THE SCIENCE SCRIBE: MASTERY GUIDES

STRUCTURE & BONDING

FOR LEVEL TWO CHEMISTRY

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STRUCTURE & BONDING OVERVIEW:

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Types of Substances

Metallic

Aim To At least:
- Draw diagrams of how atoms are arranged in a metal.
- Explain physical properties of metals with reference to how particles are arranged and bonded.
- State the particles present in metallic substances and the forced between atoms.

Ionic

Aim To At least:
- Draw diagrams of how ions are arranged in an ionic substance.
- Explain physical properties of ionic substances with reference to how particles are arranged and bonded.
- State the particles present in ionic substances and the forces between them.

3D Extended Covalent Network

Aim To At Least:
- Describe the shape of silica, graphite and diamond.
- Explain the physical properties of silica, graphite and diamond with reference to how the particles are bonded.

Molecular

Polar / Non-Polar

Aim To At Least:
- Draw Lewis Structures
- Determine the shape using VSEPR and quote bond angles.
- Draw the shape.
- Identify polar and non-polar bonds.
- Identify polar and non-polar molecules.
- Predict physical properties.
- State the particles present and the forces between them.

Energetics

Aim To At Least:
- Gain fluency in using mol ratios in calculations.
- Sketch endothermic and exothermic graphs.
- Identify physical changes (e.g: melting) as exo or endo.
- Identify if a reaction is exo or endo based on enthalpy being negative or positive.
- Perform bond energy calculations by identifying which bonds are broken and formed.

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Mastery: Be able to be given any two different types of substances and compare and contrast their physical properties in depth with the aid of accurate diagrams (of lewis structures, metals, etc).

Mastery: Performs calculations quickly and accurately with appropriate rounding.

METALLIC

PHYSICAL PROPERTIES

DESCRIPTION OF STRUCTURE:

Made up of atoms in a sea of electrons. Electrons are delocalised (free to move around).

Therefore, metals are good conductors of heat and electricity. *Electrical conductivity requires free electrons or ions.*

TYPE OF BONDING: METALLIC

These are relatively strong and will require a fairly large amount of heat energy to overcome.

Therefore, metals tend to have a fairly high melting and boiling point.

Metallic bonds do not break in contact with water.

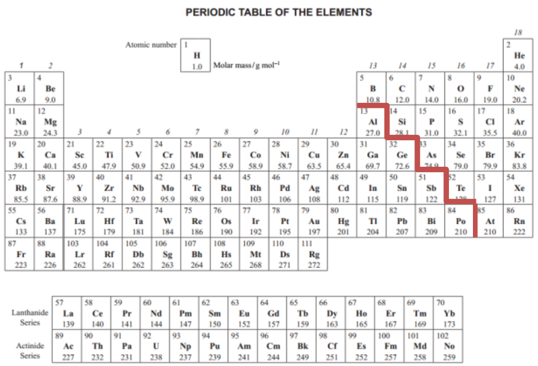
Therefore, metals will not dissolve in water.

When a force is applied, the metal bonds are not broken but are redistributed.

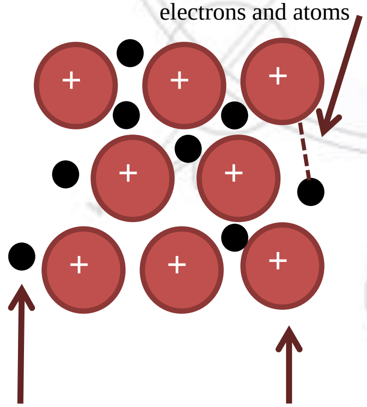
Therefore, metals are malleable (can be shaped/bent) and ductile (can be pulled into a wire).

HOW TO SPOT A METAL

Metals are everything on the **left** of the *stairs* in the Periodic Table.



DIAGRAM



WRITING FRAMES

ELECTRICAL CONDUCTIVITY (EXAMPLE WITH Mg)

For something to conduct electricity, it must have delocalised electrons or mobile ions. **Mg** is a metal. In **Mg**, the atoms are held together by strong metallic bonds in a sea of delocalised electrons. Therefore, **Mg** can conduct electricity.

HIGH MELTING POINTS (EXAMPLE WITH Cu)

Cu is a metal. In **Cu** metal, the atoms are held together by strong metallic bonds in a sea of delocalised electrons. A lot of heat energy is required to break the metallic bonds to separate the **Cu** atoms. Therefore, **Cu** has a high melting point.

SOLUBILITY IN WATER (EXAMPLE WITH Zn)

Zn is a metal. In **Zn** metal, the atoms are held together by strong metallic bonds in a sea of delocalised electrons. The metallic bonds do not break in contact with water. Therefore, **Zn** does not dissolve in water.

DUCTILE, MALLEABLE (EXAMPLE WITH Pb)

Pb is a metal. In **Pb** metal, the atoms are held together by strong metallic bonds in a sea of delocalised electrons. When a force is applied to a metal, the metallic bonds are not broken but are redistributed. Therefore, **Pb** is malleable (can be shaped) and ductile (can be drawn into wires).

WRITING FRAME KEY POINTS

All the writing frames above cover the following points:
- States that the example is a metal.
- States that the type of particle which metals is made of are called atoms.
- States how the atoms are arranged.
- States the type of bonding between particles (metallic bonding)
- Relates the structure to its property.
- Finishes the paragraph with a concise summary.

Highly recommended: including a diagram (see left).

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IONIC

PHYSICAL PROPERTIES

DESCRIPTION OF STRUCTURE:

As a solid, cations (+) and anions (-) held rigidly in place by strong ionic bonds in a 3D crystal lattice.

Therefore, ionic solids do not conduct electricity. *Electrical conductivity requires free electrons or ions.*

TYPE OF BONDING: IONIC

These are very strong and will require a large amount of heat energy to overcome. Ions are mobile when liquid.

Therefore, ions have a very high melting and boiling point. When molten, liquid, ionic substances can conduct electricity.

Ionic bonds are overcome by δ^+ to anion **and** δ^- to cation attraction between water and ionic solids. The ions are then mobile.

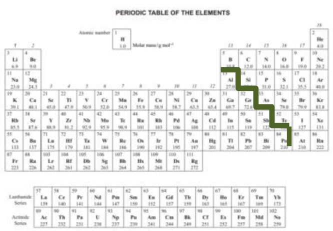
Therefore, ions are soluble (will dissolve) in water. Dissolved ionic substances will conduct electricity.

When a force is applied, the cations align with other cations **and** anions align with each other giving a repulsion.

Therefore, ionic solids will **shatter** under enough force.

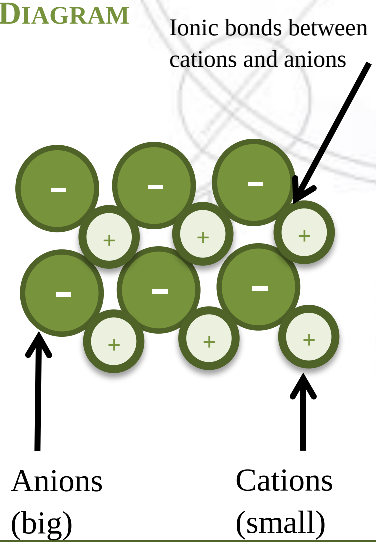
HOW TO SPOT AN IONIC SUBSTANCE

1) Something on the **left** of the *stairs* with something on the **right.**



2) A cation with any anion from The Table of Ions (Year 11 Science, not given in Year 12)

DIAGRAM



WRITING FRAMES

ELECTRICAL CONDUCTIVITY (EXAMPLE WITH SOLID $MgCl_2$)

For something to conduct electricity, it must have delocalised electrons or mobile ions. $MgCl_2$ is an ionic solid. In $MgCl_2$, the cations and anions are held rigidly in place by very strong ionic bonds in a 3D crystal lattice. There are no mobile electrons, or ions, therefore $MgCl_2$ does not conduct electricity in the solid state.

HIGH MELTING POINTS (EXAMPLE WITH SOLID $CuSO_4$)

$CuSO_4$ is an ionic substance. In solid $CuSO_4$, the cations and anions are held rigidly in place by very strong ionic bonds in a 3D crystal lattice. A lot of heat energy is required to break the ionic bonds to separate the Cu^{2+} and SO_4^{2-} ions. Therefore, $CuSO_4$ has a high melting point.

SOLUBILITY IN WATER (EXAMPLE WITH $ZnCl_2$)

$ZnCl_2$ is an ionic substance. In $ZnCl_2$ the cations and anions are held rigidly in place by very strong ionic bonds in a 3D crystal lattice. The ionic bonds are overcome by δ^+ to anion and δ^- to cation attraction between water and ionic solids. The ions are then mobile. Therefore, $ZnCl_2$ dissolves in water.

WRITING FRAME KEY POINTS

All the writing frames above cover the following points:
- States that the example is an ionic substance.
- States that the type of particle which metals is made of are called ions (cations/anions).
- States how the ions are arranged.
- States the type of bonding between ions (ionic bonding, avoid **electrostatic**)
- Relates the structure to its property.
- Finishes the paragraph with a concise summary.

Recommend including: a diagram (example on left).

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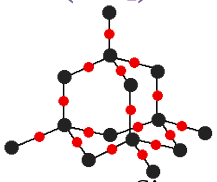
3D EXTENDED COVALENT SOLID

HOW TO SPOT A 3D EXT. COVALENT

You are limited to three. Silica (SiO_2), Graphite (C) and Diamond (C).

Allotropes are the different forms an element can take. Diamond and graphite are allotropes of carbon.

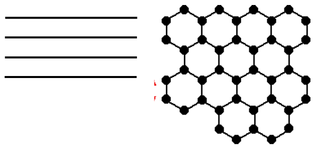
SILICA (SiO_2)



STRUCTURE: Si covalently bonded to a total of four O in a tetrahedron. Each O is covalently bonded to two Si in total.

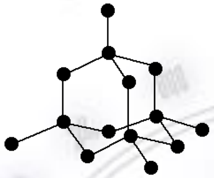
Made only of Si and O

GRAPHITE (C)



STRUCTURE: Each C is covalently bonded to 3 other carbons in a trigonal planar geometry to form layers and supplies 1 free electron. Weak intermolecular bonds between layers. Made of C.

DIAMOND (C)



STRUCTURE: Each C is covalently bonded to 4 other carbons in a tetrahedron.

Made only of C.

MELTING POINTS: Covalent bonds are also called intramolecular forces. Intramolecular forces are **very strong** and will require a lot of **heat energy** to overcome. This means 3D extended covalent network solids have high melting points.

HARDNESS: The **intra**molecular forces also need a lot of force to break them. This makes them hard. However, graphite has weak **inter**molecular forces between layers which needs very little force to overcome. Therefore, layers in graphite can slide.

ELECTRICAL CONDUCTIVITY: There are no mobile electrons or ions present. The exception is graphite, where each carbon can supply one free electron that is mobile. Therefore, graphite can conduct electricity.

SOLUBILITY: Intramolecular forces are very strong and do not break in solvents such as water. Therefore, extended covalent network solids do not dissolve.

WRITING FRAMES

ELECTRICAL CONDUCTIVITY (EXAMPLE WITH GRAPHITE)

For something to conduct electricity, it must have delocalised electrons or mobile ions. **Graphite** is a 3D extended covalent network solid made of **carbon**. In **graphite**, Each C is covalently bonded to 3 other carbons in a trigonal planar geometry to form layers and supplies1 delocalised electron. Therefore, **graphite** can conduct electricity.

ELECTRICAL CONDUCTIVITY (EXAMPLE WITH SILICA)

For something to conduct electricity, it must have delocalised electrons or mobile ions. **Silica** is a 3D extended covalent network solid made of **silicon and oxygen**. In **silica**, Each Si atom is covalently bonded to a total of four O atoms in a tetrahedron. Each O is also covalently bonded to two Si in total. There are no free electrons. Therefore, **silica** cannot conduct electricity.

HIGH MELTING POINTS (EXAMPLE WITH DIAMOND)

Diamond is a 3D extended covalent network solid made of **carbon** atoms. In **diamond**, each C is covalently bonded to 4 other carbons in a tetrahedron. A lot of heat energy is required to break the covalent bonds (intramolecular bonds) to separate the C atoms. Therefore, **diamond** has a high melting point.

HARDNESS (EXAMPLE WITH Diamond)

Diamond is a 3D extended covalent network solid made of **carbon** atoms. In **diamond**, each C is covalently bonded to 4 other carbons in a tetrahedron. A lot of force is required to break the covalent bonds (intramolecular bonds) to separate the C atoms. Therefore, **diamond** is very hard.

WRITING FRAME KEY POINTS

All the writing frames above cover the following points:
- States that the example is a 3D extended covalent network solid.
- States that the solid is made of atoms, and the types of atoms.
- States how the atoms are arranged (e.g: tetrahedral, what they bond to, layers).
- States the type of bonding between particles (covalent, intramolecular – say both. Intermolecular for layers.)
- Relates the structure to its property.
- Finishes the paragraph with a concise summary.

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MOLECULAR I

PHYSICAL PROPERTIES

DESCRIPTION OF STRUCTURE:

Made up of molecules (could be polar or non-polar). No free ions or electrons present.

Therefore, molecular substances do not conduct electricity. *Electrical conductivity requires free electrons or ions.*

TYPE OF BONDING: INTERMOLECULAR FORCES

These are **very** weak and only require little heat energy to overcome.

Therefore, molecular substances have very low melting and boiling points.

Polar molecules dissolve in **polar** substances because they are attracted to each other. This *leaves behind* non-polar molecules, which are not attracted to anything.

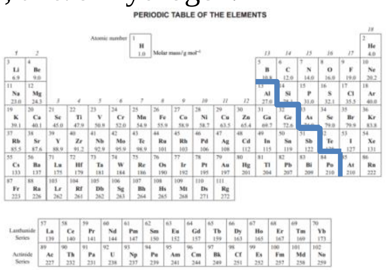
Like dissolves like.
Polar dissolves in polar.
Non-polar dissolves in non-polar.
Polar and non-polar do not

Non-polar molecules can form instantaneous dipoles, allowing them to be very slightly soluble in polar solvents.

Non-polar molecules are only very slightly soluble in polar solvents.

SPOT A MOLECULAR SPECIES

Made of atoms on the **right** of the *stairs*, and/or hydrogen.



OR learn the other 3 substances really well, and treat these as "everything else".

DIAGRAM

This involves drawing Lewis Structures and using VSEPR to determine the shapes.
Sorry, there is no shortcut here.
As an incentive, there has always been a question about Lewis Structures/ Shapes/ Bond Angles. It's not a case of "it might be asked", because it **definitely will be.**

HOW TO: DRAW LEWIS STRUCTURES (excl. SO_3 at Level II)

Show all lone pairs.

H_2O CO_2

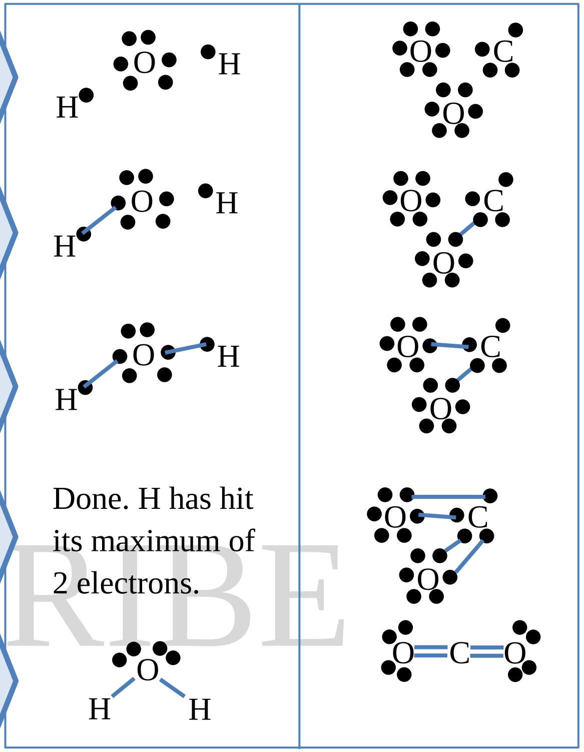
STEP 1: Draw dot-diagrams of each atom involved, showing only the valence electrons.

STEP 2: connect one dot from the central atom to a dot from one of the other atoms.

STEP 3: Make sure all the 'other atoms' have been joined to the central atom at least once.

STEP 4: Pair up as many electrons as you can from the central atom to the other atoms.

STEP 5: Draw your Lewis Structure Diagram



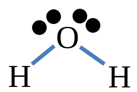
HOW TO: DETERMINE THE SHAPE OF A MOLECULE

Learn Lewis Structures first.

STEP 1: Count the regions of electron density around the central atom. Single, double and triple lines (bonds) count as **one** region. Every **lone pair** counts as **one region.**

STEP 2: Use the table on the next page to determine the shape. Note, the table is not given in assessments. Learn it.

H_2O



There are 2 lone pairs.
There are 2 bonding pairs.
In total, there are 4 regions.

Water is bent/v-shape with bond angles of about 104.5°

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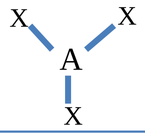
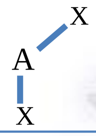
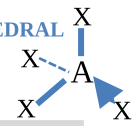
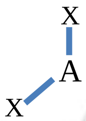
MOLECULAR II

SHAPES OF MOLECULES:

Regions	0 Lone Pairs	1 Lone Pairs	2 Lone Pairs
2	X — A — X **LINEAR** *180°*	When looking for regions, we only care about the **central atom.** Lone pairs, single, double and triple bonds count as **one region**	
3	**TRIGONAL PLANAR** *120°* 	**BENT** ***JUST UNDER 120°*** 	
4	**TETRAHEDRAL** *109.5°* 	**TRIGONAL PYRAMID** *~107°* 	**BENT** *~104.5°* 

The **parent shape** is the shape listed in the "0 lone pairs" column. As we move across a row, we are simply swapping out bonds for lone pairs. Note that we **do not** show lone pairs **OR multiple bonds** when we draw shapes.

VSEPR THEORY:

Regions of electron density repel each other. Regions occupied by lone pairs have the greater repulsion compared to bonding pairs.

POLARITY OF MOLECULES:

Polar Molecules: have polar bonds. The vector dipoles do not cancel and the molecule is asymmetric.

No-polar Molecules: have non-polar bonds. **OR** has polar bonds, but the dipoles cancel and the molecule is symmetric.

Note: to determine if dipoles cancel out, use the tug-of-war red-ribbon analogy. Central atom = red ribbon, bond = rope, atoms = people pulling. If the ribbon moves, the dipoles do not cancel.

Polar bonds will always be present if two atoms in a bond are different. This is because different atoms have different electronegativity. Electronegativity is the ability to pull on covalently bonded electrons. Atoms higher up, and to the right, on the Periodic Table have higher electronegativity and are marked by δ^-. Lower and to the left atoms are given δ^+.

WRITING FRAMES

SHAPES OF MOLECULES (EXAMPLE WITH NH_3)

NH_3 has **4** regions of electron density, giving it a parent shape of **tetrahedral** with bond angles of **109.5°**. However, **3** of these regions are occupied by bonding pairs of electrons (**N-H**) and **one** is occupied by a lone pair of electrons. This gives it a **trigonal pyramid** shape, and since the lone pair exerts more repulsion than the bonding pairs (VSEPR) there is a bond angle of about **107°** to achieve maximum separation and minimum repulsion.

POLAR MOLECULES (EXAMPLE WITH CH_3Cl)

A polar molecule has polar bonds and the vector dipoles in the molecule do not cancel. The molecule is asymmetric. CH_3Cl contains **3 polar C-H bonds and one polar C-Cl bond**. These are arranged in a **tetrahedral** geometry about a central **C** atom. The vector dipoles do not cancel out and the molecule is asymmetric, making the overall molecule polar.

NON-POLAR MOLECULES (EXAMPLE WITH BF_3)

A non-polar molecule has no polar bonds, OR it has polar bonds but the vector dipoles cancel out and the molecule is symmetric.BF_3 contains **3 polar B-F bonds**. These are arranged in a **trigonal planar** geometry about a central **B** atom. The vector dipoles cancel out and the molecule is symmetric, making the overall molecular non-polar.

MELTING POINTS (EXAMPLE WITH I_2)

I_2 is a discrete molecular substance with very strong intramolecular forces between **I** atoms. However, very weak intermolecular forces exist between I_2 molecules. The intermolecular forces require very little heat energy to break, therefore I_2 has a low melting point.

SOLUBILITY IN WATER & CYCLOHEXANE (EXAMPLE WITH I_2)

I_2 is non-polar molecule, therefore we expect it to dissolve in non-polar solvents such as **cyclohexane**. We do not expect I_2 to dissolve in **water** because water is polar. However, I_2 is actually very slightly soluble in **water** because I_2 has the ability to form instantaneous dipole attractions.

WRITING FRAME KEY POINTS

In all cases above, the inclusion of diagrams is highly recommended.

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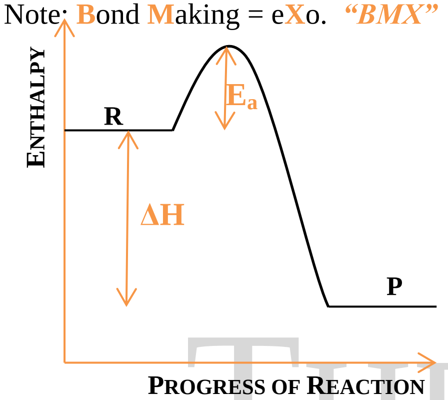
ENERGETICS I

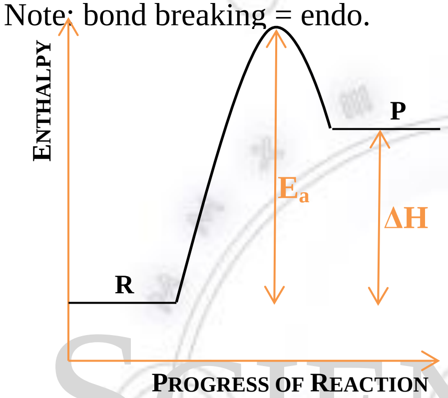
EXOTHERMIC

Releases energy. Feels hot.
ΔH (enthalpy) is negative.
Note: **B**ond **M**aking = e**X**o. *"BMX"*



ENDOTHERMIC

Absorbs energy. Feels cold.
ΔH (enthalpy) is positive.
Note: bond breaking = endo.



R: reactants **P:** products **ΔH:** enthalpy **E_a:** activation energy
Activation energy is sometimes called the *energy barrier*. Note that you may be asked to sketch the shape of energy curves like above.

ENTHALPY

is a number in the units of kJ mol^{-1}. This is read aloud as "kilojoules per mole", or "**kilojoules for one mole**"

Understanding this is **essential** to working with mole ratios. You are highly likely to be asked to perform calculations using ratios.

EXAMPLES		RATIOS
$2Mg + O_2 \rightarrow 2MgO$	ΔH = -1200 kJ mol^{-1}	2Mg : 1 O_2 : 2 MgO : -1200 kJ
$2H_2 + 1C \rightarrow CH_4$	ΔH = -75 kJ mol^{-1}	$2H_2$: 1 C : 1 CH_4 : -75 kJ

CALCULATING ENTHALPY

METHOD ONE: "ΔH = P – R"

Take the energy of the products and minus the energy of the reactants. This is pretty much what is shown on the graphs above.

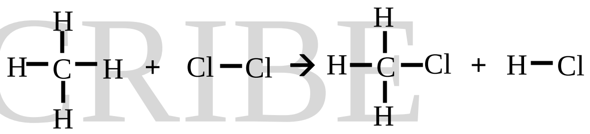
e.g: the energy of the reactants is 700 kJ mol^{-1}. The energy of the products is 200 kJ mol^{-1}. Therefore, ΔH = -500 kJ mol^{-1}.

METHOD TWO: "ΔH = SUM ALL BONDS BROKEN – SUM ALL BONDS FORMED"

Bond energy calculations can be spotted by the list of data given.

E.g: Calculate ΔH for: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$
You may use the following data:
C-H: 99 kJ mol^{-1} H-Cl: 103 kJ mol^{-1}
C-Cl: 81 kJ mol^{-1} Cl-Cl: 58 kJ mol^{-1}

STEP ONE: draw the reaction out as a diagram.



STEP TWO: Decide which bonds are broken and formed.

BROKEN:	**FORMED:**
1x C-H	1x C-Cl
1x Cl-Cl	1x H-Cl

Tip: imagine you made models of CH_4 and Cl_2, then only using those two models had to make CH_3Cl and HCl.

STEP THREE: Apply and use the formula.
3s.f. recommended.

ΔH = Bonds Broken – Bonds Formed
= [(C-H) + (Cl-Cl)] - [(C-Cl) + (H-Cl)]
= [(99) + (58)] - [(81) + (103)]
= [157] - [184]
= 27.0 kJ mol^{-1}

NOTES: * Try bond energy calculations from

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ENERGETICS II

METHOD THREE: "Ratios" – FIND MASS OR MOL NEEDED TO RELEASE/ABSORB X AMOUNT OF ENERGY.

E.g: $2Mg + O_2 \rightarrow 2MgO$ ΔH = -1200 kJ mol^{-1}
Calculate the mass of Mg needed to release **300 kJ** of energy. M(Mg) = 24.0 g mol^{-1}

STEP ONE: write the ratio against energy. Remove negative sign. Call this **known.**

2Mg : 1200 kJ simplifies to… 1 Mg : **600 kJ (known)**

TIP: ***"what's given is known"*** - the question gives you a number in **kJ**. Therefore your known is the number in the ratio that has the units given in **kJ**.

STEP TWO: the energy needed or wanted is the **unknown.**

unknown = 300 kJ.

STEP THREE: multiply by **"unknown over known"**.

1 Mg x (unknown/known) = 1 x (300/600)
= 0.5 mol of Mg.
m(Mg) = n x M = 0.5 x 24 = 12.0g *3sf*

Check if the question wanted the final answer in mass (g) or mol.

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METHOD THREE: "Ratios" – FIND ENERGY RELEASED WHEN X MOL/GRAMS IS USED.

E.g: $2Mg + O_2 \rightarrow 2MgO$ ΔH = -1200 kJ mol^{-1}
Calculate the energy released when **12g of Mg** is used. M(Mg) = 24.0 g mol^{-1}

STEP ONE: write the ratio against energy. Remove negative sign. Call this **known.**

2Mg : 1200 kJ simplifies to… **1 Mg** : 600 kJ **(known)**

TIP: ***"what's given is known"*** – the question **gives** you a number in **mol** (if it's in gram, convert it to mol quickly). Therefore your **known** is the number in the ratio given in **mol**.

STEP TWO: convert any other values to mol. Call this **unknown.**

12g of Mg in mol: n = m / M
n(Mg) = 12g/24.0g mol^{-1} = **0.5 mol (unknown)**

STEP THREE: multiply by **"unknown over known"**.

600 kJ x (unknown/known) = 600 kJ x (0.5/1)
= 300 kJ released

Write ***released*** if original enthalpy was negative. 3sf recommended.

NOTES: