ANSWERS TO UNIT IX : SOLUTION CHEMISTRY

1. The solution is saturated if a visible amount of solid NaCl is present. The solution is NOT saturated if the NaCl was added only a few seconds before, because the salt hasn't had enough time to completely dissolve. If the newly–made salt water mixture is constantly stirred the resulting solution might or might not be saturated — only the eventual observation of undissolved NaCl allows you to say the solution is saturated.
2. Normally, the hotter a solvent is the more solute it can dissolve. Therefore, you would expect warming of a saturated solution to allow the solution to dissolve more solute and become "unsaturated".
3. Some solutions found in nature are: sea, lake and river waters, the air (oxygen and nitrogen), rocks (solid solutions of minerals), water lying in puddles on soil (contains dissolved minerals from the soil), fruit juices, tree sap (such as maple syrup) and various biological fluids.
4. Glass is not soluble in water.
5. i) Only the smallest bulb glows so there is very little conductivity and very low ion concentration.
   ii) Compounds 3, 4, 5, 7, 8, 10
   iii) It has the same conductivity as pure water and therefore the same concentration of ions. This can be interpreted to mean glucose does not produce ions.
   iv) The non–conducting compounds start with a carbon atom (are organic).
   v) HCl and H_2SO_4 are acids; KOH and NaOH are bases.
   vi) NaCl and NH_4NO_3 are salts.
   vii) NaSCN, NaOH, Na_3PO_4
   viii) Substances in the solid phase do not conduct electricity.
   ix) The phase must be a liquid (melted substance or aqueous solution).
   x) The greater the concentration of ions, the greater the conductivity.
   xi) A reaction occurs between water and acetic acid to produce ions.
   xii) The acetic acid solution, and its ions, are being diluted in concentration.
6. Conducting = a, c, d, f, g, i ; Non–conducting = b, e, h, j
7. Organic compounds and nonpolar compounds (which can be the same compound in some cases)
8. c, d, f, i, k, l, o, q, s, t, u, v, x
9. (a) nonpolar (b) polar (c) polar (d) nonpolar
10. (a) polar (c) polar (e) polar (g) nonpolar
    (b) nonpolar (d) nonpolar (f) polar (h) polar
11. HCl is expected to have a higher boiling temperature than F_2 because HCl is a polar molecule and experiences dipole–dipole forces in addition to London forces. F_2 experiences only London forces.
12. The low boiling temperature of CF_4 is expected because only London forces are involved. The higher boiling temperature of CHF_3 is explained by the fact that the molecule is polar. The dipole–dipole forces in CHF_3 hold the molecules together to a greater degree and raise the boiling temperature.
13. (a) Going up column 15 of the periodic table, the atoms Sb, As and P have fewer and fewer electrons and therefore smaller London forces hold molecules to their neighbours. As a result, it is easier to melt the compounds. (Although the molecules are all polar, the dipole–dipole forces are almost the same for each molecule because the electronegativity of Sb, As and P are almost identical.)
    (b) NH_3 contains the N–H bond, which means that hydrogen bonding is present in NH_3 but not in the others. Since hydrogen bonds are much stronger than London forces, the melting temperature is higher than otherwise expected.
14. c, e, g, h

15. Propane molecules are held next to neighbouring molecules in the liquid phase by weak London forces. Such forces are not very "sticky" and freely allow one molecule to "slide" or "flow" past one another, leading to a low viscosity (low resistance to flow). Glycerine has three O–H groups which can hydrogen bond strongly to neighbouring molecules, preventing the molecules from sliding freely past each other and leading to a high viscosity.

16. The molecule with the higher boiling temperature is the one with hydrogen bonding in addition to London forces. Hence, molecules with N, O or F bonded to H have higher boiling temperatures.
(a) $CH_3–CH_2–OH$ (b) H_2O (c) CH_3NH_2

17.

Solvent	Polar or nonpolar?	Solvent	Polar or nonpolar?
water	Polar	acetic acid	Polar
methanol	Polar	chloroform	Polar
ethanol	Polar	carbon tetrachloride	Nonpolar
benzene	Nonpolar	heptane	Nonpolar
ethoxyethane	Polar	liquid ammonia	Polar
acetone	Polar		

18. Both hexane and Br_2 are nonpolar; "like dissolves like". Water is polar and does not dissolve nonpolar Br_2 to a great extent.

19. The long carbon chain can help dissolve nonpolar solutes, while the ionic end helps to dissolve polar solutes.

20. Nonpolar solvents can only attach to solutes using weak London forces; these forces are unable to overcome the strong bonds holding an ionic compound together so that nonpolar solvents are unable to dissolve ionic compounds.

21. Pentane is held together in the liquid phase by weak London forces. Pentane is not affected by the polar character of water, or its potential for hydrogen bonding, but water **does** exert weak London forces which to a certain extent are able to overcome the London forces holding $C_5H_{12}(l)$ together .

22. (a) Only the highly polar water can dissolve appreciable amounts of ionic KCl(s).
(b) The large "nonpolar" part of $CH_3CH_2CH_2CH_2Br$ is dissolved to the greatest extent by the greater London forces available with CH_3CH_2OH.
(c) The large nonpolar octane molecule is dissolved to the greatest extent by the greater London forces available with CH_3CH_2OH.

23. (a) London force
(b) London force
(c) Dipole–dipole and London forces
(d) Hydrogen bonding
(e) Covalent bond
(f) London force
(g) Dipole–dipole and London forces
(h) London force
(i) Dipole–dipole and London forces
(j) Ionic bond
(k) Hydrogen bond
(l) London force

24. (a) Xe (b) HBr (c) HO-CH_2CH_2-OH (d) Br_2 (e) CCl_4 (f) H_2O (g) CH_3F (h) HI

25. a, d

26. For $I_2(s)$ try any of ethanol, acetone, heptane or carbon tetrachloride.
For $NaNO_3$ try water
For carbon disulphide try any of ethanol, acetone, heptane or carbon tetrachloride
For $H_2C{=}O$ try any of water, ethanol, acetone, heptane or carbon tetrachloride
For sulphur try any of ethanol, acetone, heptane or carbon tetrachloride

27. X is water (polar). A is sodium chloride (soluble in water). Liquids Y and Z must be nonpolar solvents (do not dissolve NaCl). Nonpolar naphthalene must be C (insoluble in polar water). Polar benzoic acid must be B (slightly soluble in polar water; fairly soluble to soluble in the nonpolar solvents).

28. (a) $KBr(s) \longrightarrow K^+(aq) + Br^-(aq)$
(b) $HCl(g) \longrightarrow H^+(aq) + Cl^-(aq)$
(c) $Na_2SO_4(s) \longrightarrow 2Na^+(aq) + SO_4^{2-}(aq)$
(d) $Ca(OH)_2(s) \longrightarrow Ca^{2+}(aq) + 2\,OH^-(aq)$
(e) $Al_2(SO_4)_3(s) \longrightarrow 2\,Al^{3+}(aq) + 3\,SO_4^{2-}(aq)$
(f) $K_3PO_4(s) \longrightarrow 3\,K^+(aq) + PO_4^{3-}(aq)$
(g) $AlCl_3(s) \longrightarrow Al^{3+}(aq) + 3Cl^-(aq)$
(h) $(NH_4)_2S(s) \longrightarrow 2\,NH_4^+(aq) + S^{2-}(aq)$

29. Water is plentiful, cheap, nontoxic/nonpolluting and an excellent solvent for many ionic and polar solutes.

30. $[SO_4^{2-}] = 3 \times 0.135\ M = \mathbf{0.405\ M}$

31. $[BaCl_2] = \dfrac{10.0\ g}{0.600\ L} \times \dfrac{1\ mol\ BaCl_2}{208.3\ g} = 0.0800\ M$; $[Cl^-] = 2 \times [BaCl_2] = 2 \times 0.0800\ M = \mathbf{0.160\ M}$

32. $[HCl] = 0.300\ M \times \dfrac{55.0\ mL}{135.0\ mL} = 0.1222\ M$; $[Cl^-] = [HCl] = 0.1222\ M$

$[CaCl_2] = 0.550\ M \times \dfrac{80.0\ mL}{135.0\ mL} = 0.3259\ M$; $[Cl^-] = 2 \times [CaCl_2] = 2 \times 0.3259\ M = 0.6519\ M$

total $[Cl^-] = 0.1222\ M + 0.6519\ M = \mathbf{0.774\ M}$

33. $[MgCl_2] = 0.250\ M \times \dfrac{350.0\ mL}{275.0\ mL} = 0.3182\ M$; $[Cl^-] = 2 \times [MgCl_2] = 2 \times 0.3182\ M = \mathbf{0.636\ M}$

34. (a) moles $K_2SO_4 = 0.20\ \dfrac{mol}{L} \times 0.60\ L = 0.12\ mol$

so that: # of moles $K^+ = 2 \times$ moles $K_2SO_4 = \mathbf{0.24\ mol}$,
and: # of moles SO_4^{2-} = moles $K_2SO_4 = \mathbf{0.12\ mol}$

(b) moles $Na_3PO_4 = 0.300\ \dfrac{mol}{L} \times 0.450\ L = 0.135\ mol$

so that: # of moles $Na^+ = 3 \times$ moles $Na_3PO_4 = \mathbf{0.405\ mol}$,
and: # of moles PO_4^{3-} = moles $Na_3PO_4 = \mathbf{0.135\ mol}$

(c) moles $MnCl_2 = 0.160\ \dfrac{mol}{L} \times 0.0750\ L = 0.0120\ mol$

so that: # of moles Mn^{2+} = moles $MnCl_2 = \mathbf{0.0120\ mol}$,
and: # of moles $Cl^- = 2 \times$ moles $MnCl_2 = \mathbf{0.0240\ mol}$

(d) moles $Al_2(SO_4)_3 = 0.235\ \dfrac{mol}{L} \times 0.0950\ L = 0.022\,33\ mol$

so that: # of moles $Al^{3+} = 2 \times$ moles $Al_2(SO_4)_3 = 2 \times 0.022\,33\ mol = \mathbf{0.0447\ mol}$,
and: # of moles $SO_4^{2-} = 3 \times$ moles $Al_2(SO_4)_3 = 3 \times 0.022\,33\ mol = \mathbf{0.0670\ mol}$

35. $[BaCl_2] = 0.200\ M \times \frac{100.0\ mL}{250.0\ mL} = 0.0800\ M$; $[Ba^{2+}] = [BaCl_2] = \mathbf{0.0800\ M}$

$[Cl^-] = 2 \times [BaCl_2] = 2 \times 0.0800\ M = 0.160\ M$

$[NaCl] = 0.400\ M \times \frac{150.0\ mL}{250.0\ mL} = 0.240\ M$; $[Na^+] = [NaCl] = \mathbf{0.240\ M}$; $[Cl^-] = [NaCl] = 0.240\ M$

total $[Cl^-] = 0.160\ M + 0.240\ M = \mathbf{0.400\ M}$

36. $[Na_3PO_4] = 0.200\ M \times \frac{75.0\ mL}{100.0\ mL} = 0.150\ M$; $[Na^+] = 3 \times [Na_3PO_4] = 3 \times 0.150\ M = \mathbf{0.450\ M}$

$[PO_4^{3-}] = [Na_3PO_4] = 0.150\ M$

$[K_3PO_4] = 0.800\ M \times \frac{25.0\ mL}{100.0\ mL} = 0.200\ M$; $[K^+] = 3 \times [K_3PO_4] = 3 \times 0.200\ M = \mathbf{0.600\ M}$

$[PO_4^{3-}] = [Na_3PO_4] = 0.200\ M$

$[PO_4^{3-}]$ (total) $= 0.150\ M + 0.200\ M = \mathbf{0.350\ M}$

37. $[Na_3PO_4] = 0.325\ M \times \frac{15.0\ mL}{50.0\ mL} = 0.0975\ M$; $[Na^+] = 3 \times [Na_3PO_4] = 3 \times 0.0975\ M = \mathbf{0.293\ M}$

$[PO_4^{3-}] = [Na_3PO_4] = \mathbf{0.0975\ M}$

$[K_2SO_4] = 0.225\ M \times \frac{35.0\ mL}{50.0\ mL} = 0.1575\ M$; $[K^+] = 2 \times [K_2SO_4] = 2 \times 0.1575\ M = \mathbf{0.315\ M}$

$[SO_4^{2-}] = [K_2SO_4] = \mathbf{0.158\ M}$

38. $[K_2CrO_4] = \frac{3.25\ g}{0.1000\ L} \times \frac{1\ mol}{194.0\ g} = 0.1675\ M$; $[K^+] = 2 \times [K_2CrO_4] = 2 \times 0.1675\ M = 0.3351\ M$

$[CrO_4^{2-}] = [K_2CrO_4] = \mathbf{0.168\ M}$

$[K_2Cr_2O_7] = \frac{1.75\ g}{0.1000\ L} \times \frac{1\ mol}{294.0\ g} = 0.059\ 52\ M$; $[K^+] = 2 \times [K_2Cr_2O_7] = 2 \times 0.059\ 52\ M = 0.1190\ M$

$[Cr_2O_7^{2-}] = [K_2Cr_2O_7] = \mathbf{0.0595\ M}$

total $[K^+] = 0.3351 + 0.1190 = \mathbf{0.454\ M}$