CHEMDU · COMMUNITY CHEMISTRY · LEVEL 2 ADVANCED

LECTURE L2-6

Solutions & Solubility

Molarity in Your Mop Bucket: Why Bleach Dilution Saves Lives

Duration: 75 minutes

Advanced lecture script — pre-requisite: Level 1

HOOK (3 minutes)

Teacher holds up (or shows photos of):

A bleach bottle with dilution instructions

A lemonade mix (powdered drink mix)

A medicine dosing cup (mL markings)

A pool chlorine test kit

Teacher says: *"A bleach bottle says: 'Add 1/3 cup bleach per gallon of water for sanitizing.' If you add 2 cups instead, you create dangerous fumes and burn your skin.*

Lemonade mix says: 'Add 1 scoop per 8 oz of water.' If you add 3 scoops, you get sour, undrinkable lemonade — too concentrated.

- Today's question: How do chemists measure concentration — and how does that keep you safe? *

By the end of this session, you will be able to:

Calculate the molarity of a solution (like bleach)

Perform dilution calculations ($M_1V_1 = M_2V_2$)

Predict whether a precipitate (solid) will form when mixing two solutions

Understand solubility rules using household examples"

SEGMENT 1: Review from Level 1 and Previous Level 2 Lectures (5 minutes)

Teacher says: "Before we go deeper, let's recall what you already know."

Review from Level 1 (Solutions & Solubility - Basic)

Level 1 Concept	Definition	Household Example
Solution	A mixture where one thing dissolves completely into another	Saltwater
Solute	The thing that gets dissolved	Sugar, salt, lemonade powder
Solvent	The liquid that does the dissolving	Water, alcohol
Like dissolves like	Polar dissolves polar; non-polar dissolves non-polar	Water + salt (yes); water + oil (no)

Level 1 Concept	Definition	Household Example
Concentration	How much solute is in a given amount of solvent	Weak vs. strong lemonade
Dilution	Adding solvent to make a solution less concentrated	Adding water to juice

Review from Level 2-5 (Stoichiometry)

Level 2-5 Concept	Formula	Example
Moles	Mass ÷ Molar mass	10 g NaCl ÷ 58.44 g/mol = 0.171 mol
Molar mass	Sum of atomic masses	NaCl = 22.99 + 35.45 = 58.44 g/mol

> Quick check (show of hands / chat): "What is the molar mass of water (H_2O)?" (18.016 g/mol) "What is the molar mass of table salt (NaCl)?" (58.44 g/mol) "Does oil dissolve in water? Why or why not?" (No — oil is non-polar, water is polar)

Teacher: "Good. Now let's learn the most common way chemists measure concentration: molarity."

SEGMENT 2: Molarity — Moles per Liter (12 minutes)

> Teacher says: "Concentration tells you how much solute is dissolved in a given amount of solvent. Chemists use molarity (mol-LAIR-i-tee)."

Molarity (M) = number of moles of solute ÷ liters of solution

Units: M = mol/L (moles per liter)

Teacher: "A 1 M solution has 1 mole of solute dissolved in enough solvent to make 1 liter of solution."

Household Analogy: Lemonade

Concentration	Lemonade Example	Chemistry Example
Very low (dilute)	1 scoop per 2 gallons (barely sweet)	0.1 M NaCl (very salty? no — actually not salty)
Medium	1 scoop per 8 oz (normal)	1 M NaCl (quite salty)
Very high (concentrated)	3 scoops per 8 oz (too sweet)	5 M NaCl (very salty — can burn)

Teacher: "In chemistry, we use molarity to describe solutions like bleach, pool chlorine, and medicine."

Calculating Molarity — Step by Step

Formula:

M = moles of solute ÷ liters of solution

Step-by-step method:

Step	What to Do
Step 1	Convert grams of solute to moles (using molar mass).
Step 2	Convert volume to liters (if in mL, divide by 1000).
Step 3	Divide moles by liters.

Worked Example 1: Saltwater Solution

Problem: You dissolve 5.84 grams of NaCl (table salt) in enough water to make 0.500 liters of solution. What is the molarity?

Step 1: Convert grams to moles

Molar mass of NaCl = 58.44 g/mol

Step	Calculation
Moles = 5.84 g ÷ 58.44 g/mol	= 0.100 mol

Step 2: Volume is already in liters (0.500 L)

Step 3: Calculate molarity

Step	Calculation
M = 0.100 mol ÷ 0.500 L	= 0.200 M

Answer: The saltwater solution is 0.200 M NaCl.

Worked Example 2: Sugar (Sucrose) in Tea

Problem: You dissolve 34.2 grams of sugar ($C_{12}H_{22}O_{11}$, molar mass = 342.3 g/mol) in enough water to make 0.250 liters of solution. What is the molarity?

Step 1: Convert grams to moles

Step	Calculation
Moles = 34.2 g ÷ 342.3 g/mol	= 0.100 mol

Step 2: Volume = 0.250 L

Step 3: Calculate molarity

Step	Calculation
M = 0.100 mol ÷ 0.250 L	= 0.400 M

Answer: The sugar solution is 0.400 M (less sweet than 1 M — that would be very sweet).

Worked Example 3: Bleach (Sodium Hypochlorite)

Problem: Household bleach is about 5% sodium hypochlorite (NaOCl) by mass. That's approximately 0.75 M. But let's calculate: If you have 0.75 moles of NaOCl dissolved in 1.00 liter of water, what is the molarity?

Step 1: Moles already given (0.75 mol)

Step 2: Volume = 1.00 L

Step 3: Calculate molarity

Step	Calculation
M = 0.75 mol ÷ 1.00 L	= 0.75 M

Answer: Household bleach is about 0.75 M NaOCl.

Teacher: "Concentrated industrial bleach is much higher — up to 5 M or more. That's why it's dangerous. Always dilute concentrated chemicals."

Worked Example 4: Medicine (Liquid Ibuprofen)

Problem: Infant ibuprofen is 50 mg of ibuprofen per 1.25 mL of solution. What is the molarity? (Molar mass of ibuprofen = 206.3 g/mol)

Step 1: Convert mg to grams

Step	Calculation
50 mg = 50 ÷ 1000 = 0.050 g	

Step 2: Convert grams to moles

Step	Calculation
Moles = 0.050 g ÷ 206.3 g/mol	= 0.000242 mol

Step 3: Convert mL to liters

Step	Calculation
1.25 mL = 1.25 ÷ 1000 = 0.00125 L	

Step 4: Calculate molarity

Step	Calculation
M = 0.000242 mol ÷ 0.00125 L	= 0.194 M

Answer: Infant ibuprofen is about 0.19 M.

Partner talk (1 minute): "Tell your partner: If you dissolve 0.50 moles of salt in 2.0 liters of water, what is the molarity?" (0.50 ÷ 2.0 = 0.25 M)

SEGMENT 3: Dilution — Making a Solution Less Concentrated (12 minutes)

Teacher says: "Often, you start with a concentrated stock solution and need to dilute it for safe use. Bleach, pool chlorine, and many cleaners come concentrated."

Dilution: Adding solvent (usually water) to decrease concentration.

The Dilution Formula ($M_1V_1 = M_2V_2$)

$M_1V_1 = M_2V_2$

M_1 = initial molarity (concentrated)

V_1 = initial volume (what you take)

M_2 = final molarity (diluted)

V_2 = final volume (after adding water)

What the formula means: The total number of moles of solute stays the same ($M \times V$ = moles). You're just adding water.

Worked Example 1: Diluting Bleach for Cleaning

Problem: You have concentrated bleach at 5.0 M. You need 1.0 liter of 0.50 M bleach for cleaning. How much concentrated bleach do you need to use?

Step 1: Identify knowns

Variable	Value
M_1 (concentrated)	5.0 M
V_1 (what we want to find)	?
M_2 (diluted)	0.50 M
V_2 (final volume)	1.0 L

Step 2: Use $M_1V_1 = M_2V_2$

Step	Calculation
(5.0 M) × V_1 = (0.50 M) × (1.0 L)	
V_1 = (0.50 × 1.0) ÷ 5.0	
V_1 = 0.50 ÷ 5.0	

Step	Calculation
$V_1 = 0.10$ L	

Step 3: Convert to mL if needed

0.10 L × 1000 = 100 mL

Answer: Take 100 mL (about ⅓ cup — matches the label) of concentrated bleach and add water to make 1.0 liter total.

Worked Example 2: Pool Chlorine

Problem: Pool chlorine shock is 12.0 M sodium hypochlorite. You need 5.0 liters of 3.0 M chlorine solution for your pool. How much concentrated shock do you need?

Step 1: Identify knowns

Variable	Value
M_1	12.0 M
V_1	?
M_2	3.0 M
V_2	5.0 L

Step 2: Use $M_1V_1 = M_2V_2$

Step	Calculation
$(12.0\text{ M}) \times V_1 = (3.0\text{ M}) \times (5.0\text{ L})$	
$V_1 = (3.0 \times 5.0) \div 12.0$	
$V_1 = 15.0 \div 12.0$	
$V_1 = 1.25$ L	

Answer: Take 1.25 liters of concentrated shock and add water to make 5.0 liters total.

Safety note: Always add chlorine to water, not water to chlorine. Adding water to concentrated chlorine can cause splashing and dangerous fumes.

Worked Example 3: Making Lemonade from Concentrate

Problem: You have frozen lemonade concentrate. The instructions say: "Mix 1 can concentrate with 4 cans water." If the concentrate is 4.0 M in sugar, what is the final sugar concentration?

Step 1: Identify knowns

Let 1 can = 1 volume unit. $V_1 = 1$ unit $M_1 = 4.0$ M $V_2 = 1 + 4 = 5$ units (concentrate + water)

Step 2: Use $M_1V_1 = M_2V_2$

Step	Calculation
$(4.0\ M) \times (1) = M_2 \times (5)$	
$M_2 = 4.0 \div 5$	
$M_2 = 0.80\ M$	

Answer: The final lemonade is 0.80 M sugar — much less sweet than the concentrate.

Worked Example 4: Medicine Dilution

Problem: A pharmacist has a 2.0 M solution of a liquid medicine. A child needs 0.50 M solution. How much water should be added to 100 mL of the concentrated medicine?

Step 1: Identify knowns

Variable	Value
M_1	2.0 M
V_1	100 mL
M_2	0.50 M
V_2	? (total final volume)

Step 2: Use $M_1V_1 = M_2V_2$

Step	Calculation
$(2.0\ M) \times (100\ mL) = (0.50\ M) \times V_2$	
$V_2 = (2.0 \times 100) \div 0.50$	
$V_2 = 200 \div 0.50$	
$V_2 = 400\ mL$	

Step 3: Find how much water to add

Step	Calculation
Water to add = $V_2 - V_1$	= 400 mL - 100 mL = 300 mL

Answer: Add 300 mL of water to 100 mL of concentrated medicine to make 400 mL of 0.50 M solution.

Safety note: Never do this without a pharmacist's instructions. Some medicines cannot be diluted with water (they may break down).

Partner talk (1 minute): *"Tell your partner: You have 100 mL of 6.0 M HCl (acid). You need 0.50 M HCl. Does the formula $V_2 = (M_1V_1) \div M_2 = (6.0 \times 100) \div 0.50 = 1200$ mL? How much water do you add? (1200 - 100 = 1100 mL)."*

SEGMENT 4: Solubility Rules — What Dissolves and What Doesn't (12 minutes)

> Teacher says: "Not everything dissolves in water. Solubility rules help you predict whether a compound will dissolve — and whether a reaction will produce a solid (called a precipitate — pree-SIP-i-tayt)."

Precipitate: A solid that forms when two solutions are mixed and a new insoluble compound is produced.

Solubility Rules (Simplified for Household Use)

Rule	Soluble (Dissolves)	Insoluble (Does NOT Dissolve)
Rule 1	All salts of Na^+, K^+, NH_4^+	(None — these always dissolve)
Rule 2	All nitrates (NO_3^-)	(None — nitrates always dissolve)
Rule 3	Most chlorides (Cl^-)	$AgCl$, $PbCl_2$, Hg_2Cl_2 (silver, lead, mercury chlorides)
Rule 4	Most sulfates (SO_4^{2-})	$CaSO_4$, $BaSO_4$, $PbSO_4$
Rule 5	Most carbonates (CO_3^{2-})	Most are insoluble except Na, K, NH_4
Rule 6	Most hydroxides (OH^-)	Most are insoluble except Na, K, NH_4 (and $Ca(OH)_2$ is slightly soluble)

Household examples:

Compound	Soluble?	Where You Find It
$NaCl$ (table salt)	Yes (Rule 1)	Kitchen
$NaHCO_3$ (baking soda)	Yes (Rule 1)	Kitchen
KNO_3 (saltpeter)	Yes (Rule 2)	Some fertilizers
$AgCl$ (silver chloride)	No (Rule 3)	Photographic film
$CaSO_4$ (gypsum)	Slightly soluble (Rule 4)	Drywall, plaster
$CaCO_3$ (chalk, limestone)	No (Rule 5)	Antacids, chalk
$Mg(OH)_2$ (milk of magnesia)	No (Rule 6)	Antacid

Using Solubility Rules to Predict Precipitates

Teacher: "When you mix two solutions, the ions exchange partners. If the new compound is insoluble, it forms a solid (precipitate)."

Example: Mixing Silver Nitrate and Table Salt

Silver nitrate ($AgNO_3$) is soluble (Rule 2 — nitrates always dissolve)

Sodium chloride (NaCl) is soluble (Rule 1 — Na^+ always dissolves)

When mixed, they exchange partners to form AgCl and $NaNO_3$

$NaNO_3$ is soluble (Rule 2)

AgCl is NOT soluble (Rule 3)

Result: A white solid (AgCl) precipitates out

Household connection: This is how some water filters remove silver ions from water.

Household Precipitate: Hard Water Scaling

Teacher: "Hard water contains calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. When you heat water, calcium carbonate ($CaCO_3$) forms and precipitates as white scale on your kettle, coffee maker, and shower head."

Reaction:

text

$Ca^{2+}(aq) + 2HCO_3^-(aq) \rightarrow CaCO_3(s) + CO_2(g) + H_2O(l)$

How to remove scale: Vinegar (acetic acid) dissolves $CaCO_3$ — that's why vinegar is good for cleaning coffee makers.

Household Precipitate: Soap Scum

Teacher: "Soap contains sodium stearate. Hard water contains calcium ions. When they mix, calcium stearate forms — a white, insoluble solid called soap scum. That's the ring in your bathtub."

> Partner talk (1 minute): "Tell your partner: If you mix $Pb(NO_3)_2$ (lead nitrate) and KI (potassium iodide), what precipitate forms? (PbI_2 — lead iodide — is a yellow solid)."

SEGMENT 5: Concentration Units for Household Products (8 minutes)

> Teacher says: "Molarity (M) is common in chemistry labs. But household products use other concentration units."

Concentration Unit	Formula	House Example
Percent by mass (% w/w)	(mass solute ÷ mass solution) × 100%	Vinegar is 5% acetic acid
Percent by volume (% v/v)	(volume solute ÷ volume solution) × 100%	Rubbing alcohol is 70% isopropyl alcohol
Parts per million (ppm)	(mass solute ÷ mass solution) × 1,000,000	Bottled water: "Calcium: 15 ppm"
Molarity (M)	moles solute ÷ liters solution	Bleach: 0.75 M NaOCl

Worked Example: Percent by Mass (Vinegar)

Problem: Vinegar is labeled as "5% acetic acid." How many grams of acetic acid are in 100 grams of vinegar?

Step	Calculation
Percent means grams per 100 g	5% = 5 g acetic acid per 100 g vinegar

Answer: 5 grams.

Worked Example: Percent by Volume (Rubbing Alcohol)

Problem: Rubbing alcohol is 70% isopropyl alcohol by volume. How many mL of isopropyl alcohol are in 500 mL of rubbing alcohol?

Step	Calculation
70% = 70 mL per 100 mL	For 500 mL: (70 ÷ 100) × 500 = 350 mL

Answer: 350 mL of isopropyl alcohol.

Worked Example: Parts per Million (ppm)

Problem: A water test shows 2.0 ppm of lead. How many grams of lead are in 1,000,000 grams of water?

Step	Calculation
2.0 ppm = 2.0 g lead per 1,000,000 g water	

Answer: 2.0 grams of lead per million grams of water.

Safety note: The EPA action level for lead in drinking water is 15 ppb (parts per billion) — much lower! 2.0 ppm is dangerously high.

SEGMENT 6: Putting It All Together — Household Solution Problems (6 minutes)

Teacher says: "Let's do one complete problem that uses everything from today's lecture."

Problem: You have a 12.0 M concentrated HCl solution (pool acid). You need 500 mL of 1.0 M HCl for cleaning. You also want to know the percent by mass of the diluted solution (density = 1.02 g/mL). HCl molar mass = 36.46 g/mol.

Part 1: How much concentrated HCl do you need?

Step	Calculation
$M_1V_1 = M_2V_2$	$(12.0\ \text{M}) \times V_1 = (1.0\ \text{M}) \times (0.500\ \text{L})$
$V_1 = (1.0 \times 0.500) \div 12.0$	= 0.0417 L = 41.7 mL

Answer Part 1: Take 41.7 mL of concentrated HCl.

Part 2: How much water do you add?

Step	Calculation
Water to add = 500 mL - 41.7 mL	= 458.3 mL

Answer Part 2: Add 458.3 mL of water.

Part 3: What is the percent by mass of the diluted solution?

Step	Calculation
1.0 M means 1.0 mol HCl per liter	
Mass HCl in 1 L = 1.0 mol × 36.46 g/mol	= 36.46 g
Mass of 1 L solution = 1000 mL × 1.02 g/mL	= 1020 g
Percent by mass = (36.46 ÷ 1020) × 100%	= 3.57%

Answer Part 3: The diluted HCl is about 3.6% by mass.

CLOSING — The 60-Second Challenge (5 minutes)

Teacher says: *"Pair up. Person A: 60 seconds — explain what molarity is and how to calculate it (use the saltwater example). Person B: 60 seconds — you need 1.0 liter of 0.10 M bleach from 5.0 M concentrated bleach. How much concentrate do you need? ($M_1V_1 = M_2V_2$: $5.0 \times V_1 = 0.10 \times 1.0 \rightarrow V_1 = 0.020$ L = 20 mL)."*

Final takeaway table (show on screen / read aloud):

You learned…	Household Example
Molarity (M) = moles ÷ liters	0.75 M bleach, 0.19 M infant ibuprofen
Dilution formula ($M_1V_1 = M_2V_2$)	100 mL of 5.0 M bleach + water to 1 L = 0.50 M

You learned...	Household Example
Solubility rules	NaCl dissolves (Rule 1); AgCl does not (Rule 3)
Precipitate = insoluble solid formed when mixing solutions	Hard water scale ($CaCO_3$), soap scum (calcium stearate)
Percent by mass	Vinegar: 5% acetic acid
Percent by volume	Rubbing alcohol: 70% isopropyl
Parts per million (ppm)	Lead in water: 2.0 ppm (dangerous)
Never add water to concentrated acid	Add acid to water slowly (safety)

Final line (preview of L2-7): "Next session: Acids & Bases (Advanced) — calculating pH, titrating vinegar to find its concentration, and understanding buffers (like your blood). See you then."

SUPPLEMENTARY MATERIALS FOR L2-6 (No Grade)

Resource	Household Connection	Description	How to Find It
PhET "Molarity" simulation	Interactive concentration visual	Drag solute, add water	Search "PhET molarity"
PhET "Dilution" simulation	See concentration change	Add water, watch Molarity decrease	Search "PhET dilution"
Solubility rules table	Printable reference	Predict precipitates	Search "solubility rules chart"
Hard water cleaning	Vinegar vs. scale	DIY cleaning experiment	Search "vinegar descaling coffee maker"

"This week, look at a household cleaner label. Does it say 'concentrated'? Does it give dilution instructions? For example: 'Mix 1 part cleaner with 10 parts water.' Next time, tell us what product you found and what the dilution ratio was."