

**Full Name:** .....

**Student ID #:** .....

University of Canterbury

## Mid Year Examination and Test Period 2007

Prescription Number(s):      CHEM 114

Paper Title:                      Introductory Chemistry

Time Allowed:                    TWO HOURS

Number of pages:                19

Answer **ALL** questions

Please write your answers in the spaces provided.

Total marks = 110: you should allocate 1 minute per mark. Allow 10 minutes for reading time and checking time.

NOTE:                              There is a periodic table with atomic masses at the end of this paper.

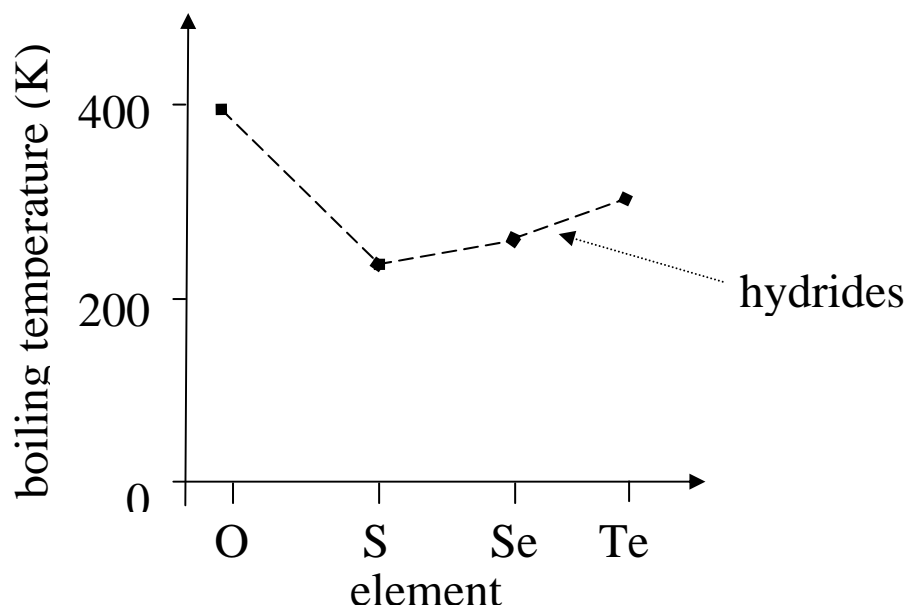
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For examiners use only

1	2	3	4	5	6	7
8	9	10	11	12		<b>Total</b>

1. (10 marks)

The graph below shows the boiling points of the group-16 **hydrides**, ( $\text{H}_2\text{O}$ ,  $\text{H}_2\text{S}$  etc).



(a) (3 marks)

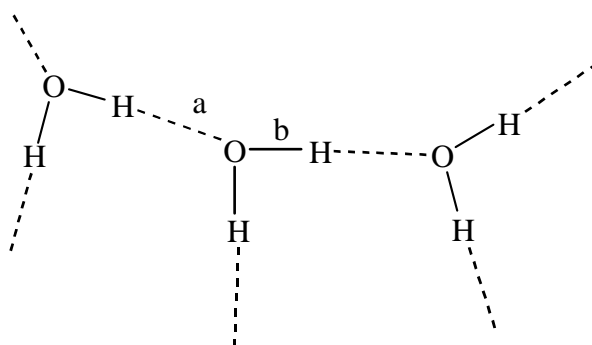
Explain the rise in the boiling points of the hydrides of the group-16 elements from sulfur to tellurium (S, Se, Te).

(b) (3 marks)

Explain why the boiling point of  $\text{H}_2\text{O}$  does not follow the trend set by the other group-16 hydrides.

(c) (4 marks)

The diagram shows a representation of some molecules in a sample of liquid water.

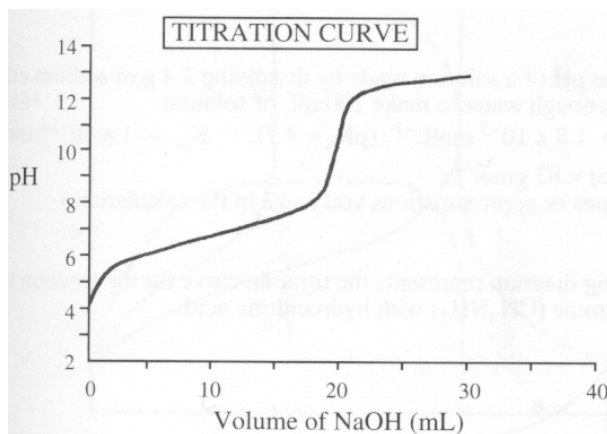


Choose the letter (a or b) that shows:

- (i) an intermolecular bond \_\_\_\_\_
- (ii) a hydrogen bond \_\_\_\_\_
- (iii) a covalent bond \_\_\_\_\_
- (iv) a bond that is broken during boiling \_\_\_\_\_

2. (20 marks)

- (a) An acid with the general formula HA gives a yellow solution, whereas a solution of its conjugate base,  $A^-$ , is deep red. When equal concentrations of HA and  $A^-$  are present an orange colour is observed. When 15 mL of a solution of HA is titrated with  $0.1 \text{ mol L}^{-1}$  sodium hydroxide solution the pH changes as shown below.



(i) (2 marks)

Is HA a strong or weak acid? Give a reason for your answer.

(ii) (1 mark)

What is the conjugate acid of base  $A^-$ ?

(iii) (1 mark)

What is the colour of the solution at  $\text{pH} = 10$ ?

(iv) (2 marks)

What is the concentration of the HA in the initial solution?

(v) (1 mark)

What is the pH when the colour of the solution is orange?

(vi) (1 mark)

Give, to the nearest whole number, the  $pK_a$  of the acid HA.

(b) Answer the following for propanoic acid,  $C_2H_5COOH$ , which is a weak acid.

(i) (2 marks)

Write an expression for the acid ionisation constant,  $K_a$ , in terms of the concentrations of chemical species in solution.

(ii) (3 marks)

Given  $K_a = 1.4 \times 10^{-5}$ , calculate the pH of a  $0.1 \text{ mol L}^{-1}$  solution of propanoic acid.

Explain any assumptions that you make.

(c) Buffer solutions involve acid-base chemistry and are important to many fields of science.

(i) (1 mark)

What are the properties of a buffer solution?

(ii) (1 mark)

How would you make a buffer solution containing the weak acid HA?

(iii) Use the example from (ii) to show how your buffer solution responds to addition of:

(A)  $\text{H}_3\text{O}^+$  ions: (1 mark)

(B)  $\text{OH}^-$  ions: (1 mark)

(d) (3 marks)

An acid, HA, has  $K_a = 1.8 \times 10^{-5}$ . Calculate the pH of a solution that, at equilibrium, contains  $0.8 \text{ mol L}^{-1}$  of the conjugate base,  $\text{A}^-$ , and  $1.2 \text{ mol L}^{-1}$  of the acid (HA).

3. (8 marks)

When a piece of copper is placed in a colourless solution of silver nitrate, crystals form on the copper surface and a blue solution results. However, when a silver wire is placed in a blue solution of copper(II) nitrate no changes are observed.

(a) (2 marks)

What are the crystals that have formed on the surface of the copper? Write a half-equation for this process.

(b) (2 marks)

How is the colour change of the solution accounted for? Write a half-equation for this process.

(c) (2 marks)

In what order would copper and silver appear in a metal activity series? Explain your answer.

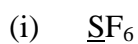
(d) (2 marks)

What is a sacrificial metal? Give an example of the use of such a metal.

4. (11 marks)

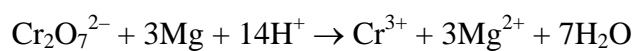
(a) (2 marks)

Calculate the oxidation numbers of the sulfur atom in the following ions or molecules:



(b) (2 marks)

Identify the element, or elements, being oxidised or reduced in the following balanced equation.



Element(s) oxidised: \_\_\_\_\_

Element(s) reduced: \_\_\_\_\_

(c) (4 marks)

Balance the following ion-electron half equations in acid solution:



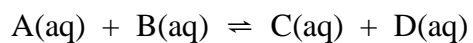
(d) (3 marks)

Write the full, balanced, redox equation for the overall reaction comprising the two half reactions in question (d).

5. (7 marks)

(a) (3 marks)

Consider this reaction:



At 25°C,  $K_c = 7.2$  for this reaction and an analysis of the equilibrium mixture gave:

$$[\text{A}] = 0.75 \text{ mol L}^{-1}$$

$$[\text{B}] = 0.36 \text{ mol L}^{-1}$$

$$[\text{C}] = 2.40 \text{ mol L}^{-1}$$

Calculate the equilibrium concentration of D.

(b) (2 marks)

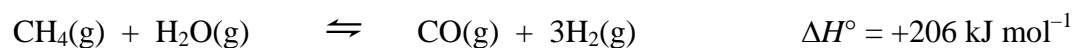
Explain the difference between a reaction quotient ( $Q$ ) and an equilibrium constant ( $K$ ).

(c) (2 marks)

State Le Chatelier's principle.

6. (12 marks)

Natural gas is an important industrial resource. The first step in the manufacture of other products from natural gas is the formation of synthesis gas (the CO/H<sub>2</sub> mixture):



(a) (1 mark)

Is the reaction exothermic or endothermic? \_\_\_\_\_

(b) (1 mark)

Write the equilibrium constant expression for this reaction.

(c) (3 marks)

To get a high yield of synthesis gas (the CO/H<sub>2</sub> mixture) should a **high** or **low** temperature be used? Give the reasoning for your choice.

(d) (3 marks)

To get a high yield of synthesis gas (the CO/H<sub>2</sub> mixture) should a **high** or **low** pressure be used? Give the reasoning for your choice.

(e) (2 marks)

A nickel catalyst is used in this process. What effect does this catalyst have on the proportions of gases at equilibrium?

(f) (2 marks)

In what way would the **value** of  $K$  for reaction (1) be changed if the temperature were raised after this system had reached equilibrium? Explain your answer.

7. (10 marks)

Barium hydroxide,  $\text{Ba}(\text{OH})_2$ , is shaken with water at  $25^\circ\text{C}$  until no more dissolves. The concentration of barium ions in this saturated solution is  $0.108 \text{ mol L}^{-1}$ .

(a) (2 marks)

Write an equation to describe the equilibrium process occurring in the saturated solution.

(b) (2 marks)

Write the expression for the solubility product ( $K_{\text{sp}}$ ) for barium hydroxide.

(c) (2 marks)

Calculate the solubility product ( $K_{\text{sp}}$ ) for this system at  $25^\circ\text{C}$ .

(d) (4 marks)

100 mL of  $1.00 \times 10^{-3} \text{ mol L}^{-1}$  sodium sulfate solution is mixed with 50 mL of  $2.00 \times 10^{-3} \text{ mol L}^{-1}$  barium chloride solution. ( $K_{\text{sp}}$  of  $\text{BaSO}_4 = 1.0 \times 10^{-10}$ .)

Will a precipitate of barium sulfate be formed under these conditions?

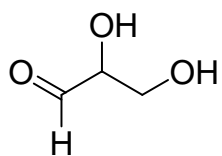
8. (8 marks)

(a) (2 marks)

Draw the structure of 3,7-dimethyloctanoic acid.

(b) (3 marks)

Give the systematic name of the following organic compound.



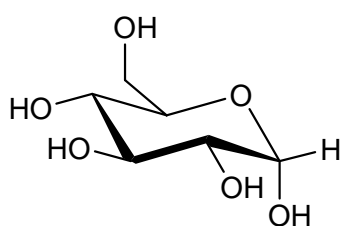
(c) (3 marks)

Draw a constitutional isomer of the compound shown in part (b) above. Briefly explain your reasoning.

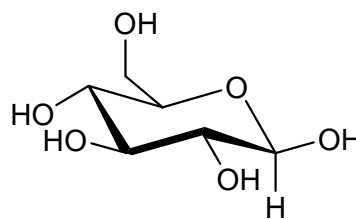
9. (5 marks)

(a) (1 mark)

The structures below show different anomers of glucose. Using a circle, indicate the hemiacetal carbon on one of these molecules.



$\alpha$ -D-Glucose



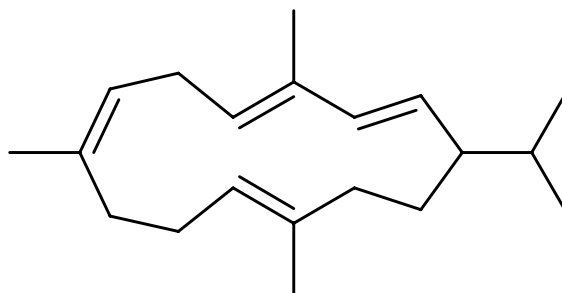
$\beta$ -D-Glucose

(b) (4 marks)

These anomers can interchange in solution by a *mutarotation*. Briefly explain this process.

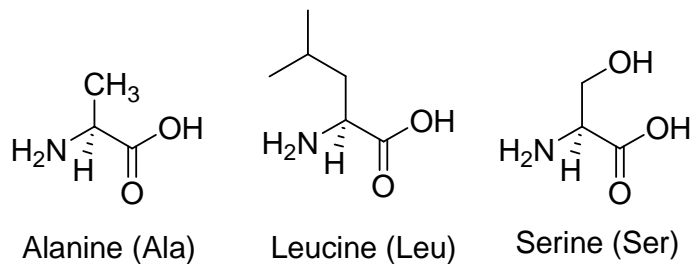
10. (8 marks)

Clearly identify the isoprene units in the cyclic terpene shown. Using arrows, indicate the head-to-tail linkages. Circle the bonds that represent extra C-C links.



11. (6 marks)

The structures of the amino acids alanine, leucine and serine are given below.



(a) (4 marks)

Draw the structure of the tripeptide Ser-Ala-Leu. Clearly indicate, with arrows, any peptide bonds.

(b) (2 marks)

Select one of the amino acids shown above, and draw it in the *Zwitterionic* form. Circle any chiral centres in your structure

12. (5 marks)

Shown below is a selection of natural products (A - N). Which of these is:

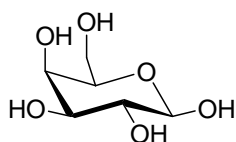
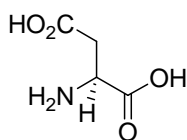
(a) A mono-unsaturated fatty acid?

(b) A pentose sugar?

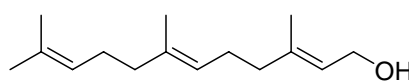
(c) A triester?

(d) A disaccharide?

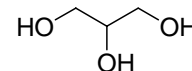
(e) A sesquiterpene?

 $\beta$ -D-Galactose (A)

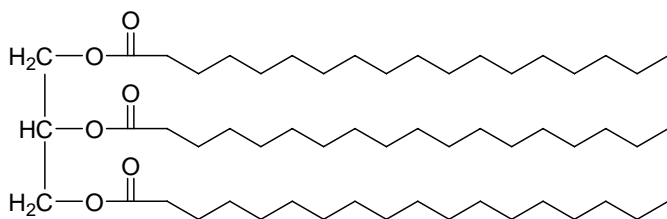
Aspartic Acid (B)



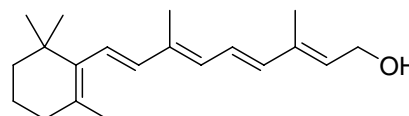
Farnesol (C)



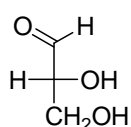
Glycerol (D)



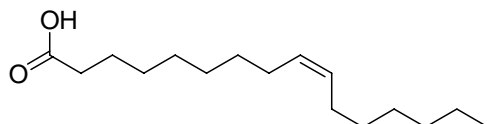
A fat (E)



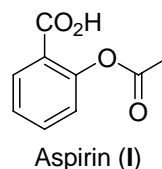
Vitamin A (F)



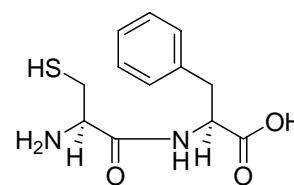
D-Glyceraldehyde (G)



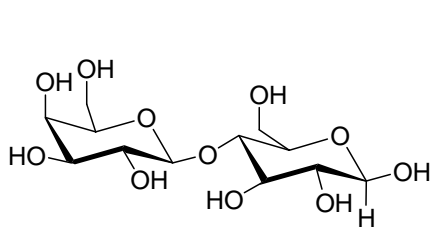
Palmitic Acid (H)



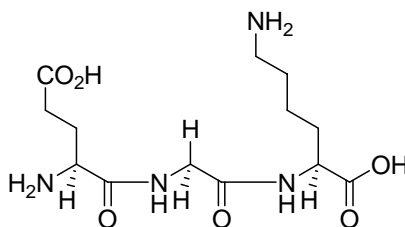
Aspirin (I)



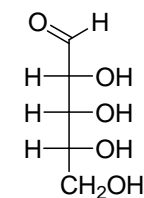
Cys-Phe (J)



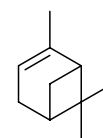
Lactose (K)



Glu-Gly-Lys (L)



D-Ribose (M)

 $\alpha$ -Pinene (N)**END OF PAPER**

## Periodic Table

1 <b>H</b> 1.008																	2 <b>He</b> 4.00
3 <b>Li</b> 6.94	4 <b>Be</b> 9.01											5 <b>B</b> 10.8	6 <b>C</b> 12.01	7 <b>N</b> 14.01	8 <b>O</b> 16.00	9 <b>F</b> 19.0	10 <b>Ne</b> 20.2
11 <b>Na</b> 23.0	12 <b>Mg</b> 24.3											13 <b>Al</b> 27.0	14 <b>Si</b> 28.1	15 <b>P</b> 31.0	16 <b>S</b> 32.1	17 <b>Cl</b> 35.5	18 <b>Ar</b> 39.9
19 <b>K</b> 39.1	20 <b>Ca</b> 40.1	21 <b>Sc</b> 45.0	22 <b>Ti</b> 47.9	23 <b>V</b> 50.9	24 <b>Cr</b> 52.0	25 <b>Mn</b> 54.9	26 <b>Fe</b> 55.9	27 <b>Co</b> 58.9	28 <b>Ni</b> 58.7	29 <b>Cu</b> 63.5	30 <b>Zn</b> 65.4	31 <b>Ga</b> 69.7	32 <b>Ge</b> 72.6	33 <b>As</b> 74.9	34 <b>Se</b> 79.0	35 <b>Br</b> 79.9	36 <b>Kr</b> 83.8
37 <b>Rb</b> 85.5	38 <b>Sr</b> 87.6	39 <b>Y</b> 88.9	40 <b>Zr</b> 91.2	41 <b>Nb</b> 92.9	42 <b>Mo</b> 95.9	43 <b>Tc</b> (99)	44 <b>Ru</b> 101.1	45 <b>Rh</b> 102.9	46 <b>Pd</b> 106.4	47 <b>Ag</b> 107.9	48 <b>Cd</b> 112.4	49 <b>In</b> 114.8	50 <b>Sn</b> 118.7	51 <b>Sb</b> 121.8	52 <b>Te</b> 127.6	53 <b>I</b> 126.9	54 <b>Xe</b> 131.3
55 <b>Cs</b> 132.9	56 <b>Ba</b> 137.3	57-71 see below	72 <b>Hf</b> 178.5	73 <b>Ta</b> 181.0	74 <b>W</b> 183.9	75 <b>Re</b> 186.2	76 <b>Os</b> 190.2	77 <b>Ir</b> 192.2	78 <b>Pt</b> 195.1	79 <b>Au</b> 197.0	80 <b>Hg</b> 200.6	81 <b>Tl</b> 204.4	82 <b>Pb</b> 207.2	83 <b>Bi</b> 209.0	84 <b>Po</b> (210)	85 <b>At</b> (210)	86 <b>Rn</b> (222)
87 <b>Fr</b> (223)	88 <b>Ra</b> (226)	89-103 see below	104 <b>Rf</b> (257)	105 <b>Db</b> (260)	106 <b>Sg</b> (263)	107 <b>Bh</b> (262)	108 <b>Hs</b> (265)	109 <b>Mt</b> (266)	110	111	112						

57 <b>La</b> 138.9	58 <b>Ce</b> 140.1	59 <b>Pr</b> 140.9	60 <b>Nd</b> 144.2	61 <b>Pm</b> (147)	62 <b>Sm</b> 150.4	63 <b>Eu</b> 152.0	64 <b>Gd</b> 157.3	65 <b>Tb</b> 158.9	66 <b>Dy</b> 162.5	67 <b>Ho</b> 164.9	68 <b>Er</b> 167.3	69 <b>Tm</b> 168.9	70 <b>Yb</b> 173.0	71 <b>Lu</b> 175.0
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89 <b>Ac</b> (227)	90 <b>Th</b> 232.0	91 <b>Pa</b> (231)	92 <b>U</b> 238.1	93 <b>Np</b> (237)	94 <b>Pu</b> (242)	95 <b>Am</b> (243)	96 <b>Cm</b> (247)	97 <b>Bk</b> (245)	98 <b>Cf</b> (251)	99 <b>Es</b> (254)	100 <b>Fm</b> (253)	101 <b>Md</b> (256)	102 <b>No</b> (254)	103 <b>Lr</b> (257)
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