

**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.

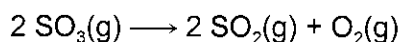
Answers to Multiple-Choice Questions		
1. _____	6. _____	10. _____
2. _____	7. _____	11. _____
3. _____	8. _____	12. _____
4. _____	9. _____	13. _____
5. _____		14. _____

Page	Score
2-4	_____/ 42
5	_____/ 15
6	_____/ 11
7	_____/ 12
<b>TOTAL</b>	_____/ 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.

- Which of the following is an important safety rule that must be followed in a chemical laboratory?
  - Always wear safety goggles in the lab.
  - If acid or base spills on your skin, wash it off with plenty of water.
  - Wear shoes that will protect your feet from liquid spills.
  - Never point the opening of a test tube at yourself or a neighbor.
  - All of these** are important laboratory safety rules.
- Which of the following substances reacts vigorously (and dangerously!) with water?
  - acetic anhydride
  - ethylene
  - propane
  - HCOOH
  - HC≡CH

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

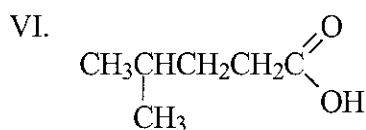
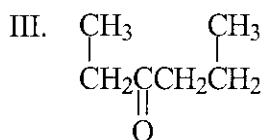
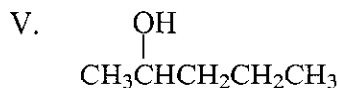
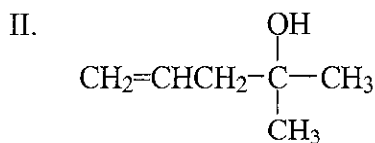
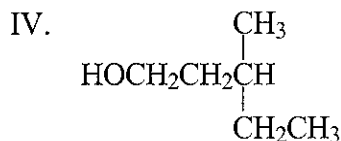
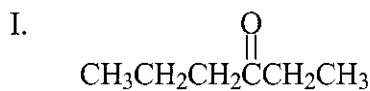


- Calculate  $\Delta S^\circ_{\text{system}}$  at 25°C. The result is:
  - 196.6 J/K
  - 188.1 J/K
  - 17.1 J/K
  - 17.1 J/K
  - 188.1 J/K
- Calculate  $\Delta G^\circ_{\text{system}}$  at 25°C. The result is:
  - 346.07 kJ
  - 141.73 kJ
  - 70.87 kJ
  - 70.87 kJ
  - 141.73 kJ
- At what temperature is this reaction least product-favored?



- 273 K
- 543 K
- 373 K
- 300 K
- This reaction is product-favored at all temperatures.

Consider these structures as you answer the next six questions:



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

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

7. Which substance is chiral?

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

8. Which two structures are identical?

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

9. Which substance is a carboxylic acid?

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

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:



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<sub>2</sub> is halved, the rate will change by a factor of:

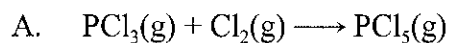
- A. ½  
B. 1  
C. 1.5  
D. 2  
E. 4  
F. 6  
G. 8

14. The rate of reaction is found to be  $1.17 \times 10^{-3}$  mol/L·s when the concentration of NO is 0.020 mol/L and the concentration of O<sub>2</sub> is 0.010 mol/L. What is the value of the rate constant?

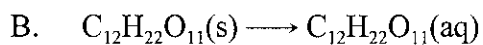
- A.  $6.0 \text{ L}^2/\text{mol}^2\cdot\text{s}$   
B.  $2.9 \times 10^2 \text{ L}^2/\text{mol}^2\cdot\text{s}$   
C.  $6.0 \times 10^2 \text{ L}^2/\text{mol}^2\cdot\text{s}$   
D.  $6.0 \text{ L}/\text{mol}\cdot\text{s}$   
E.  $2.9 \times 10^2 \text{ L}/\text{mol}\cdot\text{s}$   
F.  $6.0 \times 10^2 \text{ L}/\text{mol}\cdot\text{s}$

**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  $\Delta S$  for each process below and explain your choice.



Choose sign + - Explain

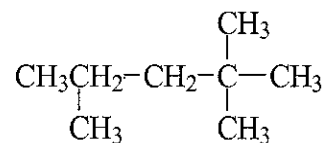
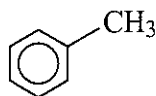


Choose sign + - Explain

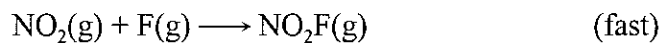
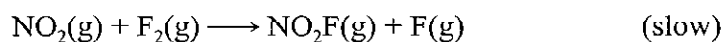
C. Air leaks from a spacecraft into outer space.

Choose sign + - Explain

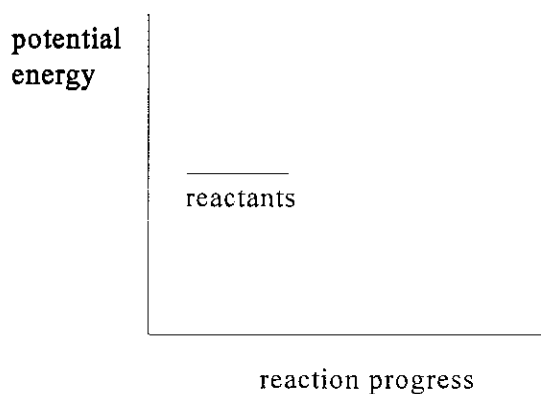
16. (6 pts.) Circle the structure of the substance that has the highest octane. Explain your choice.



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



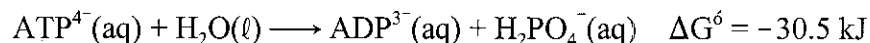
- A. What is the balanced equation for the overall reaction?
- B. Write the rate law for the reaction.
- C. Identify all reaction intermediates (if there are any). If there are none, write "none".
- D. Identify all catalysts (if there are any). If there are none, write "none".
- E. On these axes, draw a potential energy versus reaction progress diagram. Label the transition state (or transition states). The overall reaction is exothermic.



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



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



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

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 be used in any of the colored coatings. The food colorings have different solubilities in water.)

## Selected Thermodynamic Values\*

Species	$\Delta H_f^\circ(298.15\text{K})$ kJ/mol	$S^\circ(298.15\text{K})$ J/K · mol	$\Delta G_f^\circ(298.15\text{K})$ kJ/mol
<b>Aluminum</b>			
Al(s)	0	28.3	0
AlCl <sub>3</sub> (s)	-704.2	110.67	-628.8
Al <sub>2</sub> O <sub>3</sub> (s)	-1675.7	50.92	-1582.3
<b>Aqueous Solutions</b>			
Ca <sup>2+</sup> (aq)	-542.96	-55.2	-553.04
CO <sub>3</sub> <sup>2-</sup> (aq)	-676.26	-53.1	-528.10
H <sup>+</sup> (aq)	0	0	0
HCO <sub>2</sub> <sup>-</sup> (aq)	-410	91.6	-335
HCO <sub>2</sub> H(aq)	-410	164	-356
HCO <sub>3</sub> <sup>-</sup> (aq)	-691.11	95.0	-587.06
H <sub>2</sub> CO <sub>3</sub> (aq)	-698.7	191	-623.42
OH <sup>-</sup> (aq)	-229.94	-10.54	-157.30
<b>Barium</b>			
BaCl <sub>2</sub> (s)	-858.6	123.68	-810.4
BaC(s)	-553.5	70.42	-525.1
BaSO <sub>4</sub> (s)	-1473.2	132.2	-1362.2
<b>Beryllium</b>			
Be(s)	0	9.5	0
Be(OH) <sub>2</sub> (s)	-902.5	51.9	-815.0
<b>Bromine</b>			
Br(g)	111.884	175.022	82.396
Br <sub>2</sub> (l)	0	152.2	0
Br <sub>2</sub> (g)	30.907	245.463	3.110
BrF <sub>3</sub> (g)	-255.60	292.53	-229.43
HBr(g)	-36.40	198.655	-53.45
<b>Calcium</b>			
Ca(s)	0	41.42	0
Ca(g)	178.2	158.804	144.3
Ca <sup>2+</sup> (g)	1925.90	---	---
CaC <sub>2</sub> (s)	-59.8	69.96	-64.9
CaCO <sub>3</sub> (s; calcite)	-1206.92	92.9	-1128.79

Species	$\Delta H_f^\circ(298.15\text{K})$ kJ/mol	$S^\circ(298.15\text{K})$ J/K · mol	$\Delta G_f^\circ(298.15\text{K})$ kJ/mol
CaCl <sub>2</sub> (s)	-795.8	104.6	-748.1
CaF <sub>2</sub> (s)	-1219.6	68.87	-1167.3
CaH <sub>2</sub> (s)	-186.2	42.	-147.2
CaO(s)	-635.09	39.75	-604.03
CaS(s)	-482.4	56.5	-477.4
Ca(OH) <sub>2</sub> (s)	-986.09	83.39	-898.49
Ca(OH) <sub>2</sub> (aq)	-1002.82	-74.5	-868.07
CaSO <sub>4</sub> (s)	-1434.11	106.7	-1321.79
<b>Carbon</b>			
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 <sub>4</sub> (l)	-135.44	216.40	-65.21
CCl <sub>4</sub> (g)	-102.9	309.85	-60.59
CHCl <sub>3</sub> (liq)	-134.47	201.7	-73.66
CHCl <sub>3</sub> (g)	-103.14	295.71	-70.34
CH <sub>4</sub> (g; methane)	-74.81	186.264	-50.72
C <sub>2</sub> H <sub>2</sub> (g; ethyne)	226.73	200.94	209.20
C <sub>2</sub> H <sub>4</sub> (g; ethene)	52.26	219.56	68.15
C <sub>2</sub> H <sub>6</sub> (g; ethane)	-84.68	229.60	-32.82
C <sub>3</sub> H <sub>8</sub> (g; propane)	-103.8	269.9	-23.49
C <sub>6</sub> H <sub>6</sub> (l; benzene)	49.03	172.8	124.5
C <sub>6</sub> H <sub>12</sub> (l)	-126.7	296.018	-4.035
C <sub>6</sub> H <sub>12</sub> O <sub>6</sub> (s) (glucose)	-1267	---	-919
C <sub>8</sub> H <sub>18</sub> (l)	-249.952	361.205	6.707
CH <sub>3</sub> OH(l; methanol)	-238.66	126.8	-166.27
CH <sub>3</sub> OH(g; methanol)	-200.66	239.81	-161.96
C <sub>2</sub> H <sub>5</sub> OH(l; ethanol)	-277.69	160.7	-174.78
C <sub>2</sub> H <sub>5</sub> OH(g; ethanol)	-235.10	282.70	-168.49
CH <sub>3</sub> COOH(l)	-276.981	160.666	-173.991
CO(g)	-110.525	197.674	-137.168
CO <sub>2</sub> (g)	-393.509	213.74	-394.359
CS <sub>2</sub> (g)	117.36	237.84	67.12
COCl <sub>2</sub> (g)	-218.8	283.53	-204.6
<b>Cesium</b>			
Cs(s)	0	85.23	0
Cs <sup>+</sup> (g)	457.964	---	---
CsCl(s)	-443.04	101.17	-414.53
<b>Chlorine</b>			
Cl(g)	121.679	165.198	105.680
Cl <sup>-</sup> (g)	-233.13	---	---
Cl <sub>2</sub> (g)	0	223.066	0
HCl(g)	-92.307	186.908	-95.299
HCl(aq)	-167.159	56.5	-131.278



Species	$\Delta H_f^\circ(298.15\text{K})$ kJ/mol	$S^\circ(298.15\text{K})$ J/K · mol	$\Delta G_f^\circ(298.15\text{K})$ kJ/mol
<b>Chromium</b>			
Cr(s)	0	23.77	0
Cr <sub>2</sub> O <sub>3</sub> (s)	-1139.7	81.2	-1058.1
CrC(s)	-556.5	123.0	-486.1
<b>Copper</b>			
Cu(s)	0	33.150	0
CuO(s)	-157.3	42.63	-129.7
CuCl <sub>2</sub> (s)	-220.1	108.07	-175.7
<b>Fluorine</b>			
F <sub>2</sub> (g)	0	202.78	0
F(g)	78.99	158.754	61.91
F <sup>-</sup> (g)	-255.39	—	—
F <sup>-</sup> (aq)	-332.63	-13.8	-278.79
HF(g)	-271.1	173.779	-273.2
HF(aq)	-332.63	-13.8	-278.79
<b>Hydrogen</b>			
H <sub>2</sub> (g)	0	130.684	0
H(g)	217.965	114.713	203.247
H <sup>+</sup> (g)	1536.202	—	—
H <sub>2</sub> O(l)	-285.830	69.91	-237.129
H <sub>2</sub> O(g)	-241.818	188.825	-228.572
H <sub>2</sub> O <sub>2</sub> (l)	-187.78	109.6	-120.35
<b>Iodine</b>			
I <sub>2</sub> (s)	0	116.135	0
I <sub>2</sub> (g)	62.438	260.69	19.327
I(g)	106.838	180.791	70.250
I <sup>-</sup> (g)	-197.	—	—
ICl(g)	17.78	247.551	-5.46
<b>Iron</b>			
Fe(s)	0	27.78	0
FeO(s)	-272	—	—
Fe <sub>2</sub> O <sub>3</sub> (s, hematite)	-824.2	87.40	-742.2
Fe <sub>2</sub> O <sub>3</sub> (s, magnetite)	-1118.4	146.4	-1015.4
FeCl <sub>2</sub> (s)	-341.79	117.95	-302.30
FeCl <sub>3</sub> (s)	-399.49	142.3	-344.00
Fe <sub>3</sub> S <sub>4</sub> (s, pyrite)	-178.2	52.93	-166.9
Fe(CO) <sub>5</sub> (l)	-774.0	338.1	-705.3
<b>Lead</b>			
Pb(s)	0	64.31	0
PbCl <sub>2</sub> (s)	-359.41	136.3	-314.10

Species	$\Delta H_f^\circ(298.15\text{K})$ kJ/mol	$S^\circ(298.15\text{K})$ J/K · mol	$\Delta G_f^\circ(298.15\text{K})$ kJ/mol
<b>Lead</b>			
PbO(s, yellow)	-217.32	68.70	-187.89
PbS(s)	-100.4	91.2	-98.7
<b>Lithium</b>			
Li(s)	0	29.12	0
Li <sup>+</sup> (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
<b>Magnesium</b>			
Mg(s)	0	32.68	0
MgCl <sub>2</sub> (g)	-641.32	89.62	-591.79
MgCO <sub>3</sub> (s)	-1111.689	65.584	-1028.124
MgO(s)	-601.70	26.94	-569.43
Mg(OH) <sub>2</sub> (s)	-924.54	63.18	-833.51
MgS(s)	-346.0	50.33	-341.8
<b>Mercury</b>			
Hg(l)	0	76.02	0
HgCl <sub>2</sub> (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
<b>Nickel</b>			
Ni(s)	0	29.87	0
NiO(s)	-239.7	37.99	-211.7
NiCl <sub>2</sub> (s)	-305.332	97.65	-259.032
<b>Nitrogen</b>			
N <sub>2</sub> (g)	0	191.61	0
N(g)	472.704	153.298	455.563
NH <sub>3</sub> (g)	-46.11	192.45	-16.45
N <sub>2</sub> H <sub>4</sub> (l)	50.63	121.21	149.34
NH <sub>4</sub> Cl(s)	-314.43	94.6	-202.87
NH <sub>4</sub> Cl(aq)	-299.66	169.9	-210.52
NH <sub>4</sub> NO <sub>3</sub> (s)	-365.56	151.08	-183.87
NH <sub>4</sub> NO <sub>3</sub> (aq)	-399.87	259.8	-190.56
NO(g)	90.25	210.76	86.55
NO <sub>2</sub> (g)	33.18	240.06	51.31
N <sub>2</sub> O(g)	82.05	219.85	104.20
N <sub>2</sub> O <sub>4</sub> (g)	9.16	304.29	97.89
NOCl(g)	51.71	261.69	66.08
HNO <sub>3</sub> (l)	-174.10	155.60	-80.71
HNO <sub>3</sub> (g)	-135.06	266.38	-74.72

Species  $\Delta H_f^\circ(298.15\text{K})$   $S^\circ(298.15\text{K})$   $\Delta G_f^\circ(298.15\text{K})$   
kJ/mol J/K · mol kJ/mol

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 <sub>2</sub> CO <sub>3</sub> (s)	-1130.68	134.98	-1044.44
<b>Sulfur</b>			
S(s, rhombic)	0	31.80	0
S(g)	278.805	167.821	238.250
S <sub>2</sub> Cl <sub>2</sub> (g)	-18.4	331.5	-31.8
SF <sub>6</sub> (g)	1209.	291.82	-1105.3
H <sub>2</sub> S(g)	-20.63	205.79	-33.56
SO <sub>2</sub> (g)	-296.830	248.22	-300.194
SO <sub>3</sub> (g)	-395.72	256.76	-371.06
SOCl <sub>2</sub> (g)	-212.5	309.77	-198.3
H <sub>2</sub> SO <sub>4</sub> (l)	-813.989	156.904	-690.003
H <sub>2</sub> SO <sub>4</sub> (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 <sub>4</sub> (l)	-511.3	248.6	-440.1
SnCl <sub>4</sub> (g)	-471.5	365.8	-432.2
SnO <sub>2</sub> (s)	-580.7	52.3	-519.6

Titanium

Ti(s)	0	30.63	0
TiCl <sub>4</sub> (l)	-804.2	252.34	-737.2
TiCl <sub>4</sub> (g)	-763.2	354.9	-726.7
TiO <sub>2</sub> (s)	-939.7	49.92	-884.5

Zinc

Zn(s)	0	41.63	0
ZnCl <sub>2</sub> (s)	-415.05	111.46	-369.398
ZnO(s)	-348.28	43.64	-318.30
ZnS(s, sphalerite)	-205.98	57.7	-20.29

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

Species  $\Delta H_f^\circ(298.15\text{K})$   $S^\circ(298.15\text{K})$   $\Delta G_f^\circ(298.15\text{K})$   
kJ/mol J/K · mol kJ/mol

<b>Oxygen</b>			
O <sub>2</sub> (g)	0	205.138	0
O(g)	249.170	161.055	231.731
O <sub>3</sub> (g)	142.7	238.93	163.2
<b>Phosphorus</b>			
P <sub>4</sub> (s, white)	0	164.36	0
P <sub>4</sub> (s, red)	-70.4	91.2	-48.4
P(g)	314.64	163.193	278.25
PH <sub>3</sub> (g)	5.4	310.23	13.4
PCl <sub>3</sub> (g)	-287.0	311.78	-267.8
P <sub>4</sub> O <sub>10</sub> (s)	-2984.0	228.86	-2697.7
H <sub>3</sub> PO <sub>4</sub> (s)	-1279.0	110.5	-1119.1
<b>Potassium</b>			
K(s)	0	64.18	0
KCl(s)	-436.747	82.59	-409.14
KClO <sub>3</sub> (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 <sub>4</sub> (l)	-457.3	277.8	-443.8
SiC(s)	-65.3	16.61	-62.8
SiCl <sub>4</sub> (g)	-657.01	330.73	-616.98
SiH <sub>4</sub> (g)	34.3	204.62	56.9
SiF <sub>4</sub> (g)	-1614.94	282.49	-1572.65
SiO <sub>2</sub> (s, quartz)	-910.94	41.84	-856.64

Silver

Ag(s)	0	42.55	0
Ag <sub>2</sub> O(s)	-31.05	121.3	-11.20
AgCl(s)	-127.068	96.2	-109.789
AgNO <sub>3</sub> (s)	-124.39	140.92	-33.41

Sodium

Na(s)	0	51.21	0
Na(g)	107.32	153.712	76.761
Na <sup>+</sup> (g)	609.558	—	—
NaBr(s)	-361.062	86.82	-348.983
NaCl(s)	-411.153	72.13	-384.138
NaCl(g)	-176.65	229.81	-196.66

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

$$T_F = T_C + (9^\circ F/5^\circ C) + 32^\circ F$$

$$T_K = T_C + 273.15 \quad d = m/V$$

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

$$\% \text{ yield} = (\text{actual yield/theoretical yield}) \times 100\%$$

$$\text{mass \%} = (\text{mass of element per mole compound})/(\text{mass per mole compound}) \times 100\%$$

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

$$\text{moles solute after dilution} = \text{moles solute before dilution}$$

$$M_m = \text{molar mass}$$

$$PV = nRT$$

$$P = F/A$$

$$P = P_A + P_B + P_C + \dots$$

$$P = g d h$$

$$PV = \text{constant (at const. T, n)}$$

$$\text{mole fraction of A} = n_A/n = P_A/P$$

$$V = n V_m$$

$$V/T = \text{constant (at const. P, n)}$$

$$P = nRT/VM_m$$

$$P = dRT/M_m$$

$$u_{\text{rms}} = \frac{\sqrt{3RT}}{M_m}$$

$$\text{rate of effusion} = \frac{1}{\sqrt{M_m}}$$

$$(P + a \frac{n^2}{V^2})(V - bn) = nRT$$

$$\text{energy of emitted photon} = E_i - E_f = h\nu$$

$$E = h\nu$$

$$c = \lambda\nu$$

$$\lambda = h/mv$$

$$E = mc^2$$

$$E = hc/\lambda$$

$$\Delta x \cdot \Delta(mv) \geq h/4\pi$$

$$H\psi = E\psi$$

$$n = 1, 2, 3, \dots$$

$$l = 0, 1, 2, \dots, (n-1)$$

$$m_l = -l, -l+1, \dots, 0, \dots, l-1, l$$

$$m_s = \pm 1/2$$

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

$$\Delta E = q + w$$

$$w = -P\Delta V$$

$$H = E + PV$$

$$\Delta H = H_{\text{prod}} - H_{\text{react}}$$

$$q = C\Delta T = mc\Delta T = nC_m\Delta T$$

$$\Delta H = \Sigma(a\Delta H_f^\circ(\text{products})) - \Sigma(b\Delta H_f^\circ(\text{reactants}))$$

$$\Delta H = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed})$$

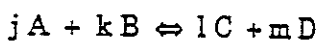
$$\Delta S = \Sigma(aS^\circ(\text{products})) - \Sigma(bS^\circ(\text{reactants}))$$

$$\Delta S_{\text{universe}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$$

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

$$\Delta G = \Delta H - T\Delta S$$

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



$$K_c = [C]^l [D]^m / [A]^j [B]^k$$

$$Q = [C]^l [D]^m / [A]^j [B]^k$$

$$E = E^\circ - (RT/nF) \ln Q = -(0.0592V/n) \log Q$$

$$\text{pH} = \text{pK}_a + \log([\text{base}]/[\text{conjugate acid}])$$

$$P = cRT$$

$$c = P/RT$$

$$K_p = K_c(RT)^{\Delta n}$$

$$\text{Solubility of gas} = k_H P$$

$$\Delta T_b = K_b c_{mi}$$

$$\Delta T_f = K_f c_{mi}$$

$$\Pi V = nRT$$

$$\Pi = cR$$

$$\text{mass \%} = (\text{mass solute})/(\text{mass solution}) \times 100\%$$

$$\text{molality} = c_m = (\text{moles solute})/(\text{kg solvent})$$

$$\text{mole fraction} = (\text{moles solute})/(\text{total moles solution})$$

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

$$\ln(N/N_0) = -kt = -(0.693/t_{1/2}) t$$

$$\Delta E = \Delta mc^2$$

0th order reaction

$$\text{Rate} = k[A]^0 = k$$

$$[A] = -kt + [A]_0$$

1st order reaction

$$\text{Rate} = k[A]$$

$$\ln[A] = -kt + \ln[A]_0$$

2nd order reaction

$$\text{Rate} = k[A]^2$$

$$1/[A] = kt + 1/[A]_0$$