

1. Compound Formulation

Target Compound	Required "Moles" (Input Units)	Rule-Based Formulation Logic	Hint
Water (H₂O)	2 Hydrogen + 1 Oxygen	IF 2H + 1O THEN H₂O	"Water is made of 2 Hydrogens and 1 Oxygen."
Methane (CH₄)	1 Carbon + 4 Hydrogen	IF 1C + 4H THEN CH₄	"Methane is a simple hydrocarbon. It has 1 Carbon and 4 Hydrogens."
Calcium Carbonate (CaCO₃)	1 Calcium + 1 Carbon + 3 Oxygen	IF 1Ca + 1C + 3O THEN CaCO₃	"Calcium carbonate needs 1 Calcium, 1 Carbon, and 3 Oxygens."
Sodium Hydroxide (NaOH)	1 Sodium + 1 Oxygen + 1 Hydrogen	IF 1Na + 1O + 1H THEN NaOH	"This base is a 1:1:1 ratio of Sodium, Oxygen, and Hydrogen."
Silver Nitrate (AgNO₃)	1 Silver + 1 Nitrogen + 3 Oxygen	IF 1Ag + 1N + 3O THEN AgNO₃	"To form this salt solution, you need 1 Silver, 1 Nitrogen, and 3 Oxygen atoms."

Copper (II) Sulfate (<chem>CuSO4</chem>)	1 Copper + 1 Sulfur + 4 Oxygen	IF 1Cu + 1S + 4O THEN CuSO₄	"The sulfate ion (SO ₄) requires four Oxygen atoms attached to one Sulfur."
Hydrochloric Acid (HCl)	1 Hydrogen + 1 Chlorine	IF 1H + 1Cl THEN HCl	"Hydrochloric Acid needs 1 Hydrogen and 1 Chlorine."
Sodium Chloride (NaCl)	1 Sodium + 1 Chlorine	IF 1Na + 1Cl THEN NaCl	"To form this, you need 1 Sodium and 1 Chlorine."
Hydrochloric Acid (HCl)	1 Hydrogen + 1 Chlorine	IF 1H + 1Cl THEN HCl	"Hydrochloric Acid needs 1 Hydrogen and 1 Chlorine."

2. Elements/Elements/Compounds Used

Element of Compound	Symbol	State	Category	Energy Source	Metal Reactivity
Magnesium	Mg	solid	metal	Initial heat (spark)	High
Sodium	Na	solid	metal		Very High
Iron	Fe	solid	metal		Moderate
Carbon	C	solid	non-metal		

Oxygen	O_2	Gas	non-metal		
Hydrogen	H_2	Gas	non-metal		
Chlorine	Cl_2	Gas	non-metal		
Hydrochloric Acid	HCl	liquid	acid		
Sodium Hydroxide	NaOH	liquid	base		
Silver Nitrate	$AgNO_3$	liquid	salt solution		
Sodium Chloride	NaCl	liquid	salt solution		
Copper (II) Sulfate	$CuSO_4$	liquid	salt solution		
Methane	CH_4	gas	fuel		
Water	H_2O	liquid	solvent	Electricity (high)	
Calcium Carbonate	$CaCO_3$	solid	carbonate	Heat (high)	
Zinc	Zn	solid	metal		Moderate to High
Calcium	Ca	solid	metal		High

3. Reaction Types

A. Synthesis

- If ElementA is “metal” AND ElementB is “non-metal”
- Then product is “Ionic Compound”, reaction type is “synthesis”, and energy flow is “exothermic (energy release)”
- All Possibilities:

IF (Reactant s)	THEN (Product)	Balanced Equation	Visual Effect	Hint (if only 1 reactant is placed)
Mg + O₂	MgO	2Mg + O ₂ → 2MgO	Intense White Flash	Magnesium burns only when oxygen is present. Check if a gas that supports burning is added.
Fe + O₂	Fe₂O₃	4Fe + 3O ₂ → 2Fe ₂ O ₃	Glow/Color change to Rust	Iron reacts slowly with the air. Try adding oxygen or heat to make the reaction faster.
Mg + Cl₂	MgCl₂	Mg + Cl ₂ → MgCl ₂	White Solid Formation	Magnesium can form a salt with a halogen. Try adding Chlorine gas.
Ca + O₂	CaO	2Ca + O ₂ → 2CaO	Bright Glow/Heat	Calcium reacts with Oxygen to form a metal oxide.

$C + O_2$	CO_2	$C + O_2 \rightarrow CO_2$	Heat Release	Carbon reacts with Oxygen during burning.
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B. Decomposition

- IF ReactantA is “compound” AND Energy Input is “high”
- THEN Reactant Type is “Decomposition Reaction”, Elements are split, and BUBBLES show (as a form of gas release)
- All possibilities:

IF (Reactant)	Energy Input	THEN (Products)	Balanced Equation	Visual Effect	Hint (if no energy is applied)
$H_2O (+$ Electricity)	Electricity (High)	$H_2 + O_2$	$2H_2O \rightarrow 2H_2 + O_2$	Constant Bubbles	Water is stable. You need electricity to split it into gases.

CaCO₃ (+ Heat)	Heat (high)	CaO + CO₂	$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$	Gas release (Bubbles)	Calcium Carbonate requires “High Heat” to undergo thermal decomposition.
NaCl (Molten)	Electricity (high)	Na + Cl₂	$2\text{NaCl} \rightarrow 2\text{Na} + \text{Cl}_2$	Metal formation at the electrode	Sodium Chloride has very strong ionic bonds. Thermal heat isn't enough; try using Electricity.

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C. Single Displacement

- IF ReactantA is “Moderate” or “High” Metal Reactivity AND ReactantB is “Acid”
 - THEN Reaction Type is “Single Displacement”, H₂ is released IF ReactantA OR ReactantB is HCl and BUBBLES show ○ OR Cu is released if ReactantA OR ReactantB is CuSO₄
 - All possibilities:

IF (Reactants)	THEN (Products)	Balanced Equation	Visual Effect	Hint (If metal is too weak)
Zn + HCl	ZnCl ₂ + H ₂	Zn + 2HCl → ZnCl ₂ + H ₂	Vigorous Bubbling	This acid needs a 'Reactive Metal' to release its hydrogen. Try Zinc.
Mg + HCl	MgCl ₂ + H ₂	Mg + 2HCl → MgCl ₂ + H ₂	High Heat/Rapid Bubbles	Magnesium is very reactive with acids.
Fe + CuSO ₄	FeSO ₄ + Cu	Fe + CuSO ₄ → FeSO ₄ + Cu	Iron turns Reddish/Brown	Iron is more reactive than Copper. It can replace Copper out of the solution.
Zn + CuSO ₄	ZnSO ₄ + Cu	Zn + CuSO ₄ → ZnSO ₄ + Cu	Solution fades from Blue to Clear	A displacement is possible here. Check if Zinc is stronger than Copper.

D. Double Displacement

- IF ReactantA is "Salt Solution" AND ReactantB is "Salt Solution" •
THEN Reaction Type is "Double Displacement", create a "Precipitate"

- All Possibilities:

IF (Reactant s)	THEN (Products)	Balanced Equation	Visual Effect	Hint (Contextual Situations)
$\text{AgNO}_3 + \text{NaCl}$	$\text{AgCl} + \text{NaNO}_3$	$\text{AgNO}_3 + \text{NaCl} \rightarrow \text{AgCl(s)} + \text{NaNO}_3$	Milk-white Precipitate	Try mixing two clear salt solutions to see if an insoluble solid forms.
$\text{AgNO}_3 + \text{HCl}$	$\text{AgCl} + \text{HNO}_3$	$\text{AgNO}_3 + \text{HCl} \rightarrow \text{AgCl(s)} + \text{HNO}_3$	White Cloudy Particles	Silver ions react strongly with chlorides. Is there a chloride source nearby?

E. Neutralization

- IF ReactantA is "Acid" AND ReactantB is "Base"
- THEN Reaction Type is "Neutralization", Output "Water + Salt", and
show Energy Indicator (Heat Release).

IF (Reactant s)	THEN (Products)	Balanced Equation	Visual Effect	Hint
HCl + NaOH	NaCl + H ₂ O	HCl + NaOH → NaCl + H ₂ O	Energy Bar: Max Heat	When an acid reacts with a base, they cancel each other out and form water and salt.

F. Combustion

- IF ReactantA is "CH₄" AND ReactantB is "Oxygen"
- THEN Reaction Type is "Combustion", show Flames, and set Energy

Indicator to "Exothermic".

IF (Reactant s)	THEN (Products)	Balanced Equation	Visual Effect	Hint (if oxygen is missing)
CH ₄ + O ₂	CO ₂ + H ₂ O	CH ₄ + 2O ₂ → CO ₂ + 2H ₂ O	Blue Flame Animation	Methane is a fuel, but fire needs an oxidizer. Add Oxygen gas.

Mg + O₂	MgO	2Mg + O ₂ → 2MgO	Bright Flame (also Synthesis)	Magnesium is a combustible metal, but fire needs an oxidizer. What gas from the inventory helps things burn?
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