THE UNIVERSITY OF CALGARY

FACULTY OF SCIENCE

Chemistry 203 (*Mostly* Fall 2018)

Term Test 1

Practice for Winter 2019

Date: October 15, 2018 **Time Allotted: 2 hours**

FIRST NAME: ____________________ **LAST NAME:** __________________________

Lecture section:

❑	L01	MWF	11:00 AM	Dr. Yuen-ying Carpenter
❑	L02	MWF	12:00 PM	Dr. Yuen-ying Carpenter
❑	L03	TR	8:00 AM	Dr. Peter Kusalik

LAB SECTION: *(e.g. B01)* _________________________

CHECK: Does your exam have **13 pages** including this cover page and formula sheet?

Before you hand in your exam, *double-check that…*	
Your exam booklet has…	Your scantron is bubbled with…
❑ **Name**	❑ **Student ID**
❑ **Lab** section	❑ Last **name**
❑ **Student ID** on Page 2	❑ **Version** number (*from this cover page*)
	❑ **Section I** and **II** answers

This is a closed-book examination. The use of resources including cameras, audio players and headphones, or wireless access devices such as cell phones, Blackberries, etc., during the examination will not be allowed. Only non-programmable calculators are permitted. A data and formula sheet is provided on the last page of the exam.

This test consists of **12 single-answer multiple choice** questions (total 24 marks), **4 mixed-multiple-choice scenarios** (total 14 marks) and **2 written answer** questions (total 14 marks + 1 mark significant digits + 1 mark for units). The total value for the test is 54 marks. *All questions must be answered to obtain full marks.*

The time limit for the exam includes the time necessary to fill in the answers for the multiple-choice questions on the optical score sheet provided.

AT THE END OF THE EXAM, HAND IN THE OPTICAL SCORE SHEET & THE ENTIRE EXAM PAPER

Failing to encode this Exam Booklet or your Optical Score Sheet correctly, for your name, ID and laboratory section, will result in the loss of two marks

Do not write in the table below. For administration only.

Page 9	Page 10	Page 11	Sigfigs *(Section III)*	Units *(Section III)*

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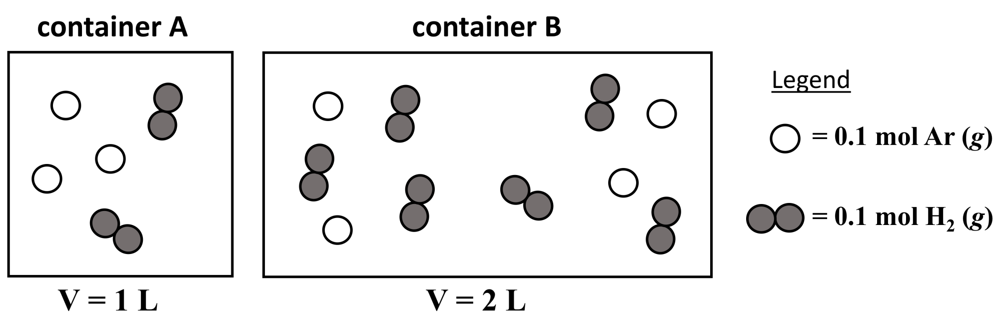
Student ID #:

SECTION I – Single-answer multiple choice (2 marks per question = 24 marks)
Select the single best answer and encode it on the Optical Score Sheet

1. You fill a rigid flask with a mixture of carbon dioxide and oxygen gases. What happens to the partial pressure (P) and mole fraction (X) of CO_2 if you then **remove half of the oxygen gas**? *Assume that the temperature remains constant.*

   a. P_{CO2} stays the same and X_{CO2} increases
   b. P_{CO2} stays the same and X_{CO2} stays the same
   c. P_{CO2} increases and X_{CO2} increases
   d. P_{CO2} decreases and X_{CO2} increases
   e. P_{CO2} decreases and X_{CO2} stays the same

2. Consider the following two containers of gas that are at the same temperature:



   Which of the following statements comparing these two containers is **false**?

   a. Container A has a higher mole fraction of Ar (X_{Ar}) than Container B.
   b. Container A has a higher mass density (d *or* ρ) than Container B.
   c. Container A has a higher total pressure (P_{total}) than Container B.
   d. Container A has a higher partial pressure of Ar (P_{Ar}) than Container B.

3. Consider the reaction shown in this **balanced** chemical equation:

$$SiO_2\ (s) + 2\ H_2O\ (g) \rightarrow SiH_4\ (g) + 2\ O_2\ (g)$$

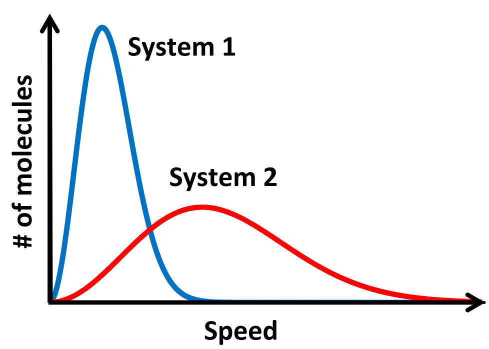
A rigid flask is filled with 0.20 mol SiO_2 (*s*) and 0.40 mol H_2O (g). The *initial* partial pressure of H_2O (g) is 1.0 atm. If the reaction goes to completion and the temperature stays constant, what is the **final total pressure** in the flask? *Assume that solids occupy negligible volume*.

a. 0.50 atm
b. 0.67 atm
c. 1.0 atm
d. 1.5 atm

4. Under which of the following conditions is the ideal gas law expected **not** to be valid?

a. Low temperature and high pressure
b. High temperature and low pressure
c. High T and large molar mass
d. Low pressure and small molar mass

5. The following curves show the distribution of **molecules vs. speed** for two different samples of gas, System 1 and System 2. *The area under both curves is equal*.



If there is *only one difference* between the two systems, which of these statements could apply?

a. The average speed of the particles could be the same in both systems.
b. The average kinetic energy of the particles could be the same in both systems.
c. The temperature could be lower in System 2 compared to System 1.
d. The mass of each particle could be higher in System 2 compared to System 1.

6. You have prepared 100.0 mL of a $NaNO_3$ solution of a known concentration. You then divide this original solution exactly equally into two clean beakers, labeled A and B. You then add 50.0 mL of water to Beaker A. Which of these statements about Beaker A is ***incorrect***?

a. Beaker A has a lower concentration of $NaNO_3$ than the original solution.
b. Beaker A has a lower number of moles of $NaNO_3$ than the original solution.
c. Beaker A has a lower concentration of $NaNO_3$ than Beaker B.
d. Beaker A has a lower number of moles of $NaNO_3$ than Beaker B.

7. A single container is filled with equal masses of 2 different gases: oxygen (O_2), and ozone (O_3). Which statement below is **false** about the properties of these two gases?

a. Both gases must be at the same temperature.
b. Both gases must have the same concentration.
c. The mole fraction of O_2 is larger than the mole fraction of O_3.
d. The sum of the mole fractions will equal 1.

8. In tutorial 2, you looked at one reaction that could produce phosphine gas, PH_3, through the following balanced reaction:

$$P_4\ (s) + 6\ H_2\ (g) \rightarrow 4\ PH_3\ (g) \qquad \Delta_r H^\circ = +\ 24\ \text{kJ/(mol}\cdot\text{rxn)}$$

In a lab test, 0.60 kJ of heat was *consumed* when a sample white phosphorus (P_4) was reacted with excess hydrogen gas at constant pressure. How many **moles of PH_3 (g)** were produced in this experiment?

a. 0.025 mol
b. 0.10 mol
c. 3.6 mol
d. 14 mol

9. The overall process for the *endothermic* decomposition of HCℓ (g) into hydrogen and chlorine gases involves **breaking** two Cℓ–H bonds and **forming** one Cℓ–Cℓ bond and one H–H bond.

$$2\ HC\ell\ (g) \rightarrow H_2\ (g) + C\ell_2\ (g)$$

Which statement is **true** about the bond dissociation enthalpies ($\Delta_{BDE}H°$) for these bonds?

	Sign for $\Delta_{BDE}H°(C\ell–C\ell)$	**Magnitude of {$\Delta_{BDE}H°(C\ell–C\ell) + \Delta_{BDE}H°(H–H)$}**
a.	Positive	**Smaller** than 2 × $\Delta_{BDE}H°(C\ell–H)$
b.	Positive	**Larger** than 2 × $\Delta_{BDE}H°(C\ell–H)$
c.	Negative	**Smaller** than 2 × $\Delta_{BDE}H°(C\ell–H)$
d.	Negative	**Larger** than 2 × $\Delta_{BDE}H°(C\ell–H)$

10. Consider the following balanced chemical equation:

$4\ NO\ (g) + 6\ H_2O\ (g) \rightarrow 4\ NH_3\ (g) + 5\ O_2\ (g)$ $\Delta_{rxn}H° > 0$

If the reaction produced **liquid ammonia** NH_3 (ℓ) instead of ammonia gas, then…

a. … a larger amount of energy in the form of heat would be absorbed by the system.
b. … a larger amount of energy in the form of heat would be released by the system.
c. … a smaller amount of energy in the form of heat would be absorbed by the system.
d. … a smaller amount of energy in the form of heat would be released by the system.

11. Ethanol (C_2H_6O) can be prepared by the fermentation of glucose ($C_6H_{12}O_6$), as shown in the balanced chemical equation below:

$$C_6H_{12}O_6\ (aq) \rightarrow 2\ C_2H_6O\ (aq) + 2\ CO_2\ (g)$$

If a student used 1.50 mol of glucose in their fermentation experiment and collected 64.5 g of pure ethanol, what was that student's percent yield?

a. 46.7 %
b. 50.0 %
c. 93.3 %
d. 96.7 %

11. Suppose you perform a multi-step experiment on a single sample of an ideal gas (starting from a particular temperature and pressure).

- In step 1, you compress the sample by doing 50 J of work on it
- In step 2, you heat the sample using 50 J of energy.
- In step 3, you allow the gas to return to its original state (*i.e.* to its original temperature and pressure).

What do we know about the internal energy change (ΔU_3) *only in step 3*?

a. $\Delta U_3 = +\ 100$ J
b. $\Delta U_3 = -\ 100$ J
c. $\Delta U_3 = +\ 150$ J
d. $\Delta U_3 < 0$ but cannot be determined exactly

********************END OF MULITIPLE CHOICE QUESTIONS SECTION****************

SECTION II: Mixed multiple choice. (14 marks)

Encode your answer(s) on the Optical Scoring Sheet.

Partial credit is possible in some questions. If the question asks you to 'Select All', selecting any incorrect statements will result in a deduction from the points earned in that question

Scenario 1: You have a sealed flask filled with 2.0 mol of benzene, C_6H_6 (ℓ).

Use this information to answer **both** of the next two questions **(Q12, Q13).**

12. How many moles of **hydrogen atoms** are in this flask?

Marks 1

a. 1.0 mol
b. 2.0 mol
c. 3.0 mol
d. 6.0 mol
e. 12 mol

13. *Explain why* you selected the answer that you did in the previous question. ***Select all*** of the facts which you needed to use in calculating your answer.

Marks 2

a. … because there are 2.0 moles of benzene molecules
b. … because half of the atoms in each benzene molecule are hydrogen atoms.
c. … because of the coefficients in the balanced chemical reaction.
d. … because there are 6 hydrogen atoms in each molecule of benzene.
e. … because hydrogen has the formula H_2 in its standard state.

Scenario 2: You place a **cold cube of granite** into a **warm container of wax** and let them come to thermal equilibrium.

The specific heat capacity of granite is smaller than that of wax.
The cube of granite and the wax in the container have the same mass.

Use this information to answer **both** of the next two questions **(Q14, Q15).**

14. Will the final temperature (T_f) be closer to the initial temperature of the granite or the initial temperature of the wax?

Marks 1

a. T_f is closer to the initial temperature of the wax
b. T_f is closer to the initial temperature of the granite
c. T_f is halfway between the two initial temperatures

15. *Explain why* you selected the answer that you did in the previous question. ***Select all that apply.***

Marks 2

a. …because a smaller temperature change occurs for the object with the higher specific heat capacity.
b. …because a larger temperature change occurs for the object with the higher specific heat capacity.
c. …because more heat is transferred to the object with the higher specific heat capacity.
d. …because less heat is transferred to the object with the higher specific heat capacity.
e. …because equal heat transferred means that the temperature change is equal.

Scenario 3: Consider the following hypothetical reaction

$$2\ X\ (aq) + Y_2\ (g) \rightarrow 2\ XY\ (g)$$

In this situation …

- ✓ The reaction goes to completion, *and*
- ✓ The volume of the container and temperature are constant during the reaction, *and*...
- ✓ The **limiting reactant is X (aq)**.

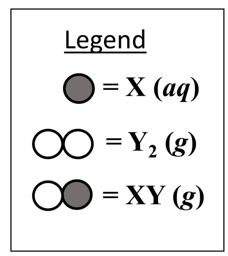
Use this information to answer the next three questions **(Q16, Q17, Q18).**

16. How will the **total pressure** *before* the reaction compare to the total pressure *after* the reaction? *Select only one answer*.

Marks 2

a. Pressure *before* the reaction is higher because the total number of moles was higher
b. Pressure *before* the reaction is higher because the solution occupies volume
c. Pressure *after* the reaction is higher because of the number of moles of gas is higher
d. Pressure *after* the reaction is higher because the excess reactant is a gas

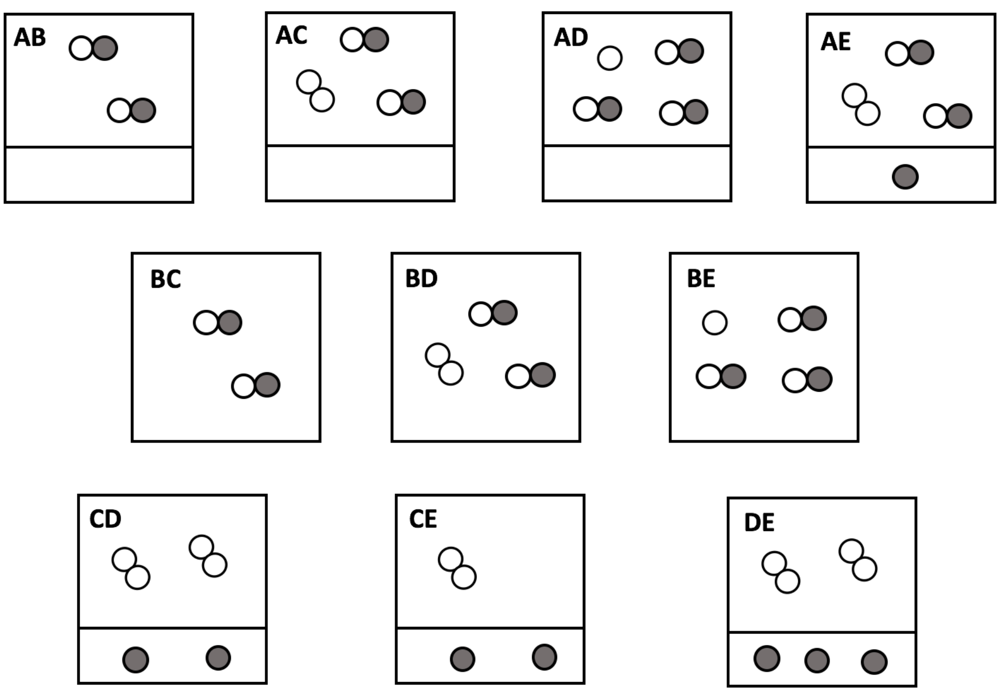
Choose **a matching pair of boxes** from the set below which you could use to correctly represent this scenario **before** and **after** the reaction described.
Fill in the two-letter code for your choices on your scantron sheet.



17. Which box did you choose to represent the contents of the container **after the reaction**?

18. Which box did you choose to represent the contents of the container **before the reaction**?

Marks 3



Scenario 4: Let's revisit that balanced chemical equation from Tutorial 2 again.

$$P_4\ (s) + 6\ H_2\ (g) \rightarrow 4\ PH_3\ (g) \qquad \Delta_{rxn}H° > 0$$

Use this information to answer **both** of the next two questions **(Q19, Q20).**

19. Is work being done by or on the system in this reaction? What is the sign for w?

Marks 1

a. On the system and $w > 0$
b. On the system and $w < 0$
c. By the system and $w > 0$
d. By the system and $w < 0$
e. No work is being done and $w = 0$

20. *Explain why* you selected the answer that you did in the previous question.
Select all that apply

Marks 2

a. … because the reaction is exothermic, so energy is released.
b. … because the reaction is endothermic, so energy is absorbed.
c. … because there were 7 moles before the reaction and only 4 moles after.
d. … because there were 6 moles of gas before the reaction and only 4 moles after.
e. … because it is a closed system no energy can be transferred to the surroundings.

**************END OF MIXED MULTIPLE CHOICE QUESTIONS SECTION*************

SECTION III: Written Answers. (14 marks + 1 mark sigfigs + 1 mark units)
Write your answers *in ink* in the space provided.
Show all work for full credit and **write final numerical answers with units in the boxes.**

Marks 5 This Page

21. Methanol (CH_3OH) has been discussed as a possible fuel for the future as it can be ready made from various green sources, and is also easily transported as a liquid. The **balanced thermochemical equation** for the combustion of liquid methanol is given by:

$$2\ CH_3OH\ (\ell) + 3\ O_2\ (g) \rightarrow 4\ H_2O\ (\ell) + 2\ CO_2\ (g) \qquad \Delta_{rxn}H° = -1453\ \text{kJ/mol·rxn at } 25°C$$

a. Determine the standard enthalpy change for this reaction ($\Delta_{rxn}H°$) **per mole of H_2O (ℓ) produced** at 25°C.

$\Delta_{rxn}H° =$

b. Given the standard enthalpies of formation in the table below, calculate the value of the **standard molar enthalpy of formation** ($\Delta_f H°$) liquid methanol, CH_3OH (ℓ) at 25°C.

Substance	Δ_fH° at 25°C (kJ/mol)
CH_3OH (ℓ)	???
CO_2 (g)	– 393.5
H_2O (ℓ)	– 285.8
H_2O (g)	– 241.8

$\Delta_f H° =$

c. Write the **balanced chemical equation** which *defines* the standard molar enthalpy of formation ($\Delta_f H°$) of CH_3OH (ℓ) at 25°C.

—Question 21 continues on next page—

—Question 21 continued from previous page—

Marks 6 This Page

$2\ CH_3OH\ (\ell) + 3\ O_2\ (g) \rightarrow 4\ H_2O\ (\ell) + 2\ CO_2\ (g)$ $\Delta_{rxn}H° = -1453$ kJ/mol·rxn at 25°C

d. An experiment is performed where 0.10 moles of CH_3OH (ℓ) and 0.25 moles of O_2 (g) are placed in a rigid (*fixed volume*) 7.00 L vessel and allowed to react.

Calculate the **total pressure (in atm)** after the reaction takes place if the final temperature is 35°C. *You should ignore the volume of any liquid that may be present.*

P_{total} =

e. What is the **mole fraction of CO_2**, χ_{CO2}, in the final gas mixture in part (d) above?

χ_{CO2} =

22. Nitrogen tetraoxide is converted to nitrogen dioxide as shown in the reaction below. We can use Kinetic Molecular Theory of Gases to describe the reactants and the products for this reaction.

Marks
3

$$N_2O_4\ (g) \rightarrow 2\ NO_2\ (g)\ .$$

a. Clearly state any **two** of the assumptions that form the basis of Kinetic Molecular Theory.

b. If we know that the products and reactants are at the *same temperature* and that the *reaction goes to completion*, **do we have enough information to predict the total pressure change**? Explain why or why not.

********************END OF LONG ANSWER SECTION*******************

Periodic Table

1 1A	2 2A	3	4	5	6	7	8	9	10	11	12	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	2 **He** 4.003
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** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
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** (98)	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
55 **Cs** 132.9	56 **Ba** 137.3	57* **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	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)
87 **Fr** (223)	88 **Ra** 226.0	89** **Ac** (227)	104 **Rf** (261)	105 **Ha** (262)	106 **Sg** (263)	107 **Ns** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Uun** (269)	111 **Uuu** (272)							

Lanthanides *	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
Actinides **	90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** 237.0	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

Strong acids: HCℓ, HBr, HI, HNO_3, H_2SO_4, $HC\ell O_4$, $HC\ell O_3$
Strong bases: Hydroxides of Group 1 (Li to Cs) and Group 2 (Ca, Sr, Ba)

Constants:

Avogadro's number: $N_A = 6.022 \times 10^{23}$ mol^{-1}
Gas constant, R = 0.08205 L atm mol^{-1} K^{-1}
= 8.314 kPa L mol^{-1} K^{-1}
= 8.314 J mol^{-1} K^{-1}
$K_w = 1.00 \times 10^{-14}$ at 298K
Faraday: F = 96,485 C / mol electrons

Conversion factors:

1 J = 1 kg m^2 s^{-2} 1 Pa = 1 kg m^{-1} s^{-2}
T K = T °C + 273.15
1 L = 10^{-3} m^3 1 L atm = 101.3 J
1 atm = 760.0 torr = 101.3 kPa = 760.0 mm Hg = 1.013 bar
1 C = 1 J / V 1 A = 1 C / s

$PV = nRT$

$\Delta U = q + w$
$w_{PV} = -P\Delta V = -\Delta n_{gas}RT$
$q = m\,C\,\Delta T$

$\Delta U = \Delta H - P\Delta V$
$\Delta_r H° = \sum n_p \Delta_f H°_{prod.} - \sum n_r \Delta_f H°_{react.}$

$\Delta G = \Delta H - T\Delta S$
$\Delta G = \Delta G° + RT \ln Q$
$\Delta G° = -RT \ln K$
$\Delta_r G° = \sum n_p \Delta_f G°_{prod.} - \sum n_r \Delta_f G°_{react.}$
$\Delta G° = -n_e F E°$

$\Delta_r S° = \sum n_p\, S°_{prod.} - \sum n_r\, S°_{react.}$

For $ax^2 + bx + c = 0$:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

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

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

$$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$$

$k = A\, e^{\frac{-E_a}{RT}}$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{-E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$\overline{E_K} = \frac{3}{2}RT \qquad E_K = \frac{1}{2}mv^2$

$K_w = K_a K_b$

$\mathrm{pH} = -\log[\mathrm{H_3O^+}]$

$$\mathrm{pH} = \mathrm{p}K_a + \log\left(\frac{[\mathrm{A^-}]}{[\mathrm{HA}]}\right)$$

$E_{cell} = E_{cathode} - E_{anode}$

$$E = E° - \frac{RT}{n_e F}\ln Q$$

$$E = E° - \frac{0.0592}{n_e}\log Q \quad \textit{at 298K}$$