	THOMPSON RIVERS UNIVERSITY, OPEN LEARNING
THOMPSON RIVERS UNIVERSITY OPEN LEARNING	**CHEM 1523 • PRINCIPLES OF CHEMISTRY**
	PRACTICE EXAMINATION

TIME ALLOWED: 3 HOURS	**MATERIALS PERMITTED:**
	▪ Calculator
TOTAL PAGES (INCLUDING THIS PAGE): 11	▪ Course materials are **not** permitted
TOTAL MARKS: 100	**MATERIALS PROVIDED:**
	▪ A table of units and conversion factors
	▪ A table of some SI-derived units
	▪ A table of physical and chemical constants
	▪ A table of vapour pressure of water
	▪ A list of various formula

STUDENT: PLEASE COMPLETE THIS SECTION—*PRINT CLEARLY.*	**OPEN LEARNING FACULTY MEMBER: PLEASE COMPLETE THIS SECTION—*PRINT CLEARLY.***
Surname	
_____	
First Name	Student's Mark_____%
_____	Name
Student Number	_____
_____	I.D. Number
Open Learning Faculty Member's Name	_____
_____	Signature
Student's Signature (required)	_____
_____	Date
Date	_____
_____	Entered Into Portal: ___ Yes ___ No

Instructions

■ Unless otherwise indicated, write all your answers in the exam answer booklets provided.

■ When you have finished, return all papers, including the exam and the exam answer booklets, in the envelope. *Failure to do so may result in a FAIL grade.*

General Information

The formats of this practice exam and the attached tables and formula list are similar to those of your final exam. For your own benefit, **do not look at this exam until you have completed your review of the course** and have submitted and received feedback on all assignments. We suggest that, when you write this "exam," you isolate yourself for three hours. By simulating exam conditions in this way, you will learn how to manage your time on the final exam. Also, remember that the final exam is *closed book*.

The Practice Exam Answer Key should provide sufficient information to indicate which concepts you may have forgotten or never really learned. When you have completed your review of the exam, phone your Open Learning Faculty Member to discuss any points of concern.

Instructions

A calculator is permitted.

No course materials are allowed during this examination.

You will be provided with a periodic table.

Also provided, at the back of the exam, are:

- A table of units and conversion factors
- A table of some SI-derived units
- A table of physical and chemical constants
- A table of vapour pressure of water
- A list of various formulas

This examination consists of six questions to be answered with calculations and/or short paragraphs. You must complete **all** of these questions. The mark for each part of a question is shown in parentheses to the left of it.

Answer ALL of the following SIX questions. *(Total marks: 100)*

The mark allocation for each part of a question is shown in parentheses to the left.

(3 marks) 1. a. Determine the heat of formation of methane (CH_4), given that $\Delta H°_f$ for CO_2 is -394 kJ mol^{-1}, $\Delta H°_f$ for $H_2O(g)$ is -286 kJ mol^{-1}, and ΔH_{comb} for CH_4 is -890 kJ mol^{-1}.

(9 marks)   b. Consider the reaction

$$KClO_{4(s)} \longrightarrow KCl_{(s)} + 2O_{2(g)}\,.$$
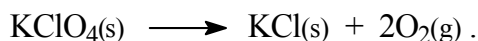
   i.   Calculate $\Delta S°$ given that $S°(KClO_4(s)) = 151$ J K^{-1} mol^{-1}, $S°(KCl(s)) = 83$ J K^{-1} mol^{-1}, and $S°(O_2(g)) = 205$ J K^{-1} mol^{-1}.

   ii. Calculate the standard free energy change and equilibrium constant for the above reaction at 25°C, given that

   $\Delta H°_f(KClO_4) = -432$ kJ mol^{-1} and $\Delta H°_f(KCl) = -437$ kJ mol^{-1}.

   iii. Comment on whether your calculated value of $\Delta S°$ in part (i) above is in accordance with what you would predict from inspection of the balanced equation.

   iv. If the reaction is spontaneous, write the expression for the equilibrium constant.

(5 marks)   c. The volume of a sample of ideal gas contracts from 6.6 L to 3.3 L under an applied pressure of 1.7 atm. As the gas contracts, the system gives off 850 J of heat to the surroundings. Calculate ΔE for this change in state.

(2 marks)   d. Note which, if any, of the following statements are true, and correct any that are untrue.

   i.   At constant temperature and pressure, a system proceeds spontaneously to a state of minimum enthalpy.

   ii. The free energy change for an exothermic reaction is positive.

   iii. Reactions for which ΔH and ΔS are both positive tend to proceed spontaneously at high temperature.

   iv. At constant temperature and pressure, equilibrium corresponds to the condition of minimum free energy.

(5 marks)   2.   a.   A piece of linen cloth believed to date from Biblical times (about 2000 years old) was subjected to carbon dating. A sample was pyrolyzed to yield carbon dioxide that was trapped and its radioactivity was measured. In units of counts per minute per gram of carbon, the average reading 14.0 compared to a count of 15.3 in carbon from living tissue. Linen is made from flax—a type of flowering plant. Assuming that the flax would have given a reading of 15.3 when alive, determine whether the cloth is likely to have originated in Biblical times. (Assume that $t_{1/2}$ for carbon-14 is 5760 years.)

*(6 marks)*   b.   In a kinetic experiment for a reaction in which

$$A + B \rightarrow C ,$$
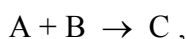
the following data were recorded:

[A] (M)	[B] (M)	Rate of C (M/s)
0.020	0.020	2.0×10^{-6}
0.040	0.040	8.0×10^{-6}
0.040	0.060	1.8×10^{-5}

Determine the order of the reaction, the rate equation, and the rate constant.

(2 marks)   c.   The oxidation of NO by O_3 is first order in each of the reactants. Under experimental conditions the rate constant is 1.5×10^7 mol s^{-1}. Determine the rate of reaction if [NO] and [O_3] are each 2.0×10^{-8} M initially.

(2 marks)   d.   If the rate law for the reaction

$$A \rightarrow B$$
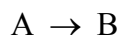
is in the form rate $= k\,[A]^{m}$, determine the order from the following data:

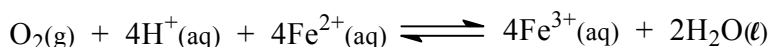| [A] (M)	Rate (M/s)
1.0	2.0×10^{-5}
2.0	8.0×10^{-5}
4.0	3.2×10^{-4}

(8 marks)   3.   a.   Sketch the titration curve for the neutralization of 50 mL of 0.10 M lactic acid ($C_3H_6O_3$) by 0.10 M sodium hydroxide. Calculate the pH after the addition of 0, 10, 25, 50, and 60 mL of the base. Label the equivalence point, the mid-equivalence point, and the buffer region. (K_a for lactic acid is 1.4×10^{-4}.)

(5 marks)   b.   How would you prepare 1.0 L of buffer solution of pH 5.50 using 0.10 M acetic acid and solid potassium acetate? (K_a for acetic acid is 1.8×10^{-5}.)

(2 marks)   c.   Calculate the pH of 25 mL of a solution containing 6.00 g of potassium formate, KCO_2H. (K_a for formic acid is 1.7×10^{-4}.)

(2 marks)   d.   In concentrated sulphuric acid, nitric acid can act as a base according to the Brønsted definition. Draw the Lewis structure for the conjugate base of HNO_3 and write the equation for the acid-base reaction when HNO_3 is dissolved in H_2SO_4.

(2 marks)   e.   Determine the pH of a solution in which the equilibrium

$$CO_{2(g)} + H_2O_{(\ell)} \rightleftharpoons HCO_3^-{}_{(aq)} + H^+{}_{(aq)}$$
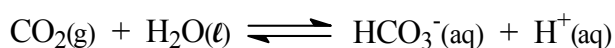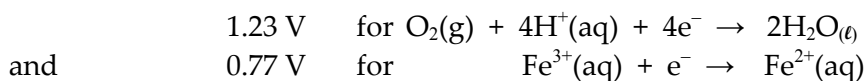
occurs and in which $[HCO_3^-] = 2.4 \times 10^{-2}$ M, $[CO_2] = 1.2 \times 10^{-3}$ M, and $K = 7.9 \times 10^{-7}$.

(9 marks)   4. a.   Calculate the free energy change and equilibrium constant for the cell represented by the reaction equation

$$O_{2(g)} + 4H^+{}_{(aq)} + 4Fe^{2+}{}_{(aq)} \rightleftharpoons 4Fe^{3+}{}_{(aq)} + 2H_2O_{(\ell)}$$

Standard reduction potentials are:

             1.23 V   for $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O_{(\ell)}$
and   0.77 V   for $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$

(2 marks)   b.   Calculate the half-cell potential for $Cu/Cu^{2+}(aq)$ at 25°C if $[Cu^{2+}] = 5.0$ M.

(4 marks)   c.   Calculate the time it takes to deposit 0.100 g of copper from a copper sulphate solution if a 3.50 amp current is passed through the solution.

(4 marks)   d.   If you have the half-cells Cu/Cu^{2+}, Cr/Cr^{3+}, Mg/Mg^{2+}, Zn/Zn^{2+}, Ag/Ag^+, Fe/Fe^{2+}, in which each solution is 1.0 M, explain the following:

        i.   Which pair would be combined to give the cell with the highest voltage?

        ii.   Which pair would be combined to give the cell with the lowest voltage?

Standard reduction potentials are:

$$
\begin{array}{lll}
0.34 \text{ V} & \text{for} & Cu^{2+}(aq) + 2e^- \rightarrow Cu(s), \\
-0.74 \text{ V} & \text{for} & Cr^{3+}(aq) + 3e^- \rightarrow Cr(s), \\
-2.37 \text{ V} & \text{for} & Mg^{2+}(aq) + 2e^- \rightarrow Mg(s), \\
-0.76 \text{ V} & \text{for} & Zn^{2+}(aq) + 2e^- \rightarrow Zn(s), \\
0.80 \text{ V} & \text{for} & Ag^+(aq) + e^- \rightarrow Ag(s), \\
\text{and} \quad -0.44 \text{ V} & \text{for} & Fe^{2+}(aq) + 2e^{-s} \rightarrow Fe(s).
\end{array}
$$

(5 marks) 5. a. For the equilibrium

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$$
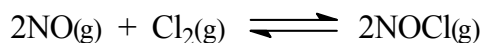
the following partial pressures were measured at 25°C:

$$P_{NO} = 0.115 \text{ atm}, \quad P_{Cl_2} = 0.181 \text{ atm}, \quad P_{NOCl} = 0.258 \text{ atm}$$

Calculate K_c at 25°C.

(2 marks) b. What concentration of sulphide ion must be present in order for copper(II) sulphide to just start to precipitate from a solution of 0.50 M copper nitrate?

$$K_{sp}(CuS) = 6.0 \times 10^{-36}$$

(2 marks) c. What mass of copper(II) sulphide will dissolve in 1.0 L of water at 25°C?

(2 marks) d. For the equilibrium,

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad K_p = 80 .$$

explain whether the system is in equilibrium when

$$P_{NO_2} = 1.0 \text{ atm} \quad \text{and} \quad P_{N_2O_4} = 0.0040 \text{ atm}.$$

(2 marks) e. For the equilibrium

$$2HF(g) \rightleftharpoons H_2(g) + F_2(g) \qquad \Delta H = 536 \text{ kJ} ,$$

state the effect of the following:

i. Increasing the temperature

ii. Adding a catalyst

iii. Adding hydrogen

iv. Decreasing the volume

(3 marks)   6. a.   A 400 g sample of a gas in a 5.00 L container exerts a pressure of 10.0 atm at 25°C. If a fire broke out and raised the temperature of the cylinder to 1105°C, what would be the pressure in the cylinder? Assume no rupture, no loss of gas, and no significant expansion.

(5 marks)   b.   In the reaction of calcium carbonate and hydrochloric acid, carbon dioxide gas is formed according to the reaction

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$$
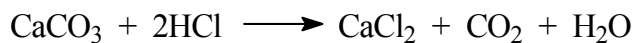
If 1.00 L of 2.0 M HCl is added to 1.00 kg of $CaCO_3$, what would be the volume of dry CO_2 formed at 25°C and a pressure of 1.05 atm?

(4 marks)   c.   What is the density of carbon dioxide gas under these conditions?

(3 marks)   d.   Calculate the relative rates of effusion for the two allotropes of the element oxygen, O_2 and O_3.

Units and Conversion Factors

Base Units			
Quantity	SI Unit	Symbol	Conversion Factors
Length	metre	m	$1\ cm = 10^{-2}\ m$ $1\ nm = 10^{-9}\ m$ $1\ \mathring{A} = 10^{-10}\ m$ $1\ inch = 2.54 \times 10^{-2}\ m$
Mass	kilogram	kg	$1\ g = 10^{-3}\ kg$ $1\ mg = 10^{-6}\ kg$ $1\ lb = 0.454\ kg$
Time	second	s	$1\ day = 8.6 \times 10^{4}\ s$
Temperature	kelvin	K	$0°C = 273.15\ K$
Amount	mole	mol	
Electric current	ampere	A	

Derived Units			
Quantity	SI Unit	Symbol	Conversion Factors
Volume	cubic metre	m^3	$1\ L = 10^{-3}\ m^3$ $= 1000\ cm^3$ $1\ mL = 1\ cm^3$
Energy	joule	J	$1\ cal = 4.184\ J$ $1\ L\ atm = 101.3\ J$ $1\ eV = 1.602 \times 10^{-19}\ J$
Pressure	pascal	Pa	$1\ atm = 1.01 \times 10^{5}\ Pa$ $= 760\ torr\ or\ mm\ Hg$
Force	newton	N	
Frequency	hertz	Hz	$1\ s^{-1} = 1\ Hz$
Electric charge	coulomb	C	
Electric potential difference	volt	V	

Some SI-Derived Units

Quantity	SI Unit	Symbol	Definition
Energy	joule	J	$kg\,m^2\,s^{-2}$
Force	newton	N	$kg\,m\,s^{-2}$ (or $J\,m^{-1}$)
Pressure	pascal	Pa	$kg\,m^{-1}\,s^{-2}$ (or $N\,m^{-2}$)
Power	watt	W	$kg\,m^2\,s^{-3}$ (or $J\,s^{-1}$)
Frequency	hertz	Hz (or s^{-1})	s^{-1}
Electric charge	coulomb	C	$A\,s$
Electric potential difference	volt	V	$kg\,m^2\,s^{-3}\,A^{-1}$ (or $J\,s^{-1}\,A^{-1}$)

Physical and Chemical Constants

Quantity	Symbol	Value
Atomic mass unit	amu	$1.661 \times 10^{-27}\,kg$
Avogadro constant	N or N_A	$6.022 \times 10^{23}\,mol^{-1}$
Electronic charge	e	$1.602 \times 10^{-19}\,C$
Faraday constant	F	$9.648 \times 10^4\,C\,mol^{-1}$
Gas constant	R	$8.314\,J\,mol^{-1}\,K^{-1}$ $= 0.0821\,L\,atm\,mol^{-1}\,K^{-1}$
Mass of electron	m_e	$9.110 \times 10^{-31}\,kg$
Mass of neutron	m_n	$1.675 \times 10^{-27}\,kg$
Mass of proton	m_p	$1.673 \times 10^{-27}\,kg$
Planck constant	h	$6.626 \times 10^{-34}\,J\,s$
Rydberg constant	R_H	$2.18 \times 10^{-18}\,J$
Speed of light in a vacuum	c	$2.998 \times 10^8\,m\,s^{-1}$

Vapor Pressure of Water

T (K)	P (atm)	P (mm Hg)	T (K)	P (atm)	P (mm Hg)
273	0.0061	4.6	298	0.0313	23.8
274	0.0065	4.9	299	0.0332	25.2
275	0.0070	5.3	300	0.0351	26.7
276	0.0075	5.7	301	0.0372	28.3
277	0.0080	6.1	302	0.0395	30.0
278	0.0086	6.5	303	0.0418	31.8
279	0.0092	7.0	304	0.0443	33.7
280	0.0099	7.5	305	0.0470	35.7
281	0.0105	8.0	306	0.0496	37.7
282	0.0113	8.6	307	0.0525	39.9
283	0.0121	9.2	308	0.0555	42.2
284	0.0129	9.8	313	0.0728	55.3
285	0.0138	10.5	318	0.0946	71.9
286	0.0147	11.2	323	0.1217	92.5
287	0.0158	12.0	328	0.1553	118.0
288	0.0168	12.8	333	0.1966	149.4
289	0.0179	13.6	338	0.2467	187.5
290	0.0191	14.5	343	0.3075	233.7
291	0.0204	15.5	348	0.3804	289.1
292	0.0217	16.5	353	0.4672	355.1
293	0.0230	17.5	358	0.5705	433.6
294	0.0246	18.7	363	0.6918	525.8
295	0.0261	19.8	368	0.8341	633.9
296	0.0278	21.1	373	1.0000	760.0
297	0.0295	22.4	378	1.1922	906.1

Formula List

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad PV = nRT \qquad \frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2}$$

$$\left(P + \frac{n^2 a}{V^2} \right)(V - nb) = nRT \qquad P_1 = X_1 P_{\text{total}} \qquad X_1 = \frac{n_1}{n_1 + n_2}$$

$$P_T = P_1 + P_2 + P_3 + ... + P_n \qquad u_{\text{rms}} = \sqrt{\frac{3RT}{M}} \qquad \frac{\text{rate}_A}{\text{rate}_B} = \sqrt{\frac{M_B}{M_A}}$$

$$K_p = K_c (RT)^{\Delta n} \qquad M = \frac{n}{V} \qquad M_1 V_1 = M_2 V_2$$

$$[H^+] = \sqrt{K_a \, x \, [\text{acid}]} \qquad [H^+] = K_a \, x \, \frac{[\text{acid}]}{[\text{salt}]}$$

$$[OH^-] = \sqrt{\frac{K_w \, x \, [\text{salt}]}{K_a}}$$

$$pH = -\log [H^+] \qquad pH + pOH = 14 \qquad K_w = [H^+][OH^-] = 10^{-14}$$

$$\Delta E = q + w \qquad \Delta E = \Delta H - RT\Delta n \qquad \Delta G° = \Delta H° - T\Delta S°$$

$$-\frac{1}{a}\frac{\Delta[A]}{dt} = -\frac{1}{b}\frac{\Delta[B]}{dt} = \frac{1}{c}\frac{\Delta[C]}{dt} = \frac{1}{d}\frac{\Delta[D]}{dt} \qquad -\frac{\Delta[A]}{dt} = k$$

$$-\frac{\Delta[A]}{dt} = k[A] \qquad -\frac{\Delta[A]}{dt} = k[A]^2 \qquad \ln\frac{[A]_o}{[A]_t} = kt$$

$$\frac{1}{[A]_t} = kt + \frac{1}{[A]_o} \qquad t_{1/2} = \frac{0.693}{k} \qquad t_{1/2} = \frac{1}{k[A]_o}$$

$$\Delta G° = -nFE° \qquad \Delta G° = -RT \ln K$$

$$E = E° - \frac{0.0257\,V}{n} \ln\left(\frac{[\text{products}]}{[\text{reactants}]} \right) \qquad \ln\left(\frac{k_2}{k_1} \right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$