BRITISH COLUMBIA
Ministry of Education

Chemistry 12

Examination Booklet

August 2006

Form A

DO NOT OPEN ANY EXAMINATION MATERIALS UNTIL INSTRUCTED TO DO SO.

FOR FURTHER INSTRUCTIONS REFER TO THE RESPONSE BOOKLET.

Contents: 17 pages
50 multiple-choice questions
8 written-response questions

Examination: 2 hours
Additional Time Permitted: 60 minutes

PART A: MULTIPLE CHOICE

Suggested Time: 80 minutes

INSTRUCTIONS: For each question, select the **best** answer and record your choice on the **Answer Sheet** provided. Using an HB pencil, completely fill in the bubble that has the letter corresponding to your answer.

You have **Examination Booklet Form A**. In the box above #1 on your **Answer Sheet**, fill in the bubble as follows.

Exam Booklet Form/ Cahier d'examen	A	B	C	D	E	F	G	H
	●	○	○	○	○	○	○	○

1. Which of the following would **not** be units for reaction rate?

   A. g/s
   B. M/min
   C. kJ/mol
   D. kPa/min

2. Consider the reaction:

   $$2Al(s) + 3CuCl_2(aq) \rightarrow 2AlCl_3(aq) + 3Cu(s)$$

   What is the rate of Al consumption in mol/min if $0.98\,g$ Cu are produced in 2.5 minutes?

   A. $4.1 \times 10^{-3}\ mol/min$
   B. $6.2 \times 10^{-3}\ mol/min$
   C. $9.3 \times 10^{-3}\ mol/min$
   D. $3.9 \times 10^{-1}\ mol/min$

3. Which of the following describes what happens to the KE and PE as an activated complex forms products?

	KE	PE
A.	decreases	increases
B.	decreases	decreases
C.	increases	increases
D.	increases	decreases

Use the following reaction mechanism to answer questions 4 and 5.

Step 1:	$2NO \rightarrow N_2O_2$	(fast)
Step 2:	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$	(slow)
Step 3:	$N_2O + H_2 \rightarrow N_2 + H_2O$	(fast)

4. Increasing the concentration of which of the following substances would cause the greatest increase in the reaction rate?

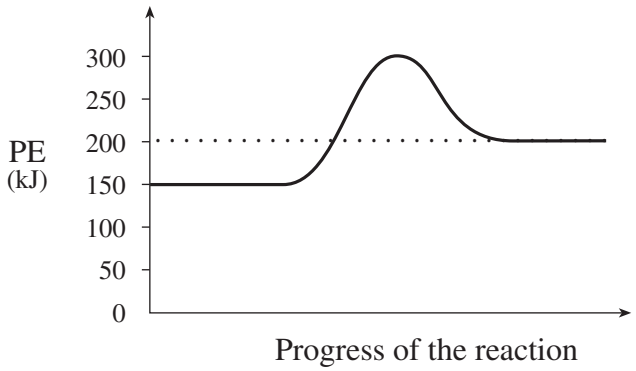
A. H_2
B. NO
C. N_2O
D. H_2O

5. Which of the following are products in the overall reaction?

I	N_2
II	N_2O_2
III	N_2O
IV	H_2O

A. I and II only
B. I and IV only
C. II and III only
D. III and IV only

Use the following diagram to answer questions 6 and 7.



6. Which of the following are the values for the activation energy (E_a) and change in enthalpy (ΔH) for the reverse reaction?

	E_a (kJ)	ΔH (kJ)
A.	300	–50
B.	150	+50
C.	100	–50
D.	100	+50

7. If the above PE diagram represents a reversible reaction that reaches equilibrium, which of the following must be true for the forward reaction?

   A. Enthalpy change favours products and entropy is increasing.
   B. Enthalpy change favours reactants and entropy is increasing.
   C. Enthalpy change favours products and entropy is decreasing.
   D. Enthalpy change favours reactants and entropy is decreasing.

8. Consider the following:

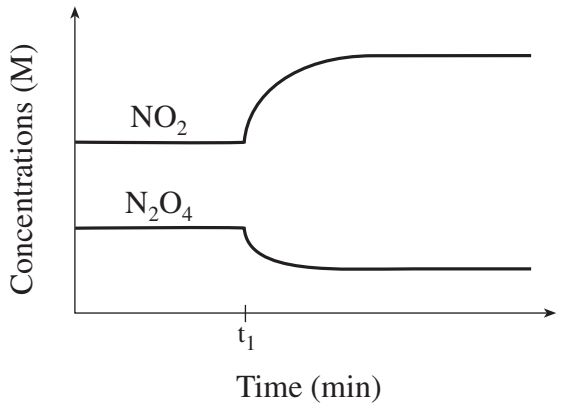
$$\text{energy} + NH_4SH(s) \overset{?}{\rightleftarrows} NH_3(g) + H_2S(g)$$

Which of the following describes how enthalpy and entropy change in the forward direction?

	Enthalpy	Entropy
A.	increasing	increasing
B.	increasing	decreasing
C.	decreasing	decreasing
D.	decreasing	increasing

9. Consider the following diagram for the equilibrium system:

$$N_2O_4(g) + \text{energy} \rightleftarrows 2NO_2(g)$$



Which of the following stresses was applied at time t_1?

A. $[NO_2]$ was increased.
B. $[N_2O_4]$ was decreased.
C. Temperature was increased.
D. Temperature was decreased.

10. Styrene is manufactured as follows:

$$C_6H_5CH_2CH_3(g) + 123\,kJ \rightleftarrows C_6H_5CHCH_2(g) + H_2(g)$$

styrene

Which of the following describes the temperature and pressure needed for the maximum yield of styrene?

	Temperature	Pressure
A.	low	low
B.	low	high
C.	high	low
D.	high	high

11. Consider the following reactions:

I	$Na_2O(s) \rightleftarrows 2Na(\ell) + \frac{1}{2}O_2(g)$	$K_{eq} = 2 \times 10^{-25}$
II	$Na_2O_2(s) \rightleftarrows 2Na(\ell) + O_2(g)$	$K_{eq} = 5 \times 10^{-29}$
III	$2Na_2O(s) \rightleftarrows 4Na(\ell) + O_2(g)$	$K_{eq} = 3 \times 10^{-14}$

Which of the following lists the reactions in order, from the greatest $[O_2]$ at equilibrium, to the least $[O_2]$ at equilibrium?

A. I, II, III
B. I, III, II
C. III, I, II
D. III, II, I

12. Consider the equilibrium:

$$CaCO_3(s) \rightleftarrows CaO(s) + CO_2(g)$$

In a $5.0\,L$ container at equilibrium there are $2.42\,g$ CO_2, $1.00\,g$ $CaCO_3$ and $1.00\,g$ CaO. Which of the following is the value of K_{eq}?

A. 0.055
B. 0.011
C. 0.020
D. 91

13. Consider the following equilibrium:

$$CCl_4(g) \rightleftarrows C(s) + 2Cl_2(g)$$

Initially, $0.31\,mol$ CCl_4 was placed in a $1.0\,L$ container. At equilibrium, $[Cl_2] = 0.060\,M$. Which of the following is the value of K_{eq}?

A. 3.9×10^{-4}
B. 1.3×10^{-2}
C. 1.4×10^{-2}
D. 7.8×10^{1}

14. Consider the following equilibrium:

$$3NO_2(g) \rightleftarrows N_2O_5(g) + NO(g) \qquad K_{eq} = 1.0 \times 10^{-11}$$

Initially, some NO_2, N_2O_5 and NO were placed in a container and allowed to reach equilibrium. When equilibrium was established, it was found that the pressure had increased. Which of the following explains what happened?

A. Trial $K_{eq} > K_{eq}$ so the system shifted left.
B. Trial $K_{eq} < K_{eq}$ so the system shifted left.
C. Trial $K_{eq} > K_{eq}$ so the system shifted right.
D. Trial $K_{eq} < K_{eq}$ so the system shifted right.

15. Which condition is essential to prepare a saturated solution of an ionic salt?

A. an excess of solute
B. any amount of solute
C. a temperature of 25°C
D. a fixed volume of solvent

16. Which compound will have the greatest solubility?

A. CoS
B. CuS
C. FeS
D. MgS

17. What is the net ionic equation for the reaction between equal volumes of 0.20 M BaS and 0.20 M $BeSO_4$?

A. $Be^{2+}(aq) + S^{2-}(aq) \rightarrow BeS(s)$
B. $Ba^{2+}(aq) + SO_4{}^{2-}(aq) \rightarrow BaSO_4(s)$
C. $BaS(aq) + BeSO_4(aq) \rightarrow BaSO_4(s) + BeS(s)$
D. $Ba^{2+}(aq) + S^{2-}(aq) + Be^{2+}(aq) + SO_4{}^{2-}(aq) \rightarrow BaSO_4(s) + Be^{2+}(aq) + S^{2-}(aq)$

18. Which of the following substances will have the least effect on the equilibrium in a saturated solution of $PbI_2(s)$?

A. HI
B. Na_2S
C. $NaNO_3$
D. $Pb(NO_3)_2$

19. Which equation has the K_{sp} expression: $K_{sp} = \left[Al^{3+}\right]^2 \left[SO_4{}^{2-}\right]^3$?

A. $2Al^{3+}(aq) + 3SO_4{}^{2-}(aq) \rightarrow Al_2(SO_4)_3(s)$

B. $Al_2(SO_4)_3(s) \rightleftarrows Al^{3+}(aq) + SO_4{}^{2-}(aq)$

C. $Al_2(SO_4)_3(s) \rightleftarrows 2Al^{3+}(aq) + 3SO_4{}^{2-}(aq)$

D. $3Al^{3+}(aq) + 2SO_4{}^{2-}(aq) \rightleftarrows Al_2(SO_4)_3(s)$

20. What is the K_{sp} for $Zn(OH)_2$ if it has a solubility of 1.3×10^{-7} mol/L ?

A. 2.2×10^{-21}

B. 8.8×10^{-21}

C. 1.7×10^{-14}

D. 3.6×10^{-4}

21. Which compound will have the lowest solubility?

A. $AgNO_3$

B. $AgBrO_3$

C. $SrSO_4$

D. $SrCO_3$

22. A definition for a Brønsted-Lowry acid should contain which of the following phrases?

A. the donation of H^+

B. the donation of OH^-

C. the acceptance of H^+

D. the acceptance of OH^-

23. Which equation represents the reaction of a Brønsted-Lowry base with water?

A. $2Na + 2H_2O \rightarrow 2NaOH + H_2$

B. $N_2H_4 + H_2O \rightleftarrows N_2H_5^+ + OH^-$

C. $HPO_4^{2-} + H_2O \rightleftarrows H_3O^+ + PO_4^{3-}$

D. $H_2C_2O_4 + H_2O \rightleftarrows H_3O^+ + HC_2O_4^-$

24. Given the equilibrium:

$$H_2BO_3^- + H_2PO_4^- \rightleftarrows H_3BO_3 + HPO_4^{2-}$$

Which is the strongest acid?

A. HPO_4^{2-}

B. H_3BO_3

C. $H_2PO_4^-$

D. $H_2BO_3^-$

25. Which species will result in a solution with the greatest $[H_3O^+]$?

A. NaCN

B. Na_3PO_4

C. Na_2CO_3

D. $Na_2C_2O_4$

26. Which species is **not** amphiprotic?

A. H_2O

B. H_3BO_3

C. $H_2PO_4^-$

D. $H_2C_6H_5O_7^-$

27. At a given temperature a sample of pure water has a $pH = 7.10$.
Which of the following is true?

	Sample	Reason
A.	acidic	$pH > 7.00$
B.	basic	$pH > 7.00$
C.	neutral	$pOH < pH$
D.	neutral	$[H_3O^+] = [OH^-]$

28. Which of the following is a definition of pH?

A. $pH = \log[H_3O^+]$
B. $pH = pOH + 14$
C. $pH = -\log[H_3O^+]$
D. $pH = pOH + pK_w$

29. What is the mass of $NaOH$ required to prepare $100.0\,mL$ of $NaOH(aq)$ that has a $pH = 13.62$?

A. $0.38\,g$
B. $0.42\,g$
C. $1.67\,g$
D. $2.40 \times 10^{-14}\,g$

30. Which of the following hypothetical acids would have the lowest conductivity?

	Acid	K_a
A.	$0.5\,M$ HY	1.0×10^{-1}
B.	$1.0\,M$ HA	1.0×10^{-6}
C.	$1.0\,M$ H_2B	1.0×10^{-2}
D.	$2.0\,M$ HX	1.0×10^{-3}

31. What is the net ionic equation for the hydrolysis of NH_4Cl ?

A. $NH_4Cl(aq) \rightleftarrows NH_4^+(aq) + Cl^-(aq)$

B. $Cl^-(aq) + H_2O(\ell) \rightleftarrows HCl(aq) + OH^-(aq)$

C. $NH_4^+(aq) + H_2O(\ell) \rightleftarrows H_3O^+(aq) + NH_3(aq)$

D. $NH_4^+(aq) + H_2O(\ell) \rightleftarrows HNH_4^{2+}(aq) + OH^-(aq)$

32. What is the approximate pH of a 0.1M solution of the salt NH_4Cl?

A. 1.0
B. 5.0
C. 7.0
D. 9.0

33. Consider the following indicator equilibrium:

$$\underset{\text{colourless}}{HIn(aq)} + H_2O(\ell) \rightleftarrows H_3O^+(aq) + \underset{\text{blue}}{In^-(aq)}$$

What is the effect of adding HCl to a blue sample of this indicator?

	Equilibrium Shift	Colour Change
A.	left	less blue
B.	left	more blue
C.	right	less blue
D.	right	more blue

34. An indicator has a $K_a = 4 \times 10^{-6}$. Which of the following is true for this indicator?

	pH at Transition Point	Indicator
A.	4.0	methyl orange
B.	4.0	bromcresol green
C.	5.4	methyl red
D.	5.4	bromcresol green

35. Oxalic acid dihydrate is a pure, stable, crystalline substance. Which of the following describes one of its uses in acid-base titrations?

A. buffer
B. primary standard
C. chemical indicator
D. stoichiometric indicator

36. What is the net ionic equation that describes the reaction of $HCl(aq)$ with $Pb(OH)_2(s)$?

A. $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
B. $2HCl(aq) + Pb(OH)_2(s) \rightarrow PbCl_2(s) + 2H_2O(\ell)$
C. $2H^+(aq) + 2Cl^-(aq) + Pb(OH)_2(s) \rightarrow PbCl_2(s) + 2H_2O(\ell)$
D. $2H^+(aq) + 2Cl^-(aq) + Pb^{2+}(aq) + 2OH^-(aq) \rightarrow Pb^{2+}(aq) + 2Cl^-(aq) + 2H_2O(\ell)$

37. Which of the following would be used to prepare an acidic buffer solution?

A. HF and H_3O^+
B. H_2S and NaHS
C. NH_3 and NH_4Cl
D. HNO_3 and $NaNO_3$

38. Four samples of rain are collected from different geographic regions and the pH is measured for each sample.

Sample	pH
1	2.8
2	4.0
3	6.2
4	6.8

Which of the above samples would be classified as *acid rain*?

A. 1 only
B. 1 and 2
C. 1, 2 and 3
D. 1, 2, 3 and 4

39. Which of the following best describes the process of *oxidation*?

A. the process in which oxygen is given off
B. the process in which electrons are gained
C. the process in which the oxidation number decreases
D. the process in which the oxidation number increases

40. What is the oxidation number of N in the mercury(II) compound $Hg(NH_3)_2Cl_2$?

A. -6
B. -4
C. -3
D. $+3$

41. Which of the following combinations will react spontaneously under standard conditions?

A. $Ag + Br_2$
B. $Ni + Co^{2+}$
C. $Zn + Mg^{2+}$
D. $Au + HNO_3$

42. Which of the following is a correctly balanced reduction half-reaction?

A. $2HCN + 2e^- \rightarrow C_2N_2 + 2H^+$

B. $2Sb + 3H_2O + 6e^- \rightarrow Sb_2O_3 + 6H^+$

C. $NO_3^- + 3H^+ + 3e^- \rightarrow HNO_2 + H_2O$

D. $Sb_2O_5 + 6H^+ + 4e^- \rightarrow 2Sb(OH)_2^+ + H_2O$

43. Which of the following ion concentrations could be determined by a redox titration using nitric acid? Assume the use of a suitable indicator.

A. Br^-

B. Ni^{2+}

C. Fe^{2+}

D. Mn^{2+}

44. A solution of $KMnO_4$ is standardized using oxalic acid $(H_2C_2O_4)$ according to the following equation:

$$2MnO_4^- + 5H_2C_2O_4 + 6H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The titration of $0.134\,g$ of oxalic acid required $24.70\,mL$ of $KMnO_4$ solution. What is the molarity of the $KMnO_4$ solution?

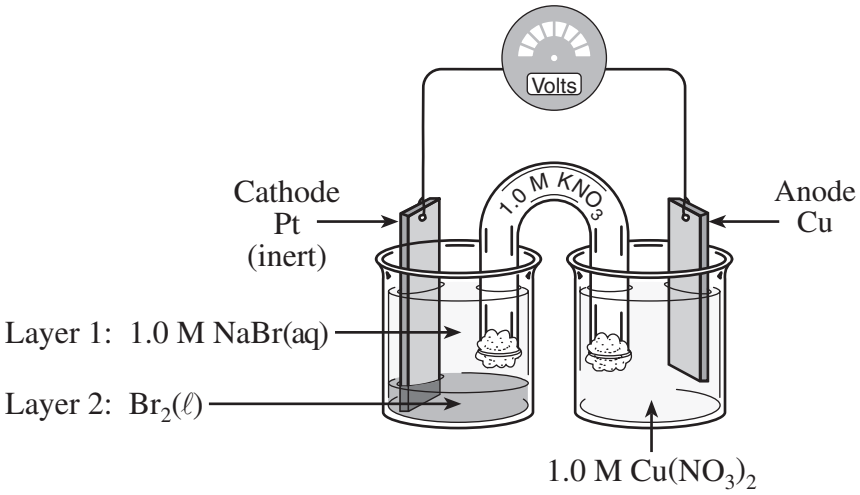
A. 5.96×10^{-4} M

B. 1.49×10^{-3} M

C. 2.41×10^{-2} M

D. 6.03×10^{-2} M

Use the following diagram to answer questions 45 to 47.



45. What is the cathode reaction for this cell?

A. $Na^+ + e^- \rightarrow Na$

B. $Br_2 + 2e^- \rightarrow 2Br^-$

C. $2Br^- \rightarrow Br_2 + 2e^-$

D. $H_2O \rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^-$

46. Which of the following best describes the movement of potassium ions and electrons as the cell operates?

	K^+ Ion Movement	Electron Movement
A.	towards the Cu	towards the Pt
B.	towards the Cu	towards the Cu
C.	towards the Pt	towards the Cu
D.	towards the Pt	towards the Pt

47. What is the standard cell voltage?

A. −0.75 V

B. +0.62 V

C. +0.75 V

D. +1.43 V

48. A student constructs three standard electrochemical cells using the metals Pd, Cd and Ga with 1.0 M solutions of their ions. The student then records the voltages of Cell 1 and Cell 2 in the following table.

Cell	Anode	Cathode	Voltage
1	Ga	Pd	+1.18 V
2	Ga	Cd	+0.16 V
3	Cd	Pd	?

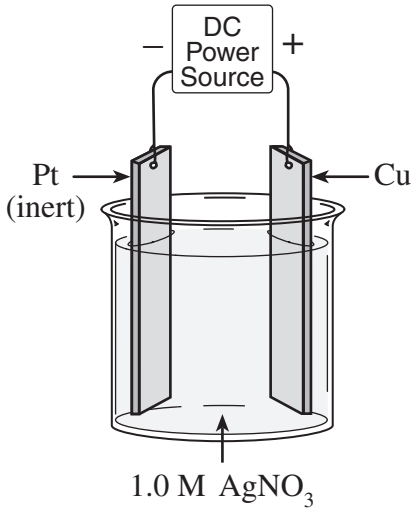
What voltage should Cell 3 produce?

A. −1.34 V
B. −1.02 V
C. +1.02 V
D. +1.34 V

49. Which of the following would prevent the corrosion of an iron nail?

A. Store the nail in $Cl_2(g)$.
B. Store the nail in dry air.
C. Store the nail in a beaker of distilled water.
D. Store the nail wrapped in cobalt wire in a beaker of distilled water.

50. Consider the electrolytic cell shown in the following diagram:



Which of the following describes the anion movement and electrode masses for the above cell?

	Anion Movement	Mass of Pt Electrode	Mass of Cu Electrode
A.	to the Cu	increases	increases
B.	to the Cu	increases	decreases
C.	to the Pt	decreases	increases
D.	to the Pt	decreases	decreases

You have **Examination Booklet Form A**. In the box above #1 on your **Answer Sheet**, ensure that you have filled in the bubble as follows.

Exam Booklet Form/ Cahier d'examen	A	B	C	D	E	F	G	H
	●	○	○	○	○	○	○	○

This is the end of the multiple-choice section.
Answer the remaining questions in the Response Booklet.

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

14 **Si** Silicon 28.1 — Atomic Number, Symbol, Name, Atomic Mass

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce Cerium 140.1	**Pr** Praseodymium 140.9	**Nd** Neodymium 144.2	**Pm** Promethium (145)	**Sm** Samarium 150.4	**Eu** Europium 152.0	**Gd** Gadolinium 157.3	**Tb** Terbium 158.9	**Dy** Dysprosium 162.5	**Ho** Holmium 164.9	**Er** Erbium 167.3	**Tm** Thulium 168.9	**Yb** Ytterbium 173.0	**Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.

ATOMIC MASSES OF THE ELEMENTS

Based on mass of C^{12} at 12.00.
Values in parentheses are the mass number of the most stable or best known isotopes for elements that do not occur naturally.

Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	(227)
Aluminum	Al	13	27.0
Americium	Am	95	(243)
Antimony	Sb	51	121.8
Argon	Ar	18	39.9
Arsenic	As	33	74.9
Astatine	At	85	(210)
Barium	Ba	56	137.3
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.0
Bismuth	Bi	83	209.0
Boron	B	5	10.8
Bromine	Br	35	79.9
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.1
Californium	Cf	98	(251)
Carbon	C	6	12.0
Cerium	Ce	58	140.1
Cesium	Cs	55	132.9
Chlorine	Cl	17	35.5
Chromium	Cr	24	52.0
Cobalt	Co	27	58.9
Copper	Cu	29	63.5
Curium	Cm	96	(247)
Dubnium	Db	105	(262)
Dysprosium	Dy	66	162.5
Einsteinium	Es	99	(252)
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(257)
Fluorine	F	9	19.0
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.7
Germanium	Ge	32	72.6
Gold	Au	79	197.0
Hafnium	Hf	72	178.5
Helium	He	2	4.0
Holmium	Ho	67	164.9
Hydrogen	H	1	1.0
Indium	In	49	114.8
Iodine	I	53	126.9
Iridium	Ir	77	192.2
Iron	Fe	26	55.8
Krypton	Kr	36	83.8
Lanthanum	La	57	138.9
Lawrencium	Lr	103	(262)
Lead	Pb	82	207.2
Lithium	Li	3	6.9
Lutetium	Lu	71	175.0
Magnesium	Mg	12	24.3
Manganese	Mn	25	54.9
Mendelevium	Md	101	(258)
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.9
Neodymium	Nd	60	144.2
Neon	Ne	10	20.2
Neptunium	Np	93	(237)
Nickel	Ni	28	58.7
Niobium	Nb	41	92.9
Nitrogen	N	7	14.0
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.0
Palladium	Pd	46	106.4
Phosphorus	P	15	31.0
Platinum	Pt	78	195.1
Plutonium	Pu	94	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.1
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.0
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.9
Rubidium	Rb	37	85.5
Ruthenium	Ru	44	101.1
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.4
Scandium	Sc	21	45.0
Selenium	Se	34	79.0
Silicon	Si	14	28.1
Silver	Ag	47	107.9
Sodium	Na	11	23.0
Strontium	Sr	38	87.6
Sulphur	S	16	32.1
Tantalum	Ta	73	180.9
Technetium	Tc	43	(98)
Tellurium	Te	52	127.6
Terbium	Tb	65	158.9
Thallium	Tl	81	204.4
Thorium	Th	90	232.0
Thulium	Tm	69	168.9
Tin	Sn	50	118.7
Titanium	Ti	22	47.9
Tungsten	W	74	183.8
Uranium	U	92	238.0
Vanadium	V	23	50.9
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.0
Yttrium	Y	39	88.9
Zinc	Zn	30	65.4
Zirconium	Zr	40	91.2

NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

* *Aqueous solutions are readily oxidized by air.*
** *Not stable in aqueous solutions.*

Positive Ions (Cations)

Al^{3+}	Aluminum	Pb^{4+}	Lead(IV), plumbic
NH_4^+	Ammonium	Li^+	Lithium
Ba^{2+}	Barium	Mg^{2+}	Magnesium
Ca^{2+}	Calcium	Mn^{2+}	Manganese(II), manganous
Cr^{2+}	Chromium(II), chromous	Mn^{4+}	Manganese(IV)
Cr^{3+}	Chromium(III), chromic	Hg_2^{2+}	Mercury(I)*, mercurous
Cu^+	Copper(I)*, cuprous	Hg^{2+}	Mercury(II), mercuric
Cu^{2+}	Copper(II), cupric	K^+	Potassium
H^+	Hydrogen	Ag^+	Silver
H_3O^+	Hydronium	Na^+	Sodium
Fe^{2+}	Iron(II)*, ferrous	Sn^{2+}	Tin(II)*, stannous
Fe^{3+}	Iron(III), ferric	Sn^{4+}	Tin(IV), stannic
Pb^{2+}	Lead(II), plumbous	Zn^{2+}	Zinc

Negative Ions (Anions)

Br^-	Bromide	OH^-	Hydroxide
CO_3^{2-}	Carbonate	ClO^-	Hypochlorite
ClO_3^-	Chlorate	I^-	Iodide
Cl^-	Chloride	HPO_4^{2-}	Monohydrogen phosphate
ClO_2^-	Chlorite	NO_3^-	Nitrate
CrO_4^{2-}	Chromate	NO_2^-	Nitrite
CN^-	Cyanide	$C_2O_4^{2-}$	Oxalate
$Cr_2O_7^{2-}$	Dichromate	O^{2-}	Oxide**
$H_2PO_4^-$	Dihydrogen phosphate	ClO_4^-	Perchlorate
CH_3COO^-	Ethanoate, acetate	MnO_4^-	Permanganate
F^-	Fluoride	PO_4^{3-}	Phosphate
HCO_3^-	Hydrogen carbonate, bicarbonate	SO_4^{2-}	Sulphate
$HC_2O_4^-$	Hydrogen oxalate, binoxalate	S^{2-}	Sulphide
HSO_4^-	Hydrogen sulphate, bisulphate	SO_3^{2-}	Sulphite
HS^-	Hydrogen sulphide, bisulphide	SCN^-	Thiocyanate
HSO_3^-	Hydrogen sulphite, bisulphite		

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

SOLUBILITY PRODUCT CONSTANTS AT 25°C

Name	Formula	K_{sp}
Barium carbonate	$BaCO_3$	2.6×10^{-9}
Barium chromate	$BaCrO_4$	1.2×10^{-10}
Barium sulphate	$BaSO_4$	1.1×10^{-10}
Calcium carbonate	$CaCO_3$	5.0×10^{-9}
Calcium oxalate	CaC_2O_4	2.3×10^{-9}
Calcium sulphate	$CaSO_4$	7.1×10^{-5}
Copper(I) iodide	CuI	1.3×10^{-12}
Copper(II) iodate	$Cu(IO_3)_2$	6.9×10^{-8}
Copper(II) sulphide	CuS	6.0×10^{-37}
Iron(II) hydroxide	$Fe(OH)_2$	4.9×10^{-17}
Iron(II) sulphide	FeS	6.0×10^{-19}
Iron(III) hydroxide	$Fe(OH)_3$	2.6×10^{-39}
Lead(II) bromide	$PbBr_2$	6.6×10^{-6}
Lead(II) chloride	$PbCl_2$	1.2×10^{-5}
Lead(II) iodate	$Pb(IO_3)_2$	3.7×10^{-13}
Lead(II) iodide	PbI_2	8.5×10^{-9}
Lead(II) sulphate	$PbSO_4$	1.8×10^{-8}
Magnesium carbonate	$MgCO_3$	6.8×10^{-6}
Magnesium hydroxide	$Mg(OH)_2$	5.6×10^{-12}
Silver bromate	$AgBrO_3$	5.3×10^{-5}
Silver bromide	$AgBr$	5.4×10^{-13}
Silver carbonate	Ag_2CO_3	8.5×10^{-12}
Silver chloride	$AgCl$	1.8×10^{-10}
Silver chromate	Ag_2CrO_4	1.1×10^{-12}
Silver iodate	$AgIO_3$	3.2×10^{-8}
Silver iodide	AgI	8.5×10^{-17}
Strontium carbonate	$SrCO_3$	5.6×10^{-10}
Strontium fluoride	SrF_2	4.3×10^{-9}
Strontium sulphate	$SrSO_4$	3.4×10^{-7}
Zinc sulphide	ZnS	2.0×10^{-25}

RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature.

STRENGTH OF ACID: STRONG → WEAK

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large
Hydriodic	HI	$\rightarrow$	$H^+ + I^-$	very large
Hydrobromic	HBr	$\rightarrow$	$H^+ + Br^-$	very large
Hydrochloric	HCl	$\rightarrow$	$H^+ + Cl^-$	very large
Nitric	HNO_3	$\rightarrow$	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	$\rightarrow$	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	$\rightleftarrows$	$H^+ + H_2O$	1.0
Iodic	HIO_3	$\rightleftarrows$	$H^+ + IO_3^-$	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	$\rightleftarrows$	$H^+ + HC_2O_4^-$	5.9×10^{-2}
Sulphurous ($SO_2 + H_2O$)	H_2SO_3	$\rightleftarrows$	$H^+ + HSO_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	$\rightleftarrows$	$H^+ + SO_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	$\rightleftarrows$	$H^+ + H_2PO_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
Citric	$H_3C_6H_5O_7$	$\rightleftarrows$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	$\rightleftarrows$	$H^+ + NO_2^-$	4.6×10^{-4}
Hydrofluoric	HF	$\rightleftarrows$	$H^+ + F^-$	3.5×10^{-4}
Methanoic, formic	$HCOOH$	$\rightleftarrows$	$H^+ + HCOO^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}
Benzoic	C_6H_5COOH	$\rightleftarrows$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}
Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftarrows$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	$\rightleftarrows$	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftarrows$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}
Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}
Carbonic ($CO_2 + H_2O$)	H_2CO_3	$\rightleftarrows$	$H^+ + HCO_3^-$	4.3×10^{-7}
Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftarrows$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}
Hydrogen sulphite ion	HSO_3^-	$\rightleftarrows$	$H^+ + SO_3^{2-}$	1.0×10^{-7}
Hydrogen sulphide	H_2S	$\rightleftarrows$	$H^+ + HS^-$	9.1×10^{-8}
Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftarrows$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}
Boric	H_3BO_3	$\rightleftarrows$	$H^+ + H_2BO_3^-$	7.3×10^{-10}
Ammonium ion	NH_4^+	$\rightleftarrows$	$H^+ + NH_3$	5.6×10^{-10}
Hydrocyanic	HCN	$\rightleftarrows$	$H^+ + CN^-$	4.9×10^{-10}
Phenol	C_6H_5OH	$\rightleftarrows$	$H^+ + C_6H_5O^-$	1.3×10^{-10}
Hydrogen carbonate ion	HCO_3^-	$\rightleftarrows$	$H^+ + CO_3^{2-}$	5.6×10^{-11}
Hydrogen peroxide	H_2O_2	$\rightleftarrows$	$H^+ + HO_2^-$	2.4×10^{-12}
Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftarrows$	$H^+ + PO_4^{3-}$	2.2×10^{-13}
Water	H_2O	$\rightleftarrows$	$H^+ + OH^-$	1.0×10^{-14}
Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small
Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	very small

STRENGTH OF BASE: WEAK → STRONG

ACID-BASE INDICATORS

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

STANDARD REDUCTION POTENTIALS OF HALF-CELLS

Ionic concentrations are at 1M in water at 25°C.

Oxidizing Agents		Reducing Agents	E° (Volts)
$F_2(g) + 2e^-$	⇄	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	⇄	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	⇄	$2H_2O$	+1.78
$MnO_4^- + 8H^+ + 5e^-$	⇄	$Mn^{2+} + 4H_2O$	+1.51
$Au^{3+} + 3e^-$	⇄	$Au(s)$	+1.50
$BrO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}Br_2(\ell) + 3H_2O$	+1.48
$ClO_4^- + 8H^+ + 8e^-$	⇄	$Cl^- + 4H_2O$	+1.39
$Cl_2(g) + 2e^-$	⇄	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇄	$2Cr^{3+} + 7H_2O$	+1.23
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	⇄	H_2O	+1.23
$MnO_2(s) + 4H^+ + 2e^-$	⇄	$Mn^{2+} + 2H_2O$	+1.22
$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_2(s) + 3H_2O$	+1.20
$Br_2(\ell) + 2e^-$	⇄	$2Br^-$	+1.09
$AuCl_4^- + 3e^-$	⇄	$Au(s) + 4Cl^-$	+1.00
$NO_3^- + 4H^+ + 3e^-$	⇄	$NO(g) + 2H_2O$	+0.96
$Hg^{2+} + 2e^-$	⇄	$Hg(\ell)$	+0.85
$\frac{1}{2}O_2(g) + 2H^+(10^{-7}\,M) + 2e^-$	⇄	H_2O	+0.82
$2NO_3^- + 4H^+ + 2e^-$	⇄	$N_2O_4 + 2H_2O$	+0.80
$Ag^+ + e^-$	⇄	$Ag(s)$	+0.80
$\frac{1}{2}Hg_2^{2+} + e^-$	⇄	$Hg(\ell)$	+0.80
$Fe^{3+} + e^-$	⇄	Fe^{2+}	+0.77
$O_2(g) + 2H^+ + 2e^-$	⇄	H_2O_2	+0.70
$MnO_4^- + 2H_2O + 3e^-$	⇄	$MnO_2(s) + 4OH^-$	+0.60
$I_2(s) + 2e^-$	⇄	$2I^-$	+0.54
$Cu^+ + e^-$	⇄	$Cu(s)$	+0.52
$H_2SO_3 + 4H^+ + 4e^-$	⇄	$S(s) + 3H_2O$	+0.45
$Cu^{2+} + 2e^-$	⇄	$Cu(s)$	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	⇄	$H_2SO_3 + H_2O$	+0.17
$Cu^{2+} + e^-$	⇄	Cu^+	+0.15
$Sn^{4+} + 2e^-$	⇄	Sn^{2+}	+0.15
$S(s) + 2H^+ + 2e^-$	⇄	$H_2S(g)$	+0.14
$2H^+ + 2e^-$	⇄	$H_2(g)$	+0.00
$Pb^{2+} + 2e^-$	⇄	$Pb(s)$	−0.13
$Sn^{2+} + 2e^-$	⇄	$Sn(s)$	−0.14
$Ni^{2+} + 2e^-$	⇄	$Ni(s)$	−0.26
$H_3PO_4 + 2H^+ + 2e^-$	⇄	$H_3PO_3 + H_2O$	−0.28
$Co^{2+} + 2e^-$	⇄	$Co(s)$	−0.28
$Se(s) + 2H^+ + 2e^-$	⇄	H_2Se	−0.40
$Cr^{3+} + e^-$	⇄	Cr^{2+}	−0.41
$2H_2O + 2e^-$	⇄	$H_2 + 2OH^-(10^{-7}\,M)$	−0.41
$Fe^{2+} + 2e^-$	⇄	$Fe(s)$	−0.45
$Ag_2S(s) + 2e^-$	⇄	$2Ag(s) + S^{2-}$	−0.69
$Cr^{3+} + 3e^-$	⇄	$Cr(s)$	−0.74
$Zn^{2+} + 2e^-$	⇄	$Zn(s)$	−0.76
$Te(s) + 2H^+ + 2e^-$	⇄	H_2Te	−0.79
$2H_2O + 2e^-$	⇄	$H_2(g) + 2OH^-$	−0.83
$Mn^{2+} + 2e^-$	⇄	$Mn(s)$	−1.19
$Al^{3+} + 3e^-$	⇄	$Al(s)$	−1.66
$Mg^{2+} + 2e^-$	⇄	$Mg(s)$	−2.37
$Na^+ + e^-$	⇄	$Na(s)$	−2.71
$Ca^{2+} + 2e^-$	⇄	$Ca(s)$	−2.87
$Sr^{2+} + 2e^-$	⇄	$Sr(s)$	−2.89
$Ba^{2+} + 2e^-$	⇄	$Ba(s)$	−2.91
$K^+ + e^-$	⇄	$K(s)$	−2.93
$Rb^+ + e^-$	⇄	$Rb(s)$	−2.98
$Cs^+ + e^-$	⇄	$Cs(s)$	−3.03
$Li^+ + e^-$	⇄	$Li(s)$	−3.04

Overpotential Effect

Overpotential Effect

STRONG

STRENGTH OF OXIDIZING AGENT

WEAK

WEAK

STRENGTH OF REDUCING AGENT

STRONG

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Place Personal Education Number (PEN) here.

Course Code = CH 12
AUGUST 2006

Exam Booklet Form/ Cahier d'examen A B C D E F G H

Student Instructions

1. Place your Personal Education Number (PEN) label at the top of this Booklet **AND** fill in the bubble (Form A, B, C, D, E, F, G or H) that corresponds to the letter on your Examination Booklet.
2. Use a pencil to fill in bubbles when answering questions on your Answer Sheet.
3. Use a pencil or blue- or black-ink pen when answering written-response questions in this Booklet.
4. Read the Examination Rules on the back of this Booklet.

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Question 1								
0	1	2	3	4			(.5)	NR
☐	☐	☐	☐	☐			☐	☐
Question 2								
0	1	2	3	4			(.5)	NR
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Question 3								
0	1	2	3	4			(.5)	NR
☐	☐	☐	☐	☐			☐	☐
Question 4								
0	1	2	3				(.5)	NR
☐	☐	☐	☐				☐	☐
Question 5								
0	1	2	3	4	5		(.5)	NR
☐	☐	☐	☐	☐	☐		☐	☐
Question 6								
0	1	2	3				(.5)	NR
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Question 7								
0	1	2	3	4			(.5)	NR
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Question 8								
0	1	2	3				(.5)	NR
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Chemistry 12

AUGUST 2006

Response Booklet

BRITISH COLUMBIA
Ministry of Education

PART B: WRITTEN RESPONSE

Suggested Time: 40 minutes

INSTRUCTIONS: Answer the following questions in the space provided in this **Response Booklet.** You are expected to communicate your knowledge and understanding of chemical principles in a clear and logical manner. Your steps and assumptions leading to a solution must be written in this **Response Booklet**. Answers must include units where appropriate and be given to the correct number of significant figures. **For questions involving calculations, full marks will NOT be given for providing only an answer.**

1. Consider the reaction: $2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$

   State two different methods that would increase the rate of this reaction.
   Explain each in terms of collision theory. **(4 marks)**

   Method 1: _____

   Explanation: _____

   Method 2: _____

   Explanation: _____

2. Consider the equilibrium: $CO_2(g) + H_2(g) \rightleftarrows CO(g) + H_2O(g)$ $K_{eq} = 1.60$

   Initially, $8.2\,mol$ of CO and $8.2\,mol$ of H_2O are placed in a $2.0\,L$ container and allowed to react.
   Calculate the equilibrium concentrations of CO_2 and CO. **(4 marks)**

3. What is the maximum $\left[Pb^{2+}\right]$ that can exist in a saturated solution of $BaSO_4$ without causing precipitate formation? **(4 marks)**

4. Given the reactants:

$$H_2C_2O_4 + HCOO^- \rightleftarrows$$

Complete the acid-base equilibrium equation in the box above.
Determine whether reactants or products will be favoured and explain why. **(3 marks)**

5. Calculate the pH of a $0.30\,M\ H_2S$ solution. Begin by writing the equation for the predominant reaction. **(5 marks)**

6. What mass of $NaOH(s)$ is required to just neutralize $50.0\,mL$ of $2.0\,M\ H_2SO_4$? Begin by writing the balanced equation for the neutralization reaction. **(3 marks)**

7. Balance the following in acidic solution.

$$FeS + NO_2^- \rightarrow NO + SO_4^{2-} + Fe^{3+} \quad \text{(acidic)}$$

(4 marks)

8. The electrolysis of copper(II) sulphate solution using copper electrodes is used in the refining of copper. Write the anode and cathode half-reactions and describe what would be observed at each electrode as the cell operates. **(3 marks)**

Anode Half-Reaction: _____

Cathode Half-Reaction: _____

Observations:

anode: _____

cathode: _____

END OF EXAMINATION

Examination Rules

1. The time allotted for this examination is two hours.
   You may, however, take up to 60 minutes of additional time to finish.
2. Answers entered in the Examination Booklet will not be marked.
3. Cheating on an examination will result in a mark of zero. The Ministry of Education considers cheating to have occurred if a student breaks any of the following rules:

   - Candidates must not give or receive assistance of any kind in answering an examination question during an examination, including allowing one's paper to be viewed by others or copying answers from another student's paper.
   - Candidates must not possess any book, paper or item that might assist in writing an examination, including a dictionary or piece of electronic equipment, that is not specifically authorized for the examination by ministry policy.
   - Candidates must immediately follow the invigilator's order to stop writing at the end of the examination time and must not alter an Examination Booklet, Response Booklet or Answer Sheet after the invigilator has asked students to hand in examination papers.
   - Candidates must not communicate with another student during the examination.
   - Candidates must not remove any piece of the examination materials from the examination room, including work pages.
   - Candidates must not take or knowingly use any secure examination materials prior to the examination session.

4. The use of inappropriate language or content may result in a mark of zero being awarded.
5. Upon completion of the examination, return all examination materials to the supervising invigilator.