

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												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
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**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)
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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 μ s after which it decayed to element 110 by loss of an α -particle

Chapter 15 – 17

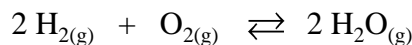
Chemical Equilibrium

Equilibrium I: Basic Principles and Calculations

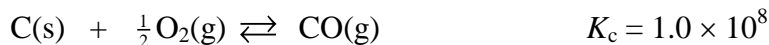
Remember the important associations about mass actions and equilibrium constant expressions:

- ✓ Reverse the direction the equation is written → invert K
- ✓ Add chemical equations → multiply the K 's for the reactions
- ✓ Increase stoichiometric coefficients by a factor → raise K to the power of factor

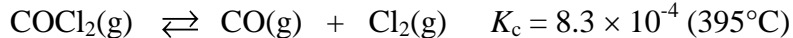
1. What is the calculated K_c for



given the the following reactions:



2. For the reaction:



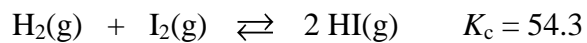
- a. What direction will the reaction proceed if 0.100 mol of COCl_2 is placed in a 2.0 L container and heated to 395°C ?

- b. What direction will the reaction proceed if 0.030 mol of each gas are placed in a 2.0 L vessel and heated?

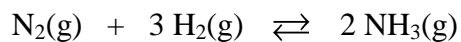
- c. For question a, what is the final concentration of each gas?

- d. For question b, what is the final concentration of each gas?

3. A quantity of 0.10 mol of I₂ and 0.10 mol H₂ are placed in a 1.00-L reaction vessel at 430°C. Calculate the equilibrium concentration of all species after equilibrium has been established.



4. The K_c for the reaction



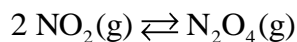
At 300°C is 0.45. Predict whether the reaction will proceed to the right, left, or is already at equilibrium when 0.10 mol N₂, 0.30 mol H₂, and 0.2 mol NH₃ are placed in a 2.00-L container and heated to 300°C. If a reaction occurs, what is the final concentration of each species?

5. The following quantities of reagents are introduced into a 1.00-L reaction vessel: 0.15 mol H_2 , 0.23 mol I_2 , and 0.015 mol HI. The reaction vessel is then thermostatted at 430°C . Convince yourself that the system is not at equilibrium and will shift right (to produce more product). What are the equilibrium concentrations of all species? (See problem 3 for additional information.)
6. For question 5, what will be the effect on the equilibrium concentrations if the volume of the container is reduced to 500.0 mL with no loss of reagents.

7. Consider the system at equilibrium in problem 4: what will be the new equilibrium concentrations if the volume of the container is reduced to 1.00 L with no loss of reactants or products?
8. Consider the system at equilibrium in problem 4: what will be the new equilibrium concentrations if the total pressure in the container is increased by adding 1.0 atm of helium gas?

Equilibrium Problems Using K_p

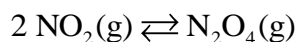
1. Nitrogen dioxide is a component of the brown smog seen over some industrialized cities. The brown nitrogen dioxide participates in an equilibrium with colorless dinitrogen tetraoxide according to the equation



The $K_{p,\text{atm}}$ for the reaction is 7.5 at 298K (25°C). What is the partial pressure of each gas (in atm) if 0.10 mol of N_2O_4 is placed in a 1.0 L container, sealed, and allowed to come to equilibrium at 298 K?

Unimportant information pertaining to the problem: The N_2O_4 is transferred as a solid at -100°C then the reaction vessel is sealed and the N_2O_4 allowed to vaporize at the experimental temperature.

2. Nitrogen dioxide is a component of the brown smog seen over some industrialized cities. The brown nitrogen dioxide participates in an equilibrium with colorless dinitrogen tetraoxide according to the equation



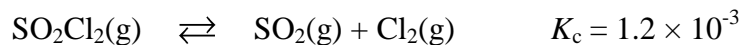
The $K_{p,\text{atm}}$ for the reaction is 7.5 at 298K. What is the partial pressure of each gas (in atm) if a $\text{NO}_2/\text{N}_2\text{O}_4$ mixture, already at equilibrium, is introduced into a container to a total pressure of 150 mmHg?

Equilibrium II: A Couple More Equilibrium Problems

1. A solution of 0.1 M acetic acid is about 1.4% ionized in water as measured by solution's electrical conductivity. What is K_c for



2. A quantity of 0.050 mol of SO_2 gas and 0.025 mol of Cl_2 gas are introduced into an evacuated 1.75 L flask and the following equilibrium is established at 303 K:



What are the final concentrations of each gas?

Some Relative Acid-Conjugate Base Strengths

Strong Acids		K_a	Conjugate Bases	
perchloric acid	HClO ₄	large	perchlorate	ClO ₄ ⁻
hydroiodic acid	HI	large	iodide	I ⁻
hydrobromic acid	HBr	large	bromide	Br ⁻
hydrochloric acid	HCl	large	chloride	Cl ⁻
sulfuric acid	H ₂ SO ₄	large	hydrogen sulfate	HSO ₄ ⁻
nitric acid	HNO ₃	large	nitrate	NO ₃ ⁻

Weak Acids			Conjugate Bases	
hydrogen sulfate	HSO ₄ ⁻	1.1×10^{-2}	sulfate	SO ₄ ⁻
nitrous acid	HNO ₂	7.2×10^{-4}	nitrite	NO ₂ ⁻
formic acid	HCO ₂ H	1.8×10^{-4}	formate	HCO ₂ ⁻
acetic acid	CH ₃ COOH	1.8×10^{-5}	acetate	CH ₃ COO ⁻
carbonic acid	H ₂ CO ₃	4.4×10^{-7}	hydrogen carbonate	HCO ₃ ⁻
ammonium ion	NH ₄ ⁺	5.6×10^{-10}	ammonia	NH ₃
hydrogen carbonate	HCO ₃ ⁻	4.8×10^{-11}	carbonate	CO ₃ ²⁻
ammonia	NH ₃	very small	amide ion	NH ₂ ⁻

Equilibrium III: Basic Acid-Base Equilibrium

1. What are the species (equilibrium) concentrations of H_3O^+ , OH^- , and Cl^- in 0.10 M hydrochloric acid?
2. What are the concentrations of each species in a solution prepared to be 0.10 M acetic acid (CH_3COOH)? $K_a = 1.75 \times 10^{-5}$
3. What is the approximate pH of 0.075 M formic acid? $K_a = 1.7 \times 10^{-4}$

4. What is the K_a of nitrous acid if a 0.050 M solution has a pH of 2.34?
5. What is the pH of 0.010 M ammonia? $K_b = 1.8 \times 10^{-5}$
6. Assuming that $K_a = 1.75 \times 10^{-5}$ for acetic acid, what is K_b for acetate ion? What is the pH of 0.010 M sodium acetate?

Equilibrium IV: Polyprotic Acid-Base Equilibrium

1. Calculate the approximate pH of a solution prepared to be 0.0010 M malonic acid ($\text{H}_2\text{C}_3\text{H}_2\text{O}_4$, $K_1 = 1.5 \times 10^{-3}$, $K_2 = 2.0 \times 10^{-6}$).

2. Calculate the concentration of all species in 0.10 M H_3PO_4 .

$$K_1 = 7.5 \times 10^{-3} \quad K_2 = 6.2 \times 10^{-8} \quad K_3 = 4.8 \times 10^{-13}$$

3. Calculate the pH of the solution prepared to be 0.015 M sodium malonate ($\text{Na}_2\text{C}_3\text{H}_2\text{O}_4$)

Equilibrium V: Acid-Base Buffers and Titrimetry

1. Calculate the pH of the solution which is prepared to be 0.10 M in nitrous acid and 0.15 M sodium nitrite.

2. What is the calculated pH of the buffer solution formed by dissolving 4.2 g of acetic acid and 9.0 g of sodium acetate in water and diluting to 500.0 mL?

3. A 10.0 mL quantity of 0.1 M HCl is mixed with 95 mL of 0.15 M sodium nitrite. What is the pH of the new solution?

4. What is the calculated pH of the solution formed by mixing 10.0 mL of 0.15 M NaOH with 85 mL of 0.10 M benzoic acid?

Titration Problems

1. In 1 or 2 sentences, explain back-titration.

2. Name and give the formulas for any 2 different substances used in common antacids.

3. Write the reaction of HCl with one of the two substances listed in question 2. If you cannot answer question 2, write the reaction of HCl with barium hydroxide.

4. To a 0.100 g sample of an antacid was added 50.00 mL of 0.100 M HCl. The antacid tablet dissolved and CO₂ gas was produced. The solution was boiled and cooled to remove the last of the CO₂. Phenolphthalein was added to the solution and the excess HCl titrated with standard 0.100 M NaOH to the phenolphthalein endpoint. It required 3.00 mL of the NaOH.
 - a. What color is the phenolphthalein endpoint?

 - b. What is the number of moles of HCl neutralized per gram of antacid?

 - c. What is the percentage CaCO₃ in the antacid?

5. 25 mL of 0.1 M acetic acid is titrated with 0.1 M NaOH. Calculate the pH of the solution after the addition of the following amounts of base. What acid-base indicator would be best to indicate endpoint?

0 mL of NaOH

1 mL

5 mL

15 mL

25 mL

30 mL

For personal extra credit, calculate more points and plot the curve of pH vs Volume of base added. Then compare this curve to that obtained by titrating 25 mL of 0.1 M HCl with 0.1 M NaOH.

