

Topics in the November 2007 Exam Paper for CHEM1102

Click on the links for resources on each topic.

2007-N-2:

- [Strong Acids and Bases](#)
- [Weak Acids and Bases](#)

2007-N-3:

- [Weak Acids and Bases](#)
- [Calculations Involving \$pK_a\$](#)
- [Periodic Trends in Aqueous Oxide](#)

2007-N-4:

- [Solubility Equilibrium](#)

2007-N-5:

- [Hydrolysis of Metal Ions](#)
- [Coordination Chemistry](#)

2007-N-6:

- [Physical States and Phase Diagrams](#)
- [Intermolecular Forces and Phase Behaviour](#)

2007-N-7:

- [Kinetics](#)

2007-N-8:

- [Coordination Chemistry](#)

2007-N-9:

- [Structural Determination](#)
- [Carboxylic Acids and Derivatives](#)

2007-N-10:

- [Alkenes](#)
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- [Aldehydes and Ketones](#)
- [Carboxylic Acids and Derivatives](#)

2007-N-11:

- [Aromatic Compounds](#)
- [Carboxylic Acids and Derivatives](#)

2007-N-12:

- [Carboxylic Acids and Derivatives](#)

2007-N-13:

- [Structural Determination](#)

2007-N-14:

- Synthetic Strategies

CHEMISTRY 1B - CHEM1102SECOND SEMESTER EXAMINATION**CONFIDENTIAL****NOVEMBER 2007****TIME ALLOWED: THREE HOURS**

GIVE THE FOLLOWING INFORMATION IN BLOCK LETTERS

FAMILY NAME		SID NUMBER	
OTHER NAMES		TABLE NUMBER	

INSTRUCTIONS TO CANDIDATES

- All questions are to be attempted. There are 22 pages of examinable material.
- Complete the written section of the examination paper in **INK**.
- Read each question carefully. Report the appropriate answer and show all relevant working in the space provided.
- The total score for this paper is 100. The possible score per page is shown in the adjacent tables.
- Each new question of the short answer section begins with a •.
- Electronic calculators, including programmable calculators, may be used. Students are warned, however, that credit may not be given, even for a correct answer, where there is insufficient evidence of the working required to obtain the solution.
- Numerical values required for any question, standard electrode reduction potentials, a Periodic Table and some useful formulas may be found on the separate data sheet.
- Page 24 is for rough working only.

OFFICIAL USE ONLY**Multiple choice section**

Pages	Marks	
	Max	Gained
2-10	36	

Short answer section

Page	Marks		Marker
	Max	Gained	
11	5		
12	6		
13	4		
14	6		
15	4		
16	3		
17	3		
18	5		
19	5		
20	7		
21	5		
22	5		
23	6		
Total	64		

- Often pH is used to characterise acidic solutions. Give a brief definition of pH.

Marks
5

--

Describe the difference between a strong acid and a weak acid.

--

In general, can pH be used to define the strength of an acid? Explain your answer.

--

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- Rank $\text{H}_2\text{O}(\text{l})$, $\text{H}_2\text{S}(\text{aq})$ and $\text{HF}(\text{aq})$ in order of their Brønsted acid strengths. Explain your reasoning.

Marks
2

- Buffer systems are frequently used in chemistry. Briefly describe a buffer system and how it functions? Use equations where appropriate.

4

What ratio of concentrations of acetic acid to sodium acetate would you require to prepare a buffer with $\text{pH} = 4.00$? The K_a of acetic acid is 1.8×10^{-5} M.

Answer:

- Barium sulfate is used as a contrast agent for X-ray images of intestines. What is the solubility product constant, K_{sp} , for BaSO_4 , given that a maximum of 1.167×10^{-8} g will dissolve in 500 mL of water?

Marks
4

Answer:

What advantage would there be in administering BaSO_4 as a slurry that also contains 0.5 M Na_2SO_4 ?

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- What is a chelate ligand?

Marks
4

Draw all possible isomers of $[\text{CoCl}_2(\text{en})_2]$. en = ethylenediamine = $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

- Explain briefly why the $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ cation has a K_a of 6×10^{-3} M, whilst the $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ cation has a K_a of 4×10^{-9} M.

2

Marks
3

- You may recall from a lecture demonstration or your laboratory work that solid CO_2 sublimates under ambient conditions while ice melts. Define the terms sublimation and melting.

What is a triple point (*e.g.* in the phase diagram of CO_2 or H_2O)?

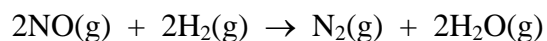
What does the different behaviour of ice and solid CO_2 indicate about the relative positions of their respective triple points?

- Carbon has a number of allotropes, the two major ones being graphite and diamond. The phase diagram of carbon shows that diamond is not the stable allotrope under normal conditions. Why then does diamond exist under normal conditions?

1

Marks
3

- Hydrogenation of nitric oxide to nitrogen and water is a potential means of reducing smog-forming NO_x gases:



The initial rates of this reaction at constant temperature were determined at the following combination of initial pressures (P_0).

Run	P_0 (H ₂) / kPa	P_0 (NO) / kPa	Rate / kPa s ⁻¹
1	53.3	40.0	0.137
2	53.3	20.3	0.033
3	38.5	53.3	0.213
4	19.6	53.3	0.105

Derive an expression for the rate law for this reaction.

Answer:

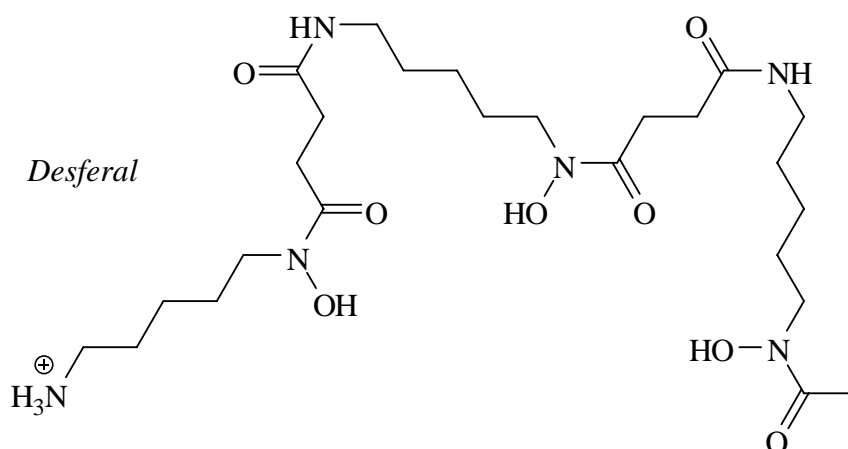
Calculate the value of the rate constant.

Answer:

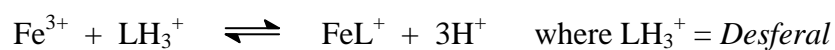
What is the order of the reaction?

Marks
3

- Hemochromatosis or “iron overload” is a potentially fatal disorder in which excess iron is deposited in the bodily organs as insoluble hydrated iron(III) oxide. It can be treated by administration of desferioxamine B (*Desferal*), a natural substance isolated from fungi.



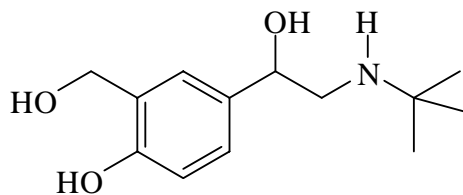
Desferal is taken over 8-12 hour periods up to six times per week. A value of $\log K = 30.6$ is associated with the following equilibrium:



Briefly describe the chemical basis for the use of *Desferal* in iron overload therapy.

- The structure of salbutamol, a drug used to treat bronchospasms, is given below.

Marks
5



Give the molecular formula of salbutamol.

Calculate the m/z value for the major peak you would expect to see for the molecular ion in the high resolution mass spectrum.

[Atomic masses: ${}^1\text{H} = 1.0078$; ${}^{12}\text{C} = 12.0000$; ${}^{16}\text{O} = 15.9949$; ${}^{14}\text{N} = 14.0031$]

Answer:

Give the structure(s) of the major organic products formed when salbutamol is treated with the following reagents.

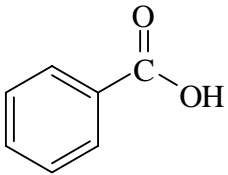
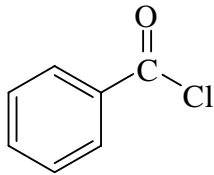
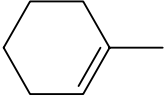
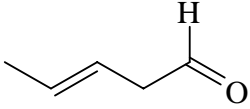
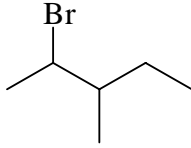
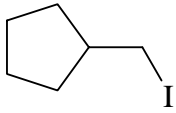
cold HCl (1 M)

NaOH (1 M)

$\text{Cr}_2\text{O}_7^{2-} / \text{H}^+$

Marks
5

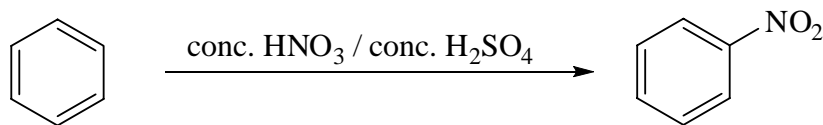
- Complete the following table.

Starting material	Reagents / Conditions	Major organic product(s)
		
	HCl	
	1. NaBH ₄ 2. H ⁺ / H ₂ O	
	hot conc. KOH ethanol (solvent)	
	CN ⁻	

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- A mixture of concentrated nitric and sulfuric acids generates the nitronium ion, NO_2^+ . Benzene will react with such a mixture to give nitrobenzene.

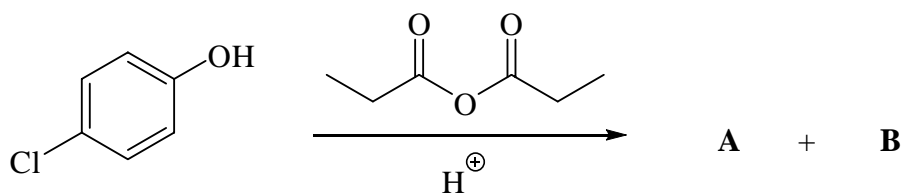
Marks
2



What 3-part name is given to the mechanism of this nitration reaction?

- Consider the reaction sequence below.

2

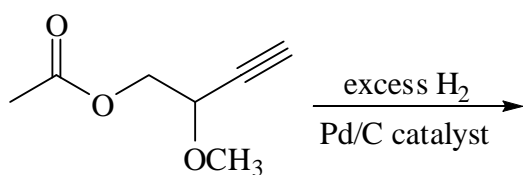


Draw the structures of products **A** and **B**.

A	B
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- Draw the structure of the product, **C**, from the following reaction.

3

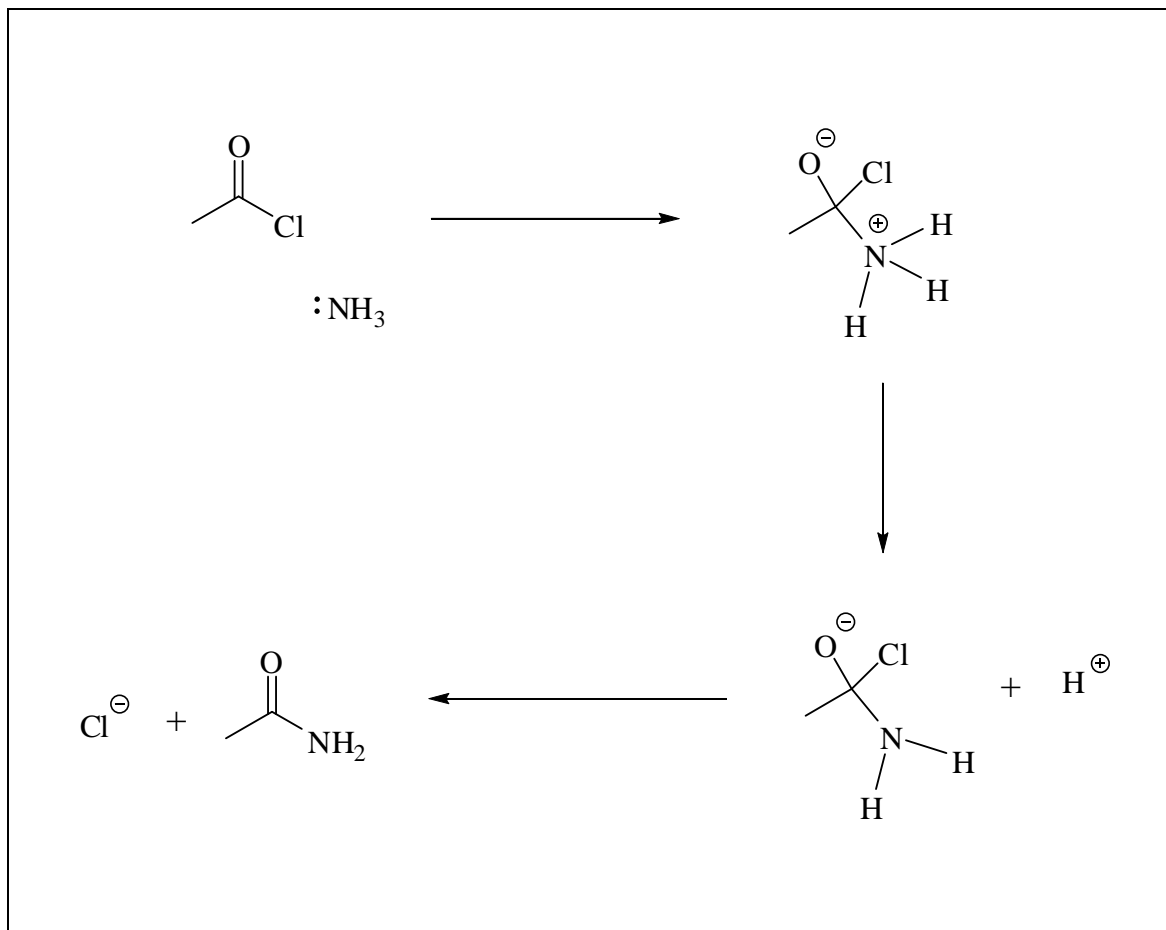


C

Product **C** undergoes hydrolysis when heated with 4 M NaOH. Give the structures of the products (in their correct ionic states) formed in this reaction.

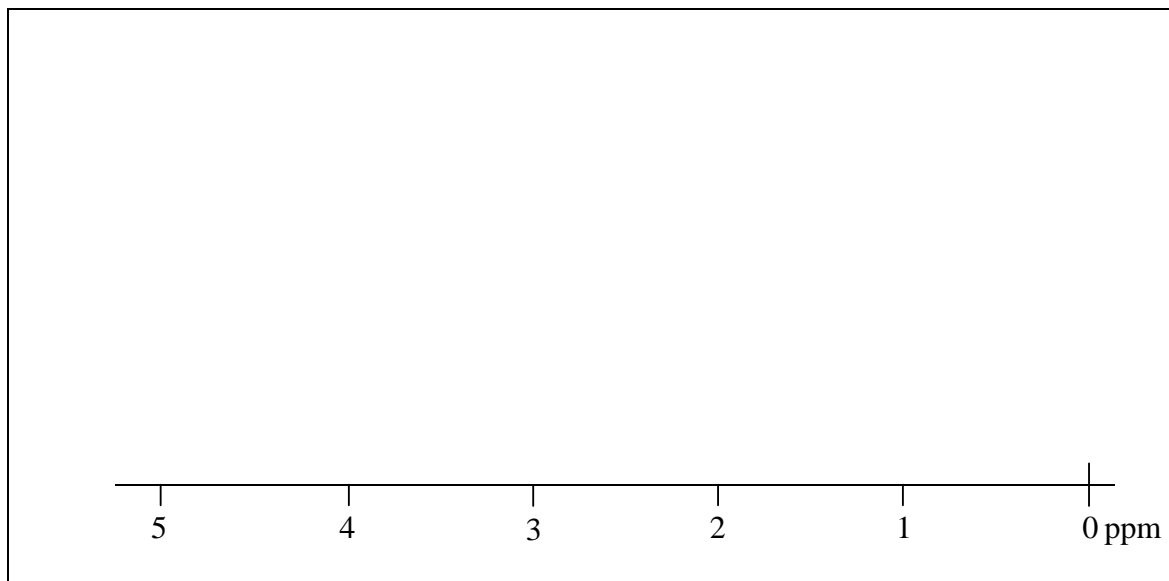
Marks
5

- The incomplete proposed mechanism for the reaction of acetyl chloride with ammonia is shown below. Complete the mechanism by adding curly arrows to illustrate the bonding changes that take place.

**THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.**

- Sketch the ^1H NMR spectrum of bromoethane, $\text{CH}_3\text{CH}_2\text{Br}$. The signals appear at 1.7 and 3.3 ppm. Clearly indicate the splitting patterns of both signals and show their relative intensities.

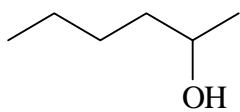
Marks
5



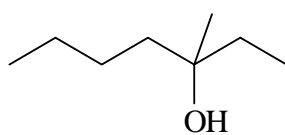
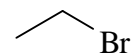
THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- Devise a synthesis of 3-methylheptan-3-ol using the two starting materials shown. Show the structures of any intermediate products involved, as well as the reagents required for each step. More than one step is required.

Marks
6



and



Would the product be isolated as a racemic mixture or a single enantiomer or is the product achiral?

CHEM1102 - CHEMISTRY 1B
DATA SHEET

Physical constants

Avogadro constant, $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

Faraday constant, $F = 96485 \text{ C mol}^{-1}$

Planck constant, $h = 6.626 \times 10^{-34} \text{ J s}$

Speed of light in vacuum, $c = 2.998 \times 10^8 \text{ m s}^{-1}$

Rydberg constant, $E_R = 2.18 \times 10^{-18} \text{ J}$

Boltzmann constant, $k_B = 1.381 \times 10^{-23} \text{ J K}^{-1}$

Gas constant, $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$
 $= 0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$

Charge of electron, $e = 1.602 \times 10^{-19} \text{ C}$

Mass of electron, $m_e = 9.1094 \times 10^{-31} \text{ kg}$

Mass of proton, $m_p = 1.6726 \times 10^{-27} \text{ kg}$

Mass of neutron, $m_n = 1.6749 \times 10^{-27} \text{ kg}$

Properties of matter

Volume of 1 mole of ideal gas at 1 atm and 25 °C = 24.5 L

Volume of 1 mole of ideal gas at 1 atm and 0 °C = 22.4 L

Density of water at 298 K = 0.997 g cm⁻³

Conversion factors

1 atm = 760 mmHg = 101.3 kPa

0 °C = 273 K

1 L = 10⁻³ m³

1 Å = 10⁻¹⁰ m

1 eV = 1.602 × 10⁻¹⁹ J

1 Ci = 3.70 × 10¹⁰ Bq

1 Hz = 1 s⁻¹

Decimal fractions

Fraction	Prefix	Symbol
10 ⁻³	milli	m
10 ⁻⁶	micro	μ
10 ⁻⁹	nano	n
10 ⁻¹²	pico	p

Decimal multiples

Multiple	Prefix	Symbol
10 ³	kilo	k
10 ⁶	mega	M
10 ⁹	giga	G

CHEM1102 - CHEMISTRY 1B**Standard Reduction Potentials, E°**

Reaction	E° / V
$\text{S}_2\text{O}_8^{2-} + 2\text{e}^- \rightarrow 2\text{SO}_4^{2-}$	+2.01
$\text{Co}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Co}^{2+}(\text{aq})$	+1.82
$\text{Ce}^{4+}(\text{aq}) + \text{e}^- \rightarrow \text{Ce}^{3+}(\text{aq})$	+1.72
$\text{Au}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Au}(\text{s})$	+1.50
$\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$	+1.36
$\text{O}_2 + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$	+1.23
$\text{Br}_2 + 2\text{e}^- \rightarrow 2\text{Br}^-(\text{aq})$	+1.10
$\text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{Mn}^{3+} + 2\text{H}_2\text{O}$	+0.96
$\text{Pd}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pd}(\text{s})$	+0.92
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$	+0.80
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Cu}^+(\text{aq}) + \text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.53
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}^{2+}(\text{aq})$	+0.15
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0 (by definition)
$\text{Fe}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.04
$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Pb}(\text{s})$	-0.13
$\text{Sn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Sn}(\text{s})$	-0.14
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$	-0.24
$\text{Co}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Co}(\text{s})$	-0.28
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.44
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.74
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.76
$2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$	-0.83
$\text{Cr}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.89
$\text{Al}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Al}(\text{s})$	-1.68
$\text{Mg}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Mg}(\text{s})$	-2.36
$\text{Na}^+(\text{aq}) + \text{e}^- \rightarrow \text{Na}(\text{s})$	-2.71
$\text{Ca}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ca}(\text{s})$	-2.87
$\text{Li}^+(\text{aq}) + \text{e}^- \rightarrow \text{Li}(\text{s})$	-3.04

CHEM1102 - CHEMISTRY 1B

Useful formulas

<p>Quantum Chemistry</p> $E = h\nu = hc/\lambda$ $\lambda = h/mv$ $4.5k_B T = hc/\lambda$ $E = -Z^2 E_R (1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$	<p>Electrochemistry</p> $\Delta G^\circ = -nFE^\circ$ <p>Moles of $e^- = It/F$</p> $E = E^\circ - (RT/nF) \times 2.303 \log Q$ $= E^\circ - (RT/nF) \times \ln Q$ $E^\circ = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E^\circ - \frac{0.0592}{n} \log Q \text{ (at 25 }^\circ\text{C)}$
<p>Acids and Bases</p> $pK_w = \text{pH} + \text{pOH} = 14.00$ $pK_w = \text{p}K_a + \text{p}K_b = 14.00$ $\text{pH} = \text{p}K_a + \log \{ [A^-] / [HA] \}$	<p>Gas Laws</p> $PV = nRT$ $(P + n^2 a/V^2)(V - nb) = nRT$
<p>Colligative properties</p> $\pi = cRT$ $P_{\text{solution}} = X_{\text{solvent}} \times P^\circ_{\text{solvent}}$ $p = kc$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	<p>Kinetics</p> $t_{1/2} = \ln 2/k$ $k = Ae^{-E_a/RT}$ $\ln[A] = \ln[A]_0 - kt$ $\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$
<p>Radioactivity</p> $t_{1/2} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ $^{14}\text{C age} = 8033 \ln(A_0/A_t)$	<p>Thermodynamics & Equilibrium</p> $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G = \Delta G^\circ + RT \ln Q$ $\Delta G^\circ = -RT \ln K$ $K_p = K_c (RT)^{\Delta n}$
<p>Miscellaneous</p> $A = -\log_{10} \frac{I}{I_0}$ $A = \epsilon cl$ $E = -A \frac{e^2}{4\pi\epsilon_0 r} N_A$	<p>Mathematics</p> <p>If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$</p> $\ln x = 2.303 \log x$

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 HYDROGEN H 1.008																	2 HELIUM He 4.003
3 LITHIUM Li 6.941	4 BERYLLIUM Be 9.012											5 BORON B 10.81	6 CARBON C 12.01	7 NITROGEN N 14.01	8 OXYGEN O 16.00	9 FLUORINE F 19.00	10 NEON Ne 20.18
11 SODIUM Na 22.99	12 MAGNESIUM Mg 24.31											13 ALUMINIUM Al 26.98	14 SILICON Si 28.09	15 PHOSPHORUS P 30.97	16 SULFUR S 32.07	17 CHLORINE Cl 35.45	18 ARGON Ar 39.95
19 POTASSIUM K 39.10	20 CALCIUM Ca 40.08	21 SCANDIUM Sc 44.96	22 TITANIUM Ti 47.88	23 VANADIUM V 50.94	24 CHROMIUM Cr 52.00	25 MANGANESE Mn 54.94	26 IRON Fe 55.85	27 COBALT Co 58.93	28 NICKEL Ni 58.69	29 COPPER Cu 63.55	30 ZINC Zn 65.39	31 GALLIUM Ga 69.72	32 GERMANIUM Ge 72.59	33 ARSENIC As 74.92	34 SELENIUM Se 78.96	35 BROMINE Br 79.90	36 KRYPTON Kr 83.80
37 RUBIDIUM Rb 85.47	38 STRONTIUM Sr 87.62	39 YTRIUM Y 88.91	40 ZIRCONIUM Zr 91.22	41 NIوبيUM Nb 92.91	42 MOLYBDENUM Mo 95.94	43 TECHNETIUM Tc [98.91]	44 RUTHENIUM Ru 101.07	45 RHODIUM Rh 102.91	46 PALLADIUM Pd 106.4	47 SILVER Ag 107.87	48 CADMIUM Cd 112.40	49 INDIUM In 114.82	50 TIN Sn 118.69	51 ANTIMONY Sb 121.75	52 TELLURIUM Te 127.60	53 IODINE I 126.90	54 XENON Xe 131.30
55 CAESIUM Cs 132.91	56 BARIUM Ba 137.34	57-71	72 HAFNIUM Hf 178.49	73 TANTALUM Ta 180.95	74 TUNGSTEN W 183.85	75 RHENIUM Re 186.2	76 OSMIUM Os 190.2	77 IRIDIUM Ir 192.22	78 PLATINUM Pt 195.09	79 GOLD Au 196.97	80 MERCURY Hg 200.59	81 THALLIUM Tl 204.37	82 LEAD Pb 207.2	83 BISMUTH Bi 208.98	84 POLONIUM Po [210.0]	85 ASTATINE At [210.0]	86 RADON Rn [222.0]
87 FRANCIUM Fr [223.0]	88 RADIUM Ra [226.0]	89-103	104 RUTHERFORDIUM Rf [261]	105 DUBNIUM Db [262]	106 SEABORGIUM Sg [266]	107 BOHRIUM Bh [262]	108 HASSIUM Hs [265]	109 MEITNERIUM Mt [266]	110 DARMSTADIUM Ds [271]	111 ROENTGENIUM Rg [272]							

	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
LANTHANIDES	LANTHANUM La 138.91	CERIUM Ce 140.12	PRASEODYMIUM Pr 140.91	NEODYMIUM Nd 144.24	PROMETHIUM Pm [144.9]	SAMARIUM Sm 150.4	EUROPIUM Eu 151.96	GADOLINIUM Gd 157.25	TERBIUM Tb 158.93	DYSPROSIUM Dy 162.50	HOLMIUM Ho 164.93	ERBIUM Er 167.26	THULIUM Tm 168.93	YTTERBIUM Yb 173.04	LUTETIUM Lu 174.97
ACTINIDES	ACTINIUM Ac [227.0]	THORIUM Th 232.04	PROTACTINIUM Pa [231.0]	URANIUM U 238.03	NEPTUNIUM Np [237.0]	PLUTONIUM Pu [239.1]	AMERICIUM Am [243.1]	CURIUM Cm [247.1]	BERKELIUM Bk [247.1]	CALIFORNIUM Cf [252.1]	EINSTEINIUM Es [252.1]	FERMIUM Fm [257.1]	MENDELEVIUM Md [256.1]	NOBELIUM No [259.1]	LAWRENCIUM Lr [260.1]