BRITISH COLUMBIA
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Chemistry 12

Examination Booklet
August 2007

Form A

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

FOR FURTHER INSTRUCTIONS REFER TO THE RESPONSE BOOKLET.

Contents: 16 pages
50 multiple-choice questions

Examination: 2 hours
Additional Time Permitted: 60 minutes

PART A: MULTIPLE CHOICE
Value: 62.5% of the examination

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 factor affects the reaction rate of heterogeneous reactions, but not of homogeneous reactions?

   A. catalyst
   B. temperature
   C. surface area
   D. concentration

2. Consider the following reaction:

$$CH_3COOH(aq) + NaHCO_3(s) \rightarrow NaCH_3COO(aq) + CO_2(g) + H_2O(\ell)$$

   Which of the following properties could best be used to measure the reaction rate?

   A. the volume of CO_2
   B. the volume of H_2O
   C. the mass of CH_3COOH
   D. the surface area of $NaHCO_3$

3. Consider the following reaction:

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

   If $0.56\,g$ Cu is produced in 1.0 minute, what mass of Al is used up in 20.0 seconds?

   A. $0.053\,g$
   B. $0.12\,g$
   C. $0.16\,g$
   D. $0.37\,g$

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

Step 1	$NO + O_2 \rightarrow OONO$
Step 2	$\boxed{?} + OONO \rightarrow 2NO_2$
Overall	$2NO + O_2 \rightarrow 2NO_2$

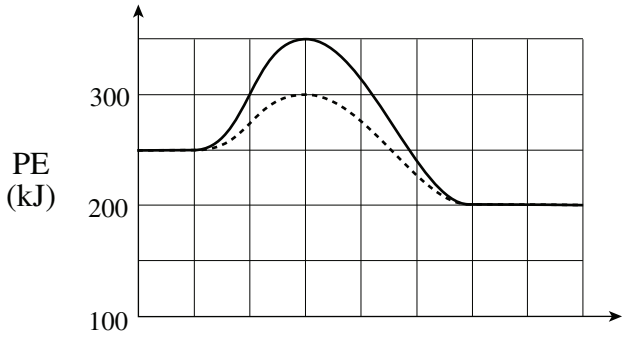
4. What substance is missing in Step 2?

	Missing Substance
A.	O_2
B.	NO
C.	NO_2
D.	OONO

5. Which of the following substances could represent an activated complex from the above mechanism?

	Activated Complex
A.	O_2
B.	NO
C.	NO_2
D.	N_2O_4

6. Consider the following PE diagram:



Which of the following is true for the **reverse reaction**?

		ΔH	E_a
A.	catalyzed	−50 kJ	100 kJ
B.	catalyzed	+50 kJ	150 kJ
C.	uncatalyzed	−50 kJ	100 kJ
D.	uncatalyzed	+50 kJ	150 kJ

7. What is true for reacting systems that spontaneously go to completion?

A. They are exothermic and their entropy increases.
B. They are exothermic and their entropy decreases.
C. They are endothermic and their entropy increases.
D. They are endothermic and their entropy decreases.

8. Consider the following equation:

$$2C(s) + 2H_2(g) + \text{energy} \overset{?}{\rightleftarrows} C_2H_4(g)$$

Which of the following occurs when C and H_2 are combined?

	Enthalpy Change	Entropy Change	Result
A.	increasing	decreasing	no reaction
B.	increasing	decreasing	reacts completely
C.	increasing	increasing	equilibrium
D.	decreasing	decreasing	no reaction

9. Consider the following equilibrium system:

$$2NO(g) + O_2(g) \rightleftarrows 2NO_2(g)$$

An equilibrium mixture of $NO(g)$, $O_2(g)$ and $NO_2(g)$ is transferred from a $1.0\,L$ container to a $2.0\,L$ container. Which reaction is favoured and what happens to the $[NO_2]$?

	Reaction Favoured	$[NO_2]$
A.	reverse	increases
B.	reverse	decreases
C.	forward	increases
D.	forward	decreases

10. Methanol (CH_3OH) is produced according to the following equilibrium equation:

$$CO(g) + 2H_2(g) \rightleftarrows CH_3OH(g) + \text{energy}$$

Which conditions would favour a high yield of methanol?

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

11. Consider the following equilibrium equation:

$$MgO(s) + SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftarrows MgSO_4(s)$$

Which expression represents the $[O_2]$ at equilibrium?

A. $[O_2] = \dfrac{1}{K_{eq}[SO_2]}$

B. $[O_2] = \left(K_{eq}[SO_2]\right)^2$

C. $[O_2] = \left(\dfrac{1}{K_{eq}[SO_2]}\right)^2$

D. $[O_2] = \dfrac{[MgSO_4]}{K_{eq}[MgO][SO_2]}$

12. Consider the following equilibrium system:

$$\text{energy} + COBr_2(g) \rightleftarrows CO(g) + Br_2(g)$$

Which of the following statements is true?

A. Decreasing $[CO]$ will increase K_{eq}.

B. Increasing $[COBr_2]$ will increase K_{eq}.

C. Increasing the temperature will decrease K_{eq}.

D. Decreasing the temperature will decrease K_{eq}.

13. Consider the following equilibrium equation:

$$N_2H_6CO_2(s) \rightleftarrows 2NH_3(g) + CO_2(g)$$

Initially, $0.245\,\text{mol}$ $N_2H_6CO_2$ is placed in a $1.0\,\text{L}$ container. At equilibrium, $[CO_2] = 0.18\,\text{M}$. What is the value of K_{eq}?

A. 5.8×10^{-3}

B. 2.3×10^{-2}

C. 3.2×10^{-2}

D. 6.5×10^{-2}

14. Consider the following equilibrium equation:

$$H_2(g) + C_2N_2(g) \rightleftarrows 2HCN(g) \qquad K_{eq} = 1.20$$

Initially, $0.86\,\text{mol}$ H_2, $2.8\,\text{mol}$ C_2N_2 and $1.6\,\text{mol}$ HCN are placed in a $2.0\,\text{L}$ flask. Which of the following is true?

A. Trial $K_{eq} > K_{eq}$ so the reaction proceeds to the left.

B. Trial $K_{eq} < K_{eq}$ so the reaction proceeds to the left.

C. Trial $K_{eq} < K_{eq}$ so the reaction proceeds to the right.

D. Trial $K_{eq} > K_{eq}$ so the reaction proceeds to the right.

15. Which of the following solutes is a non-electrolyte?

A. H_2CO_3

B. $H_2C_2O_4$

C. CH_3OCH_3

D. CH_3COOH

16. Which of the following best describes a saturated solution?

A. It is at equilibrium.
B. It has high energy and is unstable.
C. It has extra capacity to dissolve solute.
D. Its rate of crystallization is less than the rate of dissolving.

17. What is observed when equal volumes of 0.2 M $CuSO_4$ and 0.2 M $Be(NO_3)_2$ are mixed?

A. $BeSO_4$ precipitates.
B. No precipitate forms.
C. $Cu(NO_3)_2$ precipitates.
D. Both $BeSO_4$ and $Cu(NO_3)_2$ precipitate.

18. Which of the following is the complete ionic equation for the precipitation reaction between $Fe(NO_3)_3(aq)$ and $Na_2CO_3(aq)$?

A. $2Fe^{3+}(aq) + 3CO_3^{2-}(aq) \rightarrow Fe_2(CO_3)_3(s)$
B. $2Fe(NO_3)_3(aq) + 3Na_2CO_3(aq) \rightarrow Fe_2(CO_3)_3(s) + 6NaNO_3(s)$
C. $Fe^{3+}(aq) + 3NO_3^-(aq) + 2Na^+(aq) + CO_3^{2-}(aq) \rightarrow Fe_2(CO_3)_3(s) + Na^+(aq) + NO_3^-(aq)$
D. $2Fe^{3+}(aq) + 6NO_3^-(aq) + 6Na^+(aq) + 3CO_3^{2-}(aq) \rightarrow Fe_2(CO_3)_3(s) + 6Na^+(aq) + 6NO_3^-(aq)$

19. What is the K_{sp} expression for a saturated solution of $NaHSO_3$?

A. $K_{sp} = [Na^+][HSO_3^-]$
B. $K_{sp} = \dfrac{[Na^+][HSO_3^-]}{[NaHSO_3]}$
C. $K_{sp} = [Na^+][H^+][SO_3^{2-}]$
D. $K_{sp} = \dfrac{[NaHSO_3]}{[Na^+][H^+][SO_3^{2-}]}$

20. What is the K_{sp} for the salt Ag_2CrO_4 when its solubility is found to be 2.9×10^{-4} M?

A. 9.8×10^{-11}
B. 2.4×10^{-11}
C. 8.4×10^{-8}
D. 2.9×10^{-4}

21. Which salt would be used to determine the presence of $S^{2-}(aq)$ by a precipitation reaction?

A. Na_2S
B. $MgCl_2$
C. K_3PO_4
D. $Pb(NO_3)_2$

22. Which of the following is a characteristic that is common to bases?

A. They react with metals to produce OH^-.
B. They produce a yellow colour in bromthymol blue solution.
C. They produce solutions with $[OH^-]$ smaller than 1.0×10^{-7} M.
D. They produce solutions with $[H_3O^+]$ smaller than 1.0×10^{-7} M.

23. What is a common substance found in solid drain cleaner?

A. Na
B. HCl
C. NaCl
D. NaOH

24. Which equation contains a Brønsted-Lowry acid-base pair?

A. $2H_2(g) + O_2(g) \rightleftarrows 2H_2O(g)$
B. $NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$
C. $Zn(s) + 2HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$
D. $H_2O(\ell) + HCN(aq) \rightleftarrows H_3O^+(aq) + CN^-(aq)$

25. Which solution would have the greatest electrical conductivity?

A. 0.1 M HCl
B. 0.1 M NH_3
C. 0.1 M H_3BO_3
D. 0.1 M CH_3OH

26. Which acid has the strongest conjugate base?

A. H_2O_2
B. H_2CO_3
C. HCO_3^-
D. $HC_2O_4^-$

27. What is the equilibrium expression for the water ionization constant?

A. $K_w = K_a \times K_b$
B. $K_w = 1.0 \times 10^{-14}$
C. $K_w = pH + pOH$
D. $K_w = [H_3O^+][OH^-]$

28. What is the $[H_3O^+]$ in 100.0 mL of 0.0050 M NaOH ?

A. 5.0×10^{-17} M
B. 2.0×10^{-13} M
C. 2.0×10^{-12} M
D. 2.0×10^{-11} M

29. What is the pH of a 2.5 M KOH solution?

A. −0.40
B. 0.40
C. 13.60
D. 14.40

30. What is the value of K_b for $H_2PO_4^-$?

A. 1.3×10^{-12}

B. 6.2×10^{-8}

C. 1.6×10^{-7}

D. 7.5×10^{-3}

31. One of the products of the reaction between $HCl(aq)$ and $NH_4OH(aq)$ undergoes hydrolysis. What is the net ionic equation for this hydrolysis reaction?

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

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

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

D. $HCl(aq) + NH_4OH(aq) \rightleftarrows NH_4Cl(aq) + H_2O(\ell)$

32. One of the species in the chemical indicator HIn^- exhibits a yellow colour. If acid is added, the indicator turns red. Which of the following is correct?

	Red	Yellow
A.	In^{2-}	H_2In
B.	In^{2-}	HIn^-
C.	HIn^-	H_2In
D.	H_2In	HIn^-

33. An indicator changes colour in the pH range of $6.40 - 7.20$.
What is the K_a for this indicator?

A. 4.0×10^{-7}

B. 1.6×10^{-7}

C. 0.80

D. 6.80

34. A 25.0 mL sample of the weak acid H_2S is titrated with 31.8 mL of 0.30 M NaOH (a strong base). What is the concentration of the acid?

A. 0.19 M
B. 0.24 M
C. 0.38 M
D. 0.76 M

35. Which of the following is the net ionic equation for the titration reaction of $NH_3(aq)$ with $HCl(aq)$?

A. $H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
B. $NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$
C. $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$
D. $NH_3(aq) + H^+(aq) + Cl^-(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$

36. What is the main function of a buffer solution?

A. to neutralize acids
B. to resist changes in pH
C. to maintain solution neutrality
D. to prevent acids from mixing with bases

37. Which of the following would commonly be used to prepare a buffer solution?

A. HCl and KCl
B. NH_3 and NH_4Cl
C. H_2S and Na_2SO_4
D. Na_2CO_3 and NaOH

38. Which of the following represents a reaction that can occur between a non-metallic oxide and water?

A. $SO_2 + H_2O \rightarrow H_2SO_3$

B. $Na_2O + H_2O \rightarrow 2NaOH$

C. $CaO + H_2O \rightarrow Ca(OH)_2$

D. $NO_2 + H_2O \rightarrow H_2NO + O_2$

39. What is true about a chemical species that loses electrons during a chemical reaction?

A. It is oxidized.
B. It is called a cathode.
C. It is an oxidizing agent.
D. Its oxidation number decreases.

40. How does the oxidation number change for O if Na_2O_2 is converted to Na and O_2?

A. decreases by 1
B. no change
C. increases by 1
D. increases by 2

Use the following half-reactions to answer questions 41 and 42.

1	$2H_2SO_3 + 2H^+ + 4e^- \rightarrow S_2O_3^{2-} + 3H_2O$
2	$SnCl_6^{2-} + 2e^- \rightarrow Sn^{2+} + 6Cl^-$
3	$\frac{1}{2}Hg_2^{2+} + e^- \rightarrow Hg(\ell)$
4	$Sb_2O_5 + 6H^+ + 4e^- \rightarrow 2Sb(OH)_2^+ + H_2O$

41. A redox reaction occurs when Sb_2O_5 is mixed with $S_2O_3^{2-}$, but no reaction occurs when Sb_2O_5 is mixed with Hg. A solution of $SnCl_6^{2-}$ has no effect on $S_2O_3^{2-}$. Which of the following describes the order of the half-reaction reduction potentials from highest to lowest?

A. $2 > 1 > 4 > 3$
B. $2 > 4 > 1 > 3$
C. $3 > 1 > 4 > 2$
D. $3 > 4 > 1 > 2$

42. The initial voltage of a standard electrochemical cell based on the half-reactions 3 and 4 above, is $0.22\,V$. If Hg_2^{2+} is reduced, what is the reduction potential for half-reaction 4?

A. $-0.58\,V$
B. $+0.58\,V$
C. $+0.63\,V$
D. $+1.02\,V$

43. If $Fe^{3+}(aq)$ and $Cl^-(aq)$ are mixed, $FeCl_3(aq)$ results. However, if $Fe^{3+}(aq)$ and $I^-(aq)$ are mixed, $FeI_3(aq)$ does not result. Which of the following best describes why?

A. FeI_3 is soluble.
B. I^- is oxidized in the solution.
C. Fe^{3+} forms an acidic solution.
D. Fe^{3+} is too strong a reducing agent.

44. Bleaching powder, $CaCl(ClO)$, reacts when it dissolves in water as follows:

$$CaCl(ClO) + 2H^+ \rightarrow Ca^{2+} + Cl_2 + H_2O$$

Which of the following is the correct half-reaction for the reduction part of this process?

A. $2Cl^- \rightarrow Cl_2 + 2e^-$

B. $2e^- + 2Cl^- \rightarrow Cl_2$

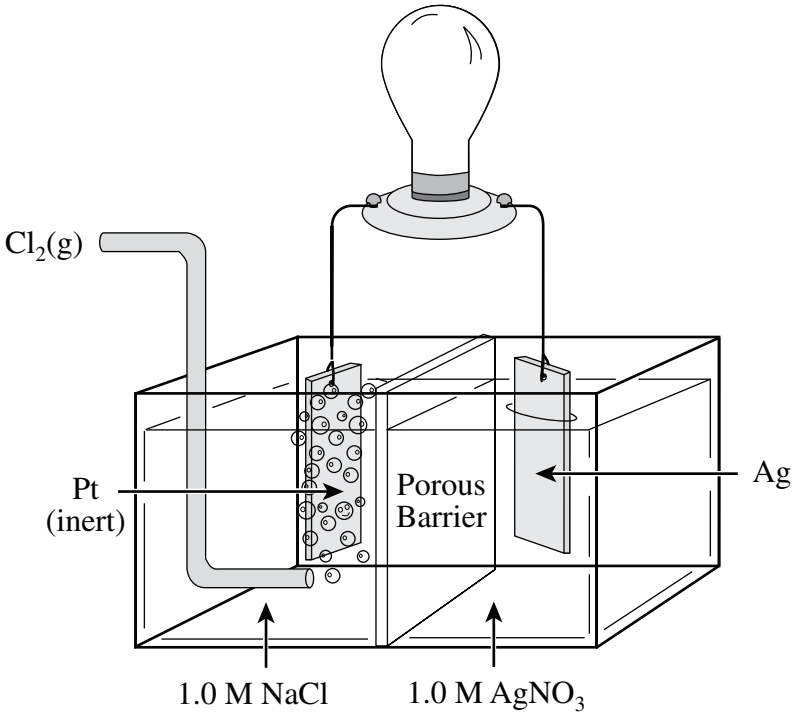
C. $4H^+ + 2ClO^- \rightarrow Cl_2 + 2H_2O + 2e^-$

D. $2e^- + 4H^+ + 2ClO^- \rightarrow Cl_2 + 2H_2O$

45. A redox titration is carried out by adding purple $KMnO_4$ solution from a burette to a solution of H_2O_2 in a flask, under acidic conditions. Which of the following would correctly describe the observed colour and the product formed in the flask before the equivalence point is reached?

	Observed Colour	Product Formed
A.	remains purple	H_2
B.	remains purple	O_2
C.	becomes colourless	H_2
D.	becomes colourless	O_2

Use the following diagram to answer questions 46 and 47.



46. Which of the following gives the anode material and its correct half-reaction?

	Anode	Anode Half-reaction
A.	Pt	$2Cl^- \rightarrow Cl_2 + 2e^-$
B.	Cl_2	$Cl_2 + 2e^- \rightarrow 2Cl^-$
C.	Ag	$Ag \rightarrow Ag^+ + e^-$
D.	Ag	$Ag^+ + e^- \rightarrow Ag$

47. After the cell has operated for a time, ion migration through the porous barrier has taken place. What observation would be expected from the resulting mixtures?

A. A solid would form on the silver electrode.
B. A precipitate would form in both half-cells.
C. A precipitate would form in the silver half-cell only.
D. A precipitate would form in the chlorine half-cell only.

48. As a standard $Zn-Ni$ electrochemical cell is allowed to reach equilibrium, several changes take place. Which of the following best describes the typical changes which occur?

	Cell Voltage	$[Ni^{2+}]$
A.	drops to zero	equals the $[Zn^{2+}]$
B.	drops to zero	decreases to a low value
C.	drops to some low but non-zero value	equals the $[Zn^{2+}]$
D.	changes from positive to negative	decreases to zero

49. Which of the following methods will **not** prevent corrosion of a piece of iron?

A. painting it
B. wrapping copper wire around it
C. wrapping magnesium ribbon around it
D. connecting it to the negative terminal of a DC power supply

50. Which of the following species is consumed during the electrolysis of aqueous $CuSO_4$ when using a copper cathode and a carbon anode?

A. O_2
B. Cu
C. Cu^{2+}
D. SO_4^{2-}

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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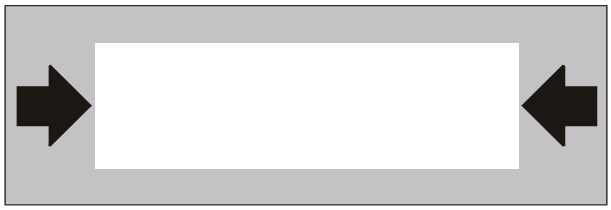

Course Code = CH 12

AUGUST 2007

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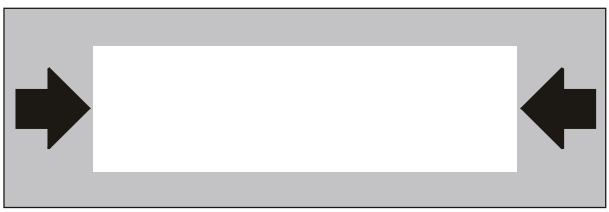


Course Code = CH 12

Chemistry 12

AUGUST 2007

Response Booklet

BRITISH COLUMBIA
The Best Place on Earth

PART B: WRITTEN RESPONSE
Value: 37.5% of the examination

Suggested Time: 40 minutes

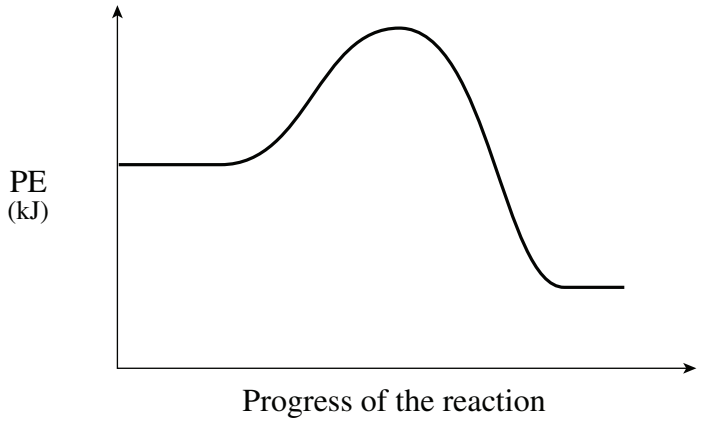
INSTRUCTIONS: Answer the following questions in the space provided in this **Response Booklet.** You are expected to communicate your knowledge and understanding of chemical principles in a clear and logical manner. Your steps and assumptions leading to a solution must be written in this **Response Booklet**. 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. **(4 marks)**

A catalyzed decomposition of ozone (O_3) occurs in a series of steps as illustrated below:

Step 1	$O_3 + \text{sunlight} \rightarrow O_2 + O$
Step 2	$O_3 + NO \rightarrow NO_2 + O_2$
Step 3	$NO_2 + O \rightarrow NO + O_2$
Overall Reaction	
Catalyst	

Write the equation for the overall reaction and then identify the catalyst in the spaces above.
The PE diagram below represents the uncatalyzed decomposition of ozone. On the PE diagram, sketch a curve that could represent the mechanism for the catalyzed decomposition.



2. **(4 marks)**

Consider the following equilibrium:

$$H_2(g) + CO_2(g) \rightleftarrows CO(g) + H_2O(g) \qquad K_{eq} = 0.12$$

Initially, 1.0 mol of CO and 1.0 mol H_2O are placed in a 2.0 L container.
Calculate the equilibrium of $[CO]$.

3. **(4 marks)**

Consider the equilibrium for a saturated solution of $CaCO_3$:

$$CaCO_3(s) \rightleftarrows Ca^{2+} + CO_3^{2-}$$

What is the maximum $\left[Mg^{2+}\right]$ that can exist in a saturated solution of $CaCO_3$ without causing a precipitate to form?

4. **(3 marks)**

Complete the following equilibrium, then predict whether reactants or products will be favoured and explain why.

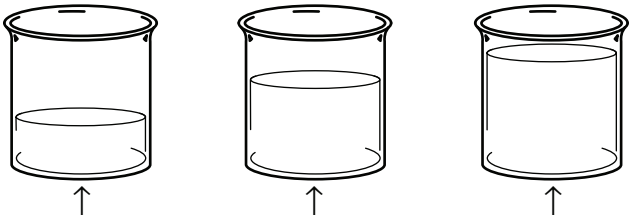
$$HSO_3^- + H_2PO_4^- \rightleftarrows$$

5. **(5 marks)**

Calculate the pH of a $0.35\,M$ solution of the salt ammonium bromide.
Begin by writing the equation for the predominant equilibrium.

6. **(3 marks)**

The following three solutions are mixed together in a fourth container:



40.0 mL of 1.0 M HCl | 60.0 mL of 1.0 M HBr | 100.0 mL of 0.50 M NaOH

What pH results?

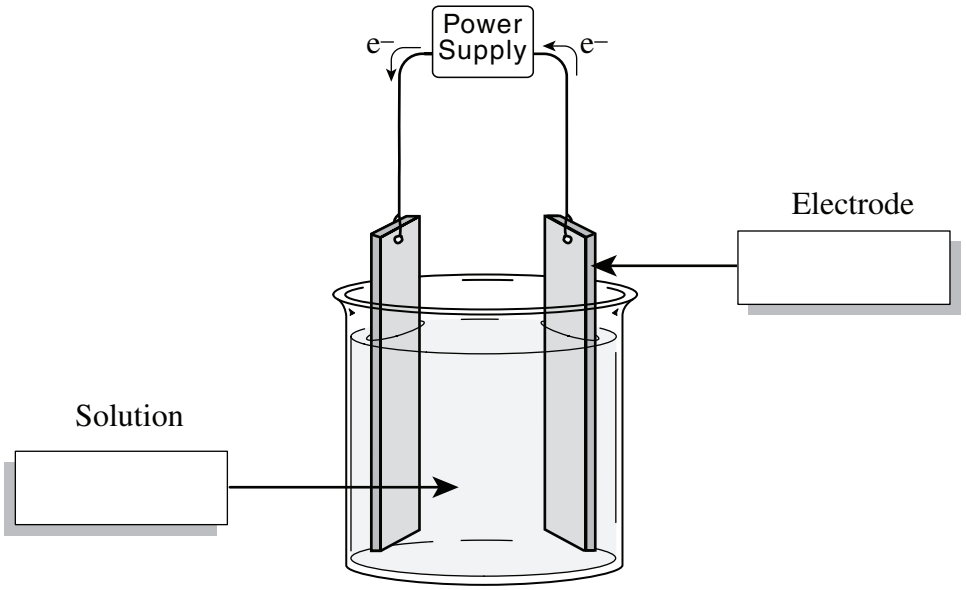
7. **(4 marks)**

Balance the following redox equation in acidic solution:

$$H_2O_2 + SCN^- \rightarrow NH_4^+ + H_2O + HCO_3^- + HSO_4^- \qquad \text{(acidic)}$$

8. **(3 marks)**

During the electrolysis of an ionic solution it was observed that gas bubbles formed on the anode, and a solid formed on the cathode. On the diagram below, provide possible substances for the two parts indicated, and the anode half-reaction.



Anode half-reaction

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 students break any of the following rules:

   - Students must not be in possession of or have used any secure examination materials prior to the examination session.
   - Students must not communicate with other students during the examination.
   - Students 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.
   - Students 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.
   - Students must not copy, plagiarize or present as one's own, work done by any other person.
   - Students 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.
   - Students must not remove any piece of the examination materials from the examination room, including work pages.

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.