1971

Molarity and molality are two ways of expressing concentration.

(a) Clearly distinguish between them

(b) Indicate an experimental situation where expressing concentrations as molarity is particularly appropriate.

(c) Indicate an experimental situation where expressing concentration as molality is particularly appropriate.

1973

The molar solubility of silver bromide is diminished by the addition of a small amount of solid potassium bromide to a saturated solution. However, the molar solubility of silver bromide is increased by the addition of solid potassium nitrate, a salt whose ions are not common to those of silver bromide.

Explain these experimental observations in terms of the principles involved.

1974

Two beakers, one containing 100 milliliters of a 0.10 molal solution of sucrose (a nonvolatile nonelectrolyte) the other containing 100 milliliters of pure water, are placed side by side in a closed system, such as under a bell jar. Explain in terms of the principles involved what changes, if any, occur to bring the system to equilibrium.

1975

Alcohol dissolves in water to give a solution that boils at a lower temperature than pure water. Salt dissolves in water to give a solution that boils at a higher temperature than pure water. Explain these facts from the standpoint of vapor pressure.

1977

The solubility of $Zn(OH)_2$ is not the same in the following solutions as it is in pure water. In each case state whether the solubility is greater or less than that in water and briefly account for the change in solubility.

(a) 1Bmolar HCl

(b) 1Bmolar $Zn(NO_3)_2$

(c) 1Bmolar NaOH

(d) 1Bmolar NH_3

1978

The freezing point and electrical conductivities of three aqueous solutions are given below.

Solution (0.010 molal)	Freezing Point	Electrical Conductivity
sucrose	−0.0186°C	almost zero
formic acid	−0.0213°C	low
sodium formate	−0.0361°C	high

Explain the relationship between the freezing point and electrical conductivity for each of the solutions above. Account for the differences in the freezing points among the three solutions.

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1980

(a) A solution containing 3.23 grams of an unknown compound dissolved in 100.0 grams of water freezes at −0.97°C. The solution does not conduct electricity. Calculate the molecular weight of the compound. (The molal freezing point depression constant for water is 1.86°C kg $mole^{-1}$)

(b) Elemental analysis of this unknown compound yields the following percentages by weight H = 9.74%; C = 38.70%; O = 51.56%. Determine the molecular formula for the compound.

(c) Complete combustion of a 1.05 gram sample of the compound with the stoichiometric amount of oxygen gas produces a mixture of $H_2O(g)$ and $CO_2(g)$. What is the pressure of this gas mixture when it is contained in a 3.00 liter flask at 127°C?

1980

Account for the differences in solubility described in each of the following experimental observations:

(a) $BaCO_3$, $BaSO_3$, and $BaSO_4$ are only slightly soluble in water, but the first two dissolve in HCl solution whereas $BaSO_4$ does not.

(b) CuS cannot be dissolved by warm dilute HCl but it does dissolve in warm dilute HNO_3.

(c) AgCl, Hg_2Cl_2 and $PbCl_2$ are only slightly soluble in water, but AgCl does dissolve in ammonia solution whereas the other two do not.

(d) $Fe(OH)_3$ and $Al(OH)_3$ are only slightly soluble in water, but $Al(OH)_3$ dissolves in concentrated NaOH whereas $Fe(OH)_3$ does not.

1984

Give a scientific explanation for the following observations. Use equations or diagrams if they are relevant.

(a) It takes longer to cook an egg until it is hard-boiled in Denver (altitude 1 mile above sea level) than it does in New York City (near sea level).

(b) Burn coal containing a significant amount of sulfur leads to acid rain.

(c) Perspiring is a mechanism for cooling the body.

(d) The addition of antifreeze to water in a radiator decreases the likelihood that the liquid in the radiator will either freeze or boil.

1985

The formula and the molecular weight of an unknown hydrocarbon compound are to be determined by elemental analysis and the freezing-point depression method.

(a) The hydrocarbon is found to contain 93.46 percent carbon and 6.54 percent hydrogen. Calculate the empirical formula of the unknown hydrocarbon.

(b) A solution is prepared by dissolving 2.53 grams of p-dichlorobenzene (molecular weight 147.0) in 25.86 grams of naphthalene (molecular weight 128.2). Calculate the molality of the p-dichlorobenzene solution.

(c) The freezing point of pure naphthalene is determined to be 80.2°C. The solution prepared in (b) is found to have an initial freezing point of 75.7°C. Calculate the molal freezing-point depression constant of naphthalene.

(d) A solution of 2.42 grams of the unknown hydrocarbon dissolved in 26.7 grams of naphthalene is found to freeze initially at 76.2°C. Calculate the apparent molecular weight of the unknown hydrocarbon on the basis of the freezing-point depression experiment above.

(e) What is the molecular formula of the unknown hydrocarbon?

1987

In 1884 the Swedish chemist Svante Arrhenius proposed that salts dissociate into two or more separate, independent, ionic fragments when they dissolve in water.

(a) Give one piece of experimental evidence that more than 1 mole of particles is formed when 1 mole of a salt dissolves in water.
(b) Give one piece of experimental evidence that the particles formed when a salt dissolves in water are charged.
(c) Explain why the heat of neutralization is always the same when 1 mole of any monoprotic strong acid reacts with enough strong base to form a neutral solution.
(d) Explain why hydrogen chloride, HCl, dissociated when it dissolves in water but not when it dissolves in benzene.

1988

The normal boiling and freezing points of argon are 87.3 K and 84.0 K, respectively. The triple point is at 82.7 K and 0.68 atmosphere.

(a) Use the data above to draw a phase diagram for argon. Label the axes and label the regions in which the solid, liquid and gas phases are stable. On the phase diagram, show the position of the normal boiling point.
(b) Describe any changes that can be observed in a sample of solid argon when the temperature is increased from 40 K to 160 K at a constant pressure of 0.50 atmosphere.
(c) Describe any changes that can be observed in a sample of liquid argon when the pressure is reduced from 10 atmospheres to 1 atmosphere at a constant temperature of 100 K, which is well below the critical temperature.
(d) Does the liquid phase of argon have a density greater than, equal to, or less than the density of the solid phase? Explain your answer, using information given in the introduction to this question.

1989

Consider three unlabeled bottles, each contain small pieces of one of the following metals.

Magnesium
Sodium
Silver

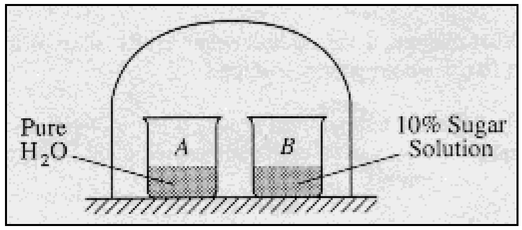
The following reagents are used for identifying the metals.

Pure water
A solution of 1.0 molar HCl
A solution of concentrated HNO_3

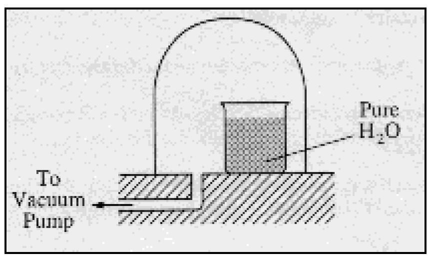
(a) Which metal can be easily identified because it is much softer than the other two? Describe a chemical test that distinguishes this metal from the other two, using only one of the reagents above. Write a balanced chemical equation for the reaction that occurs.
(b) One of the other two metals reacts readily with the HCl solution. Identify the metal and write the balanced chemical equation for the reaction that occurs when this metal is added to the HCl solution. Use the table of standard reduction potentials (attached) to account for the fact that this metal reacts with HCl while the other does not.
(c) The one remaining metal reacts with the concentrated HNO_3 solution. Write a balanced chemical equation for the reaction that occurs.
(d) The solution obtained in (c) is diluted and a few drops of 1 M HCl is added. Describe what would be observed. Write a balanced chemical equation for the reaction that occurs.

1994

Discuss the following phenomena in terms of the chemical and physical properties of the substances involved and general principles of chemical and physical change.

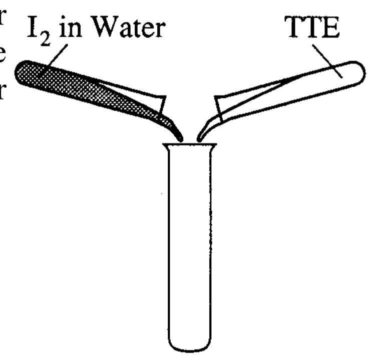


(a) As the system shown above approaches equilibrium, what change occurs to the volume of water in beaker A? What happens to the concentration of the sugar solution in beaker B? Explain why these changes occur.



(b) A bell jar connected to a vacuum pump is shown above. As the air pressure under the bell jar decreases, what behavior of water in the beaker will be observed? Explain why this occurs.

(c) A water solution of I_2 is shaken with an equal volume of a nonpolar solvent such as TTE (trichlorotrifluoroethane). Describe the appearance of this system after shaking. (A diagram may be helpful.) Account for this observation.

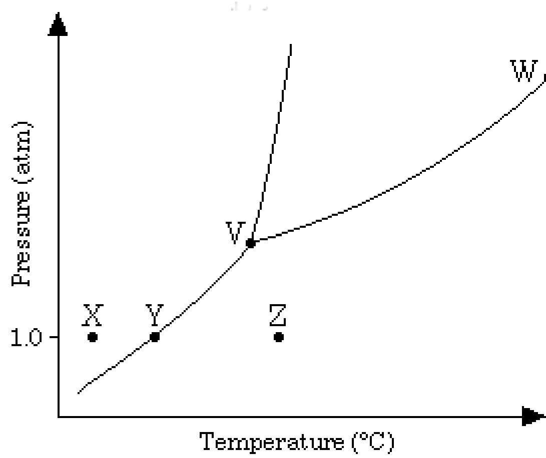


1994

For each of the following, use appropriate chemical principles to explain the observation.

(a) Sodium chloride may be spread on an icy sidewalk in order to melt the ice; equimolar amounts of calcium chloride are even more effective.
(b) At room temperature, NH_3 is a gas and H_2O is a liquid, even though NH_3 has a molar mass of 17 grams and H_2O has a molar mass of 18 grams.
(c) C (graphite) is used as a lubricant, whereas C (diamond) is used as an abrasive.
(d) Pouring vinegar onto the white residue inside a kettle used for boiling water results in a fizzing/bubbling phenomenon.

1995



The phase diagram for a pure substance is shown above. Use this diagram and your knowledge about changes of phase to answer the following questions.

(a) What does point *V* represent? What characteristics are specific to the system only at point *V*?.
(b) What does each point on the curve between *V* and *W* represent?
(c) Describe the changes that the system undergoes as the temperature slowly increases from *X* to *Y* to *Z* at 1.0 atmosphere.
(d) In a solid-liquid mixture of this substance, will the solid float or sink? Explain.

1995

Lead iodide is a dense, golden yellow, slightly soluble solid. At 25°C, lead iodide dissolves in water forming a system represented by the following equation.

$$PbI_{2(s)} \rightarrow Pb^{2+} + 2\ I^- \qquad \Delta H = +46.5 \text{ kilojoules}$$

(a) How does the entropy of the system $PbI_{2(s)} + H_2O_{(l)}$ change as $PbI_{2(s)}$ dissolves in water at 25°C? Explain

(b) If the temperature of the system were lowered from 25°C to 15°C, what would be the effect on the value of K_{sp}? Explain.

(c) If additional solid PbI_2 were added to the system at equilibrium, what would be the effect on the concentration of I^- in the solution? Explain.

(d) At equilibrium, $\Delta G = 0$. What is the initial effect on the value of ΔG of adding a small amount of $Pb(NO_3)_2$ to the system at equilibrium? Explain.

1998

Answer each of the following using appropriate chemical principles.

(a) Why does it take longer to cook an egg in boiling water at high altitude than it does at sea level?

(b) When NH_3 gas is bubbled into an aqueous solution of $CuCl_2$, a precipitate forms initially. On further bubbling, the precipitate disappears. Explain these two observations.

(c) Dimethyl ether, $H_3C\text{-}O\text{-}CH_3$, is not very soluble in water. Draw a structural isomer of dimethyl ether that is much more soluble in water and explain the basis of its increased water solubility.

(d) Identify a chemical species that is

(i) capable of oxidizing $Cl^-(aq)$ under standard conditions

(ii) capable of reducing $Cl_2(aq)$ under standard conditions. In each case, justify your choice.

2003

For each of the following, use appropriate chemical principles to explain the observations. Include chemical equations as appropriate.

(a) In areas affected by acid rain, statues and structures made of limestone (calcium carbonate) often show signs of considerable deterioration.

(b) When table salt (NaCl) and sugar ($C_{12}H_{22}O_{11}$) are dissolved in water, it is observed that

(i) both solution have higher boiling points than pure water, and

(ii) the boiling point of 0.10 *M* NaCl*(aq)* is higher than that of 0.10 *M* $C_{12}H_{22}O_{11}$*(aq)*.

(c) Methane gas does not behave as an ideal gas at low temperatures and high pressures.

(d) Water droplets form on the outside of a beaker containing an ice bath.