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Precipitation and Solubility with the Valence card game

A 50-minute lesson on solubility, precipitation reactions and ionic equations for Year 10 (Grades 10–11)

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valence-2b95b.web.app/get

Valence is a free chemistry card game: every card is an element, and students combine cards into real compounds to fight. In **Act 5**, the Wastewater Treatment Plant, each enemy is a dissolved ion with an **ion gauge**, emptied by adding the partner ion that forms a precipitate.

Learning goals

1. Explain the terms soluble, insoluble, precipitate and spectator ion.
2. Use simple solubility rules to predict whether mixing two solutions gives a precipitate, and name it.
3. Write ionic equations with state symbols for precipitation reactions (an extension for Year 10, core in Grade 11).
4. Explain how precipitation is used to test water and treat wastewater, and two ways the game is simpler than real chemistry.

HOW THE ION GAUGE WORKS IN ACT 5

- Each enemy's gauge holds **2 or 3 batches** of one dissolved ion. Every attack with a compound that supplies the **partner ion** settles one batch as a precipitate.
- Cards that work on each ion:

Cl^-	$AgNO_3$, AgF
Ag^+	chlorides such as NaCl, KCl, HCl (not Cl_2)
SO_4^{2-}	$BaCl_2$, $Ba(OH)_2$
Ba^{2+}	H_2SO_4, $CuSO_4$, $MgSO_4$
Ca^{2+}	Na_2CO_3, CO_2
Cu^{2+}	NaOH, LiOH, $Ca(OH)_2$, $Ba(OH)_2$, H_2S
Fe^{3+}	NaOH, LiOH, $Ca(OH)_2$, $Ba(OH)_2$

- When the gauge is empty, the enemy skips a turn, loses its armour, takes 25% more damage and deals 30% less.
- The boss, the Copper Sulfate Wastewater Hydra, starts as Cu^{2+}. At half health its sulfate head wakes: a new SO_4^{2-} gauge, more armour and strength; any earlier weakening ends.



Act 5 enemies and, on the right, the boss.

Curriculum links

- **Australia**: Year 10 patterns in synthesis, decomposition and displacement reactions, AC9S10U07
- **New Zealand**: NCEA Level 1 Chemistry and Biology 92021 (chemical reactions in context, including precipitation); Level 2 Chemistry 91911 (qualitative analysis, solubility rules)
- **Ontario**: Grade 10 SNC2D C2.5, C3.3 (a precipitate as evidence of chemical change); Grade 11 SCH3U C2.6, E2.5, E3.4 (precipitates, net ionic equations)
- **British Columbia**: Science 10, single and double replacement reactions; Chemistry 11, using a solubility chart to predict precipitation

Ontario says "double displacement", BC "double replacement". Not endorsed by any education authority.

Before class

- Install Valence: free, no ads, no account, works offline.
- **Act 5 comes after Acts 1 to 4**, so few students reach it in one lesson. Parts A, B and D need no game; Part C uses the enemies on page 3.
- Optional demo (eye protection, gloves): dilute (about 0.1 mol/L) silver nitrate into salt water; dilute sodium hydroxide into copper sulfate. Silver nitrate stains skin and NaOH harms eyes. Collect the waste as heavy-metal waste, not down the sink.
- If asked: in the game CO_2 settles Ca^{2+} at once. Really CO_2 gives carbonate only in basic solution (limewater), and excess CO_2 dissolves $CaCO_3$ again.
- Print pages 2 and 3 for each student. Page 4 is the answer key.

Lesson plan

5 min	Hook. "Two clear solutions make a white cloud. Where did the solid come from?"
12 min	Part A: soluble or insoluble, using the solubility table.
13 min	Part B: swap the ion partners to predict precipitates, then write ionic equations and spot the spectator ions.
10 min	Part C: match each Act 5 enemy to its partner ion, precipitate and a card that works.
10 min	Discuss D1 and D2 (D3 is an extension), then the exit ticket at the bottom of page 3.

STUDENT WORKSHEET

Precipitation and Solubility

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Name _____ Class _____ Date _____

Soluble
Dissolves in water. Its ions spread out and the solution stays clear.

Insoluble
Does not dissolve in water (or hardly at all).

Precipitate
An insoluble solid that forms when two solutions are mixed.

Spectator ion
An ion that stays dissolved and takes no part in the reaction.

A Soluble or insoluble?

COMPOUNDS CONTAINING	USUALLY	EXCEPTIONS
Li^+, Na^+, K^+ (group 1), NH_4^+ or NO_3^-	**soluble**	none
Cl^- (chlorides)	**soluble**	AgCl is insoluble
SO_4^{2-} (sulfates)	**soluble**	$BaSO_4$ is insoluble ($CaSO_4$ only slightly soluble)
CO_3^{2-} (carbonates)	**insoluble**	group 1 and NH_4^+ carbonates are soluble
OH^- (hydroxides)	**insoluble**	group 1 and $Ba(OH)_2$ are soluble ($Ca(OH)_2$ slightly)

A1. Write **S** (soluble) or **I** (insoluble) under each compound. Check the first row of the table before the others.

$NaNO_3$	AgCl	$CuSO_4$	$BaSO_4$	$CaCO_3$	KOH	$Cu(OH)_2$	$MgCl_2$	$Fe(OH)_3$	Na_2CO_3

A2. Sea water is full of Na^+ and Cl^- ions, yet it is clear. Use the table to explain why.

B Predicting a precipitate

Swap the partners. List the four ions, swap partners, and check each new pair in the table. An insoluble pair is the precipitate; the other ions are spectators.

Example. $AgNO_3(aq)$ + NaCl(aq): new pairs AgCl and $NaNO_3$. AgCl is insoluble, so a white precipitate forms. Ionic equation: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$. Spectator ions: Na^+ and NO_3^-.

B1. Complete the table. Colours: AgCl, $BaSO_4$ and $CaCO_3$ are white; $Cu(OH)_2$ is pale blue; $Fe(OH)_3$ is red-brown.

SOLUTIONS MIXED	NEW PAIRS	PRECIPITATE, COLOUR	SPECTATOR IONS
$BaCl_2$ + Na_2SO_4			
$CuSO_4$ + NaOH			
$CaCl_2$ + Na_2CO_3			
KNO_3 + NaCl			
$FeCl_3$ + KOH			

B2. Write the ionic equation, with state symbols, for the second and fifth mixtures.

B3. A few drops of dilute nitric acid, then silver nitrate, are added to tap water. It turns slightly cloudy white. Which ion does the tap water contain?



STUDENT WORKSHEET

Precipitation and Solubility



C The Wastewater Treatment Plant (Act 5)

C1. Each enemy is a dissolved ion. Cards: $AgNO_3$ | $NaCl$ | $BaCl_2$ | $MgSO_4$ | Na_2CO_3 | $NaOH$

ENEMY	PARTNER ION	PRECIPITATE	COLOUR	A CARD THAT WORKS
 Salt Water Jellyfish Cl^-				
 Silver Plating Wastewater Ag^+				
 Hard Water Scale Golem Ca^{2+}				
 Sulfuric Wastewater Mist SO_4^{2-}				
 Blue-Green Copper Wastewater Cu^{2+}				
 Red Iron Wastewater Serpent Fe^{3+}				

C2. The boss is copper sulfate solution, $CuSO_4(aq)$. It starts as its Cu^{2+} head, and at half health the SO_4^{2-} head wakes. Which card from the list works on each head? Write an ionic equation for each.

C3. One card in the game works on **both** heads: barium hydroxide, $Ba(OH)_2$. Use its two ions to explain why, and name the two precipitates that form.

D Where the game simplifies



D1. In the game, every attack settles **one** batch, whatever the ion.

$Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3$ but $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$. How many OH^- ions do 10 Fe^{3+} ions need? And 10 Cu^{2+}?



D2. In the game, an empty gauge means the ions are gone.

In a real treatment tank the precipitate is still in the water, as a solid. Name two steps that get it out.



D3. *Extension.* The Hard Water Scale Golem is weak to acids.

Kettle scale and limestone are $CaCO_3$. Why does vinegar remove scale, and what does this tell you about whether a precipitate always stays solid?

EXIT TICKET



Potassium sulfate solution is mixed with barium nitrate solution. Name the precipitate, write the ionic equation with state symbols, and name the spectator ions.

Precipitation and Solubility

A Soluble or insoluble?

$NaNO_3$	$AgCl$	$CuSO_4$	$BaSO_4$	$CaCO_3$	KOH	$Cu(OH)_2$	$MgCl_2$	$Fe(OH)_3$	Na_2CO_3
S	I	S	I	I	S	I	S	I	S

The table is simplified: it leaves out lead and other ions. Watch for Na_2CO_3 marked insoluble because "carbonates are insoluble": the group 1 exception wins, which is why the first row is checked first.

A2. Sodium chloride is soluble (sodium compounds and chlorides are soluble), so the Na^+ and Cl^- ions stay dissolved and spread out. No solid forms, so the water stays clear. Accept "Na^+ and Cl^- do not form an insoluble pair".

B Predicting a precipitate

SOLUTIONS MIXED	NEW PAIRS	PRECIPITATE	SPECTATOR IONS
$BaCl_2 + Na_2SO_4$	$BaSO_4$, $NaCl$	$BaSO_4$, white	Na^+, Cl^-
$CuSO_4 + NaOH$	$Cu(OH)_2$, Na_2SO_4	$Cu(OH)_2$, pale blue	Na^+, SO_4^{2-}
$CaCl_2 + Na_2CO_3$	$CaCO_3$, $NaCl$	$CaCO_3$, white	Na^+, Cl^-
$KNO_3 + NaCl$	KCl, $NaNO_3$	none (both soluble)	K^+, NO_3^-, Na^+, Cl^-: no reaction, all stay dissolved
$FeCl_3 + KOH$	$Fe(OH)_3$, KCl	$Fe(OH)_3$, red-brown	K^+, Cl^-

Accept pairs written as names, and "blue" for $Cu(OH)_2$ or "orange-brown" for $Fe(OH)_3$.

B2. $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$ and $Fe^{3+}(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s)$. Watch for missing 2 and 3: the charges must balance on both sides.

B3. Chloride ions (Cl^-): $Ag^+ + Cl^- \rightarrow AgCl(s)$, white. This is the standard test for chloride in water. Nitric acid is added first so that carbonate in hard water cannot give a false white precipitate. Accept "chlorine" only if the student shows Cl^-.

C The Wastewater Treatment Plant (Act 5)

C1. Salt Water Jellyfish: Ag^+, $AgCl$, white, $AgNO_3$. Silver Plating Wastewater: Cl^-, $AgCl$, white, $NaCl$ or $BaCl_2$. Hard Water Scale Golem: CO_3^{2-}, $CaCO_3$, white, Na_2CO_3. Sulfuric Wastewater Mist: Ba^{2+}, $BaSO_4$, white, $BaCl_2$. Blue-Green Copper Wastewater: OH^-, $Cu(OH)_2$, pale blue, $NaOH$. Red Iron Wastewater Serpent: OH^-, $Fe(OH)_3$, red-brown, $NaOH$. $MgSO_4$ fits none of these six (in the game it works on the Barium Poison Cloud, Ba^{2+}). Also accept other cards the game marks green: AgF for Cl^-; any chloride such as KCl, HCl or $CaCl_2$ for Ag^+; CO_2 for Ca^{2+}; $Ba(OH)_2$ for SO_4^{2-}; $LiOH$, $Ca(OH)_2$ or $Ba(OH)_2$ for Cu^{2+} and Fe^{3+}; H_2S for Cu^{2+} (black CuS, so accept "black").

C2. Cu^{2+} head: $NaOH$, $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$. SO_4^{2-} head: $BaCl_2$, $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$.

C3. $Ba(OH)_2$ gives Ba^{2+} ions, which settle SO_4^{2-} as $BaSO_4$, and OH^- ions, which settle Cu^{2+} as $Cu(OH)_2$. Both precipitates form at once: $CuSO_4(aq) + Ba(OH)_2(aq) \rightarrow Cu(OH)_2(s) + BaSO_4(s)$. Here there are no spectator ions.

D Where the game simplifies

D1. 10 Fe^{3+} need 30 OH^-; 10 Cu^{2+} need 20 OH^-. The amount of the added ion depends on the charges, so real treatment plants measure how much to add.

D2. Let the solid settle to the bottom (sedimentation), then pour off the clear water (decanting) or filter it. The settled sludge is removed and disposed of safely. Accept "filtration" and "settling" or "centrifuging".

D3. Vinegar is an acid. It reacts with $CaCO_3$ to make soluble calcium ions, carbon dioxide and water, so the scale dissolves and fizzes. A precipitate can dissolve again if the conditions change, for example in acid. In the game, the copper and iron wastewater enemies resist acids for the same reason: their hydroxide precipitates dissolve in acid, so acid keeps Cu^{2+} and Fe^{3+} in solution.

Exit ticket. Barium sulfate, $BaSO_4$ (white). $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$. Spectator ions: K^+ and NO_3^-. Watch for KNO_3 given as the precipitate: nitrates and potassium compounds are always soluble.