IB Chemistry – SL

Topic 3 Questions

1. Which pair of elements reacts most readily?

A. $Li + Br_2$

B. $Li + Cl_2$

C. $K + Br_2$

D. $K + Cl_2$

(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_2

B. Li and Br_2

C. K and Cl_2

D. K and Br_2

(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. Cl^-, Ar, K^+

B. K^+, Ar , Cl^-

C. Cl^-, K^+, Ar

D. Ar, Cl^-, 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. SiO_2

B. $SiCl_4$

C. NaCl

D. Na_2O

(Total 1 mark)

16. Which equation represents the first ionization energy of fluorine?

A. $F(g) + e^- \rightarrow F^-(g)$

B. $F^-(g) \rightarrow F(g) + e^-$

C. $F^+(g) \rightarrow F(g) + e^-$

D. $F(g) \rightarrow F^+(g) + e^-$

(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 $\rightarrow$ Cs for the alkali metals.
II. The melting points increase from F $\rightarrow$ I for the halogens.
III. The melting points decrease from Na $\rightarrow$ 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_2

II. P_4O_6

III. SO_2

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. $Ca^{2+} < Cl^{-} < K^{+}$

B. $K^{+} < Ca^{2+} < Cl^{-}$

C. $Ca^{2+} < K^{+} < Cl^{-}$

D. $Cl^{-} < K^{+} < Ca^{2+}$

(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 Na^+ than from 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

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(1)

(iii) sulfur dioxide

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(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_2, 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_2 rather than Br_2 would react more vigorously with a solution of I^-.

(2)

(b) State the acid-base properties of the following period 3 oxides.

$$MgO \quad Al_2O_3 \quad P_4O_6$$

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*.

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(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 Cl_2 rather than Br_2 would react more vigorously with a solution of I^-.

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(2)

(Total 5 marks)

IB Chemistry – SL

Topic 3 Answers

1. D

[1]

2. B

[1]

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]

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]**.*

$Na_2O + H_2O \rightarrow 2NaOH$;
$SO_3 + H_2O \rightarrow H_2SO_4$; 4
Must be balanced for marks.
Award marks for alternative correct equations such as SO_3 with 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 P_4, S_8, 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 <u>used</u> or <u>occupied</u>/<u>outer</u> 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 <u>increased</u> 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; 4
max

(ii) $2Li + 2H_2O \rightarrow 2Li^+ + 2OH^- + H_2$ / $2K + 2H_2O \rightarrow 2K^+ + 2OH^- + H_2$;
Accept LiOH/KOH.

pH ≥ 11;
LiOH/KOH is a strong base/strong alkali/high concentration of OH^-; 3

[7]

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

(ii) *sodium oxide*
basic;

(iii) *sulfur dioxide*
acidic; 3

(b) (i) $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$;

(ii) $SO_2 + H_2O \rightarrow H_2SO_3$; 2
Accept NaOH and $H^+ + HSO_3^-$/$2H^+ + SO_3^{2-}$.

[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

[5]

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]**.*

$SO_2 + H_2O \rightarrow H_2SO_3/SO_3 + H_2O \rightarrow H_2SO_4/$

$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4/P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$;

$Na_2O + H_2O \rightarrow 2NaOH/MgO + H_2O \rightarrow Mg(OH)_2$; 5
Accept equation using P_2O_3 or P_2O_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 <u>bonding</u> 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) Cl_2 stronger oxidising agent;
Cl_2 has greater attraction for electrons/has a higher electron affinity; 2
Accept converse statements for Br_2.

(b) MgO – basic oxide/alkali;
$MgO + 2HCl \rightarrow MgCl_2 + H_2O/MgO + H_2O \rightarrow Mg(OH)_2$;

Al_2O_3 – amphoteric oxide/acidic and basic oxide;
$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$;
$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-/Al_2O_3 + 2OH^- \rightarrow 2AlO_2^- + H_2O$;

P_4O_6 – acidic oxide;
$P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$; 7
All equations must be balanced.

[13]

36. (i) minimum energy required to remove one (mole of) electron(s) from
(one mole of) (a) <u>gaseous</u> atom(s)/*OWTTE*; 1

(ii) $2Li(s) + 2H_2O(1) \rightarrow 2LiOH(aq) + H_2(g)/Li(s) + H_2O(1) \rightarrow LiOH(aq) + 1/2H_2(g)$; 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_{eff}; 3

(iv) phosphorus has a higher (effective) nuclear charge/Z_{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;
Si^{4+} formed by electron loss, Si^{4-} formed by electron gain;
Si^{4+} : 2.8 arrangement/2 (complete) energy levels/electrons in n = 2;
Si^{4-} : 2.8.8 arrangement/3 (complete) energy levels/electrons in n = 3;
explanation of proton : electron ratio;
higher effective nuclear charge/Z_{eff} in 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]**.*

$Na_2O + H_2O \rightarrow 2NaOH$ **and** $SO_3 + H_2O \rightarrow H_2SO_4$; 3

Must be balanced for mark.
Award marks for alternative correct equations such as SO_3 with 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; 2
max

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) $Al(g) \rightarrow Al^+(g) + e$; 1

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

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

(c) $2Li + 2H_2O \rightarrow 2LiOH + H_2$;

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 <u>bonding</u> 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) Cl_2 is a stronger oxidizing agent/Chlorine's outer shell closer to nucleus;
Cl_2 has greater attraction for electrons/has a higher electron affinity; 2

Accept converse argument for Br_2.

[5]