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MINISTRY USE ONLY

BRITISH COLUMBIA

Chemistry 12

JANUARY 2004

Course Code = CH

Student Instructions

1. Place the stickers with your Personal Education Number (PEN) in the allotted spaces above. **Under no circumstance is your name or identification, other than your Personal Education Number, to appear on this booklet.**
2. Ensure that in addition to this examination booklet, you have a **Data Booklet** and an **Examination Response Form**. Follow the directions on the front of the Response Form.
3. **Disqualification** from the examination will result if you bring books, paper, notes or unauthorized electronic devices into the examination room.
4. When instructed to open this booklet, **check the numbering of the pages** to ensure that they are numbered in sequence from page one to the last page, which is identified by

   END OF EXAMINATION .

5. At the end of the examination, place your Response Form inside the front cover of this booklet and return the booklet and your Response Form to the supervisor.

Question 1:

1. . (5)

Question 2:

2. . (3)

Question 3:

3. . (3)

Question 4:

4. . (4)

Question 5:

5. . (5)

Question 6:

6. . (3)

Question 7:

7. . (4)

Question 8:

8. . (3)

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GENERAL INSTRUCTIONS

1. Aside from an approved calculator, electronic devices, including dictionaries and pagers, are **not** permitted in the examination room.

2. All multiple-choice answers must be entered on the Response Form using an **HB pencil**. Multiple-choice answers entered in this examination booklet will **not** be marked.

3. For each of the written-response questions, write your answer in the space provided in this booklet.

4. Ensure that you use language and content appropriate to the purpose and audience of this examination. Failure to comply may result in your paper being awarded a zero.

5. This examination is designed to be completed in **two hours**. *Students may, however, take up to 30 minutes of additional time to finish.*

CHEMISTRY 12 PROVINCIAL EXAMINATION

1. This examination consists of **two** parts:

		Value	Suggested Time
PART A:	60 multiple-choice questions	60	80
PART B:	8 written-response questions	30	40
	Total:	**90 marks**	**120 minutes**

2. The following tables can be found in the separate **Data Booklet**:
   - Periodic Table of the Elements
   - Atomic Masses of the Elements
   - Names, Formulae, and Charges of Some Common Ions
   - Solubility of Common Compounds in Water
   - Solubility Product Constants at 25°C
   - Relative Strengths of Brønsted-Lowry Acids and Bases
   - Acid-Base Indicators
   - Standard Reduction Potentials of Half-cells

   No other reference materials or tables are allowed.

3. **A calculator is essential for the Chemistry 12 Provincial Examination.** The calculator must be a hand-held device designed primarily for mathematical computations involving logarithmic and trigonometric functions and may be capable of performing graphing functions. Computers, calculators with a QWERTY keyboard or symbolic manipulation abilities, and electronic writing pads will not be allowed. Students must not bring any external devices (peripherals) to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, CD-ROMs, libraries or external keyboards. Students may have more than one calculator available during the examination, of which one may be a scientific calculator. Calculators may not be shared and must not have the ability to either transmit or receive electronic signals. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

   Calculators must not have any information programmed into memory that would not be acceptable in paper form. Specifically, calculators must not have any built-in notes, definitions, or libraries. There is no requirement to clear memories at the beginning of the examination but the use of calculators with built-in notes is equivalent to the use of notes in paper form. Any student deemed to have cheated on a provincial examination will receive a "0" on that examination and will be permanently disqualified from the Provincial Examination Scholarship Program.

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PART A: MULTIPLE CHOICE

Value: 60 marks **Suggested Time: 80 minutes**

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

1. Which of the following factors only affects the rate of heterogeneous reactions?

   A. nature of reactants
   B. presence of a catalyst
   C. temperature of reactants
   D. surface area of reactants

2. Consider the following reactions in open systems:

I.	$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$
II.	$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$
III.	$CaO_{(s)} + SiO_{2(s)} \rightarrow CaSiO_{3(s)}$
IV.	$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow NaNO_{3(aq)} + AgCl_{(s)}$

   In which of the above could reaction rate be determined by $\frac{\Delta \text{ mass of system}}{\Delta \text{ time}}$?

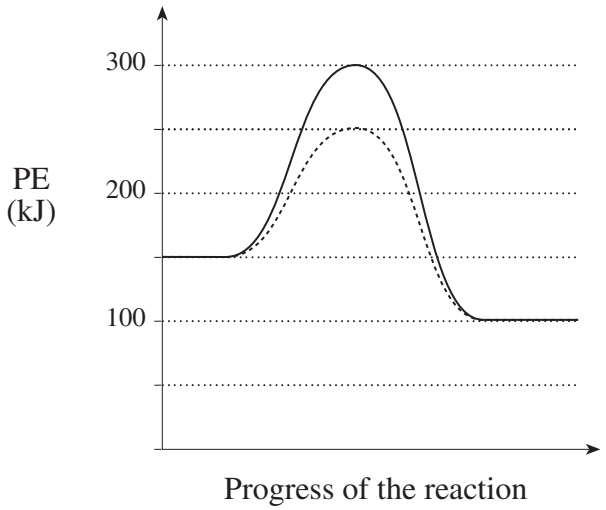
   A. I
   B. II
   C. III
   D. IV

3. Which of the following best describes *activation energy*?

   A. PE of activated complex
   B. $(\text{PE of products}) - (\text{PE of reactants})$
   C. $(\text{PE of reactants}) - (\text{PE of activated complex})$
   D. $(\text{PE of activated complex}) - (\text{PE of reactants})$

OVER

4. Consider the following PE diagram:



Which of the following is true for the forward reaction?

	Reaction	PE of Activated Complex (kJ)	ΔH (kJ)
A.	catalyzed	100	–50
B.	uncatalyzed	300	–50
C.	catalyzed	250	+50
D.	uncatalyzed	150	–50

5. Consider the following reaction:

$$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$$

Why would this reaction probably involve more than one step?

A. There is insufficient activation energy.
B. This reaction has high activation energy.
C. Reactions between gases are typically slow.
D. A successful collision between more than two molecules is unlikely.

6. Consider the following reaction mechanism:

Step 1	$O_3 \rightarrow O_2 + O$
Step 2	$O_3 + O \rightarrow 2O_2$

Which of the following could represent the activated complex for Step 2?

A. O
B. O_2
C. O_3
D. O_4

7. In a certain reaction $\Delta H = -136\,\text{kJ}$ and $E_a = 96\,\text{kJ}$. Which of the following is true of its reverse reaction?

A. The reverse reaction is exothermic and $E_a = -40\,\text{kJ}$.
B. The reverse reaction is exothermic and $E_a = 40\,\text{kJ}$.
C. The reverse reaction is endothermic and $E_a = 96\,\text{kJ}$.
D. The reverse reaction is endothermic and $E_a = 232\,\text{kJ}$.

8. Two experiments were performed involving the following equilibrium. The temperature was the same in both experiments.

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

In experiment A, $1.0\,\text{M}$ H_2 and $1.0\,\text{M}$ I_2 were initially added to a flask and equilibrium was established. In experiment B, $2.0\,\text{M}$ HI was initially added to a second flask and equilibrium was established. Which of the following statements is always true about the equilibrium concentrations?

A. $[H_2]$ equals $[HI]$ in experiment A.

B. $[HI]$ equals $2[H_2]$ in experiment A.

C. $[HI]$ in experiment A equals $[HI]$ in experiment B.

D. $[HI]$ in experiment A equals $\frac{1}{2}[I_2]$ in experiment B.

OVER

9. Which of the following reactions is accompanied by an increase in enthalpy?

A. $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)} + 113\,kJ$

B. $2H_{2(g)} + O_{2(g)} - 484\,kJ \rightleftarrows 2H_2O_{(g)}$

C. $2SO_{3(g)} \rightleftarrows 2SO_{2(g)} + O_{2(g)} \qquad \Delta H = +197\,kJ$

D. $4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} \qquad \Delta H = -111.4\,kJ$

10. Two substances are mixed and no reaction occurs. With respect to enthalpy and entropy, which of the following could explain why no reaction occurs?

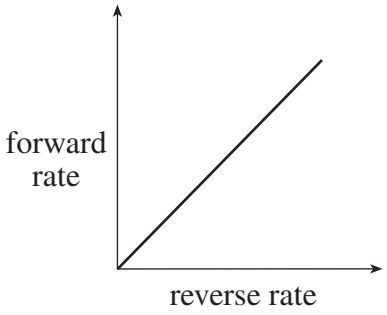
	Enthalpy	Entropy
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

11. Consider the following reaction:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)}$$

Which of the following diagrams represents what happens to the forward and reverse reaction rates when the catalyst Fe_3O_4 is added?

A.



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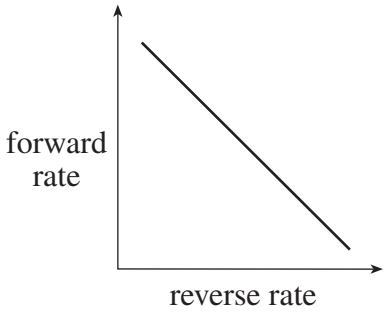

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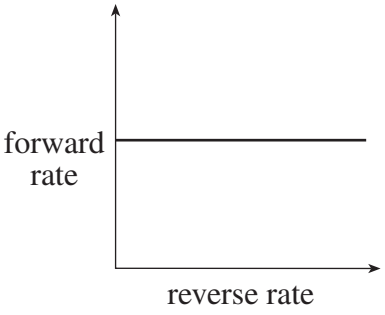

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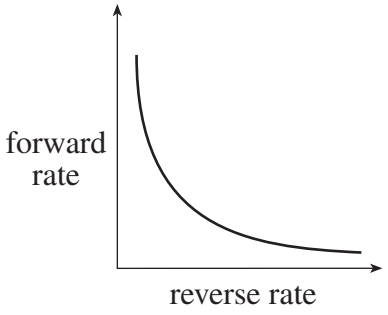
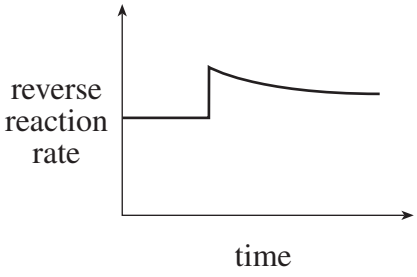


12. Temperature is gradually decreased then held constant in an exothermic equilibrium. Which of the following represents the change in the reverse reaction rate?

A.



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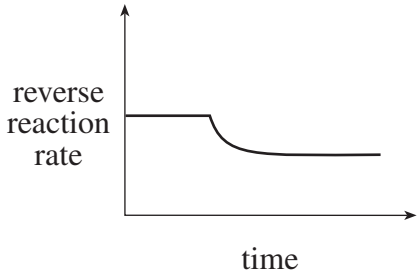

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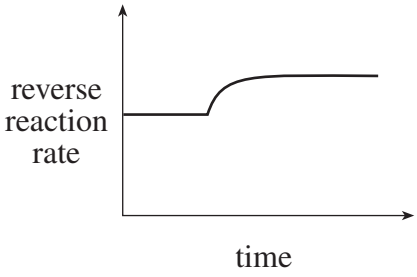

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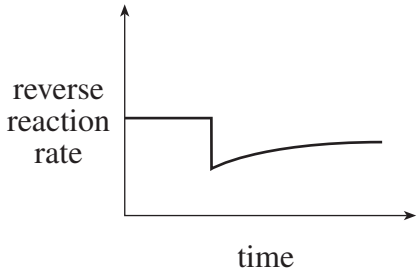


OVER

13. Consider the following equilibrium:

$$CaCO_{3(s)} + 2HF_{(g)} \rightleftarrows CaF_{2(s)} + H_2O_{(g)} + CO_{2(g)}$$

Which of the following represents the equilibrium $[H_2O]$?

A. $[H_2O] = \dfrac{[HF]^2}{K_{eq}[CO_2]}$

B. $[H_2O] = \dfrac{K_{eq}[HF]^2}{[CO_2]}$

C. $[H_2O] = \dfrac{[HF]^2[CaCO_3]}{K_{eq}[CO_2][CaF_2]}$

D. $[H_2O] = \dfrac{K_{eq}[HF]^2[CaCO_3]}{[CO_2][CaF_2]}$

14. Which of the following reactions will proceed furthest toward completion?

A. $Si_{(s)} + O_{2(g)} \rightleftarrows SiO_{2(s)} \qquad K_{eq} = 2.0 \times 10^{142}$

B. $2HBr_{(g)} \rightleftarrows H_{2(g)} + Br_{2(g)} \qquad K_{eq} = 7.0 \times 10^{-20}$

C. $2H_2O_{(g)} \rightleftarrows 2H_{2(g)} + O_{2(g)} \qquad K_{eq} = 7.3 \times 10^{-18}$

D. $C_2H_{4(g)} + H_{2(g)} \rightleftarrows C_2H_{6(g)} \qquad K_{eq} = 9.0 \times 10^{19}$

15. Consider the following equilibrium:

$$CH_{4(g)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + 3H_{2(g)} \qquad K_{eq} = 5.67$$

An equilibrium mixture of this system was found to contain the following concentrations: $[CH_4] = 0.59\,M$, $[H_2O] = 0.63\,M$, $[CO] = 0.25\,M$.
What was the equilibrium $[H_2]$?

A. 0.26 M
B. 0.64 M
C. 2.0 M
D. 8.4 M

Use the following information to answer questions 16 and 17.

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 49.5 \text{ at } 440°C$$

16. If 5.0 M HI is initially placed into a container, what will be the equilibrium $[HI]$?

    A. 0.33 M
    B. 3.9 M
    C. 4.4 M
    D. 4.8 M

17. If 0.120 M H_2, 0.120 M I_2 and 0.844 M HI are placed into a container at 440°C, which of the following is true as equilibrium is approached?

    A. $[I_2]$ decreases significantly.
    B. $[HI]$ decreases significantly.
    C. $[H_2]$ decreases significantly.
    D. $[H_2]$ remains the same.

18. Which of the following solutes will produce a molecular solution?

    A. HCl
    B. Fe_3S_3
    C. HNO_3
    D. CH_3OH

19. Which of the following would best describe the solubility of a solute?

    A. litres per gram
    B. moles per litre
    C. grams per mole
    D. moles per second

OVER

20. Which compound will have the lowest solubility?

A. FeS

B. $CaSO_4$

C. $AgBrO_3$

D. $Fe(NO_3)_3$

21. Which of the following precipitates may form when equal volumes of 0.3M $AgNO_3$, 0.3M $SrCl_2$ and 0.3M Na_2CO_3 are mixed together?

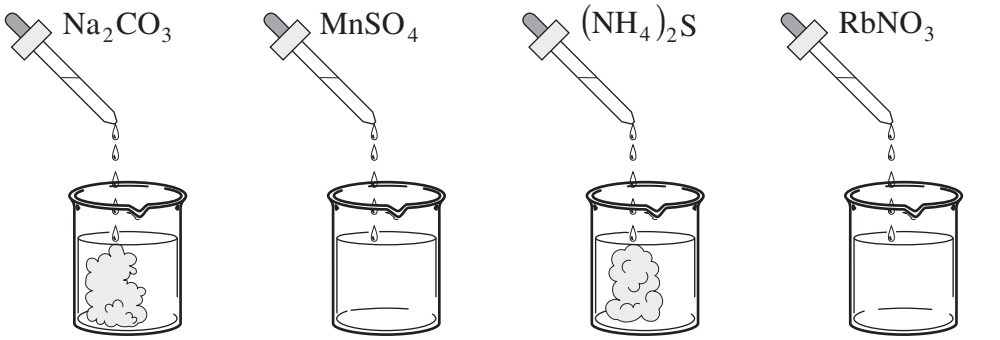
A. $SrCO_3$ and AgCl

B. Ag_2CO_3 and AgCl

C. $SrCO_3$ and Ag_2CO_3

D. $SrCO_3$, Ag_2CO_3 and AgCl

22. An experiment is conducted to identify an unknown cation that is present in each of four beakers.



Which of the following could be the unknown cation?

A. Ag^{+}

B. Fe^{+3}

C. Ba^{+2}

D. Be^{+2}

23. Given the equilibrium reaction:

$$2NaNO_{3(aq)} + Ag_2S_{(s)} \rightleftarrows 2AgNO_{3(aq)} + Na_2S_{(aq)}$$

Which K_{sp} expression best describes the net ionic reaction?

A. $K_{sp} = \left[Ag^+\right]^2 \left[S^{2-}\right]$

B. $K_{sp} = \dfrac{1}{\left[Ag^+\right]^2 \left[S^{2-}\right]}$

C. $K_{sp} = \dfrac{\left[Ag^+\right]^2 \left[S^{2-}\right]}{\left[Ag_2S\right]}$

D. $K_{sp} = \dfrac{\left[AgNO_3\right]^2 \left[Na_2S\right]}{\left[NaNO_3\right]^2}$

24. ~~For the salt $PbCl_2$, what will be the value for its K_{sp} when a solution with $\left[Pb^{+2}\right]$ of 0.2 M is mixed with an equal volume of a chloride ion solution at 0.2 M?~~

A. ~~1.2×10^{-5}~~
B. ~~8.0×10^{-3}~~
C. ~~1.0×10^{-2}~~
D. ~~4.0×10^{-2}~~

25. Two salt solutions were mixed and a Trial K_{sp} was calculated to be 2.0×10^{-9}. The K_{sp} value is 1.0×10^{-10}. From this information, which of the following is a true statement?

	K_{sp} comparison	Outcome
A.	Trial $K_{sp} < K_{sp}$	precipitate forms
B.	Trial $K_{sp} > K_{sp}$	precipitate forms
C.	Trial $K_{sp} < K_{sp}$	no precipitate forms
D.	Trial $K_{sp} > K_{sp}$	no precipitate forms

OVER

26. A saturated solution of $SrSO_4$ has a $\left[SO_4^{2-}\right]$ of 1.0×10^{-4} M.
What is the $\left[Sr^{2+}\right]$?

A. 3.4×10^{-3} M
B. 5.8×10^{-4} M
C. 1.0×10^{-4} M
D. 3.4×10^{-7} M

27. Which of the following is a common property of acid solutions?

A. They have a $pH > 7$.
B. They turn red litmus blue.
C. They have a slippery feeling.
D. They turn pink phenolphthalein colourless.

28. What is a general characteristic of all Brønsted-Lowry bases?

A. They all accept H^+ .
B. They all accept OH^- .
C. They will turn litmus a pink colour.
D. They will react with acids to produce H_2 gas.

29. Select the equation that best represents the reaction of CH_3NH_2 acting as a base with water.

A. $CH_3NH_{2(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3NH_3^+{}_{(aq)} + OH^-{}_{(aq)}$
B. $CH_3NH_{2(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3NH^-{}_{(aq)} + H_3O^+{}_{(aq)}$
C. $CH_3NH_{2(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3NH_2OH^-{}_{(aq)} + H^+{}_{(aq)}$
D. $CH_3NH_{2(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3^+{}_{(aq)} + NH_{3(aq)} + OH^-{}_{(aq)}$

30. Which of the following solutions will show the greatest electrical conductivity?

A. $0.1\,\text{M}\ \text{HCl}$
B. $0.5\,\text{M}\ \text{H}_2\text{CO}_3$
C. $0.5\,\text{M}\ \text{H}_3\text{BO}_3$
D. $0.1\,\text{M}\ \text{H}_2\text{C}_2\text{O}_4$

31. When comparing $0.10\,\text{M}\ \text{HPO}_4^{2-}$ and $0.10\,\text{M}\ \text{HC}_2\text{O}_4^{-}$ as acids, which of the following is true?

A. $\text{HC}_2\text{O}_4^{-}$ is weaker and its pH is larger.
B. HPO_4^{2-} is stronger and its pH is larger.
C. HPO_4^{2-} is weaker and its pH is smaller.
D. $\text{HC}_2\text{O}_4^{-}$ is stronger and its pH is smaller.

32. Which of the following will have the smallest K_b value?

A. IO_3^{-}
B. NH_3
C. CN^{-}
D. HPO_4^{2-}

33. Which of the following equations can be used to calculate pOH ?

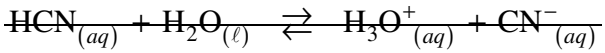
A. $\text{pOH} = -\log \text{K}_w$
B. $\text{pOH} = \text{pK}_w + \text{pH}$
C. $\text{pOH} = \text{pK}_w - \text{pH}$
D. $\text{pOH} = -\log\left[\text{H}_3\text{O}^{+}\right]$

OVER

34. Which of the following solutions would have a $pH = 2.00$?

A. 0.010 M HCl
B. 0.010 M HCN
C. 0.010 M H_2SO_4
D. 0.010 M NaOH

35. ~~Consider the following acid equilibrium:~~



~~When writing the K_a expression for HCN, why is $H_2O_{(\ell)}$ not included in the expression?~~

A. ~~The concentration of $H_2O_{(\ell)}$ is too large.~~
B. ~~The concentration of $H_2O_{(\ell)}$ is too small.~~
C. ~~The concentration of $H_2O_{(\ell)}$ does not exist.~~
D. ~~The concentration of $H_2O_{(\ell)}$ is relatively constant.~~

36. What is the K_b value for $HC_6H_5O_7^{2-}$?

A. 1.0×10^{-14}
B. 5.9×10^{-10}
C. 2.4×10^{-8}
D. 4.1×10^{-7}

37. Which of the following describes the dissociation of calcium chloride?

A. $CaCl_{(s)} \rightarrow Ca^{+}_{(aq)} + Cl^{-}_{(aq)}$
B. $Ca_2Cl_{(s)} \rightarrow Ca_2^{+}{}_{(aq)} + Cl^{-}_{(aq)}$
C. $CaCl_{2(s)} \rightarrow Ca^{2+}_{(aq)} + Cl_2^{-}{}_{(aq)}$
D. $CaCl_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2Cl^{-}_{(aq)}$

38. Which of the following properties is true for a solution of KNO_3 ?

A. It is neutral.
B. It is very basic.
C. It is slightly basic.
D. It is slightly acidic.

39. Which term does the following statement best describe? *A mixture of a weak acid and its conjugate base, each with distinguishing colours.*

A. buffer
B. titration
C. indicator
D. primary standard

40. A weak acid is titrated with a strong base using the indicator phenolphthalein to detect the end point. What is the approximate pH at the transition point?

A. 7.0
B. 8.0
C. 9.0
D. 10.0

41. Which of the following titrations always results in pH = 7.0 at the equivalence point?

A. A weak acid is titrated with a weak base.
B. A weak acid is titrated with a strong base.
C. A strong acid is titrated with a weak base.
D. A strong acid is titrated with a strong base.

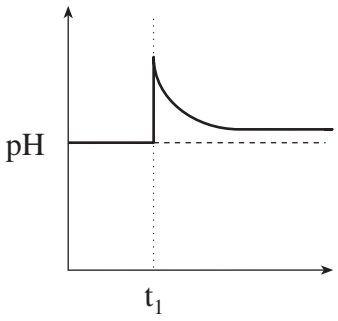
42. What volume of 0.500 M NaOH is required to neutralize 25.0 mL of 0.250 M HBr ?

A. 5.00 mL
B. 12.5 mL
C. 20.0 mL
D. 25.0 mL

OVER

43. Which of the following graphs best describes the effect on the pH of a buffer solution when a small amount of acid is added at t_1 ?

A.



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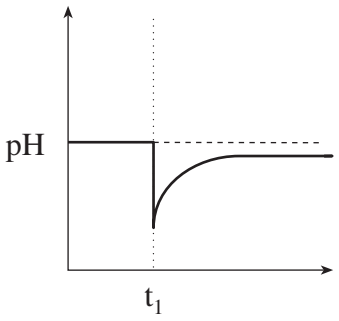

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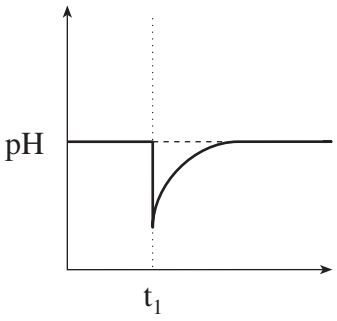

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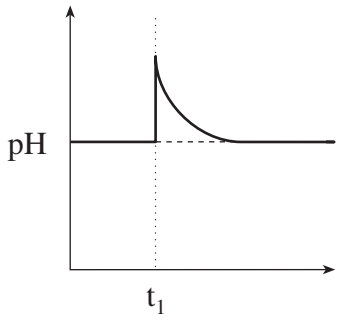


44. A buffer solution is prepared using sufficient amounts of H_2S and NaHS. What limits this buffer's effectiveness when NaOH is added?

A. $[H_2S]$
B. $[HS^-]$
C. $[OH^-]$
D. $[H_3O^+]$

45. What is produced when MgO is added to water?

A. the metal Mg
B. the acid $HMgO$
C. the base $Mg(OH)_2$
D. the amphiprotic species H_2MgO

46. Which of the following is a major source of $NO_{2(g)}$, which contributes to the problem of acid rain?

A. a fuel cell
B. an air conditioner
C. a nuclear power plant
D. the automobile engine

47. Identify the oxidizing agent in the following equation:

$$Pb + PbO_2 + 4H^+ + 2SO_4^{2-} \rightarrow 2PbSO_4 + 2H_2O$$

A. H^+
B. Pb
C. PbO_2
D. SO_4^{2-}

48. Which of the following is a redox equation?

A. $2H_2 + O_2 \rightarrow 2H_2O$
B. $Ag_2CrO_4 \rightarrow 2Ag^+ + CrO_4^{2-}$
C. $Ag(NH_3)_2^+ + 2H^+ + Cl^- \rightarrow AgCl + 2NH_4^+$
D. $Mn(OH)_2 + 2HC_2H_3O_2 \rightarrow Mn^{2+} + 2H_2O + 2C_2H_3O_2^-$

OVER

49. Which of the following contains molybdenum with its highest oxidation number?

A. $MoCl_5$
B. Mo_2S_3
C. MoO_4^{2-}
D. Mo_6Cl_{12}

50. Which of the following skeletal half-reactions are not oxidations?

I.	$ClO^- \rightarrow ClO_3^-$
II.	$C_2H_5OH \rightarrow C_2H_4O_2$
III.	$NO_2 \rightarrow N_2O_4$

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

51. Consider the following half-reactions under standard conditions:

I.	$ClO_2 + e^- \rightarrow ClO_2^-$
II.	$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$
III.	$Fe^{3+} + 3e^- \rightarrow Fe$

In an experiment when ClO_2 and Fe were combined, they reacted. In a second experiment when $PbSO_4$ and Fe were combined, there was no observable change. Which of the following shows the reduction half-reactions I, II and III in order of decreasing E° ?

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

52. Which of the following combinations will react spontaneously?

A. $I_2 + Cu^{2+}$
B. $Pb^{2+} + Ag$
C. $Zn^{2+} + Mg$
D. $Sn^{2+} + Ni^{2+}$

53. Consider the following skeletal redox equation for a reaction in basic solution:

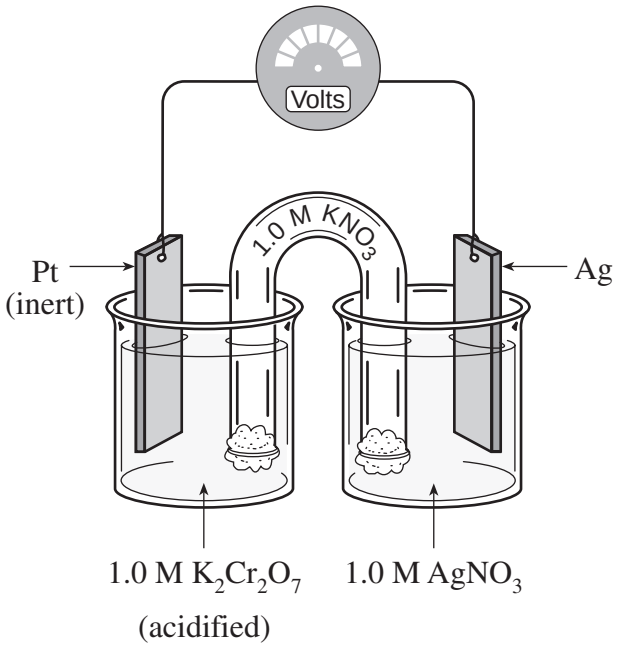
$$Zn + NO_3^- \rightarrow ZnO_2^{2-} + NH_3 \qquad (\text{basic})$$

Which of the following best represents the reduction half-reaction occurring in this solution?

A. $9H^+ + NO_3^- + 8e^- \rightarrow NH_3 + 3H_2O$
B. $3H_2O + NO_3^- + 5e^- \rightarrow NH_3 + 6OH^-$
C. $6H_2O + NO_3^- + 8e^- \rightarrow NH_3 + 9OH^-$
D. $4OH^- + Zn + 2e^- \rightarrow ZnO_2^{2-} + 2H_2O$

OVER

Use the following diagram to answer questions 54 to 56.



54. Which of the following represents the overall cell reaction?

A. $Cr_2O_7^{2-} + H^+ + Ag \rightarrow Ag^+ + Cr^{3+} + H_2O$
B. $Cr_2O_7^{2-} + 14H^+ + 9Ag \rightarrow 9Ag^+ + Cr^{3+} + 7H_2O$
C. $Cr_2O_7^{2-} + 14H^+ + 6Ag \rightarrow 6Ag^+ + 2Cr^{3+} + 7H_2O$
D. $Cr_2O_7^{2-} + 14H^+ + 6Ag^+ \rightarrow 6Ag + 2Cr^{3+} + 7H_2O$

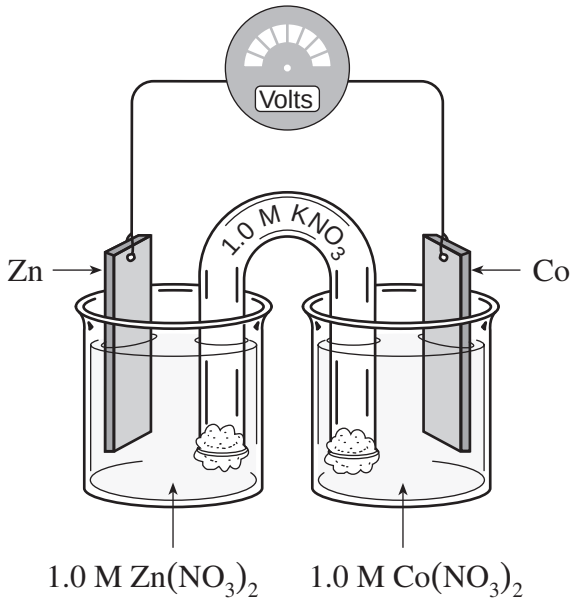
55. What happens to the pH at each electrode?

	pH at Anode	pH at Cathode
A.	increases	decreases
B.	increases	increases
C.	stays the same	decreases
D.	stays the same	increases

56. What is the cell voltage at equilibrium?

A. −0.43 V
B. 0.00 V
C. +0.43 V
D. +2.03 V

57. Consider the following diagram:



Which of the following best describes the Co^{2+} ion movement and the mass of the zinc electrode as the cell operates?

	Co^{2+} movement	Mass of zinc electrode
A.	toward the Co electrode	increases
B.	toward the Co electrode	decreases
C.	toward the Zn electrode	increases
D.	toward the Zn electrode	decreases

OVER

58. Which of the following would protect an iron pipeline from rusting?

A. connecting it to a solution of silver nitrate
B. connecting it to the positive terminal of a direct current power supply
C. connecting it to the negative terminal of a direct current power supply
D. connecting it to electrodes made of copper which are buried beside the pipeline

59. Which of the following best describes a car battery as it is being recharged?

A. It is an electrolytic cell.
B. It is an electrochemical cell.
C. It is an example of a short circuit.
D. It is a system moving to a state of lower potential energy.

60. What are the most likely products of the electrolysis of 1.0 M MgI_2 using inert electrodes?

A. H_2 and I_2
B. Mg and I_2
C. H_2 and O_2
D. Mg and O_2

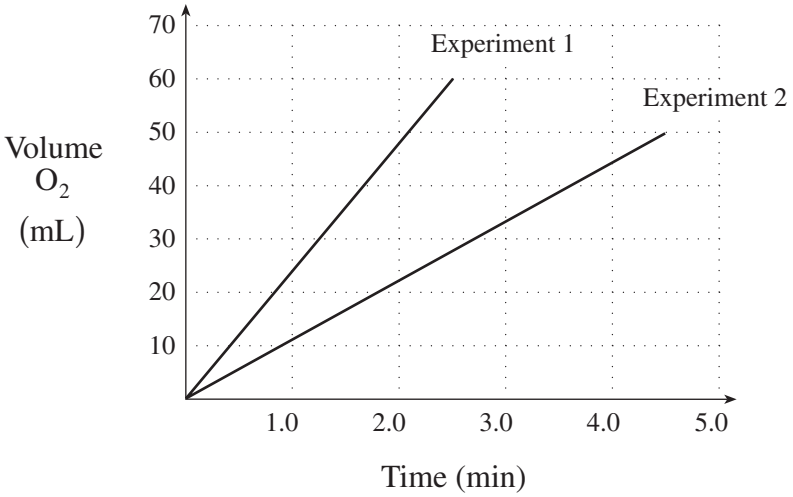
This is the end of the multiple-choice section.
Answer the remaining questions directly in this examination booklet.

PART B: WRITTEN RESPONSE

Value: 30 marks **Suggested Time: 40 minutes**

INSTRUCTIONS: 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 the spaces below the questions. 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. The release of $O_{2(g)}$ resulting from the decomposition of bleach was measured in two different experiments. Data was collected and the following graph was drawn:



a) Calculate the average rate of reaction for each experiment. **(2 marks)**

Experiment 1:

Experiment 2:

b) Identify a variable from Experiment 1 and how it was changed to produce the different reaction rate for Experiment 2. Explain using collision theory. **(3 marks)**

OVER

2. Consider the following equilibrium system:

$$C_{(s)} + 2H_{2(g)} \rightleftarrows CH_{4(g)} \qquad \Delta H = -75\,kJ$$

State **three** different ways to make more $C_{(s)}$ react. **(3 marks)**

i) _____

ii) _____

iii) _____

3. Sufficient $Na_2SO_{4(s)}$ is added to $0.10\,M\ Ba(NO_3)_2$ to cause a precipitate to form.

a) Write the net ionic equation for the precipitate formation. **(1 mark)**

b) Calculate the $\left[SO_4^{2-}\right]$ at the moment the precipitate starts to form. **(2 marks)**

4. a) Write the equation to represent the reaction that results when NH_4^+ ions are mixed with HCO_3^- ions. **(2 marks)**

b) Identify the **two** bases in the reaction in part a). **(1 mark)**

c) Predict whether the reaction will favour the reactants or products. Justify your answer. **(1 mark)**

Prediction: _____

Justification: _____

5. Calculate the pH of 0.60 M NH_4I. Start by writing the equation for the predominant equilibrium reaction. **(5 marks)**

OVER

6. A solution of $NaOH_{(aq)}$ was standardized by titration using oxalic acid $\left(H_2C_2O_{4(s)}\right)$ as the primary standard. The following data was collected:

$$\text{Mass of } H_2C_2O_{4(s)} \text{ used} = 1.02\,\text{g}$$

$$\text{Volume of } NaOH_{(aq)} \text{ used} = 40.6\,\text{mL}$$

Calculate the concentration of the $NaOH_{(aq)}$. **(3 marks)**

7. Balance the following skeletal redox equation in acidic solution: **(4 marks)**

$$MnO_4^- + As_2O_3 \rightarrow Mn^{2+} + AsO_4^{3-} \qquad \text{(acidic)}$$

8. Draw an electrolytic cell that could be used to plate an iron ring with gold.
   Be sure to include all of the necessary parts. In addition, label the anode, solution used and composition of the electrodes. **(3 marks)**

END OF EXAMINATION

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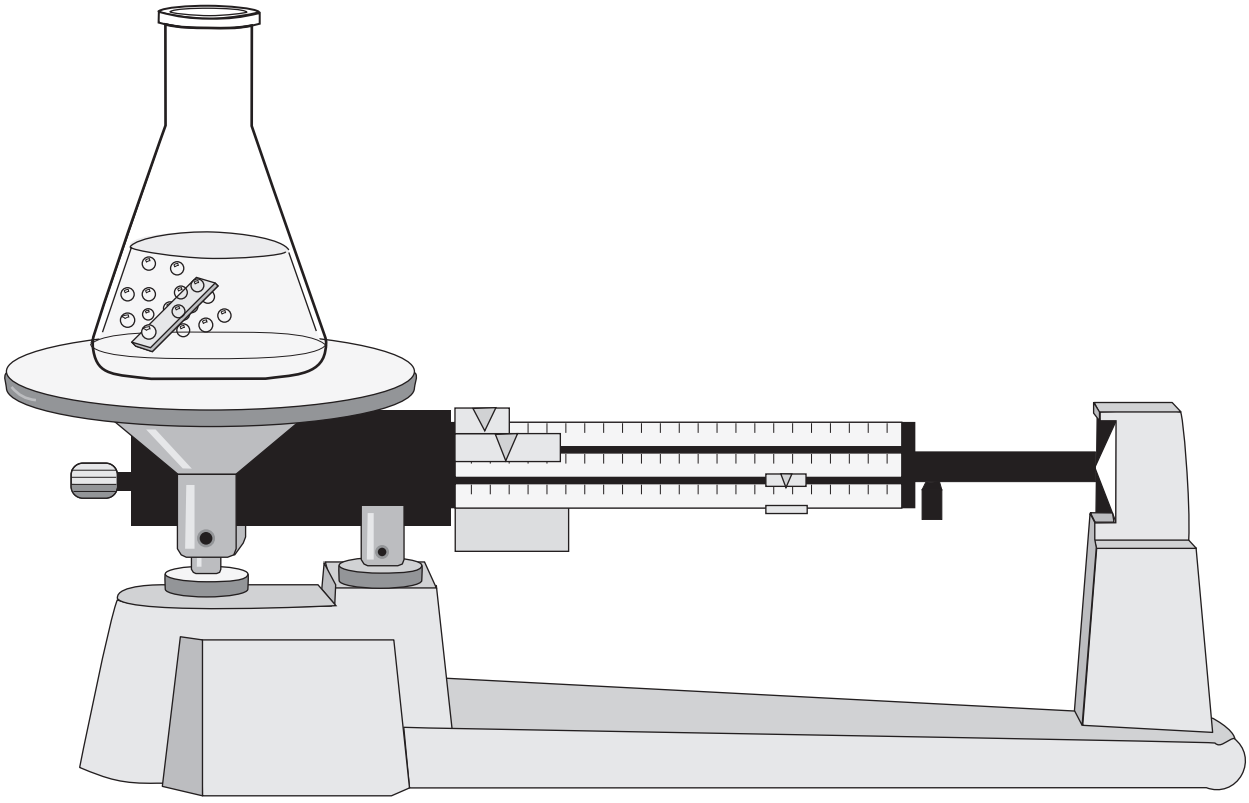
Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



Revised January 2000

CONTENTS

REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 80th edition, CRC Press, Boca Raton, 1999.

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 — Atomic Number
Si — Symbol
Silicon — Name
28.1 — 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 (top) → WEAK (bottom)

STRENGTH OF BASE: WEAK (top) → STRONG (bottom)

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

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