What type of bonding?

A Level

Part A Covalent and ionic chlorides

Which of the following sets contain two covalent chlorides and two ionic chlorides?

1	$NaCl$	$BaCl_2$	CCl_4	ICl
2	$BeCl_2$	$SiCl_4$	$PbCl_4$	SCl_2
3	$CaCl_2$	$SiCl_4$	PCl_3	SCl_2

- **1, 2** and **3** are correct
- **1** and **2** only are correct
- **2** and **3** only are correct
- **1** only is correct
- **3** only is correct

Part B Calcium chloride

Which of **ionic, metallic, purely covalent** or **polar covalent** best describes the type of bonding present in $CaCl_2$?

Part C Phosphorus trichloride

Which of **ionic, metallic, purely covalent** or **polar covalent** best describes the type of bonding present in PCl_3?

Part D Chlorine

Which of **ionic, metallic, purely covalent** or **polar covalent** best describes the type of bonding present in Cl_2?

Part E Sodium

Which of **ionic, metallic, purely covalent** or **polar covalent** best describes the type of bonding present in Na?

Part F Silicon dioxide

Which of **ionic, metallic, purely covalent** or **polar covalent** best describes the type of bonding present in SiO_2?

Part A adapted with permission from UCLES, A-Level Chemistry, June 1991, Paper 1, Question 31;
Parts B-F created for isaacphysics.org by R. Less

s-block metal salts

A Level

Part A RbF vs. CsCl

The lattice energies of rubidium fluoride, RbF, and caesium chloride, CsCl, are $-760\,\mathrm{kJ\ mol^{-1}}$ and $-650\,\mathrm{kJ\ mol^{-1}}$, respectively.

What is the lattice energy of caesium fluoride, CsF, likely to be?

- $-800\,\mathrm{kJ\ mol^{-1}}$
- $-720\,\mathrm{kJ\ mol^{-1}}$
- $-620\,\mathrm{kJ\ mol^{-1}}$
- $-900\,\mathrm{kJ\ mol^{-1}}$

Part B MgS vs. KCl

Magnesium sulfide and potassium chloride are isoelectronic (have the same number of electrons).

Which of the following are reasons why the value of the lattice energy of magnesium sulfide is four to five times that of potassium chloride?

1 the higher the enthalpy change of hydration of the doubly charged cations
2 the higher electrostatic attraction between the doubly charged ions
3 the shorter internuclear distance between the doubly charged ions

- **1, 2** and **3** are correct
- **1** and **2** only are correct
- **2** and **3** only are correct
- **1** only is correct

Part A adapted with permission from UCLES, A-Level Chemistry June 1995, Paper 4, Question 6;
Part B adapted with permission from UCLES, A-Level Chemistry, November 1994, Paper 4, Question 31

Lattice energy

A Level

Part A Lattice energy definition

Which equation defines the lattice energy of the ionic compound XY?

- $\mathrm{X^+(g) + Y^-(g) \longrightarrow XY(s)}$
- $\mathrm{X^+(s) + Y^-(s) \longrightarrow XY(s)}$
- $\mathrm{X(g) + Y(g) \longrightarrow XY(s)}$
- $\mathrm{X(s) + Y(s) \longrightarrow XY(s)}$

Part B Lattice energies

The radius and charge of each of six ions are shown in the table.

ion	$\mathrm{J^+}$	$\mathrm{L^+}$	$\mathrm{M^{2+}}$	$\mathrm{X^-}$	$\mathrm{Y^-}$	$\mathrm{Z^{2-}}$
radius/nm	0.14	0.18	0.15	0.14	0.18	0.15

The ionic solids JX, LY and MZ are of the same lattice type.

What is the correct order of their lattice energies placing the one with the highest **magnitude** (most exothermic lattice formation enthalpy) first?

- $\mathrm{LY > MZ > JX}$
- $\mathrm{MZ > LY > JX}$
- $\mathrm{JX > MZ > LY}$
- $\mathrm{JX > LY > MZ}$
- $\mathrm{MZ > JX > LY}$

Part A adapted with permission from UCLES, A-Level Chemistry, June 1996 Paper 3, Question 6;
Part B adapted with permission from UCLES, A-Level Chemistry, November 1990, Paper 1, Question 8

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XCl_n

A Level

C C C

Element X forms a chloride XCl_n which melts at $3\,^{\circ}C$. When $0.500\,g$ of the chloride reacts with an excess of acidified silver nitrate, $1.19\,g$ of $AgCl$ are formed.

Another $0.500\,g$ sample of chloride is heated strongly and chlorine gas is given off.
When the residue is treated with an excess of acidified silver nitrate, only $0.714\,g$ of $AgCl$ is precipitated.

Part A Type of bonding

Predict the type of bonding in the chloride XCl_n

Part B Formula

Calculate the value of n.

Part C Identify X

Attempt to identify X

Adapted with permission from UCLES, A-Level Chemistry, November 1995 Paper 1, Question 5

Oxides

A Level

Part A Ionic and covalent oxides

Which of the following oxides is likely to be the most ionic in character?

- Na_2O
- MgO
- Al_2O_3
- SiO_2
- P_4O_6

Part B Barium peroxide

When barium metal burns in oxygen, the ionic compound barium peroxide, BaO_2 is formed.
Which dot-and-cross diagram could represent the structure of the anion in BaO_2?

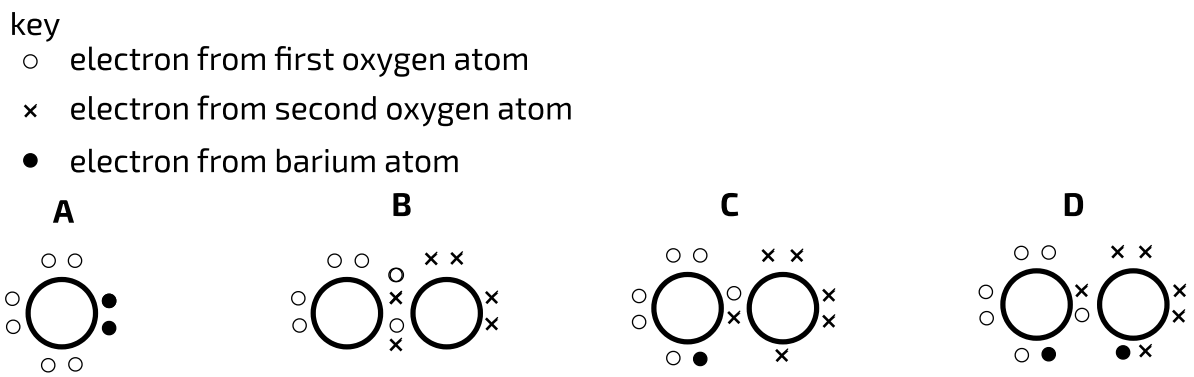

Figure 1: Dot-and-cross diagrams, with only one correctly representing barium peroxide.

- A
- B
- C
- D

Part A adapted with permission from OCSEB, A-Level Chemistry (Salters), June 1995, Paper 1, Question 18;
Part B adapted with permission from UCLES, A-Level Chemistry, November 1994, Paper 4, Question 6

Lattice enthalpy estimation

A Level

Within the ionic model, lattice enthalpies in $\mathrm{kJ\,mol^{-1}}$ may be estimated using the equation:

$$\Delta_{\mathrm{L}}H^{\ominus} = \frac{C \cdot z^{+} \cdot z^{-} \cdot \nu}{(r^{+} + r^{-})} - 2.5\nu$$

Where:

- C is a constant approximately equal to $105\,000$ units;
- z^{+} and z^{-} are the *signed* charges on the cation and anion respectively in units of e;
- ν is the number of ions in the formula (e.g. 3 for $\mathrm{MgI_2}$);
- r^{+} and r^{-} are the radii of the ions in pm;
- The -2.5ν term corrects for the difference between internal energy and enthalpy.

The table below shows the radii for certain ions.

Ion	$\mathrm{Li^+}$	$\mathrm{Na^+}$	$\mathrm{Ca^{2+}}$	$\mathrm{Cr^{3+}}$	$\mathrm{Hg^+}$	$\mathrm{O^{2-}}$	$\mathrm{F^-}$	$\mathrm{Cl^-}$	$\mathrm{Br^-}$
Radius / pm	74	102	100	62	158	140	133	180	195

Estimate the values of $\Delta_{\mathrm{L}}H^{\ominus}$ for the following compounds, using the equation given. Give your answers to 3 significant figures.

Part A LiBr

$\Delta_{\mathrm{L}}H^{\ominus}$ for LiBr

Part B $\mathrm{Na_2O}$

$\Delta_{\mathrm{L}}H^{\ominus}$ for $\mathrm{Na_2O}$

Part C $\mathrm{CaF_2}$

$\Delta_{\mathrm{L}}H^{\ominus}$ for $\mathrm{CaF_2}$

Part D $\mathrm{Cr_2O_3}$

$\Delta_{\mathrm{L}}H^{\ominus}$ for $\mathrm{Cr_2O_3}$

Part E $\mathrm{Hg_2Cl_2}$

$\Delta_{\mathrm{L}}H^{\ominus}$ for $\mathrm{Hg_2Cl_2}$

Part F **Poor approximation**

Experimentally found lattice enthalpies are:

Lattice	LiBr	$\mathrm{Na_2O}$	$\mathrm{CaF_2}$	$\mathrm{Cr_2O_3}$	$\mathrm{Hg_2Cl_2}$
$\Delta_{\mathrm{L}}H^{\ominus}$ / $\mathrm{kJ\,mol^{-1}}$	-800	-2530	-2635	-15115	-1950

For which compound is the ionic model a poor approximation?

Based on question F4.4 from the Physical Chemistry book

Ionic halides, oxides, sulfides

A Level

Part A Lattice enthalpies

Li^+	0.060
Na^+	0.095
Mg^{2+}	0.065
Ca^{2+}	0.099
Ba^{2+}	0.135
F^-	0.136
Cl^-	0.181
O^{2-}	0.140
S^{2-}	0.184

The values of the ionic radii, in nm, of several ions are given above.

Which of the following compounds, all of which have the same crystal structure, has the greatest lattice enthalpy?

- MgO
- $NaCl$
- BaS
- LiF
- CaO

Part B NaF vs. MgO

The values of two lattice energies are given below:

NaF $-915\,\mathrm{kJ\ mol^{-1}}$
MgO $-3933\,\mathrm{kJ\ mol^{-1}}$

Which of the following correct statements help to explain the difference between these two values?

1 In each of these compounds, the ions are isoelectronic (have the same number of electrons).
2 The attraction between doubly-charged ions is about four times that between singly-charged ions.
3 The interionic distance in NaF is $0.102\,\mathrm{nm}$ and that in MgO is $0.074\,\mathrm{nm}$.

- **1, 2** and **3** are correct
- **1** and **2** only are correct
- **2** and **3** only are correct
- **1** only is correct
- **3** only is correct

Part A adapted with permission from OCSEB, A-Level Chemistry, June 1995, Paper 1, Question 11;
Part B adapted with permission from UCLES, A-Level Chemistry, November 1993, Paper 4, Question 33

Essential Pre-Uni Chemistry F4.5

A Level

Rank the following sets of compounds in order of increasing magnitude of lattice enthalpy, as predicted using the ionic model:

Part A

KI, $LiCl$, $NaBr$

- $KI < NaBr < LiCl$
- $KI < LiCl < NaBr$
- $NaBr < KI < LiCl$
- $NaBr < LiCl < KI$
- $LiCl < NaBr < KI$
- $LiCl < KI < NaBr$

Part B

MgO, NaF, GaN

- $MgO < NaF < GaN$
- $GaN < NaF < MgO$
- $MgO < GaN < NaF$
- $NaF < GaN < MgO$
- $NaF < MgO < GaN$
- $GaN < MgO < NaF$

Part C

$CuCl$, $CuCl_2$, $CuBr_2$

- $CuCl < CuBr_2 < CuCl_2$
- $CuCl_2 < CuCl < CuBr_2$
- $CuBr_2 < CuCl < CuCl_2$
- $CuBr_2 < CuCl_2 < CuCl$
- $CuCl < CuCl_2 < CuBr_2$
- $CuCl_2 < CuBr_2 < CuCl$

Changing elements in lattices

A Level

Part A Calcium chloride vs. potassium bromide

What factors contribute to the lattice energy of calcium chloride being numerically greater than that of potassium bromide?

1 The radius of the chloride ion is smaller than that of the bromide ion.
2 The charge on the calcium ion is greater than that on the potassium ion.
3 Chlorine is more highly electronegative than bromine.

- **1, 2** and **3** are correct
- **1** and **2** only are correct
- **2** and **3** only are correct
- **1** only is correct
- **3** only is correct

Part B Changes in bonding

Which of the following statements are correct for the sequence of compounds below considered from left to right?

$$NaF \quad MgO \quad AlN \quad SiC$$

1 The electronegativity difference between the elements in each compound increases.
2 The formula-units of these compounds are isoelectronic (have the same number of electrons).
3 The bonding becomes increasingly covalent.

- **1, 2** and **3** are correct
- **1** and **2** only are correct
- **2** and **3** only are correct
- **1** only is correct
- **3** only is correct

Part A adapted with permission from UCLES, A-Level Chemistry, November 1992, Question 32;
Part B adapted with permission from UCLES, A-Level Chemistry, June 1993, Paper 4, Question 35