Queen's University at Kingston

Chem 112 Midterm Exam
Winter Term
Test Form A

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Time: 1 hour

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INSTRUCTIONS:

You will be given the exam paper and a computer–marked sheet on which you will answer all your questions.

- You must use a soft–lead pencil (HB or softer). The scanner will not read ink no matter how black a mark it makes.
- Do not bend or fold the computer sheet in any way or it will become jammed in the scanner.
- Write and code your name and student number and on the answer sheets in the appropriate spaces. (*Be especially careful to code in your student number properly*.)
- Please code A in the Test Form spot on the computer sheet.
- Do not mark the computer answer sheet in any way except to encode the answers. Stray marks can be read by the machine as incorrect answers!
- Make sure you've coded in all the answers. No marks are deducted for wrong answers so DO NOT LEAVE BLANKS! There is exactly one answer for each multiple-choice question.
- All multiple choice questions are worth 1 mark.
- There are 20 questions in total.
- You are allowed to use any basic, non-programming, non-communications-able calculator.
- The final page of this exam has a larger version of the periodic table found in the data sheet on the penultimate page (the values are the same in both).

PLEASE NOTE:

Proctors are unable to respond to queries about the interpretation of exam questions. Do your best to answer exam questions as written.

Good luck

1. Consider the following reaction at a certain temperature:

$H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$ $K = 2.4 \times 10^{-2}$

If 2.0 mol of $H_2(g)$, 2.0 mol of $Br_2(g)$, and 0.10 mol HBr(g) were together mixed in a 1.0-L flask, then

(a) the concentration of $Br_2(g)$ would increase
(b) the value of K would decrease to 2.5×10^{-3}
(c) the concentration of HBr(g) would increase
(d) no change would occur
(e) the total number of molecules would decrease

When the gases are mixed together, the reaction quotient $Q = [HBr]^2/[H_2][Br_2] = (0.10)^2/(2.0)(2.0) = 2.5 \times 10^{-3}$. Note - because $\Delta n = 0$ (same number of moles of gas on each side of reaction), $K_p = K_c$. As $Q < K$, the reaction will proceed to the right until Q = K, so that the concentration of HBr(g) will increase.

2. Consider the reaction

$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

At 298 K, $K_c = 1.3 \times 10^{-3}$, whereas at 783 K, $K_c = 2.2 \times 10^{-2}$. Which of the following is true?

(a) the reaction is exothermic
(b) the reaction is endothermic
(c) at 298 K, $K = 3.2 \times 10^{-2}$
(d) at 298 K, the reaction is likely to be spontaneous
(e) at 783 K, more HI(g) is produced

The equilibrium constant K_c is higher at the higher temperature (783 K) than at the lower temperature (298 K), such that the reaction is endothermic ($\Delta H > 0$)

3. The conjugate base of ammonia is:

(a) NH_2OH
(b) NH_2^-
(c) NH_4^+
(d) NH_3
(e) H_2O

The conjugate base of ammonia, NH_3, results from a dissociation of H^+ from NH_3 giving NH_2^-.

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_2^-(aq) + H_3O^+(aq)$

4. Which of the following is the weakest acid?

(a) HBr
(b) HNO_3
(c) HF
(d) HCl
(e) HI

Nitric acid is a strong acid because of the high oxidation state of N and the two oxo groups attached to N. The remaining acids are binary acids (HX) containing halogen atoms. With binary acids, the trend in the acid strength going down a column follows the H-X bond strength. With the highest charge density on F^-, it holds onto the H^+ the strongest, such that HF is a weak acid, while HCl, HBr, and HI are all strong acids.

5. Which of the following is the strongest base?

(a) morphine (pK_b = 5.79)
(b) urea (pK_b = 13.90)
(c) ammonia (pK_b = 4.75)
(d) pyridine (pK_b = 8.75)
(e) methylamine (pK_b = 3.44)

The smaller the value of pK_b (= -logK_b), the larger the basicity contant K_b and the stronger the base. Methylamine has the lowest pK_b and therefore it is the strongest base in this group.

6. Which of the following aqueous solutions gives a pH greater than 7?

(a) 10^{-8} M NH_4Cl
(b) 10^{-8} M CH_3COOH
(c) 10^{-8} M CH_3NH_2
(d) 10^{-8} M HCOOH
(e) 10^{-8} M HCl

The compounds in (a), (b), (d), and (e) would all generate H_3O^+ when in aqueous solution (pH of solution would be < 7), even at their low concentrations. The only compound in the group which is a base, and would generate OH^- in aqueous solution is (c) CH_3NH_2, which would produce a solution which has a pH > 7.

7. A 0.100 mol sample of H_2S is placed in a 10.0 L reaction vessel and heated to 1132 °C. At equilibrium, 0.0285 mol H_2 is present. What is the value of K_c for the following reaction at 1132 °C ?

$$2\ H_2S(g) \rightleftharpoons 2\ H_2(g) + S_2(g)$$

(a) 2.2×10^{-4}
(b) 2.2×10^{-3}
(c) 5.6×10^{-3}
(d) 5.6×10^{-4}
(e) 4.5×10^{-4}

Initially, the concentration of H_2S is 0.100 mol/10.0 L = 1.00×10^{-2} M, while there is no H_2 or S_2. If the concentration of H_2 at equilibrium is 0.0285 mol/10.0 L = 2.85×10^{-3} M, then that equilibrium concentration of S_2 = ½(2.85×10^{-3} M) = 1.43×10^{-3} M. The equilibrium concentration of H_2S = 1.00×10^{-2} M – 2.85×10^{-3} M = 7.2×10^{-3} M. The equilibrium concentration = $[H_2]^2[S_2]/[H_2S]^2$ = $(2.85 \times 10^{-3})^2(1.43 \times 10^{-3})/(7.2 \times 10^{-3})^2$ = 2.2×10^{-4}.

8. Consider the reaction $2\ NO_2(g) \rightleftharpoons 2\ NO(g) + O_2(g)$. If the initial partial pressure of $NO_2(g)$ is 3.0 bar, and x is the equilibrium partial pressure of $O_2(g)$, what is the correct equilibrium relationship?

(a) $K_p = x^3$
(b) $K_p = 2x^2/(3.0 - 2x)^2$
(c) $K_p = 4x^3/(3.0 - 2x)^2$
(d) $K_p = x^2/(3.0 - x)$
(e) $K_p = 2x/(3.0 - x)^2$

For every molecule of O_2 which is produced in the reaction (+x), two molecules of NO are produced (+2x) and two molecules of NO_2 are consumed (-2x). If the initial partial pressure of NO_2 is 3.0 bar, then the equilibrium partial pressures of NO_2, NO, and O_2 are (3.0 – 2x), (2x), and (x). The equilibrium constant may be expressed as:

$$K_p = (P_{NO})^2(P_{O2})/(P_{NO2})^2 = (2x)^2(x)/(3.0 - 2x)^2 = 4x^3/(3.0 - 2x)^2$$

9. When solid NH_4HS and 0.400 mol $NH_3(g)$ were placed in a 2.00 L vessel at 24 °C, the equilibrium for the reaction:

$$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$$

for which $K_c = 1.6 \times 10^{-4}$, was reached. What is the equilibrium concentration of $H_2S(g)$?

(a) 0.399 mol L^{-1}
(b) 8.0×10^{-4} mol L^{-1}
(c) 0.200 mol L^{-1}
(d) 4.0×10^{-4} mol L^{-1}
(e) 1.6×10^{-3} mol L^{-1}

The initial concentration of NH_3 is 0.400 mol/2.00 L = 0.200 mol L^{-1}, while there is no H_2S initially. Because NH_4HS is a pure solid (activity = 1), it does not appear in the expression for K_c. At equilibrium, the concentration of NH_3 would be (0.200 + x), while the concentration of H_2S would be x. $K_c = 1.6 \times 10^{-4} = (0.200 + x)(x)$. Assuming x is small compare to 0.200 gives $x = (1.6 \times 10^{-4})/(0.200) = 8.0 \times 10^{-4}$ mol L^{-1}.

10. What is the initial concentration of HClO ($K_a = 3.0 \times 10^{-8}$) that results in an aqueous solution with a pH of 5.10?

(a) 7.9×10^{-3} M
(b) 0.10 M
(c) 3.0×10^{-8} M
(d) 3.8×10^{-3} M
(e) 2.1×10^{-3} M

If the pH of the solution is 5.10, then this tells us that at equilibrium the $[H_3O^+] = [ClO^-] = 10^{-pH} = 10^{-5.10} = 7.9 \times 10^{-6}$. The acid dissociation constant $K_a = [H_3O^+][ClO^-]/[HClO]$, and therefore:

$3.0 \times 10^{-8} = (7.9 \times 10^{-6})^2/([HClO]_{initial} - 7.9 \times 10^{-6})$ rearranging gives:

$[HClO] = 7.9 \times 10^{-6} + ((7.9 \times 10^{-6})^2/(3.0 \times 10^{-8})) = 7.9 \times 10^{-6} + 2.1 \times 10^{-3} = 2.1 \times 10^{-3}$

11. What is the pOH of a solution of 0.00250 M $HClO_4$?

(a) 4.00×10^{-12}
(b) 11.40
(c) 2.60
(d) 7.00
(e) 12.40

$HClO_4$ is a strong acid, so it would produce a solution with $[H_3O]^+$ = 0.00250 M. The pH = -log(0.00250) = 2.60. The pOH = 14.00 – pH = 14.00 – 2.60 = 11.40.

12. What is the pH of a 500.0 mL solution of 0.100 M HCl(aq) after 0.0225 mol of solid $Ca(OH)_2$ is added (assuming no volume change)?

(a) 1.41
(b) 2.60
(c) 2.30
(d) 2.00
(e) 1.11

The solution of the strong acid HCl would produce 0.100 mol L^{-1} x 0.500 L = 0.0500 mol of H_3O^+. The 0.0225 mol of the strong base $Ca(OH)_2$ would produces 2 x 0.0225 mol = 0.0450 mol of OH^-, which would react with 0.0450 mol of H_3O^+ to produce water. This would leave 0.0500 – 0.0450 = 0.0050 mol of H_3O^+ in 0.500 L of solution = 0.0100 M H_3O^+. The pH would equal $-\log[H_3O]^+ = -\log(0.0100) = 2.00$

13. Given that the K_a of the $H_2PO_4^-$ anion is 6.2 x 10^{-8}, what is the pH of a 0.500 L aqueous solution prepared by adding 0.065 mol of $NaH_2PO_4(s)$ and 0.050 mol of $Na_2HPO_4(s)$?

(a) 6.79
(b) 7.10
(c) 5.39
(d) 7.32
(e) 7.21

The mixture of the salt of $H_2PO_4^-$ and the salt of its conjugate base HPO_4^{2-} would generate a buffer solution. Using the Henderson-Hasselbach equation ($pK_a = -\log K_a = -\log(6.2 \times 10^{-8}) = 7.21$), gives:

$$pH = 7.21 + \log([base]/[acid]) = 7.21 + \log((0.050\ mol/0.500\ L)/(0.065\ mol/0.500\ L))$$

$$pH = 7.21 + \log(0.77) = 7.21 + (-0.11) = 7.10$$

14. What is the pH at the stoichiometric (equivalence) point when a 25.00 mL solution of 0.100 M $NH_3(aq)$ (pK_b of NH_3 = 4.75) is titrated with a 0.200 M solution of HCl (aq)?

(a) 5.21
(b) 5.75
(c) 5.13
(d) 4.75
(e) 5.93

At the stoichiometric point of the titration of the weak base NH_3 with the strong acid HCl, the major species in solution is the conjugate acid NH_4^+ ($pK_a = 14.00 - pK_b = 14.00 - 4.75 = 9.25$) Because the concentration of HCl titrant is twice the concentration of the NH_3 analyte, the volume of 0.200 M HCl required = ½(25.00 mL) = 12.50 mL, and the total volume = 37.50 mL. The concentration of the weak acid NH_4^+ is 0.100 x (25.00/37.50) = 0.0667 M. At equilibrium, the $[NH_4^+]$ is 0.0667 – x, and $[H_3O^+] = [NH_3] = x$. $K_a = 10^{-9.25} = 5.6 \times 10^{-10} = x^2/(0.0667 - x)$. Approximating 0.0667 – x = 0.0667, and solving for x, gives $x = [H_3O^+] = 6.1 \times 10^{-6}$. pH = 5.21

15. What number of moles of solid KOH must be added to a 0.250 L solution of 0.100 M $CH_3COOH(aq)$ (K_a of CH_3COOH is 1.8 x 10^{-5}) to make the pH of the solution equal to 5.00 (assume no volume change upon addition of KOH(s))?

(a) 2.5 x 10^{-2} mol
(b) 4.4 x 10^{-2} mol
(c) 3.5 x 10^{-3} mol
(d) 4.0 x 10^{-3} mol
(e) 1.6 x 10^{-2} mol

Adding strong base to a weak acid solution will generate a buffer solution if the pH is within 1 unit of the pK_a value. For CH_3COOH, the $pK_a = -\log K_a = -\log(1.8 \times 10^{-5}) = 4.74$. The Henderson-Hasselbach equation gives:

$5.00 = 4.74 + \log([base]/[acid])$ this gives $[base]/[acid] = 10^{0.26} = 1.8$ (= ratio of moles)

if x mol of KOH is added, mol of CH_3COOH = 0.025 – x mol

$1.8 = (x)/(0.025 - x)$ rearranging $0.045 - 1.8x = x$ $0.045 = 2.8x$ $x = 1.6 \times 10^{-2}$ mol

16. At 400 K, the equilibrium concentrations of $N_2O_4(g)$ and $NO_2(g)$ are 1.00 M and 1.20 M, respectively. At 25 °C, the value of K_c is 6.10 x 10^{-3}. What is ΔH° for the following reaction?

$$N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$$

(a) 12.6 kJ mol^{-1}
(b) 51.3 kJ mol^{-1}
(c) 1.21 kJ mol^{-1}
(d) 53.1 kJ mol^{-1}
(e) -1.06 kJ mol^{-1}

Let T_1 = 298 K (25 °C) and $K_{c1} = 6.10 \times 10^{-3}$. At T_2 = 400 K, the value of $K_{c2} = [NO_2]^2/[N_2O_4] = (1.2)^2/(1.0) = 1.44$. Using the van't Hoff equation from the equation sheet ($\ln(K_2/K_1) = (-\Delta H^\circ/R)(1/T_2 - 1/T_1)$:

$$\ln(1.44/6.10 \times 10^{-3}) = (-\Delta H^\circ/8.3145)(1/400 - 1/298)$$

$$\Delta H^\circ = (8.3145 \times 5.464)/(8.56 \times 10^{-4}) = 53100\ J\ mol^{-1} = 53.1\ kJ\ mol^{-1}$$

17. The solubility of which one of these does **not** increase as the pH of the solution decreases?

(a) CaF_2
(b) Na_2CO_3
(c) $PbSO_3$
(d) $KClO_4$
(e) CuS

For each of these salts, dissolution produces cations and anions. The anions produced from CaF_2 (F^-), Na_2CO_3 (CO_3^{2-}), $PbSO_3$ (SO_3^{2-}), and CuS (S^{2-}) are weak bases. As such, decreasing the pH would increase $[H_3O^+]$ and neutralize some of the basic anions. In response to decreasing the concentration of the anions, Le Chetelier's principle would indicate that more of the salt would dissolve to return Q_{sp} to the value of K_{sp}. The exception would be $KClO_4$, as the ClO_4^- anion is the conjugate base of a very strong acid $HClO_4$. As such, it is not possible to protonate ClO_4^- and reduce its concentration with acid – solubility is independent of pH.

18. If equal volumes of 0.0040 M $Mg(NO_3)_2(aq)$ and 0.0040 M KF(aq) are mixed, what reaction, if any, occurs? The value of K_{sp} for $MgF_2(s)$ is 3.7×10^{-8}.

(a) MgF(s) precipitates
(b) $MgF_2(s)$ precipitates
(c) $KNO_3(s)$ precipitates
(d) no reaction occurs
(e) the value of K_{sp} changes to 8.0×10^{-9}

When equal volumes of two solutions are mixed, the concentrations of the solutes are reduced to one half of their original concentrations. The value of Q_{sp} for the equilibrium involving the sparingly soluble MgF_2 is equal to $[Mg^{2+}][F^-]^2 = (0.0040/2)(0.0040/2)^2 = 8.0 \times 10^{-9}$. Since this is less than K_{sp}, no precipitation of MgF_2 will occur.

19. What is the molar solubility of $BaSO_4(s)$ in a solution of 0.050 M $Na_2SO_4(aq)$? The K_{sp} of $BaSO_4$ is 1.1×10^{-10}.

(a) 2.3×10^{-6} M
(b) 1.0×10^{-5} M
(c) 2.2×10^{-9} M
(d) 5.5×10^{-12} M
(e) 3.3×10^{-6} M

The salt Na_2SO_4 contains the common ion SO_4^{2-} to the sparingly soluble $BaSO_4(s)$. $K_{sp} = [Ba^{2+}][SO_4^{2-}] = s^2$ (where s is the molar solubility)

At equilibrium $K_{sp} = 1.1 \times 10^{-10} = (s)(s + 0.050)$

We can approximate s + 0.050 by 0.050 (since K_{sp} is very small) and therefore:

$s = (1.1 \times 10^{10})/(0.050) = 2.2 \times 10^{-9}$ M

20. Consider the titration of 15.0 mL of 0.200 M H_3PO_4 with 0.200 M NaOH(aq). What is(are) the major species in solution after addition of 30.0 mL of the base?

(a) $H_2PO_4^-(aq)$
(b) PO_4^{3-} (aq)
(c) $H_2PO_4^-$ (aq) and $HPO_4^{2-}(aq)$
(d) $H_3PO_4(aq)$ and $H_2PO_4^-(aq)$
(e) $HPO_4^{2-}(aq)$

Titrating the weak triprotic acid H_3PO_4 with the strong base NaOH (of the same concentration) would result in three stoichiometric (equivalence) points: forming $H_2PO_4^-$ at the first stoichiometric point after adding 15.0 mL of NaOH, then HPO_4^{2-} at the second stoichiometric point after adding another 15.0 ml (total 30.0 mL of titrant) of NaOH, and finally PO_4^{3-} at the third stoichiometric point after adding another 15.0 mL (total 45.0 mL of titrant) of NaOH. Therefore with the addition of 30.0 mL of NaOH, the HPO_4^{2-} ion is produced. Because HPO_4^{2-} is a weak acid, it dissociates to only a very small extent and is the major species at this point in the titration

END OF EXAM

Data/Formula Sheet

Symbol	Value
R	8.31451 J K^{-1} mol^{-1}
	0.083145 L•bar mol^{-1} K^{-1}
	0.08206 L•atm mol K^{-1}
k_b	1.3807×10^{-23} J K^{-1}
N_A	6.0221×10^{23} mol^{-1}
F	96485. C mol^{-1}
e	1.6022×10^{-19} C
h	6.6261×10^{-34} J s
m_p	1.6726×10^{-27} kg
m_e	9.1094×10^{-31} kg
R_H	2.179×10^{-18} J
c	2.9979×10^{8} m s^{-1}

	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 **H** 1.008																	2 **He** 4.003
2	3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 18.99	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.1	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.84	27 **Co** 58.99	28 **Ni** 58.34	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 73.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.8
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 99	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 138.9	73 **Ta** 181.0	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** 209	85 **At** 210	86 **Rn** 222
7	87 **Fr** 223	88 **Ra** 226	89 **Ac** 227															
			6	58 **Ce** 140	59 **Pr** 141	60 **Nd** 144	61 **Pm** 145	62 **Sm** 150	63 **Eu** 152.0	64 **Gd** 157	65 **Tb** 159	66 **Dy** 163	67 **Ho** 165	68 **Er** 167	69 **Tm** 169	70 **Yb** 173.0	71 **Lu** 175.0	
			7	90 **Th** 232	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237	94 **Pu** 244	95 **Am** 243	96 **Cu** 247	97 **Bk** 247	98 **Cf** 251	99 **Es** 252	100 **Fm** 257	101 **Md** 258	102 **No** 259	103 **Lr** 262	

1 atm = 101.325 kPa = 760 mm Hg = 760 torr ***1L = 1 dm^3 0ºC = 273.15 K***

1 bar = 10^5 kPa

$E = h\nu$ $c = \lambda\nu$ $\lambda = \frac{h}{mv}$ $u_{rms} = \sqrt{\frac{3RT}{M}}$ $f(u) = 4\pi\left(\frac{m}{2\pi k_BT}\right)^{3/2} u^2 e^{-\frac{mu^2}{2k_BT}}$ $\Delta x\Delta p \ge \frac{h}{4\pi}$

$w(A) = \frac{m(A)}{m(A)+m(B)+\ldots}$ $w(A) + w(B) + \ldots = 1$ $x(A) = \frac{n(A)}{n(A)+n(B)+\ldots}$ $\Delta H = \sum_{broken} BE - \sum_{formed} BE$

$b(A) = \frac{n(A)}{m(S)}$ $c(A) = \frac{n(A)}{V}$ *density = m/V* $\Delta E = h\nu = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ $x(A) + x(B) + \ldots = 1$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$P_1V_1 = P_2V_2$ $PV = nRT$ $w = -P_e\Delta V = -\Delta n_{gas}RT$ $\Delta U = q + w$ $\Delta U = q_v$ $\Delta H = q_p$ $\Pi V = nRT$

$p_B = x_BK_H$ $p_A + p_B + \ldots = P$ $y_A = \frac{p_A}{p_A + p_B} = \frac{x_AP_A^*}{x_AP_A^* + (1-x_A)P_B^*}$ $y_B = \frac{p_B}{p_A + p_B} = \frac{(1-x_A)P_B^*}{x_AP_A^* + (1-x_A)P_B^*}$

$C_V = \frac{\Delta U}{\Delta T}$

$\Delta H = \Delta U + P\Delta V$ $C = \frac{q}{\Delta T}$ $C_P = \frac{\Delta H}{\Delta T}$ $C_P - C_V = R$ $p_A = x_AP_A^*$

$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT$ $a = \frac{27R^2T_C^2}{64P_C}$ $b = \frac{RT}{8P_C}$ $\ln\left(\frac{P_2^*}{P_1^*}\right) = -\frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ $[H^+] = \frac{-K_a + \sqrt{K_a^2 + 4K_aC_a}}{2}$ $K_p = (RT)^{\Delta n}K_c$

$\Delta S^o = \sum S^o(P) - \sum S^o(R)$ $\Delta H_T^o = \Delta H_{298}^o + \Delta C_P(T - 298)$ $\Delta H^o = \sum \Delta H_f^o(P) - \sum \Delta H_f^o(R)$

$\ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ $[H^+] = \sqrt{K_aC_a}$ $[OH^-] = \sqrt{K_bC_b}$ $pH = (pK_a + pC_a)/2$ $pOH = (pK_b + pC_b)/2$

$[OH^-] = \frac{-K_b + \sqrt{K_b^2 + 4K_bC_b}}{2}$ $pH = pK_a + \log\frac{[base]}{[acid]}$ $\frac{(U_{rms})_A}{(U_{rms})_B} = \sqrt{\frac{M_B}{M_A}}$ $\Delta S = \frac{q_{rev}}{T}$ $\Delta S = \frac{\Delta H}{T}$

$\Delta S = \frac{C\Delta T}{T}$ *or* $\Delta S = C\ln\frac{T_2}{T_1}$ $\Delta S = R\ln\frac{V_2}{V_1} = -R\ln\frac{P_2}{P_1}$ $\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ $G = H - TS$

$\Delta G^o = \Delta H^o - T\Delta S^o$ $\Delta G = \Delta G^\circ + RT\ln Q$ $\Delta G^\circ = -RT\ln K$ $S_{universe} = S_{system} + S_{surroundings}$

$KE = \frac{1}{2}mv^2$ $h\nu = KE + \phi$ M = m/n $\Delta G^o = \sum \Delta G_f^o(P) - \sum \Delta G_f^o(R)$ $w' = -nFE$

$E = E^\circ - \frac{RT}{nF}\ln Q$ $\Delta G^o = -nFE^o$ $K = \exp\left(\frac{nFE^\circ}{RT}\right)$ $E_{cell} = E_{ox} + E_{red}$ Q = nF Q = It

$[A]_t = -kt + [A]_0$ $\ln[A]_t = -kt + \ln[A]_o$ $\frac{1}{[A]_t} = \frac{1}{[A]_o} + kt$ $t_{1/2} = \frac{\ln 2}{k}$ $k = A\exp\{-E_a/RT\}$

$2r = L = a$ $4r = \sqrt{2}L = \sqrt{2}a$ $4r = \sqrt{3}L = \sqrt{3}a$ $b = \sqrt{2}a$ $c = \sqrt{3}a$

	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 **H** 1.008																	2 **He** 4.003
2	3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 18.99	10 **Ne** 20.18
3	11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.1	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.84	27 **Co** 58.99	28 **Ni** 58.34	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 73.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.8
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 99	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
6	55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 138.9	73 **Ta** 181.0	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** 209	85 **At** 210	86 **Rn** 222
7	87 **Fr** 223	88 **Ra** 226	89 **Ac** 227															
			6	58 **Ce** 140	59 **Pr** 141	60 **Nd** 144	61 **Pm** 145	62 **Sm** 150	63 **Eu** 152.0	64 **Gd** 157	65 **Tb** 159	66 **Dy** 163	67 **Ho** 165	68 **Er** 167	69 **Tm** 169	70 **Yb** 173.0	71 **Lu** 175.0	
			7	90 **Th** 232	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237	94 **Pu** 244	95 **Am** 243	96 **Cu** 247	97 **Bk** 247	98 **Cf** 251	99 **Es** 252	100 **Fm** 257	101 **Md** 258	102 **No** 259	103 **Lr** 262	