq)$ is added, it will react with the $Cu(OH)_2(s)$ formed to give a blue solution.

$Cu(OH)_2(s) + 2H^+ \longrightarrow Cu^{2+}(aq) + 2H_2O(l)$ [1]

(3 marks for chemical equations; 1 mark for explanation of the shift in equilibrium position; 1 mark for the formation of blue precipitate.)

DSE12_16

(a) Na_2O, MgO, Al_2O_3 [1]

(b) SiO_2 has a giant covalent structure, and the Si and O atoms are linked by strong covalent bonds. (Not accept strong covalent structure / giant covalent bonds) [1]

Other covalent oxides are discrete molecules attracted by weak van der Waals' forces / weak intermolecular forces / weak dipolar interactions. (NOT accept VDW forces) [1]

(c) $Al_2O_3 + 2OH^- + 3H_2O \longrightarrow 2\,Al(OH)_4^-$ [1]

OR $Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2NaAl(OH)_4$

DSE13_13

Nitrogen < lithium < beryllium < carbon (graphite) [1]

N_2 has the lowest melting point as it has a simple molecular structure, weak van der Waals' forces / intermolecular forces need to be overcome. [1]

Both Li and Be have metallic structure, metallic bond in Li is weaker than that in Be. ∴ Li < Be in melting points. [1]

C has the highest melting point as it has a giant covalent structure, large amount of energy is needed to break strong covalent bonds between atoms in melting. [1]

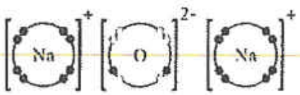
Effective communication [1]

DSE14_11

(a) Vanadium exhibits variable oxidation numbers and its ions in aqueous solution carry colors. [1]

DSE15_10

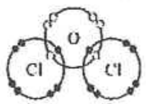
(a) (i)



[1]

It gives an alkaline / a base solution / NaOH / sodium hydroxide [1]

(ii)



[1]

It gives an acidic solution / HOCl / hypochlorous acid [1]

(b) Any TWO of the following (answers should have examples) [2]

- Fe can have variable oxidation numbers – +2, +3, Fe^{2+}, Fe^{3+}
- Fe can acts as a catalyst – e.g. Fe in Haber Process
- Fe forms colored compounds – $Fe^{2+}(aq)$ is green, $Fe^{3+}(aq)$ is yellow
- Fe can form complexes – e.g. the Fe complex in rust indictor, $K_3[Fe(CN)_6]$
- Fe has magnetic properties – e.g. iron metal can be attracted by magnets.

DSE16_14

Electrical conductivity: aluminium > sodium > silicon = sulphur (or: silicon > sulphur) [1]

Any 3 of the following items, each 1 mark [3]

- Both aluminium and sodium have giant metallic structures with delocalized / mobile electrons so that electrical conductivity of them is high / their electrical conductivity is higher than that of silicon and sulphur.
- The number of delocalized / mobile electrons of aluminium is more than that of sodium so that electrical conductivity of aluminium is higher than that of sodium.
- Silicon has giant covalent structure and its electrons are not mobile and cannot conduct electricity / its electrical conductivity is lower than that of aluminium and sodium.

  OR, Silicon has giant covalent structure and its electrons are not mobile. But silicon is a semi-metal and can conduct electricity in some conditions.
- Suphur has simple molecular structure and its electrons are not mobile and cannot conduct electricity / its electrical conductivity is lower than that of aluminium and sodium. [1]
- Effective communication

DSE17_14

$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + 16H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 10CO_2(aq) + 8H_2O(l)$ [1]

Manganese exhibits variable oxidation numbers. The oxidation number of manganese changes from +7 in MnO_4^- to +2 in Mn^{2+} in the reaction. [1]

Manganese forms colored ions in aqueous solution. $MnO_4^-(aq)$ ions exhibit purple / $Mn^{2+}(aq)$ ions exhibit pale pink. [1]

From the graph, it shows that the reaction rate increases when Mn^{2+} ions form / when the reaction proceeds. [1]

Manganese has catalytic properties. Mn^{2+} ions act as a catalyst for the reaction. [1]

Communication mark [1]

Chemical knowledge = 0 to 2, mark = 0,
Chemical knowledge = 3 to 4, mark = 0 or 1,
Incomplete answer / difficult to understand, mark = 0)

DSE18_14

$Na_2O(s)$ dissolves in water to give $NaOH(aq)$ [1]

$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$

OR $Na_2O(s)$ reacts with $HCl(aq)$ to give $NaCl(aq)$ and H_2O

$Na_2O(s) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O$

$Al_2O_3(s)$ reacts with $HCl(aq)$ to give $AlCl_3(aq)$ and H_2O [1]

$Al_2O_3(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2O(l)$

$Al_2O_3(s)$ reacts with $NaOH(aq)$ to give $NaAl(OH)_4(aq)$ and H_2O [1]

$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \longrightarrow 2NaAl(OH)_4(aq)$

$SO_2(g)$ dissolves in water to give $H_2SO_3(aq)$. [1]

$SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$

OR $SO_2(g)$ reacts with $NaOH(aq)$ to give $Na_2SO_3(aq)$ and $H_2O(l)$

$SO_2(g) + 2NaOH(aq) \longrightarrow Na_2SO_3(aq) + H_2O(l)$

Able to mention Na_2O is a basic (alkaline) oxide, Al_2O_3 is an amphoteric oxide, and SO_2 is an acidic oxide. [1]

Communication mark [1]

Chemical knowledge = 0 to 3, communication mark = 0

Chemical knowledge = 4 to 5, communication mark = 0 or 1)

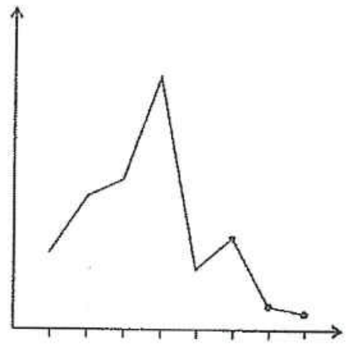
Incomplete answer or difficult to understand, communication mark = 0)

Notes:

- If the candidate gives the answer in the form of a chemical equation, it is not necessary to have the chemical equation correctly balanced.
- The answer should state the reagents and products correctly (including the water formed in the neutralization reaction).
- If the candidate gives the answer in the form of a correct ionic equation, or state the reagents and the products in correct ionic forms, the answer is considered to have correct chemical concept, but failed to state the reagents and products completely. (Maximum) Deduct 1 mark for the whole question. Example: If the candidate only stated 4 correct ionic equations, but in each of the entries the reagents and the products were not stated explicitly, maximum 3 marks will be awarded for the chemical knowledge.
- The following answers are considered to have the products stated correctly.

DSE19_14

(a) [1]



1: The m.p. of S must not be higher than that of Mg;

2: The m.p. of Cl and Ar must not be higher than that of P;

3: The m.p. of Ar must be lower than that of Cl

(b) The metallic bond in Mg is stronger than that in Na as Mg has more delocalised electrons / more outermost shell electrons than Na. [1]

OR The metallic bond in Mg is stronger than that in Na as Mg has two outermost shell delocalised electrons while Na only has one

(c) Melting of Si needs high energy to break the strong covalent bonds between Si atoms in the giant covalent structure. [1]

Melting of P only needs smaller energy to break the weak intermolecular forces. / P has a simple molecular structure, there are weak van der Waals' forces between molecules. [1]

OR Si has a giant covalent structure while P has a simple molecular structure. [1]

High energy is needed to break the strong covalent bonds between Si atoms, while smaller energy is needed to break the weak van der Waals' forces between phosphorus molecules. [1]

DSE20_12

12. • Cobalt/Co^{2+} acts as a catalyst as the rate of formation of gas bubbles (CO_2) increases / rate of reaction increases when Co^{2+} ions are added, 1
- and the pink Co^{2+} ions regenerate / remain (chemically) unchanged / do not consume at the end of reaction. 1
- Coloured ion / formation of coloured compound: $Co^{2+}(aq)$ is pink / the cobalt(III) compound formed is green. 1
- Variable oxidation states: cobalt has cobalt(II) and cobalt(III) compounds / can exist as Co^{2+} and Co^{3+}. 1

(The answers have to be illustrated with the experimental observations provided in the question.)