UNIVERSITI SAINS MALAYSIA

Final Examination
Academic Session 2007/2008

April 2008

# JIK 218 – SYSTEMATIC CHEMISTRY AND NUCLEUS CHEMISTRY
## *[KIMIA BERSISTEM DAN KIMIA NUKLEUS]*

Duration : 3 hours
*[Masa : 3 jam]*

Please ensure that this examination paper contains NINE printed pages before you begin the examination.

Answer **FIVE** questions. You may answer **either** in Bahasa Malaysia or in English.

All answers must be written in the answer booklet provided.

Each questions is worth 20 marks and the marks for each sub question is given at the end of that question.

*Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN muka surat yang bercetak sebelum anda memulakan peperiksaan ini.*

*Jawab **LIMA** soalan. Anda dibenarkan menjawab soalan **sama ada** dalam Bahasa Malaysia atau Bahasa Inggeris.*

*Setiap jawapan mesti dijawab di dalam buku jawapan yang disediakan.*

*Setiap soalan bernilai 20 markah dan markah subsoalan diperlihatkan di penghujung subsoalan itu.*

1. (a) Account for each of the following observations :

(i) The first ionization energy of K is lower than that of Li.
(ii) The trend of the first ionization energy decreases on going from N to O.
(iii) Size of ions increase as one proceeds down a group in the periodic table.
(iv) The electron affinity of Li is a negative value, whereas the electron affinity of Be is a positive value.

*Jelaskan setiap pemerhatian berikut :*

*(i) Tenaga pengionan pertama K lebih rendah dari Li.*
*(ii) Tren tenaga pengionan pertama semakin kurang dari N ke O.*
*(iii) Saiz ion bertambah apabila menuruni sesuatu kumpulan dalam jadual berkala.*
*(iv) Cita elektron Li bernilai negatif, manakala cita elektron Be bernilai positif.*

(12 marks)

(b) Predict whether each of the following oxides is acidic, basic, amphoteric, or neutral :

(i) $NO_2$
(ii) $CO_2$
(iii) BaO
(iv) $Al_2O_3$

Write chemical equations to show the acid-base and amphotheric characters of the oxide to support your prediction.

*Ramalkan sama ada setiap oksida berikut berasid, berbes, amfoterik atau neutral :*

*(i)* $NO_2$
*(ii)* $CO_2$
*(iii)* $BaO$
*(iv)* $Al_2O_3$

*Tuliskan persamaan kimia yang menunjukkan sifat asid-bes dan amfoterik oksida tersebut untuk menyokong ramalan anda.*

(8 marks)

2. (a) How does the structure of graphite account for

(i) its use as a lubricant,
(ii) its use as electrodes, and
(iii) the fact that diamond is the more stable allotrope at very high pressure?

*Bagaimanakah struktur grafit menjelaskan*

*(i) kegunaannya sebagai pelincir,*
*(ii) kegunaannya sebagai elektrod, dan*
*(iii) fakta yang menyatakan intan adalah alotrop lebih stabil pada tekanan yang tinggi?*

(4 marks)

(b) Predict the shape of the following molecules or ions :

(i) ClCN
(ii) $[PbCl_6]^{2-}$
(iii) $[SiH_3]^-$
(iv) $[SnCl_5]^-$.

*Ramalkan rupabentuk molekul atau ion berikut :*

*(i) ClCN*
*(ii)* $[PbCl_6]^{2-}$
*(iii)* $[SiH_3]^-$
*(iv)* $[SnCl_5]^-$.

(8 marks)

(c) Explain the following observations :

(i) $HNO_3$ is a stronger oxidizing agent than $H_3PO_4$.
(ii) Silicon can form an ion with six fluorine atoms, $SiF_6^{2-}$, whereas carbon is able to bond to a maximum of four, $CF_4$.
(iii) $AsH_3$ is a stronger reducing agent than $NH_3$.
(iv) Xenon forms stable compounds with fluorine, whereas argon does not.

*Jelaskan pemerhatian berikut :*

*(i)* *$HNO_3$ adalah agen pengoksidaan yang lebih kuat daripada $H_3PO_4$.*

*(ii)* *Silikon boleh membentuk suatu ion dengan enam atom fluorin, $SiF_6^{2-}$, manakala karbon hanya mampu membentuk ikatan maksima empat, $CF_4$.*

*(iii)* *$AsH_3$ ialah agen penurunan yang lebih kuat daripda $NH_3$.*

*(iv)* *Xenon membentuk sebatian yang stabil dengan fluorin, manakala argon tidak.*

(8 marks)

3. (a) Write a balance equation for the preparation of $H_2$ using

(i) magnesium and an acid
(ii) carbon and steam
(iii) methane and steam.

*Tulis persamaan berimbang untuk penyedian $H_2$ menggunakan*

*(i)* *magnesium dan suatu asid*
*(ii)* *karbon dan stim*
*(iii)* *metana dan stim.*

(6 marks)

(b) Account for each of the following observations :

(i) The $[TeF_5]^-$ ion is square pyramidal.
(ii) Phosphorus forms a pentachloride, but nitrogen does not.
(iii) $H_3PO_2$ is a monoprotic acid.
(iv) White phosphorus is extremely reactive.

*Jelaskan setiap pemerhatian berikut :*

*(i)* *Ion $[TeF_5]^-$ ialah piramid persegi.*
*(ii)* *Fosforus membentuk pentaklorida, tetapi nitrogen tidak.*
*(iii)* *$H_3PO_2$ ialah asid monoprotik.*
*(iv)* *Fosforus putih tersangat reaktif.*

(8 marks)

(c) Suggest why the H—X—H bond angles in $NH_3$, $PH_3$, $AsH_3$, and $SbH_3$ decrease from 107° for $NH_3$ to 93° for $PH_3$, 92° for $AsH_3$, and 91° for $SbH_3$.

*Cadangkan kenapa sudut ikatan H—X—H di dalam $NH_3$, $PH_3$, $AsH_3$, and $SbH_3$ berkurang daripada 107° untuk $NH_3$ kepada 93° untuk $PH_3$, 92° untuk $AsH_3$, dan 91° untuk $SbH_3$.*

(6 marks)

4. (a) Write balanced nuclear equations for the following processes :

(i) bismuth-214 undergoes beta decay
(ii) gold-195 undergoes electron capture
(iii) potassium-38 undergoes positron emission
(iv) plutonium-242 emits alpha radiation
(v) gold-201 decays to a mercury isotope.

*Tuliskan persamaan berimbang untuk proses-proses berikut :*

*(i) bismut-214 mengalami pereputan beta*
*(ii) aurum-195 mengalami proses penangkapan elekron*
*(iii) kalium-38 mengalami proses pemancaran positron*
*(iv) plutonium-242 memancar radiasi alfa*
*(v) aurum-201 mereput kepada isotop merkuri.*

(6 marks)

(b) Which of the following nuclides of group 16 elements would you expect to be radioactive?

$$^{4}_{8}O,\ ^{32}_{16}S,\ ^{78}_{34}Se,\ ^{115}_{52}Te,\ \text{or}\ ^{208}_{84}Po$$

Justify your choices.

*Yang manakah antara nuklid kumpulan 16 yang berikut yang anda jangka beradioaktif?*

$$^{4}_{8}O,\ ^{32}_{16}S,\ ^{78}_{34}Se,\ ^{115}_{52}Te,\ \text{or}\ ^{208}_{84}Po$$

*Berikan alasan kepada jawapan anda.*

(6 marks)

(c) How much energy must be supplied to break a single sodium-23 nucleus into separated protons and neutrons if the nucleus has a mass of 22.983733 amu? How much energy is required per mole of this nucleus?

*Berapa banyak tenaga yang perlu dibekalkan untuk memisahkan satu nukleus natrium-23 kepada proton dan neutron jika jisim nukleus ialah 22.983733 amu? Berapakah tenaga yang diperlukan per mol nukleus tersebut?*

(8 marks)

5. (a) (i) List three industrial uses of $O_2$ and two industrial uses of $O_3$.
(ii) Draw the Lewis structure of ozone. Explain why the O—O bond (1.28 Å) is longer in ozone than in $O_2$ (1.21Å).

*(i) Senaraikan tiga kegunaan $O_2$ dan dua kegunan $O_3$ dalam industri.*
*(ii) Lukiskan struktur ozon. Jelaskan kenapa ikatan O—O (1.28 Å) lebih panjang di dalam $O_3$ daripada di dalam $O_2$ (1.21Å).*

(6 marks)

(b) (i) Write a brief account of the chemistry of the xenon fluorides.

*Tulis nota ringkas tentang kimia xenon fluorida.*

(6 marks)

(ii) Predict the structures of $[XeO_6]^{4-}$, $XeOF_2$, $XeOF_4$, and $XeO_2F_2$.

*Ramalkan struktur $[XeO_6]^{4-}$, $XeOF_2$, $XeOF_4$ dan $XeO_2F_2$.*

(8 marks)

6. (a) The oxidation of methanol to formaldehyde can be accomplished by reaction with chromic acid :

$$6H^+(aq) + 3CH_3OH(aq) + 2H_2CrO_4(aq) \longrightarrow 3CH_2O(aq) + 2Cr^{3+}(aq) + 8H_2O(l)$$

The reaction can be studied with the stable isotope tracer $^{18}O$ and mass spectrometry. When a small amount of $CH_3{}^{18}OH$ is present in the alcohol reactant, $H_2C^{18}O$ forms. When a small amount of $H_2Cr^{18}O_4$ is present, $H_2{}^{18}O$ forms. Does chromic acid or methanol supply the O atom to the aldehyde? Explain.

*Pengoksidaan metanol kepada formaldehid boleh dilaksanakan melalui tindakbalas dengan asid kromik :*

$6H^{+}(ak) + 3CH_3OH(ak) + 2H_2CrO_4(ak) \longrightarrow 3CH_2O(ak) + 2Cr^{3+}(ak) + 8H_2O(c)$

*Tindakbalas tersebut boleh dikaji dengan penyureh $^{18}O$ dan spektrometri jisim. Apabila sedikit $CH_3{}^{18}OH$ wujud dalam reaktan alkohol, $H_2C^{18}O$ terbentuk. Apabila sedikit $H_2Cr^{18}O_4$ wujud, $H_2{}^{18}O$ terbentuk. Adakah asid kromik atau metanol yang membekalkan atom O kepada aldehid? Jelaskan.*

(10 marks)

(b) A wooden artifact from a Chinese temple has a $^{14}C$ activity of 24.9 counts per minute as compared with an activity of 32.5 counts per minute for a standard of zero age. From the half-life for $^{14}C$ decay, 5715 yr, determine the age of the artifact.

*Suatu artifak kayu dari kuil China mempunyai aktiviti 24.9 kiraan per minit berbanding dengan 32.5 kiraan per minit bagi suatu piawai umur zero. Daripada tempoh separuh hayat pereputan $^{14}C$, 5715 tahun, tentukan umur artifak tersebut.*

(10 marks)

## FUNDAMENTAL CONSTANTS*

| | | | |
|---|---|---|---|
| Atomic mass unit | 1 amu | = | $1.66053873 \times 10^{-24}$ g |
| | 1 g | = | $6.02214199 \times 10^{23}$ amu |
| Avogadro's number | $N$ | = | $6.02214199 \times 10^{23}$ / mol |
| Boltzmann's constant | $k$ | = | $1.3806503 \times 10^{-23}$ J/K |
| Electron charge | $e$ | = | $1.602176462 \times 10^{-19}$ C |
| Faraday's constant | $F$ | = | $9.64853415 \times 10^{4}$ C/mol |
| Gas constant | $R$ | = | 0.082058205 L-atm/ mol-K |
| Mass of electron | $m_e$ | = | $5.485799 \times 10^{-4}$ amu |
| | | = | $9.10938188 \times 10^{-28}$ g |
| Mass of neutron | $m_n$ | = | 1.0086649 amu |
| | | = | $1.67492716 \times 10^{-24}$ g |
| Mass of proton | $m_p$ | = | 1.0072765 amu |
| | | = | $1.67262158 \times 10^{-24}$ g |
| Pi | $\pi$ | = | 3.1415927 |
| Planck's constant | $h$ | = | $6.62606876 \times 10^{-34}$ J–s |
| Speed of light | $c$ | = | $2.99792458 \times 10^{8}$ m/s |

# WebElements: the periodic table on the world-wide web

www.webelements.com

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| hydrogen 1 H 1.0079 | | | | | | | | | | | | | | | | | helium 2 He 4.0026 |
| lithium 3 Li 6.941 | beryllium 4 Be 9.0122 | | | | | | | | | | | boron 5 B 10.811 | carbon 6 C 12.011 | nitrogen 7 N 14.007 | oxygen 8 O 15.999 | fluorine 9 F 18.998 | neon 10 Ne 20.180 |
| sodium 11 Na 22.990 | magnesium 12 Mg 24.305 | | | | | | | | | | | aluminium 13 Al 26.982 | silicon 14 Si 28.086 | phosphorus 15 P 30.974 | sulfur 16 S 32.065 | chlorine 17 Cl 35.453 | argon 18 Ar 39.948 |
| potassium 19 K 39.098 | calcium 20 Ca 40.078 | scandium 21 Sc 44.956 | titanium 22 Ti 47.867 | vanadium 23 V 50.942 | chromium 24 Cr 51.996 | manganese 25 Mn 54.938 | iron 26 Fe 55.845 | cobalt 27 Co 58.933 | nickel 28 Ni 58.693 | copper 29 Cu 63.546 | zinc 30 Zn 65.38 | gallium 31 Ga 69.723 | germanium 32 Ge 72.61 | arsenic 33 As 74.922 | selenium 34 Se 78.96 | bromine 35 Br 79.904 | krypton 36 Kr 83.80 |
| rubidium 37 Rb 85.468 | strontium 38 Sr 87.62 | yttrium 39 Y 88.906 | zirconium 40 Zr 91.224 | niobium 41 Nb 92.906 | molybdenum 42 Mo 95.96 | technetium 43 Tc [98] | ruthenium 44 Ru 101.07 | rhodium 45 Rh 102.91 | palladium 46 Pd 106.42 | silver 47 Ag 107.87 | cadmium 48 Cd 112.41 | indium 49 In 114.82 | tin 50 Sn 118.71 | antimony 51 Sb 121.76 | tellurium 52 Te 127.60 | iodine 53 I 126.90 | xenon 54 Xe 131.29 |
| caesium 55 Cs 132.91 | barium 56 Ba 137.33 | 57-70 * | lutetium 71 Lu 174.97 | hafnium 72 Hf 178.49 | tantalum 73 Ta 180.95 | tungsten 74 W 183.84 | rhenium 75 Re 186.21 | osmium 76 Os 190.23 | iridium 77 Ir 192.22 | platinum 78 Pt 195.08 | gold 79 Au 196.97 | mercury 80 Hg 200.59 | thallium 81 Tl 204.38 | lead 82 Pb 207.2 | bismuth 83 Bi 208.98 | polonium 84 Po [209] | astatine 85 At [210] | radon 86 Rn [222] |
| francium 87 Fr [223] | radium 88 Ra [226] | 89-102 ** | lawrencium 103 Lr [262] | rutherfordium 104 Rf [267] | dubnium 105 Db [268] | seaborgium 106 Sg [271] | bohrium 107 Bh [272] | hassium 108 Hs [270] | meitnerium 109 Mt [276] | darmstadtium 110 Ds [281] | roentgenium 111 Rg [280] | ununbium 112 Uub [285] | ununtrium 113 Uut [284] | ununquadium 114 Uuq [289] | ununpentium 115 Uup [288] | ununhexium 116 Uuh [293] | ununseptium 117 Uus — | ununoctium 118 Uuo [294] |

Key: element name / atomic number / symbol / atomic weight (mean relative mass)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *lanthanoids | lanthanum 57 La 138.91 | cerium 58 Ce 140.12 | praseodymium 59 Pr 140.91 | neodymium 60 Nd 144.24 | promethium 61 Pm [145] | samarium 62 Sm 150.36 | europium 63 Eu 151.96 | gadolinium 64 Gd 157.25 | terbium 65 Tb 158.93 | dysprosium 66 Dy 162.50 | holmium 67 Ho 164.93 | erbium 68 Er 167.26 | thulium 69 Tm 168.93 | ytterbium 70 Yb 173.06 |
| **actinoids | actinium 89 Ac [227] | thorium 90 Th 232.04 | protactinium 91 Pa 231.04 | uranium 92 U 238.03 | neptunium 93 Np [237] | plutonium 94 Pu [244] | americium 95 Am [243] | curium 96 Cm [247] | berkelium 97 Bk [247] | californium 98 Cf [251] | einsteinium 99 Es [252] | fermium 100 Fm [257] | mendelevium 101 Md [258] | nobelium 102 No [259] |

**Symbols and names:** the symbols and names of the elements, and their spellings are those recommended by the International Union of Pure and Applied Chemistry (IUPAC - http://www.iupac.org/). Names have yet to be proposed for the most recently discovered elements beyond 112 and so those used here are IUPAC's temporary systematic names. In the USA and some other countries, the spellings **aluminum** and **cesium** are normal while in the UK and elsewhere the common spelling is **sulphur**.
**Group labels:** the numeric system (1–18) used here is the current IUPAC convention.
**Atomic weights (mean relative masses):** Apart from the heaviest elements, these are the IUPAC 2007 values and given to 5 significant figures. Elements for which the atomic weight is given within square brackets have no stable nuclides and are represented by the element's longest lived isotope reported at the time of writing.