# 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 $\mathrm{PCl_3}$?

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## Part D Chlorine

Which of **ionic, metallic, purely covalent** or **polar covalent** best describes the type of bonding present in $\mathrm{Cl_2}$?

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## Part E Sodium

Which of **ionic, metallic, purely covalent** or **polar covalent** best describes the type of bonding present in $\mathrm{Na}$?

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## Part F Silicon dioxide

Which of **ionic, metallic, purely covalent** or **polar covalent** best describes the type of bonding present in $\mathrm{SiO_2}$?

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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

# Lattice Enthalpy Definition

A Level

## Part A Lattice enthalpy definition

Fill in the missing words:

Lattice enthalpy of formation $\Delta_{LE}H$ is the energy change when one [ ] of an ionic solid is formed from its [ ] [ ].

Lattice formation enthalpies are always [ ]. The magnitude of the lattice enthalpy is affected by both the ionic [ ] and the [ ] on the ions.

Items:

**charge** **mole** **negative** **radii** **positive** **ions** **gaseous** **atoms**

## Part B Lattice energy

For which compound is the lattice energy likely to have the greatest numerical value (i.e. the greatest magnitude, disregarding sign)?

- lithium fluoride
- rubidium chloride
- sodium chloride
- lithium iodide

Part A adapted with permission from OCSEB, A-Level Chemistry, June 1995, Special Paper, Question 4;
Part B adapted with permission from UCLES, A-Level Chemistry, November 1995, Paper 4, Question 7

# 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 $e$;
- $\nu$ 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 $\mathrm{pm}$;
- The $-2.5\nu$ 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 / $\mathrm{pm}$ | 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** $\mathrm{LiBr}$

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

**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 $\mathrm{CaF_2}$

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**Part D** $\mathrm{Cr_2O_3}$

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

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**Part E** $\mathrm{Hg_2Cl_2}$

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

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**Part F** **Poor approximation**

Experimentally found lattice enthalpies are:

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

For which compound is the ionic model a poor approximation?

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Based on question F4.4 from the Physical Chemistry book

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# Lattice Energy

A Level

## Part A Lattice energy definition

Which equation defines the lattice energy of the ionic compound $\mathrm{XY}$?

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

## Part B Lattice energies

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

| | | | | | | |
|---|---|---|---|---|---|---|
| ion | $J^+$ | $L^+$ | $M^{2+}$ | $X^-$ | $Y^-$ | $Z^{2-}$ |
| 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?

- $MZ > LY > JX$
- $LY > MZ > JX$
- $JX > LY > MZ$
- $MZ > JX > LY$
- $JX > MZ > LY$

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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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# Covalent Bonding

A Level

## Part A Number of bonding electrons

Which of the following molecules contains six bonding electrons?

- $SiCl_4$
- $H_2S$
- $CO_2$
- $C_2H_4$
- $NCl_3$

## Part B $\mathrm{P-H}$ and $\mathrm{Cl-H}$ bonds

The $\mathrm{P-H}$ bond energy is the mean (average) of the $\mathrm{H-H}$ and $\mathrm{P-P}$ values. Which of the statements are relevant to explaining why the $\mathrm{H-Cl}$ bond energy is **not** the mean of the $\mathrm{H-H}$ and $\mathrm{Cl-Cl}$ values?

Some bond energy values are given in the table below:

| bond | bond energy/$\mathrm{kJ\,mol^{-1}}$ | bond | bond energy/$\mathrm{kJ\,mol^{-1}}$ |
|---|---|---|---|
| $\mathrm{H-H}$ | 436 | $\mathrm{H-H}$ | 436 |
| $\mathrm{P-P}$ | 208 | $\mathrm{Cl-Cl}$ | 244 |
| $\mathrm{P-H}$ | 322 | $\mathrm{H-Cl}$ | 431 |

**1** The $\mathrm{Cl-H}$ bond is more polar than the $\mathrm{P-H}$ bond.

**2** $\mathrm{Cl}$ has a smaller covalent radius than $\mathrm{P}$.

**3** $\mathrm{P}$ has five valence electrons whereas $\mathrm{Cl}$ has seven.

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

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Part A adapted with permission from UCLES, A-Level Chemistry, November 1992, Paper 4, Question 5;
Part B adapted with permission from UCLES, A-Level Chemistry, June 1991, Paper 2, Question 2

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# Dipoles

A Level

## Part A Dipoles 1

Which of the following molecules has **no** permanent dipole?

- $CHCl_3$
- $CCl_2F_2$
- $C_2H_5Cl$
- $C_2Cl_4$

## Part B Dipoles 2

In which pair of molecules is the permanent dipole in molecule **I** greater than that in molecule **II**?

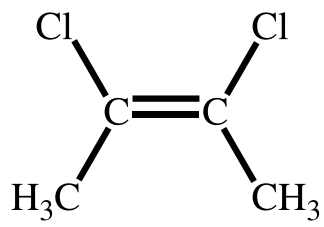
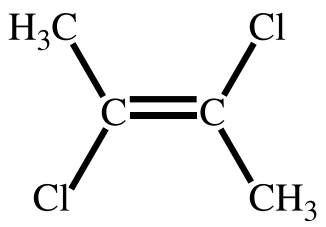
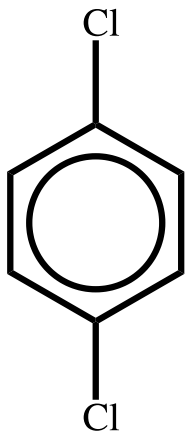
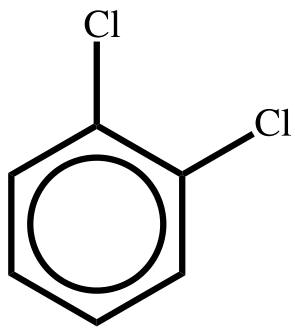
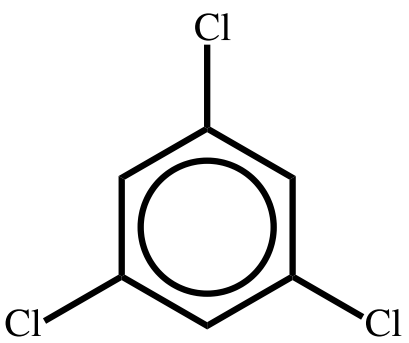
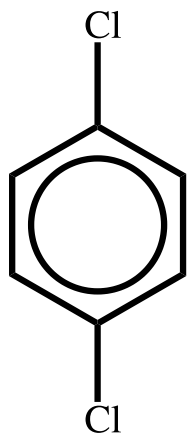
| | I | II |
|---|---|---|
| **A** |  |  |
| **B** | $CH_3CH_2Cl$ | $CH_3CHCl_2$ |
| **C** |  |  |
| **D** |  |  |

**Figure 1:** Dipoles.

The hexagonal structures are *benzene rings*. Benzene has formula $\mathrm{C_6H_6}$ and can be viewed as having alternating single and double bonds, although in actual fact all $\mathrm{C-C}$ bonds are the same length and are somewhere between single and double bonds, hence is a circle is drawn to represent this.

The hydrogen atoms are not usually drawn on. Substituted benzenes have different groups attached in place of hydrogen which are indicated.

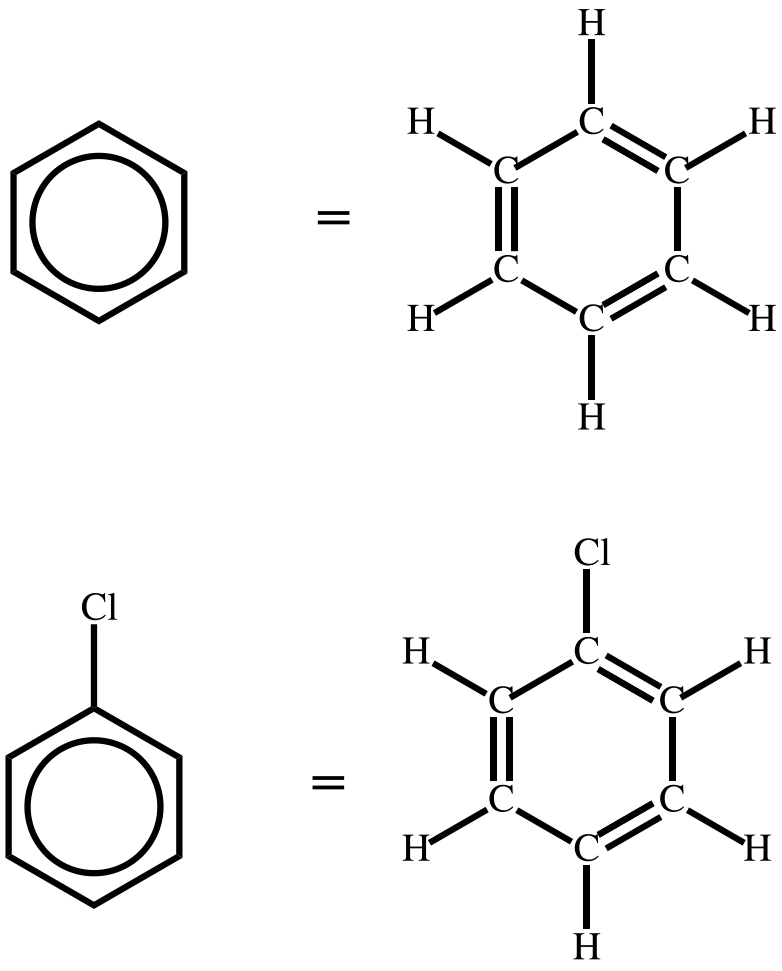



**Figure 2:** Representations of **benzene**, $C_6H_6$ and **chlorobenzene**, $C_6H_5Cl$.

- **A**
- **B**
- **C**
- **D**

Part A adapted with permission from UCLES, A-Level Chemistry, June 1994, Paper 4, Question 9;
Part B adapted with permission from UCLES, A-Level Chemistry, June 1999, Paper 3, Question 18

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# Van der Waals and Paraffin wax

A Level

## Part A Van der Waals forces

Which of the following compounds in their solid states consist of atoms or molecules held together only by van der Waals forces (due to some form of dipole-dipole interaction)?

- $H_2O$
- $MgO$
- $SiO_2$
- $Cu$
- $CO_2$

## Part B Melting point of paraffin wax

The melting point of paraffin wax (a mixture of saturated hydrocarbons which have high relative molar mass) is determined by

- covalent bonds within hydrocarbon molecules
- covalent bonds between hydrogen carbon molecules
- ionic bonds between molecules
- hydrogen bonds between molecules
- van der Waals (London dispersion) forces between the molecules

Part A adapted with permission from UCLES, A-Level Chemistry, November 1990, Paper 1, Question 1;
Part B adapted with permission from OCSEB, A-Level Chemistry, June 1994, Paper 1, Question 3

# Hydrogen Bonding and Methane

A Level

## Part A Effects of intermolecular hydrogen bonding

Which of the following statements describes a phenomenon which can be explained by intermolecular hydrogen-bonding?

- The boiling points of the alkanes increase with increasing relative molecular mass.
- Hydrogen chloride forms an acidic solution when dissolved in water.
- The melting points of the Group 1 hydroxides decrease with increasing relative formula mass ($M_r$)
- Ice has a lower density than water at $0\,^{\circ}\mathrm{C}$.
- $\mathrm{CH_3OCH_3}$ ($M_r$ = 46) has a higher boiling point than $\mathrm{CH_3CH_2CH_3}$ ($M_r$ = 44).

## Part B Condensed methane

The Voyager 2 probe has shown that the surface of Triton, a moon of the planet Neptune, contains condensed methane which flows rapidly.

Which statement explains the flow within the condensed methane?

- Methane molecules have a tetrahedral structure.
- Condensed methane has a metallic structure.
- Methane molecules contain strong $\mathrm{C{-}H}$ bonds.
- The intermolecular forces between methane molecules are weak.

Part A adapted with permission from UCLES, A-Level Chemistry, November 1990, Paper 1, Question 4;
Part B adapted with permission from UCLES, A-Level Chemistry, November 1996, Paper 4, Question 4

# Diamond and Graphite

A Level

Which structural feature is common to both diamond and graphite?

- delocalised electrons
- a carbon-carbon bond length equal to that in ethane
- each carbon atom bonded to four others
- covalent bonds between carbon atoms
- van der Waals forces

Adapted with permission from UCLES, A-Level Chemistry, November 1993, Paper 4, Question 17