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

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:

positive radii charge ions negative mole atoms gaseous

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)?

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

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;
- 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

Lattice Energy

A Level

Part A Lattice energy definition

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

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

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?

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

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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STEM SMART Chemistry Week 6

Covalent Bonding

A Level

Part A Number of bonding electrons

Which of the following molecules contains six bonding electrons?

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

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 Cl has a smaller covalent radius than P.
3 P has five valence electrons whereas 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

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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STEM SMART Chemistry Week 6

Dipoles

A Level

P P P

Part A Dipoles 1

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

- C_2Cl_4
- C_2H_5Cl
- $CHCl_3$
- CCl_2F_2

Part B Dipoles 2

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

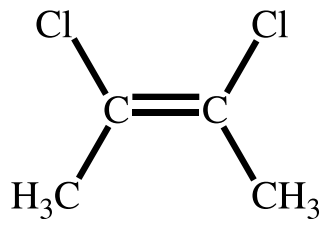
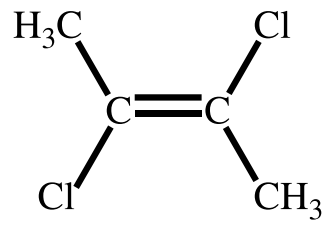
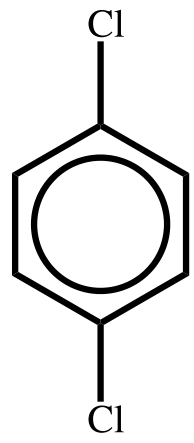
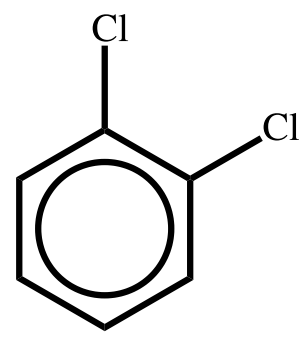
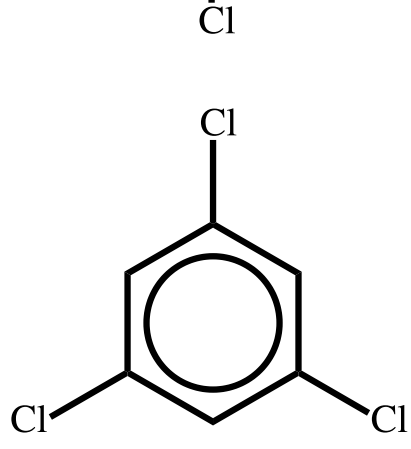
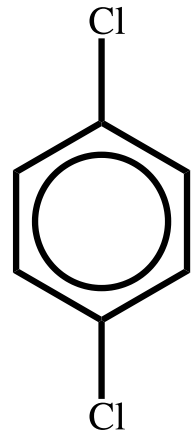
	I	II
A		
B	CH_3CH_2Cl	CH_3CHCl_2
C		
D		

Figure 1: Dipoles.

The hexagonal structures are *benzene rings*. Benzene has formula C_6H_6 and can be viewed as having alternating single and double bonds, although in actual fact all $C-C$ 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.

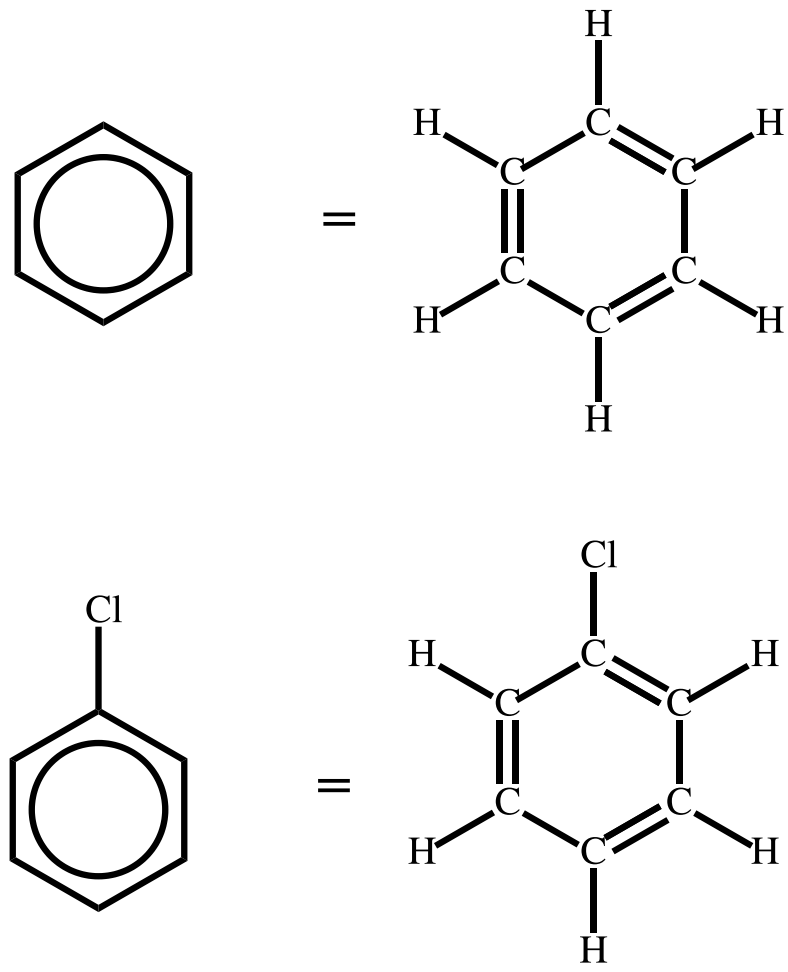


Figure 2: Representations of **benzene**, C_6H_6 and **chlorobenzene**, C_6H_5Cl.

- **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

Gameboard:
STEM SMART Chemistry Week 6

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)?

- CO_2
- SiO_2
- H_2O
- Cu
- MgO

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

Hydrogen Bonding and Methane

A Level

P P P

Part A Effects of intermolecular hydrogen bonding

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

- CH_3OCH_3 (M_r = 46) has a higher boiling point than $CH_3CH_2CH_3$ (M_r = 44).
- 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 $0\,^{\circ}C$.

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?

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

Diamond and Graphite

A Level

Which structural feature is common to both diamond and graphite?

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

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