

THE UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
CHEMISTRY 209
Winter 2013
Final Exam

Date: April 19th, 2013

Time Allotted: 3 hours

Please make sure you fill in your NAME, student ID and Lecture Section and encode all information on the optical score sheet.

Failure to do so will result in the loss of at least 2 marks.

Only Casio FX260 or similar non-programmable scientific calculators are permitted.

A Chemical Data and Formula Sheet is attached, which can be detached.

FIRST NAME: _____ LAST NAME: _____

ID: _____

Lecture Section: Please check one

- | | | | | |
|--------------------------|-----|----|----------|-------------------|
| <input type="checkbox"/> | L01 | TR | 12:30 pm | Dr. Masood Parvez |
| <input type="checkbox"/> | L02 | TR | 8:00 am | Dr. Scott Hinman |

This exam consists of 14 pages, 21 multiple choice questions worth two marks each (total 42 marks), and 4 written answer questions (total 30 marks) for a total of 72 marks. Make sure to count the number of pages (should be 14 pages excluding data sheet) and LET THE INVIGILATOR KNOW IMMEDIATELY IF YOU ARE MISSING A PAGE.

All questions must be answered to earn full marks. The answers to the multiple choice questions must be entered on the optical score sheet using pencil. Answers to the written answer questions should be written in the exam booklet in ink.

AT THE END OF THE EXAMINATION, HAND IN THE WHOLE EXAM BOOKLET AND THE OPTICAL SCORE SHEET

Do not write in spaces in the table below

Q 22	Q 23	Q24	Q25

SECTION I - Machine graded section (Total value 42 marks)
Select the best answer and encode it on the Optical Score Sheet

1. What is the mass percent of each element in sulfuric acid, H_2SO_4 ?

- a. 2.055% H, 32.70% S, 65.25% O
- b. 1.028% H, 32.69% S, 66.28% O
- c. 28.57% H, 14.29% S, 57.17% O
- d. 1.028% H, 33.72% S, 65.25% O
- e. 2.016% H, 32.07% S, 65.91% O

$$\text{Molar mass of } \text{H}_2\text{SO}_4 = 98.086$$

$$\% \text{ H} = \frac{2.016}{98.086} \times 100 = 2.055\%$$

$$\% \text{ S} = \frac{32.07}{98.086} \times 100 = 32.70\%$$

$$\% \text{ O} = \frac{64.00}{98.086} \times 100 = 65.25\%$$

2. A student analyzed a first-order reaction and obtained the graph below. Unfortunately, the student forgot to label the axes. What are the correct labels for the x and y axes?



- a. x axis = time, y axis = $\ln[A]$
- b. x axis = $\ln[\text{time}]$, y axis = $[A]$
- c. x axis = $\ln[\text{time}]$, y axis = $[A]$
- d. x axis = time, y axis = $1/[A]$
- e. x axis = $1/\text{time}$, y axis = $1/[A]$

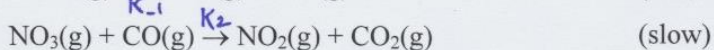
3. According to the collision theory, which one of the following does NOT affect the rate of a reaction:

- a. temperature
- b. the speed of colliding particles
- c. ΔH of the overall reaction
- d. the orientation of colliding particles
- e. the frequency with which particles collide

4. Nitrogen dioxide reacts with carbon monoxide to produce nitrogen monoxide and carbon dioxide.



A proposed mechanism for this reaction is:



What is a rate law that is consistent with the proposed mechanism?

- a. $\text{rate} = k [\text{NO}_2]^2 [\text{CO}] [\text{NO}]^{-1}$
- b. $\text{rate} = k [\text{NO}_2]^2 [\text{CO}]$
- c. $\text{rate} = k [\text{NO}_2] [\text{CO}]$
- d. $\text{rate} = k [\text{NO}_3] [\text{CO}]^2$
- e. $\text{rate} = k [\text{NO}_2]^2$

$$\begin{aligned} \text{Rate} &= k_2 [\text{NO}_3] [\text{CO}] \\ k_1 [\text{NO}_2]^2 &= k_{-1} [\text{NO}_3] [\text{NO}] \\ [\text{NO}_3] &= \frac{k_1 [\text{NO}_2]^2}{k_{-1} [\text{NO}]} \end{aligned}$$

$$\text{Rate} = k_2 \cdot \frac{k_1}{k_{-1}} \cdot \frac{[\text{NO}_2]^2}{[\text{NO}]} \cdot [\text{CO}] \quad \text{or} \quad k [\text{NO}_2]^2 [\text{CO}] [\text{NO}]^{-1}$$

5. At 25 °C, the equilibrium constant for the autoionization of water is $K_w = 1.0 \times 10^{-14}$. At 50 °C, $K_w = 5.5 \times 10^{-14}$. Determine ΔH for the autoionization of water.

- a. -55 kJ mol^{-1}
- b. 710 J mol^{-1}
- c. 55 kJ mol^{-1}
- d. 750 J mol^{-1}
- e. -14 kJ mol^{-1}

$$\ln \left(\frac{5.5 \times 10^{-14}}{1.0 \times 10^{-14}} \right) = \frac{\Delta H}{8.314 \text{ J mol}^{-1} \text{ K}^{-1}} \left(\frac{1}{298} - \frac{1}{323} \right) \text{ K}$$

$$\ln(5.5) = \frac{\Delta H}{8.314} (2.6 \times 10^{-4})$$

$$1.7047 = \Delta H \times 3.127 \times 10^{-5}$$

$$\Delta H = 54517 \text{ J mol}^{-1} \quad \text{or} \quad 55 \text{ kJ mol}^{-1}$$

6. At 500 °C, K_c for the reaction: $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is $K_c = 6.0 \times 10^{-2}$. The numerical value of K_p at this temperature is:

- a. 1.5×10^{-5}
 b. 2.5×10^{-5}
 c. 1.1×10^{-9}
 d. 2.0×10^{-5}
 e. 1.5×10^{-9}

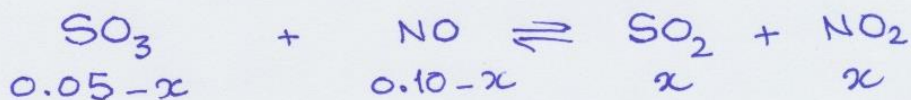
$$K_p = K_c (RT)^{\Delta n}$$

$$= 6.0 \times 10^{-2} (0.08205 \times 773)^{-2}$$

$$= 6.0 \times 10^{-2} (63.42)^{-2} = 1.5 \times 10^{-5}$$

7. An evacuated 2.0 L flask was filled with 0.10 moles $SO_3(g)$ and 0.20 moles of $NO(g)$. The following reaction was allowed to come to equilibrium: $SO_3(g) + NO(g) \rightleftharpoons SO_2(g) + NO_2(g)$
 If K_c for this reaction is 0.50, the equilibrium concentration of $SO_2(g)$ is:

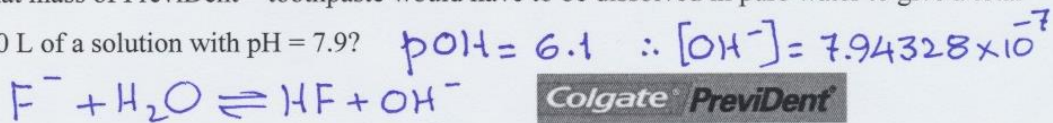
- a. 0.056 M
 b. 0.021 M
 c. 0.047 M
 d. 0.035 M
 e. 0.028 M



$$K_c = \frac{(x)(x)}{(0.05-x)(0.10-x)} = 0.50$$

- e. 0.028 M Using Quad. Eqⁿ $x = [SO_2] = 0.028 M$

8. Colgate PreviDent™ toothpaste contains 1.0 mass percent NaF. Given that HF is a weak acid with $K_a = 6.8 \times 10^{-4}$, what mass of PreviDent™ toothpaste would have to be dissolved in pure water to give a total volume of 1.00 L of a solution with pH = 7.9?



- a. 210 g
 b. 2.0 g
 c. 4.9 g
 d. 82 g
 e. 180 g

$$K_b = \frac{1.0 \times 10^{-14}}{6.8 \times 10^{-4}} = \frac{(x)^2}{F^- - x} \quad \therefore F^- = 4.292268 \times 10^{-2} \text{ moles}$$

g NaF = moles of F^- x molar mass of NaF = 1.8 g
 $[4.292268 \times 10^{-2} \times 41.9]$
 which is 1% of the toothpaste \therefore Mass = $1.8 \times 100 = 180 \text{ g}$

9. In which of the following solutions would you expect LiF to be the most soluble given that K_{sp} for LiF is 1.7×10^{-3} ?

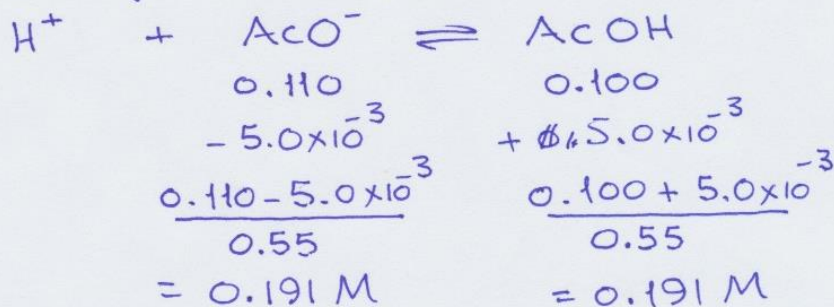
- a. 100.0 mL of pure water
- b.** 100.0 mL of 1.0 M HCl
- c. 100.0 mL of 1.0 M $\text{CH}_3\text{CO}_2\text{H}$
- d. 100.0 mL of 1.0 M NH_3
- e. 100.0 mL of 1.0 M NaOH

10. What is the resulting pH when 50.00 mL of 0.10 M HCl is added to a buffer prepared by combining 0.100 moles of acetic acid and 0.110 moles of sodium acetate with 500 mL of pure water? K_a for acetic acid is 1.8×10^{-5} .

- a.** 4.74
- b. 4.83
- c. 4.60
- d. 5.12
- e. 4.42

[I]
[C]
[E]

moles of HCl added = 5.0×10^{-3} moles



$$\text{pH} = \text{p}K_a + \log \frac{[\text{AcO}^-]}{[\text{AcOH}]} \quad \therefore \text{pH} = \text{p}K_a = 4.74$$

11. Methyl orange is an acid-base indicator which undergoes a colour change from pink at $\text{pH} < 3.2$ to orange at $\text{pH} > 4.4$. Which of the following titrations would this indicator be the most suitable for?

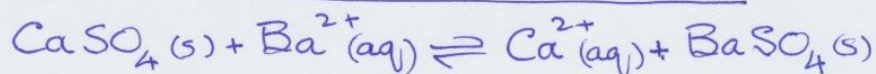
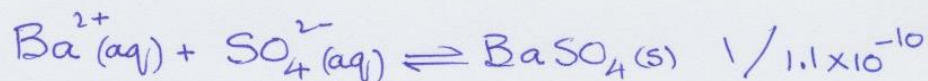
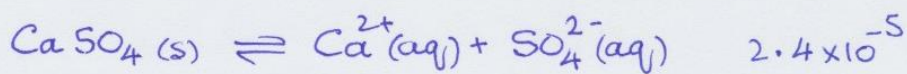
- a. 50.0 mL of 0.1 M acetic acid ($K_a = 1.8 \times 10^{-5}$) is titrated with 0.1 M NaOH?
- b. 50.0 mL of 0.1 M pyruvic acid ($K_a = 3.3 \times 10^{-3}$) is titrated with NaOH?
- c. 50.0 mL of 0.1 M NaOH is titrated with 0.1 M HCl
- d. 50.0 mL of 0.1 M pyrrolidine ($K_b = 2.0 \times 10^{-3}$) is titrated with 0.1 M HCl
- e.** 50.0 mL of 0.1 M hypochlorite ($K_b = 3.5 \times 10^{-7}$) is titrated with 0.1 M HCl

8.72
7.3
X
6.3
4.4

12. CaSO_4 has $K_{\text{sp}} = 2.4 \times 10^{-5}$ while BaSO_4 has $K_{\text{sp}} = 1.1 \times 10^{-10}$. Determine the equilibrium constant, K_{c} , for the reaction:



- (a) 2.2×10^5
 b. 2.4×10^{-5}
 c. 1.1×10^{-10}
 d. 4.4×10^{-6}
 e. 2.64×10^{-15}



$$= 2.4 \times 10^{-5} / 1.1 \times 10^{-10}$$

$$= 2.18 \times 10^5$$

Standard potentials at 25 °C which may be used in Questions 13 to 15 and 24

$\text{IO}_4^- + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{IO}_3^- + \text{H}_2\text{O}$	$E^\circ = 1.589 \text{ V}$
$\text{MnO}_4^- + 8\text{H}^+ + 4\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	$E^\circ = 1.507 \text{ V}$
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	$E^\circ = 1.360 \text{ V}$
$\text{Fe}^{3+} + 1\text{e}^- \rightleftharpoons \text{Fe}^{2+}$	$E^\circ = 0.771 \text{ V}$
$2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	$E^\circ = 0.000 \text{ V}$
$\text{HCO}_2\text{H} + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{CO} + \text{H}_2\text{O}$	$E^\circ = -0.029 \text{ V}$
$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}(\text{s})$	$E^\circ = -0.126 \text{ V}$

13. Which species is the strongest oxidizing agent under standard conditions?

- a. $\text{Pb}(\text{s})$
 (b) IO_4^-
 c. Pb^{2+}
 d. IO_3^-
 e. H_2O

14. Determine the equilibrium constant for the reaction between IO_4^- and Fe^{2+} .

$$E^\circ = 1.589 - 0.771 = 0.818 \text{ V}$$

- a. 4.32×10^{27}
 b. 1.00×10^{12}
 c. 0.57×10^{13}
 d. 1.00×10^6
 e. 5.76×10^{19}

$$E^\circ = \frac{0.0592}{2} \log K$$

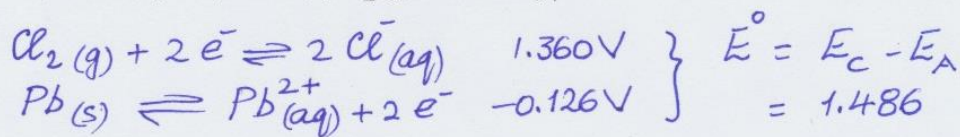
$$\frac{0.818 \times 2}{0.0592} = \log K$$

$$\log K = 27.635 \quad \therefore K = 4.32 \times 10^{27}$$

15. What is the potential of the following cell?



- a. 1.26 V
 b. 1.52 V
 c. 1.49 V
 d. 1.54 V
 e. 1.23 V



$$E = E^\circ - \frac{0.0592}{2} \log Q \quad Q = \frac{(0.200)(0.200)^2}{(0.400)}$$

$$= 1.486 - (-0.0503) = 1.54 \text{ V}$$

16. Metal objects are often plated with thin films of gold by making them the cathode in an electrolysis bath containing cyanide and $\text{Au}(\text{III})$. The plating reaction is: $\text{Au}(\text{CN})_4^- + 3\text{e}^- \rightleftharpoons \text{Au}(\text{s}) + 4\text{CN}^-$. How much time is required to electroplate 10.0 mg of gold onto a metal object employing a constant current of 100 mA?

- a. 147 seconds
 b. 49.0 seconds
 c. 73.5 seconds
 d. 212 seconds
 e. 196 seconds

$$\frac{0.010 \text{ g}}{197 \text{ g mol}^{-1}} = 5.076 \times 10^{-5} \text{ mol Au} \times 3 \text{ e}^- = 1.523 \times 10^{-4} \text{ moles e}^-$$

$$1.523 \times 10^{-4} \times 96500 = 14.695$$

$$\frac{14.695}{0.10 \text{ A}} = 147 \text{ s} \quad [100 \text{ mA} = 0.10 \text{ A}]$$

17. A single pulse of a laser yields an average of 5.00×10^{18} photons with $\lambda = 633 \text{ nm}$. If melting ice to water at 0°C requires 6.01 kJ/mol , what is the fewest number of laser pulses needed to melt 1.00 g of ice?

$$E_{\text{photon}} = hc/\lambda = \frac{6.626 \times 10^{-34} \text{ Js} \times 2.998 \times 10^8 \text{ m}}{6.33 \times 10^{-7} \text{ m}} = 1.57109 \text{ J}$$

- a. 383
b. 334
c. 212
d. 38
e. 21

$$n_{\text{ice}} = 1.00 / 18.016 = 0.05551 \text{ moles}$$

$$E \text{ to melt } 1 \text{ g ice} = 6.01 \times 10^3 \text{ J mol}^{-1} \times 0.05551 \text{ mole} = 333.59 \text{ J}$$

$$\# \text{ of Pulses} = 333.59 / 1.57109 = 212$$

18. Which response lists all the true statements about the four quantum numbers?

- I. $n =$ principal quantum number, $n = 1, 2, 3, \dots$
 II. $l =$ angular momentum quantum number, $l = 0, 1, 2, 3, \dots, (n-1)$
 III. $m_l =$ magnetic quantum number, $m_l = (-l), \dots, 0, \dots, (+l)$
 IV. $m_s =$ spin quantum number, $m_s = \pm 1/2$

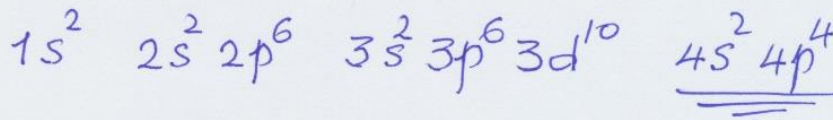
- a. I, II, and III
b. I, III, and IV
c. I, II, and IV
d. I and II
e. I and IV

19. An element with the outermost electron configuration

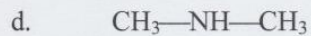
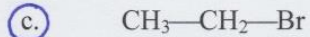
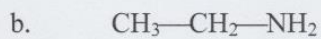


could be _____.

- a. 82Pb
b. 40Zr
c. 42Mo
d. 34Se
e. 19K



20. What compound will **not** exhibit hydrogen bonding in the liquid state?



21. It is thought that the strongest intermolecular forces between molecules of HCl are

a. covalent bonds.

b. dipole-dipole interactions.

c. ionic bonds.

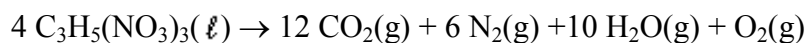
d. hydrogen bonds.

e. London forces.

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

SECTION II: Fill-in-the-blanks and long answer questions. (Total value 30 marks)Write your answers *in ink* in the space provided.**22. Fill-in-the-blanks.****10 marks**

- a. Nitroglycerine decomposes violently according to the chemical equation below. What mass of carbon dioxide gas is produced from the decomposition of 5.00 g $C_3H_5(NO_3)_3$?



$$(5.00 / 255.084) (12 / 4) (44.1) = 2.93 \text{ g}$$

2.93 g

- b. If 5.15 g $Fe(NO_3)_3$ is dissolved in enough water to make exactly 150.0 mL of solution, what is the molar concentration of nitrate ion?

$$(5.15 / 241.88) (3) (1 / 0.150) = 0.426 \text{ M}$$

0.426 M

- c. The rate constant at 366 K for a first-order reaction is $7.7 \times 10^{-3} \text{ s}^{-1}$ and the activation energy is 15.9 kJ/mol. What is the value of the frequency factor, A , in the Arrhenius equation?

$$K = A e^{-15.9 / 366 \times 8.314 \times 10^{-3}}$$

$$7.7 \times 10^{-3} = A e^{-5.225} \quad \therefore A = 1.43 \text{ s}^{-1}$$

1.43 s⁻¹

- d. A police officer is measuring traffic speed with radar operating at 1.0×10^9 Hz. What is the wavelength of this electromagnetic energy?

$$\lambda = c / \nu$$

$$= (2.998 \times 10^8 \text{ m/s}) / (1.0 \times 10^9 / \text{s}) = 0.30 \text{ m}$$

0.30 m

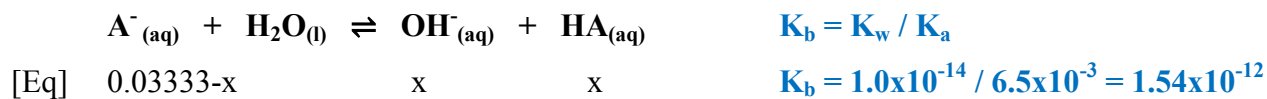
- e. Assign formal charges to all atoms of the thiocyanate ion, SCN^- . Identify the most favored structure.

S = -1**N = -1****S = +1 N = -2****S - C \equiv N****S = C = N****S \equiv C - N**

c. At the equivalence point

Volume of NaOH at equivalence point: $50 \times 0.05 / V? \times 0.010 = 25 \text{ mL}$

– the sodium salt of m-nitrobenzoic acid (Na A) will give the anion A^- , a conjugate base of the weak acid (nitrobenzoic acid). **$[A^-] = 50 \times 0.05 / 50 + 25 = 0.03333 \text{ M}$**



$$K_b = 1.54 \times 10^{-12} = \frac{(x)(x)}{0.0333 - x}; \text{ x can be ignored!}$$

$$x = [OH^-] = 2.2645 \times 10^{-7} \quad \text{or} \quad pOH = 6.645 \quad \text{and} \quad pH = 7.35$$

d. After the addition of 40 mL of titrant

$$\text{Total volume} = 50 + 40 = 0.090 \text{ L}$$

$$\text{Excess NaOH} = 40.0 - 25.0 = 0.015 \text{ L}$$

$$[OH^-] = (0.015 \text{ L} \times 0.10 \text{ mol/L}) / 0.090 \text{ L} = 0.01666 \text{ M}$$

$$\text{Therefore } pOH = 1.78 \quad \text{and} \quad pH = 12.22$$

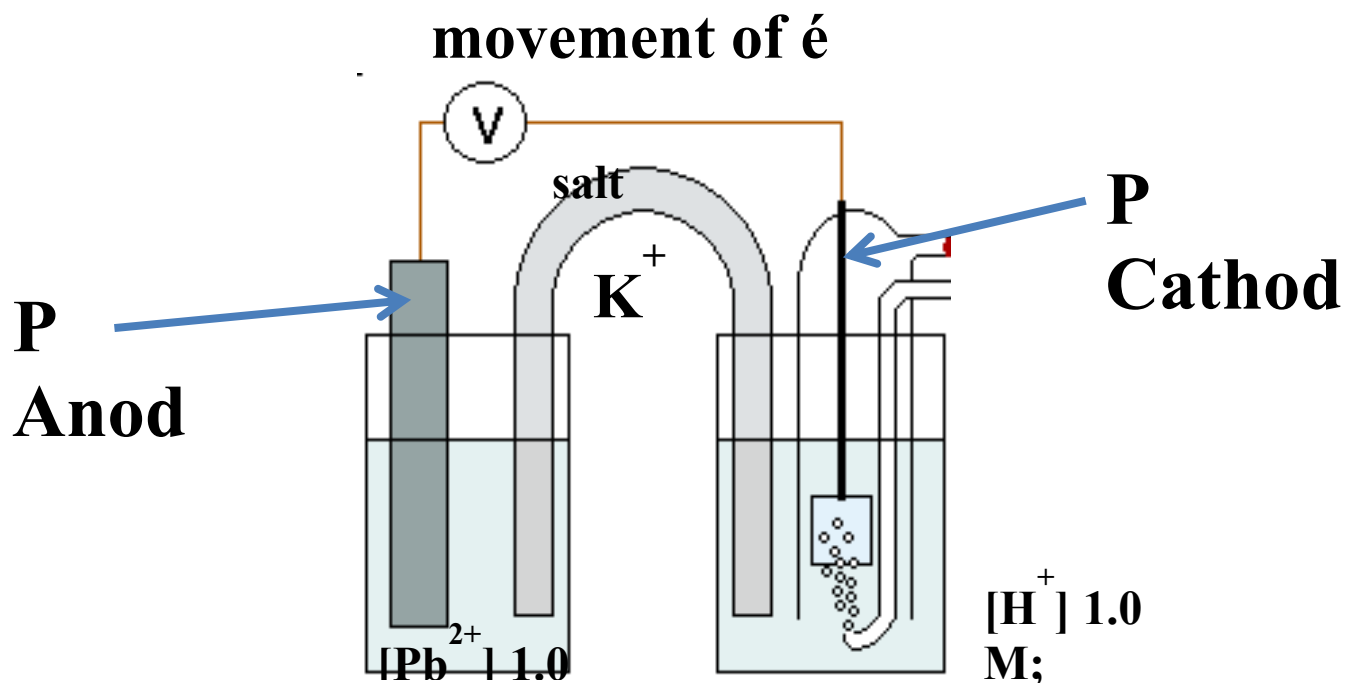
24. Long answer question (For full marks, you must show all work).

6 marks

The standard electrode potential for the $\text{Pb(s)}/\text{Pb}^{2+}$ redox couple is -0.126 V . Sketch the cell in which this potential was measured.

Identify:

- All concentrations/pressures
- The cathode and the anode
- The direction in which cations move in the salt bridge
- The direction in which electrons would move if a light bulb were connected across the cell.



flow of cations to cathode
movement of e^- anode to

25. 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 and molecular polarity. Enter your answers in the appropriate boxes:

6 Marks

Species	NCl_3	XeOF_4	SF_4
Lewis structure (2D) (Show all valence electrons) Note: $- = 2 \text{ e}$			
VSEPR structure (3D)			
Electro pair geometry	Tetrahedral	Octahedral	Trigonal bipyramidal
Molecular Geometry	Trigonal pyramidal	Square pyramidal	Distorted tetrahedral Or See saw
Bond angles	$< 109.7^\circ$	$< 90^\circ$ & $< 180^\circ$	$< 90^\circ$, $< 120^\circ$ & $< 180^\circ$
Polar or Non-polar	Polar	Polar	Polar

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

Data Sheet – CHEM 209

Periodic Table

1 1A											18 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, HNO₃, H₂SO₄, HClO₄

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

Constants:

Gas constant, $R = 0.08205 \text{ L atm mol}^{-1} \text{ K}^{-1}$
 $= 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$

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, $R_H = Rhc = 2.18 \times 10^{-18} \text{ J}$

Conversion factors:

$1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$ $1 \text{ Pa} = 1 \text{ kg m s}^{-2}$

$T(\text{K}) = T(^{\circ}\text{C}) + 273.15$

$1 \text{ L atm} = 101.3 \text{ J}$

$1 \text{ atm} = 760.0 \text{ torr} = 101.3 \text{ kPa} = 760.0 \text{ mm Hg} = 1.013 \text{ bar}$

$1 \text{ L} = 10^{-3} \text{ m}^3$

$1 \text{ C} = 1 \text{ J/V}$ $1 \text{ A} = 1 \text{ C s}^{-1}$

STP conditions: 0°C , 1 atm

Electrochemical standard state: 1 atm , 1M , 25°C

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

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

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

$$\text{pH} = -\log[\text{H}^+] \quad K_w = K_a K_b \quad K_{sp} = 1 / K_d \quad K_f = 1 / K_d \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{pH} = \text{p}K_a + \log\left(\frac{[\text{cong. base}]}{[\text{cong. acid}]}\right) \quad \text{or} \quad \text{pOH} = \text{p}K_b + \log\left(\frac{[\text{cong. acid}]}{[\text{cong. base}]}\right)$$

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

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

$$E = -R_H \left(\frac{Z}{n}\right)^2 \quad \text{or} \quad E_n = -\frac{Rhc}{n^2} \quad \text{for single electron species}$$