THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Secondary School Mathematics & Science Competition 2015

Chemistry

Date	: 26 April, 2015	Total no. of pages	: 15
Time allowed	: 12:00 - 1:15 pm (1 hour 15 minutes)	Total marks	: 60

1. Write your Candidate Number, Exam Centre Number, Seat Number, Name in English, Name of School, Form, Language and Subject in the spaces provided on the Part A MC Answer Sheet and the Part B Answer Sheet.

2. When told to open this question paper, you should check that all the questions are there. Look for the words '**END OF PAPER**' after the last question.

3. Answer **ALL** questions in Part A (40 marks)

   (a) You are advised to use an **HB** pencil to mark all your answers on the MC Answer Sheet.

   (b) Each question carries one mark.

   (c) You should mark only **ONE** answer for each question. If you mark more than one answer, you will receive **NO MARK** for that question.

4. There are SIX questions in Part B (20 marks). Answer **ANY FIVE** questions. Answers should be written in the space provided on the Part B Answer Sheet.

5. A Periodic Table is provided on the last page of the question paper.

6. No mark will be deducted for wrong answers.

7. The diagrams in this paper are not necessarily drawn to scale.

Part A: Multiple Choice Questions (40 marks)

1) When a few pieces of copper is slowly added to a colourless solution X, the solution turns blue slowly. X might be

(1) dilute silver nitrate solution.
(2) concentrated hydrochloric acid.
(3) dilute sulphuric acid.
(4) concentrated sodium chloride solution.

A) (1) only
B) (3) only
C) (2) and (3) only
D) (3) and (4) only

2) Element **A** forms two oxides with chemical formulae $\mathbf{AO_2}$ and $\mathbf{A_2O_3}$ respectively. If two moles of $\mathbf{AO_2}$ contain **x** number of atoms, then one mole of $\mathbf{A_2O_3}$ would contain

A) $\frac{3}{5}$**x** atoms.

B) $\frac{5}{6}$**x** atoms.

C) $\frac{6}{5}$**x** atoms.

D) $\frac{5}{3}$**x** atoms.

3) Rubidium (Rb) is a group I element. Which of the following statements about Rb are **CORRECT**?

(1) It can react with steam to give out a gas.
(2) It is more reactive than sodium.
(3) It has a lower melting point than that of sodium.

A) (1) and (2) only
B) (1) and (3) only
C) (2) and (3) only
D) All of the above

4) Substance **X** is a solid at room temperature and one atmospheric pressure. In its molten state, it conducts electricity. **X** might **NOT** be

A) lead(II) sulphate.
B) iodine.
C) zinc.
D) brass.

5) Which of the following statements describes the observation **CORRECTLY** when barium is put into dilute sulphuric acid?

A) It gives a gaseous product which turns lime water milky.
B) It dissolves to give a green solution.
C) No observable change.
D) White solid is formed.

6) In an experiment, excess zinc granules are added to a solution containing silver ions and aluminium ions. After complete reaction, the reaction mixture is filtered. Which of the following statement(s) concerning the experiment is/are **CORRECT**?

(1) The residue contains aluminium metal.
(2) The residue contains silver metal.
(3) The filtrate contains zinc ions.

A) (1) only
B) (2) only
C) (1) and (3) only
D) (2) and (3) only

7) Consider the following reaction,

$$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$$

In a reaction vessel of 2.00 dm^3, analysis showed that 7.00 x 10^{-3} moles $NH_3(g)$, 7.00 x 10^{-3} moles $H_2S(g)$ and 0.693 moles $NH_4HS(s)$ were presented at the equilibrium mixture. What is the equilibrium constant of the above reaction?

A) 1.23 x 10^{-5} mol^2 dm^{-6}
B) 3.55 x 10^{-5} mol dm^{-3}
C) 7.07 x 10^{-5} mol^2 dm^{-6}
D) 4.90 x 10^{-5} mol^2 dm^{-6}

8) Consider the auto-ionization of water at equilibrium,

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq) \qquad \Delta H^\Theta = +ve$$

Upon decreasing temperature, which of the following is **CORRECT**?

A) The pH rises above 7 and water becomes alkaline.
B) The pH rises above 7 and water stays neutral.
C) The pH does not change and water stays neutral.
D) The pH does not change and water becomes alkaline.

9) Which of the following hazard warning labels should be displayed in a bottle containing crude oil?

A) 

C) 

B) 

D) 

10) Consider the information below:

Substance	Melting point (^oC)	Boiling point (^oC)
W	10	90
X	-116	34
Y	16	118
Z	-138	0

Which of the substances in the above table are liquids at room temperature and pressure?

A) W and Z only
B) W and X only
C) W, X and Y only
D) X, Y and Z only

11) A mixture of potassium hydrogencarbonate and calcium carbonate is best separated by the addition of

A) water, followed by filtration.
B) limewater, followed by evaporation.
C) dilute acid, followed by evaporation.
D) silver nitrate solution, followed by filtration.

12) Consider the enthalpy changes of the following reactions:

$2NO_2(g) + 2H_2O(g) \rightarrow 3O_2(g) + N_2H_4(g)$ $\Delta H = w$
$\frac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H = x$
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ $\Delta H = y$
$N_2(g) + 2H_2(g) \rightarrow N_2H_4(g)$ $\Delta H = z$

What is the relationship between the enthalpy changes w, x, y and z?

A) $w = 2x + 2y - z$
B) $w = x + y - 2z$
C) $w = z - x + y$
D) $w = z - 2x - 2y$

13) $H_2O_2(aq)$ decomposes into $H_2O(l)$ and $O_2(g)$ in the presence of $MnO_2(s)$. Two experiments are performed to study this decomposition reaction under the same conditions, except that 50 mL of 2 M $H_2O_2(aq)$ is used in Experiment (1), while 100 mL of 1 M $H_2O_2(aq)$ is used in Experiment (2). Which of the following combinations is **CORRECT**?

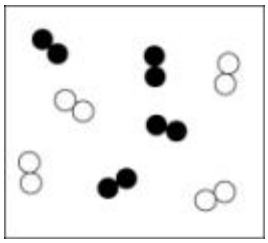
	Rate of formation of $O_2(g)$ at the start	Total volume of $O_2(g)$ formed
A)	Experiment (1) > Experiment (2)	Experiment (1) = Experiment (2)
B)	Experiment (1) > Experiment (2)	Experiment (1) > Experiment (2)
C)	Experiment (1) = Experiment (2)	Experiment (1) = Experiment (2)
D)	Experiment (1) = Experiment (2)	Experiment (1) > Experiment (2)

14) The four diagrams below represent a mixture of gases at different times at the same temperature. The equation of the reaction is shown below:

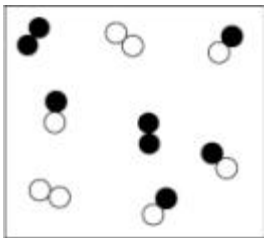
$$A_2(g) + B_2(g) \rightleftharpoons 2AB(g) \qquad \text{where } K_c = \frac{[AB(g)]_{eqm}^{\ 2}}{[A_2(g)]_{eqm}[B_2(g)]_{eqm}}$$

Which of the following diagrams has the highest value of reaction quotient?

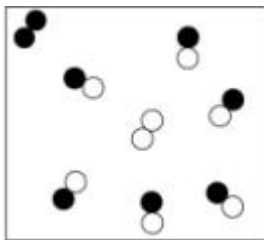
A)



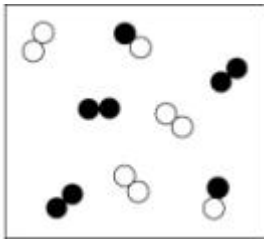
B)



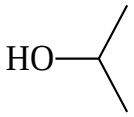
C)

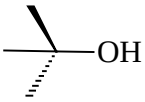


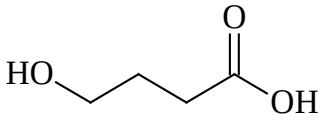
D)

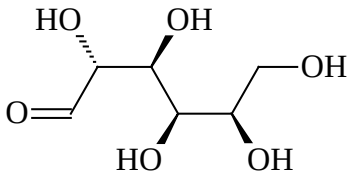


15) Compound **X** is an organic compound containing hydroxyl group(s) which can be oxidized by strong oxidizing agent (e.g. acidified potassium permanganate solution). Which of the following molecules is **NOT** compound **X**?

A) 

B) 

C) 

D) 

16) Consider that silver has only two isotopes, ^{107}Ag and ^{109}Ag. Which of the following statements about the isotopes is **INCORRECT**?

A) They can react with oxygen to form oxide.
B) The relative abundance of ^{107}Ag is 55%.
C) They have the same number of electrons.
D) They form different ions with different charge.

17) Bi is Group V element. How many electrons are in Bi^{3+}?

A) 80
B) 86
C) 206
D) 212

18) Which of the following statements about ammonium ion is **INCORRECT**?

A) It has tetrahedral shape.
B) Total number of electrons in the ammonium ion is 8.
C) The atoms are covalently bonded.
D) It can react with hot NaOH solution.

19) Which of the following has the strongest metallic bond?

A) Na
B) K
C) Ca
D) Cs

20) Which of the following does **NOT** have a giant covalent structure?

A) Silicon
B) Graphite
C) Silicon dioxide
D) C_{60}

21) Arrange the following molecules in ascending order of boiling point:

H_2O, H_2S and H_2Se

A) $H_2O < H_2S < H_2Se$
B) $H_2O < H_2Se < H_2S$
C) $H_2S < H_2Se < H_2O$
D) $H_2S < H_2O < H_2Se$

22) Equal numbers of moles of propanoic acid and ethanol are heated under reflux in the presence of concentrated sulphuric acid. Which of the following statement(s) concerning the above reaction is/are **CORRECT**?

(1) Propanoic acid, ethanol and propyl ethanoate are found in the reaction mixture.
(2) Concentrated sulphuric acid increases the rate of backward reaction.
(3) The longer the time for reaction mixture under reflux, the higher yield of the product can be obtained.

A) (2) only
B) (3) only
C) (1) and (3) only
D) (2) and (3) only

23) When chlorine gas is bubbled into an aqueous solution of a compound **X**, the solution first turns brown, and the brown colour phased out eventually. **X** could be

A) silver nitrate.
B) potassium iodide.
C) potassium sulphite.
D) sodium bromide.

24) Which of the following solutions will form white precipitates when excess ammonia solution is added?

A) Iron(II) chloride solution
B) Nickel(II) chloride solution
C) Zinc sulphate solution
D) Aluminium sulphate solution

25) The molecular formula of an acidic gas is $\mathbf{XY_2}$. If the Avogadro's Number is $\mathbf{N_A}$ mol^{-1}, how many molecules are there in 96 g of $\mathbf{XY_2}$? (Relative atomic mass of **X** : 32.0, **Y** : 16.0)

A) $\frac{1}{2}\mathbf{N_A}$

B) $\frac{3}{2}\mathbf{N_A}$

C) $\frac{4}{3}\mathbf{N_A}$

D) $\frac{5}{4}\mathbf{N_A}$

26) When carbon dioxide gas is passed into water, a colourless solution is formed. Which of the following statements concerning the solution are **CORRECT**?

(1) The electrical conductivity of the solution is increased.
(2) The solution turns phenolphthalein colourless.
(3) Limestone will be dissolved in the solution.

A) (1) and (2) only
B) (1) and (3) only
C) (2) and (3) only
D) All of the above

27) 0.800 g H_2X is dissolved in water to form a solution which requires 25.0 cm^3 of 0.500 M sodium hydroxide solution for complete neutralization. What is the relative atomic mass of X?

A) 63.0
B) 64.0
C) 126.0
D) 128.0

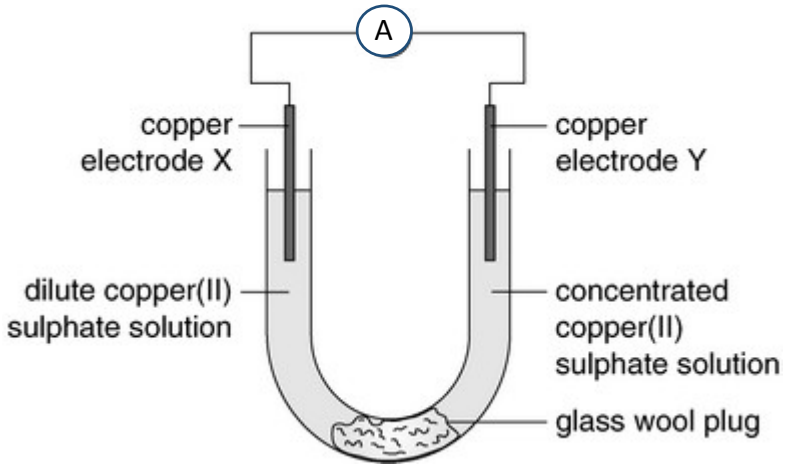
28) The following equation represents the reaction of bromine with dilute sodium hydroxide solution at room temperature:

$$Br_2(g) + 2NaOH(aq) \rightarrow NaBr(aq) + NaOBr(aq) + H_2O(l)$$

Which of the following statements concerning this reaction is **CORRECT**?

A) Bromine is oxidized and sodium hydroxide is reduced.
B) Bromine is reduced and sodium hydroxide is oxidized.
C) Bromine is served as both oxidizing agent and reducing agent.
D) Sodium hydroxide is simultaneously oxidized and reduced.

29) Consider the following set-up connected to an ammeter:



In the set-up, electrons flow in such a direction that the concentration of $Cu^{2+}(aq)$ ions on both sides becomes the same eventually.

Which of the following statements concerning the set-up are **CORRECT**?

(1) Electrode X is the anode.
(2) The mass of electrode X decreases while the mass of electrode Y increases.
(3) The glass wool plug allows electrons to flow between the two solutions.

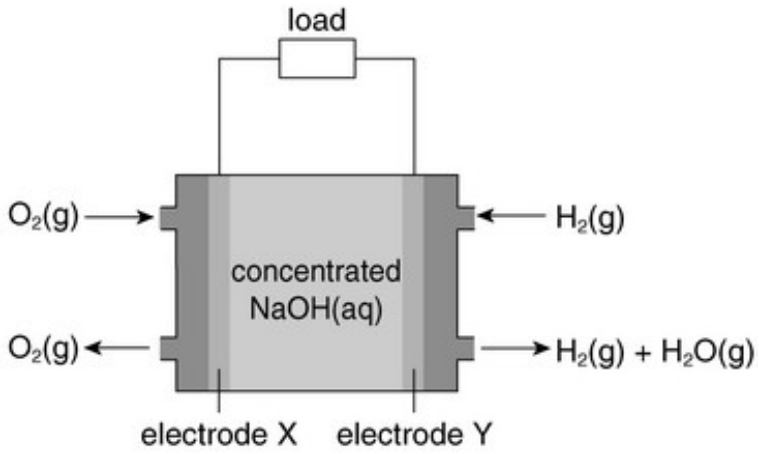
A) (1) and (2) only
B) (1) and (3) only
C) (2) and (3) only
D) All of the above

30) Which of the following reactions will give an observable colour change?

(1) Adding sodium sulphite solution to aqueous bromine.
(2) Adding concentrated nitric acid to copper.
(3) Adding silver granules to aqueous copper(II) chloride solution.

A) (1) only
B) (3) only
C) (1) and (2) only
D) (2) and (3) only

31) The following diagram shows a fuel cell. Hydrogen and oxygen are passed into the fuel cell.



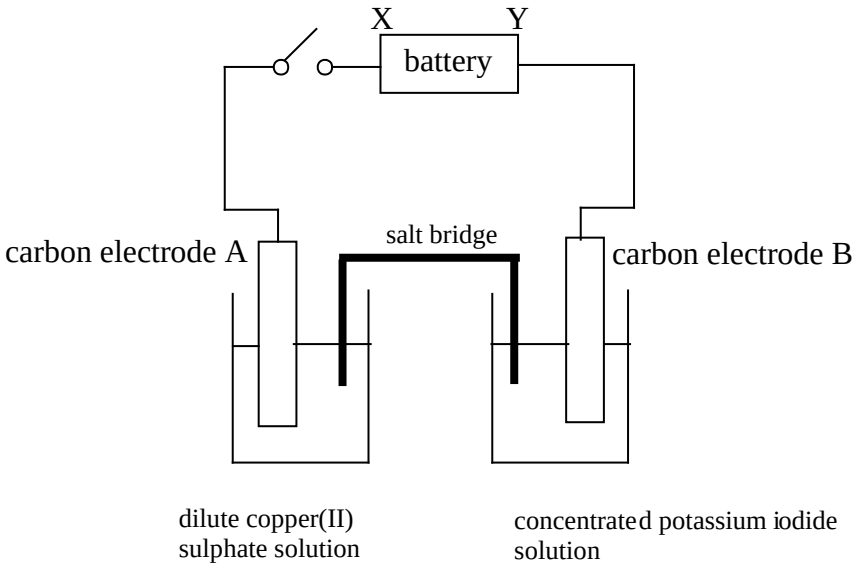
Which one of the following combinations is **CORRECT**?

	Chemical reaction that occurs at electrode X	Hydroxide ions move towards
A)	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	X
B)	$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$	X
C)	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	Y
D)	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	Y

32) Which of the following electrolytes, using graphite as electrodes, will liberate gaseous products at **BOTH** electrodes under electrolysis?

A) Molten sodium chloride
B) Dilute copper(II) chloride solution
C) Dilute sodium sulphate solution
D) Concentrated silver nitrate solution

33) A colourless gas is given off from electrode A when the circuit below is completed.



Which of the following combinations is **CORRECT**?

	Carbon electrode A	Carbon electrode B	X
A)	Anode	Cathode	Negative terminal
B)	Anode	Cathode	Positive terminal
C)	Cathode	Anode	Negative terminal
D)	Cathode	Anode	Positive terminal

34) Which of the following elements in the third period of the Periodic table is the strongest reducing agent?

A) Sodium
B) Aluminium
C) Chlorine
D) Argon

35) Polyethene is a kind of addition polymer. Which of the following statements about polyethene is **CORRECT**?

A) Polyethene decomposes to form ethene under high temperature and pressure.
B) Polyethene decolourizes bromine solution.
C) The empirical formula of polyethene is CH_2.
D) Polyethene is biodegradable.

36) In the chemical industry, ethanoic acid is manufactured by the following route:

$$\text{Compound X} \xrightarrow{1} \text{ethene} \xrightarrow{2} \text{ethanol} \xrightarrow{3} \text{ethanoic acid}$$

What are the three processes?

	1	2	3
A)	cracking	hydration	oxidation
B)	cracking	halogenation	hydration
C)	fractional distillation	halogenation	oxidation
D)	fractional distillation	oxidation	hydration

37) The empirical formula of an organic compound X is C_2H_4O. Which of the following compound(s) **COULD** be the compound X?

(1) Butanoic acid
(2) Butan-1-ol
(3) Ethanal
(4) Ethanol

A) (1) only
B) (2) and (4) only
C) (2) and (3) only
D) (1) and (3) only

38) Vegetable oil contains some unsaturated compounds. Which of the following statements about vegetable oil is **CORRECT**?

A) There are double bonds between carbon and hydrogen atoms.
B) It reacts with hydrogen gas to form compounds with higher melting point than the starting material.
C) It reacts with steam to form margarine.
D) It turns bromine solution from colourless to brown.

39) Which of the following processes does **NOT** form **BOTH** carbon dioxide and water as products?

(1) Adding sodium carbonate to dilute hydrochloric acid solution.
(2) Burning ethanol.
(3) Thermal decomposition of hydrated calcium carbonate.

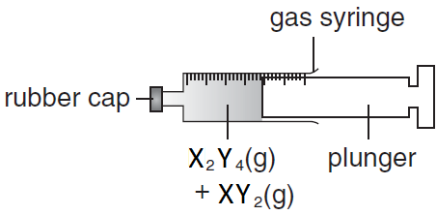
A) (1) only
B) (2) only
C) (3) only
D) None of the above

40) At room temperature, $X_2Y_4(g)$ and $XY_2(g)$ exist in equilibrium as follows:

$$X_2Y_4(g) \rightleftharpoons 2XY_2(g)$$

Pale red Dark brown

A gas syringe is filled with a pale brown mixture of $X_2Y_4(g)$ and $XY_2(g)$ at equilibrium.



What would be observed when the plunger is quickly pushed inward?

A) The mixture becomes pale.
B) The mixture becomes darken.
C) The mixture first lightens, and then becomes darken.
D) The mixture first darkens, and then becomes pale.

Part B: Short Questions (20 marks) (Answer ANY FIVE questions in this part)

41) Motor cars powered by petrol emit air pollutants such as nitrogen monoxide and carbon monoxide. Installing a device in motor cars converts these two oxides to less harmful substances.

The equation for the reaction involved in the conversion is shown below:

$$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g) \quad \text{——— (1)}$$

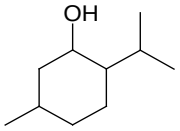
The standard enthalpy changes of formation of NO(g), CO(g) and CO_2(g) are as follows:

Compound	$\triangle H_f^{\ominus}$/ kJ mol^{-1}
NO(g)	+90.3
CO(g)	-110.5
CO_2(g)	-394.0

(a) Define the term of 'standard enthalpy changes of formation'. (1 mark)

(b) Calculate the standard enthalpy change of the above reaction (1). (3 marks)

42) Menthol is a naturally occurring alcohol with a pleasant and minty odour. Its structure is shown below:

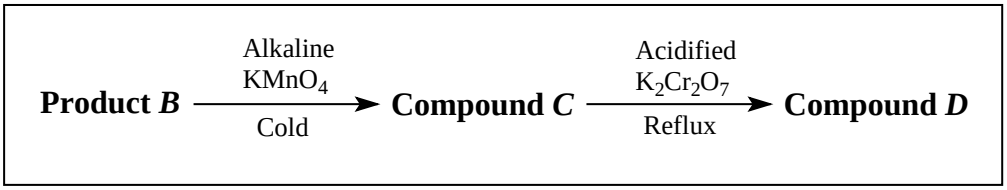


When menthol is heated under concentrated sulphuric acid, two products are formed. It is found that both products are optically active whereas **Product *A*** is the major product and **Product *B*** is the minor product.

(a) Name the reaction. (1 mark)

(b) Draw the structure of Product B. (1 mark)

(c) Study the following synthetic pathway. Draw the structure for Compound C and Compound D. (2 marks)



43) (a) Write an equation for the reaction between calcium and water. (1 mark)

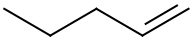
(b) Consider the reaction between zinc and silver nitrate solution.

(i) Write an ionic equation for the reaction (1 mark)

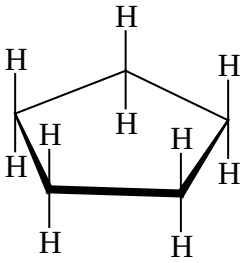
(ii) Name the type of the above reaction. (1 mark)

(iii) 6.50 g of zinc is used in the reaction. Calculate the mass of silver produced. (1 mark)

44) Both 1-pentene and cyclopentane have the molecular formula C_5H_{10}.



1-pentene



cyclopentane

Under suitable conditions, both 1-pentene and cyclopentane can react with chlorine in organic solvent.

(a) State the type of the reaction between chlorine and 1-pentene. (1 mark)

(b) Name the product of the reaction between chlorine and 1-pentene. (1 mark)

(c) When cyclopentane reacts with chlorine, five different compounds with the molecular formula $C_5H_8Cl_2$ could be formed. Draw one of the structural formula of these five compounds. (1 mark)

(d) What is the reaction condition for the reaction between chlorine and cyclopentane in organic solvent? (1 mark)

45) 17.0 mL of 0.470 M hydrochloric acid solution is put in a 2.50×10^2 mL conical flask. An indicator methyl orange is added to the acid for observing the end-point. 19.0 mL of 0.410 M of sodium hydroxide solution is then added to the acid solution.

(a) Which of the species is used in excess? (1 mark)

(b) What is the colour of the resulting solution? (1 mark)

(c) Calculate the pH of the resulting solution. (2 marks)

46) Bromine is a volatile liquid while sodium bromide is a white crystal at room temperature and one atmospheric pressure.

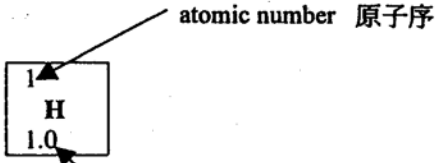
(a) Explain the difference of their melting points according to their structures. (2 marks)

(b) State and explain the electrical conductivity of liquid bromine and liquid sodium bromide respectively. (2 marks)

END OF PAPER

PERIODIC TABLE 週期表

GROUP 族



I	II											III	IV	V	VI	VII	0
																	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3											13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 40.0
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.8	27 Co 58.9	28 Ni 58.7	29 Cu 63.5	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 95.9	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 * La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 ** Ac (227)	104 Rf (261)	105 Db (262)													

*	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
**	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)