Student Name: _____   Student No: _____

Chemistry 1AA3   **Final examination**   **April 15, 2011**

McMaster University   **VERSION 1**

Instructors: P. Berti, J. Landry, P. Lock, H. Stöver

Duration: 180 min.

This test contains 26 numbered pages printed on both sides. There are 35 multiple-choice questions appearing on pages numbered 3 to 16. Page 24 is extra space for rough work. Page 25 includes some useful data and equations. There is a periodic table on page 26. You may tear off the last page to view the periodic table and to do your rough work.

You must enter your name and student number on the question sheets, as well as on the answer sheet. Your invigilator will be checking your student card for identification.

You are responsible for ensuring that your copy of the question paper is complete. Bring any discrepancy to the attention of your invigilator.

Questions 1 to 29 are each worth 2 marks, questions 30 - 35 are each worth 3 marks; the total marks available are 76. There is no additional penalty for incorrect answers.

BE SURE TO ENTER THE CORRECT VERSION OF YOUR TEST (shown near the top of page 1), IN THE SPACE PROVIDED ON THE ANSWER SHEET.

ANSWER ALL QUESTIONS ON THE ANSWER SHEET, IN PENCIL.
Instructions for entering multiple-choice answers are given on page 2.

SELECT ONE AND ONLY ONE ANSWER FOR EACH QUESTION from the answers (A) through (E). No work written on the question sheets will be marked. The question sheets may be collected and reviewed in cases of suspected academic dishonesty.

Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, etc.) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem, please ask the invigilator to deal with it for you. Do not make contact with other students directly. Keep your eyes on your own paper - looking around the room may be interpreted as an attempt to copy.

Only Casio FX 991 MS electronic calculators may be used; but they must NOT be transferred between students. Use of periodic tables or any aids, other than those provided, is not allowed.

Student Name: _____   Student No: _____

OMR EXAMINATION - STUDENT INSTRUCTIONS

NOTE: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED: YOUT EXAMINIATION RESULT DEPENDS UPON PROPER ATTENTION TO THESE INSTRUCTIONS.

The scanner, which reads the sheets, senses the bubble shaded areas by their non-reflection of light. A heavy mark must be made, completely filling the circular bubble, with an HB pencil. Marks made with a pen will NOT be sensed. Erasures must be thorough or the scanner will still sense a mark. Do NOT use correction fluid on the sheets. Do NOT put any unnecessary marks or writing on the sheet.

1. On SIDE 1 (red side) of the form, in the top box, in pen, print your student number, name, course name, and the date in the spaces provided. Then you MUST write your signature, in the space marked SIGNATURE.

2. In the second box, with a pencil, mark your student number, exam version number in the space provided and fill in the corresponding bubble numbers underneath.

3. Answers: mark only ONE choice from the alternatives (A,B,C,D,E) provided for each question. The question number is to the left of the bubbles. Make sure that the number of the question on the scan sheet is the same as the number on the test paper.

4. Pay particular attention to the Marking+ Directions on the form.

5. Begin answering the question using the first set of bubbles, marked "1".

VERSION **1**.
Enter your version number in the correct column on
your scan sheet (see p. 2 for details).

Section #1 – These questions are worth two marks each.

1. Which of the following mixtures will result in the formation of a **buffer solution**, when dissolved in 1.00 L of water?

   (i)   0.70 mol NH_3 and 0.70 mol HCl
   (ii)   0.70 mol NH_3 and 0.70 mol NH_4Cl
   (iii) 0.70 mol NH_3 and 0.35 mol NaOH
   (iv)   0.70 mol NH_4Cl and 0.35 mol NaOH

   A) ii, iii
   B) ii, iv
   C) i, ii, iv
   D) i, iii
   E) iii, iv

2. Indicate the **final pH** after combining the following solutions:

   0.100 L of 0.200 M NaOH
   0.325 L of 0.200 M sodium benzoate
   0.100 L of 0.100 M NaBr
   0.045 L of 1.00 M HCl

   Data: K_a(benzoic acid) $= 6.3 \times 10^{-5}$

   A) 4.00
   B) 5.20
   C) 3.20
   D) 4.40
   E) 4.20

3

3. A student adds 3.34 mL of HCl to 225 mL of a neutral protein solution, causing it to precipitate. The student then separately titrates 100.0 mL of the same HCl solution to its equivalence point with 11.3 mL of 0.01023 M NaOH. What is the **isoelectric point** of the protein? (Assume that the protein does not affect the pH.)

   A) 5.22
   B) 3.93
   C) 4.25
   D) 2.48
   E) 4.77

4. Which statements are **FALSE**?
   (i)   At a given temperature, HF has a lower vapour pressure than HCl.
   (ii) CH_3OCH_3 has a higher boiling point than CH_3CH_2OH.
   (iii) $CH_3CH_2CH_2CH_2CH_2OH$ has a higher viscosity than $CH_3CH_2OCH_3$.
   (iv)   Hydrogen bonds are broken when water boils.
   (v) CCl_4 is less polarizable than $CHCl_3$.

   A) iii, v
   B) i, iv
   C) ii, v
   D) i, iii
   E) ii, iv

5. A 0.150 M solution of aspirin (acetylsalicylic acid, $C_9H_8O_4$) is titrated with 0.20 M KOH(aq). **Which pH indicator** would be the best choice for this titration?

Data: K_a(aspirin) $= 3.0 \times 10^{-4}$

	Indicator	pH range of colour change
A)	Methyl orange	3.1 - 4.4
B)	Thymol blue	1 - 3
C)	Phenolphthalein	8.3 - 10.0
D)	Bromocresol purple	5.2 - 6.6
E)	Alizarin Yellow R	10.2 - 12.0

6. Calculate the **pH** of the resulting solution when 100.0 mL of a 0.100 M ammonia (NH_3) solution is titrated to the equivalence point with 0.0500 M HCl(aq).

Data: K_b(NH_3) $= 1.8 \times 10^{-5}$

A) 5.37
B) 6.80
C) 10.33
D) 4.87
E) 9.25

7. Which statement regarding the substance whose phase diagram is shown below is **FALSE**?
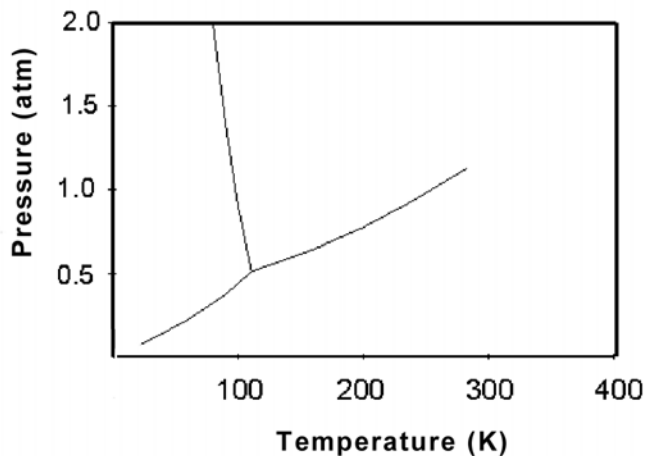
A) Compressing the solid at constant temperature cannot produce a liquid.
B) The critical temperature is greater than the triple point temperature.
C) Heating the solid at constant pressure can lead directly to the gas, with no appearance of liquid.
D) The normal boiling point is below 300 K.
E) The vapour pressure of the liquid increases with increasing temperature.

8. Which statement about reactions is **FALSE**?

A) Catalysts lower activation energies, thereby increasing reaction rates.
B) A reaction intermediate will exist at a local maximum in a reaction profile diagram.
C) The hydrogenation of cyclohexene in the presence of Pt(s) is an example of heterogeneous catalysis.
D) An exothermic reaction with one elementary step will have a higher activation energy for the reverse versus forward reaction.
E) There can be more than one transition state during a reaction.

9. An enzymatic reaction has a rate, v_0, of 2.2×10^{-4} M s^{-1} when [S] $= 10^{-2}$ M and $K_M = 10^{-5}$ M. What would the **reaction rate** be if [S] were changed to 10^{-5} M?

   A) 2.2×10^{-4} M s^{-1}
   B) 2.2×10^{-2} M s^{-1}
   C) 2.2×10^{-5} M s^{-1}
   D) 1.1×10^{-4} M s^{-1}
   E) 1.1×10^{-2} M s^{-1}

10. For the reaction aA + bB $\rightarrow$ gG + hH. Which of the following statements **must** be FALSE?

   A) $v_0 = k[A][B]$
   B) $v_0 = -1/b \times d[B]/dt$
   C) average rate $= 1/g \times \Delta[G]/\Delta t$
   D) $\Delta[A]/\Delta t = -a/h \times \Delta[H]/\Delta t$
   E) $v_0 = 1/a \times d[A]/dt$

11. In the reaction A → G, the rate constant was 8.0×10^4 $M^{-1}s^{-1}$ at 25 °C and 1.2×10^5 $M^{-1}s^{-1}$ at 50 °C. What is the **activation energy** of this reaction (kJ mol^{-1})?

   A) 59
   B) 130
   C) 150
   D) 13
   E) 6.2

12. An isolated orbital is pictured below. The lone pair electrons of the nitrogen atom in pyridine occupy this type of orbital, but the lone pairs in water do not. This type of orbital occurs somewhere in cyclohexene. **What type of orbital** is it?

   A) p
   B) sp
   C) s
   D) sp^3
   E) sp^2
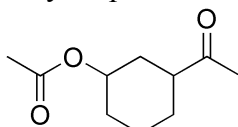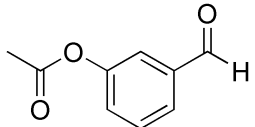
13. Which halide compounds below are expected to undergo nucleophilic substitution by an **S_N1 mechanism**, rather than S_N2?
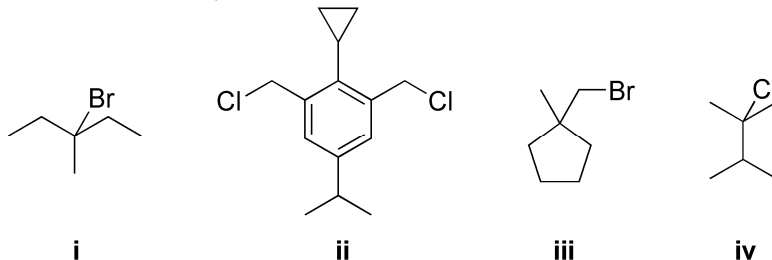
| i | ii | iii | iv |

A) ii, iii
B) ii, iv
C) i, iii
D) i, ii
E) i, iv

14. A student in the lab is given an organic compound with a molecular formula $C_9H_8O_3$. Treating this compound with concentrated HCl at high temperature gives the odour of vinegar. In a separate test, the compound does not react with PCC in CH_2Cl_2, but it does react with $KMnO_4$. The product of the reaction with $KMnO_4$ reacts with $NaHCO_3$, giving CO_2. **What is the compound**?

A) Ethyl heptanoate
B)

C) H_3C-O-$(CH_2)_7$-COOH
D)

E) 3-acetylphenol

15. Which functional group **DOES NOT** appear in the molecule below?
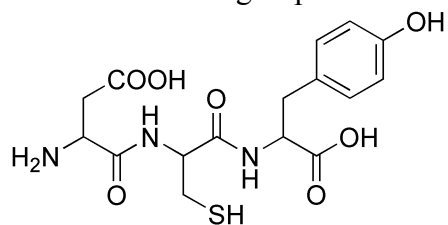
A) phenol
B) carboxylic acid
C) amide
D) alcohol
E) amine

16. **How many** substituted cyclopropene structural isomers have the molecular formula C_5H_8?

A) 2
B) 4
C) 5
D) 7
E) 1
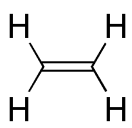
17. Indicate the **FALSE** statement regarding alkynes.

    A) Reaction of propyne with excess bromine would result in formation of 1,1,2,2-tetrabromopropane.
    B) The carbon-carbon triple bond in ethyne is three times as strong as the carbon-carbon single bond in ethane.
    C) Alkynes are linear functional groups because both carbon atoms in the triple bond are sp-hybridized.
    D) Hydrogenation of 2-hexyne or 3-hexene with excess hydrogen and a Pd catalyst results in the same product.
    E) Cyclopentyne is less stable than cyclopentene.

18. Which reaction(s) **will not proceed** as shown?

    (i)

    $$\text{benzene} \xrightarrow[\text{2.) Na}^{+}\text{ }^{-}\text{OH}]{\text{1.) Br}_2} \text{cyclohexadiene with two OH groups}$$

    (ii)

    $$\text{methylcyclopentene} \xrightarrow{\text{H}_3\text{O}^{+}} \text{1-methylcyclopentanol}$$

    (iii)

    $$\text{benzyl alcohol} \xrightarrow{\text{PCC, CH}_2\text{Cl}_2} \text{benzaldehyde}$$
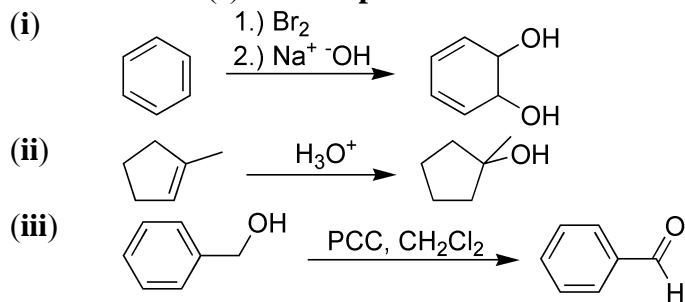
    A) iii
    B) ii, iii
    C) ii
    D) i
    E) i, iii

19. Which statement regarding S_N2 nucleophilic substitution reactions is **FALSE**?

    A) Increasing steric crowding around the electrophilic carbon will tend to favour an S_N1 over S_N2 mechanism.
    B) S_N2 reactions become nine times faster when [nucleophile] and [electrophile] both increase by a factor of three.
    C) S_N2 reactions consist of a slow first step followed by a fast second step.
    D) S_N2 reactions proceed with inversion of configuration at the electrophilic carbon atom.
    E) S_N2 reactions may involve charged or neutral nucleophiles.

20. Which of the intermediate species or reactants shown below **cannot exist** during the polymerization of ethene to form polyethylene?

    A) $R\text{-}O\text{-}[CH_2CH_2]_{13}\bullet$
    B) $R\text{-}O\bullet$
    C)

    D) $R\text{-}O\text{-}CH_2\text{-}CH_2\text{-}CH_2\bullet$
    E) $R\text{-}O\text{-}CH_2\text{-}CH_2\bullet$

21. Which of the following is an **INCORRECT** representation of a reaction mechanism? (The lone pair electrons are present but not shown in the structures.)

A)

B)

C)

D)

E)
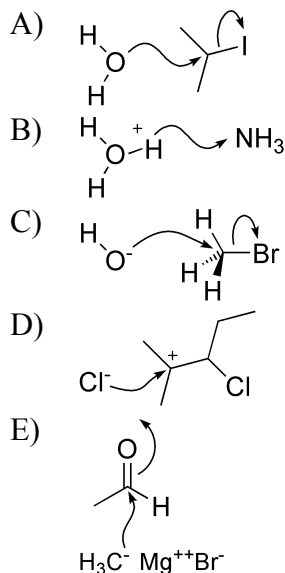
22. The **primary purpose** of recrystallization is to accomplish the following:

A) To help separate products when being analyzed by thin layer chromatography (TLC).
B) To widen the melting point range of a product.
C) Make it easier to suction filter the crude product of a reaction.
D) Remove the solvent from a reaction.
E) Purify the product of a reaction.

23. Assign the *E/Z* **configurations** for the alkene functional groups in the molecule below (from left to right):
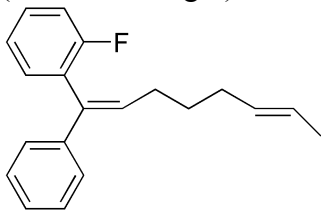
A) *cis,trans*
B) *E,Z*
C) *Z,E*
D) *Z,Z*
E) *E,E*

24. Indicate the **correct reaction types** for the reactions shown below:
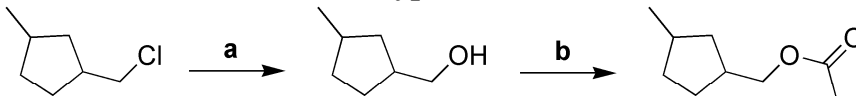
	a	b
A)	hydration	esterification
B)	hydration	Grignard
C)	nucleophilic substitution	Grignard
D)	oxidation	nucleophilic substitution
E)	nucleophilic substitution	esterification

25. Alkynes undergo hydrohalogenation reactions with two molecules of HCl, first forming a haloalkene, then a dihaloalkane. The reaction follows the Markovnikov rule for both steps. For the reaction below, what is the **product**?
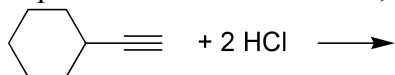
A)

B)

C)

D)

E)

26. A combinatorial library with 4 diversity sites and 15 substituents at each site, would give a library of **how many** compounds?

A) $\approx 90,000$
B) $\approx 10^9$
C) $\approx 6,000$
D) $\approx 50,000$
E) ≈ 60

27. Indicate the **FALSE** statement concerning aromatic compounds:

    A) 1,3,5-Triacetylbenzene (below) contains 12 π-electrons but is nevertheless aromatic.
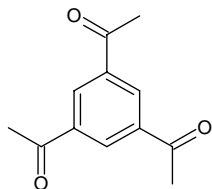
    B) The Hückel rule predicts that planar cyclic systems having (4n + 2) conjugated π-electrons are aromatic.
    C) Aromatic systems are stabilized by delocalization of their π-electrons.
    D) π-bonds in aromatic systems are more reactive towards bromine than those in linear alkenes.
    E) Aromatic systems are planar in order to allow maximum overlap between adjacent p-orbitals.

28. How many **sites of diversity** are there in this combinatorial library?
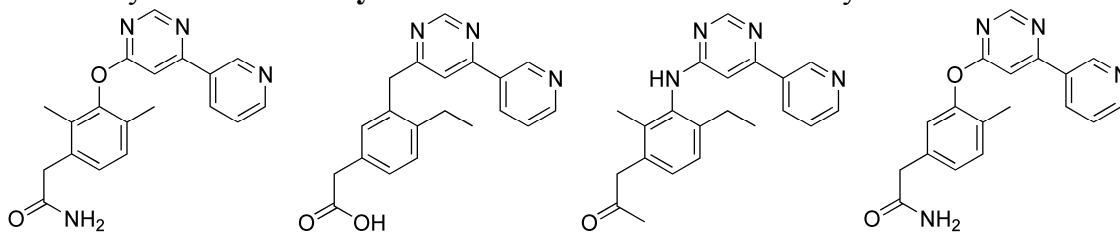
    A) 6
    B) 4
    C) 8
    D) 3
    E) 2

29. If dopamine were to be accidentally omitted from all the control wells in the bee neural cell assay, as discussed in class, **what would the control wells look like**?

Normally, the control wells look like this:

| | dopamine | − | + | − |
| | HVA | − | + | + |

neural cells

Legend:
High [dopamine]
No dopamine

A)

B)

C)

D)
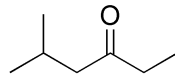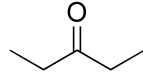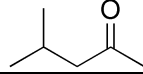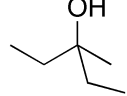
E)

Section #2 – These questions are worth three marks each.

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30. A combinatorial library was created by reacting the Grignard reagents in box **A** with the aldehydes/ketones in box **B**, followed by acid work-up. The resulting compounds were then oxidized with KMnO$_4$. Which of the following compounds **could not** be part of the combinatorial library?

A

B
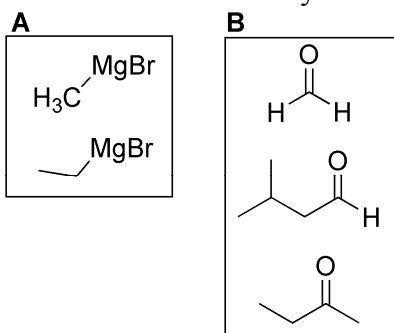
A)	
B)	
C)	
D)	
E)	

31. Which compound **is aromatic**? (You may assume that it is planar if it meets the other criteria for aromaticity.)

A)

B)

C)

D)

E)
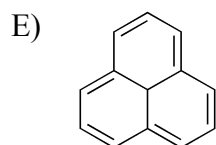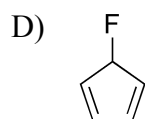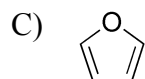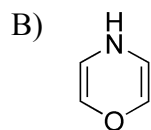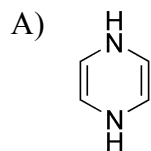
32. Indicate **suitable reagents** for the reactions shown in the scheme below.
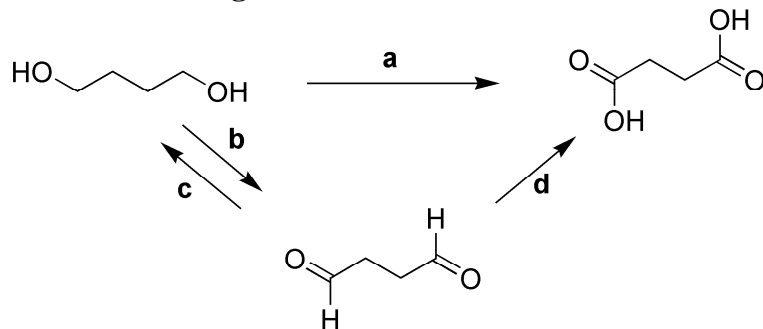
	a	b	c	d
A)	$K_2Cr_2O_7$	PCC	1. $NaBH_4$, 2. H_3O^+	PCC
B)	$K_2Cr_2O_7$	$K_2Cr_2O_7$	PCC	$KMnO_4$
C)	PCC	$KMnO_4$	1. $NaBH_4$, 2. H_3O^+	PCC
D)	$KMnO_4$	PCC	1. $NaBH_4$, 2. H_3O^+	$KMnO_4$
E)	1. $NaBH_4$, 2. H_3O^+	$KMnO_4$	PCC	1. $NaBH_4$, 2. H_3O^+

33. A researcher wishes to continuously monitor the brain function of a patient for several hours using a PET scan with radiolabelled ^{18}F-fluorodeoxyglucose ([18]FDG). After an initial injection of 2.0 pg per kg of body weight, [18]FDG is injected continuously to maintain a steady state concentration of 2.0 pg/kg. Assume a 50 kg patient, and that [18]FDG is lost only by radioactive decay. At **what rate** (in pg/h) must [18]FDG be injected?

Data: $t_{1/2}$([18]FDG) = 110 min
        pg = picogram = 10^{-12} g

A)   0.035
B)   18
C)   38
D)   0.91
E)   73

34. Which of the following statements is **FALSE** regarding the reaction of bromine with butane?

        (i)   The reaction requires an initiation step with either light or heat.

        (ii)   The major organic products will be 1-bromobutane and 2-bromobutane.

        (iii)   Formation of 3,4-dimethylhexane is possible.

        (iv)   It is possible to write at least 6 unique termination steps for this reaction.

A)   ii, iii

B)   ii, iii, iv

C)   all statements are true

D)   iii, iv

E)   i, ii

35. A combinatorial library was screened in 96 well plates for compounds with anti-cancer activity. Anti-cancer compounds kill cancer cells without affecting normal cells. Which of compounds I - V is the **most likely** to have anti-cancer activity?

	Compound				
	I	II	III	IV	V
cancer cells + compound	○	●	○	○	○
cancer cells only	●	●	○	○	●
normal cells + compound	○	●	●	○	●
normal cells only	●	●	●	●	●

● cell growth
○ no cell growth

A) III
B) I
C) IV
D) V
E) II

Extra space for rough work.

General data and equations. Other data appear with the questions.

There is a periodic table on the next page.

STP = 273.15 K, 1 atm

$R = 8.3145$ J/K·mol = 0.08206 L·atm/K·mol

1 atm = 760 mm Hg = 101.325 kPa

1 J = 1 kg m^2 s^{-2} = 1 kPa·L = 1 Pa·m^3

1 cm^3 = 1 mL

$K_w = 1.0 \times 10^{-14}$

F = 96485 C/mol

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

0°C = 273.15 K

1 m = 10^9 nm = 10^{10} Å

1 g = 10^3 mg

$v_0 = k[A]^m[B]^n$	$v = \lim_{t \to 0} \dfrac{1}{g}\dfrac{\Delta[G]}{\Delta t} = \dfrac{1}{g}\dfrac{d[G]}{dt}$
$[A]_t = [A]_0 \bullet e^{-kt}$	$ln\dfrac{[A]_t}{[A]_0} = -kt$
$[A]_t = [A]_0 - kt$	$t_{1/2} = \dfrac{ln\,2}{k} = \dfrac{0.69}{k}$
$v_0 = k[A]^2$ or $k[A][B]$	$\dfrac{d[E \bullet S]}{dt} = 0$
$v_0 = \dfrac{k_{cat}[E]_0[S]}{K_M + [S]}$	$k = Ae^{-E_a/RT}$
$ln\dfrac{k_2}{k_1} = \dfrac{E_a}{R}\left(\dfrac{1}{T_1} - \dfrac{1}{T_2}\right)$	

PERIODIC TABLE OF THE ELEMENTS

Transition Metals

Atomic weights are based on $^{12}C = 12$ and conform to the 1987 IUPAC report values rounded to 5 significant digits.
Numbers in [ ] indicate the most stable isotope.

	I 1	II 2	3	4	5	6	7	8	9	10	11	12	III 13	IV 14	V 15	VI 16	VII 17	VIII 18
1	H 1.0079																	He 4.0026 2
	Li 6.941 3	Be 9.0122 4											B 10.811 5	C 12.011 6	N 14.007 7	O 15.999 8	F 18.998 9	Ne 20.180 10
	Na 22.990 11	Mg 24.305 12											Al 26.982 13	Si 28.086 14	P 30.974 15	S 32.066 16	Cl 35.453 17	Ar 39.948 18
	K 39.098 19	Ca 40.078 20	Sc 44.956 21	Ti 47.88 22	V 50.942 23	Cr 51.996 24	Mn 54.938 25	Fe 55.847 26	Co 58.933 27	Ni 58.69 28	Cu 63.546 29	Zn 65.39 30	Ga 69.723 31	Ge 72.61 32	As 74.922 33	Se 78.96 34	Br 79.904 35	Kr 83.80 36
	Rb 85.468 37	Sr 87.62 38	Y 88.906 39	Zr 91.224 40	Nb 92.906 41	Mo 95.94 42	Tc [98] 43	Ru 101.07 44	Rh 102.91 45	Pd 105.42 46	Ag 107.87 47	Cd 112.41 48	In 114.82 49	Sn 118.71 50	Sb 121.75 51	Te 127.60 52	I 126.90 53	Xe 131.29 54
	Cs 132.91 55	Ba 137.33 56	*La 138.91 57	Hf 178.49 72	Ta 180.95 73	W 183.85 74	Re 186.21 75	Os 190.2 76	Ir 192.22 77	Pt 195.08 78	Au 196.97 79	Hg 200.59 80	Tl 204.38 81	Pb 207.2 82	Bi 208.98 83	Po [209] 84	At [210] 85	Rn [222] 86
	Fr [223] 87	Ra 226.03 88	**Ac 227.03 89	Unq [261] 104	Unp [262] 105	Unh [263] 106												

* Lanthanides

Ce 140.12 58	Pr 140.91 59	Nd 144.24 60	Pm [145] 61	Sm 150.36 62	Eu 151.97 63	Gd 157.25 64	Tb 158.93 65	Dy 162.50 66	Ho 164.93 67	Er 167.26 68	Tm 168.93 69	Yb 173.04 70	Lu 174.97 71

** Actinides

Th 232.04 90	Pa 231.04 91	U 238.03 92	Np 237.05 93	Pu [244] 94	Am [243] 95	Cm [247] 96	Bk [247] 97	Cf [251] 98	Es [252] 99	Fm [257] 100	Md [258] 101	No [259] 102	Lr [262] 103

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