HANDOUT SET

GENERAL CHEMISTRY II

Periodic Table of the Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1 **H** 1.00794																	2 **He** 4.00262
2	3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.811	6 **C** 12.011	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984	10 **Ne** 20.179
3	11 **Na** 22.9898	12 **Mg** 24.305											13 **Al** 26.98154	14 **Si** 28.0855	15 **P** 30.97376	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
4	19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.9559	22 **Ti** 47.88	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.9380	26 **Fe** 55.847	27 **Co** 58.9332	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.59	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
5	37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.9059	40 **Zr** 91.224	41 **Nb** 92.9064	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.9055	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.710	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.9045	54 **Xe** 131.29
6	55 **Cs** 132.9054	56 **Ba** 137.34	57 **La*** 138.91	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.85	75 **Re** 186.207	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.9665	80 **Hg** 200.59	81 **Tl** 204.383	82 **Pb** 207.2	83 **Bi** 208.9804	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** 226.0254	89 **Ac**** 227.0278	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (266)	110 (270)	111 (272)	112 ***** (277)						

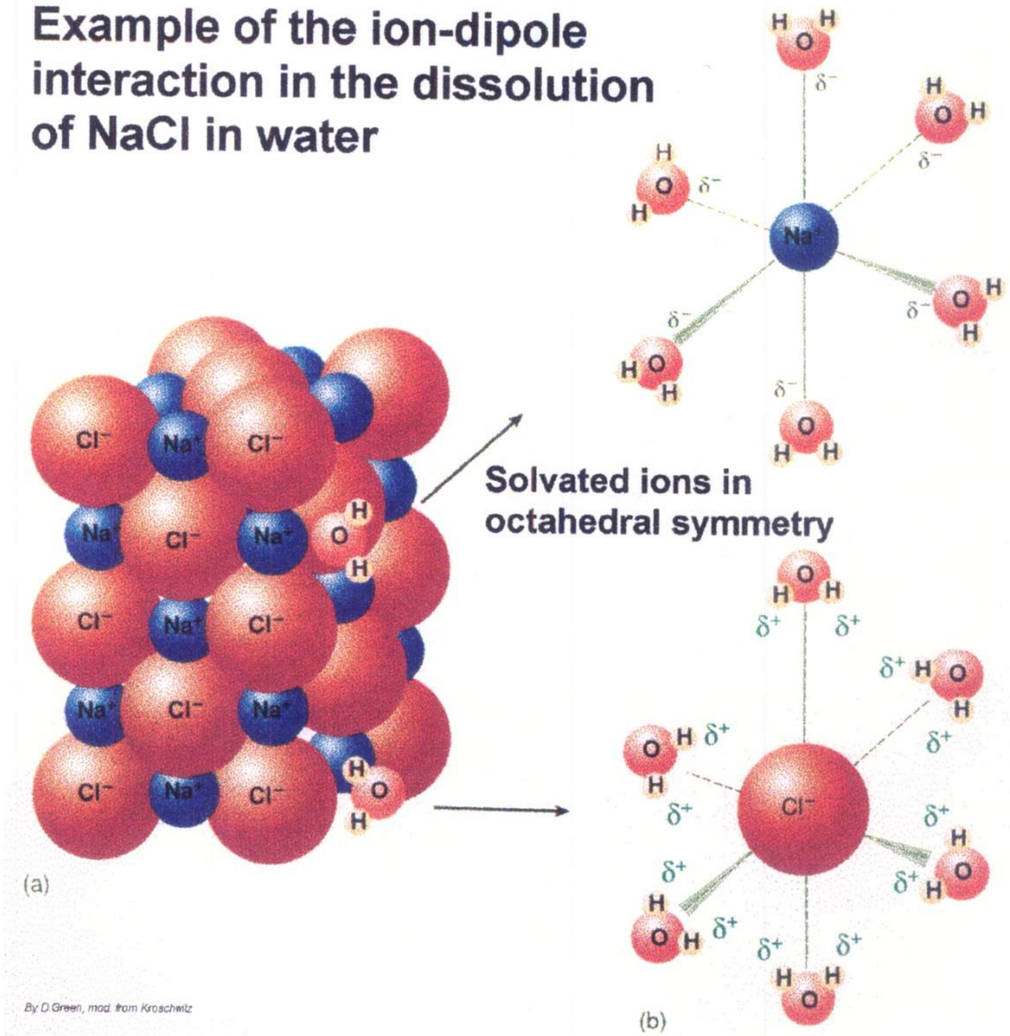
*Lanthanides	58 **Ce** 140.12	59 **Pr** 140.9077	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 164.930	68 **Er** 167.26	69 **Tm** 168.9342	70 **Yb** 173.04	71 **Lu** 174.967
**Actinides	90 **Th** 232.038	91 **Pa** 231.0659	92 **U** 238.0289	93 **Np** 237.0482	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Mass numbers in parenthesis are the mass numbers of the most stable isotopes. As of 1997 elements 110-112 have not been named.

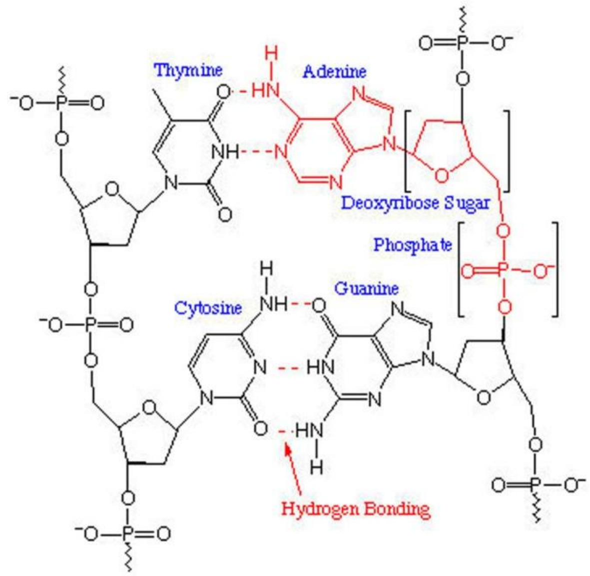
***Peter Armbruster and Sigurd Hofman synthesized a single atom at the Heavy-Ion Research Center in Darmstadt, Germany in 1996. The atom survived for 280 μs after which it decayed to element 110 by loss of an α-particle

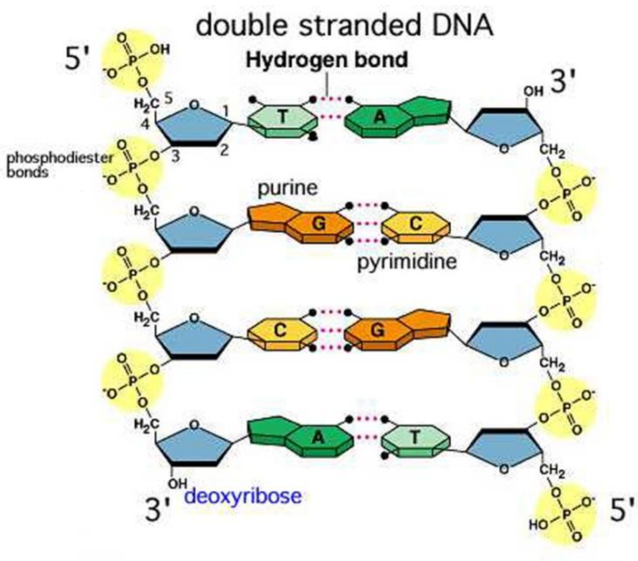
Chapter 12, 13

Intermolecular Forces: Liquids and Solids and Solutions


Example of the ion-dipole interaction in the dissolution of NaCl in water
Solvated ions in octahedral symmetry
Na+
Cl−
(a)
(b)
By D Green, mod. from Kroschwitz

Hydrogen Bonding in the Double-Helix





Dipole Moments of Selected Molecules. Unspecified temperatures are assumed to be 25°C

Compound	Dipole Moment (D)	
Cyclohexane	0	(20°C)
Cyclopentane	0	
Heptane	0	
Iso-octane	0	(20°C)
Pentane	0	
Hexane	0.08	
Toluene	0.31	(20°C)
1,4-Dioxane	0.45	
o-Xylene	0.45	
Dichloromethane	1.14	
Chloroform	1.15	
Ethyl Ether	1.15	(20°C)
2-Chlorophenol	1.24	
Methyl *t*-Butyl Ether	1.32	
o-cresol	1.35	
Phenol	1.49	
Chlorobenzene	1.56	
Bromobenzene	1.56	
p-cresol	1.58	
m-cresol	1.61	
Ethyl Alcohol	1.66	(20°C)
2-Propanol	1.66	(30°C)
Glyme	1.71	
1-Butanol	1.75	
Tetrahydrofuran	1.75	
Isobutyl Alcohol	1.79	
Ethylene Dichloride	1.83	
n-Butyl Acetate	1.84	(22°C)
Water	1.87	(20°C)
Ethyl Acetate	1.88	
1,3-Dioxane	1.90	
1-Chlorobutane	1.90	
2-Methoxyethanol	2.04	
3-Chlorophenol	2.08	
o-Dichlorobenzene	2.14	(20°C)
4-Chlorophenol	2.24	
Pyridine	2.37	
Acetone	2.69	(20°C)
Methyl *n*-Propyl Ketone	2.70	(20°C)
Methyl Ethyl Ketone	2.76	
Methanol	2.87	(20°C)
1-Propanol	3.09	(20°C)
2-Nitrophenol	3.12	
Acetonitrile	3.44	(20°C)
Dimethyl Acetamide	3.72	
3-Nitrophenol	3.76	
N,*N*-Dimethylformamide	3.86	
N-Methylpyrrolidone	4.09	(30°C)
Dimethyl Sulfoxide	4.1	
4-Nitrophenol	4.72	
Propylene Carbonate	4.94	(20°C)

Intermolecular Forces

1. From *Lange's Handbook of Chemistry,* 13th Ed. (McGraw Hill), we find ΔH_{vap} for H_2O to be 40.7 kJ/mol. We also know the vapor pressure of water at 100°C. Calculate the vapor pressure of water at 25.0°C in a closed container.

2. The vapor pressure and associated temperatures for ethanol were found in the CRC *Handbook of Chemistry and Physics.* Determine ΔH_{vap} for ethanol from these data. Is it different from water? Why?

v.p. (mm Hg)	**Temp (°C)**
40.0	19.0
400.0	63.5
760.0	78.4

3. The vapor pressures measured at several temperatures for benzene are shown in the table. Calculate the normal boiling point (1 atm) for benzene. (The literature value is 80.1°C)

Temp (°C)	**v.p. (kPa)**
0.0	4.11
10.0	6.77
20.0	10.78
40.0	25.00

4. How much energy is needed to melt an ice cube (at constant temperature) that has a mass of 28.0 g? (ΔH_{fusion} = 6.02 kJ mol^{-1})

5. How much energy is required to convert 28.0 g of ice at -12.0°C to steam at 100°C in a closed vessel? (Hint: What information not listed will be needed?)

Solutions I: Saturated and Unsaturated Solutions

1. The concentration of dissolved oxygen from the air at 1.0 atm in sea water is 3.1×10^{-4} M at 25°C. Predict the concentration of dissolved oxygen in sea water at a partial pressure O_2 of 1.0 atm (*i.e.*, pure oxygen).

2. A solution of KNO3 is prepared carefully to be 28.0 g of solid dissolved in 200.0 g of water, then slowly cooled to 0.0°C. No crystallization occurs. Is the solution unsaturated, saturated, or supersaturated? ($s^{0°C}_{KNO_3}$ = 13.3 g/100 g H_2O)

3. When a seed crystal is added, some solid precipitates from the solution prepared in question 2. Predict the quantity of solid that precipitates.

4. What is the molal concentration of the solution prepared by dissolving 60.0 g of glucose ($C_6H_{12}O_6$, 180.2 g/mol) in 100.0 mL of water?

5. What quantity of methanol (CH_3OH) must be added to 250.0 g of water to make a 0.25 *m* solution?

Solutions II: Colligative Properties

1. What is the boiling point of the solution prepared to be 10.0 g of $C_2H_6O_2$ (62.07 g mol^{-1}) dissolved in 100.0 g of water?

2. What is the predicted freezing point of the solution from (1)?

3. How many gallons of antifreeze (ethylene glycol) must be added to 4.0 gallons of water to lower the freezing point of the solution to –10.0°F (a fairly bad winter day on the east coast)? (Hint: You will probably need to use the CRC *Handbook of Chemistry and Physics*, *Merck Index*, or other resource to get some of the information you need.)

4. A solution of the male hormone, testosterone, containing 0.363 g of the hormone in 5.00 g of benzene has a freezing point of 4.27°C. What is the molar mass of testosterone? The freezing point of pure benzene is 5.50°C. Additional data: A solution of 1.13 g of naphthalene ($C_{10}H_8$) in 10.00 g of benzene had a freezing point of 0.99°C.)

5. Testosterone contains only carbon, hydrogen, and oxygen. The percentage composition of the molecule is 79.12%C and 9.79%H. What is the molecular formula and accurate molar mass?

Colligative Properties: Freezing Point Depression, Vapor Pressure Lowering,Boiling Point Elevation Additional Problems

1. Adding a nonvolatile ionic solute to water has what effect on the boiling point of the solvent?
… ☐ Does not affect the b.p.
… ☐ Lower the b.p.
… ☐ Raises the b.p.
… ☐ Cannot tell without more information, such as concentration

2. What is the van't Hoff factor?

3. What is a *colligative property* (a definition; not "it's freezing point depression", etc.)

4. Give an example of a colligative property other than freezing point depression.

5. What is the equation that relates the freezing point depression and concentration? Define each variable.

6. Calculate the molal concentration of a sucrose ($C_{12}H_{22}O_{11}$) solution that is prepared by dissolving 10.0 g of the solid in 150.0 g of water.

7. What is the freezing point of the solution prepared in question 6? The molal freezing point depression constant for water is 1.86 °C/m.

8. A certain pheromone from the gypsy moth has a percentage composition of 79.12%C, 9.79%H and 11.09%O. A solution containing 0.363 g of the compound in 5.00 g of benzene freezes at 4.27°C. What is the molar mass of the pheromone and what is its molecular formula? $K_{f,benzene}$ = 5.12°C/m.

9. Assuming complete dissociation of the solid, what is the predicted melting point of a 1.5 *m* solution of sodium chloride?

10. Draw a typical cooling curve for a pure solvent. Draw the cooling curve for a 1-m solution of the same solvent which has a molal freezing point depression constant of 2.0 °C/m. Identify each region of the curve.

11. The vapor pressure of water at 25.0°C is 23.8 torr. What is the vapor pressure of a solution of 10.0 g of glucose ($C_6H_{12}O_6$, 180.2 g mol^{-1}) dissolved in 100.0 g of water?

12. Assume no deviation from ideal behavior, what is the vapor pressure at 25°C of the solution prepared by mixing 50.0 mL of benzene with 50.0 mL of hexane? Some important information is given in the table. Not all information may be necessary.

Property	**Hexane**	**Benzene**
Formula	C_6H_{14}	C_6H_6
Vapor Pressure at 25°C (mm Hg)	151.6	95.1
Density (g/mL)	0.659	0.874
Normal boiling point (°C)	68.7	80.1

An Application of the van't Hoff Factor in Acid/Base Equilibrium

The freezing point of 0.10 *m* acetic acid is -0.19°C. What is the van't Hoff factor for acetic acid at this concentration and what fraction (in percentage) of the acetic acid molecules are ionized?

Hints:

$$i = \frac{\Delta T_{measured}}{\Delta T_{theoretical}}$$

$$\text{percentage ionization} = \frac{[\mathrm{H}^+]}{C_{\text{total acetic acid}}} \times 100 = \frac{[\mathrm{CH_3CO_2^-}]}{C_{\text{total acetic acid}}} \times 100$$