

Full Name:

Student ID #:

UNIVERSITY OF CANTERBURY

Examination 2005

Prescription Number(s):	CHEM 121
Paper Title:	General Chemistry

Time Allowed: TWO HOURS

Number of pages: 17

Before commencing work, read the instructions on this page.

1. This is both your examination paper and your answer book. You may use the blank page opposite for any additional working pertaining to that question.
2. Please ensure that your name has been entered in the appropriate spaces above.
3. ANSWER ALL QUESTIONS.

Total marks = 100: you should allocate about 1 minute per mark.

4. It is good examination practice to read through the whole paper before you start answering the questions.

NOTE: There is a page of formulae and some constants and a periodic table after p15.

Please write your answers in the spaces provided

1-7	8-9, 13	10-12
14-15, 19	16-18	Total

1.

(7 marks)

Species	Electron configuration	Electric charge	Element symbol
A	$1s^2 2s^2 2p^6$	+3	Al
B	$1s^2 2s^2 2p^6$		F
C	[Argon core] $3d^9$	+2	
D	[Argon core] $3d^{10} 4s^2 4p^6$	-1	

(a) Complete the table above (A has been completed for you).

(b) Species A and B are **isoelectronic**. Define the term isoelectronic.

(c) Define the term **isotope**.

2.

(6 marks)

Briefly explain the difference between the boiling points of the following pairs of substances. Each answer should include a discussion of the attractive forces that are present.

(a) H_2O b.p. $100\text{ }^\circ\text{C}$ and H_2S b.p. $-62\text{ }^\circ\text{C}$

(b) HBr b.p. $-67\text{ }^\circ\text{C}$; Kr b.p. $-152\text{ }^\circ\text{C}$

3.

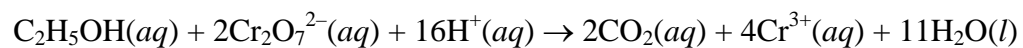
(4 marks)

An ideal gas is in a cylinder and has a volume of 500 mL at $30\text{ }^\circ\text{C}$ and a pressure of 710 Torr. The gas is compressed to a volume of 25 mL and the temperature is raised to $820\text{ }^\circ\text{C}$. What is the new pressure in the cylinder (in Torr)?

4.

(6 marks)

Alcohol ($\text{C}_2\text{H}_5\text{OH}$) levels in blood can be determined by redox titration with potassium dichromate solution according to the balanced equation:

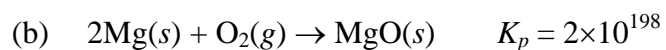
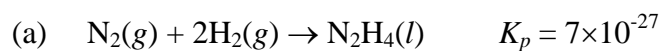


What is the blood alcohol level in mass percent if 8.76 mL of $0.04988 \text{ mol L}^{-1}$ of $\text{K}_2\text{Cr}_2\text{O}_7$ solution is required for titration of a 10.002 g sample of blood?

[$M[\text{C}_2\text{H}_5\text{OH}] = 46.05 \text{ g mol}^{-1}$.]

5. (2 marks)

Assuming that gaseous reactants and products are present at 1 atm partial pressure, indicate whether the following reactions are spontaneous or non-spontaneous. (2 marks)



6. (6 marks)

The specific heat of aluminium is $0.900 \text{ J } ^\circ\text{C}^{-1} \text{ g}^{-1}$.

(a) How much energy is required to raise the temperature of an 850 g block of aluminium from $22.8 \text{ }^\circ\text{C}$ to $94.6 \text{ }^\circ\text{C}$?

(b) What is the molar heat capacity of aluminium?

7. (3 marks)

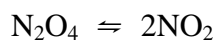
The First Law of Thermodynamics may be written as:

$$\Delta U = q + w$$

Define each of the terms in the above expression

8. (6 marks)

At $T = 298\text{K}$ the equilibrium constant (K_c) is 0.12 mol L^{-1} for the reaction

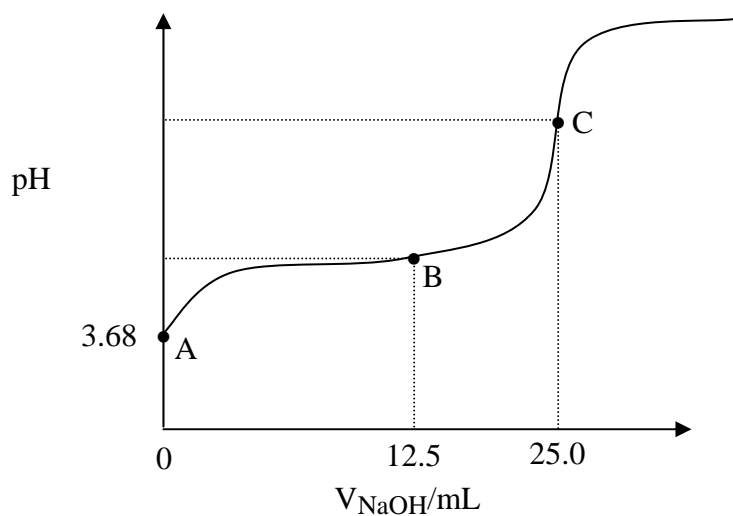


(a) If the equilibrium concentration of NO_2 is 0.15 mol L^{-1} , what is the equilibrium concentration of N_2O_4 .

(b) K_c is not the thermodynamic equilibrium constant. Calculate the value of K you would need if you wished to use the formula $\Delta G^\circ = RT \ln K$?

9.

(20 marks)



The figure above shows the titration curve obtained (using a pH meter) when a 20.0 ml sample of a solution of weak acid, HA, of concentration 0.125 mol L^{-1} is titrated with NaOH solution. The NaOH solution has unknown concentration, C_{NaOH} , and V_{NaOH} represents the volume in mL of NaOH which has been added.

[Data: $K_w = 1.00 \times 10^{-14}$.]

- (a) **On the figure above** clearly indicate and label the following:
- the equivalence point
 - a buffer region
- (b) Calculate C_{NaOH} .

Question 9 continued on the next page

Question 9 continued

- (c) Using the initial pH value for the solution (3.68), calculate K_a (the acid dissociation constant) for HA.
- (d) What is the pH at point B?
- (e) Prove the general result that K_b (base ionisation constant for the base X^- (ie conjugate base of the acid, HX) is given by $K_b(X^-) = K_w/K_a(HX)$.

Question 9 continued on the next page

Question 9 continued

(f) Calculate the pH at the equivalence point in the titration.

(g) The endpoint of this titration could be detected using an indicator. Of the indicators listed below, which would be the most suitable? Explain the reason for your answer.

Indicator	pK_a (indicator)
Bromophenol blue	3.8
Bromophenol blue	6.8
Phenolphthalein	9.1
Alizarin yellow R	11.1

10.

(9 marks)

The data in the table were obtained for the reaction:



$[\text{ClO}_2]_0 / \text{mol L}^{-1}$	$[\text{OH}^-]_0 / \text{mol L}^{-1}$	Initial rate / $\text{mol L}^{-1} \text{s}^{-1}$
0.0500	0.100	0.0575
0.100	0.100	0.230
0.100	0.0500	0.115

- (a) Determine the rate law for the above reaction.
- (b) Calculate the value of the rate constant, k , and state the units of k .
- (c) What would be the initial rate for an experiment with $[\text{ClO}_2]_0 = 0.175 \text{ mol L}^{-1}$ and $[\text{OH}^-]_0 = 0.0844 \text{ mol L}^{-1}$?

11.

(6 marks)

The decomposition of hydrogen peroxide was studied at a particular temperature. The following data were obtained.

Time / seconds	[H₂O₂] / mol L⁻¹
0	1.0000
1200	0.370
2400	0.137

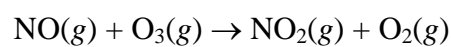
(a) Calculate the value of the rate constant, k .

(b) Calculate the concentration of hydrogen peroxide at 4000 seconds after the start of the reaction.

12.

(6 marks)

Some experimental results for the temperature dependence of the rate constant for the gas phase reaction



are as shown in the table.

T / K	k / s^{-1}
-78	1.08×10^9
25	12.0×10^9

Determine the activation energy E_a for the reaction.

13.

(4 marks)

Given $K_{\text{sp}}(\text{AgCl}) = 1.6 \times 10^{-10}$, calculate the molar solubility of AgCl in a 0.002 mol L^{-1} AgNO_3 solution?

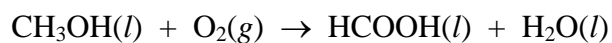
14.

(12 marks)

Given the following data:

	$\Delta H_f^\circ / \text{kJ mol}^{-1}$	$S^\circ / \text{J K}^{-1} \text{mol}^{-1}$
$\text{CH}_3\text{OH}(l)$	-238.7	126.8
$\text{HCOOH}(l)$	-409.2	129.0
$\text{H}_2\text{O}(l)$	-285.8	69.9
$\text{O}_2(g)$	0.0	205.1

For the reaction:

(a) Calculate ΔS° at 298 K.(b) Calculate ΔH° at 298 K.(c) Calculate ΔG° at 298 K.

Question 14 continued

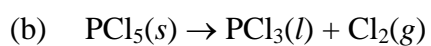
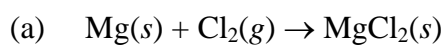
(d) Calculate K at 298 K.

(e) Estimate ΔG° at **3000 K**, assuming that ΔH° and ΔS° are independent of temperature.

15.

(2 marks)

Predict the sign of ΔS for the following reactions:



The table of E^0 values is for use in Questions 16 and 17.

Oxidant/reductant	E^0 / V	Oxidant/reductant	E^0 / V
$\text{Zn}^{2+}(\text{aq}) \text{Zn}(\text{s})$	-0.76	$\text{I}_2(\text{aq}), 2\text{I}^-(\text{aq})$	+0.54
$\text{Fe}^{2+}(\text{aq}) \text{Fe}(\text{s})$	-0.44	$\text{Fe}^{3+}(\text{aq}), \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Sn}^{2+}(\text{aq}) \text{Sn}(\text{s})$	-0.14	$\text{Br}_2(\text{aq}), 2\text{Br}^-(\text{aq})$	+1.07
$\text{Pb}^{2+}(\text{aq}) \text{Pb}(\text{s})$	-0.13	$\text{Cl}_2(\text{aq}), 2\text{Cl}^-(\text{aq})$	+1.36
$2\text{H}^+(\text{aq}), \text{H}_2(\text{g})$	0.00	$\text{Au}^{3+}(\text{aq}) \text{Au}^+(\text{aq})$	+1.50
$\text{Cu}^{2+}(\text{aq}) \text{Cu}(\text{s})$	+0.34	$\text{MnO}_4^-(\text{aq}), \text{Mn}^{2+}(\text{aq})$	+1.52
$\text{Ag}^+(\text{aq}) \text{Ag}(\text{s})$	+0.80	$\text{Au}^+(\text{aq}) \text{Au}(\text{s})$	+1.68

16. (2 marks)

(a) Which is the strongest reductant given in the table?

(b) Which is the strongest oxidant given in the table?

17. (4 marks)

(a) Calculate $E^0(\text{cell})$ for the electrochemical cell:



(b) Is the reaction spontaneous under standard conditions? YES / NO (Delete one)

Explain your answer.

18.

(12 marks)

For the electrochemical cell based on the following half-reactions:



- (a) Determine the overall cell reaction.
- (b) Calculate E°_{cell} .
- (c) Calculate ΔG for the reaction at 25 °C.
- (d) Calculate K for the reaction at 25 °C.
- (e) Calculate E_{cell} at 25 °C when $[\text{Au}^{3+}] = 0.010 \text{ mol L}^{-1}$ and $[\text{Tl}^{+}] = 1.0 \times 10^{-4} \text{ mol L}^{-1}$.

19.

(3 marks)

Mercury has an enthalpy of vaporisation of $58.51 \text{ kJ mol}^{-1}$ and an entropy of vaporisation of 92.92 J K^{-1} . What is the normal boiling point of mercury?

END OF PAPER