SOLUTIONS

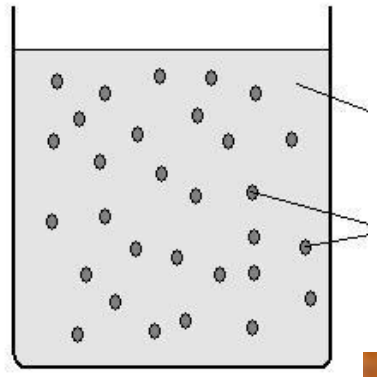
Lecture №

Date

The way of expressing the concentration of the solution

disperse systems

dispersion medium	dispersed phase

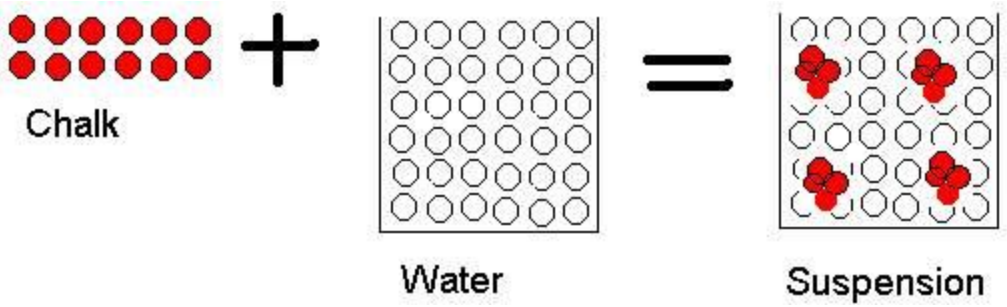


The **mixture** of **chalk** powder and **water**

water is a dispersion medium

chalk powder are dispersed phase

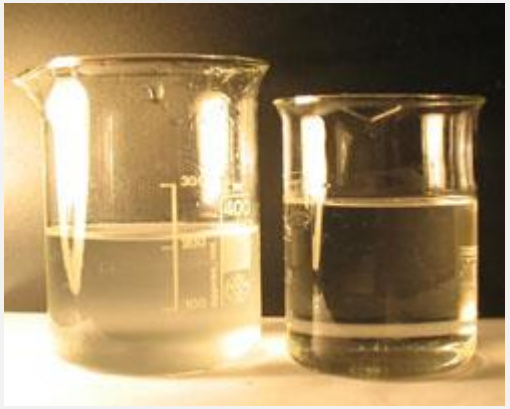
The Difference Between Solution & disperse systems (suspension)

- Sometimes when we mix substances they stay in clusters. We therefore say it is **<u>insoluble</u>** in water.
- E.g. Chalk + Water = Suspension
- 

- Eventually the particles sink to the bottom to form sediment.

	solute
solution	
	solvent

- The **solvent** is the component of a solution that does not change its state in forming the solution or the component that is present in excess.



sugar and water mixture

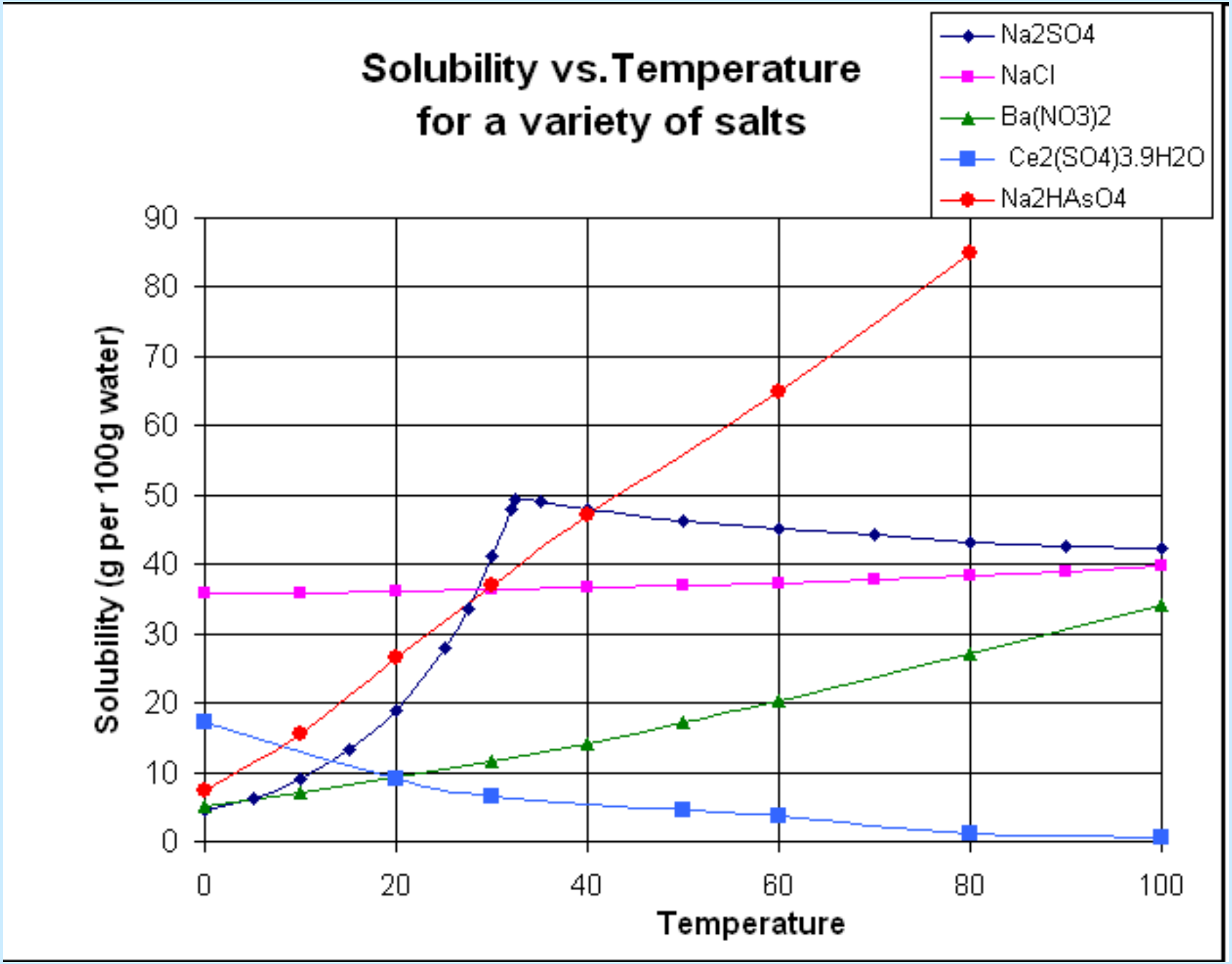
Water is a solvent,

Sugar is a solute

Solubility

- is the ability of a substance to dissolve in a solvent under these conditions

Solubility ratio
shows how many grams of substance can be dissolved in 100 g solvent at a given temperature.

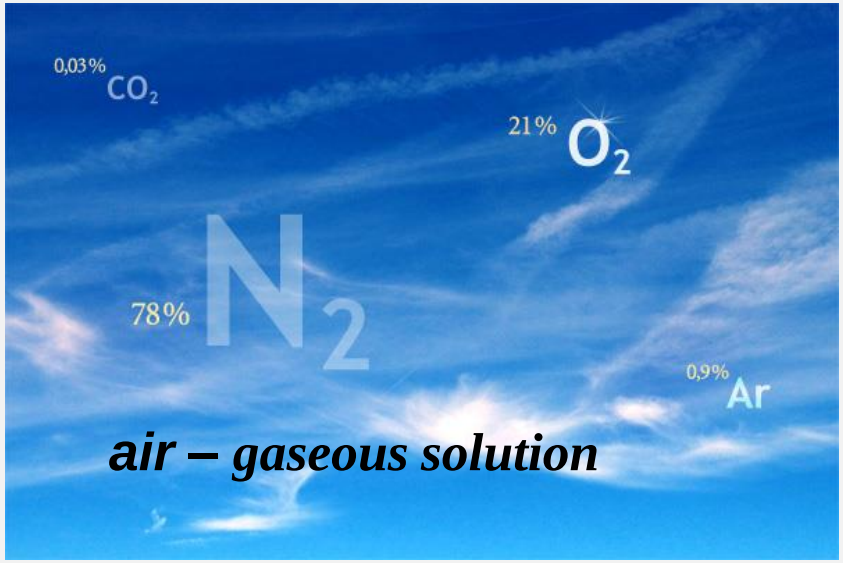

Solubility vs.Temperature
for a variety of salts
Na2SO4
NaCl
Ba(NO3)2
Ce2(SO4)3.9H2O
Na2HAsO4
Solubility (g per 100g water)
Temperature
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100

Solutions are classified according to several criteria:

- Depending on the nature of the solvent solutions are divided into aqueous and non-aqueous (alcohol, ammonia, benzene);

- Depending on the concentration of hydrogen ions solutions can be acidic, neutral and alkaline;

- Depending on the physical state of the solvent and solute solutions are divided into gas, liquid and solid.

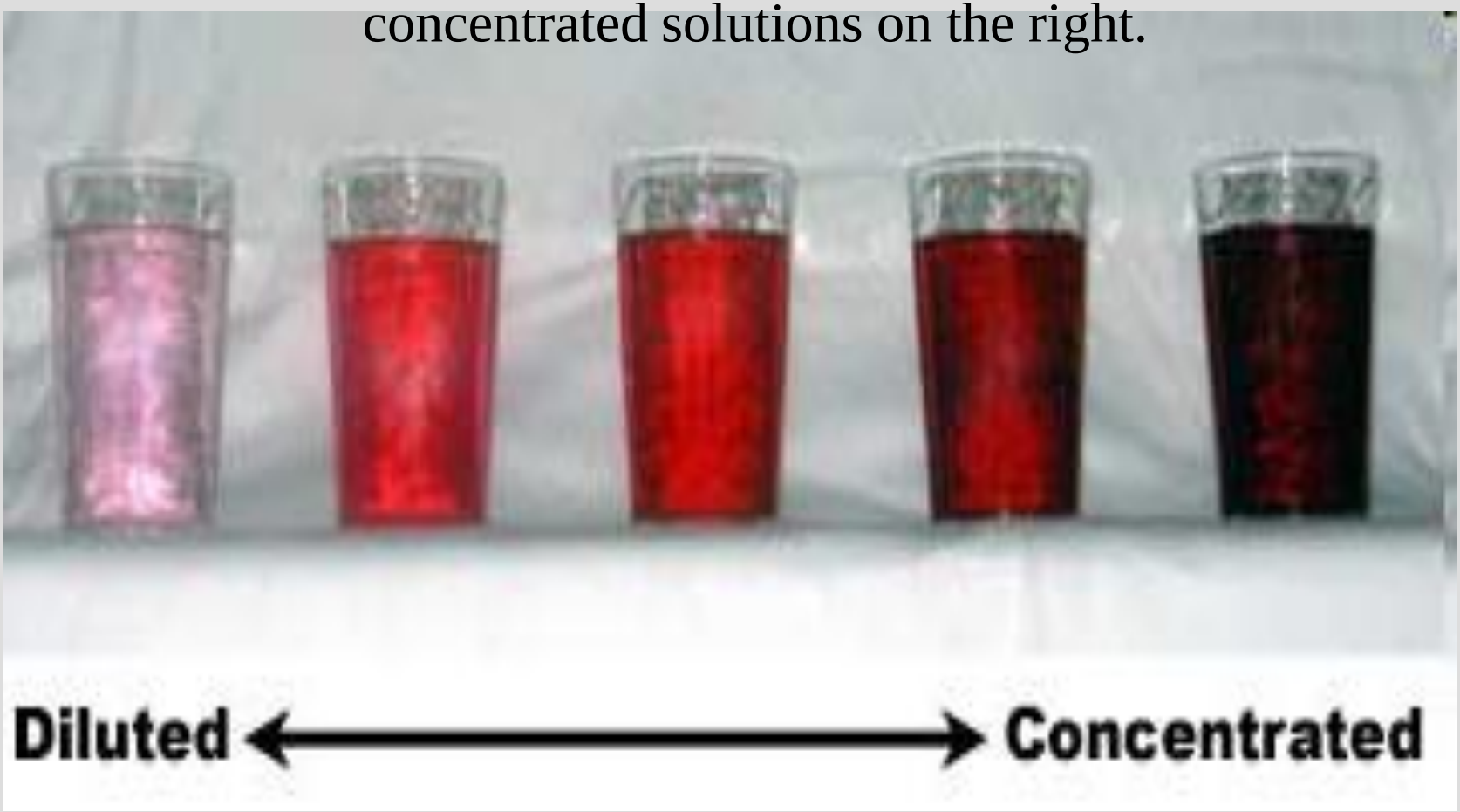


air – gaseous solution

- liquid solution

alloy– solid solution

These glasses containing red dye demonstrate qualitative changes in concentration.
The solutions on the left are more dilute, compared to the more concentrated solutions on the right.



Qualitative description of solutions

- saturated
- unsaturated
- concentrated
- dilute

Quantitative notation of solution

- mass percent ω,%;
- molar concentration (molarity) C_M, mol / L;
- molar concentration of equivalent C_N, mol / L;
- molal concentration C_m, mol / L;
- titer, g / ml.

Mass percent

- mass percent (ω) is the mass of solute present in the total mass of solute plus solvent, multiplied by 100 %.

$$\omega = \frac{\text{m(solute)}}{\text{m(solution)}} \times 100\% = \frac{\text{m(solute)}}{\text{m(solute)} + \text{m(solvent)}} \times 100\%$$

Task 1

40 g of sodium chloride is diluted in 160 g of water. Calculate the mass percent of the resulting solution.

$$m\,(\text{solution}) = m(H_2O) + m(NaCl) = 160 + 40 = 200\ (g)$$

$$\omega = \frac{40.0\text{g}\,(\text{NaCl})}{200.0\text{g}\,(\text{solution})} \times 100\% = 20\%\,(\text{NaCl})$$

MOLAR CONCENTRATION (MOLARITY)

- Molarity (C_M) is the number of moles of solute per one liter of the solution, [mol/L].

$$C_M = \frac{\text{moles of solute}}{\text{liters of solution}} = \frac{\nu \text{ solute}}{\text{V solution}}$$

The amount of the substance is

$$\nu = \frac{m}{M}$$

m – is the mass of substance, g

M – is the molar mass of the substance, g/mol

Task 2

Calculate the molarity of a solution prepared by dissolving 11.5 *g* of solid NaOH in water to make 1.50 L of solution.

$$C_M = \frac{\text{m NaOH (g)}}{\text{M NaOH (g/mol)} \times \text{V solution}}$$

M(NaOH) = Am(Na) + Am(O) + Am(H) = 23 + 16 + 1 = 40 (g/mol)

$$C_M = \frac{11.5\,(\text{g})}{40\,(\text{g/mol}) \times 1.5\,(\text{L})} = 0.192\,(\text{mol/L})$$

0.192 M NaOH

answer 0.192 mol of NaOH is contained per 1liter of solution

NORMALITY

- The molar concentration of equivalent (C_N) is the number of equivalents of solute per liter of solution.

$$C_N = \frac{\text{m solute (g)}}{E_m \text{ solute (g/mol)} \times \text{V solution (L)}} = \text{mol/L}$$

E m – is the equivalent mass of the solute

Compounds	Molar Mass	Equivalent Mass
HCl	36.5	36.5
HNO_3	63.0	63.0
H_2SO_4	98.0	49.0
H_3PO_4	98.0	32.7
NaOH	40.0	40.0
KOH	56.1	56.1

Task 3

A solution of sulfuric acid contains 86g of acid per liter of solution. Calculate the normality of this solution.

$$C_N = \frac{m(H_2SO_4)}{E_m(H_2SO_4) \times V(\text{solution})}$$

$$E_m(H_2SO_4) = \frac{M(H_2SO_4)}{2} = \frac{98}{2} = 49\,(\text{g/mol})$$

$$C_N = \frac{86}{49 \times 1} = 1.8\,(\text{mol/L})$$

The answer is **1.8*N* H_2SO_4 solution**

Neutralization Reaction

- The reaction between a solution of acid solution and a solution of base

equivalent of any acid will exactly neutralize the same equivalent of any base.

Equivalent of acid = Equivalent of base

C_N acid × V acid = C_N base × V base

Task 4

What volume of a 0.075*N* NaOH solution is required to react exactly with 0.135L of 0.45*N* phosphoric acid solution?

$$C_N \text{ acid} \times V \text{ acid} = C_N \text{ base} \times V \text{ base}$$

$$V_{base} = \frac{C_N \text{ acid} \times V \text{ acid}}{C_N \text{ base}} = \frac{0.45 \times 0.135}{0.075} = 0.81\,(\text{L})$$

Titer

- Titer of solution (T) is the amount of solute in grams per volume of solution in milliliters:

$$T = \frac{m\,(solute)}{V\,(solution)} = g/mL$$

Task 5

Calculate the titer of 10% solutions of sodium chloride (ρ = 1.071 g/ml).

$V_{solution}$ = 1L = 1000 mL

$$m_{(solution} = V \times \rho = 1000 \times 1.071 = 1071 \text{ g}$$

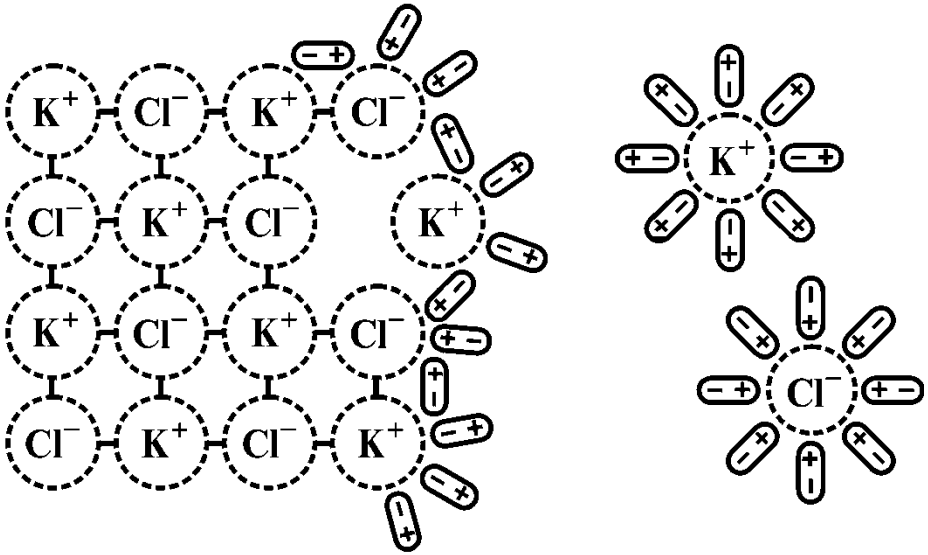
m (solution) —— 100 %

m (NaCl) —— 10 %

$$m(MnCl_2) = \frac{m(solution) \times 10\%}{100\ \%} = \frac{1071 \times 10}{100} = 107.1 \text{ g}$$

$$T = \frac{m(NaCl)}{V_{solution}} = \frac{107.1 \text{ gr}}{1000 \text{ mL}} = 0{,}1071 \text{ g/mL}$$

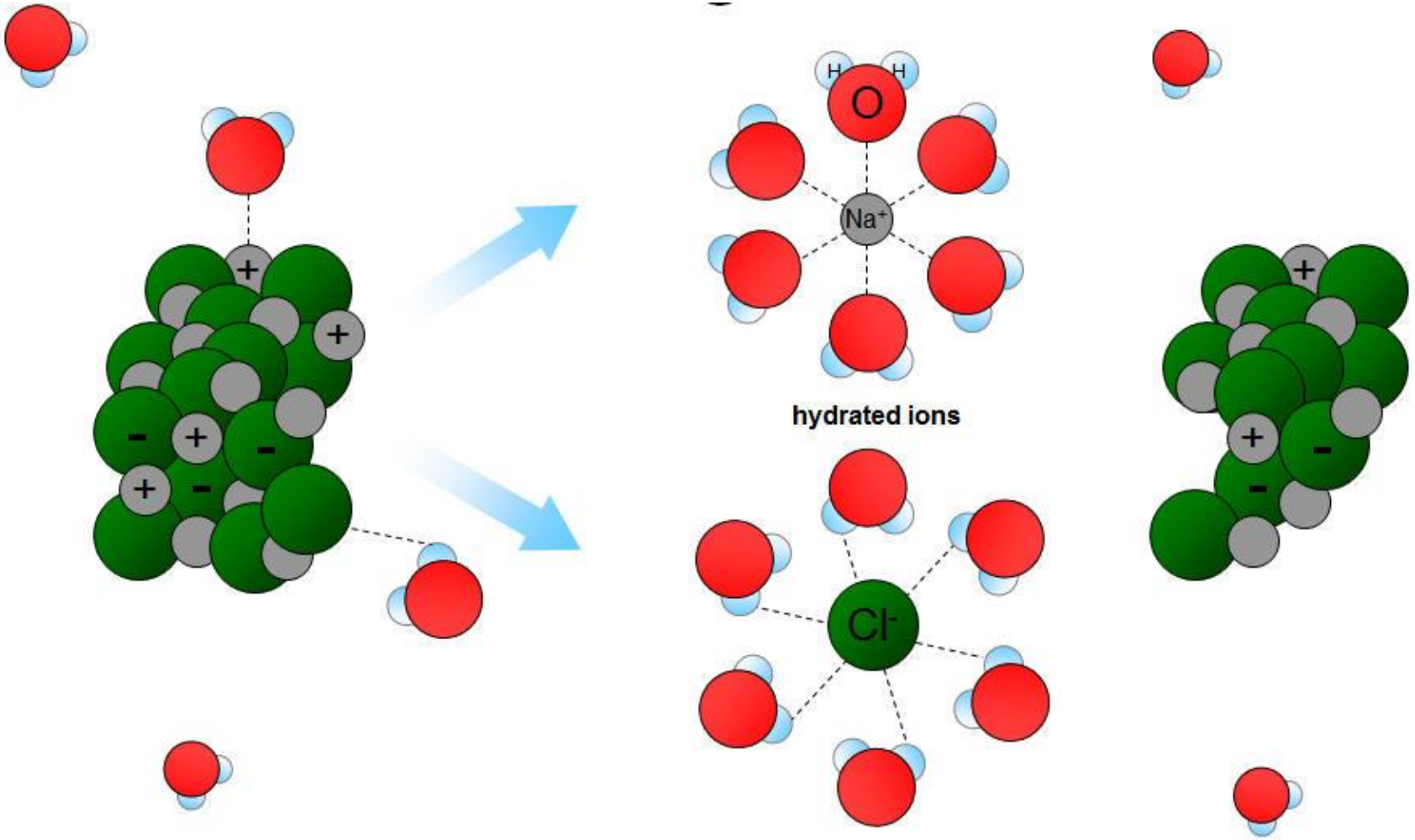
Solution process



Dissolving of an ionic crystal in water

attractions between the solvent molecules and the ions of the solid must overcome the large attractions between the oppositely charged ions

- a general rule is – **“like dissolves like”**.
- That is, polar solvents are more likely to dissolve ionic and polar solutes, and nonpolar solvents are more likely to dissolve nonpolar solutes.



A spontaneous distribution of substance, which is dissolved, between solvent molecules, is called ***dissolution***.
However, the dissolution cannot be regarded as a mechanical process, since the properties of the solute and solvent change in a formation of the solution.

Crystallization refers to the formation of solid crystals from a homogeneous solution. It is essentially a solid-liquid separation technique and a very important one at that.

Crystallization

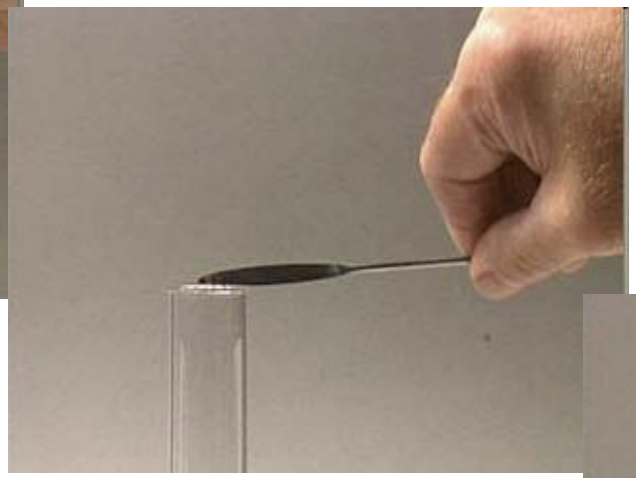
Solubility Table
Common Ionic Compounds

	Group 1				Group 2			Transition Metals					
	NH_4^+	Li^+	Na^+	K^+	Mg^{2+}	Ca^{2+}	Ba^{2+}	Al^{3+}	Fe^{3+}	Cu^{2+}	Ag^+	Zn^{2+}	Pb^{2+}
F^-	sol	sol	sol	sol	insol	insol	sl sol	sol	sl sol	sol	sol	sol	insol
Cl^-	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	insol	sol	sol
Br^-	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	insol	sol	sl sol
I^-	sol	sol	sol	sol	sol	sol	sol	sol			insol	sol	insol
OH^-	sol	sol	sol	sol	insol	sl sol	sol	insol	insol	insol		insol	insol
S^{2-}	sol	sol	sol	sol					insol	insol	insol	insol	insol
SO_4^{2-}	sol	sol	sol	sol	sol	sl sol	insol	sol	sol	sol	sl sol	sol	insol
CO_3^{2-}	sol	sol	sol	sol	insol	insol	insol				insol	insol	insol
NO_3^-	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol	sol
PO_4^{3-}	sol	insol	sol	sol	insol	insol	insol	insol	insol	insol	insol	insol	insol
CrO_4^{2-}	sol	sol	sol	sol	sol	sol	insol		insol	insol	insol	insol	insol
$CH_3CO_2^-$	sol	sol	sol	sol	sol	sol	sol	sl sol	sol	sol	sol	sol	sol

sol — soluble
sl sol — slightly soluble
insol — insoluble
(blank) — compound does not exist

Like dissolve like

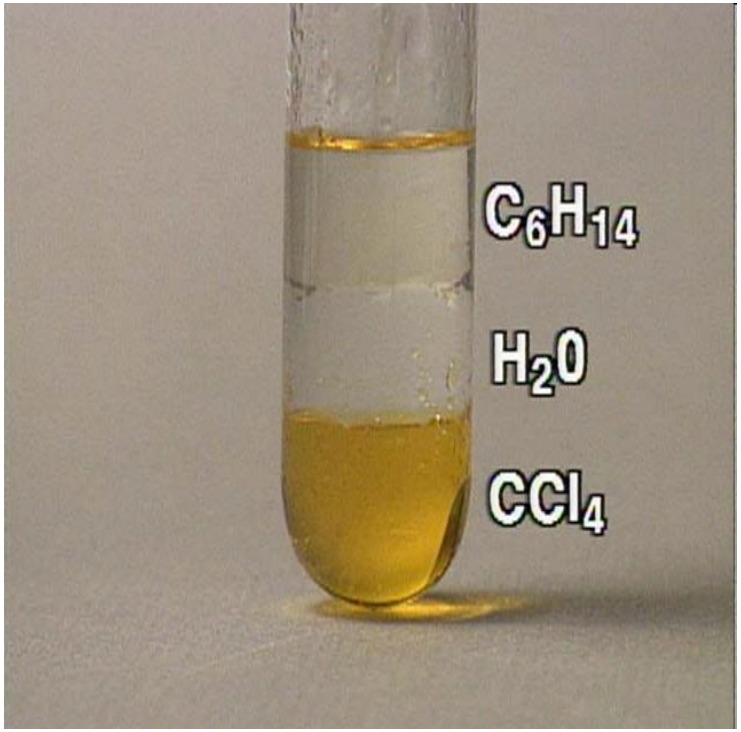
- Nonpolar **carbon tetrachloride** is poured into a test tube. When a nonpolar colored solid is added, the solid dissolves in the carbon tetrachloride.

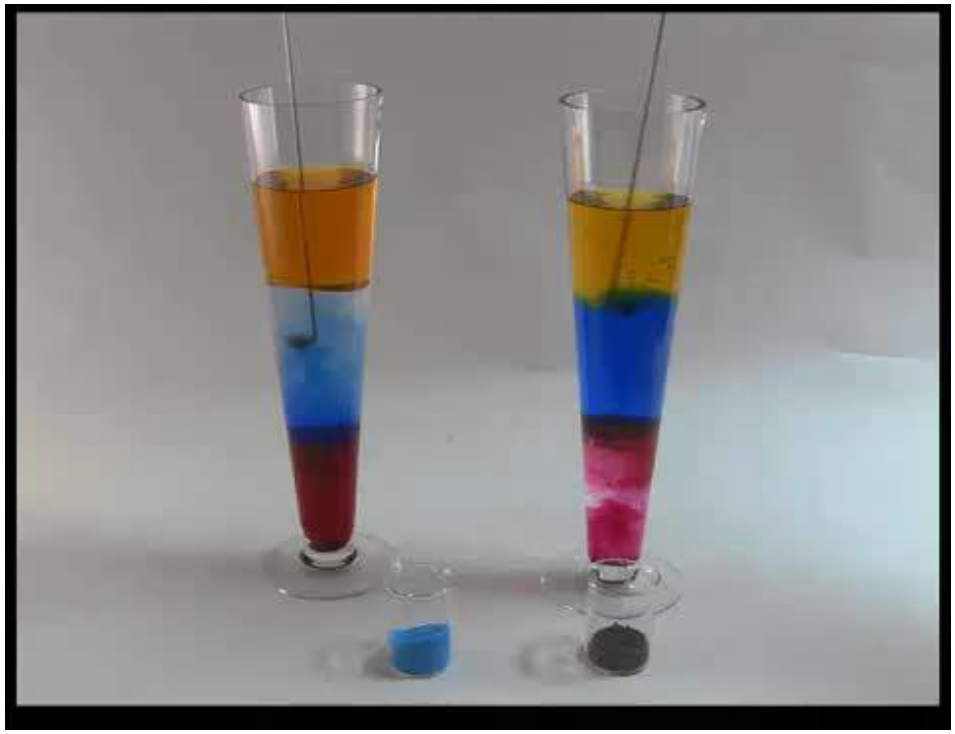


Like dissolve like

- When polar water is added to the test tube, it forms a layer on top of the carbon tetrachloride, since water is immiscible with, and less dense than carbon tetrachloride.
- When nonpolar hexane is added to the test tube, it forms a layer on top of the water, since hexane is immiscible with, and less dense than water.

- When the test tube is vigorously shaken, the two nonpolar liquids form a single layer at the bottom of the test tube, and the polar water layer sits above this layer.



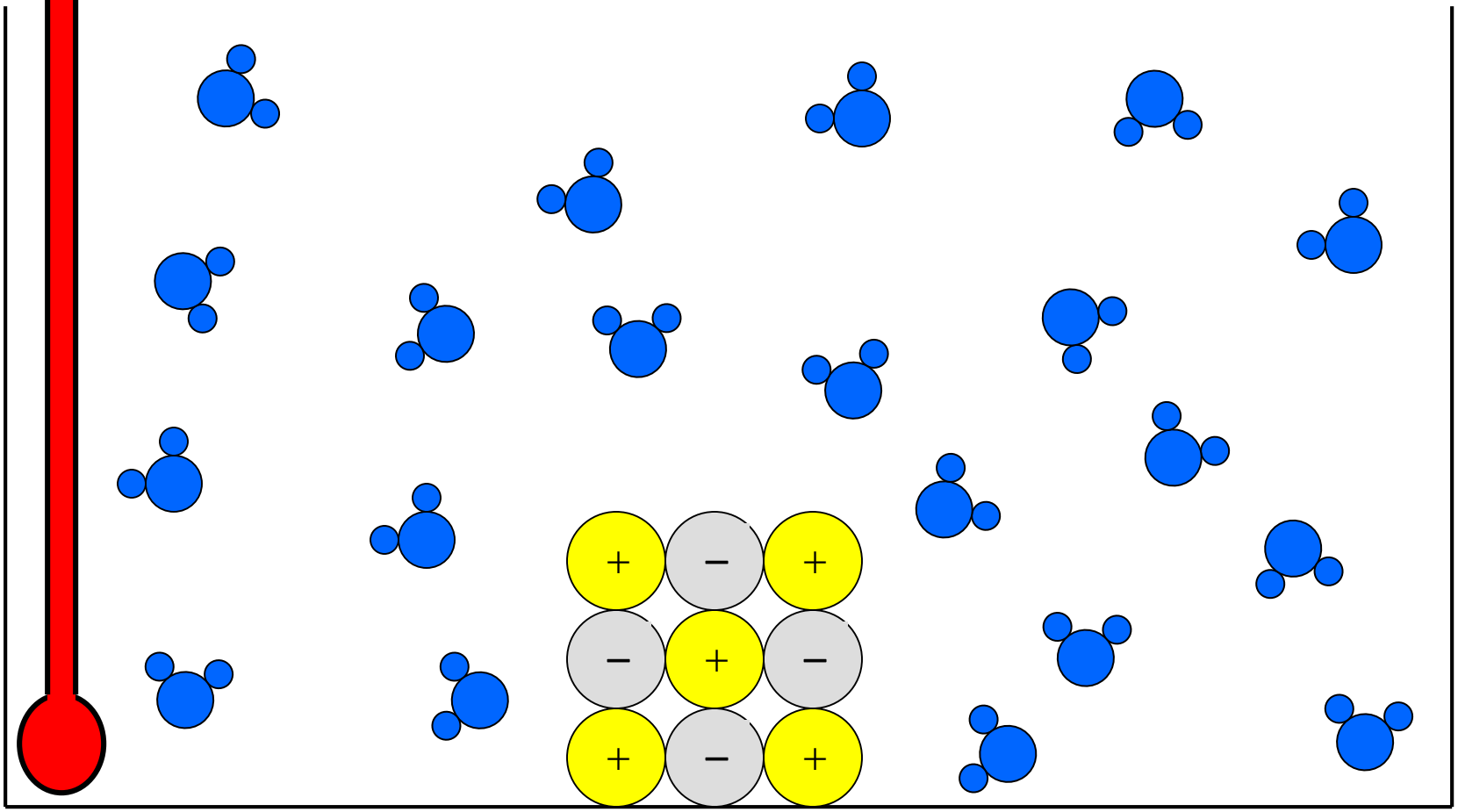


Heat of Solution

- A dissolving reaction is either ***endothermic*** or ***exothermic***!
- If there is a net gain of heat from the solvent by the solute, then the overall process is ***endothermic***.
- If there is a net release of heat from the solute to the solvent, then the overall process is ***exothermic***.
- Dissolving is described from the "point of view" of the ***solute***.
- If the reaction is ***endothermic***, then the solute will absorb heat from the solvent and the solvent's temperature will decrease.
- If the reaction is ***exothermic***, then the solute will release heat to the solvent and the solvent's temperature will increase.

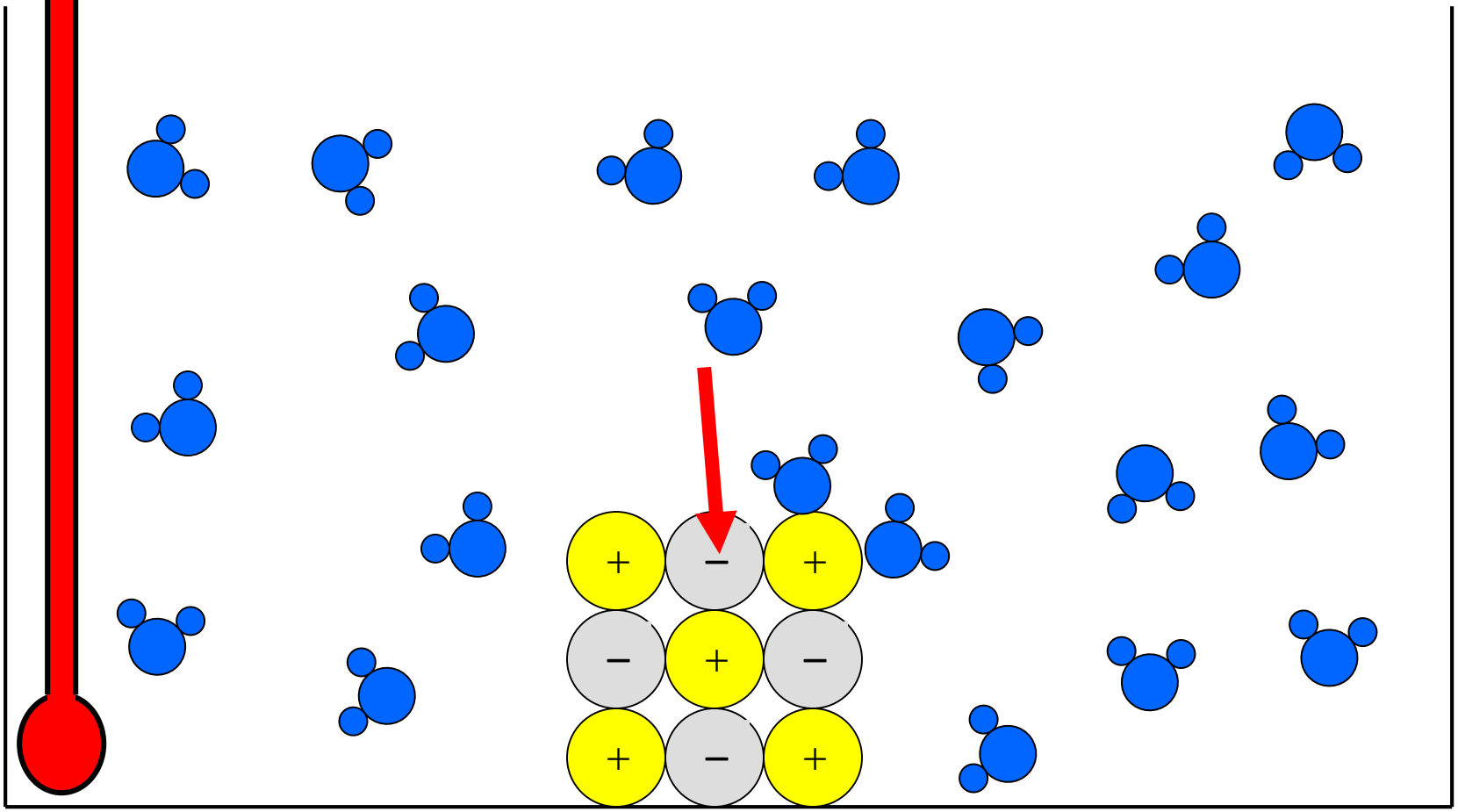
Heat of Solution

?thermic Dissolving Reaction



Heat of Solution

?thermic Dissolving Reaction



Heat of Solution

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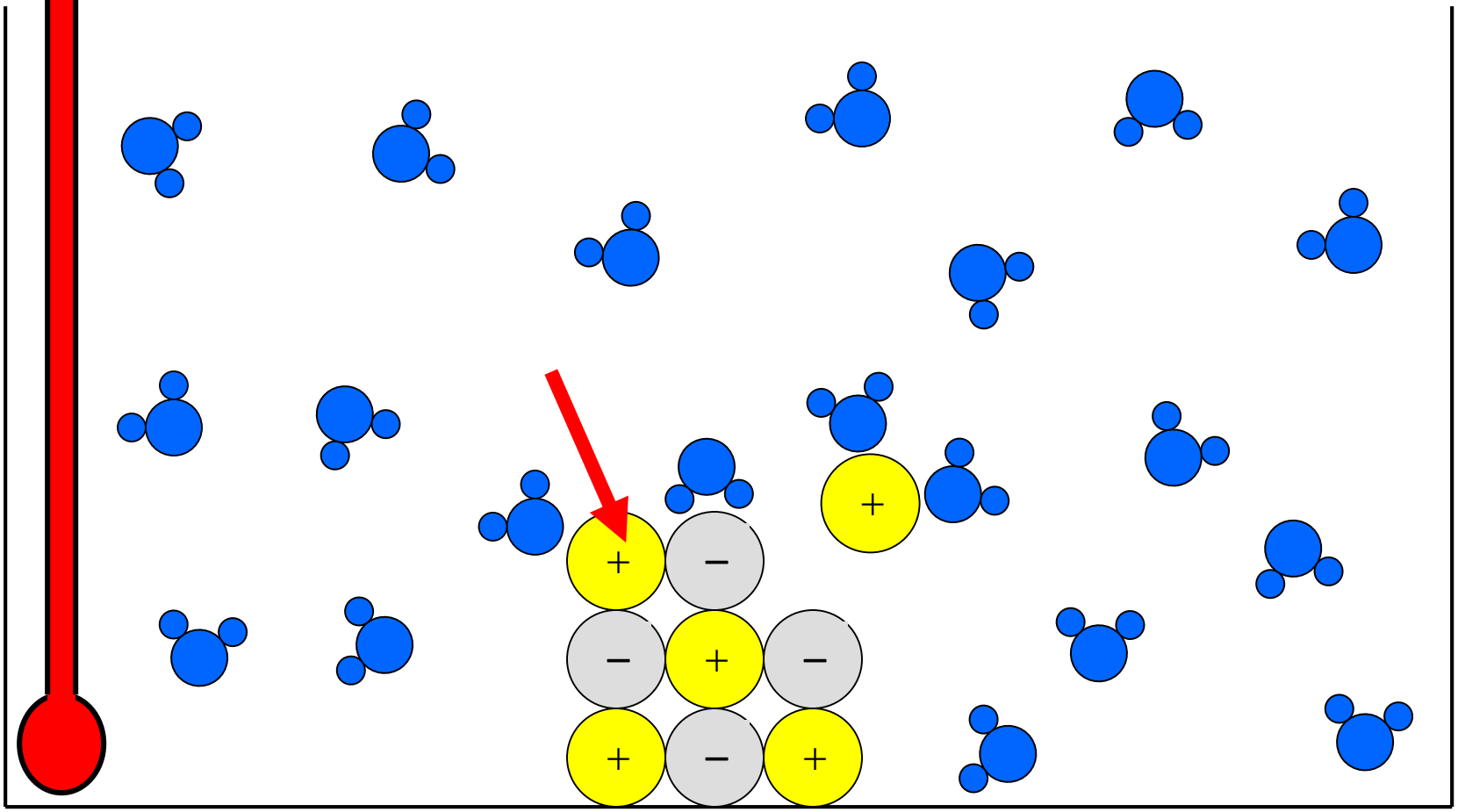

Heat of Solution

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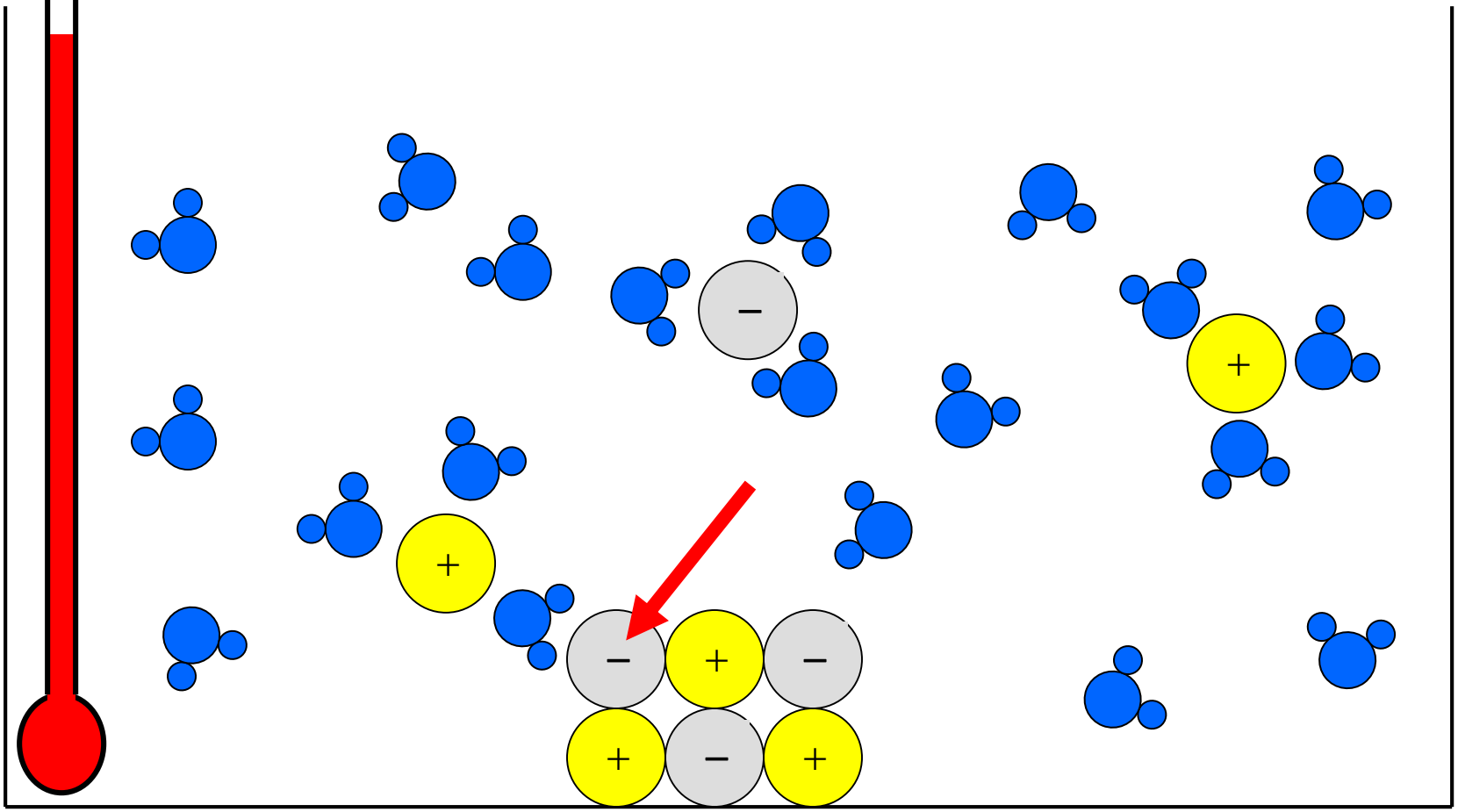
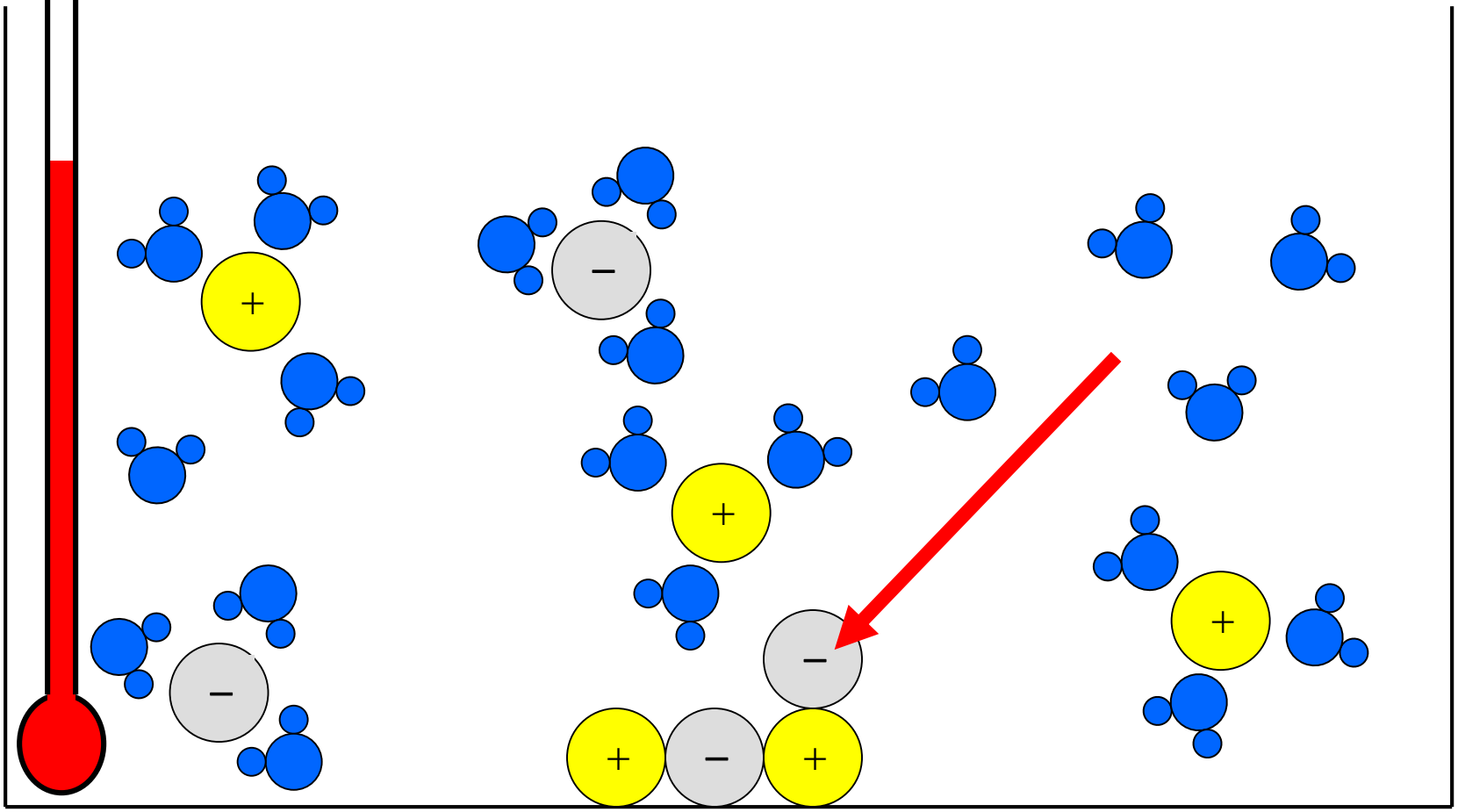


Heat of Solution

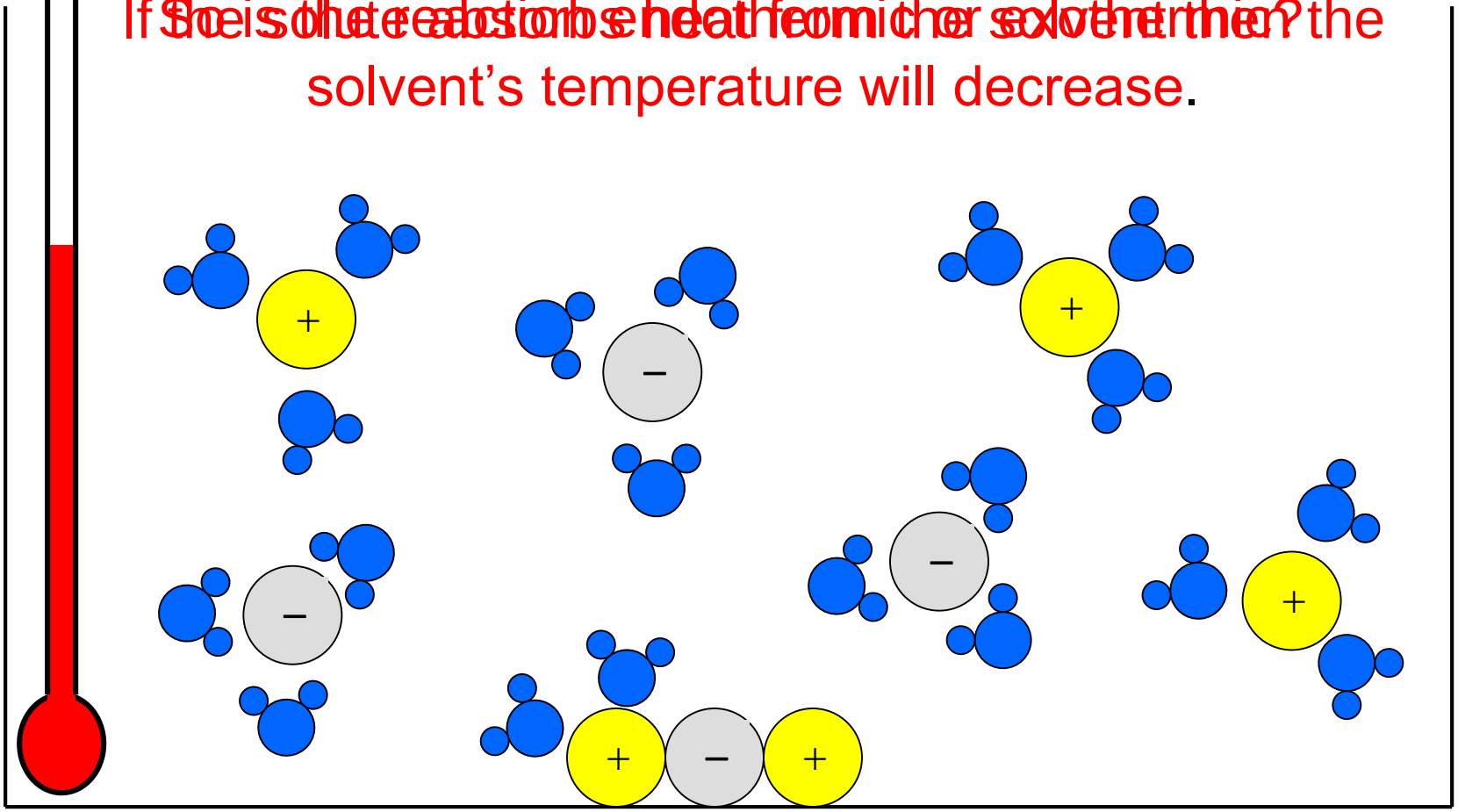
?thermic Dissolving Reaction



Heat of Solution

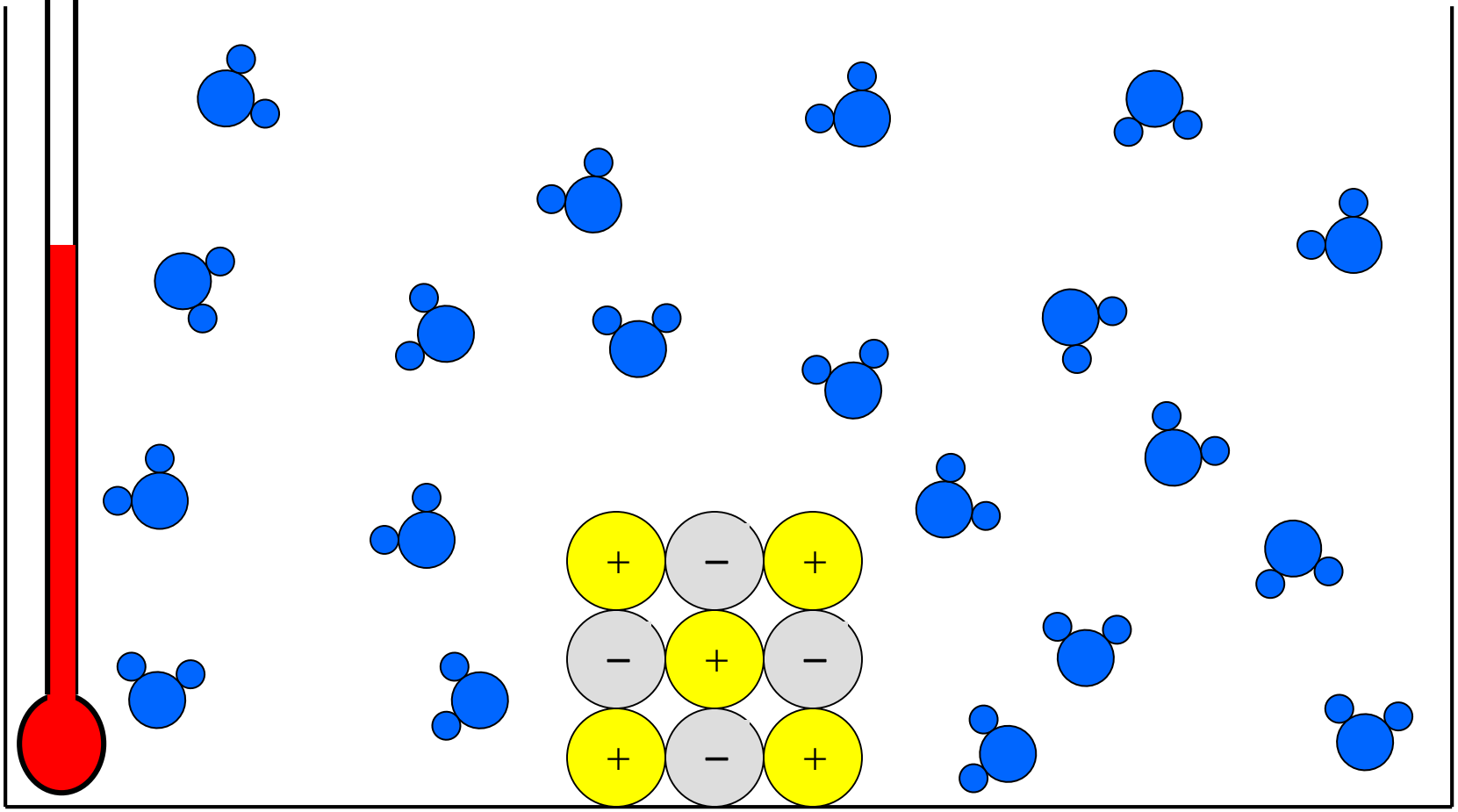
Endothermic Dissolving Reaction

If the reaction absorbs heat from the solvent, then the solvent's temperature will decrease.



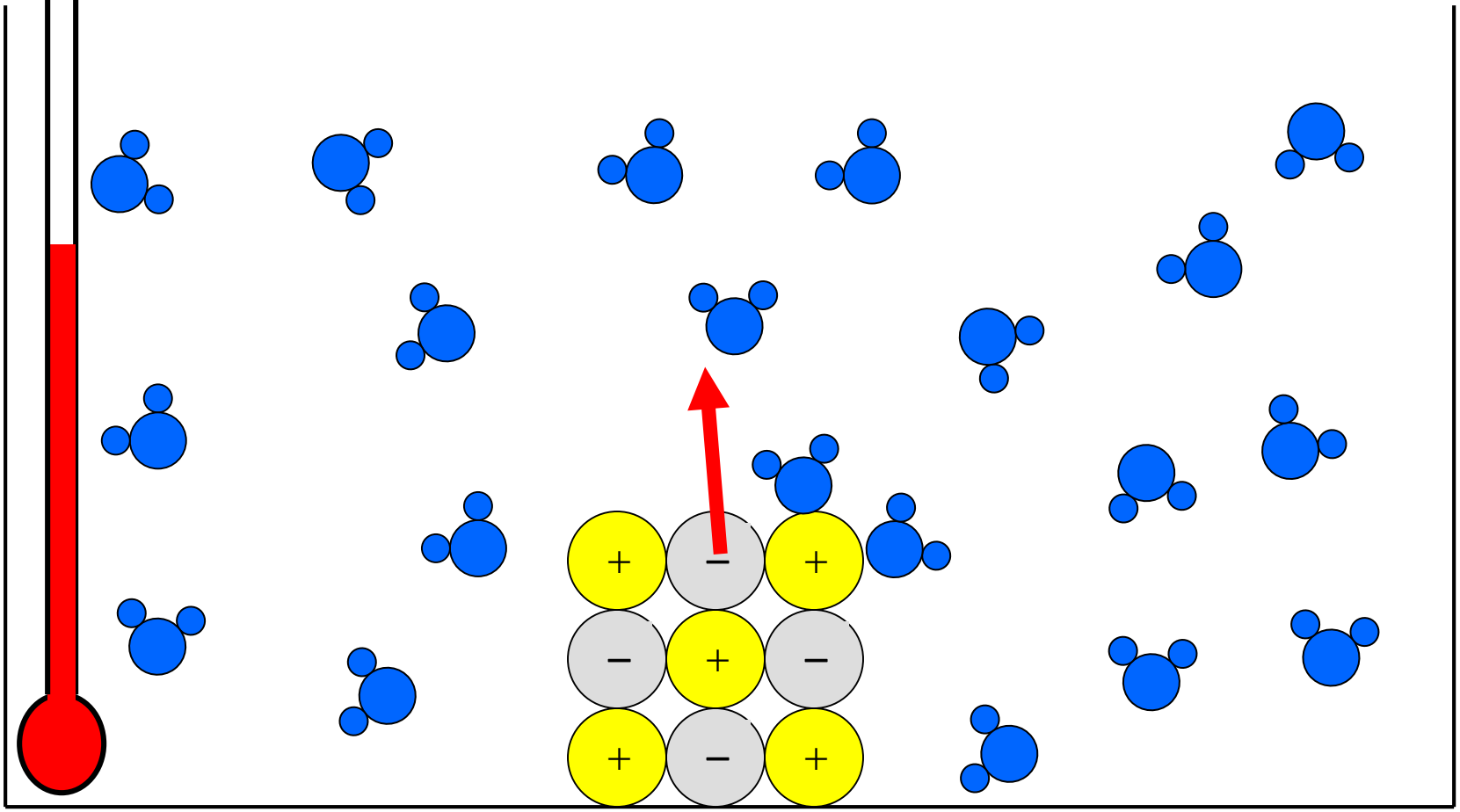
Heat of Solution

?thermic Dissolving Reaction



Heat of Solution

?thermic Dissolving Reaction



Heat of Solution

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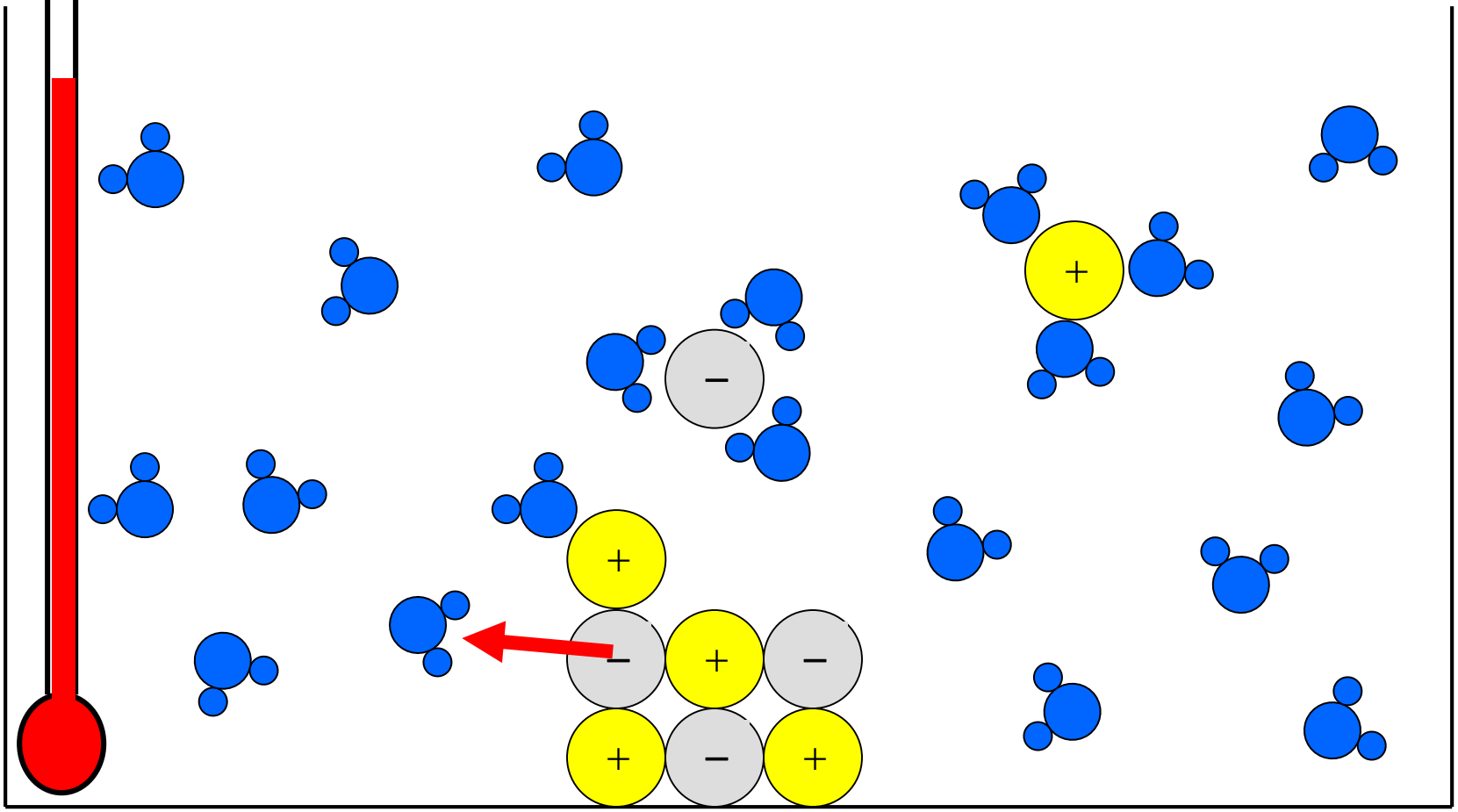

Heat of Solution

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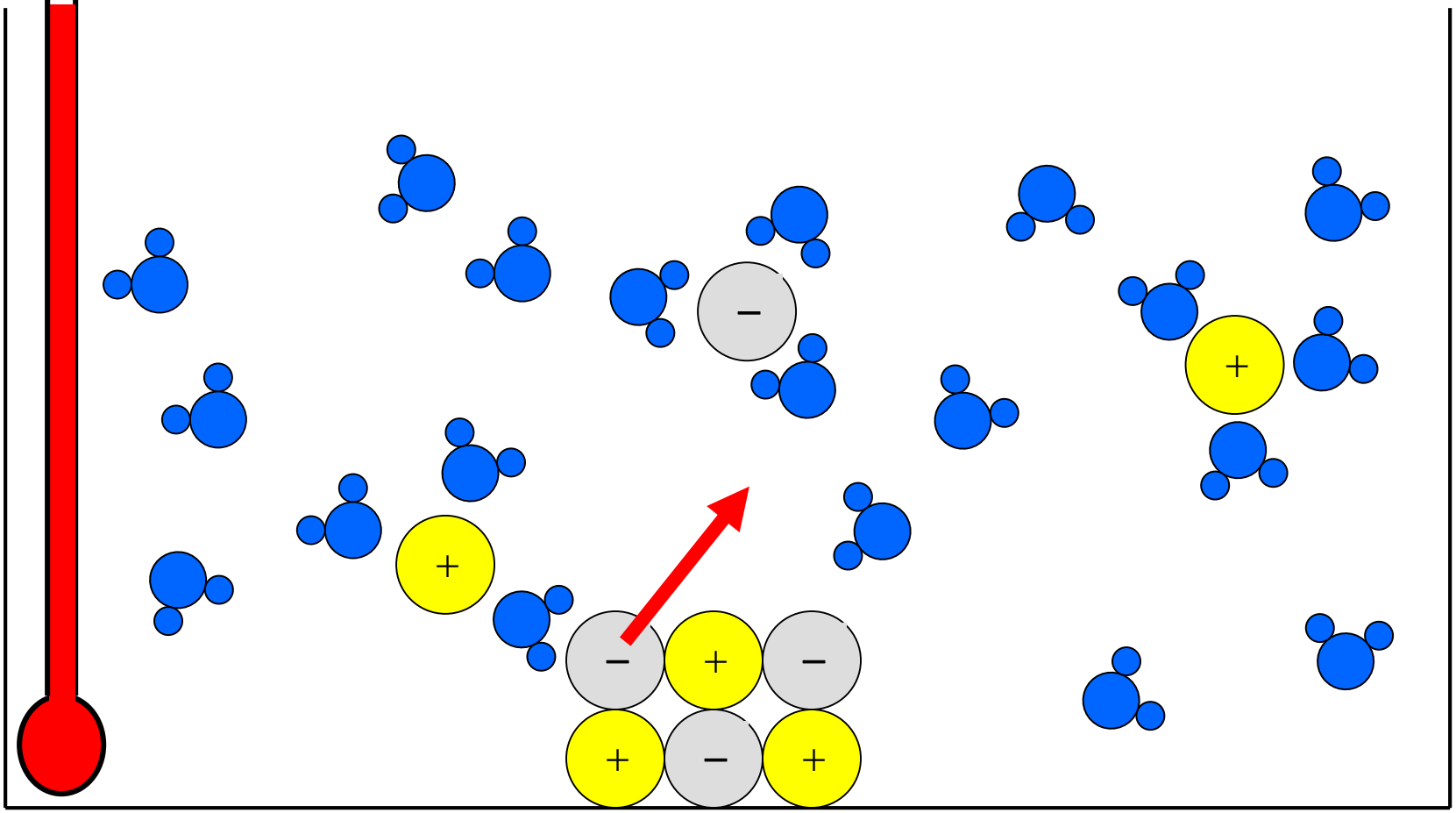
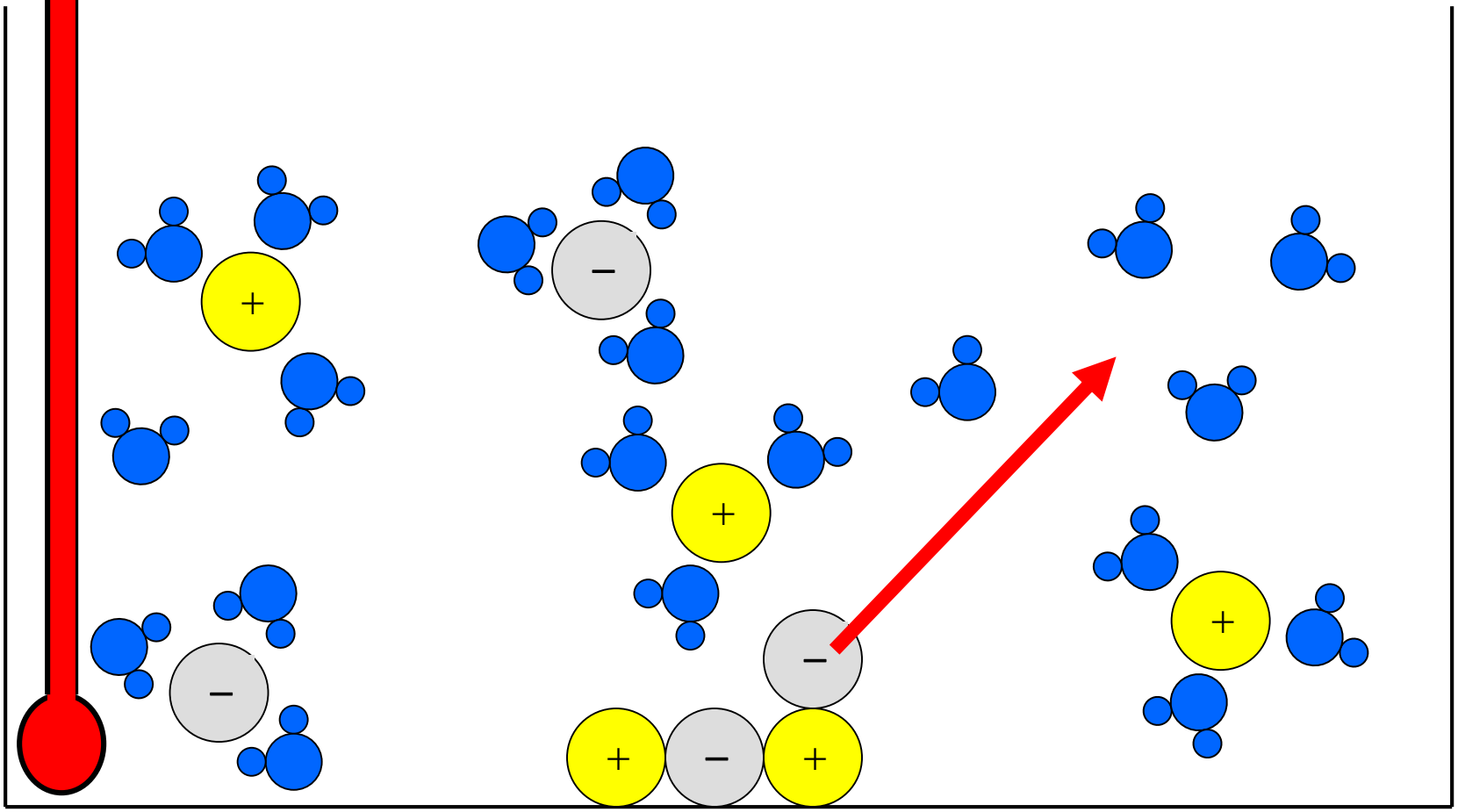


Heat of Solution

?thermic Dissolving Reaction



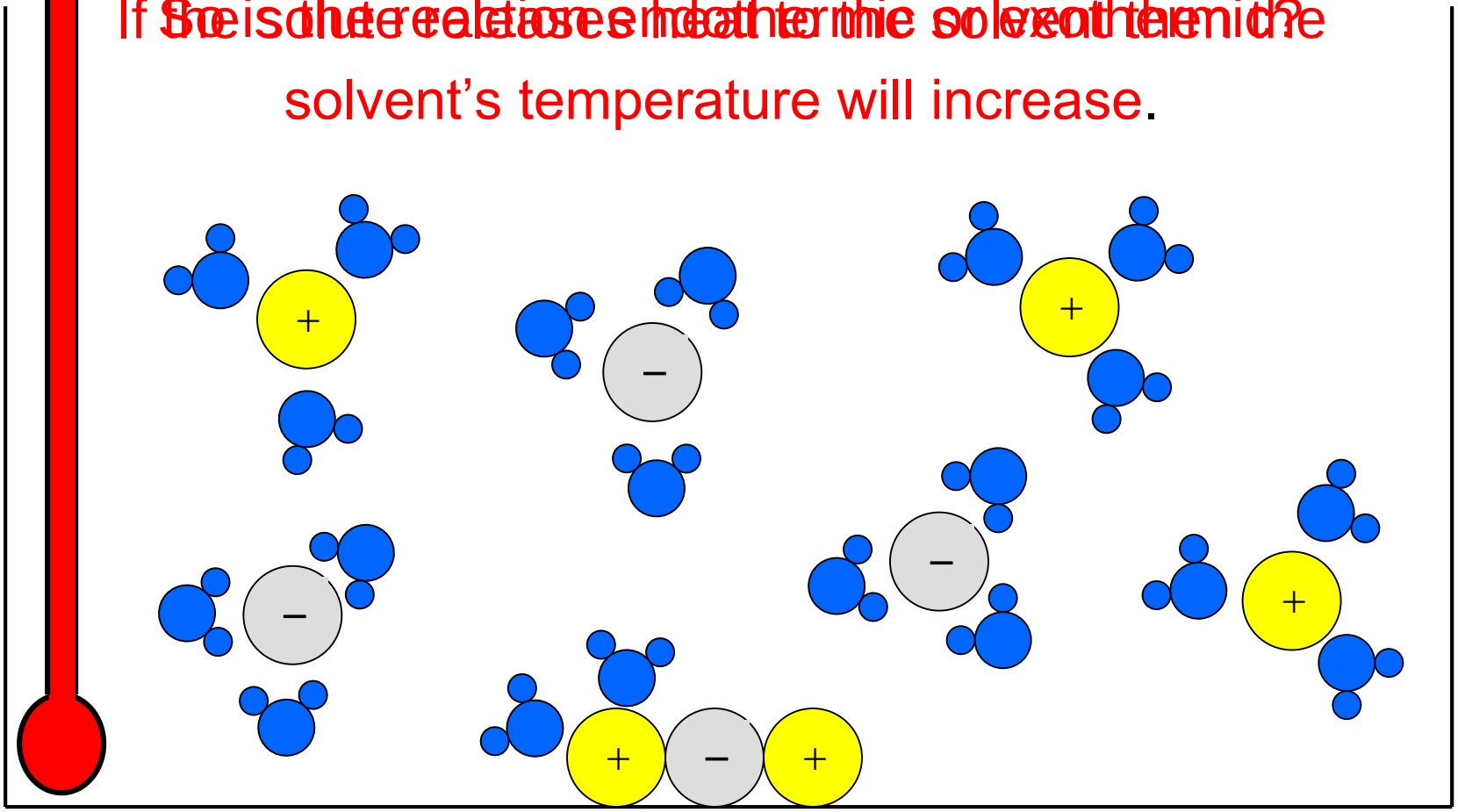
Heat of Solution

Exothermic Dissolving Reaction

If the reaction releases heat to the solvent it is exothermic

So is the reaction endothermic or exothermic?

solvent's temperature will increase.



Heat of Solution

- MOST dissolving reactions of **solid**s in water are ***ENDOTHERMIC***.
- **HOWEVER**, the dissolving of most **acids**, **bases**, and **gases** in water is an ***EXOTHERMIC*** reaction!
- This means that when an ***acid*** is dissolved in water, *the temperature of the water increases*.
- This means that when a ***base*** is dissolved in water, *the temperature of the water increases*.
- This means that when a ***gas*** is dissolved in water, *the temperature of the water increases*.
- When **carbon dioxide** is pumped into water to make soda, *the temperature of the water increases*.