CHEM 1032
SPRING 2023
UNIT ASSESSMENT 4

SECTION: _____

NAME: Key

TUID: | | | | | | | | | |

Before the Unit Assessment begins, read the rest of this page, and follow the instructions.

!!! Do not turn this page until given the signal to begin !!!

Put away everything besides pencil(s) and a scientific calculator.

- Non-programmable (scientific) calculators are permitted. Graphing calculators **are not permitted** (such as these models: TI-83, TI-84, TI-89, Casio FX-9750).
- Any other electronic devices - including cell phones, smart phones, and smart watches - **are not permitted**. If you are not sure what is permitted, ask *before* the exam begins.

When you are told to begin work, open the booklet and read the directions.

A periodic table and other useful information can be found on the next page.

Grading. Each question is graded by your instructor using the scale below.

1 - Excellent
- The student demonstrates a deep understanding of concepts and problem-solving techniques.
- Calculations are clear and legibly written.
- Any mistakes are minor or careless errors that do not indicate a major conceptual misunderstanding.

0.5 - Fair
- The student demonstrates a partial understanding of concepts and techniques.
- Calculations are clear and legibly written but contain errors.
  - The student may have started out correctly but gone on a tangent or not finished the problem.
  - The student may have used pattern matching to answer a different, more familiar question instead.

0 - Unsatisfactory/Incomplete
- The student did not demonstrate an understanding of the problem or has minimal understanding.
- Calculations are unclear, missing, or incomplete.
  - The student may have written some appropriate formulas or diagrams, but nothing further.
  - The student may have done something entirely wrong.
  - The student may have written almost nothing or nothing at all.

Unit Assessment Time: 50 minutes.
It is to your advantage to answer every question.

!!! Do not turn this page until given the signal to begin !!!

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																		2 **He** 4.0026
3 **Li** 6.94	4 **Be** 9.0122												5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.180
11 **Na** 22.990	12 **Mg** 24.305												13 **Al** 26.982	14 **Si** 28.085	15 **P** 30.974	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078(4)		21 **Sc** 44.956	22 **Ti** 47.867	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.845(2)	27 **Co** 58.933	28 **Ni** 58.693	29 **Cu** 63.546(3)	30 **Zn** 65.38(2)	31 **Ga** 69.723	32 **Ge** 72.630(8)	33 **As** 74.922	34 **Se** 78.971(8)	35 **Br** 79.904	36 **Kr** 83.798(2)
37 **Rb** 85.468	38 **Sr** 87.62		39 **Y** 88.906	40 **Zr** 91.224(2)	41 **Nb** 92.906(2)	42 **Mo** 95.95	43 **Tc**	44 **Ru** 101.07(2)	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60(3)	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57-70 *	71 **Lu** 174.97	72 **Hf** 178.49(2)	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23(2)	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po**	85 **At**	86 **Rn**
87 **Fr**	88 **Ra**	89-102 **	103 **Lr**	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Ds**	111 **Rg**	112 **Cn**	113 **Nh**	114 **Fl**	115 **Mc**	116 **Lv**	117 **Ts**	118 **Og**

57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** [144.91]	62 **Sm** 150.36(2)	63 **Eu** 151.96	64 **Gd** 157.25(3)	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05
89 **Ac** [227.03]	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**

Units:

amu *atomic mass unit*
atm *atmosphere*
g *gram*
h *hour*
J *joule*
K *kelvin*
mmHg *unit of pressure*
M *molarity*
K *kelvin*
L *liter*
mol *mole*
s *second*

Symbols:

H *enthalpy*
ν *frequency*
M *molar mass*
mol *mole*
P *pressure*
t *time*
T *temperature*
V *volume*

Constants:

N_A *Avogadro's number*
R *ideal gas constant*

SI (Metric) Prefixes:

c *centi-*
d *deci-*
k *kilo-*
m *milli-*

!!!! FOR CREDIT, BE CLEAR AND WRITE LEGIBLY !!!!

Vanadium (V) is the 20th most abundant element in the Earth's crust and it is an essential nutrient which helps with glucose metabolism but too much results in toxicity. To chemists vanadium is interesting because it can shift between five oxidation states, each being a different color.

(1) $VO_2^{+}{}_{(aq)} + 2\ I^-_{(aq)} \rightarrow VO^{2+}{}_{(aq)} + I_{2\ (s)}$

(2) $VO^{2+}{}_{(aq)} + 2\ I^-_{(aq)} \rightarrow V^{3+}{}_{(aq)} + I_{2\ (s)}$

(3) $V^{3+}{}_{(aq)} + 2\ I^-_{(aq)} \rightarrow V^{2+}{}_{(aq)} + I_{2\ (s)}$

(4) $V^{2+}{}_{(aq)} + 2\ I^-_{(aq)} \rightarrow V_{(s)} + I_{2\ (s)}$

Compound	Color
VO_2^+	yellow
VO^{2+}	blue
V^{3+}	teal
V^{2+}	purple
V	white

Part I – Multiple Choice Questions (1 pt each)

Excellent Answer = 1 pt *Fair Answer = 0.5 pts* *Unsatisfactory Answer = 0 pts*

D 1. What is the oxidation state of vanadium in VO^{2+}?

A. + 1
B. + 2
C. + 3
D. + 4

+4 -2
VO^{2+}

D 2. If the number of collisions increased in Reaction (3), what would you expect to occur?

0.5 → A. The reaction rate would increase.
0.5 → B. The rate constant would increase.
C. The reaction order would increase.
D. Both A and B.

collisions increase w/ temp
And Rate & k ↑ with temp.

A 3. Determine E^o_{cell} for Reaction (3) and the color of the solution.

A. - 0.795 V - Teal
0.5 → B. - 0.795 V - Purple
C. + 0.795 V - Teal
D. + 0.795 V - Purple

V^{3+} (teal) → V^{2+} (purple) red cat −0.255 V
$2I^- \rightarrow I_2$ ox anode 0.54 V

$E^\circ_{cell} = -0.255 - 0.54\ V$
$= -0.795$
rxn nonspon, so will stay as V^{3+} = teal

C 4. What would you expect the units of the rate constant to be if Reaction (4) were an elementary reaction?

If elementary coefficients = exponents

$Rate = k[V^{2+}][I^-]^2$

$\frac{M}{s} = \left(\frac{1}{M^2 s}\right)(M)\ (M^2)$

A. M^{-3}
B. $M\ s^{-1}$
C. $M^{-2}\ s^{-1}$
D. $M^{-3}\ s^{-1}$

298 K ↓ 323 K ↓

____ 5. Reaction (3) was run at two temperatures, 25.0 °C and 50.0 °C, which resulted in rate constants of 35.8 and 393 M^{-2} s^{-1}, respectively. What is the value of the activation energy?

A. 99.5 kJ/mol
B. 76.7 kJ/mol
C. 35.1 kJ/mol
D. 22.6 kJ/mol

$$\ln\left(\frac{35.8\ M^{-2}s^{-1}}{393\ M^{-2}s^{-1}}\right) = \frac{Ea}{8.314\ J/mol\cdot K}\left(\frac{1}{323K} - \frac{1}{298K}\right)$$

$E_a = 76{,}692$ J/mol → 76.7 kJ/mol

Part II – Open Answer Questions – *See Page 1 for full grading details*

Excellent Answer = 1 pt *Fair Answer = 0.5 pts* *Unsatisfactory Answer = 0 pts*

6. Balance the redox reaction in acidic conditions. Circle your final answer.

$$VO^{2+}_{(aq)} + 2\ I^-_{(aq)} \rightarrow V^{3+}_{(aq)} + I_{2\ (s)}$$

Show your work in this box.

$$2\left(1e^- + 2H^+ + \overset{4+}{VO^{2+}} \rightarrow \overset{3+}{V^{3+}} + H_2O\right)$$

$$2e^- + 4H^+ + 2VO^{2+} \rightarrow 2V^{3+} + 2H_2O$$

$$2\overset{2-}{I^-} \rightarrow \overset{0}{I_2} + 2e^-$$

+

$$4H^+ + 2VO^{2+} + 2I^- \rightarrow 2V^{3+} + I_2 + 2H_2O$$

	R	P
H	4	4
V	2	2
O	2	2
I	2	2
+/-	+6	+6

✓ Balanced

7. Instead of I^-, what reactant would you suggest that will make all four reactions spontaneous at standard conditions? Explain your answer.

Explain your answer here….

$I_2 + 2e^- \rightarrow 2I^- \quad E^\circ = 0.54\ V$

In all reactions vanadium is being reduced so it is the cathode. The reduction potentials range from VO^{2+} $E^\circ = 1.00\ V$ to V^{2+} $E^\circ = -1.13\ V$. In order for all reactions to be (+) E°_{cell} the anode (oxidized species) must be a good reducing agent, which will have very (-) E°_{cell}, specifically it has to be more (-) than V^{2+}.

$Al_{(s)}$ $(-1.662\ V) \longrightarrow Li_{(s)}$ $(-3.04\ V)$ are all acceptable answers.

WRITE COMPOUND HERE →

8. Data collected for Reaction (2) are shown below. Determine the rate law for the reaction, **including** the value of *k*.

	$[VO^{2+}]$ (M)	$[I^-]$ (M)	Initial Rate (M/s)
1	0.10	0.05	6.50
2	0.10	0.10	13.0
3	0.20	0.20	52.0
4	0.30	0.10	39.0

Show your work in this box.

1 to 2 → VO^{2+} constant. I^- doubled from 0.05 → 0.10, rate also doubled 6.50 → 13.0. Therefore I^- is 1st order

2 to 4 → I^- constant. VO^{2+} tripled from 0.10 → 0.30, rate also tripled 13.0 → 39.0. Therefore VO^{2+} is 1st order.

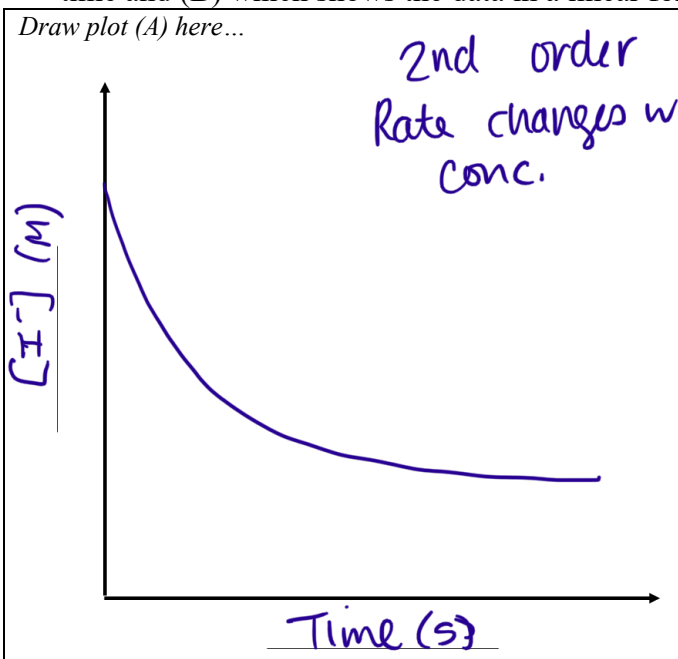
$Rate = k[VO^{2+}][I^-]$

$6.50\ M/s = k(0.10\ M)(0.05\ M) \quad k = 1300\ s^{-1}M^{-1}$

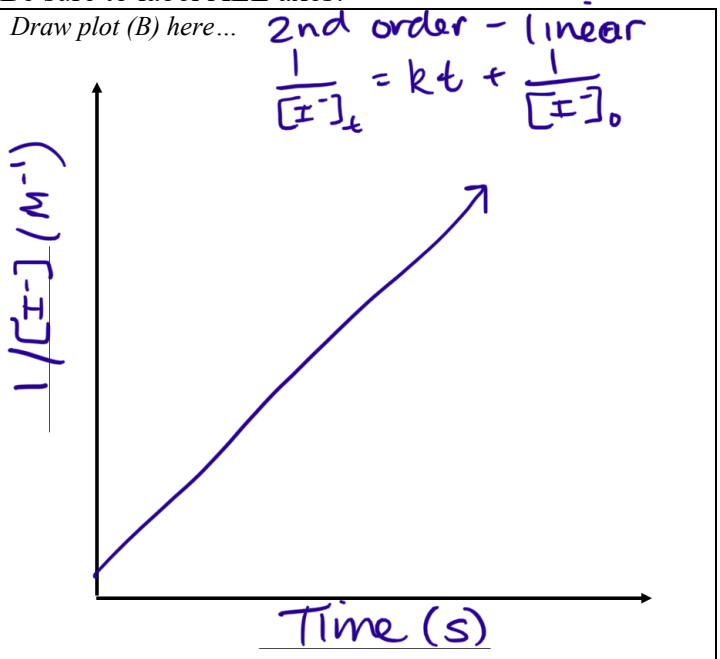
WRITE RATE LAW HERE → $Rate = (1300\ s^{-1})[VO^{2+}][I^-]$

9. Reaction (1) is second order in [I^-]. Sketch two plots: (A) which shows the raw data for concentration versus time and (B) which shows the data in a linear form. Be sure to label ALL axes!

Draw plot (A) here…



Draw plot (B) here…



10. What is the value of ΔG for Reaction (4) at 25 °C when the concentration of V^{2+} and I^- are both 0.05 M?

Show your work in this box.

$V^{2+} + 2I^- \rightarrow V_{(s)} + I_{2(s)}$ (reaction is balanced, $2e^- = n$)

ΔG = nonstandard conditions, need to determine E_{cell}.

$E^\circ_{cell} = -1.13\,V - 0.54\,V = -1.67\,V$ $\quad Q = \frac{1}{[V^{2+}][I^-]^2}$

$E_{cell} = -1.67\,V - \frac{0.0592\,V}{2} \log\left(\frac{1}{(0.05)(0.05)^2}\right)$

$E_{cell} = -1.78\,V$

$\Delta G = -nFE_{cell}$ $\quad \Delta G = -2(96{,}485) - 1.78$

WRITE ΔG HERE → $+344.5\ kJ/mol$

END OF EXAM
!!! DON'T FORGET TO CHECK YOUR WORK !!!!

Useful information:

1 atm = 760 mmHg 1 mmHg = 1 torr 0 ºC = 273 K

R = 8.314 J/(mol K) = 0.08206 (L atm)/(mol K)

$E_{cell} = E_{cathode} - E_{anode}$ $\Delta G° = -nFE^{o}_{cell}$ F = 96,485 C/mol e^-

$E^{o}_{cell} = \frac{0.0592\ V}{n} \log K$ (at T = 25 °C) $E_{cell} = E^{o}_{cell} - \frac{0.0592\ V}{n} \log Q$ (at T = 25 °C)

$[A] = -kt + [A]_o$ $t_{½} = \frac{[A]_o}{2k}$

$\ln[A]_t = -kt + \ln[A]_o$ $t_{½} = \frac{0.693}{k}$

$\frac{1}{[A]_t} = kt + \frac{1}{[A]_o}$ $t_{½} = \frac{1}{k[A]_o}$

$k = Ae^{-Ea/RT}$ $\ln k = -\frac{E_a}{R}\left(\frac{1}{T}\right) + \ln A$ $\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$

Half-Reaction	***E*° (V)**
$F_2\,(g) + 2\ e^- \longrightarrow 2\ F^-\,(aq)$	+2.866
$H_2O_2\,(aq) + 2\ H^+ + 2\ e^- \longrightarrow 2\ H_2O\,(l)$	+1.78
$Au^{3+}\,(aq) + 3e^- \longrightarrow Au\,(s)$	+1.498
$Cl_2\,(g) + 2\ e^- \longrightarrow 2\ Cl^-\,(aq)$	+1.35827
$O_2\,(g) + 4\ H^+\,(aq) + 4e^- \longrightarrow 2\ H_2O\,(l)$	+1.229
$Pt^{2+}\,(aq) + 2\ e^- \longrightarrow Pt\,(s)$	+1.20
$Br_2\,(aq) + 2e^- \longrightarrow 2\ Br^-\,(aq)$	+1.0873
$VO_2^+\,(aq) + 2\ H^+ + e^- \longrightarrow VO^{2+}\,(g) + H_2O\,(l)$	+1.00
$Ag^+\,(aq) + e^- \longrightarrow Ag\,(s)$	+0.7996
$Fe^{3+}\,(aq) + e^- \longrightarrow Fe^{2+}\,(aq)$	+0.771
$I_2\,(s) + 2\ e^- \longrightarrow 2\ I^-\,(aq)$	+0.54
$Cu^{2+}\,(aq) + 2\ e^- \longrightarrow Cu\,(s)$	+0.34
$VO^{2+}\,(g) + 2\ H^+ + e^- \longrightarrow V^{3+}\,(aq) + H_2O\,(l)$	+0.337
$2\ H^+\,(aq) + 2\ e^- \longrightarrow H_2\,(g)$	0.00
$Pb^{2+}\,(aq) + 2\ e^- \longrightarrow Pb\,(s)$	−0.1262
$Sn^{2+}\,(aq) + 2\ e^- \longrightarrow Sn\,(s)$	−0.1375
$V^{3+}\,(aq) + e^- \longrightarrow V^{2+}\,(aq)$	−0.255
$Co^{2+}\,(aq) + 2\ e^- \longrightarrow Co\,(s)$	−0.28
$Cd^{2+}\,(aq) + 2\ e^- \longrightarrow Cd\,(s)$	−0.4030
$Fe^{2+}\,(aq) + 2\ e^- \longrightarrow Fe\,(s)$	−0.447
$Cr^{3+}\,(aq) + 3\ e^- \longrightarrow Cr\,(s)$	−0.744
$Zn^{2+}\,(aq) + 2\ e^- \longrightarrow Zn\,(s)$	−0.7618
$V^{2+}\,(aq) + 2\ e^- \longrightarrow V\,(s)$	−1.13
$Al^{3+}\,(aq) + 3\ e^- \longrightarrow Al\,(s)$	−1.662
$Na^+\,(aq) + e^- \longrightarrow Na\,(s)$	−2.71
$Ca^{2+}\,(aq) + 2\ e^- \longrightarrow Ca\,(s)$	−2.868
$Ba^{2+}\,(aq) + 2\ e^- \longrightarrow Ba\,(s)$	−2.912
$K^+\,(aq) + e^- \longrightarrow K\,(s)$	−2.931
$Li^+\,(aq) + e^- \longrightarrow Li\,(s)$	−3.04

USE THIS PAGE FOR SCRAP. IT WILL NOT BE GRADED.