IBO   IB DIPLOMA PROGRAMME
       PROGRAMME DU DIPLÔME DU BI
       PROGRAMA DEL DIPLOMA DEL BI

CHEMISTRY
HIGHER LEVEL
PAPER 1

Friday 7 November 2003 (afternoon)

1 hour

INSTRUCTIONS TO CANDIDATES

• Do not open this examination paper until instructed to do so.
• Answer all the questions.
• For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.

883-152

The Periodic Table

Key: Atomic Number / Element / Atomic Mass

1	2		3	4	5	6	7	0
1 **H** 1.01								2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01		5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31		13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96 … 30 **Zn** 65.37	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91 … 48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.34	57† **La** 138.91 … 80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89‡ **Ac** (227)						

Transition metals (Period 4): 21 **Sc** 44.96, 22 **Ti** 47.90, 23 **V** 50.94, 24 **Cr** 52.00, 25 **Mn** 54.94, 26 **Fe** 55.85, 27 **Co** 58.93, 28 **Ni** 58.71, 29 **Cu** 63.55, 30 **Zn** 65.37

Transition metals (Period 5): 39 **Y** 88.91, 40 **Zr** 91.22, 41 **Nb** 92.91, 42 **Mo** 95.94, 43 **Tc** 98.91, 44 **Ru** 101.07, 45 **Rh** 102.91, 46 **Pd** 106.42, 47 **Ag** 107.87, 48 **Cd** 112.40

Transition metals (Period 6): 72 **Hf** 178.49, 73 **Ta** 180.95, 74 **W** 183.85, 75 **Re** 186.21, 76 **Os** 190.21, 77 **Ir** 192.22, 78 **Pt** 195.09, 79 **Au** 196.97, 80 **Hg** 200.59

† Lanthanides:

58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.35	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97

‡ Actinides:

| 90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

1. Which solution contains the smallest amount of H^+ ions?

    A. 10.0 cm^3 of $0.250 \text{ mol dm}^{-3}$ HCl

    B. 20.0 cm^3 of $0.250 \text{ mol dm}^{-3}$ HCl

    C. 10.0 cm^3 of $0.500 \text{ mol dm}^{-3}$ HCl

    D. 10.0 cm^3 of $0.250 \text{ mol dm}^{-3}$ H_2SO_4

2. A hydrocarbon contains 90 % by mass of carbon. What is its empirical formula?

    A. CH_2

    B. C_3H_4

    C. C_7H_{10}

    D. C_9H_{10}

3. Lithium hydroxide reacts with carbon dioxide as follows.

$$2LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O$$
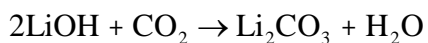
What mass (in grams) of lithium hydroxide is needed to react with 11 g of carbon dioxide?

    A.   6

    B.   12

    C.   24

    D.   48

4. Which statement is correct for the emission spectrum of the hydrogen atom?

   A.   The lines converge at lower energies.

   B.   The lines are produced when electrons move from lower to higher energy levels.

   C.   The lines in the visible region involve electron transitions into the energy level closest to the nucleus.

   D.   The line corresponding to the greatest emission of energy is in the ultraviolet region.

5. What is the correct sequence for the processes occurring in a mass spectrometer?

   A.   vaporization, ionization, acceleration, deflection

   B.   vaporization, acceleration, ionization, deflection

   C.   ionization, vaporization, acceleration, deflection

   D.   ionization, vaporization, deflection, acceleration

6. Which pair would react together most vigorously?

   A.   Li and Cl_2

   B.   Li and Br_2

   C.   K and Cl_2

   D.   K and Br_2

7. Which properties of period 3 elements increase from sodium to argon?

   I.   Nuclear charge
   II.   Atomic radius
   III. Electronegativity

   A.   I and II only

   B.   I and III only

   C.   II and III only

   D.   I, II and III

8. Which general trends are correct for the oxides of the period 3 elements (Na_2O to Cl_2O)?

      I.   Acid character decreases.

      II.   Electrical conductivity (in the molten state) decreases.

      III.   Bonding changes from ionic to covalent.

    A.   I and II only

    B.   I and III only

    C.   II and III only

    D.   I, II and III

9. Which is the correct description of polarity in F_2 and HF molecules?

    A.   Both molecules contain a polar bond.

    B.   Neither molecule contains a polar bond.

    C.   Both molecules are polar.

    D.   Only one of the molecules is polar.

10. Which types of bonding are present in CH_3CHO in the liquid state?

      I.   Single covalent bonding

      II.   Double covalent bonding

      III.   Hydrogen bonding

    A.   I and II only

    B.   I and III only

    C.   II and III only

    D.   I, II and III

11. Which of the following increase(s) for the bonding between carbon atoms in the sequence of molecules C_2H_6, C_2H_4 and C_2H_2 ?

     I.   Number of bonds

     II.   Length of bonds

     III.   Strength of bonding

A.   I only

B.   I and III only

C.   III only

D.   I, II and III

12. Which of the following contain a bond angle of $90°$?

     I. PCl_4^+

     II. PCl_5

     III. PCl_6^-

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

13. Which allotropes contain carbon atoms with sp^2 hybridization?

     I.   Diamond

     II.   Graphite

     III. C_{60} fullerene

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

14. Which change in conditions would increase the volume of a fixed mass of gas?

	Pressure / kPa	Temperature / K
A.	Doubled	Doubled
B.	Halved	Halved
C.	Doubled	Halved
D.	Halved	Doubled

15. The average bond enthalpies for O—O and O==O are 146 and 496 kJ mol^{-1} respectively. What is the enthalpy change, in kJ, for the reaction below?

$$H—O—O—H(g) \rightarrow H—O—H(g) + \tfrac{1}{2}O{=}{=}O(g)$$
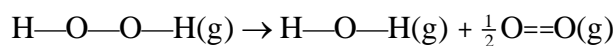
A.   – 102

B.   + 102

C.   + 350

D.   + 394

16. Which reaction has the greatest positive entropy change?

A. $CH_4(g) + 1\tfrac{1}{2}O_2(g) \rightarrow CO(g) + 2H_2O(g)$

B. $CH_4(g) + 1\tfrac{1}{2}O_2(g) \rightarrow CO(g) + 2H_2O(l)$

C. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

D. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

17. What is the energy change (in kJ) when the temperature of 20 g of water increases by 10 °C?

    A. $20 \times 10 \times 4.18$

    B. $20 \times 283 \times 4.18$

    C. $\dfrac{20 \times 10 \times 4.18}{1000}$

    D. $\dfrac{20 \times 283 \times 4.18}{1000}$

18. The lattice enthalpy values for lithium fluoride and calcium fluoride are shown below.

$$LiF(s) \quad \Delta H^{\ominus} = +1022 \text{ kJ mol}^{-1}$$
$$CaF_2(s) \quad \Delta H^{\ominus} = +2602 \text{ kJ mol}^{-1}$$
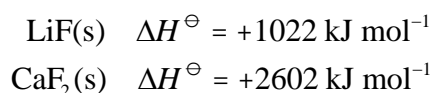
Which of the following statements help(s) to explain why the value for lithium fluoride is less than that for calcium fluoride?

    I.   The ionic radius of lithium is less than that of calcium.

    II.   The ionic charge of lithium is less than that of calcium.

    A.   I only

    B.   II only

    C.   I and II

    D.   Neither I nor II

19. The rate of a reaction between two gases increases when the temperature is increased and a catalyst is added. Which statements are both correct for the effect of these changes on the reaction?

	Increasing the temperature	Adding a catalyst
A.	Collision frequency increases	Activation energy increases
B.	Activation energy increases	Activation energy does not change
C.	Activation energy does not change	Activation energy decreases
D.	Activation energy increases	Collision frequency increases

20. The rate expression for a reaction is shown below.

rate = $k[A]^2[B]^2$

Which statements are correct for this reaction?

I.   The reaction is second order with respect to both A and B.

II.   The overall order of the reaction is 4.

III. Doubling the concentration of A would have the same effect on the rate of reaction as doubling the concentration of B.

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

21. The rate of a reversible reaction is altered by the addition of a heterogeneous catalyst. Which statement correctly describes the role of the catalyst?

A.   It alters the enthalpy change of the reaction.

B.   It decreases the activation energy of the forward reaction.

C.   It increases the activation energy of the reverse reaction.

D.   It increases the rate of the forward reaction but decreases the rate of the reverse reaction.

22. What will happen to the position of equilibrium and the value of the equilibrium constant when the temperature is increased in the following reaction?

$$Br_2(g) + Cl_2(g) \rightleftharpoons 2BrCl(g) \qquad \Delta H = +14 \text{ kJ}$$

	Position of equilibrium	**Value of equilibrium constant**
A.	Shifts towards the reactants	Decreases
B.	Shifts towards the reactants	Increases
C.	Shifts towards the products	Decreases
D.	Shifts towards the products	Increases

Turn over

23. A liquid and its vapour are at equilibrium inside a sealed container. Which change would alter the equilibrium vapour pressure of the liquid in the container?

    A.   Adding more liquid

    B.   Adding more vapour

    C.   Decreasing the volume of the container

    D.   Decreasing the temperature

24. Which of the following is/are formed when a metal oxide reacts with a dilute acid?

        I.   A metal salt

        II.   Water

        III.   Hydrogen gas

    A.   I only

    B.   I and II only

    C.   II and III only

    D.   I, II and III

25. Which is a conjugate acid-base pair in the following reaction?

$$HNO_3 + H_2SO_4 \rightleftharpoons H_2NO_3^+ + HSO_4^-$$
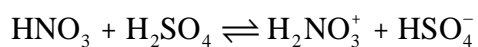
    A. HNO_3 and H_2SO_4

    B. HNO_3 and $H_2NO_3^+$

    C. HNO_3 and HSO_4^-

    D. $H_2NO_3^+$ and HSO_4^-

26. Which equation represents an acid-base reaction according to the Lewis theory **but** not the Brønsted-Lowry theory?

A. $NH_3 + HCl \rightleftharpoons NH_4Cl$

B. $2H_2O \rightleftharpoons H_3O^+ + OH^-$

C. $NaOH + HCl \rightleftharpoons NaCl + H_2O$

D. $CrCl_3 + 6NH_3 \rightleftharpoons [Cr(NH_3)_6]^{3+} + 3Cl^-$

27. When the following 1.0 mol dm^{-3} aqueous solutions are arranged in order of **increasing** pH, which is the correct order?

    I.   Ammonium chloride

    II.   Ammonium ethanoate

    III.   Sodium ethanoate

A. I, II, III

B. II, I, III

C. III, I, II

D. III, II, I

Turn over

28. An acid-base indicator, HIn, dissociates according to the following equation.

$$HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$$
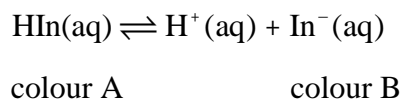
colour A   colour B

Which statement about this indicator is correct?

    I.   In a strongly acidic solution colour B would be seen.

    II.   In a neutral solution the concentrations of $HIn(aq)$ and $In^-(aq)$ must be equal.

    III.   It is suitable for use in titrations involving weak acids and weak bases.

    A.   I only

    B.   II only

    C.   III only

    D.   None of the above

29. Magnesium is a more reactive metal than copper. Which is the strongest oxidizing agent?

    A.   Mg

    B. Mg^{2+}

    C.   Cu

    D. Cu^{2+}

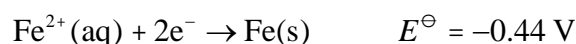**30.** In which reaction does chromium undergo a change in oxidation number?

    A. $Cr_2O_3 + 3H_2SO_4 \rightarrow Cr_2(SO_4)_3 + 3H_2O$

    B. $Cr_2(SO_4)_3 + 6NaOH \rightarrow 2Cr(OH)_3 + 3Na_2SO_4$

    C. $K_2Cr_2O_7 + 4H_2SO_4 + 6HCl \rightarrow Cr_2(SO_4)_3 + K_2SO_4 + 7H_2O + 3Cl_2$

    D. $2K_2CrO_4 + H_2SO_4 \rightarrow K_2Cr_2O_7 + K_2SO_4 + H_2O$

31. When the following equation is balanced, what is the coefficient for Ce^{4+} ?

$$\_SO_3^{2-} + \_H_2O + \_Ce^{4+} \rightarrow \_SO_4^{2-} + \_H^+ + \_Ce^{3+}$$
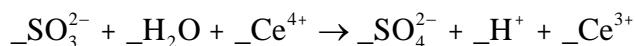
A. 1

B. 2

C. 3

D. 4

32. The standard electrode potentials for two half-cells involving iron are given below.

$$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s) \qquad E^\ominus = -0.44 \text{ V}$$

$$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq) \qquad E^\ominus = +0.77 \text{ V}$$
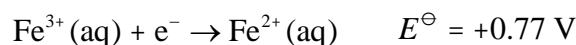
What is the equation and the cell potential for the spontaneous reaction that occurs when the two half-cells are connected?

A. $3Fe^{2+}(aq) \rightarrow Fe(s) + 2Fe^{3+}(aq)$ $E^\ominus = +1.21$ V

B. $Fe^{2+}(aq) + Fe^{3+}(aq) \rightarrow 2Fe(s)$ $E^\ominus = +0.33$ V

C. $Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq)$ $E^\ominus = +0.33$ V

D. $Fe(s) + 2Fe^{3+}(aq) \rightarrow 3Fe^{2+}(aq)$ $E^\ominus = +1.21$ V

33. Metallic tin can be produced by the electrolysis of a molten salt containing Sn^{2+} ions. Which change(s) would double the amount of tin produced?

   I.   Doubling the current passed during electrolysis

   II.   Doubling the time used for electrolysis

   III.   Using Sn^{4+} ions instead of Sn^{2+} ions

A.   I only

B.   II only

C.   I and II only

D.   I, II and III

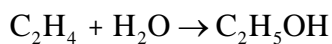**34.** Which formulas represent butane or its isomer?

      I. $CH_3(CH_2)_2CH_3$

      II. $CH_3CH(CH_3)CH_3$

      III. $(CH_3)_3CH$

  A.   I and II only

  B.   I and III only

  C.   II and III only

  D.   I, II and III

35. Which compound can exist as optical isomers?

  A. $CH_3CHBrCH_3$

  B. $CH_2BrCHBrCH_3$

  C. $CH_2BrCHBrCH_2Br$

  D. $CHBr_2CHBrCHBr_2$

36. Which is the correct description of the following reaction?

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$

  A.   Addition

  B.   Condensation

  C.   Dehydration

  D.   Hydrogenation

37. Which isomer of $C_3H_6O_2$ has a ^1H NMR spectrum with a different number of peaks from the others?

    A. $HCOOCH_2CH_3$

    B. CH_3COOCH_3

    C. CH_3OCH_2CHO

    D. CH_3CH_2COOH

38. Which statements support the idea that benzene contains delocalized electrons?

    I.   It undergoes substitution rather than addition reactions.

    II.   Its enthalpy change of combustion is greater than its enthalpy change of hydrogenation.

    III.   All its carbon-carbon bonds are the same length.

    A.   I and II only

    B.   I and III only

    C.   II and III only

    D.   I, II and III

39. Which statement about the reactions of halogenoalkanes with aqueous sodium hydroxide is correct?

    A.   Primary halogenoalkanes react mainly by an S_N1 mechanism.

    B.   Chloroalkanes react faster than iodoalkanes.

    C.   Tertiary halogenoalkanes react faster than primary halogenoalkanes.

    D.   The rate of an S_N1 reaction depends on the concentration of aqueous sodium hydroxide.

40. Which alkene can be formed by the dehydration of pentan-2-ol?

A. $CH_2CHCH(CH_3)_2$

B. $CH_2C(CH_3)CH_2CH_3$

C. $CH_3CHCHCH_3$

D. $CH_2CH(CH_2)_2CH_3$