Université d'Ottawa · University of Ottawa

Faculté des science
Chimie

Faculty of Science
Chemistry

CHM 1301

DATE: December 9, 2013
9:30 am

Dr. Rashmi Venkateswaran

TIME: 3 hours

Page 1 of 19

FULL STUDENT NAME: (Print)________________________________
STUDENT NUMBER:____________________________________

INSTRUCTIONS:

1. Write your answers on the exam. Please BOLD or HIGHLIGHT your final answer.

2. You are allowed to use electronic calculators during the exam (TI 30X, TI 34, TI 36, Casio 290 or 300).

3. Equations and constants are given on pages 17 and 18. A periodic table of the elements is included (page 19).

4. **Use the correct number of significant figures at all times.**

5. Marks allotted to each question are shown in brackets. The exam is out of 100.

7. Use the back of sheets for rough work. Three extra (blank) pages (14, 15 and 16) have also been included.

8. You are advised to read through the exam paper before you begin to write. Answer <u>first</u> those questions that you can do right away, proceeding to more difficult questions thereafter. Allow <u>about</u> <u>ten</u> <u>minutes</u> near the end of the exam period to read quickly through your answers, checking for obvious errors. **Good luck!**

Quest.	1	2	3	4	5	6	7	8	9	10	
Marks	/10	/10	/10	/10	/10	/10	/12	/8	/10	/10	/100

(10) 1. A microwave oven operating at 1.22×10^8 nm is used to heat 150.0 mL of water (roughly the volume of a tea cup) from 20.0 °C to 95.0 °C. Calculate the number of photons needed if 92.0 percent of microwave energy is converted to the thermal energy of water. (d_{water} =1.00 g/mL; c_{water} = 4.184 J/g°C)

$$E_T = mc\Delta T = (150.0\,mL)\left(1.00\,\frac{g}{mL}\right)\left(4.184\,\frac{J}{g°C}\right)(95.0° - 20.0°)$$

$$= 4.71 \times 10^4\,J$$

$$E/photon = h\nu = \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,Js)(3.00\times10^{8}\,\frac{m}{s})}{1.22\times10^{8}\times10^{-9}\,m} \qquad 1.63\times10^{-24}\,\frac{J}{photon}$$

[5] $$E_T = E/photon \cdot \#photons \Rightarrow \#photons = \frac{E}{E/photon} = \frac{4.71\times10^{4}\,J}{1.63\times10^{-24}\,\frac{J}{photon}}$$

$$= \boxed{2.89\times10^{28}\,photons}$$

With energy loss, #photons = $2.89 \times 10^{28}/0.92 = 3.14 \times 10^{28}$ photons

(b) In a photoelectric effect experiment, photons having an energy of 361.3 kJ/mol are absorbed by a metal and the maximum kinetic energy of the resulting electrons is KE = 162.6 kJ/mol.

i) Calculate the binding energy (work function) of ONE electron in the metal. $KE/e^- = \frac{162.6\times10^{3}\,J/mol}{6.022\times10^{23}\,e^-/mol} = 2.70\times10^{-19}\,J$

$$E/phot = \frac{361.3\times10^{3}\,J/mol}{6.022\times10^{23}\,phot/mol} = 6.00\times10^{-19}\,J$$

$$KE = h\nu - BE \Rightarrow BE = h\nu - KE = (6.00\times10^{-19} - 2.70\times10^{-19})\,J = \boxed{3.30\times10^{-19}\,J/e^-}$$

ii) Calculate the wavelength of the light.

[5]

$$E = h\nu = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{(6.626\times10^{-34}\,Js)(3.00\times10^{8}\,\frac{m}{s})}{6.00\times10^{-19}\,J}$$

$$= \boxed{3.31\times10^{-7}\,m = 331\,nm}$$

iii) Calculate the velocity of the electrons.

$$KE = \frac{1}{2}mv^2 \qquad v^2 = \frac{2KE}{m} = \frac{2(2.70\times10^{-19}\,J)}{9.11\times10^{-31}\,kg}$$

$$\boxed{v = 7.70\times10^{5}\,\frac{m}{s}}$$

(10) 2. (a) The carbon dioxide exhaled by astronauts must be removed from the spacecraft atmosphere. One way to do this is to react the gaseous carbon dioxide with solid lithium hydroxide, which results in the formation of solid lithium carbonate and liquid water. The carbon dioxide output of an astronaut is about 1.0 kg/day. What is the minimum mass of lithium hydroxide required for a six-day space shuttle flight involving five astronauts?

$$CO_{2(g)} + 2LiOH_{(s)} \rightarrow Li_2CO_{3\,(s)} + H_2O_{(l)}$$

$$n_{CO_2} = \frac{m}{MM} = \frac{1.0\times10^3\,g}{44.0\,\frac{g}{mol}} = \left(22.7\,\frac{mol}{person\cdot day}\right)(6\,day)(5\,person) = 6.82\times10^2\,mol\,CO_2$$

$$1\,mol\,CO_2 \rightarrow 2\,mol\,LiOH$$

[5] $$\therefore n_{LiOH} = 2n_{CO_2} = 2(6.82\times10^2\,mol) = 1.36\times10^3\,mol$$

$$m_{LiOH} = n\cdot MM = (1.36\times10^3\,mol)\left(6.941+16.0+1.00794\,\frac{g}{mol}\right)$$
$$= 3.27\times10^4\,g = \boxed{32.7\,kg}$$

(b) The combustion of what volume of ethane (C_2H_6) measured at 23.0 °C and 752 mm Hg would be required to heat 855 g of water from 25.0 °C to 98.0 °C? c_{water} = 4.184 J/g°C; Δ_fH° (CO_2) = -393.5 kJ/mol; Δ_fH° (H_2O (l)) = -285.8 kJ/mol; Δ_fH° (C_2H_6) = -84.7 kJ/mol

$$E_T = mc\Delta T = (855\,g)\left(4.184\,\frac{J}{g°C}\right)(98.0° - 25.0°C)$$
$$= 2.61\times10^5\,J$$

$$C_2H_{6\,(g)} + \frac{7}{2}O_{2\,(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$$

$$\Delta_rH^\circ = [2\Delta_fH^\circ_{CO_2} + 3\Delta_fH^\circ_{H_2O}] - [\Delta_fH^\circ_{C_2H_6}]$$

[5] $$= [2(-393.5) + 3(-285.8) - (-84.7)]\,\frac{kJ}{mol}$$

$$= -1.5579\times10^6\,\frac{J}{mol}$$

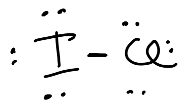
$$V = \frac{nRT}{P} = \frac{(0.168\,mol)\left(0.08314\,\frac{bar\,L}{mol\,K}\right)(296.2\,K)}{\left(\frac{752}{760}\times1.01325\,bar\right)} = \boxed{4.11\,L}$$

$$1\,mol\,C_2H_6 \rightarrow 1.5597\times10^6\,J/mol$$
$$x \rightarrow 2.61\times10^5\,J$$
$$1.5597\times10^6\,\frac{J}{mol}\,x = 2.61\times10^5\,J \qquad x = 0.168\,mol$$

(10) 3. Iodine forms three compounds with chlorine: ICl, ICl_3, and ICl_5.

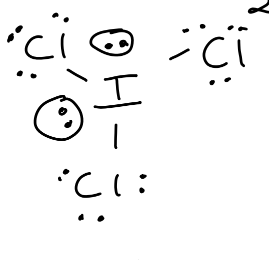
(a) Showing all your work, determine the molecular geometries of all three molecules.

ICl: I: $7e^-$
Cl: $7e^-$
$14e^-$
$-2e^-$ 1-Cl bond
$12e^-$
$12e^-$ - 2 x $6e^-$ per atom
0



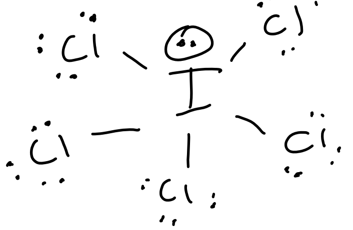
[6] MG = linear

ICl_3: I: $7e^-$
Cl = $(7e^-)3$
$28e^-$
$6e^-$ 3 x I-Cl bond
$22e^-$
$18e^-$ 3 x $6e^-$ per Cl
$4e^-$
$4e^-$ → 2 lone pair
0



MG = trigonal bipyramidal

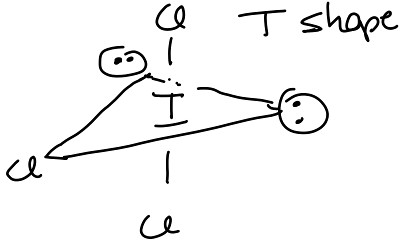
ICl_5: I: $7e^-$
Cl: $(7e^-)5$
$42e^-$
5 x I-Cl $10e^-$
$32e^-$
5 x $6e^-$ per Cl $30e^-$
$2e^-$
lone pair $2e^-$
0

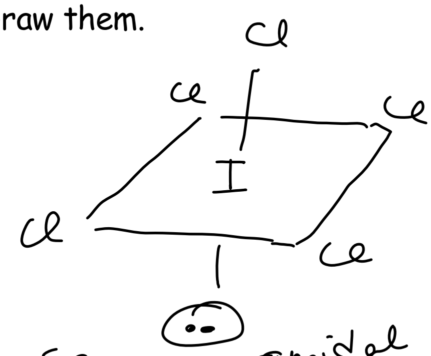


MG = octahedral

(b) What are the shapes of all three molecules? Draw them.

I–Cl – linear





square pyramidal

[3]

(c) What are the main angles in each of the three molecules? Are they polar?

I-Cl → 180° - polar because I & Cl different EN
I-Cl_3 → 180°, 90° → polar because of lone pairs vs Cl in plane
I-Cl_5 → 180°, 90° → polar because axial lone pair + Cl don't balance

[1]

(10) 4. (a) When heated, lithium reacts with nitrogen to form lithium nitride:

$3\,Li\,(s) + \frac{1}{2}N_2\,(g) \rightarrow Li_3N$ (unbalanced)

What is the theoretical yield of Li_3N when 12.3 g of Li is heated with 33.6 g of N_2? If the actual yield of Li_3N is 5.89 g, what is the percent yield of the reaction?

$$3Li(s) + \frac{1}{2}N_2(g) \rightarrow Li_3N(s)$$

[5]

m	12.3 g	33.6 g	? 5.89 g
MM	6.941 $\frac{g}{mol}$	28.0 $\frac{g}{mol}$	34.823 $\frac{g}{mol}$

$n_{Li} = \frac{m}{MM} = \frac{12.3 g}{6.941 \frac{g}{mol}} = 1.77 mol$

$n_{N_2} = \frac{m}{MM} = \frac{33.6 g}{28.0 \frac{g}{mol}} = 1.20 mol$

∴ Li is the limiting reagent (need 6 mol Li for each 1 mol N_2)

∴ n_{Li_3N} formed $= \frac{1}{3} n_{Li} = \frac{1}{3}(1.77 mol) = 0.591 mol$

$m_{Li_3N} = (0.591 mol)(34.823 g/mol) = \boxed{20.6 g}$

$\%\ yield = \frac{act}{theor} \times 100\% = \frac{5.89 g}{20.6 g} \times 100\% = \boxed{28.6\%}$

(b) A sample of zinc metal reacts completely with an excess of hydrochloric acid:

$Zn\,(s) + 2HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$

The hydrogen gas produced is collected over water at 25.0 °C. The volume of the gas is 7.80 L and the pressure is 0.980 atm. Calculate the mass of zinc metal consumed in the reaction.

$n = \frac{PV}{RT} = \frac{(0.980 atm)(7.80 L)}{(0.08206 \frac{L atm}{mol K})(298.2 K)} = 0.312 mol\ H_2$ collected

[5]

$n_{H_2} = n_{Zn} = 0.312 mol$

$m_{Zn} = nMM = (0.312 mol)(65.38 \frac{g}{mol}) = \boxed{20.4 g}$

(10) 5. (a) The following initial rate information was collected at 25°C for the reaction:

$$2\,I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2\,SO_4^{2-}(aq)$$

Experiment	$[I^-]_0$ (mol/L)	$[S_2O_8^{2-}]_0$ (mol/L)	Initial Rate (mol/L·s)
1	0.125	0.150	4.4×10^{-2}
2	0.375	0.150	1.3×10^{-1}
3	0.125	0.050	1.5×10^{-2}

∴ m = 1

×3

÷3

×3

÷3

∴ n = 1

$= k[I^-]^m[S_2O_8^{2-}]^n$

i) Determine the rate law expressed by this data.

$\frac{Rate\ 2}{Rate\ 1} = \frac{\cancel{k}(0.375)^m(\cancel{0.150})^n}{\cancel{k}(0.125)^m(\cancel{0.150})^n} = \left(\frac{0.375}{0.125}\right)^m = \boxed{3^m} = \frac{0.13}{4.4\times10^{-2}} = \boxed{3}$ $3^m = 3^1$ $m = 1$

$\frac{Rate\ 1}{Rate\ 3} = \frac{\cancel{k}(\cancel{0.125})^m(0.150)^n}{\cancel{k}(\cancel{0.125})^m(0.050)^n} = \left(\frac{0.150}{0.050}\right)^n = \boxed{3^n} = \frac{4.4\times10^{-2}}{1.5\times10^{-2}} = \boxed{3}$ $3^n = 3^1$ $n = 1$

[4]

$\underline{Rate = k[I^-][S_2O_8^{2-}]}$

ii) Calculate the rate constant with the CORRECT units.

use any trial $\underline{\text{Trial 3}}$ $1.5\times10^{-2}\,\frac{mol}{L\,s} = k\left(0.125\,\frac{mol}{L}\right)\left(0.050\,\frac{mol}{L}\right)$

$$\boxed{k = 2.4\,\frac{L}{mol\,s}}$$

b) The light-emitting decay of excited mercury atoms is first order, with a half-life of 4.20×10^{-7} s. A sample contains 4.5×10^{-6} mol/L of excited mercury atoms.

$t_{1/2} = 4.20\times10^{-7}\,s$ $k = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{4.20\times10^{-7}\,s} = 1.65\times10^{6}\,s^{-1}$

i) At what time will the concentration be 4.5×10^{-7} mol/L?

$\ln\frac{[A]_t}{[A]_0} = -kt$ $\ln\frac{(4.5\times10^{-7}\,\frac{mol}{L})}{(4.5\times10^{-6}\,\frac{mol}{L})} = -(1.65\times10^{6}\,s^{-1})\,t$

[2]

$t = 1.40\times10^{-6}\,s = 1.40\,\mu s$

ii) What will the concentration of mercury atoms be after 2.5×10^{-6} s?

$\ln\frac{[A]_t}{(4.5\times10^{-6}\,\frac{mol}{L})} = -(1.65\times10^{6}\,s^{-1})(2.5\times10^{-6}\,s)$

$$\boxed{[A]_t = 7.3\times10^{-8}\,\frac{mol}{L}}$$

$\ln_e\frac{[A]_t}{4.5\times10^{-6}} = -4.125$

$e^{-4.125} = \frac{[A]_t}{4.5\times10^{-6}}$

$[A]_t = 4.5\times10^{-6}\,e^{-4.125}$

b) The reaction of CO with Cl_2 gives phosgene ($COCl_2$), a nerve gas used in World War I. Even though the stoichiometry is simple, the mechanism has several steps:

1. $Cl_2(g) \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2\,Cl\,(g)$ Fast reversible equilibrium

2. $Cl\,(g) + CO(g) \xrightarrow{k_2} COCl(g)$ Slow

3. $COCl\,(g) + Cl\,(g) \xrightarrow{k_3} COCl_2(g)$ Fast

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i) Show that the elementary reactions of the proposed mechanism can be added to provide a balanced equation for the reaction.

$CO + Cl_2 \rightarrow COCl_2$

[1]

ii) Identify any intermediates in the mechanism.

Cl , $COCl$

[1]

iii) What is the rate law yielded by this mechanism?

[2]

$\text{Rate}_{\text{fwd}①} = \text{Rate}_{\text{rev}①}$ Ⓐ $k_1 [Cl_2] = k_{-1} [Cl]^2$

Rate is determined by slow step (RDS) ②

Ⓑ $\therefore \text{Rate} = k_2 [Cl][CO]$ but $[Cl]$ is an intermediate!

using Ⓐ solve for $[Cl] \Rightarrow [Cl] = \sqrt{\frac{k_1}{k_{-1}} [Cl_2]} = \left(\frac{k_1}{k_{-1}}\right)^{1/2} [Cl_2]^{1/2}$

from Ⓑ

$$\begin{aligned} \text{Rate} &= k_2 [Cl][CO] \\ &= k_2 \left(\frac{k_1}{k_{-1}}\right)^{1/2} [Cl_2]^{1/2} [CO] \\ &= k' [Cl_2]^{1/2} [CO] \end{aligned}$$

, where $k' = k_2 \left(\frac{k_1}{k_{-1}}\right)^{1/2}$

(10) 6. (a) The solubility of calcium phosphate in water is 3.5 x 10^{-5} g/L. Use this information to calculate K_{sp} for the salt.

$$Ca_3(PO_4)_2 \Rightarrow MM = 3(40.078\ \frac{g}{mol}) + 2(30.973762\ \frac{g}{mol}) + 8(15.9994\ \frac{g}{mol})$$

$$= 310.176724\ \frac{g}{mol}$$

[5]

$$s = \text{solubility}\left(Ca_3(PO_4)_2\right) = \frac{\left(3.5\times10^{-5}\ \frac{g}{L}\right)}{310.176724\ \frac{g}{mol}} = 1.1\times10^{-7}\ \frac{mol}{L}$$

$$Ca_3(PO_4)_2\ (s) \rightleftharpoons 3\,Ca^{2+}\ (aq) + 2\ PO_4^{3-}\ (aq)$$

I	some	—	—
C	$-s$	$3s$	$2s$
E	some	$3s$	$2s$

$$K_{sp} = [Ca^{2+}]^3[PO_4^{3-}]^2 = (3s)^3(2s)^2 = 27s^3 \cdot 4s^2 = 108\ s^5$$

$$= 108(1.1\times10^{-7})^5$$

$$= \underline{\underline{2.0\times10^{-33}}}$$

(b) What mass of BaF_2 (K_{sp} = 1.8 x 10^{-7}) will dissolve in 0.500 L of 0.100 mol/L NaF solution?

$$BaF_2\ (s) \rightleftharpoons Ba^{2+}\ (aq) + 2F^-\ (aq)$$

[5]

I	some	—	$0.100\ \frac{mol}{L}$
C	$-s$	s	$2s$
E	some	s	$2s+0.100$

$$K_{sp} = 1.8\times10^{-7} = [Ba^{2+}][F^-]^2 = s(2s+0.100)^2 = 1.8\times10^{-7}$$

Assume $2s << 0.100$ $\therefore$ $2s + 0.100 \approx 0.100$

$$s(0.100)^2 = 1.8\times10^{-7}$$

$$s = 1.8\times10^{-5}\ \frac{mol}{L}$$

$$n_{BaF_2} = cV = \left(1.8\times10^{-5}\ \frac{mol}{L}\right)(0.500 L) = 9.0\times10^{-6}\ mol$$

$$m_{BaF_2} = nMM = (9.0\times10^{-6}\ mol)(137.327 + 2(18.998403)\ \frac{g}{mol}$$

$$= 1.6\times10^{-3}\ g = \boxed{1.6\ mg}$$

(12) 7. (a) Consider the titration of 30.0 mL of 0.200 mol/L HCOONa (aq) with 6.0 mol/L HCl (aq). (K_a for HCOOH is 1.8×10^{-4})

i) What is the original pH of the solution of HCOONa?

$HCOONa \rightarrow Na^+ + HCOO^-$
(conj. base)

$HCOO^-(ap) + H_2O(l) \rightleftharpoons HCOOH(ap) + OH^-(aq)$

	$HCOO^-$	H_2O	$HCOOH$	OH^-
I	$0.200\ \frac{mol}{L}$	/	—	—
C	$-x$		x	x
E	$0.200 - x$		x	x

$K_b = \frac{K_w}{K_a} = \frac{1.0\times10^{-14}}{1.8\times10^{-4}} = 5.6\times10^{-11} = \frac{[HCOOH][OH^-]}{[HCOO^-]} = \frac{x^2}{0.200 - x} = 5.6\times10^{-11}$

assume $x \ll 0.200 \therefore 0.200 - x \approx 0.200$ $\therefore \frac{x^2}{0.200} = 5.6\times10^{-11}$ $x = 3.3\times10^{-6}\ \frac{mol}{L} = [OH^-]$

$pOH = -\log[OH^-] = -\log(3.3\times10^{-6}) = 5.48$ $pH = 14.00 - pOH = 14.00 - 5.48 = \boxed{8.52}$

ii) What is the pH of the solution halfway through the titration?

HCl reacts with $HCOO^-$ → not $\rightleftharpoons$ because of strong acid

First find equivalence pt! $C_AV_A = C_BV_B$ (since 1:1)

$\left(6.0\ \frac{mol}{L}\right)V_A = \left(0.200\ \frac{mol}{L}\right)(30.0\ mL)$ $V_A = 1.00\ mL$

[6] $\therefore$ The V_{Acid} halfway through titration is 0.50 mL.

$HCl(aq) + HCOO^-(aq) \rightarrow HCOOH(aq) + Cl^-(aq)$

$6.0\ \frac{mol}{L}\left(\frac{0.50\ mL}{30.50\ mL}\right)$ $0.200\ \frac{mol}{L}\left(\frac{30.00\ mL}{30.50\ mL}\right)$

use LR

	HCl	$HCOO^-$	$HCOOH$	Cl^-
I	$0.098\ \frac{mol}{L}$	$0.197\ \frac{mol}{L}$	—	—
C	-0.098	-0.098	0.098	—
E	/	0.099	0.098	

Left with Buffer!

$pH = pKa + \log\frac{[A^-]}{[HA]}$

$pH = -\log(1.8\times10^{-4}) + \log\left(\frac{0.099}{0.098}\right)$

$= \boxed{3.75}$

iii) What is the pH at the equivalence point?

$HCl(aq) + HCOO^-(aq) \rightarrow HCOOH(aq) + Cl^-(ap)$

$6.0\ \frac{mol}{L}\left(\frac{1.0\ mL}{31.00\ mL}\right)$ $0.200\ \frac{mol}{L}\left(\frac{30.00\ mL}{31.00\ mL}\right)$

	HCl	$HCOO^-$	$HCOOH$	Cl^-
I	$0.193_5\ \frac{mol}{L}$	0.193_5	—	—
C	-0.193_5	-0.193_5	0.193_5	—
E	$\cancel{0}$	/	0.193_5	

must REDO ICE!

$HCOOH(aq) + H_2O(l) \rightleftharpoons HCOO^-(aq) + H_3O^+(aq)$

	$HCOOH$	H_2O	$HCOO^-$	H_3O^+
I	0.193_5	/	—	—
C	$-x$		x	x
E	$0.193_5 - x$		x	x

$K_a = \frac{[HCOO^-][H_3O^+]}{[HCOOH]} = \frac{x^2}{0.193_5 - x} = 1.8\times10^{-4} \Rightarrow x^2 = 1.8\times10^{-4}(0.193_5 - x)$

$x^2 + 1.8\times10^{-4}x - 3.5\times10^{-5} = 0$ $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

(use (+) root) $= \frac{-1.8\times10^{-4} \pm \sqrt{(1.8\times10^{-4})^2 - 4(1)(-3.5\times10^{-5})}}{2}$

$= 5.8\times10^{-3}\ \frac{mol}{L} = [H^+]$

$pH = -\log[H^+]$
$= -\log(5.8\times10^{-3}) = \boxed{2.23 \text{ or } 2.24}$

$K_b = 1.8\times10^{-5}$

(b) What is the pH of a buffer solution containing 35.0 g of NH_4Cl dissolved in 1.00 L of 1.00 mol/L NH_3? $MM_{NH_4Cl} = 14.01 + 4(1.01) + 35.45\ \frac{g}{mol} = 53.5\ \frac{g}{mol}$

$n_{NH_4Cl} = \frac{35.0\ g}{53.5\ \frac{g}{mol}} = 0.654\ mol$ in 1.00 L $\Rightarrow$ $0.654\ \frac{mol}{L}$ of NH_4^+

[6]

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

$$= -\log\left(\frac{K_w}{K_b}\right) + \log\frac{[A^-]}{[HA]}$$

$$= -\log\left(\frac{1.00\times10^{-14}}{1.8\times10^{-5}}\right) + \log\frac{\left(1.00\ \frac{mol}{L}\right)}{\left(0.654\ \frac{mol}{L}\right)}$$

$$= \boxed{9.44}$$

ii) Calculate the pH of the system if 5.0 mL of 12.0 mol/L HCl is added to the buffer. HCl added reacts with NH_3

	$HCl_{(aq)}$ +	$NH_{3(aq)}$ →	$NH_4^+{}_{(aq)}$ +	$Cl^-{}_{(aq)}$
	$12.0\ \frac{mol}{L}\left(\frac{5.00\ mL}{1005\ mL}\right)$	$1.00\ \frac{mol}{L}\left(\frac{1000\ mL}{1005\ mL}\right)$	$0.654\ \frac{mol}{L}\left(\frac{1000\ mL}{1005\ mL}\right)$	—
I	$5.97\times10^{-2}\ \frac{mol}{L}$	$0.995\ \frac{mol}{L}$	$0.651\ \frac{mol}{L}$	—
C	-5.97×10^{-2}	-5.97×10^{-2}	$+5.97\times10^{-2}$	
E	/	$0.935\ \frac{mol}{L}$	$0.710\ \frac{mol}{L}$	—

only buffer left!

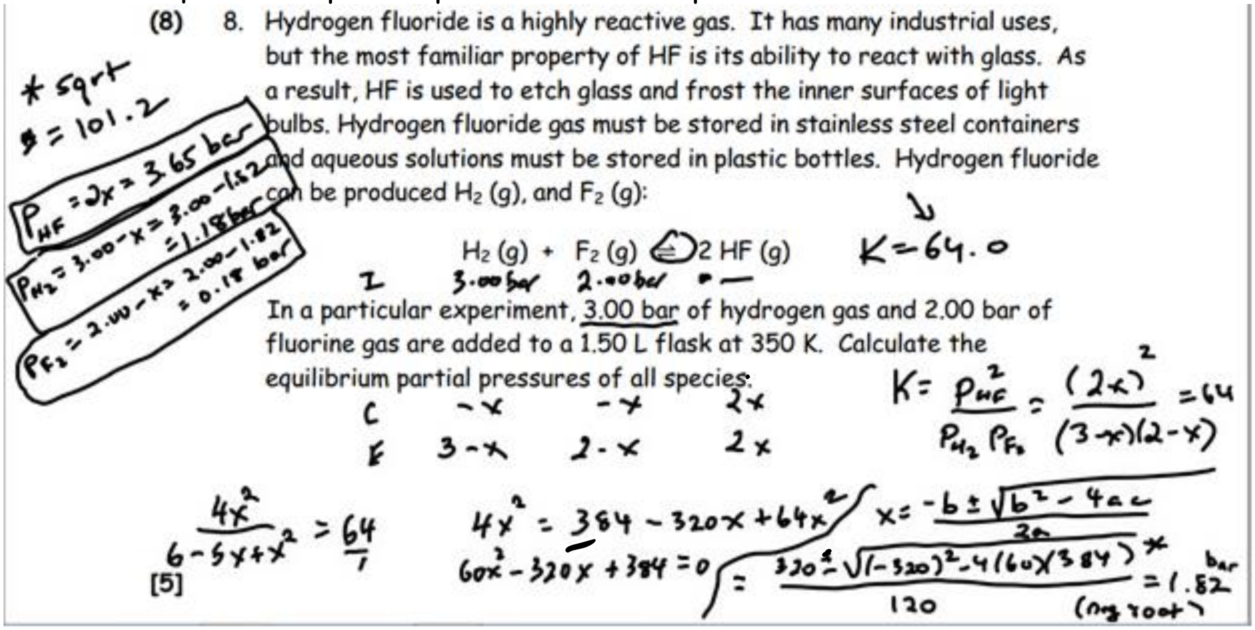
$$pH = pK_a + \log\frac{[A^-]}{[HA]} = -\log 5.6\times10^{-10} + \log\left(\frac{0.935}{0.710}\right)$$

$$= 9.37$$ (reasonable → pH decreases when we add acid but only slightly)

(8) 8. Hydrogen fluoride is a highly reactive gas. It has many industrial uses, but the most familiar property of HF is its ability to react with glass. As a result, HF is used to etch glass and frost the inner surfaces of light bulbs. Hydrogen fluoride gas must be stored in stainless steel containers and aqueous solutions must be stored in plastic bottles. Hydrogen fluoride can be produced H_2 (g), and F_2 (g):

$$H_2(g) + F_2(g) \rightleftharpoons 2\,HF(g)$$

In a particular experiment, 3.00 bar of hydrogen gas and 2.00 bar of fluorine gas are added to a 1.50 L flask at 350 K. Calculate the equilibrium partial pressures of all species.



(8) 8. Hydrogen fluoride is a highly reactive gas. It has many industrial uses, but the most familiar property of HF is its ability to react with glass. As a result, HF is used to etch glass and frost the inner surfaces of light bulbs. Hydrogen fluoride gas must be stored in stainless steel containers and aqueous solutions must be stored in plastic bottles. Hydrogen fluoride can be produced H_2 (g), and F_2 (g):

$H_2(g) + F_2(g) \rightleftharpoons 2\,HF(g)$

In a particular experiment, 3.00 bar of hydrogen gas and 2.00 bar of fluorine gas are added to a 1.50 L flask at 350 K. Calculate the equilibrium partial pressures of all species.

* sqrt
= 101.2

$\boxed{P_{HF} = 2x = 3.65 \text{ bar}}$

$\boxed{P_{H_2} = 3.00 - x = 3.00 - 1.82 = 1.18 \text{ bar}}$

$\boxed{P_{F_2} = 2.00 - x = 2.00 - 1.82 = 0.18 \text{ bar}}$

$K = 64.0$

I 3.00 bar 2.00 bar —

C $-x$ $-x$ $2x$

E $3-x$ $2-x$ $2x$

$$K = \frac{P_{HF}^2}{P_{H_2}P_{F_2}} = \frac{(2x)^2}{(3-x)(2-x)} = 64$$

$$\frac{4x^2}{6-5x+x^2} = \frac{64}{1}$$

$$4x^2 = 384 - 320x + 64x^2$$

$$60x^2 - 320x + 384 = 0$$

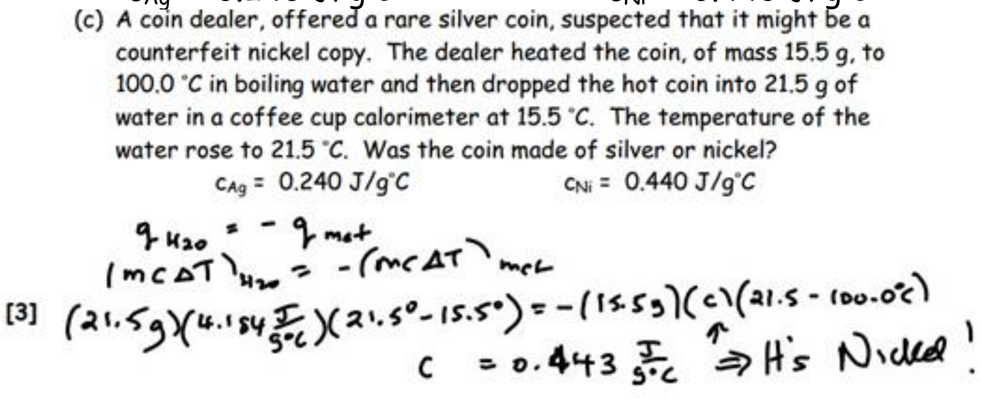
$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a} = \frac{320 \pm \sqrt{(-320)^2 - 4(60)(384)}}{120}\,{}^{*} = 1.82 \text{ bar}$$

(neg root)

[5]

[5] A coin dealer, offered a rare silver coin, suspected that it might be a counterfeit nickel copy. The dealer heated the coin, of mass 15.5 g, to 100.0 °C in boiling water and then dropped the hot coin into 21.5 g of water in a coffee cup calorimeter at 15.5 °C. The temperature of the water rose to 21.5 °C. Was the coin made of silver or nickel?

c_{Ag} = 0.240 J/g°C c_{Ni} = 0.440 J/g°C



(c) A coin dealer, offered a rare silver coin, suspected that it might be a counterfeit nickel copy. The dealer heated the coin, of mass 15.5 g, to 100.0 °C in boiling water and then dropped the hot coin into 21.5 g of water in a coffee cup calorimeter at 15.5 °C. The temperature of the water rose to 21.5 °C. Was the coin made of silver or nickel?

c_{Ag} = 0.240 J/g°C c_{Ni} = 0.440 J/g°C

$$q_{H_2O} = -q_{met}$$

$$(mc\Delta T)_{H_2O} = -(mc\Delta T)_{met}$$

[3] $(21.5\,g)(4.184\,\frac{J}{g^\circ C})(21.5^\circ - 15.5^\circ) = -(15.5\,g)(c)(21.5 - 100.0^\circ C)$

$c = 0.443\,\frac{J}{g^\circ C}$ ⇒ It's Nickel!

[3]

(10) 9. Police officers confiscate a packet of white powder that they believe contains heroin. Purification by a forensic chemist yields a 38.70 mg sample for combustion analysis. This sample gives 97.46 mg of carbon dioxide and 20.81 mg of water. A second sample is analysed for its nitrogen content, which is found to be 3.8%. Show by calculations whether these data are consistent with the formula for heroin, $C_{21}H_{22}NO_5$.

$$n_C = n_{CO_2} = \frac{m}{MM} = \frac{97.46\times10^{-3}\ g}{44.01\ g/mol} = \underline{2.214\times10^{-3}\ mol}$$

$$m_C = n_C MM_C = (2.214\times10^{-3}\ mol)(12.01\ \tfrac{g}{mol}) = \underline{2.660\times10^{-2}\ g}$$

$$n_{H_2O} = \frac{m}{MM} = \frac{20.81\times10^{-3}\ g}{18.02\ g/mol} = 1.155\times10^{-3}\ mol$$

$$n_H = 2n_{H_2O} = 2(1.155\times10^{-3}\ mol) = \underline{2.310\times10^{-3}\ mol}$$

$$m_H = n_H MM_H = (2.310\times10^{-3}\ mol)(1.01\ g/mol) = \underline{2.333\times10^{-3}\ g}$$

$$m_N = 3.8\%\ (38.70\ mg) = \underline{1.5}\ mg$$

$$n_N = \frac{m}{MM} = \frac{1.471\times10^{-3}\ g}{14.01\ g/mol} = \underline{1.05\times10^{-4}\ mol}$$

$$m_O = m_{comp} - m_C - m_H - m_N = 38.70\ mg - 26.60\ mg - 2.333\ mg - 1.5\ mg$$
$$= \underline{8.3\ mg}$$

$$\therefore n_O = \frac{m}{MM} = \frac{8.3\times10^{-3}\ g}{16.01\ g/mol} = \underline{5.2\times10^{-4}\ mol}$$

$$C_{\frac{2.214\times10^{-3}}{1.05\times10^{-4}}}\quad H_{\frac{2.310\times10^{-3}}{1.05\times10^{-4}}}\quad N_{\frac{1.05\times10^{-4}}{1.05\times10^{-4}}}\quad O_{\frac{5.2\times10^{-4}}{1.05\times10^{-4}}}$$

$$C_{21}\ H_{22}\ N\ O_5$$

Yes it is cocaine

(10) 10. Your parents have offered to pay your tuition for the fall semester of University if you can explain to them why you have selected the courses you chose and why they will be potentially helpful in getting you a job. You, of course, choose Chemistry to demonstrate how important it is to our lives today. Using **any one** of the topics covered during the semester, write a letter of minimum length 1 page and using at least 3 chemical concepts within your chosen topic (clearly explained and not just repeated from class) to demonstrate why a knowledge of chemistry is essential in our daily lives.

Various answers!

Equations and Constants

Gas Laws

$PV = nRT$

$P_{Total} = P_1 + P_2 + P_3 + \ldots$

$d = m/V = P(MM)/RT$

$KE = (1/2)mv_{av}^2$

$$\mathbf{u_{rms}} = \sqrt{\frac{3\mathbf{RT}}{\mathbf{M}}}$$

$$\frac{RateA}{RateB} = \sqrt{\frac{M_b}{M_a}}$$

$$P + \frac{n^2 a}{V^2}(V - nb) = nRT$$

Equilibrium

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

$K = [C]^c[D]^d/[A]^a[B]^b$

$K_{sp} = [C]^c[D]^d$

Acid/Base

$pOH = -\log[OH^-]$

$pH = -\log[H^+]$

$pH + pOH = 14$

$K_a \cdot K_b = K_w$

$$pH = pK_a + log\frac{[A^-]}{[HA]}$$

$$pH = \frac{pK_{a1} + pK_{a2}}{2}$$

$C_1V_1 = C_2V_2$

$$ln\left(\frac{K_1}{K_2}\right) = \frac{\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Electrochemistry

$\Delta G^o = -nFE^o$

$$E = E^o - \frac{RT}{nF}\ln(Q)$$

$$\text{Or } E = E^o - \frac{0.059}{n}\log(Q) \quad \text{at } 25^oC$$

$Q = I \cdot t$

Quantum Mechanics

$\lambda \cdot \nu = c$

$E = h \cdot \nu$

$$m = \frac{h}{\lambda c}$$

$E = \frac{1}{2} m u^2$

$\lambda = h/mu$

Energy of state = -2.178×10^{-18} J / n^2

$\Delta x \cdot \Delta p \geq h / 4\pi$

$E = -C(1/n^2)$

Liquids and Colligative Properties

$\ln(P_1/P_2) = \Delta H^\circ/R\ (1/T_2 - 1/T_1)$

$P_{solution} = X_{solvent} \cdot P^o_{solvent}$

$\Delta T_{BP} = K_{BP} \cdot m$

$\Delta T_{FP} = K_{FP} \cdot m$

$\Delta T = K \cdot m \cdot i$

$\Pi = cRT$

molality = n(solute)/m (solvent (kg))

General INFORMATION

$n = m/MM$

$d = m/V$

$C = n/V$

1 atm = 760 Torr = 760 mm Hg = 1.01325 x 10^5 Pa = 1.01325 bar = 101.325 kPa

Thermodynamics

$$\Delta U = q$$

$$w_{system} = -P\Delta V$$

$$\Delta E = q + w$$

$$\Delta H = \Delta E + P\Delta V$$

$$q_P = \Delta E + P\Delta V$$

$$\Delta E = nCv\Delta T$$

$$\Delta H = q_p = m\,Cp\,\Delta T$$

$$C_p = C_V + R$$

$$\Delta H_{rxn}{}^{\circ} = \Delta n_p \Delta H_f \Delta(\text{products}) -$$

$$\Delta n_r \Delta H_f \Delta(\text{reactants})$$

$$q_{rev} = -w_{max} = nRT \ln(V_2/V_1)$$

$$\Delta S = q_{rev} / T$$

$$\Delta S_{T1-T2} = nC_p \ln(T_2/T_1)$$

$$\Delta S_{T1-T2} = nC_V \ln(T_2/T_1)$$

$$\Delta S^0_{surroundigs} = \frac{q_{surroundigs}}{T} = \frac{-\Delta H_{sys}}{T}$$

$$\Delta G^o = \Delta H^o - T\Delta S^o$$

$$\Delta G = \Delta G^o + RT \ln(Q)$$

$$\Delta G^o = -RT \ln(K)$$

Kinetics

$$\text{Rate} = k[A]^x[B]^y[C]^z$$

$$\text{Rate} = k$$

$$\text{Rate} = k[A]$$

$$\text{Rate} = k[A]^2$$

$$[A] = -kt + [A]_0$$

$$\ln[A] = -kt + \ln[A]_0$$

$$1/[A] = kt + 1/[A]_0$$

$$t = [A]_0 / 2k$$

$$\ln 2 = kt$$

$$k = Ae^{-Ea/RT}$$

$$ln\left(\frac{k_1}{k_2}\right) = \frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Bonding

$$DE = k\,(Q_1Q_2 / r)$$

$$DH_{rxn} = Sn_pD(\text{reactants}) -$$

$$Sn_rD(\text{products})$$

Formal Charge = #valence e^- in free atom - #lone pair e^- - 1/2(# bonding e^-)

Data For Water and Other Constants

Density d_{water} = 1.00 g/mL (25°C)

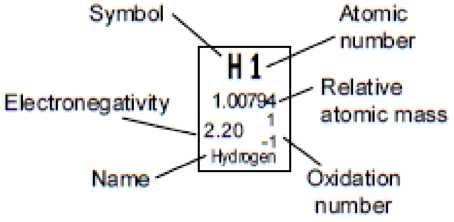
c_{water} = 4.184 J g^{-1} °C^{-1} (liquid)

Avogadro's Number	*N*	6.022×10^{23}	mol^{-1}
Boltzmann's constant	*k*	1.30866×10^{-23}	$J\cdot K^{-1}$
Faraday's constant	*F*	96,485	$C\cdot mol^{-1}$
Gas constant	*R*	8.31451	$J\cdot K^{-1}\cdot mol^{-1}$
	R	0.08206	$L\cdot atm\cdot K^{-1}\cdot mol^{-1}$
Mass of Electron	m_e	$9.10938188 \times 10^{-31}$ kg	
Planck's constant	*h*	6.62608×10^{-34}	$J\cdot s$
Speed of Light	*c*	2.99792458×10^{8}	$m\cdot s^{-1}$

$K_w = 1.00 \times 10^{-14}$

General Information: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Prof Mokeur's Periodic Table



	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIII	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	H 1 1.00794 2.20 1 -1 Hydrogen																	He 2 4.002602 - 0 Helium
2	Li 3 6.941 0.98 1 Lithium	Be 4 9.012182 1.57 2 Beryllium											B 5 10.811 2.04 3 Boron	C 6 12.0107 2.55 4 -4 Carbon	N 7 14.0067 3.04 5,3 -3 Nitrogen	O 8 15.9994 3.44 -2 Oxygen	F 9 18.998403 3 98 -1 Fluorine	Ne 10 20.1797 - 0 Neon
3	Na 11 22.989769 0.93 1 Sodium	Mg 12 24.3050 1.31 2 Magnesium											Al 13 26.981539 1.61 3 Aluminum	Si 14 28.0855 1.90 4 -4 Silicon	P 15 30.973762 2.19 5,3 -3 Phosphorus	S 16 32.065 2.58 6,4,2 -2 Sulfur	Cl 17 35.453 3.16 -1 7,5,3,1 Chlorine	Ar 18 39.948 - 0 Argon
4	K 19 39.0983 0.82 1 Potassium	Ca 20 40.078 1.0 2 Calcium	Sc 21 44.95592 1.36 3 Scandium	Ti 22 47.867 1.54 4 Titanium	V 23 50.9415 1.63 5 Vanadium	Cr 24 51.9961 1.66 6,3 Chromium	Mn 25 54.938045 1.55 7,4,2 Manganese	Fe 26 55.845 1.83 3,2 Iron	Co 27 58.933195 1.88 3,2 Cobalt	Ni 28 58.6934 1.91 2 Nickel	Cu 29 63.546 1.9 2,1 Copper	Zn 30 65.38 1.65 2 Zinc	Ga 31 69.723 1.81 3 Gallium	Ge 32 72.64 2.01 4,2 -4 Germanium	As 33 74.92160 2.18 5,3 -3 Arsenic	Se 34 78.96 2.55 6,4,2 -2 Selenium	Br 35 79.904 2.96 -1 5,3,1 Bromine	Kr 36 83.798 3.00 0,2 Krypton
5	Rb 37 85.4678 0.82 1 Rubidium	Sr 38 87.62 0.95 2 Strontium	Y 39 88.90585 1.22 3 Yttrium	Zr 40 91.224 1.33 4 Zirconium	Nb 41 92.90638 1.6 5 Niobium	Mo 42 95.96 2.16 6,4 Molybdenum	Tc 43 98.9062 1.9 7,4 Technetium	Ru 44 101.07 2.2 4,3 Ruthenium	Rh 45 102.90550 2.28 3 Rhodium	Pd 46 106.42 2.2 4,2 Palladium	Ag 47 107.8682 1.93 1 Silver	Cd 48 112.411 1.69 2 Cadmium	In 49 114.818 1.78 3 Indium	Sn 50 118.710 1.96 4,2 -4 Tin	Sb 51 121.760 2.05 5,3 -3 Antimony	Te 52 127.60 2.1 6,4,2 -2 Tellurium	I 53 126.90447 2.7 -1 7,5,3,1 Iodine	Xe 54 131.293 2.60 0,6 4,2 Xenon
6	Cs 55 132.90545 0.79 1 Cesium	Ba 56 137.327 0.89 2 Barium	La 57 138.9057 1.1 3 Lanthanum	Hf 72 178.49 1.3 4 Hafnium	Ta 73 180.94788 1.5 5 Tantalum	W 74 183.84 2.36 6,4 Tungsten	Re 75 186.207 1.9 4 Rhenium	Os 76 190.23 2.2 4 Osmium	Ir 77 192.217 2.2 4,3 Iridium	Pt 78 195.084 2.28 4,2 Platinum	Au 79 196.96657 2.54 3 Gold	Hg 80 200.59 2.0 2,1 Mercury	Tl 81 204.3833 1.62 3,1 Thallium	Pb 82F 207.2 2.33 4,2 Lead	Bi 83 208.98040 2.02 3 Bismuth	Po 84 208.9824 2.0 4,2 -2 Polonium	At 85 209.9871 2.2 -1 Astatine	Rn 86 222.0176 2.2 0 Radon
7	Fr 87 223.0197 0.7 1 Francium	Ra 88 226.0254 0.9 2 Radium	Ac 89 227.0278 1.1 3 Actinium	Rf 104 261.11 - - Rutherfordium	Db 105 262.11 - - Dubnium	Sg 106 263.12 - - Seaborgium	Bh 107 262.12 - - Bohrium	Hs 108 264 - - Hassium	Mt 109 266.1378 - - Meitnerium	Ds 110 269 - - Darmstadtium	Rg 111 272 - - Roentgenium	Cn 112 277 - - Copernicium	Uut 113 284 - - Ununtrium	Fl 114 289 - - Flerovium	Uup 115 288 - - Ununpentium	Lv 116 292 - - Livermorium	Uus 117 293 - - Ununseptium	Uuo 118 294 - - Ununoctium

Lanthanoids	6	Ce 58 140.116 1.12 4,3 Cerium	Pr 59 140.90765 1.13 3 Praseodymium	Nd 60 144.242 1.14 3 Neodymium	Pm 61 144.9127 1.13 3 Promethium	Sm 62 150.36 1.17 3 Samarium	Eu 63 151.964 1.2 3,2 Europium	Gd 64 157.25 1.2 3 Gadolinium	Tb 65 158.92535 1.2 3 Terbium	Dy 66 162.500 1.22 3 Dysprosium	Ho 67 164.93032 1.23 3 Holmium	Er 68 167.259 1.24 3 Erbium	Tm 69 168.93421 1.25 3 Thulium	Yb 70 173.054 1.1 3 Ytterbium	Lu 71 174.9668 1.27 3 Lutetium
Actinoids	7	Th 90 232.03806 1.3 4 Thorium	Pa 91 231.03588 1.5 5 Protactinium	U 92 238.02891 1.38 6 Uranium	Np 93 237.0482 1.36 5 Neptunium	Pu 94 244.0642 1.28 4 Plutonium	Am 95 243.0614 1.3 3 Americium	Cm 96 247 1.3 3 Curium	Bk 97 247.0703 1.3 3 Berkelium	Cf 98 251.0796 1.3 3 Californium	Es 99 252.03 1.3 3 Einsteinium	Fm 100 257.0951 1.3 3 Fermium	Md 101 258.01 1.3 3 Mendelevium	No 102 259.1009 1.3 3 Nobelium	Lr 103 260.1053 1.3 3 Lawrencium

Atomic masses are measured relative to the carbon isotope ^{12}C (IUPAC-2010