Grade 11 Chemistry

Solutions and Solubility

Class 11

Solubility

- The ability of a solvent to dissolve a solute depends on the forces of attraction between the particles
- **Solubility** – the amount of solute that dissolves in a given quantity of solvent at a certain temperature
  - Ex: NaCl in water at 20°C is 36g per 100ml of water

Saturated vs. Unsaturated

- Saturated solution – formed when no more solute will dissolve in a solution

- Supersaturated solution – formed when excess solute is present

- Unsaturated solution – a solution that is not yet saturated and can therefore dissolve more solute
  - Ex: a 20g sample of NaCl dissolved in 100mL of water at 20°C is unsaturated. The solution has the potential to dissolve another 16g of salt

- Soluble – solubility is greater than 1g per 100ml of solvent

- Insoluble – solubility is less than 0.1g per 100ml of solvent

- Slightly soluble – solubility between 0.1g to 1g

Factors that Affect Solubility

- **Molecule Size** – Small molecules are more soluble than large molecules

Name	Methanol	Ethanol	Propanol	Butanol	Pentanol
Chemical Formula	CH_3OH	CH_3CH_2OH	$CH_3CH_2CH_2OH$	$CH_3CH_2CH_2CH_2OH$	$CH_3CH_2CH_2CH_2CH_2OH$
Solubility	Infinitely soluble	Infinitely soluble	Very Soluble	9g/100ml (25°C)	3g/100ml (25°C)

- **Temperature**
  - Solubility of solids increases with temperature
    - Caffeine's solubility in water is 2.2g/100ml at 25°C but increases to 40g/100ml at 100°C
  - Solubility of most liquids is not as greatly affected by temperature
  - Solubility of gases decreases with higher temperatures
    - Causes heat pollution in lakes; heated water causes the dissolved oxygen in the water to decrease
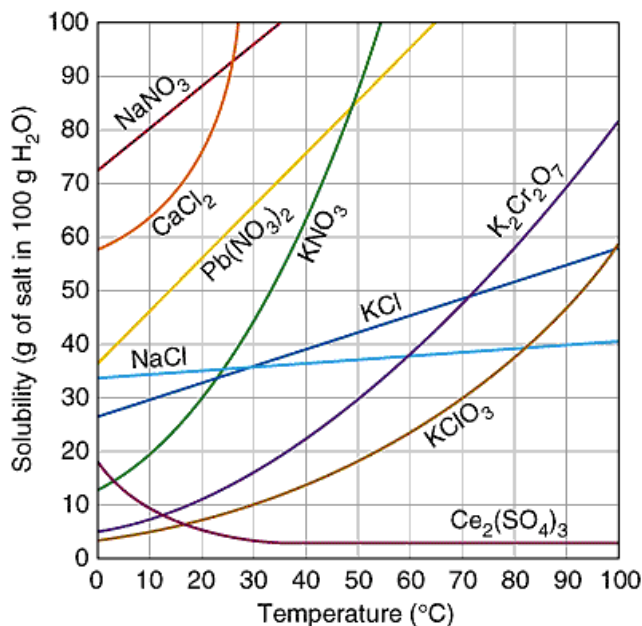
Solubility Curve
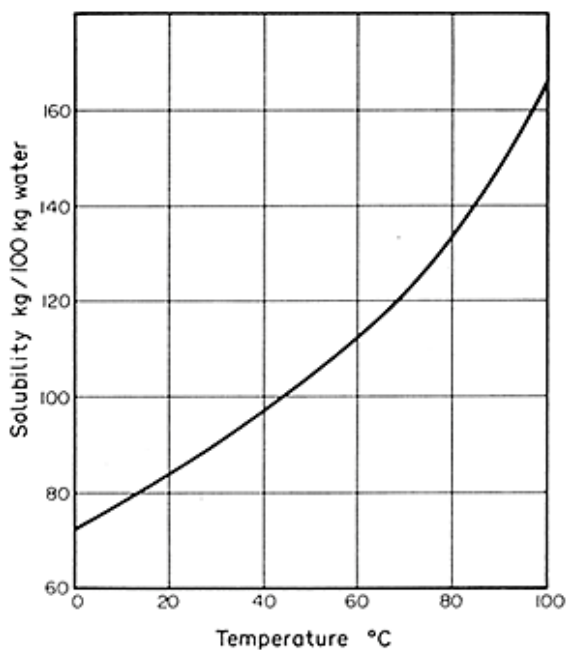
- The line represents saturation
- Anything above the line is supersaturated
- Anything below the line is unsaturated

STOP # Checkpoint STOP

25.0 ml of a saturated solution of $K_2Cr_2O_7$ at 90°C is cooled to 50°C.

What mass will precipitate from the solution?

- **Pressure** – Changes in pressure have little effect on solid and liquid solutions but has a great effect on gas
- The solubility of a gas is proportional to the pressure of the gas above the liquid
  - Ex: Carbonated Drinks – inside a soft drink bottle, the pressure of CO_2 is 400kPa. Once you open the bottle, the gas escapes and the pressure of CO_2 is reduced to 0.03kPa
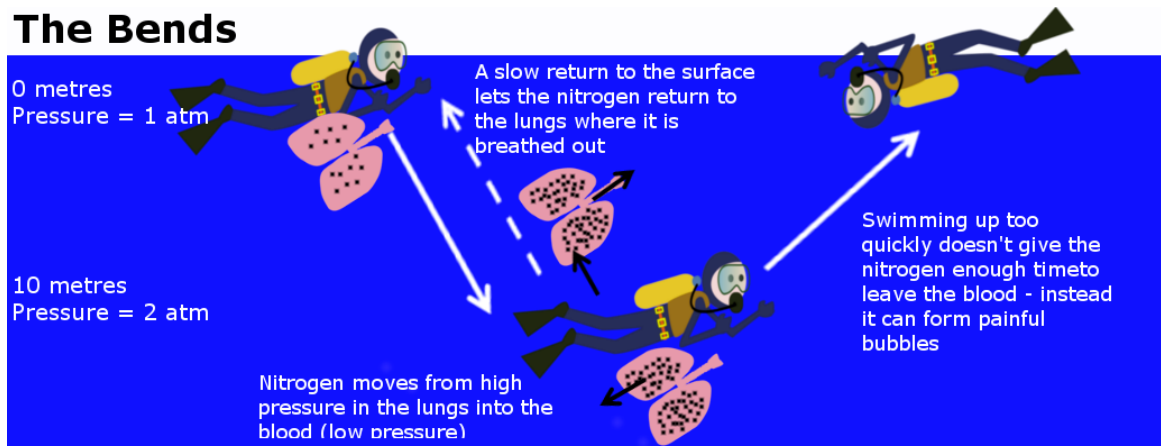 - Carbon dioxide's solubility decreases as pressure decreases, which causes the fizzing

Scuba Diving

- As a scuba diver goes deeper underwater, the water pressure increases
- Solubility of nitrogen gas dissolves in diver's blood because pressure increases

- If the diver comes out of the water too quickly, the pressure suddenly decreases and the nitrogen gas is no longer soluble
- Bubbles of nitrogen gas form in the blood, known as a condition called "the bends"

The Bends

0 metres
Pressure = 1 atm

A slow return to the surface lets the nitrogen return to the lungs where it is breathed out

10 metres
Pressure = 2 atm

Swimming up too quickly doesn't give the nitrogen enough time to leave the blood - instead it can form painful bubbles

Nitrogen moves from high pressure in the lungs into the blood (low pressure)

Factors that Affect Solubility

Ionic Substances

- Effect of Ion Charge
  – Compounds of ions with small charges tend to be soluble while compounds of ions with large charges tend to be insoluble
  – Increasing the charge increases the force that holds the ions together
  – Ex: Alkali metal cations are soluble Na^+; PO_4^{3-} is insoluble except when bonded to alkali metals

- Effect of Ion Size
  - Compounds with smaller ions tend to be less soluble than compounds with larger ions
  - Ions of metals are smaller than their corresponding neutral atom
  - Ions of non-metals are larger than their corresponding neutral atom
- Attraction between ions depends on the **charge to size ratio** – the higher the charge and/or smaller the size, the greater the attraction
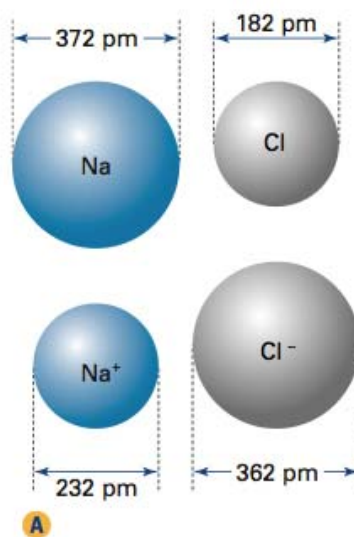

Table 9.1 General Solubility Guidelines

Guideline	Cations	Anions	Result	Exceptions
1	$Li^+, Na^+, K^+,$ Rb^+, Cs^+, NH_4^+	$NO_3^-, CH_3COO^-,$ ClO_3^-	soluble	$Ca(ClO_3)_2$ is insoluble
2	Ag^+, Pb^{2+}, Hg^+	$CO_3^{2-}, PO_4^{3-},$ O^{2-}, S^{2-}, OH^-	insoluble	BaO and $Ba(OH)_2$ are soluble. Group 2 sulfides tend to decompose.
3		Cl^-, Br^-, I^-	soluble	
4	$Ba^{2+}, Ca^{2+}, Sr^{2+}$		insoluble	
5	$Mg^{2+}, Cu^{2+}, Zn^{2+},$ $Fe^{2+}, Fe^{3+}, Al^{3+}$	SO_4^{2-}	soluble	

Poppy Seeds

- Poppy seeds come from the poppy plant, which is an opioid (morphine)
- Poppy seeds have around 0.025% morphine by weight
- A medical oral dose of morphine is 10-30mg
- You would need to consume 40g of poppy seeds to get the same effect as 10mg of morphine

- 40g is around 12 poppy seeds bagels

- Do not eat poppy seed bagels before taking a drug test because it could lead to a false positive reading for your employer/sports competition

Concentration of Solutions

- Concentration – the amount of solute per quantity of solvent
- Many ways to express concentration:
  - Mass/Volume Percent
  - Mass/Mass Percent
  - Volume/Volume Percent
  - Parts per Million or Parts per Billion
  - Molar Concentration

Mass/Volume Percent

Mass/Volume Percent = $\dfrac{\text{Mass of solute (g)}}{\text{Volume of solution (ml)}}$ x 100%

Practice: A pharmacist adds 2.00ml of distilled water to 4.00 g of a powdered drug. The final volume of the solution is 3.00ml. What is the concentration of the drug in g/100ml of solution? What is the percent (m/v) of the solution?

Mass/Mass Percent

Mass/Mass Percent = $\underline{\text{Mass of solute (g)}}$ x 100%

Mass of solution (g)

Practice: $CaCl_2$ can be used to melt ice on roads. A sample of slush had a mass of 23.47g. When the slush was evaporated the residue had a mass of 4.58g (assume no other solutes were present). What was the mass/mass percent? How many grams were present in 100g of solution?

Volume/Volume Percent

Volume/Volume Percent = $\underline{\text{Volume of solute (ml)}}$ x 100%

Volume of solution (ml)

Practice: Rubbing alcohol is sold as 70% (v/v) solution of isopropyl alcohol in water. What volume of isopropyl alcohol is used to make 500 ml of rubbing alcohol?

Parts per Million/Billion

$$ppm = \underline{\text{Mass of solute}} \quad \times 10^6$$
$$\text{Mass of solution}$$

$$ppb = \underline{\text{Mass of solute}} \quad \times 10^9$$
$$\text{Mass of solution}$$

Practice: A fungus on peanuts produces a deadly toxin. Any shipment of peanuts with more than 25ppb is rejected. If a company receives 20t of peanuts, what is the maximum mass (in g) of fungus that is allowed?

Molar Concentration

$$\text{Molar Concentration (mol/L)} = \underline{\text{Amount of Solute (mol)}}$$
$$\text{Volume of solution (L)}$$

Practice: A saline solution contains 0.90g of NaCl, dissolved in 100ml of solution. What is the molar concentration of the solution?

Concept Organizer — Summary of Sections 8.1 to 8.3

Concentration can be expressed in different ways
- g/100 mL
- (m/v)% (m/m)% (v/v)%
- ppm, ppb
- mol/L

Solutions
- solid (e.g., steel)
- liquid (e.g., juice)
- gas (e.g., air)

Rate of dissolving (how fast the solute dissolves)
depends on
- temperature
- agitation
- particle size

Solubility (g/100 mL) (how much solute dissolves)
depends on
- molecule size
- temperature
- pressure

Attraction between particles
- ion-dipole attraction → ionic compounds dissolve in polar solvents e.g., NaCl in H_2O
- dipole-dipole attraction → polar covalent compounds dissolve in polar solvents e.g., sugar in H_2O
- no polar or ionic attraction → non-polar compounds dissolve in non-polar solvents e.g., oil in benzene