

THE UNIVERSITY OF CALGARY  
FACULTY OF SCIENCE  
FINAL EXAMINATION  
CHEMISTRY 209  
Version A

Date: Tuesday, April 22<sup>nd</sup>, 2014

Time: 12:00 noon – 3:00 pm

FIRST NAME: \_\_\_\_\_ LAST NAME: \_\_\_\_\_

ID # \_\_\_\_\_

Please circle your lecture section number below.

Lec. 01 Dr. M. Parvez  
(Tu/Th 12:30 pm)

Lec. 02 Dr. E. Sullivan  
(Tu/Th 8:00 am)

This is a closed-book examination. The use of camera devices, MP3 Players and headphones, or wireless access devices such as cell phones, Blackberries, etc., during the examination will not be allowed. Only non-programmable calculators are permitted. A Chemical Data Sheet is provided at the end of the exam and can be removed for quick reference. All questions must be answered to obtain full marks. **The answers to the multiple choice section must be entered on the optical score sheet using a pencil within the 3 hour exam.** The answers to the long answer questions must be written in the space provided on the question sheets AND written in non-erasable ink to be eligible for re-grading.

This test consists of 22 multiple choice questions worth 2 marks each (total 44 marks) and 4 long answer questions (total 34 marks). The total value for the test is 78 marks. The exam has 15 pages make sure you have all 15 pages.

AT THE END OF THE EXAMINATION, HAND IN THE OPTICAL SCORE SHEET AND THE ENTIRE  
EXAM PAPER

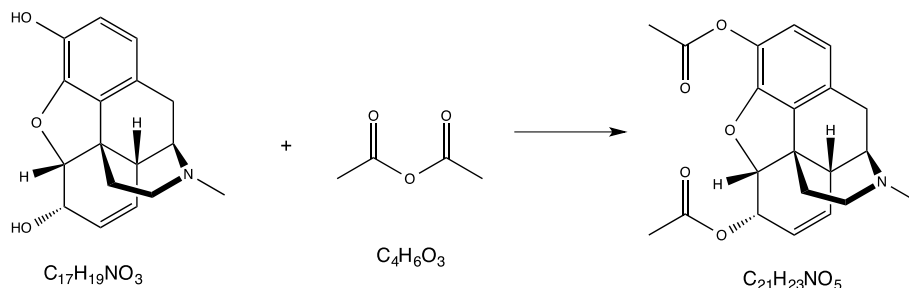
**Failing to encode this Exam Booklet or your Optical Score Sheet correctly, for your Name, Exam Version (A or B), ID and Lecture Section, will result in the loss of two marks**

DO NOT WRITE IN THIS BOX, FOR GRADING PURPOSES ONLY!

Q 23	Q 24	Q25	Q26

**SECTION I - Machine graded section (Total value 44)**  
**To be answered on provided Optical Score Sheet**

1. Morphine reacts in a 1:1 mole ratio with acetic anhydride to form Heroin, as shown below:



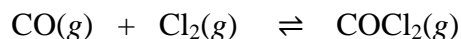
If we had 14.00 g of Morphine ( $C_{17}H_{19}NO_3$ , 285.34 g/mol) and 5.00 mL of acetic anhydride ( $C_4H_6O_3$ , 102.09 g/mol,  $d = 1.082$  g/mL), which reagent would **limit** the amount of Heroin ( $C_{21}H_{23}NO_5$ , 369.45 g/mol) that forms?

- A) Morphine  
B) Acetic anhydride  
C) Heroin  
D) We would have exactly the same amount of the product since the reaction involves a 1:1 mole ratio of the reactants.  
E) Insufficient information given
2. Tetrafluoroethylene,  $C_2F_4$ , can be converted to octafluorocyclobutane which can be used as a refrigerant or an aerosol propellant. A plot of  $1/[C_2F_4]$  vs. time gives a straight line with a slope of  $0.0448 \text{ L mol}^{-1} \text{ s}^{-1}$ . What is the **rate law** for this reaction?
- A)  $\text{Rate} = 0.0448 \text{ L mol}^{-1} \text{ s}^{-1} [C_2F_4]$   
B)  $\text{Rate} = 22.3 \text{ mol L}^{-1} \text{ s} [C_2F_4]$   
C)  $\text{Rate} = 0.0448 \text{ L mol}^{-1} \text{ s}^{-1} [C_2F_4]^2$   
D)  $\text{Rate} = 22.3 \text{ mol L}^{-1} \text{ s} [C_2F_4]^2$   
E)  $\text{Rate} = 0.0448 \text{ s}^{-1} [C_2F_4]$

3. The decomposition of dimethylether at 504 °C is first order with a half-life of 1570. seconds. What fraction of dimethylether (  $[A]_t / [A]_o$  ) remains after 4710. seconds?

- A) 1/3
- B) 1/6
- C) 1/8
- D) 1/16
- E) 1/32

4. Carbon monoxide and chlorine combine in an equilibrium reaction to produce the highly toxic product, phosgene ( $\text{COCl}_2$ ).

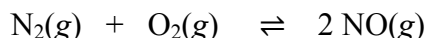


If the equilibrium constant for this reaction is  $K_c = 248$ , predict, if possible, what will happen when the reactants and product are combined with the concentrations shown below:

$$[\text{CO}] = [\text{Cl}_2] = 0.010 \text{ mol L}^{-1}; [\text{COCl}_2] = 0.070 \text{ mol L}^{-1}$$

- A) The reaction will proceed to the right.
- B) The reaction will proceed to the left.
- C) The reaction is at equilibrium, and no change in concentrations will occur.
- D) The container volume needs to be specified before a prediction can be made.
- E) The temperature needs to be specified before a prediction can be made.

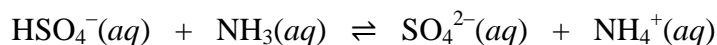
5. Nitric oxide is formed in automobile exhaust when nitrogen and oxygen in air react at high temperatures.



The equilibrium constant  $K_p$  for the reaction is 0.0025 at 2127 °C. If a container is charged with 8.00 bar of nitrogen and 5.00 bar of oxygen and the mixture is allowed to reach equilibrium, what will be the equilibrium partial pressure of nitrogen?

- A) 0.16 bar
- B) 0.31 bar
- C) 3.1 bar
- D) 7.7 bar
- E) 7.8 bar

6. The acid dissociation constant  $K_a$  equals  $1.26 \times 10^{-2}$  for  $\text{HSO}_4^-$  and is  $5.6 \times 10^{-10}$  for  $\text{NH}_4^+$ . Which statement about the following equilibrium is **correct**?



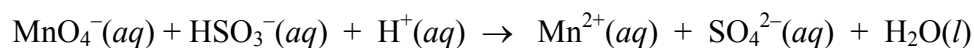
- A) The reactants will be favored because ammonia is a stronger base than the sulfate anion.
- B) The products will be favored because the hydrogen sulfate ion is a stronger acid than the ammonium ion.
- C) Neither reactants nor products will be favored because all of the species are weak acids or bases.
- D) The initial concentrations of the hydrogen sulfate ion and ammonia must be known before any prediction can be made.
- E) This reaction is impossible to predict, since the strong acid and the weak base appear on the same side of the equation.

7. What is the pH of a 1.0 L aqueous solution containing  $1.0 \times 10^{-8}$  mol of  $\text{HNO}_3$ ?
- A) 8.00
  - B) 7.02
  - C) 7.00
  - D) 6.98
  - E) 6.00
8. Exactly 100 mL of 0.10 M  $\text{HNO}_2$  are titrated with 100 mL of a 0.10 M KOH solution. What is the pH at the equivalence point? ( $K_a$  for  $\text{HNO}_2 = 7.1 \times 10^{-4}$ )
- A) 2.22
  - B) 7.00
  - C) 7.92
  - D) 8.07
  - E) 11.9
9. Buffer solutions with the component concentrations shown below were prepared. Which of them should have the **lowest** pH?
- A)  $[\text{CH}_3\text{COOH}] = 0.25 \text{ mol L}^{-1}$ ,  $[\text{CH}_3\text{COO}^-] = 0.25 \text{ mol L}^{-1}$
  - B)  $[\text{CH}_3\text{COOH}] = 0.75 \text{ mol L}^{-1}$ ,  $[\text{CH}_3\text{COO}^-] = 0.75 \text{ mol L}^{-1}$
  - C)  $[\text{CH}_3\text{COOH}] = 0.75 \text{ mol L}^{-1}$ ,  $[\text{CH}_3\text{COO}^-] = 0.25 \text{ mol L}^{-1}$
  - D)  $[\text{CH}_3\text{COOH}] = 0.25 \text{ mol L}^{-1}$ ,  $[\text{CH}_3\text{COO}^-] = 0.75 \text{ mol L}^{-1}$
  - E)  $[\text{CH}_3\text{COOH}] = 1.00 \text{ mol L}^{-1}$ ,  $[\text{CH}_3\text{COO}^-] = 1.00 \text{ mol L}^{-1}$

10. Barium sulfate ( $\text{BaSO}_4$ ) is a slightly soluble salt, with  $K_{\text{sp}} = 1.1 \times 10^{-10}$ . What mass of  $\text{Ba}^{2+}$  ions will be present in 1.0 L of a saturated solution of barium sulfate?

- A)  $< 10^{-7} \text{ g}$
- B)  $1.0 \times 10^{-5} \text{ g}$
- C) 0.0014 g
- D) 0.0024 g
- E)  $> 0.05 \text{ g}$

11. Balance the following redox equation using the smallest integers possible and select the correct coefficient for the hydrogen sulfite ion,  $\text{HSO}_3^-$ .

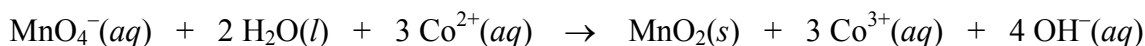


- A) 1
- B) 2
- C) 3
- D) 5
- E) 10

12. Calculate  $E^\circ_{\text{cell}}$  and indicate whether the overall reaction shown is spontaneous or nonspontaneous:

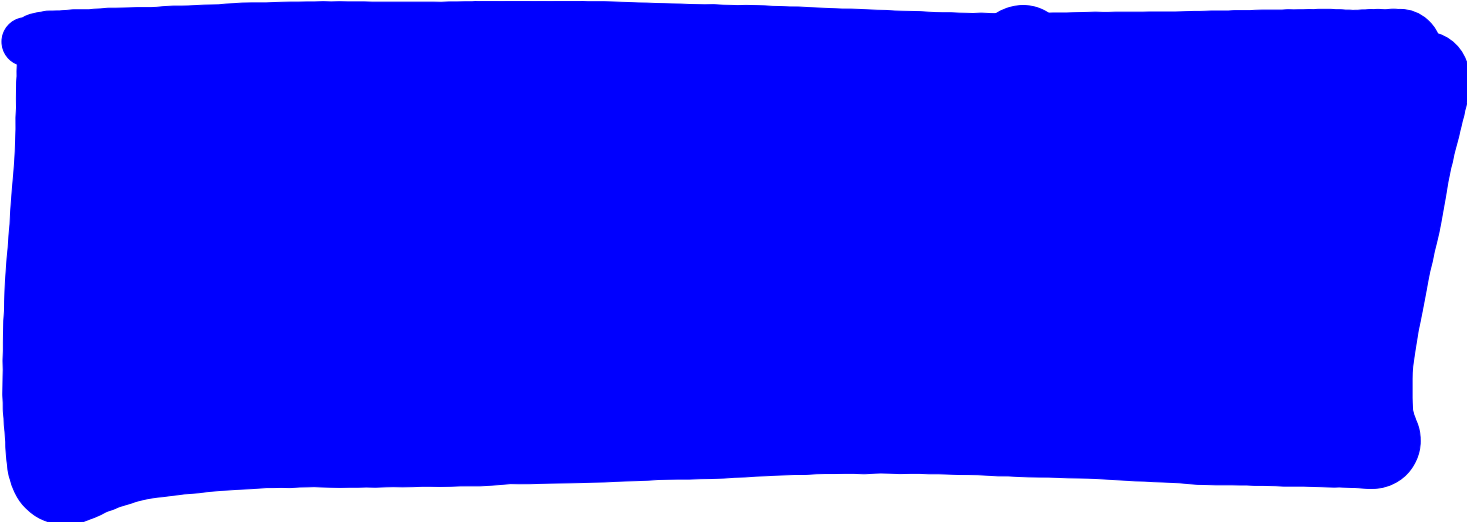


Overall reaction:



- A)  $E^\circ_{\text{cell}} = -1.23 \text{ V}$ , spontaneous
- B)  $E^\circ_{\text{cell}} = -1.23 \text{ V}$ , nonspontaneous
- C)  $E^\circ_{\text{cell}} = 1.23 \text{ V}$ , spontaneous
- D)  $E^\circ_{\text{cell}} = 1.23 \text{ V}$ , nonspontaneous
- E)  $E^\circ_{\text{cell}} = -0.05 \text{ V}$ , nonspontaneous

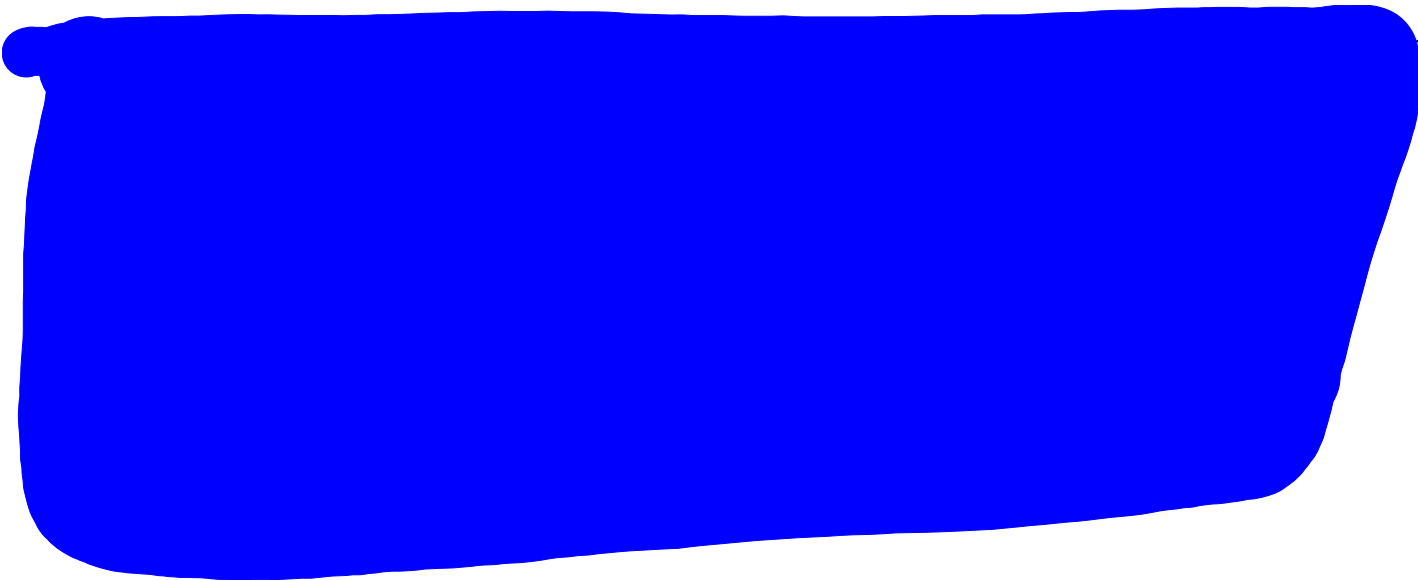
Material in this question was not covered this year.



17. Which of the following would represent **diamagnetic** species?

- i. Ca
- ii. Ge
- iii. Se

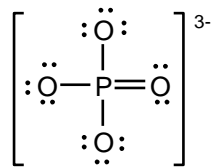
- A) i only
- B) ii only
- C) iii only
- D) ii & iii only
- E) None of the above





19. Which of the following are organized in an incorrect order?
- A) Increasing Ionic Size:  $\text{Mg}^{2+} < \text{F}^- < \text{N}^{3-}$
  - B) Decreasing first ionization energy:  $\text{F} > \text{Br} > \text{K}$
  - C) Increasing electronegativity:  $\text{N} < \text{O} < \text{F}$
  - D) Decreasing Atomic size:  $\text{Se} > \text{S} > \text{Si}$
  - E) They are all in correct orders
20. Which of the following structures will have a single lone pair of electrons on the central atom?
- i.  $\text{SbF}_3$
  - ii.  $\text{BrCl}_3$
  - iii.  $\text{PCl}_5$
- A) i only
  - B) ii only
  - C) iii only
  - D) i & ii only
  - E) All of them will
21. Which of the following compound(s) has(have) bent molecular shape(s)?
- i.  $\text{SO}_2$
  - ii.  $\text{NOCl}$
  - iii.  $\text{CO}_2$
- A) i only
  - B) ii only
  - C) iii only
  - D) i & ii only
  - E) i & iii only

22. In the following Lewis structure for phosphate, phosphorus has a formal charge of \_\_\_\_\_ and an oxidation state of \_\_\_\_\_.

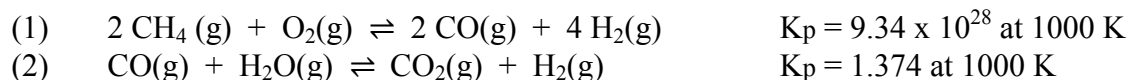


- A) 0, -3  
B) 0, 5  
C) 5, -3  
D) 5, 5  
E) 3, 5

\*\*\*\*\* END OF MULTIPLE CHOICE QUESTIONS SECTION \*\*\*\*\*

**SECTION II: To be graded manually (Total value 34)****For full marks show all your work.**

23. Using methane ( $\text{CH}_4$ ) and steam ( $\text{H}_2\text{O}(\text{g})$ ) as a source of hydrogen ( $\text{H}_2$ ) for ammonia ( $\text{NH}_3$ ) synthesis requires high temperatures. Rather than burning  $\text{CH}_4$  separately to heat the mixture, it is more efficient to inject some  $\text{O}_2$  into the reaction mixture. All the  $\text{H}_2$  is, thus, released for the synthesis, and the heat of reaction for the combustion of  $\text{CH}_4$  helps to maintain the required temperature. Imagine the reaction, occurring in two steps, as follows:

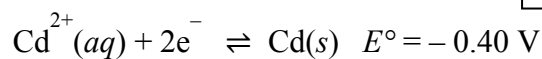
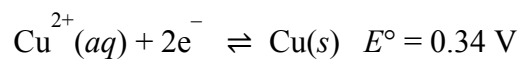


Marks <b>6</b>
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- (a) Write the overall equation for the reaction of methane, steam, and oxygen to form just carbon dioxide and hydrogen.
- (b) What is  $K_p$  for the overall reaction?
- (c) What is  $K_c$  for the overall reaction?
- (d) A mixture of 2.0 mol of  $\text{CH}_4$ , 1.0 mol of  $\text{O}_2$ , and 2.0 mol of steam ( $\text{H}_2\text{O}(\text{g})$ ), with a total pressure of 30. bar, reacts at 1000. K at a constant volume. Assuming that the reaction has gone to completion and the ideal gas law is a valid assumption, what is the final total pressure?

24. A voltaic cell has one half-cell with a Cu bar in a 1.00 mol/L  $\text{Cu}^{2+}$  salt, and the other half-cell with a Cd bar in the same volume of a 1.00 mol/L  $\text{Cd}^{2+}$  salt.

Marks <b>8</b>
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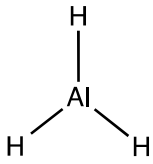
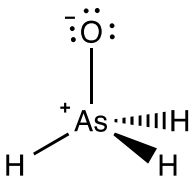
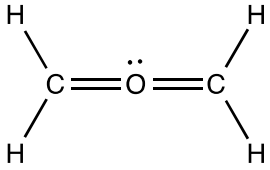
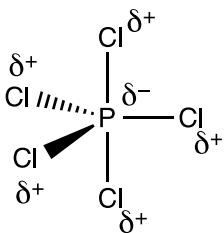
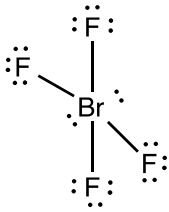
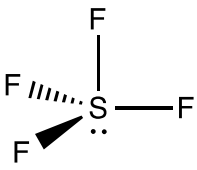


- a. Find  $E^{\circ}_{\text{cell}}$  and  $K$ .
- b. As the cell operates,  $[\text{Cd}^{2+}]$  increases. Find  $E_{\text{cell}}$  when  $[\text{Cd}^{2+}]$  is 1.95 mol/L.
- c. Write a balanced chemical equation for the reaction, keeping in mind the value of  $K$ , setup an ICE Table, and find  $E_{\text{cell}}$ , and  $[\text{Cu}^{2+}]$  at equilibrium.

25. Every diagram drawn in the table below was drawn by a person just learning about chemistry. Help this person out by associating each diagram with one of the statements A. through G. below to explain why a given structure is incorrect or correct. Each statement can only be used once, choose the statement that best matches the structures given below.

Marks 6
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- A. The formal charges are not minimized.  
 B. The central atom cannot have an expanded octet.  
 C. The dipoles are drawn incorrectly.  
 D. The formal charge(s) have not been included.  
 E. Lone pairs are missing.  
 F. The bond angles and thus geometry are incorrect.  
 G. The structure is correct.

Lewis Diagram	Letter for the error	VSEPR Diagram	Letter for the error
			
			
			

26. For the species given below, draw Lewis (2D) and VSEPR (3D) structures and identify electron pair geometries, molecular geometries, bond angles around the central atom, net polarity and hybridization. Enter your answers in the appropriate boxes. **Note: Lewis structures need to show all electron groups and all non-zero formal charges.**

Marks <b>14</b>
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Molecule	<b>COBrF</b>	<b>SiF<sub>4</sub></b>	<b>SeCl<sub>3</sub><sup>-</sup></b>	<b>I<sub>3</sub><sup>-</sup></b>
<b>Lewis structure (2D)</b>				
<b>VSEPR structure (3D)</b>				
<b>Electron pair geometry</b>				
<b>Molecular geometry</b>				
<b>Bond angles</b>				
<b>Net Polarity</b>				
<b>Hybridization</b>				

\*\*\*\*\*END OF WRITTEN ANSWER SECTION\*\*\*\*\*

# Data Sheet – CHEM 209

## Periodic Table

Periodic Table																		18
1 1A																	2 8A	
1 H 1.008	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 He 4.003	
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 19.00	10 Ne 20.18	
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95	
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80	
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 (98)	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	
55 Cs 132.9	56 Ba 137.3	57* La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	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)	
87 Fr (223)	88 Ra 226.0	89** Ac (227)	104 Rf (261)	105 Ha (262)	106 Sg (263)	107 Ns (262)	108 Hs (265)	109 Mt (266)	110 Uun (269)	111 Uuu (272)								

Lanthanides \*

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	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)

Actinides \*\*

Strong Acids: HCl, HBr, HI, HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, HClO<sub>4</sub>

Strong Bases: Hydroxides of Group 1A (Li to Cs) and Group 2A (Ca, Sr, Ba)

### Constants:

Gas constant,  $R = 0.08205 \text{ L atm mol}^{-1} \text{ K}^{-1}$   
 $= 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$  or  $0.08314 \text{ L bar mol}^{-1} \text{ K}^{-1}$   
 Avogadro's number:  $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$   
 Faraday:  $F = 96,485 \text{ C / mol electrons}$   
 Planck's constant  $h = 6.626 \times 10^{-34} \text{ Js}$   
 Speed of light,  $c = 2.998 \times 10^8 \text{ m/s}$   
 Rydberg constant,  $R = 1.09678 \times 10^{-7} \text{ m}^{-1}$   
 Factoring constant,  $R_H = R/hc = 2.18 \times 10^{-18} \text{ J}$

### Conversion factors:

$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$        $1 \text{ Pa} = 1 \text{ kg m s}^{-2}$   
 $T(K) = T(^{\circ}\text{C}) + 273.15$   
 $1 \text{ L atm} = 101.3 \text{ J}$   
 $1 \text{ atm} = 760.0 \text{ torr} = 101.3 \text{ kPa} = 760.0 \text{ mm Hg} = 1.013 \text{ bar}$   
 $1 \text{ L} = 10^{-3} \text{ m}^3$   
 $1 \text{ C} = 1 \text{ J / V}$        $1 \text{ A} = 1 \text{ C s}^{-1}$   
 STP conditions:  $0^{\circ}\text{C}$ ,  $1 \text{ atm}$   
 Electrochemical standard state:  $1 \text{ atm}$ ,  $1 \text{ M}$ ,  $25^{\circ}\text{C}$

$$[A]_t = -kt + [A]_0 \quad \ln[A]_t = -kt + \ln[A]_0 \quad \frac{1}{[A]_t} = kt + \frac{1}{[A]_0} \quad \ln\left(\frac{[A]_0}{[A]_t}\right) = kt$$

$$t_{1/2} = \frac{[A]_0}{2k} \quad t_{1/2} = \frac{0.693}{k} \quad t_{1/2} = \frac{1}{k[A]_0} \quad k = Ae^{\frac{-E_a}{RT}} \quad \ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta H}{R} \left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2}\right) \quad PV = nRT \quad K_p = K_c(RT)^{\Delta n} \quad ax^2 + bx + c = 0$$

$$\text{pH} = -\log[\text{H}^+] \quad K_w = K_a K_b \quad \text{pH} = \text{p}K_a + \log\left(\frac{[\text{cong. base}]}{[\text{cong. acid}]}\right) \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$E^{\circ} = E^{\circ}_{\text{cathode}} - E^{\circ}_{\text{anode}} \quad E = E^{\circ} - \frac{0.0592}{n_e} \log Q \quad E^{\circ} = \frac{0.0592}{n_e} \log K \quad \text{or} \quad nFE^{\circ} = RT \ln K$$

$$c = \lambda \nu \quad E = h\nu \quad E = mc^2 \quad \frac{1}{\lambda} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad \Delta E = -R_H \left(\frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2}\right)$$