CHEMISTRY 104
Prof. J.W. Moore
EXAM I, February 25, 2000

Name Key

Sec: ________ **T.A.:** ____________________

FORM B
(Blue)

INSTRUCTIONS

1. This exam consists of 7 pages, 4 pages of formulas and data, and a periodic table. If a page is missing, raise your hand and ask a T.A. to give you a replacement. Print your name in the space at the top of each page; do it now!

2. The periodic table contains constants and conversion factors that may be useful. Some possibly useful formulas are found on the last page of the exam (just before the periodic table).

3. You will have 50 minutes to work on the exam.

4. Many of the questions are multiple-choice; answer multiple-choice questions inside the test and **transfer your answers to the spaces provided below. A penalty of 3 points will be assessed if this is not done.**

5. There is no need to show work on multiple-choice questions. Show your work clearly on open-ended questions so that graders can understand how you arrived at the solution. Round answers to the correct number of significant figures; include appropriate units.

6. Communicating in any way with another student during this exam will be considered to be one form of cheating.

Answers to Multiple-Choice Questions

1.	E	6.	D	10.	A
2.	A	7.	D	11.	F
3.	B	8.	B	12.	D
4.	B	9.	F	13.	D
5.	A			14.	B

Page	Score
2-4	____ / 42
5	____ / 15
6	____ / 11
7	____ / 12
TOTAL	____ / 80

Multiple-Choice Questions. There is ***one*** best response to each question. Read ***all*** responses, choose the ***best*** one, circle it on this page, and **write the letter corresponding to that response in the appropriate numbered space on page one of the exam.** Each multiple-choice question is worth three points.

1. Which of the following is an important safety rule that must be followed in a chemical laboratory?

   A. Always wear safety goggles in the lab.
   B. If acid or base spills on your skin, wash it off with plenty of water.
   C. Wear shoes that will protect your feet from liquid spills.
   D. Never point the opening of a test tube at yourself or a neighbor.
   (E.) **All of these** are important laboratory safety rules.

2. Which of the following substances reacts vigorously (and dangerously!) with water?

   (A.) acetic anhydride
   B. ethylene
   C. propane
   D. HCOOH
   E. HC≡CH

The next **two** questions refer to the reaction:

$$2\,SO_3(g) \longrightarrow 2\,SO_2(g) + O_2(g)$$

$\Delta S^\circ = 2S^\circ(SO_2) + S^\circ(O_2) - 2S^\circ(SO_3)$
$= 2(248.22) + 205.138 - 2(256.76)$
$= 188.058$ J/K

3. Calculate ΔS°_{system} at 25°C. The result is:

   A. 196.6 J/K
   (B.) 188.1 J/K
   C. 17.1 J/K
   D. −17.1 J/K
   E. −188.1 J/K

$\Delta G^\circ = 2\Delta G_f^\circ(SO_2) - 2\Delta G_f^\circ(SO_3)$
$= 2(-300.194) - 2(-371.06)$
$= 141.732$ kJ

4. Calculate ΔG°_{system} at 25°C. The result is:

   A. 346.07 kJ
   (B.) 141.73 kJ
   C. 70.87 kJ
   D. −70.87 kJ
   E. −141.73 kJ

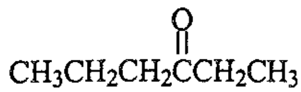
5. At what temperature is this reaction least product-favored?

$$S_2Cl_2(g) \longrightarrow 2\,S(g) + Cl_2(g) \qquad \Delta H^\circ = 297.2\text{ kJ} \quad \Delta S^\circ = 227.2\text{ J/K}$$

favored at high T

   (A.) 273 K
   B. 543 K
   C. 373 K
   D. 300 K
   E. This reaction is product-favored at all temperatures.

Consider these structures as you answer the next six questions:

I.


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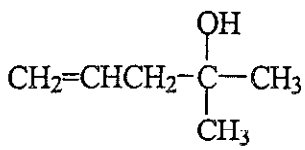

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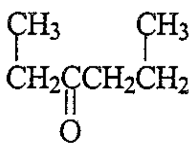

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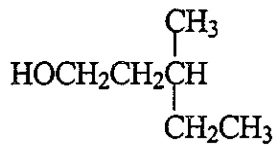
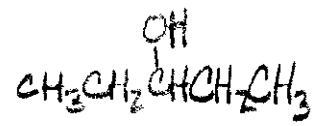
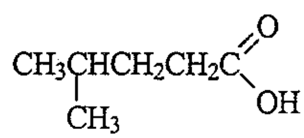


V.



VI.


6. Which substance can be oxidized to an aldehyde by potassium permanganate?

A. I
B. II
C. III
D. IV
E. V
F. VI
G. None of them.

7. Which substance is chiral?

A. I
B. II
C. III
D. IV
E. V
F. VI
G. None of them.

8. Which two structures are identical?

A. I and II
B. I and III
C. II and IV
D. II and V
E. III and IV
F. IV and VI
G. No two structures are identical.

9. Which substance is a carboxylic acid?

A. I
B. II
C. III
D. IV
E. V
F. VI
G. None of them.

10. Which two structures are constitutional isomers?

- (A.) I and II
- B. I and III
- C. II and IV
- D. II and V
- E. III and IV
- F. IV and VI
- G. No two structures are constitutional isomers.

11. Which substance has the highest boiling point?

- A. I
- B. II
- C. III
- D. IV
- E. V
- (F.) VI

The next three questions refer to the reaction:

$2\,NO(g) + O_2(g) \longrightarrow 2\,NO_2(g)$ Rate = $k\,[NO]^2\,[O_2]$ (from experiments)

12. The order of the reaction overall is:

- A. 0
- B. 1
- C. 2
- (D.) 3
- E. 4
- F. 5

13. If the concentration of NO is doubled and the concentration of O_2 is halved, the rate will change by a factor of:

- A. ½
- B. 1
- C. 1.5
- (D.) 2
- E. 4
- F. 6
- G. 8

14. The rate of reaction is found to be 1.17×10^{-3} mol/L·s when the concentration of NO is 0.020 mol/L and the concentration of O_2 is 0.010 mol/L. What is the value of the rate constant?

- A. 6.0 $L^2/mol^2 \cdot s$
- (B.) $2.9 \times 10^2\ L^2/mol^2 \cdot s$
- C. $6.0 \times 10^2\ L^2/mol^2 \cdot s$
- D. 6.0 L/mol·s
- E. 2.9×10^2 L/mol·s
- F. 6.0×10^2 L/mol·s

$$k = \frac{\text{Rate}}{[NO]^2[O_2]} = \frac{1.17 \times 10^{-3}\ mol\ L^{-1} s^{-1}}{(0.020\ mol\ L^{-1})^2 (0.010\ mol\ L^{-1})} = 292\ mol^{-2} L^2 s^{-1}$$

Open-Ended Questions. Show all work, use correct numbers of significant figures, and write answers in the spaces provided and explain answers clearly when asked to do so.

15. *(9 pts.)* Predict the sign of ΔS for each process below and explain your choice.

A. $PCl_3(g) + Cl_2(g) \longrightarrow PCl_5(g)$

3pts Choose sign + (−) Explain 2 moles of gases are converted to 1 mole of gas

B. $C_{12}H_{22}O_{11}(s) \longrightarrow C_{12}H_{22}O_{11}(aq)$

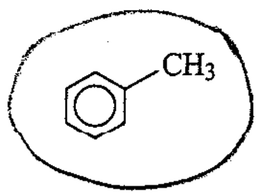
3pts Choose sign (+) − Explain solid dissolving becomes dispersed among solvent molecules

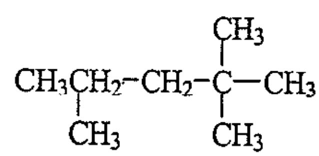
C. Air leaks from a spacecraft into outer space.

3pts Choose sign (+) − Explain volume available to gas molecules is much bigger

16. *(6 pts.)* Circle the structure of the substance that has the highest octane. Explain your choice.

3pts $CH_3CH_2CH_2CH_2CH_2CH_2CH_3$





3pts aromatics have higher octane than branched hydrocarbons than unbranched hydrocarbons.

17. *(11 pts.)* The equations below represent the mechanism for a reaction. Answer each of the questions below about this reaction.

$$NO_2(g) + F_2(g) \longrightarrow NO_2F(g) + F(g) \qquad \text{(slow)}$$

$$NO_2(g) + F(g) \longrightarrow NO_2F(g) \qquad \text{(fast)}$$

A. What is the balanced equation for the overall reaction?

2pts $2\,NO_2(g) + F_2(g) \longrightarrow 2\,NO_2F(g)$

B. Write the rate law for the reaction.

2pts Rate = $k[NO_2][F_2]$ (rate law determined by slow step)

C. Identify all reaction intermediates (if there are any). If there are none, write "none".

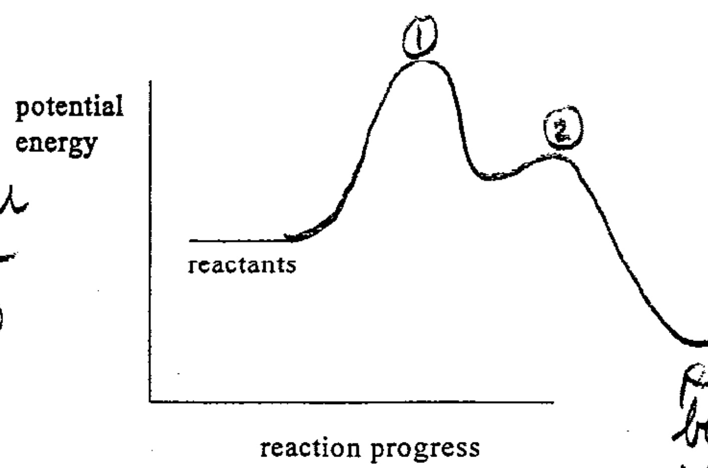
2pts F(g)

D. Identify all catalysts (if there are any). If there are none, write "none".

2pts None

E. On these axes, draw a potential energy versus reaction progress diagram. Label the transition state (or transition states). The overall reaction is exothermic.

① and ② are transition states 1 pt



1st hump higher than 2nd because 1st step is slow 1 pt.

products must be lower than reactants (exothermic) 1 pt

18. *(6 pts.)* The conversion of glucose to glucose 6-phosphate is endergonic.

$$\text{glucose} + H_2PO_4^- \longrightarrow \text{glucose 6-phosphate}^{2-} + H_2O + H^+ \quad \Delta G^\circ = 13.8 \text{ kJ}$$

Therefore, a supply of free energy is required to force this reaction to occur. Explain how the ATP reaction

$$ATP^{4-}(aq) + H_2O(\ell) \longrightarrow ADP^{3-}(aq) + H_2PO_4^-(aq) \quad \Delta G^\circ = -30.5 \text{ kJ}$$

can be coupled to the glucose reaction to force the glucose reaction to occur.

The ATP reaction is product-favored and can be coupled with the glucose reaction to force the latter to occur. If the two reactions occur together the overall ΔG° is negative

$$\text{glucose} + H_2PO_4^- \rightarrow \text{glucose 6-phosphate}^{2-} + H_2O + H^+ \quad \Delta G_1^\circ = 13.8 \text{ kJ}$$

$$ATP^{4-} + H_2O \rightarrow ADP^{3-} + H_2PO_4^- \quad \Delta G_2^\circ = -30.5 \text{ kJ}$$

$$\text{glucose} + ATP^{4-} \rightarrow \text{glucose 6-phosphate}^{2-} + ADP^{3-} + H^+$$

$$\Delta G_{total} = \Delta G_1^\circ + \Delta G_2^\circ = -16.7 \text{ kJ}$$

19. *(6 pts.)* Your friend has just learned that she is allergic to FD&C Yellow dye #5, which is used to add color to many foods. Your friend likes M&Ms, but she is afraid to eat any because she might have an allergic reaction. You have a bottle of yellow food coloring that contains FD&C Yellow #5. Explain how you could set up experiments to determine which color or colors of M & Ms contain FD&C Yellow #5. (M&Ms are chocolate candies covered by a hard coating that is dyed different colors using FD&C approved food coloring. More than a single FD&C dye may used in any of the colored coatings. The food colorings have different solubilities in water.)

Set up a paper chromatography experiment.
Use FD&C #5 as a known standard
Remove colored coatings from each color of M&Ms, dissolve color in a little water, spot on paper, and develop.
Compare with known standard to see which contain FD&C yellow #5.

Selected Thermodynamic Values*

Species	ΔH_f°(298.15K) kJ/mol	S°(298.15K) J/K · mol	ΔG_f°(298.15K) kJ/mol
Aluminum			
Al(s)	0	28.3	0
$AlCl_3$(s)	−704.2	110.67	−628.8
Al_2O_3(s)	−1675.7	50.92	−1582.3
Aqueous Solutions			
Ca^{2+}(aq)	−542.96	−55.2	−553.04
CO_3^{2-}(aq)	−676.26	−53.1	−528.10
H^+(aq)	0	0	0
HCO_2^-(aq)	−410	91.6	−335
HCO_2H(aq)	−410	164	−356
HCO_3^-(aq)	−691.11	95.0	−587.06
H_2CO_3(aq)	−698.7	191	−623.42
OH^-(aq)	−229.94	−10.54	−157.30
Barium			
$BaCl_2$(s)	−858.6	123.68	−810.4
BaO(s)	−553.5	70.42	−525.1
$BaSO_4$(s)	−1473.2	132.2	−1362.2
Beryllium			
Be(s)	0	9.5	0
$Be(OH)_2$(s)	−902.5	51.9	−815.0
Bromine			
Br(g)	111.884	175.022	82.396
Br_2(ℓ)	0	152.2	0
Br_2(g)	30.907	245.463	3.110
BrF_3(g)	−255.60	292.53	−229.43
HBr(g)	−36.40	198.695	−53.45
Calcium			
Ca(s)	0	41.42	0
Ca(g)	178.2	158.884	144.3
Ca^{2+}(g)	1925.90	—	—
CaC_2(s)	−59.8	69.96	−64.9
$CaCO_3$(s; calcite)	−1206.92	92.9	−1128.79
$CaCl_2$(s)	−795.8	104.6	−748.1
CaF_2(s)	−1219.6	68.87	−1167.3
CaH_2(s)	−186.2	42.	−147.2
CaO(s)	−635.09	39.75	−604.03
CaS(s)	−482.4	56.5	−477.4
$Ca(OH)_2$(s)	−986.09	83.39	−898.49
$Ca(OH)_2$(aq)	−1002.82	−74.5	−868.07
$CaSO_4$(s)	−1434.11	106.7	−1321.79
Carbon			
C(s, graphite)	0	5.740	0
C(s, diamond)	1.895	2.377	2.900
C(g)	716.682	158.096	671.257
CCl_4(ℓ)	−135.44	216.40	−65.21
CCl_4(g)	−102.9	309.85	−60.59
$CHCl_3$(liq)	−134.47	201.7	−73.66
$CHCl_3$(g)	−103.14	295.71	−70.34
CH_4(g, methane)	−74.81	186.264	−50.72
C_2H_2(g, ethyne)	226.73	200.94	209.20
C_2H_4(g, ethene)	52.26	219.56	68.15
C_2H_6(g, ethane)	−84.68	229.60	−32.82
C_3H_8(g, propane)	−103.8	269.9	−23.49
C_6H_6(ℓ, benzene)	49.03	172.8	124.5
C_6H_{14}(ℓ)	−198.782	296.018	−4.035
$C_6H_{12}O_6$(s) (glucose)	−1267	—	−919
C_8H_{18}(ℓ)	−249.952	361.205	6.707
CH_3OH(ℓ, methanol)	−238.66	126.8	−166.27
CH_3OH(g, methanol)	−200.66	239.81	−161.96
C_2H_5OH(ℓ, ethanol)	−277.69	160.7	−174.78
C_2H_5OH(g, ethanol)	−235.10	282.70	−168.49
CH_3COOH(ℓ)	−276.981	160.666	−173.991
CO(g)	−110.525	197.674	−137.168
CO_2(g)	−393.509	213.74	−394.359
CS_2(g)	117.36	237.84	67.12
$COCl_2$(g)	−218.8	283.53	−204.6
Cesium			
Cs(s)	0	85.23	0
Cs^+(g)	457.964	—	—
CsCl(s)	−443.04	101.17	−414.53
Chlorine			
Cl(g)	121.679	165.198	105.680
Cl^-(g)	−233.13	—	—
Cl_2(g)	0	223.066	0
HCl(g)	−92.307	186.908	−95.299
HCl(aq)	−167.159	56.5	−131.228

Species	ΔH_f°(298.15K) kJ/mol	S°(298.15K) J/K · mol	ΔG_f°(298.15K) kJ/mol
Chromium			
$Cr(s)$	0	23.77	0
$Cr_2O_3(s)$	−1139.7	81.2	−1058.1
$CrCl_3(s)$	−556.5	123.0	−486.1
Copper			
$Cu(s)$	0	33.150	0
$CuO(s)$	−157.3	42.63	−129.7
$CuCl_2(s)$	−220.1	108.07	−175.7
Fluorine			
$F_2(g)$	0	202.78	0
$F(g)$	78.99	158.754	61.91
$F^-(g)$	−255.39	—	—
$F^-(aq)$	−332.63	−13.8	−278.79
$HF(g)$	−271.1	173.779	−273.2
$HF(aq)$	−332.63	−13.8	−278.79
Hydrogen			
$H_2(g)$	0	130.684	0
$H(g)$	217.965	114.713	203.247
$H^+(g)$	1536.202	—	—
$H_2O(\ell)$	−285.830	69.91	−237.129
$H_2O(g)$	−241.818	188.825	−228.572
$H_2O_2(\ell)$	−187.78	109.6	−120.35
Iodine			
$I_2(s)$	0	116.135	0
$I_2(g)$	62.438	260.69	19.327
$I(g)$	106.838	180.791	70.250
$I^-(g)$	−197.	—	—
$ICl(g)$	17.78	247.551	−5.46
Iron			
$Fe(s)$	0	27.78	0
$FeO(s)$	−272.	—	—
Fe_2O_3(s, hematite)	−824.2	87.40	−742.2
Fe_3O_4(s, magnetite)	−1118.4	146.4	−1015.4
$FeCl_2(s)$	−341.79	117.95	−302.30
$FeCl_3(s)$	−399.49	142.3	344.00
FeS_2(s, pyrite)	−178.2	52.93	−166.9
$Fe(CO)_5(\ell)$	−774.0	338.1	−705.3
Lead			
$Pb(s)$	0	64.81	0
$PbCl_2(s)$	−359.41	136.0	−314.10

Species	ΔH_f°(298.15K) kJ/mol	S°(298.15K) J/K · mol	ΔG_f°(298.15K) kJ/mol
PbO(s, yellow)	−217.32	68.70	−187.89
$PbS(s)$	−100.4	91.2	−98.7
Lithium			
$Li(s)$	0	29.12	0
$Li^+(g)$	685.783	—	—
$LiOH(s)$	−484.93	42.80	−438.95
$LiOH(aq)$	−508.48	2.80	−450.58
$LiCl(s)$	−408.701	59.33	−384.37
Magnesium			
$Mg(s)$	0	32.68	0
$MgCl_2(g)$	−641.32	89.62	−591.79
$MgCO_3(s)$	−1111.689	65.584	−1028.124
$MgO(s)$	−601.70	26.94	−569.43
$Mg(OH)_2(s)$	−924.54	63.18	−833.51
$MgS(s)$	−346.0	50.33	−341.8
Mercury			
$Hg(\ell)$	0	76.02	0
$HgCl_2(s)$	−224.3	146.0	−178.6
HgO(s, red)	−90.83	70.29	−58.539
HgS(s, red)	−58.2	82.4	−50.6
Nickel			
$Ni(s)$	0	29.87	0
$NiO(s)$	−239.7	37.99	−211.7
$NiCl_2(s)$	−305.332	97.65	−259.032
Nitrogen			
$N_2(g)$	0	191.61	0
$N(g)$	472.704	153.298	455.563
$NH_3(g)$	−46.11	192.45	−16.45
$N_2H_4(\ell)$	50.63	121.21	149.34
$NH_4Cl(s)$	−314.43	94.6	−202.87
$NH_4Cl(aq)$	−299.66	169.9	−210.52
$NH_4NO_3(s)$	−365.56	151.08	−183.87
$NH_4NO_3(aq)$	−399.87	259.8	−190.56
$NO(g)$	90.25	210.76	86.55
$NO_2(g)$	33.18	240.06	51.31
$N_2O(g)$	82.05	219.85	104.20
$N_2O_4(g)$	9.16	304.29	97.89
$NOCl(g)$	51.71	261.69	66.08
$HNO_3(\ell)$	−174.10	155.60	−80.71
$HNO_3(g)$	−135.06	266.38	−74.72

Species	ΔH_f°(298.15K) kJ/mol	S°(298.15K) J/K · mol	ΔG_f°(298.15K) kJ/mol
Oxygen			
O_2(g)	0	205.138	0
O(g)	249.170	161.055	231.731
O_3(g)	142.7	238.93	163.2
Phosphorus			
P_4(s, white)	0	164.36	0
P_4(s, red)	−70.4	91.2	−48.4
P(g)	314.64	163.193	278.25
PH_3(g)	5.4	310.23	13.4
PCl_3(g)	−287.0	311.78	−267.8
P_4O_{10}(s)	−2984.0	228.86	−2697.7
H_3PO_4(s)	−1279.0	110.5	−1119.1
Potassium			
K(s)	0	64.18	0
KCl(s)	−436.747	82.59	−409.14
$KClO_3$(s)	−397.73	143.1	−296.25
KI(s)	−327.90	106.32	−324.892
KOH(s)	−424.764	78.9	−379.08
KOH(aq)	−482.37	91.6	−440.50
Silicon			
Si(s)	0	18.83	0
$SiBr_4$(ℓ)	−457.3	277.8	−443.8
SiC(s)	−65.3	16.61	−62.8
$SiCl_4$(g)	−657.01	330.73	−616.98
SiH_4(g)	34.3	204.62	56.9
SiF_4(g)	−1614.94	282.49	−1572.65
SiO_2(s, quartz)	−910.94	41.84	−856.64
Silver			
Ag(s)	0	42.55	0
Ag_2O(s)	−31.05	121.3	−11.20
AgCl(s)	−127.068	96.2	−109.789
$AgNO_3$(s)	−124.39	140.92	−33.41
Sodium			
Na(s)	0	51.21	0
Na(g)	107.32	153.712	76.761
Na^+(g)	609.358	—	—
NaBr(s)	−361.062	86.82	−348.983
NaCl(s)	−411.153	72.13	−384.138
NaCl(g)	−176.65	229.81	−196.66
NaCl(aq)	−407.27	115.5	−393.133
NaOH(s)	−425.609	64.455	−379.484
NaOH(aq)	−470.114	48.1	−419.150
Na_2CO_3(s)	−1130.68	134.98	−1044.44
Sulfur			
S(s, rhombic)	0	31.80	0
S(g)	278.805	167.821	238.250
S_2Cl_2(g)	−18.4	331.5	−31.8
SF_6(g)	1209.	291.82	−1105.3
H_2S(g)	−20.63	205.79	−33.56
SO_2(g)	−296.830	248.22	−300.194
SO_3(g)	−395.72	256.76	−371.06
$SOCl_2$(g)	−212.5	309.77	−198.3
H_2SO_4(ℓ)	−813.989	156.904	−690.003
H_2SO_4(aq)	−909.27	20.1	−744.53
Tin			
Sn(s, white)	0	51.55	0
Sn(s, gray)	−2.09	44.14	0.13
$SnCl_4$(ℓ)	−511.3	248.6	−440.1
$SnCl_4$(g)	−471.5	365.8	−432.2
SnO_2(s)	−580.7	52.3	−519.6
Titanium			
Ti(s)	0	30.63	0
$TiCl_4$(ℓ)	−804.2	252.34	−737.2
$TiCl_4$(g)	−763.2	354.9	−726.7
TiO_2(s)	−939.7	49.92	−884.5
Zinc			
Zn(s)	0	41.63	0
$ZnCl_2$(s)	−415.05	111.46	−369.398
ZnO(s)	−348.28	43.64	−318.30
ZnS(s, sphalerite)	−205.98	57.7	−201.29

*Taken from "The NBS Tables of Chemical Thermodynamic Properties," 1982.

Possibly useful formulas (most constants are on the back of the periodic table):

$T_F = T_C + (9°F/5°C) + 32°F$ $T_K = T_C + 273.15$ $d = m/V$

$N_A = 6.022 \times 10^{23}\ mol^{-1}$ % yield = (actual yield/theoretical yield) x 100%

mass % = (mass of element per mole compound)/(mass per mole compound) x 100%

c = molarity = $n_{solute}/V_{solution}$ = amount solute/volume solution

moles solute after dilution = moles solute before dilution M_m = molar mass

$PV = nRT$ $P = F/A$ $P = P_A + P_B + P_C + \ldots$

$P = g\,d\,h$ PV = constant (at const. T, n) mole fraction of A = $n_A/n = P_A/P$

$V = n V_m$ V/T = constant (at const. P, n) $P = mRT/VM_m$ $P = dRT/M_m$

$u_{rms} = \frac{\sqrt{(3RT)}}{M_m}$ rate of effusion $= \frac{1}{\sqrt{M_m}}$ $(P + a\frac{n^2}{V^2})(V - bn) = nRT$

energy of emitted photon = $E_i - E_f = h\nu$ $E = h\nu$ $c = \lambda\nu$ $\lambda = h/mv$

$E = mc^2$ $E = hc/\lambda$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $H\psi = E\psi$

$n = 1, 2, 3, \ldots$ $l = 0, 1, 2, \ldots, (n-1)$ $m_l = -l, -l+1, \ldots, 0, \ldots, l-1, l$ $m_s = \pm 1/2$

$E = -2.178 \times 10^{-18}\ J\ (Z^2/n^2)$ $n = 1, 2, 3, 4, \ldots$

$\Delta E = q + w$ $w = -P\Delta V$ $H = E + PV$ $\Delta H = H_{prod} - H_{react}$

$q = C\Delta T = mc\Delta T = nC_m\Delta T$ $\Delta H = \Sigma(a\Delta H_f^o(\text{products})) - \Sigma(b\Delta H_f^o(\text{reactants}))$

ΔH = Σ(bonds broken) − Σ(bonds formed) $\Delta S = \Sigma(aS^o(\text{products})) - \Sigma(bS^o(\text{reactants}))$

$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$ $\Delta S_{surroundings} = -\Delta H_{system}/T$

$\Delta G = \Delta H - T\Delta S$ $\Delta G^o = -RT\ln K_{th} = \Delta H^o - T\Delta S^o$

$j\,A + k\,B \Leftrightarrow l\,C + m\,D$ $K_c = [C]^l[D]^m/[A]^j[B]^k$ $Q = [C]_0^l[D]_0^m/[A]_0^j[B]_0^k$

$E = E^o - (RT/nF)\ln Q = -(0.0592V/n)\log Q$ pH = pKa + log([base]/[conjugate acid])

$P = cRT$ $c = P/RT$ $K_p = K_c(RT)^{\Delta n}$

Solubility of gas = $k_H P$ $\Delta T_b = K_b c_m i$ $\Delta T_f = K_f c_m i$ $\Pi V = nRTi$ $\Pi = c$I

mass % = (mass solute)/(mass solution) x 100% molality = c_m = (moles solute)/(kg solvent)

mole fraction = (moles solute)/(total moles solution)

For an equation: $ax^2 + bx + c = 0$, *the roots are:* $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

$\ln(N/N_0) = -kt = -(0.693/t_{1/2})\,t$ $\Delta E = \Delta mc^2$

0th order reaction	Rate = $k[A]^0 = k$	$[A] = -kt + [A]_0$
1st order reaction	Rate = $k[A]$	$\ln[A] = -kt + \ln[A]_0$
2nd order reaction	Rate = $k[A]^2$	$1/[A] = kt + 1/[A]_0$