

## IB Chemistry – SL

### Topic 3 Questions

1. Which pair of elements reacts most readily?

- A. Li + Br<sub>2</sub>
- B. Li + Cl<sub>2</sub>
- C. K + Br<sub>2</sub>
- D. K + Cl<sub>2</sub>

(Total 1 mark)

2. Which of the following properties of the halogens increase from F to I?

- I. Atomic radius
  - II. Melting point
  - III. Electronegativity
- A. I only
  - B. I and II only
  - C. I and III only
  - D. I, II and III

(Total 1 mark)

3. Which pair would react together most vigorously?

- A. Li and Cl<sub>2</sub>
- B. Li and Br<sub>2</sub>
- C. K and Cl<sub>2</sub>
- D. K and Br<sub>2</sub>

(Total 1 mark)

4. For which element are the group number and the period number the same?

- A. Li
- B. Be
- C. B
- D. Mg

(Total 1 mark)

5. Which of the physical properties below decrease with increasing atomic number for both the alkali metals and the halogens?

- I. Atomic radius
- II. Ionization energy
- III. Melting point

- A. I only
- B. II only
- C. III only
- D. I and III only

(Total 1 mark)

6. Rubidium is an element in the same group of the periodic table as lithium and sodium. It is likely to be a metal which has a

- A. high melting point and reacts slowly with water.
- B. high melting point and reacts vigorously with water.
- C. low melting point and reacts vigorously with water.
- D. low melting point and reacts slowly with water.

(Total 1 mark)

7. When the following species are arranged in order of **increasing** radius, what is the correct order?

- A.  $\text{Cl}^-$ , Ar,  $\text{K}^+$
- B.  $\text{K}^+$ , Ar,  $\text{Cl}^-$
- C.  $\text{Cl}^-$ ,  $\text{K}^+$ , Ar
- D. Ar,  $\text{Cl}^-$ ,  $\text{K}^+$

(Total 1 mark)

8. What increases **in equal steps of one** from left to right in the periodic table for the elements lithium to neon?

- A. the number of occupied electron energy levels
- B. the number of neutrons in the most common isotope
- C. the number of electrons in the atom
- D. the atomic mass

(Total 1 mark)

9. Which property decreases down group 7 in the periodic table?

- A. atomic radius
- B. electronegativity
- C. ionic radius
- D. melting point

**(Total 1 mark)**

10. Which properties are typical of most non-metals in period 3 (Na to Ar)?

- I. They form ions by gaining one or more electrons.
  - II. They are poor conductors of heat and electricity.
  - III. They have high melting points.
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

**(Total 1 mark)**

11. A potassium atom has a larger atomic radius than a sodium atom. Which statement about potassium correctly explains this difference?

- A. It has a larger nuclear charge.
- B. It has a lower electronegativity.
- C. It has more energy levels occupied by electrons.
- D. It has a lower ionization energy.

**(Total 1 mark)**

12. Which factors lead to an element having a low value of first ionization energy?

- I. large atomic radius
  - II. high number of occupied energy levels
  - III. high nuclear charge
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

**(Total 1 mark)**

13. Which statement about electronegativity is correct?
- A. Electronegativity decreases across a period.
  - B. Electronegativity increases down a group.
  - C. Metals generally have lower electronegativity values than non-metals.
  - D. Noble gases have the highest electronegativity values.

(Total 1 mark)

14. Which statement is correct for a periodic trend?
- A. Ionization energy increases from Li to Cs.
  - B. Melting point increases from Li to Cs.
  - C. Ionization energy increases from F to I.
  - D. Melting point increases from F to I.

(Total 1 mark)

15. Which compound of an element in period 3 reacts with water to form a solution with a pH greater than 7?
- A.  $\text{SiO}_2$
  - B.  $\text{SiCl}_4$
  - C.  $\text{NaCl}$
  - D.  $\text{Na}_2\text{O}$

(Total 1 mark)

16. Which equation represents the first ionization energy of fluorine?
- A.  $\text{F}(\text{g}) + \text{e}^- \rightarrow \text{F}^-(\text{g})$
  - B.  $\text{F}^-(\text{g}) \rightarrow \text{F}(\text{g}) + \text{e}^-$
  - C.  $\text{F}^+(\text{g}) \rightarrow \text{F}(\text{g}) + \text{e}^-$
  - D.  $\text{F}(\text{g}) \rightarrow \text{F}^+(\text{g}) + \text{e}^-$

(Total 1 mark)

17. Which statement is correct for the halogen group?
- A. Halide ions are all reducing agents, with iodide ions being the weakest.
  - B. Halogens are all oxidizing agents, with chlorine being the strongest.
  - C. Chloride ions can be oxidized to chlorine by bromine.
  - D. Iodide ions can be oxidized to iodine by chlorine.

(Total 1 mark)

18. Which of the following statements are correct?

- I. The melting points decrease from Li → Cs for the alkali metals.
- II. The melting points increase from F → I for the halogens.
- III. The melting points decrease from Na → Ar for the period 3 elements.

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

(Total 1 mark)

19. Which element is a transition metal?

- A. Ca
- B. Cr
- C. Ge
- D. Se

(Total 1 mark)

20. When Na, K, and Mg are arranged in **increasing** order of atomic radius (smallest first), which order is correct?

- A. Na, K, Mg
- B. Na, Mg, K
- C. K, Mg, Na
- D. Mg, Na, K

(Total 1 mark)

21. Which oxides produce an acidic solution when added to water?

- I. SiO<sub>2</sub>
- II. P<sub>4</sub>O<sub>6</sub>
- III. SO<sub>2</sub>

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

(Total 1 mark)

22. Which series is arranged in order of **increasing** radius?

- A.  $\text{Ca}^{2+} < \text{Cl}^- < \text{K}^+$
- B.  $\text{K}^+ < \text{Ca}^{2+} < \text{Cl}^-$
- C.  $\text{Ca}^{2+} < \text{K}^+ < \text{Cl}^-$
- D.  $\text{Cl}^- < \text{K}^+ < \text{Ca}^{2+}$

**(Total 1 mark)**

23. Describe the acid-base character of the oxides of the period 3 elements Na to Ar. For sodium oxide and sulfur trioxide, write balanced equations to illustrate their acid-base character.

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**(Total 4 marks)**

24. Table 6 of the Data Booklet lists melting points of the elements. Explain the trend in the melting points of the alkali metals, halogens and period 3 elements.

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**(Total 8 marks)**

25. (i) Explain how the first ionization energy of K compares with that of Na and Ar.

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(3)

(ii) Explain the difference between the first ionization energies of Na and Mg.

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(4)

(iii) Suggest why much more energy is needed to remove an electron from  $\text{Na}^+$  than from  $\text{Mg}^+$ .

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(1)

(Total 8 marks)

26. Nitrogen is found in period 2 and group 5 of the periodic table.

(i) Distinguish between the terms *period* and *group*.

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(1)

(ii) State the electron arrangement of nitrogen and explain why it is found in period 2 and group 5 of the periodic table.

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(3)

(Total 4 marks)

27. Table 8 of the Data Booklet gives the atomic and ionic radii of elements. State and explain the difference between

(i) the atomic radius of nitrogen and oxygen.

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(2)

(ii) the atomic radius of nitrogen and phosphorus.

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(1)

(iii) the atomic and ionic radius of nitrogen.

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(2)

(Total 5 marks)

28. State and explain the trends in the atomic radius and the ionization energy

(i) for the alkali metals Li to Cs.

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(4)



(ii) for the period 3 elements Na to Cl.

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(4)  
(Total 8 marks)

29. (i) Describe **three** similarities and **one** difference in the reactions of lithium and potassium with water.

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(4)

(ii) Give an equation for **one** of these reactions. Suggest a pH value for the resulting solution, and give a reason for your answer.

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(3)  
(Total 7 marks)

30. (a) Classify each of the following oxides as acidic, basic or amphoteric.

(i) aluminium oxide

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(1)

(ii) sodium oxide

.....

(1)

(iii) sulfur dioxide

.....

(1)

(b) Write an equation for each reaction between water and

(i) sodium oxide

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(1)

(ii) sulfur dioxide.

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(1)

(Total 5 marks)

31. This question is about Period 3 elements and their compounds.

(a) Explain, in terms of their structure and bonding, why the element sulfur is a non-conductor of electricity and aluminium is a good conductor of electricity.

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(4)

(b) Explain, in terms of its structure and bonding, why silicon dioxide, SiO<sub>2</sub>, has a high melting point.

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(2)

(Total 6 marks)

32. Explain why

(i) the first ionization energy of magnesium is lower than that of fluorine.

(2)

(ii) magnesium has a higher melting point than sodium.

(3)

(Total 5 marks)

33. Discuss the acid-base nature of the period 3 oxides. Write an equation to illustrate the reaction of one of these oxides to produce an acid, and another equation of another of these oxides to produce a hydroxide. (Total 5 marks)
34. Information about the halogens appears in the Data Booklet.
- (i) Explain why the ionic radius of chlorine is less than that of sulfur. (2)
- (ii) Explain what is meant by the term *electronegativity* and explain why the electronegativity of chlorine is greater than that of bromine. (3)
- (Total 5 marks)
35. (a) (i) State the meaning of the term *electronegativity* and explain why the noble gases are not assigned electronegativity values. (2)
- (ii) State and explain the trend in electronegativity across period 3 from Na to Cl. (2)
- (iii) Explain why Cl<sub>2</sub> rather than Br<sub>2</sub> would react more vigorously with a solution of I<sup>-</sup>. (2)
- (b) State the acid-base properties of the following period 3 oxides.
- MgO   Al<sub>2</sub>O<sub>3</sub>   P<sub>4</sub>O<sub>6</sub>
- Write equations to demonstrate the acid-base properties of each compound. (7)
- (Total 13 marks)
36. (i) Define the term *ionization energy*. (1)
- (ii) Write an equation for the reaction of lithium with water. (1)
- (iii) State and explain the trend in the ionization energy of alkali metals down the group. (3)
- (iv) Explain why the electronegativity of phosphorus is greater than that of aluminium. (2)
- (v) Table 8 in the Data Booklet contains two values for the ionic radius of silicon. Explain, by reference to atomic structure and electron arrangements, why the two values are very different. (4)
- (Total 11 marks)
37. Explain why sulfur has a lower first ionization energy than oxygen, and also a lower first ionization energy than phosphorus. (Total 4 marks)
38. With reference to the types of bonding present in period 3 elements:
- (i) explain why Mg has a higher melting point than Na. (2)

- (ii) explain why Si has a very high melting point. (2)
- (iii) explain why the other non-metal elements of period 3 have low melting points. (2)

(Total 6 marks)

39. Describe the acid-base character of the oxides of the period 3 elements Na to Ar. For sodium oxide and sulfur trioxide, write balanced equations to illustrate their acid-base character.

(Total 3 marks)

40. Explain the following statements.

(a) The first ionization energy of sodium is

(i) less than that of magnesium.

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(2)

(ii) greater than that of potassium.

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(1)

(b) The electronegativity of chlorine is higher than that of sulfur.

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(2)

(Total 5 marks)

41. (a) (i) Define the term *ionization energy*.

.....

.....

(2)

(ii) Write an equation, including state symbols, for the process occurring when measuring the first ionization energy of aluminium.

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(1)

- (b) The first ionization energies of the elements are shown in Table 7 of the Data Booklet. Explain why the first ionization energy of magnesium is greater than that of sodium.

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(2)

- (c) Lithium reacts with water. Write an equation for the reaction and state **two** observations that could be made during the reaction.

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(3)

(Total 8 marks)

42. (a) State the meaning of the term *electronegativity*.

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(1)

- (b) State and explain the trend in electronegativity across period 3 from Na to Cl.

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(2)

- (c) Explain why  $\text{Cl}_2$  rather than  $\text{Br}_2$  would react more vigorously with a solution of  $\text{I}^-$ .

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(2)

(Total 5 marks)

## IB Chemistry – SL

### Topic 3 Answers

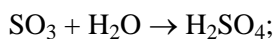
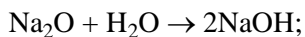
1. D [1]
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3. C [1]
4. B [1]
5. B [1]
6. C [1]
7. B [1]
8. C [1]
9. B [1]
10. A [1]
11. C [1]
12. A [1]
13. C [1]
14. D [1]
15. D [1]
16. D [1]
17. D [1]
18. A [1]
19. B [1]
20. D [1]
21. C [1]

[1]

22. C

[1]

23. oxides of: Na, Mg: basic;  
Al: amphoteric;  
Si to Cl: acidic;  
Ar: no oxide;  
*All four correct [2], two or three correct [1].*



4

*Must be balanced for marks.*

*Award marks for alternative correct equations such as  $\text{SO}_3$  with  $\text{NaOH}$ .*

[4]

24. *alkali metals:*  
metallic bonding/a bed of cations in a sea of electrons;  
as radius increases down the group, valence electrons are further away from nucleus (and strength of metallic bonding decreases);

*halogens:*

non-polar/van der Waals' forces between molecules;

as size increases van der Waals' forces increase (and melting point increases);

*period 3 elements:*

increase in melting points of metals (Na, Mg, Al) due to increase in number of valence electrons **and** decrease in size/the way atoms are packed as solids;

*Award mark just for "increased number of delocalized or valence electrons".*

*silicon:*

network covalent solid (with very high melting point);

*Award mark also for "many or strong covalent bonds".*

*P → Ar:*

simple molecular (atomic in case of Ar) substances with weak van der Waals' forces (and lower melting points);

trend in  $\text{P}_4$ ,  $\text{S}_8$ ,  $\text{Cl}_2$ , Ar due to size/mass of particles;

8

*Award mark for "decreasing mass or size".*

*Molecular formulae not necessary.*

[8]

25. (i) and (ii) marked together.

*K less than Na because*

electron removed (from K) is from higher energy level/further from nucleus/in  $n = 4$  compared to  $n = 3$ ;

this is more important than the extra 8 protons in K/OWTTE;

increase repulsion by extra shell of electrons/greater shielding effect;

so less strongly attracted by nucleus;

*K less than Ar because*

electron removed (from K) is from higher energy level/further from nucleus/in  $n = 4$  compare to  $n = 3$ ;

and has only one more proton;

increase repulsion by extra shell of electrons/greater shielding effect;  
so less strongly attracted by nucleus;

*Mg greater than Na because*

(Mg has) greater nuclear charge/one more proton/12 protons compare to 11;  
electron removed is in same (main) higher energy level/shell;  
smaller (atomic) radius;  
so more strongly attracted by nucleus;

7

*Accept opposite worded arguments, i.e. why Na is greater than K.*

*Award [7] for any seven correct but accept less/more strongly attracted to nucleus once only.*

(iii) second electron in Na removed from  $n = 2$ , whereas second electron in Mg removed from  $n = 3$

1

[8]

26. (i) period is a horizontal row in the periodic table and a group is a vertical column/OWTTE;

1

(ii) 2,5;  
electrons in two energy levels/shells;  
five outer/valence electrons;

3

[4]

27. (i) atomic radius of  $N > O$  because O has greater nuclear charge; greater attraction for the outer electrons/OWTTE;

2

(ii) atomic radius of  $P > N$  because P has outer electrons in an energy level further from the nucleus/OWTTE;

1

(iii)  $N^{3-} > N$ /ionic radius  $>$  atomic radius because  $N^{3-}$  has more electrons than protons; so the electrons are held less tightly/OWTTE;

2

*Award [1] for greater repulsion in  $N^{3-}$  due to more electrons (no reference to protons).*

[5]

28. (i) *Li to Cs*  
atomic radius increases;  
because more full energy levels are used or occupied/outer electrons further from nucleus/outer electrons in a higher shell;  
ionization energy decreases;  
because the electron removed is further from the nucleus/increased repulsion by inner-shell electrons;

4

*Accept increased shielding effect.*

(ii) *Na to Cl*  
atomic radius decreases;  
because nuclear charge increases **and** electrons are added to same main (outer) energy level;  
ionization energy increases;  
because nuclear charge increases **and** the electron removed is closer to the nucleus/is in the same energy level;

4

*Accept "core charge" for "nuclear charge".*

*In (i) and (ii) explanation mark dependent on correct trend.*

[8]

29. (i) *similarities [3 max]*

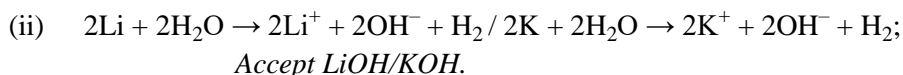


the metal floats/moves on the surface;  
 fizzing/effervescence/bubbles; (*accept sound is produced*)  
 solution gets hot;  
 solution becomes alkaline/basic;  
 they react to form the metal hydroxide;  
 hydrogen is evolved;

*differences [1 max]*

flame/hydrogen burns with potassium (and not with lithium)  
 /reaction faster/more vigorous with potassium/slower or  
 less vigorous with lithium;  
 max

4



pH  $\geq$  11;

LiOH/KOH is a strong base/strong alkali/high concentration of OH<sup>-</sup>;

3

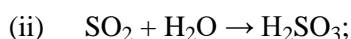
[7]

30. (a) (i) *aluminium oxide*  
 amphoteric;

(ii) *sodium oxide*  
 basic;

(iii) *sulfur dioxide*  
 acidic;

3



*Accept NaOH and  $\text{H}^+ + \text{HSO}_3^-$  /  $2\text{H}^+ + \text{SO}_3^{2-}$ .*

2

[5]

31. (a) sulfur is (simple) molecular;  
 (contains) covalent bonds/no delocalized electrons/all (outer) electrons used  
 in bonding;  
 aluminium contains positive ions and delocalized electrons;  
 (delocalized) electrons move (when voltage applied or current flows);

4

(b) silicon dioxide is macromolecular/giant covalent;  
 many/strong covalent bonds must be broken;

2

*Award max [1] if no mention of covalent.*

*Do not accept weakened instead of broken.*

[6]

32. (i) electron removed from higher energy level/further from nucleus/  
 greater atomic radius;

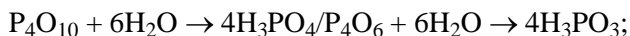
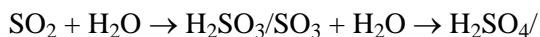
increased repulsion by extra inner shell electrons/increased shielding  
 effect;

2

(ii) Mg has twice as many/more delocalized electrons (compared to Na);  
 the ionic charge is twice as big/greater in Mg (than Na);  
 (electrostatic) attraction between ions and electrons is much greater;

3

33. oxides of Na, Mg are basic  
Al is amphoteric  
Si, P, S and Cl are acidic  
*Award 7 correct [3], 6/5 correct [2] and 4/3 correct [1].*



*Accept equation using  $\text{P}_2\text{O}_3$  or  $\text{P}_2\text{O}_5$ .*

5

[5]

34. (i) (chlorine has) an extra proton/more protons/greater nuclear charge/  
17+ compared to 16+;  
outer electrons attracted more strongly;

2

- (ii) ability of atom to attract bonding pair of electrons/electrons in a  
covalent bond;

chlorine has a smaller radius/(electrons) closer to nucleus/in lower  
energy level;

repelled by fewer inner electrons/decreased shielding effect;

3

[5]

35. (a) (i) the ability of an atom to attract a bonding pair of electrons;  
inert/do not react/do not attract electrons/stable electron  
configuration/full outer electron shell/do not form bonds;

2

- (ii) electronegativity increases (along period 3 from Na to Cl);  
number of protons increases/nuclear charge increase/core charge  
increase/size of atom decreases;

2

*Do not accept "greater nuclear attraction".*

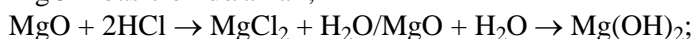
- (iii)  $\text{Cl}_2$  stronger oxidising agent;

$\text{Cl}_2$  has greater attraction for electrons/has a higher electron affinity;

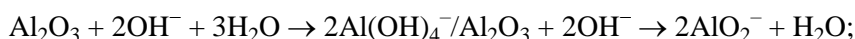
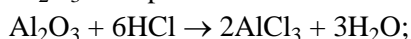
2

*Accept converse statements for  $\text{Br}_2$ .*

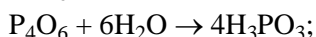
- (b)  $\text{MgO}$  – basic oxide/alkali;



$\text{Al}_2\text{O}_3$  – amphoteric oxide/acidic and basic oxide;



$\text{P}_4\text{O}_6$  – acidic oxide;



7

*All equations must be balanced.*

[13]

36. (i) minimum energy required to remove one (mole of) electron(s) from  
(one mole of) (a) gaseous atom(s)/OWTTE;

1

(ii)  $2\text{Li(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{LiOH(aq)} + \text{H}_2\text{(g)}$ / $\text{Li(s)} + \text{H}_2\text{O(l)} \rightarrow \text{LiOH(aq)} + 1/2\text{H}_2\text{(g)}$ ; 1  
*State symbols not required*

(iii) (ionization energy) decreases;  
 radius increases/valence electrons further away from nucleus/  
 electron removed from higher shell;  
 (nuclear charge increases but) shielding/screening effect increases/  
 more electrons between nucleus and valence electron/lower effective  
 nuclear charge/ $Z_{\text{eff}}$ ; 3

(iv) phosphorus has a higher (effective) nuclear charge/ $Z_{\text{eff}}$ ;  
 radius of P is smaller;  
 electron pair/bonding electrons attracted more strongly; 2

(v) both have same number of protons/14 protons/nuclear charge/core charge;  
 $\text{Si}^{4+}$  formed by electron loss,  $\text{Si}^{4-}$  formed by electron gain;  
 $\text{Si}^{4+}$  : 2.8 arrangement/2 (complete) energy levels/electrons in  $n = 2$ ;  
 $\text{Si}^{4-}$  : 2.8.8 arrangement/3 (complete) energy levels/electrons in  $n = 3$ ;  
 explanation of proton : electron ratio;  
 higher effective nuclear charge/ $Z_{\text{eff}}$  in  $\text{Si}^{4+}$ ; 4

[11]

37.  $IE_S < IE_O$ :

valence electron in S in  $n = 3$ , in O in  $n = 2/e^-$  further away/S has another  
 electron shell/atomic radius of S greater than that of O;  
 less attracted to nucleus/experiences greater screening from inner electrons;  
 $IE_S < IE_P$ :

electron removed from S is paired;

greater repulsion due to two electrons in the same (p) orbital/paired  
 electrons in S; 4

[4]

38. (i) Mg has greater nuclear charge/greater charge on cation/more  
 valence  $e^-$ /greater number of delocalized electrons/Na has lesser  
 nuclear charge/lesser charge on cation/less valence  $e^-$ /lesser number of delocalized  
 electrons; stronger attraction between cation and delocalized/  
free/valence electrons; 2

*If neither mark scored, accept stronger metallic bonding in Mg  
 for [1 max].*

(ii) giant/network/lattice/macromolecular structure;  
 many/strong covalent bonds (need to be broken); 2

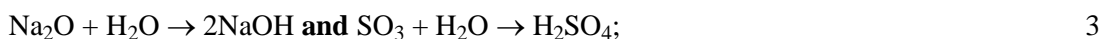
(iii) (simple) molecular substances;  
 weak van der Waals'/dispersion/London forces between molecules; 2  
*"Weak intermolecular forces" not sufficient for second mark*

[6]

39. Oxides of: Na and Mg are basic;  
 Al is amphoteric;  
 Si to Cl are acidic;

Ar has no oxide;

*All four correct award [2], two or three correct award [1].*



*Must be balanced for mark.*

*Award marks for alternative correct equations such as  $\text{SO}_3$  with  $\text{NaOH}$ .*

[3]

40. (a) (i) Na has lower nuclear charge/number of protons; electrons being removed are from same energy level/shell; **or** Na has larger radius/electron further from nucleus; max 2

*Award this mark if both electron arrangements are given.*

- (ii) Na electron closer to nucleus/in lower energy level/Na has less shielding effect; 1

*Allow counter arguments for Mg in (i) and K in (ii).*

- (b) chlorine has a higher nuclear charge; attracts the electron **pair**/electrons in bond more strongly; 2

[5]

41. (a) (i) the (minimum) energy required/needed for the removal of one electron; from a gaseous/isolated atom; 2

- (ii)  $\text{Al}(\text{g}) \rightarrow \text{Al}^+(\text{g}) + \text{e}$ ; 1

*Do not penalize the answer if (g) is after e.*

- (b) greater nuclear charge/greater number of protons/atom radius is smaller; stronger attraction (for electron); 2

- (c)  $2\text{Li} + 2\text{H}_2\text{O} \rightarrow 2\text{LiOH} + \text{H}_2$ ; *Ignore state symbols.*

effervescence/fizzing/bubbles/*OWTTE*;  
lithium moves around/decrease in size of piece;  
*Accept dissolves or disappears.*

- heat produced; 3

*Award [1] each for any two of last three observations.*

[8]

42. (a) the ability of an element/atom/nucleus to attract a bonding pair of electrons; 1

- (b) electronegativity increases (along period 3 from Na to Cl); number of protons increases/nuclear charge increases/core charge increases /size of atoms decreases; 2

*Do not accept greater nuclear attraction.*

- (c)  $\text{Cl}_2$  is a stronger oxidizing agent/Chlorine's outer shell closer to nucleus;  $\text{Cl}_2$  has greater attraction for electrons/has a higher electron affinity; 2

*Accept converse argument for  $\text{Br}_2$ .*

[5]