University of Waterloo

CHEM 13 NEWS EXAM 2007

UNIVERSITY OF WATERLOO
DEPARTMENT OF CHEMISTRY

10 MAY 2007 **TIME: 75 MINUTES**

This exam is being written by several thousand students. Please be sure that you follow the instructions below. We'll send you a report on your performance. Top performers are eligible for a prize.

1. Print your **name** here: _____

2. Print your **school name** and **city** on your STUDENT RESPONSE sheet.

3. Select, and enter on the STUDENT RESPONSE sheet, one of the following CODE numbers:

Code 1 **Ontario**, now studying Grade 12 Chemistry in a nonsemestered school

Code 2 **Ontario**, now studying Grade 12 Chemistry in a semestered school

Code 3 **Ontario**, Grade 12 Chemistry already completed

Code 4 Any **other Ontario** student

Code 5 **Manitoba or Saskatchewan** high school student

Code 6 **Québec** high school student

Code 7 **Québec** CEGEP student

Code 8 **Alberta or British Columbia** high school student

Code 9 **New Brunswick, Newfoundland, Nova Scotia, or Prince Edward Island** high school student

Code 10 **Northwest Territories, Nunavut, or Yukon** high school student

Code 11 High school student **outside Canada**

Code 12 **Teacher**

4. **Print your name** (last name, first name and optional middle initial) **on the STUDENT RESPONSE sheet**. Also fill in the corresponding circles below your printed name.

5. **Carefully detach the last page. It is the datasheet.**

6. Now answer the exam questions. Questions are **not** in order of difficulty. Indicate your choice on the STUDENT RESPONSE sheet by marking one letter beside the question number.
   - Mark only one answer for each question.
   - Questions are all of the same value.
   - **There is a penalty** (1/4 off) for each incorrect answer, but no penalty if you do not answer.

7. Take care that you make firm, **black** pencil marks, just filling the oval.

   Be careful that any erasures are complete—make the sheet white again.

Carefully detach the last page.
It is the Data Sheet.

1 In which of the following series are the atomic orbitals given in order of increasing energy?

A 3d, 4s, 4p, 4d, 4f, 5s

B 2s, 3s, 2p, 3p, 3d, 4s

C 4s, 3d, 4p, 4d, 4f, 5s

***D** 4s, 3d, 4p, 5s, 4d, 5p

E 1s, 2s, 3s, 4s, 2p, 3p

2 What is the ground state electron configuration of Ar?

***A** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

B $1s^2\ 2s^2\ 2p^6$

C $1s^2\ 2s^2\ 3s^2\ 3p^6$

D $1s^2\ 2s^2\ 2p^3\ 3s^2\ 3p^3$

E $1s^2\ 1p^6\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

3 Which of the following ions, in its ground electronic state, does **not** have the same electronic configuration as a ground state Ar atom?

A P^{3-}

B Cl^-

C K^+

D Ca^{2+}

***E** Sc^{2+}

4 Which of the following molecules is linear?

A H_2O

B O_3

C NH_3

***D** HCN

E HONO

5 Which of the following molecules has polar bonds but is nonpolar?

A N_2H_4

***B** CCl_4

C HNO_3

D CH_2Cl_2

E F_2O

6 Why is the boiling point of iodine chloride (I-Cl) greater than that of bromine (Br_2)?

A ICl is heavier than Br_2.

B ICl is a covalent compound and Br_2 is not.

C The I-Cl bond is stronger than the Br–Br bond.

***D** ICl is a polar molecule and Br_2 is nonpolar.

E ICl is an ionic compound and Br_2 is not.

7 What is the molecular geometry of phosphorus pentachloride, PCl_5 ?

A square pyramidal

***B** trigonal bipyramidal

C pentagonal

D trigonal pyramidal

E octahedral

8 Which of the following correctly characterizes the bonds and geometry of C_2H_4?

A four σ bonds, one π bond and an H-C-C bond angle very close to 109^o

B five σ bonds, no π bonds and an H-C-C bond angle very close to 90^o

***C** five σ bonds, one π bond and an H-C-C bond angle very close to 120^o

D three σ bonds, two π bonds and an H-C-C bond angle very close to 109^o

E four σ bonds, two π bonds and an H-C-C bond angle very close to 120^o

Use the following information to answer questions 9-11.

In acidic solution, zinc metal reacts spontaneously with ReO_4^-. The unbalanced chemical equation for the reaction is given below.

$Zn(s) + ReO_4^-(aq) + H^+(aq) \rightarrow Re(s) + Zn^{2+}(aq) + H_2O(l)$

9 What is the oxidation state of rhenium (Re) in ReO_4^-?

A 0

B +1

C +3

D +4

***E** +7

10 What is the coefficient of zinc (Zn) when the equation above for the reaction is balanced using the smallest whole number coefficients?

A 1

B 2

***C** 7

D 16

E none of the above

11 For the reaction above, what element or ion is the reducing agent?

A Re(*s*)

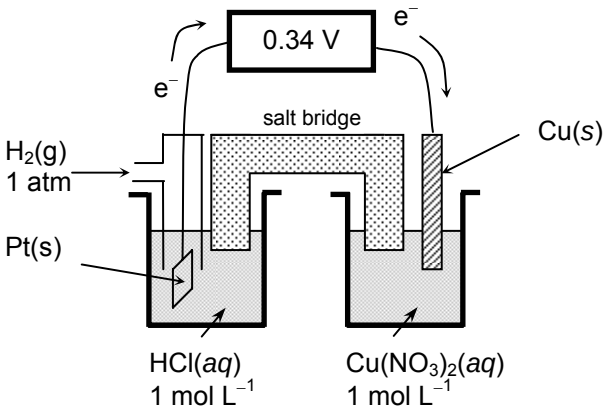
***B** Zn(*s*)

C $ReO_4^-(aq)$

D $Zn^{2+}(aq)$

E $H^+(aq)$

12 In the galvanic cell shown below, what is the reaction that occurs at the cathode?



A $H_2(g) \rightarrow 2H^+(aq) + 2e^-$

B $2H^+(aq) + 2e^- \rightarrow H_2(g)$

C $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

***D** $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

E $Pt(s) + H_2(g) + 4Cl^-(aq) \rightarrow PtCl_4^{2-}(aq) + 2H^+(aq) + 4e^-$

13 In the statements below, X refers to one of Ca, Fe, Pb, Cu or Pt. What is the identity of X?

- $X(s)$ reacts spontaneously in 1 mol L^{-1} $HCl(aq)$ to give $XCl_2(aq)$ and $H_2(g)$.
- The reaction $3X^{2+}(aq) + 2Al(s) \rightarrow 3X(s) + 2Al^{3+}(aq)$ is spontaneous under standard conditions.
- $X(s)$ is a better reducing agent than $Co(s)$ under standard conditions.

A Ca

***B** Fe

C Pb

D Cu

E Pt

Half-reaction	**E^o**
$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$	–2.84 V
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	–1.66 V
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44 V
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28 V
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.13 V
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00 V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	0.34 V
$Pt^{2+}(aq) + 2e^- \rightarrow Pt(s)$	1.18 V

14 In the laboratory, one must never dip a stirring rod into a reagent bottle. This is because

A the bottle may tip over

B the stirring rod might break

C the rod might puncture the bottle

***D** the contents of the bottle may become contaminated

E reagent can creep up the rod and come in contact with one's hand

15 What is the most accurate and precise way to measure one litre of water?

A Use a 1-L graduated cylinder.

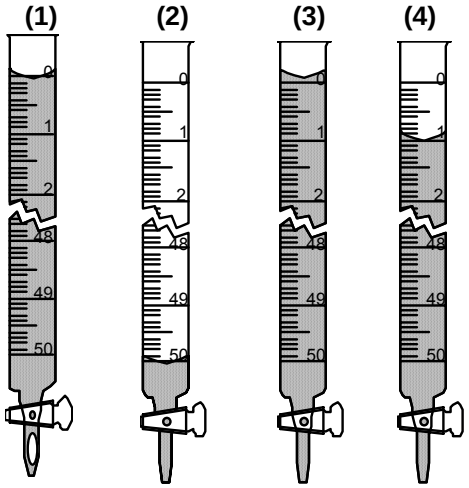
***B** Use a 1-L volumetric flask.

C Use a 100-mL volumetric flask ten times.

D Use a 100-mL pipette ten times.

E Weigh 1 kg of water using a balance that weighs to ± 1 g.

16 Examine the diagrams below carefully. Which of the burets shown below is/are ready for use?



A (1) only

B (2) only

C (3) only

***D** (4) only

E (1), (3) and (4)

17 An aqueous solution is 5.0% ethanoic acid ($HC_2H_3O_2$) by mass and its density is 0.96 g mL^{-1}. What is the molar concentration of ethanoic acid in this solution?

$HC_2H_3O_2$, 60.05 g mol^{-1}

***A** 0.80 mol L^{-1}

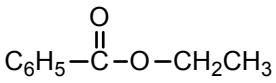
B 4.8 mol L^{-1}

C 12 mol L^{-1}

D 0.087 mol L^{-1}

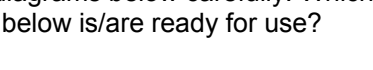
E 16 mol L^{-1}

18 Which reagents react to give ethyl benzoate ($C_6H_5COOC_2H_5$) and water? The structure of ethyl benzoate is given below.



A  and

***B**  and CH_3CH_2OH

C  and $C_6H_5CH_2OH$

D CH_3CH_2OH and C_6H_5OH

E none of the above

19 Which of the following is <u>not</u> a pair of isomers?

A ethyl benzene (C_6H_5-C_2H_5) and dimethyl benzene, $C_6H_4(CH_3)_2$

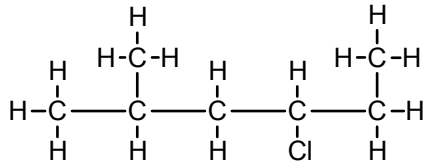
B 1-propanol ($CH_3CH_2CH_2OH$) and 2-propanol ($CH_3CHOHCH_3$)

C ethanol (C_2H_5OH) and dimethyl ether (CH_3OCH_3)

***D** 2-butanone ($CH_3COCH_2CH_3$) and 1-butanol ($CH_3CH_2CH_2CH_2OH$)

E urea (NH_2CONH_2) and ammonium cyanate (NH_4CNO)

20 What is the IUPAC name for the compound below?



For 20, D is not correct because you must number the C atoms so that the substituents have the lowest numbers possible (4+2 is less than 3+5).

A 2-chloro-1,4-dimethylpentane

B 3-chloro-1,1,4-trimethylbutane

***C** 4-chloro-2-methylhexane

D 3-chloro-5-methylhexane

E 3-chloroheptane

21 Which of the following compounds is a solid at room temperature?

A H-C≡C-H

B $CH_3CH_2CH_3$

C $CH_3CH_2CH_2OH$

D C_8H_{18}

***E** C_6H_5OH

22 How many different structural isomers are there for the compound chlorobutane (C_4H_9Cl)?

A two

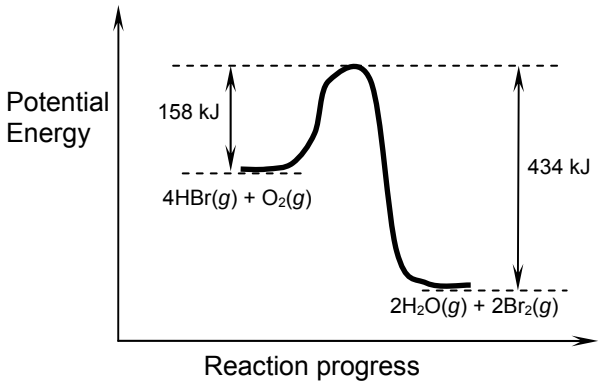
B three

***C** four

D five

E more than five

23 According to the reaction profile below, what is ΔH for the reaction $4HBr(g) + O_2(g) \rightarrow 2H_2O(g) + 2Br_2(g)$?



A 276 kJ

***B** –276 kJ

C 434 kJ

D –434 kJ

E 158 kJ

24 The enthalpy change for the reaction below is ΔH = –58 kJ (per mole of N_2O_4 formed).

$$2\ NO_2(g) \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} N_2O_4(g)$$

If k_1 and k_{-1} are the rate constants for the forward and reverse reactions, respectively, and K_c is the equilibrium constant for the reaction as written, then what is the effect of adding a catalyst on the values of k_1, k_{-1} and K_c?

A k_1 increases, k_{-1} increases, K_c increases

B k_1 decreases, k_{-1} decreases, K_c decreases

***C** k_1 increases, k_{-1} increases, K_c remains the same

D k_1 decreases, k_{-1} decreases, K_c remains the same

E k_1 remains the same, k_{-1} remains the same, K_c remains the same

25 The reaction below reaches equilibrium in a closed reaction vessel.

$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g), \quad \Delta H = 178$ kJ

Which of the following actions cause(s) an increase in the partial pressure of $CO_2(g)$?

(i) increasing the temperature
(ii) adding some $CaCO_3(s)$
(iii) increasing the volume of the reaction vessel

***A** (i) only

B (i) and (ii)

C (i), (ii) and (iii)

D (ii) only

E (i) and (iii)

26 The reaction below was studied using the method of initial rates.

$BrO_3^-(aq) + 5Br^-(aq) + 6H^+(aq) \rightarrow 3Br_2(aq) + 3H_2O(l)$

The rate law for the reaction was determined to be $Rate = k[BrO_3^-][Br^-][H^+]^2$, where *Rate* refers to the rate of consumption of BrO_3^-. Which of the following statements is **false**?

***A** If concentrations are measured in mol L^{-1} and time is measured in seconds (*s*), then the units of *k* are mol L^{-1} s^{-1}.

B The rate of consumption of Br^- is five times greater than the rate of consumption of BrO_3^-.

C The conversion of reactants into products must involve two or more simpler reactions.

D If the concentrations of all reactants are doubled, the rate of consumption of BrO_3^- will increase by a factor of sixteen.

E When the reaction reaches a state of dynamic equilibrium, $[BrO_3^-]$ stops changing.

27 Which of the following reagents could be used to separate the metal ions in an aqueous mixture of $Fe(NO_3)_3$ and $AgNO_3$?

A NH_3

B KOH

***C** NaCl

D HNO_3

E $CaCO_3$

28 The reaction below was studied using the method of initial rates.

$2\ HgCl_2(aq) + C_2O_4^{2-}(aq) \rightarrow$ products

The following data were recorded. (*Rate* refers to the initial rate of consumption of $C_2O_4^{2-}$.)

Experiment	Initial $[HgCl_2]$ (in mol L^{-1})	Initial $[C_2O_4^{2-}]$ (in mol L^{-1})	*Rate* (in mol L^{-1} hr^{-1})
1	0.0836	0.202	0.260
2	0.0836	0.404	1.04
3	0.0334	0.404	0.416

What is the rate law for the reaction?

***A** $Rate = k[HgCl_2][C_2O_4^{2-}]^2$

B $Rate = k[HgCl_2]^2[C_2O_4^{2-}]$

C $Rate = k[HgCl_2][C_2O_4^{2-}]$

D $Rate = k[HgCl_2]^2[C_2O_4^{2-}]^2$

E $Rate = k[HgCl_2]^{1/2}[C_2O_4^{2-}]$

29 A concentrated solution of ethanoic acid ($HC_2H_3O_2$) has a concentration of 17.4 mol L^{-1}. What volume of this solution is needed to prepare 0.25 L of 0.30 mol L^{-1} $HC_2H_3O_2(aq)$?

A 4.7 mL

***B** 4.3 mL

C 3.0 mL

D 2.5 mL

E 2.2 mL

30 Which of the following is a valid set of quantum numbers for an electron in a *p* orbital?

A $n = 1, l = 1, m_l = 0, m_s = ½$

B $n = 3, l = 1, m_l = 2, m_s = ½$

***C** $n = 2, l = 1, m_l = -1, m_s = ½$

D $n = 2, l = 0, m_l = 0, m_s = ½$

E $n = 2, l = 2, m_l = 0, m_s = ½$

31 For the reaction below, $\Delta H^o = -518.02$ kJ per mole of H_2S. What is ΔH_f^o for $H_2S(g)$?

$$H_2S(g) + \tfrac{3}{2}\ O_2(g) \rightarrow SO_2(g) + H_2O(g)$$

***A** -20.63 kJ mol^{-1}

B 41.26 kJ mol^{-1}

C 20.63 kJ mol^{-1}

D -497.39 kJ mol^{-1}

E -41.26 kJ mol^{-1}

	ΔH_f^o (in kJ mol^{-1})
$SO_2(g)$	-296.83
$H_2O(g)$	-241.82

32 What is the pH of 0.10 mol L^{-1} $HClO_2(aq)$?

A 1.98

B 5.11

***C** 1.55

D 2.52

E 1.00

$K_a = 1.1\times10^{-2}$ for $HClO_2$

33 Consider the reaction below.

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$$

In an experiment, 0.10 mol of O_2 and 0.10 mol of SO_3 are added to an empty 1.0-L flask and then the flask is sealed. Which of the following must be **true** at equilibrium?

A $[SO_2] = [O_2] = [SO_3]$

B $[O_2] < [SO_3]$

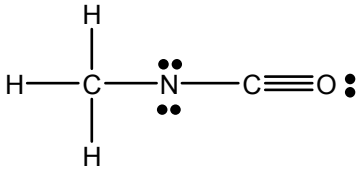
C $[O_2] = 2\ [SO_2]$

D $[O_2] = [SO_2]$

***E** $[SO_3] < [O_2]$

The reaction must go ← to establish equilibrium.

34 Which of the following statements concerning the structure below is **true**?



A There are eight σ bonds in this structure.

B The nitrogen atom is *sp*-hybridized.

C The H-C-H bond angle is 90°.

D The structure above is the most important structure for the CH_3NCO molecule.

***E** None of the statements above are true.

35 When a 10.0-g sample of a mixture of CH_4 and C_2H_6 is burned excess oxygen, exactly 525 kJ of heat is produced. What is the percentage by mass of CH_4 in the original mixture?

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l) \qquad \Delta H = -890.4 \text{ kJ (per mol } CH_4)$$

$$C_2H_6(g) + \tfrac{7}{2}\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(l) \qquad \Delta H = -1560.0 \text{ kJ (per mol } C_2H_6)$$

***A** 17%

B 21%

C 34%

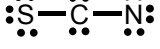
D 59%

E 87%

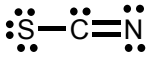
CH_4, 16.042 g mol^{-1}

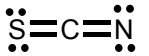
C_2H_6, 30.068 g mol^{-1}

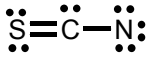
36 Which of the following is an acceptable Lewis structure for the thiocyanate ion, SCN^-?

A 

B 

C 

***D** 

E 

37 What is the pressure (in mmHg) of the gas inside the apparatus below if P_{atm} = 750 mmHg, Δh_1 = 20 mm and Δh_2 = 50 mm?

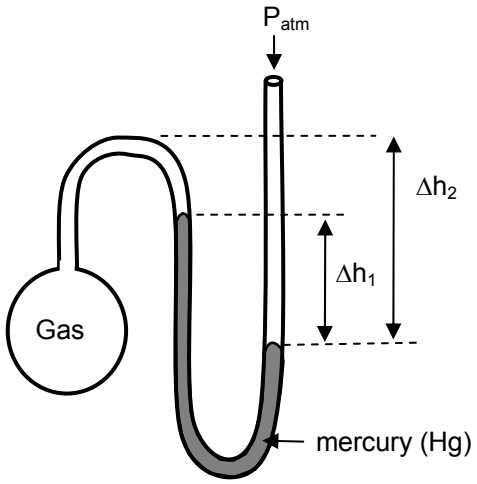
A 20 mmHg

B 50 mmHg

C 700 mmHg

***D** 730 mmHg

E 770 mmHg



38 Consider the compounds HF, HCl, HBr and HI. Of these compounds, which one has the highest boiling point and which one is the strongest acid in water?

A HF has the highest boiling point and is the strongest acid

B HI has the highest boiling point and is the strongest acid

***C** HF has the highest boiling point and HI is the strongest acid

D HI has the highest boiling point and HF is the strongest acid

E HI has the highest boiling point and HCl is the strongest acid

39 Ethanoic acid, CH_3COOH, is a weak acid in water. Which substance, when added to an aqueous solution of ethanoic acid, causes both the pH and the percentage ionization of CH_3COOH to **<u>decrease</u>**?

A $NaCH_3COO$

B NaCl

***C** CH_3COOH

D $NaNO_3$

E AgCl

40 A compound of carbon, hydrogen and oxygen is found to be 52.13% carbon by mass, 13.13% hydrogen by mass, and 34.74% oxygen by mass. What is the simplest formula of the compound?

H, 1.008 g mol^{-1}
C, 12.01 g mol^{-1}
O, 16.00 g mol^{-1}

A C_5H_8O

B $C_3H_4O_3$

***C** C_2H_6O

D CH_2O_2

E CHO

DATA SHEET
CHEM 13 NEWS EXAM 2006

DETACH CAREFULLY

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 **3B**	4 **4B**	5 **5B**	6 **6B**	7 **7B**	8 **←**	9 **8B**	10 **→**	11 **1B**	12 **2B**	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	89 **Ac** 227.0	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Uun**	111 **Uuu**	112 **Uub**	113 **Uut**					

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.00	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)

Constants:

$N_A = 6.022 \times 10^{23}$ mol^{-1}

R = 0.082058 atm L K^{-1} mol^{-1}

= 8.3145 kPa L K^{-1} mol^{-1}

= 8.3145 J K^{-1} mol^{-1}

K_w = 1.0×10^{-14} (at 298 K)

F = 96 485 C mol^{-1}

Conversion factors:

1 atm = 101.325 kPa = 760 torr = 760 mm Hg

0°C = 273.15 K

Equations: $PV = nRT$ $k\,t_{1/2} = 0.693$ $\text{pH} = \text{p}K_a + \log\left([\text{base}]/[\text{acid}]\right)$ $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$