Queen's University at Kingston

Chem 112 Final Exam

16–APR–2011
Time: 3 hour

John Carran, Gregory Jerkiewicz, Peter Loock, Donal MacArtney, Michael Mombourquette, Nick Mosey

INSTRUCTIONS:

You will be given the exam paper and a computer–marked sheet on which you will answer all your questions.

- You must use a soft-lead pencil (HB or softer). The scanner will not read ink no matter how black a mark it makes.
- Do not bend or fold the computer sheet in any way or it will become jammed in the scanner.
- Write and Code your name and student number and on the answer sheets in the appropriate spaces. (*Be especially careful to code in your student number properly*.)
- Do not mark the computer answer sheet in any way except to encode the answers. Stray marks can be read by the machine as incorrect answers!
- Make sure you've coded in all the answers. No marks are deducted for wrong answers so DO NOT LEAVE BLANKS! There is exactly one answer for each multiple-choice question.
- All Multiple Choice questions are worth 1 mark.
- There are 38 Questions in total.
- You are allowed to use any basic, non-programming, non-communications-able calculator.

PLEASE NOTE:

Proctors are unable to respond to queries about the interpretation of exam questions. Do your best to answer exam questions as written.

Good luck

1. **Consider the following two equilibria**

   $Zn(OH)_2(s) \rightleftharpoons Zn^{2+}(aq) + 2OH^-(aq)$

   $CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$

   Which of the following statements is correct when acid is added?

   A. The $Zn(OH)_2(s)$ and $CaF_2(s)$ equilibria shift to the right
   B. The $Zn(OH)_2(s)$ and $CaF_2(s)$ equilibria shift to the left
   C. The $Zn(OH)_2(s)$ equilibrium shift to the left but the CaF2(s) equilibrium shifts to the right
   D. The $Zn(OH)_2(s)$ equilibrium shifts to the right but the $CaF_2(s)$ equilibrium shifts to the left

2. **In the titration of a weak acid HA with 0.100 M NaOH the stoichiometric point is know to occur at a pH value of approximately 10. Which of the following indicator acids would be best to use to mark the endpoint of this titration?**

   A. Indicator A, $K_a = 10^{-14}$
   B. Indicator B, $K_a = 10^{-11}$
   C. Indicator C, $K_a = 10^{-8}$
   D. Indicator D, $K_a = 10^{-6}$
   E. None of these will work well

3. **For a particular reaction the equilibrium constant is 1.50×10^{-2} at 370°C and $\Delta H°$ is +16.0 kJ at 25°C. Assuming $\Delta H°$ and $\Delta S°$ are independent of temperature, calculate $\Delta S°$ for the reaction.**

   A. –18.8 J/K
   B. +18.8 J/K
   C. –10.0 J/K
   D. +10.0 J/K
   E. none of these

4. The following reaction is investigated (assume an ideal mixture):

$2N_2O\ (g) + N_2H_4\ (g) \rightleftharpoons 3\ N_2\ (g) + 2H_2O\ (g)$

initially there are 0.10 mol of N_2O and 0.25 mol of N_2H_4 in a 10.0 L container. If there are 0.06 mol of N_2O at equilibrium, how many moles of N_2 are present at equilibrium?

A. 0.09
B. 0.04
C. 0.06
D. 0.02
E. none of these

5. Which of the following will form an aldehyde upon mild oxidation?

A. $CH_3CH(OH)CH_3$
B. $CH_3CH_2CH_2OH$
C. CH_3COOH
D. $CH_3CH_2CH_2CH_3$
E. C_6H_5OH (phenol)

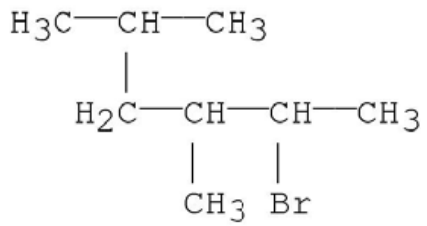
6. The standard free energy of formation of nitric oxide, NO, at 1000 K (roughly the temperature in an automobile engine during ignition) is 78 kJ/mol. Calculate the equilibrium constant for the reaction.

$N_2\ (g) + O_2\ (g) \rightleftharpoons 2NO\ (g)$

at 1000 K.

A. 1.8×10^{-19}
B. 0.99
C. 4.3×10^{-10}
D. 7.1×10^{-9}
E. 8.4×10^{-5}

7. What is the IUPAC name for the following molecule?



A. 3,5–dimethyl–2–bromohexane
B. 2–bromo–3,5–dimethylhexane
C. 2–bromo–4–isopropyl–3–methylbutane
D. 2–bromo–5,5,3–trimethylpentane
E. 2–bromo–3–methyl–4–propylbutane

8. Which of the following compounds is the most acidic

A. phenol
B. 3-chlorophenol
C. p-methylphenol
D. m-methylphenol
E. ethanol

9. (questions 9 and 10 use the same information) A galvanic cell is constructed by linking a cobalt (Co) electrode (in a Co^{2+} solution) and a silver electrode (in a Ag^{+} solution) through a salt bridge and then connecting the cobalt and silver electrodes through an external circuit. When the circuit is completed the silver is seen to plate out while Co dissolves.

$$[Co^{2+}(aq) + 2\ e^{-} \rightarrow Co(s) \qquad E^{o} = -0.28V]$$
$$[Ag^{+}(aq) + e^{-} \rightarrow Ag(s) \qquad E^{o} = 0.80\ V]$$

The cobalt electrode is weighed after 150 min and found to have decreased in mass by 0.36 g. By what amount has the silver electrode increased in mass?

A. 1.58g
B. 1.32g
C. 2.01g
D. 1.10g
E. 3.01g

10. Using the information from the question above, what is the average current drawn from the cell during that period?

A. 131 mA
B. 140 mA
C. 262 mA
D. 158 mA
E. 100 mA

11. Alkanes do not make good starting materials for the synthesis of larger molecules for the following reason

A. They are too volatile
B. They are too flexible and have many conformers
C. It is difficult to distinguish between the reactivities of the individual carbons in the molecule
D. Each carbon is sp^3 hybridised and there is free rotation around C–C bonds
E. The hydrogen atoms surrounding each carbon prevent attack from incoming nucleophiles

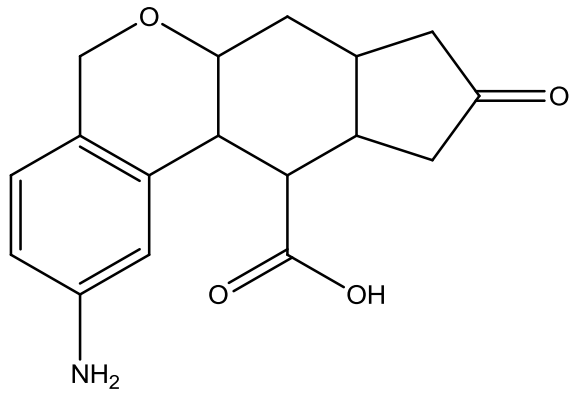
12. Which of the following molecules can be EASILY oxidized to a carboxylic acid in one step.

A. An alkene
B. An ether
C. A tertiary alcohol
D. A secondary alcohol
E. An aldehyde

13. The secondary structure of a protein refers to?

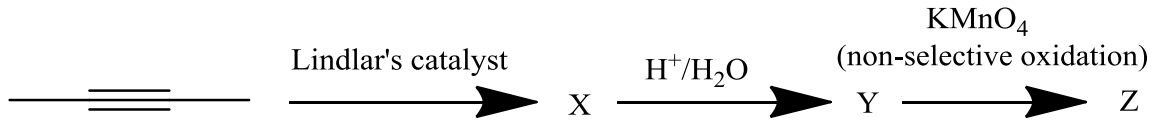
A. The sequence of amino acids in a peptide chain
B. Localised structures such as beta sheets and alpha helices
C. Dimers, trimers and tetramers of protein chains
D. The overall shape of a single folded protein chain.
E. The orientation of amide bonds linking amino acids within a protein chain

14. The following structure contains which functional groups?



A. An amine, an ester, a ketone, an aldehyde
B. An ether, an ester, a ketone, an amine
C. An ether, a carboxylic acid, a ketone, an amine
D. An ether, an aldehyde, an amine, a carboxylic acid
E. An amide, an alcohol, an ether, a ketone.

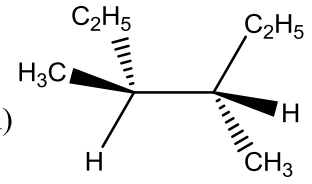
15. In the following reaction sequence a product Z is obtained. To what class of compounds does Z belong?



A. aldehyde
B. ketone
C. ester
D. carboxylic acid
E. ether

16. Which of the following molecules is the product of the hydrogenation of trans-3,4-dimethyl-3-hexene on palladium?

(A)



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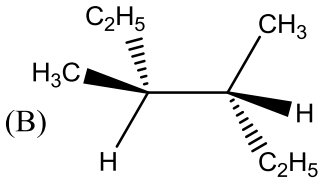

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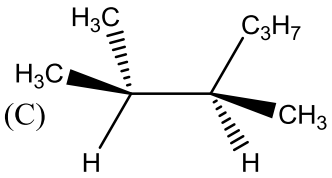

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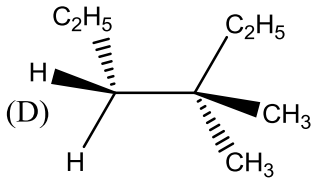
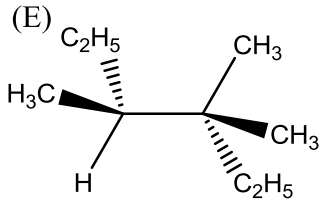


(E)



17. A reaction rate increases by a factor of 500 in the presence of a catalyst at 37ºC. The activation energy of the original reaction was found to be 95 kJ/mol. What is the activation energy of the new, catalytic pathway – all other factors being equal? In practice the catalytic pathway also has a different pre-exponential factor but you should consider this to be unchanged in the new pathway.

A. 79 kJ/mol
B. 81 kJ/mol
C. 111 kJ/mol
D. 93 kJ/mol
E. 126 kJ/mol

18. A certain reaction performed by a researcher can proceed to give either a substituted cyclopentane or a substituted cyclohexane as a product. Which of the following statements is correct regarding the MAJOR product of the reaction assuming no other information about the reaction is available?

A. The reaction will tend to give a cyclopentane product with the largest substituent in the equatorial position
B. The reaction will tend to give the boat conformation of the cyclohexane product with the largest substituent in the equatorial position
C. The reaction will tend to give the chair conformation of the cyclohexane product with the largest substituent in the equatorial position
D. The reaction will give a cyclopentane product; there are no equatorial or axial positions on a cyclopentane ring.
E. It is impossible to tell what the reaction will be from the information given here.

19. Carbon-14 is a radioactive isotope that decomposes in a first order reaction with a half-life of 5730 years to Nitrogen-14. In an archaeological excavation of a fire pit a piece of burnt wood is found to have 14% less ^{14}C than a current sample. How old is the fire pit?

A. 1250 years
B. 16200 years
C. 5630 years
D. 432 years
E. 5280 years

20. For the reversible elementary reaction $2A \leftrightarrow B+C$ the forward rate constant is 265 mol L^{-1} min^{-1} and the reverse rate constant is 392 mol L^{-1} min^{-1}. The activation energy for the forward reaction is 39.7 kJ/mol and for the reverse reaction it is 25.4 kJ/mol. Which of the following statements is true?

I. The equilibrium constant is less than 1 and will remain unchanged with increasing temperature.
II. The rate of, both, the forward and reverse reaction will increase with temperature, but the equilibrium will shift towards the products.
III. The reaction is endothermic
IV. The reaction is exothermic

A. I and III
B. I and IV
C. II and III
D. II and IV
E. Only II

21. In the reaction

$4Fe^{2+}(aq) + O_2(g) + 4H_3O^+(aq) \rightarrow 4Fe^{3+}(aq) + 6H_2O$

when the Fe^{2+} concentration alone was doubled, the rate, increased by a factor of 8. When both the Fe^{2+} concentration and the O_2 concentration were doubled, the rate increased 16-fold. When the concentrations of all three reactants were doubled, the rate increased by a factor of 32. What is the rate law of the reaction?

A. Rate = $k [Fe^{2+}]^4 [O_2] [H_3O^+]^4$
B. Rate = $k [Fe^{2+}]^4 [O_2] [H_3O^+]$
C. Rate = $k [Fe^{2+}]^3 [O_2]^4 [H_3O^+]^5$
D. Rate = $k [Fe^{2+}]^3 [O_2] [H_3O^+]$
E. Rate = $k [Fe^{2+}]^3 [O_2] [H_3O^+]^4$

22. The reaction $NO_2(g) + CO(g) \rightarrow CO_2(g) + NO(g)$ is second order in NO_2 and zeroth order in CO. Four mechanisms have been proposed. Which mechanism is correct?

A. Step 1: $NO_2(g) + CO(g) \rightarrow CO_2(g) + NO(g)$

B. Step 1: $NO_2(g) + NO_2(g) \rightarrow NO_3(g) + NO(g)$ slow
Step 2: $NO_3(g) + CO(g) \rightarrow CO_2(g) + NO_2(g)$ fast

C. Step 1: $NO_2(g) + NO_2(g) \rightleftharpoons NO_3(g) + NO(g)$ equilibrium; fast in both directions
Step 2: $NO_3(g) + CO(g) \rightarrow CO_2(g) + NO_2(g)$ slow

D. Step 1: $NO_2(g) + CO(g) \rightarrow CO_2(g) + NO(g)$ where NO_2 is in a large excess

E. Step 1: $NO_2(g) + NO_2(g) \rightleftharpoons NO_3(g) + NO(g)$ equilibrium; slow in both directions
Step 2: $NO_3(g) + CO(g) \rightarrow CO_2(g) + NO_2(g)$ slow

23. The following unbalanced redox reaction is used in acidic solution in the breathalyser test for alcohol in blood

$H^+(aq) + Cr_2O_7^{2-}(aq) + H_3CCH_2OH \rightarrow Cr^{3+}(aq) + H_3CCHO + H_2O\ (l)$.

Balance the reaction and give the number of electrons that are transferred for each turn–over of the reaction.

A. 2
B. 3
C. 6
D. 12
E. 8

24. What is the equilibrium constant for the following reaction

$2Fe^{3+}(aq) + H_2(g) \rightleftharpoons 2Fe^{2+}(aq) + 2H^+(aq)$

Consider the following standard reduction potentials:

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	**$E^o = +0.77$ V**
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	**$E^o = 0$ V (by definition)**
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	**$E^o = -0.04$ V**
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	**$E^o = -0.44$ V**

A. 8.6×10^{-40}
B. 9.5×10^{-14}
C. 5.8×10^{6}
D. 1.0×10^{13}
E. 4.6×10^{12}

25. A galvanic cell is made from the following equilibrium reaction

$Cd(s) + 2\ Ni(OH)_3(s) \rightleftharpoons Cd(OH)_2(s) + 2\ Ni(OH)_2(s)$

How will the cell potential change when the temperature is increased?

A. The cell potential will increase (become more positive or less negative)
B. The cell potential will decrease (become less positive or more negative)
C. The cell potential will not change
D. Impossible to say without having more information

26. Calculate the reaction quotient , Q, for the cell reaction, given the measured values for the cell potential. Balance the chemical equations using the smallest whole number coefficients

$Ag(s) \mid Ag^+(aq) \parallel ClO_4^-(aq), H^+(aq), ClO_3^-(aq) \mid Pt(s)$ E = +0.30 V

Consider the following standard reduction potentials:

$ClO_4^-(aq) + 2H^+(aq) + 2e^- \rightarrow ClO_3^-(aq) + H_2O(l)$	**E_0 = +1.23 V**
$Pt^{2+}(aq) + e^- \rightarrow Pt(s)$	**E_0 = +1.20 V**
$Ag^+(aq) + e^- \rightarrow Ag(s)$	**E_0 = +0.80 V**
$ClO_4^-(aq) + + H_2O(l) + 2e^- \rightarrow ClO_3^-(aq) + 2\ OH^-(aq)$	**E_0 = +0.36 V**
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	**E_0 = 0 V (by definition)**

A. 10
B. 1
C. 3.2
D. 0.1
E. 0.001

27. Consider the disproportionation reaction of $Cu^+(aq)$ to produce Cu (s) and $Cu^{2+}(aq)$. Calculate the cell potential of this reaction and indicate whether it is spontaneous or not.

$Cu^+(aq) + e^- \rightarrow Cu(s) \qquad E^0 = +0.52V$

$Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq) \qquad E^0 = +0.15V$

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s) \qquad E^0 = +0.34V$

A. E^0_{cell} = 0.34 V, spontaneous
B. E^0_{cell} = –0.67 V, non–spontaneous
C. E^0_{cell} = –0.37 V, non–spontaneous
D. E^0_{cell} = 0.37 V, spontaneous
E. E^0_{cell} = 0.18 V, spontaneous

28. What is the product of the reaction of HBr with 2-methyl-1-butene?

A. 1-bromo-1-methyl-butane
B. 1-bromo-2-methyl-butane
C. 2-bromo-2-methyl-butane
D. 1-bromo-2-methyl-butane
E. Bromo-ethyl-butane

29. The reaction $2\ H_2O_2(aq) \rightarrow 2H_2O + O_2(g)$ is catalyzed by certain ions M^-. If the mechanism is:

$H_2O_2(aq) + M^-(aq) \rightarrow 2H_2O(l) + MO^-(aq)$ (slow)
$H_2O_2(aq) + MO^-(aq) \rightarrow 2H_2O(l) + M^-(aq) + O_2(g)$ (fast)

What is the rate law for the reaction?

A. rate $= k\,[H_2O_2]^2$
B. rate $= k\,[M^-][H_2O_2]^2$
C. rate $= k\,[M^-]\,[MO^-]\,[H_2O_2]^2$
D. rate $= k\,[M^-][H_2O_2]$
E. rate $= k\,[M^-]^2[H_2O_2]$

30. Calculate the solubility product (K_{sp}, the equilibrium constant) for the reaction

$Pb^{2+}(aq) + 2I^-(aq) \rightleftharpoons PbI_2(s)$

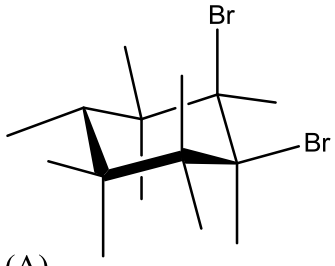
From the following concentration cell information

$Pb(s) \mid Pb^{2+}(?M,aq)\ ,\ PbI_2(saturated) \parallel Pb^{2+}(0.100M,\ aq) \mid Pb(s)\ ;\ E_{cell} = 0.0567\ V$

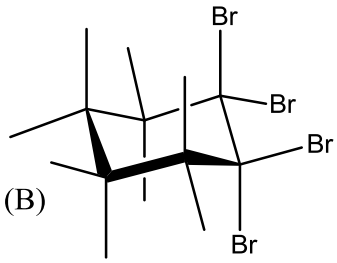
Note that the anode cell solution was prepared simply by dissolving PbI_2 in ultrapure water such that an undissolved precipitate was left, i.e. no more I^- or Pb^{2+} was added.

A. 1.33
B. 1.21×10^{-3}
C. 1.76×10^{-3}
D. 1.76×10^{-6}
E. 1.76×10^{-9}

31. Elemental analysis of a molecule gives the molecular formula C_6H_{10}. The molecule is titrated with bromine, Br_2 (a red liquid) and it is observed that after addition of one equivalent of bromine the solution turns from clear to red. What is the product of this reaction?



(A)



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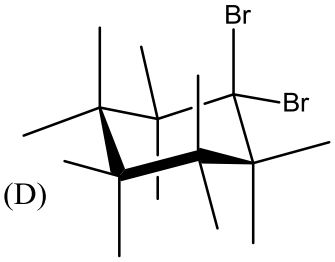

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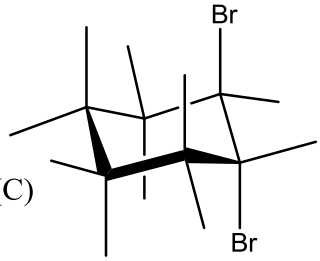

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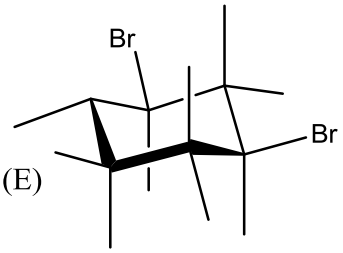

(E)

32. The vapour pressure of a liquid

A. depends on the heat of fusion.
B. determines the normal boiling point.
C. decreases as the temperature increases.
D. is equal to the kinetic energy of the molecules of the liquid.
E. is independent of the average kinetic energy of the liquid molecules.

33. The gas law represented by PV = (a constant) is:

A. Dalton's Law
B. Boyle's Law
C. The Ideal-Gas Law
D. Charles' Law
E. Avogadro's Law

34. The molecular mass of a certain compound of sulphur and oxygen is 80. Which of the following are possible simplest formulas?

1. SO 2. SO_2 3. SO_3 4. S_2O

A. 3 and 4
B. 3
C. 4
D. 4 and 2
E. 2

35. Which of the following **sets** of quantum numbers are impossible for an electron in an atom?

	n	*l*	m_l	m_s
I.	4	2	0	+1/2
II.	3	3	-3	-1/2
III.	2	0	1	+1/2
IV.	4	3	0	+1/2
V.	3	2	-2	-1

A. V is impossible, all the rest are allowed
B. II and V are impossible, all the rest are allowed
C. IV is impossible, all the rest are allowed
D. I, II, and V are impossible, all the rest are allowed
E. II, III, and V are impossible, all the rest are allowed

36. The quantum number which determines the size of an orbital is:

A. the principal quantum number (n)
B. the auxiliary (azimuthal) quantum number (l)
C. the magnetic quantum number (m_l)
D. the spin quantum number (m_s)
E. none of the above.

37. Photons of minimum energy 486 kJ mol^{-1} are needed to ionize sodium atoms. If light of 600 kJ mol^{-1} is used, what is the velocity of the emitted electrons?

A. 3.75×10^{-3} ms^{-1}
B. 6.45×10^{-5} ms^{-1}
C. 2.53×10^{2} ms^{-1}
D. 6.45×10^{5} ms^{-1}
E. 3.75×10^{4} ms^{-1}

38. The coordination number is the number of

A. ions or atoms in a crystal
B. atoms or ions in a unit cell
C. molecules in a crystal lattice
D. the valency of the atom at the centre of the unit cell
E. neighbours in contact with an atom or ion is a crystal lattice

Data/Formula Sheet

Symbol	Value
R	8.31451 J K^{-1} mol^{-1} 0.08206 L·atm mol^{-1} K^{-1}
K_b	1.3807×10^{-23} J K^{-1}
N_A	6.0221×10^{23} mol^{-1}
F	96485. C mol^{-1}
e	1.6022×10^{-19} C
h	6.6261×10^{-34} J s
m_p	1.6726×10^{-27} kg
m_e	9.1094×10^{-31} kg
R_H	2.179×10^{-18} J
c	2.9979×10^{8} m s^{-1}

	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 H 1.008																	2 He 4.003
2	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 18.99	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.1	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.84	27 Co 58.99	28 Ni 58.34	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 73.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.8
5	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 99	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
6	55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 138.9	73 Ta 181.0	74 W 183.8	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
7	87 Fr 223	88 Ra 226	89 Ac 227															

6	58 Ce 140	59 Pr 141	60 Nd 144	61 Pm 145	62 Sm 150	63 Eu 152.0	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173.0	71 Lu 175.0
7	90 Th 232	91 Pa 231.0	92 U 238.0	93 Np 237	94 Pu 244	95 Am 243	96 Cu 247	97 Bk 247	98 Cf 251	99 Es 252	100 Fm 257	101 Md 258	102 No 259	103 Lr 262

1atm = 101.325 kPa = 760 mm Hg = 760 torr ***1L = 1 dm^3 0ºC = 273.15 K***

$E = h\nu$ $c = \lambda\nu$ $\lambda = \frac{h}{mv}$ $u_{rms} = \sqrt{\frac{3RT}{M}}$ $f(u) = 4\pi\left(\frac{m}{2\pi\, k_B T}\right)^{3/2} u^2 e^{-\frac{mu^2}{2k_B T}}$ $\Delta x \Delta p \geq \frac{h}{4\pi}$

$w(A) = \frac{m\,(A)}{m\,(A) + m\,(B) + \ldots}$ $w(A) + w(B) + \ldots = 1$ $x(A) = \frac{n(A)}{n(A) + n(B) + \ldots}$ $\Delta H = \sum_{broken} BE - \sum_{formed} BE$

$b(A) = \frac{n(A)}{m(S)}$ $c(A) = \frac{n(A)}{V}$ $density = m/V$ $\Delta E = h\nu = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ $x(A) + x(B) + \ldots = 1$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$P_1V_1 = P_2V_2$ $PV = nRT$ $w = -P_e\Delta V = -\Delta n_{gas}RT$ $\Delta U = q + w$ $\Delta U = q_v$ $\Delta H = q_p$ $\Pi = CRT$

$p_B = x_B K_H$ $p_A + p_B + \ldots = P$ $y_A = \frac{p_A}{p_A + p_B} = \frac{x_A P_A^*}{x_A P_A^* + (1 - x_A) P_B^*}$ $y_B = \frac{p_B}{p_A + p_B} = \frac{(1 - x_A) P_B^*}{x_A P_A^* + (1 - x_A) P_B^*}$

$C = \frac{q}{\Delta T}$ $C_V = \frac{\Delta U}{\Delta T}$ $C_P = \frac{\Delta H}{\Delta T}$

$\Delta H = \Delta U + P\Delta V$ $C_P - C_V = R$ $p_A = x_A P_A^*$

$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT$ $a = \frac{27R^2T_C^2}{64P_C}$ $b = \frac{RT}{8P_C}$ $\ln\left(\frac{P_2^*}{P_1^*}\right) = -\frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ $[H^+] = \frac{-K_a + \sqrt{K_a^2 + 4K_aC_a}}{2}$

$\Delta S^o = \sum S^o(P) - \sum S^o(R)$ $\Delta H_T^o = \Delta H_{298}^o + \Delta C_P(T - 298)$ $\Delta H^o = \sum \Delta H_f^o(P) - \sum \Delta H_f^o(R)$

$\ln\left(\frac{K_2}{K_1}\right) = \frac{-\Delta H^\circ}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ $[H^+] = \sqrt{K_aC_a}$ $[OH^-] = \sqrt{K_bC_b}$ $pH = (pK_a + pC_a)/2$ $pOH = (pK_b + pC_b)/2$

$[OH^-] = \frac{-K_b + \sqrt{K_b^2 + 4K_bC_b}}{2}$ $pH = pK_a + \log\frac{[base]}{[acid]}$ $\frac{(U_{rms})_A}{(U_{rms})_B} = \sqrt{\frac{M_B}{M_A}}$ $\Delta S = \frac{q_{rev}}{T}$ $\Delta S = \frac{\Delta H}{T}$

$\Delta S = \frac{C\Delta T}{T}$ *or* $\Delta S = C\ln\frac{T_2}{T_1}$ $\Delta S = R\ln\frac{V_2}{V_1} = -R\ln\frac{P_2}{P_1}$ $\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$ $G = H - TS$

$3\ \Delta G^o = \Delta H^o - T\Delta S^o$ $\Delta G = \Delta G^\circ + RT\ln Q$ $\Delta G^\circ = -RT\ln K$ $S_{universe} = S_{system} + S_{surroundings}$

$KE = \frac{1}{2}mv^2$ $h\nu = KE + \phi$ $M = m/n$ $\Delta G^o = \sum \Delta G_f^o(P) - \sum \Delta G_f^o(R)$ $w' = -nFE$

$E = E^\circ - \frac{RT}{nF}\ln Q$ $\Delta G^o = -nFE^o$ $K = \exp\left(\frac{nFE^\circ}{RT}\right)$ $E_{cell} = E_{ox} + E_{red}$ $Q = nF$ $Q = It$

$[A]_t = -kt + [A]_0$ $\ln[A]_t = -kt + \ln[A]_o$ $\frac{1}{[A]_t} = \frac{1}{[A]_o} + kt$ $t_{1/2} = \frac{\ln 2}{k}$ $k = A\exp\{-E_a/RT\}$

$2r = L = a$ $4r = \sqrt{2}L = \sqrt{2}a$ $4r = \sqrt{3}L = \sqrt{3}a$ $b = \sqrt{2}a$ $c = \sqrt{3}a$