

NAME:

STUDENT ID N^o

CHEM 114: Mid-course TEST
THURSDAY 4th MAY 2006 7.00-9.00pm
Answer ALL QUESTIONS

TIME MANAGEMENT:

This examination is marked out of 120. An approximate marking scheme is provided to help you allocate your time effectively. You are encouraged to spend approximately 1 minute per mark allocated.

ANSWERS:

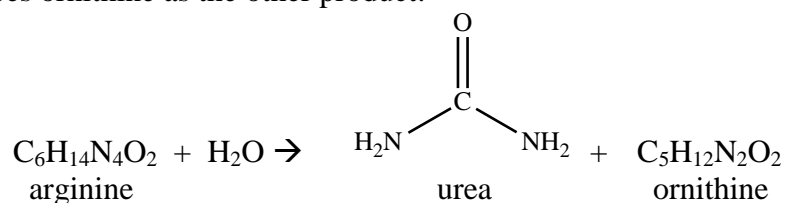
Fill in your answers in the spaces provided. If you need more space (e.g. for calculation workings) please use the blank paper on the back of the preceding page

PERIODIC TABLE:

A Periodic Table is included on a separate sheet. You are encouraged to use it.

QUESTION 1**[15 marks total]**

Humans excrete excess nitrogen in the form of an aqueous solution of urea ($\text{CH}_4\text{N}_2\text{O}$). Urea is produced in the body by the reaction of arginine with water. This reaction produces ornithine as the other product:



- (a) Calculate the mass of arginine that must have reacted when you excrete 0.105 g of urea. [5 marks]
- (b) What mass of ornithine was produced in this reaction? [3 marks]
- (c) Intramolecular and intermolecular bonding directly affect the physical properties of molecular compounds. Urea is a crystalline solid (m.p. 133°C) which is highly soluble in water. Explain the relationship between the bonding in urea and these material properties. [7 marks]

QUESTION 2**[3 marks total]**

The atomic mass of copper is 63.5. Copper exists as two isotopes copper-63 (mass = 62.9) and copper-65 (mass = 64.9). What is the approximate percentage of copper-63 atoms in samples of this element (circle the correct answer)? **[3 marks]**

- (a) 10% (b) 30% (c) 50% (d) 70% (e) 90%

QUESTION 3**[20 marks total]**

Calcium (Ca) reacts with chlorine (Cl₂) to produce calcium chloride.

- (a) Write out the electronic configurations for each of these two elements **[4 marks]**

Cl

Ca

- (b) Write out a balanced equation for the formation of calcium chloride from the elements. **[3 marks]**

- (c) If 12 g of chlorine reacts completely with calcium, how many grams of calcium chloride are produced? **[5 marks]**

- (d) Predict the nature of bonding in a sample of calcium chloride. Use this information to predict some of the **material** properties (physical properties) of calcium chloride, explaining your reasoning. **[8 marks]**

QUESTION 4**[27 marks total]**

The following table lists some enthalpy changes for processes associated with the formation of calcium chloride from calcium and chlorine.

TABLE

(A) Enthalpy change for atomisation of calcium	$\text{Ca(s)} \rightarrow \text{Ca(g)}, \Delta H = +178 \text{ kJ mol}^{-1}$
(B) Enthalpy change for atomisation of chlorine	$\frac{1}{2} \text{Cl}_2\text{(g)} \rightarrow \text{Cl(g)}, \Delta H = +121 \text{ kJ mol}^{-1}$
(C) First ionization energy of calcium	$\text{Ca(g)} \rightarrow \text{Ca}^+\text{(g)} + \text{e}^-, \Delta H = +596 \text{ kJ mol}^{-1}$
(D) Second ionization energy of calcium	$\text{Ca}^+\text{(g)} \rightarrow \text{Ca}^{2+}\text{(g)} + \text{e}^-, \Delta H = +1152 \text{ kJ mol}^{-1}$
(E) First electron affinity of chlorine	$\text{Cl(g)} + \text{e}^- \rightarrow \text{Cl}^-\text{(g)}, \Delta H = -355 \text{ kJ mol}^{-1}$
(F) Lattice enthalpy of CaCl_2	$\text{Ca}^{2+}\text{(g)} + 2 \text{Cl}^-\text{(g)} \rightarrow \text{CaCl}_2\text{(s)} \Delta H = -2237 \text{ kJ mol}^{-1}$

- (a) For the six processes (A-F) listed in the **TABLE** briefly explain the reasons for the value (the sign and the magnitude) of each enthalpy change. *[18 marks]*

- (b) Use the values given in the **TABLE** to calculate the enthalpy change for the formation of CaCl_2 . Briefly explain your reasoning. *[5 marks]*

- (c) The lattice enthalpy change for the formation of CaCl ($\text{Ca}^+ + \text{Cl}^- \rightarrow \text{CaCl}$) is predicted to be $\Delta H = -711 \text{ kJ mol}^{-1}$. Use this value, together with the relevant information from the table, to calculate the enthalpy change for the formation of CaCl. What does this value indicate about why calcium forms a dichloride (CaCl_2) rather than a mono chloride (CaCl). [4 marks]

QUESTION 5

[13 marks total]

Methanol, CH_3OH , is a liquid at room temperature and pressure. The enthalpy (ΔH_{vap}) and entropy (ΔS_{vap}) changes for the vaporization of methanol have been determined:

Enthalpy change for $\text{CH}_3\text{OH}(\text{l}) \rightarrow \text{CH}_3\text{OH}(\text{g})$,

$$\Delta H_{\text{vap}} = +37000 \text{ J mol}^{-1}$$

Entropy change for $\text{CH}_3\text{OH}(\text{l}) \rightarrow \text{CH}_3\text{OH}(\text{g})$,

$$\Delta S_{\text{vap}} = +110 \text{ J K}^{-1} \text{ mol}^{-1}$$

- (a) Is the vaporization of methanol an exothermic or an endothermic reaction? Circle the correct answer. [1 mark]

EXOTHERMIC

ENDOTHERMIC

- (b) Discuss the value of ΔH_{vap} in terms of the changes in bonding associated with vaporization. [5 marks]

- (c) Discuss the value of ΔS_{vap} in terms of the changes in order associated with vaporization. [3 marks]

- (d) At the boiling point of methanol, T, the value of $T\Delta S_{\text{vap}} = \Delta H_{\text{vap}}$. Calculate the boiling point of methanol in degrees centigrade ($^{\circ}\text{C}$). [4 marks]

QUESTION 6

[21 marks total]

The conversion of sucrose (table sugar) to glucose and fructose is an important reaction in sugar processing:

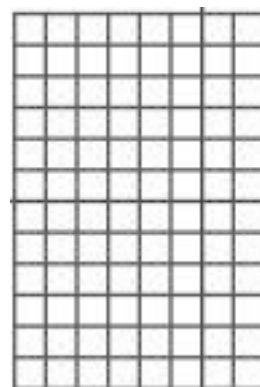
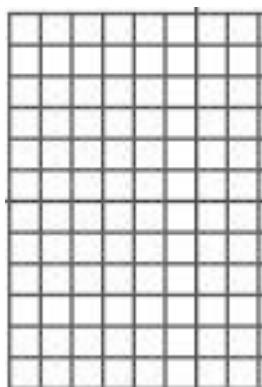


It is carried out in aqueous acid conditions. Some rate data for this reaction are presented in the following **TABLE**.

TABLE

Time (min)	[sucrose] (M)	ln [sucrose]
0	1.000	0
30	0.900	-0.105
60	0.811	-0.210
90	0.730	-0.315
120	0.657	-0.420
150	0.592	-0.525
180	0.533	-0.630
210	0.480	-0.735
240	0.432	-0.840

- (a) Plot graphs of [sucrose] vs time and ln[sucrose] vs time on the grids below. [8 marks]



(b) Is this reaction zero order, first order or second order with respect to sucrose? Briefly explain your reasoning. *[4 marks]*

(c) Estimate the half-life of the reaction *[2 marks]*

(d) Estimate approximately how long it would take to convert 75% of a 1 kg sample of sucrose to glucose and fructose. Briefly explain your reasoning. *[4 marks]*

(d) Write out a rate equation for this reaction (*i.e.* an expression linking the rate of reaction with the concentrations of sucrose and the rate constant, k , for the reaction). *[3 marks]*

QUESTION 7**[21 marks total]**

- (a) What is a calorimeter? Give a brief description of how the enthalpy change for dissolving a salt can be measured using a calorimeter. Include a brief discussion of factors which affect the accuracy of the measurement. [6 marks]

Ammonium nitrate (NH_4NO_3) is a crystalline solid. It is a constituent of cold-packs. When 5.44 g of ammonium nitrate is dissolved in 150 g of water, in a calorimeter, the temperature of the water decreases from 18.6 °C to 16.2 °C.

- (b) Is the dissolution of ammonium nitrate in water an exothermic or an endothermic reaction? Circle the correct answer. [1 mark]

EXOTHERMIC

ENDOTHERMIC

- (c) Calculate the energy change when 5.44 g of ammonium nitrate is dissolved in 150 g of water. Assume that the solution (total mass = 155.4 g) has a specific heat capacity of $4.2 \text{ J g}^{-1} \text{ K}^{-1}$ (*i.e.* it takes 4.2 J to raise the temperature of each gram of material by 1 degree). [4 marks]

- (d) Use the result from (b) to calculate the value of the molar enthalpy change for dissolving ammonium nitrate in water in kJ mol^{-1} . [5 marks]

- (e) Does ammonium nitrate dissolve in water because of a favourable enthalpy of dissolution, or a favourable entropy of dissolution, or both? Explain your reasoning. *[5 marks]*

END OF TEST