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BRITISH COLUMBIA

Chemistry 12

AUGUST 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

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	.	(5)	NR
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Question 4

0	1	2	3	4	.	(5)	NR
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Question 5

0	1	2	3	4	5	.	(5)	NR
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Question 6

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Question 7

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Question 8

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Chemistry 12

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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 reactions is most likely to proceed at the greatest rate under standard conditions?

   A. $Zn_{(s)} + S_{(s)} \rightarrow ZnS_{(s)}$

   B. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$

   C. $Cu_{(s)} + Cl_{2(g)} \rightarrow CuCl_{2(s)}$

   D. $2KOH_{(aq)} + H_2SO_{4(aq)} \rightarrow 2H_2O_{(\ell)} + K_2SO_{4(aq)}$

2. Nitrogen monoxide and hydrogen react according to the following equation:

   $$2NO_{(g)} + 2H_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$$

   If the rate of hydrogen consumption is $0.087\,g/min$, what is the rate of nitrogen production?

   A. $0.044\,g/min$

   B. $0.61\,g/min$

   C. $1.2\,g/min$

   D. $2.4\,g/min$

3. A student placed $3.0\,g$ of Mg into some HCl in two different experiments. In each case, it reacted according the following equation:

   $$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

   In the first experiment, it took 3.2 minutes for all of the Mg to react. In the second experiment, it took 5.4 minutes for all of the Mg to react. Which of the following could account for the change in rate of the second experiment?

   A. A catalyst was added.

   B. The Mg was powdered.

   C. The $[H_2]$ was decreased.

   D. The temperature was decreased.

OVER

4. Which of the following would change the value of the activation energy for a heterogeneous reaction?

   A. adding a catalyst
   B. changing the surface area
   C. changing the temperature
   D. changing the average kinetic energy

5. Consider the following reaction:

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

   As a molecule of H_2 approaches a molecule of I_2 on a collision course, how do the KE and PE change?

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

6. Which of the following reactions is endothermic?

   A. $H_{2(g)} + S_{(s)} \rightarrow H_2S_{(g)} + 20\,kJ$
   B. $4Fe_{(s)} + 3O_{2(g)} - 821\,kJ \rightarrow 2Fe_2O_{3(s)}$
   C. $CO_{2(g)} \rightarrow C_{(s)} + O_{2(g)} \qquad \Delta H = +393\,kJ$
   D. $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)} \qquad \Delta H = -92\,kJ$

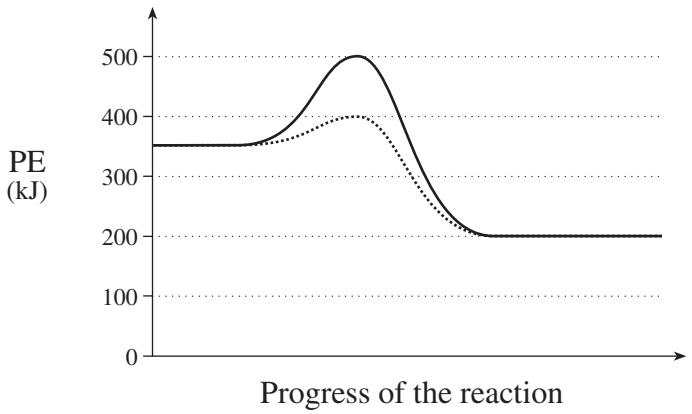
7. A reaction has the following mechanism:

Step 1	$2NO \rightarrow N_2O_2$
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3	$N_2O + H_2 \rightarrow N_2 + H_2O$

Which of the following substances is a reaction intermediate?

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

8. Consider the following PE diagram:



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

		$E_a(kJ)$	$\Delta H(kJ)$
A.	catalyzed	200	−150
B.	catalyzed	200	+150
C.	uncatalyzed	300	−150
D.	uncatalyzed	500	+150

OVER

9. Reacting systems tend toward which of the following?

	Entropy	Enthalpy
A.	minimum	maximum
B.	minimum	minimum
C.	maximum	minimum
D.	maximum	maximum

10. Consider the following equation:

$$NH_4NO_{3(s)} \overset{?}{\rightleftarrows} N_2O_{(g)} + 2H_2O_{(g)} \qquad \Delta H = -37\,kJ$$

Which of the following is true?

	Enthalpy	Entropy	Outcome
A.	favours reactants	favours reactants	reaction does not occur
B.	favours products	favours products	reaction goes to completion
C.	favours reactants	favours products	reaction reaches equilibrium
D.	favours products	favours reactants	reaction reaches equilibrium

11. Consider the following equilibrium:

$$\text{energy} + 2KClO_{3(s)} \rightleftarrows 2KCl_{(s)} + 3O_{2(g)}$$

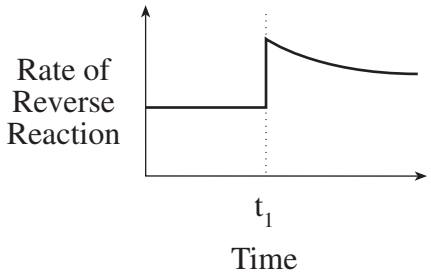
Which of the following will cause a shift to the left?

A. adding more O_2
B. adding more KCl
C. removing some $KClO_3$
D. increasing the temperature

12. Consider the equilibrium:

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

The following diagram represents the rate of the reverse reaction.



Which of the following stresses explains what happened at t_1 ?

A. $[H_2]$ increased.
B. $[N_2]$ decreased.
C. $[NH_3]$ increased.
D. $[NH_3]$ decreased.

13. Limestone is decomposed to make quicklime (CaO) according to the following equilibrium:

$$CaCO_{3(s)} + 175kJ \rightleftarrows CaO_{(s)} + CO_{2(g)}$$

Which of the following conditions would produce the greatest yield of $CaO_{(s)}$?

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

OVER

14. Consider the following equilibrium:

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \rightleftarrows H_2O_{(\ell)}$$

Which of the following represents the concentration of O_2 at equilibrium?

A. $[O_2] = \left(\dfrac{1}{K_{eq}[H_2]}\right)^2$

B. $[O_2] = K_{eq}[H_2]$

C. $[O_2] = \left(\dfrac{[H_2O]}{K_{eq}[H_2]}\right)^2$

D. $[O_2] = \sqrt{\dfrac{1}{K_{eq}[H_2]}}$

15. Consider the following equilibrium:

$$2CrO_4^{2-}{}_{(aq)} + 2H^+_{(aq)} \rightleftarrows Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(\ell)}$$

A solution of $Ba(NO_3)_2$ is added, and a precipitate of $BaCrO_4$ forms. In which direction will the equilibrium shift, and what will happen to the value of K_{eq}?

A. Equilibrium shifts left, and K_{eq} decreases.
B. Equilibrium shifts right, and K_{eq} increases.
C. Equilibrium shifts left, and K_{eq} remains constant.
D. Equilibrium does not shift, and K_{eq} remains constant.

16. Consider the following equilibrium:

$$CH_{4(g)} + H_2O_{(\ell)} \rightleftarrows CO_{(g)} + 3H_{2(g)}$$

At equilibrium, 1.2 mol CH_4, 1.2 mol H_2O, 0.080 mol CO and 0.040 mol H_2 are present in a 1.0 L container. What is the value of K_{eq} ?

A. 4.3×10^{-6}
B. 3.6×10^{-6}
C. 2.7×10^{-3}
D. 2.3×10^{5}

17. Consider the following equilibrium:

$$2NO_{(g)} + 2H_{2(g)} \rightleftarrows N_{2(g)} + 2H_2O_{(g)}$$

Initially, 0.100 mol NO, 0.0500 mol H_2 and 0.100 mol H_2O are placed in a 1.0 L container. At equilibrium, the $[H_2O] = 0.138\,M$. What is the value of K_{eq} ?

A. 3.5
B. 6.5×10^{2}
C. 1.5×10^{-3}
D. 1.3×10^{3}

18. Which of the solutes below is both ionic and most soluble?

A. RbOH
B. CH_3OH
C. $Ca(OH)_2$
D. $Fe(OH)_3$

19. Which of the following is commonly used to describe the solubility of a solute?

A. mass of solute/moles of solute
B. moles of solution/mass of solute
C. mass of solute/volume of solution
D. mass of solution/volume of solute

OVER

20. Given a saturated solution of $Ca(OH)_2$ which of the following statements is always true?

A. The $[Ca^{2+}]$ is twice that of $[OH^-]$.

B. The OH^- precipitates half as fast as the Ca^{2+} .

C. The rate of crystallization equals the rate of dissolving.

D. The rate of dissolving is greater than the rate of crystallization.

21. What happens when equal volumes of $0.20\,M$ $BaCl_2$ and $0.20\,M$ $Pb(NO_3)_2$ are mixed?

A. Only $PbCl_2$ precipitates.

B. Only $Ba(NO_3)_2$ precipitates.

C. Both $PbCl_2$ and $Ba(NO_3)_2$ precipitate.

D. No precipitate forms.

22. Which of the following best represents the net ionic reaction resulting from the mixing of equal volumes of $0.2\,M$ $Ca(NO_3)_2$ and $0.2\,M$ NaOH ?

A. $Ca^{2+}_{(aq)} + 2\,OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)}$

B. $Ca(NO_3)_{2(aq)} + 2NaOH_{(aq)} \rightarrow Ca(OH)_{2(s)} + 2NaNO_{3(aq)}$

C. $Ca^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Na^+_{(aq)} + 2\,OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)} + 2NaNO_{3(aq)}$

D. $Ca^{2+}_{(aq)} + 2NO_3^-{}_{(aq)} + 2Na^+_{(aq)} + 2\,OH^-_{(aq)} \rightarrow Ca(OH)_{2(s)} + 2Na^+_{(aq)} + 2NO_3^-{}_{(aq)}$

23. What is the K_{sp} expression for the precipitate formed when solutions of $Fe(NO_3)_3$ and $Sr(OH)_2$ are mixed?

A. $K_{sp} = [Sr^{2+}][OH^-]^2$

B. $K_{sp} = [Fe^{3+}][OH^-]^3$

C. $K_{sp} = [Sr^{2+}][2NO_3^-]$

D. $K_{sp} = [Fe^{3+}][3\,OH^-]$

24. At some temperature greater than 25°C, the K_{sp} for lead(II) sulphate becomes 1.0×10^{-7}. What is the solubility of the lead(II) sulphate at this temperature?

A. 1.0×10^{-14} M
B. 5.0×10^{-8} M
C. 2.0×10^{-7} M
D. 3.2×10^{-4} M

25. What is the maximum $\left[Pb^{2+}\right]$ possible in a 0.10 M NaCl solution?

A. 1.2×10^{-5} M
B. 6.0×10^{-5} M
C. 1.2×10^{-3} M
D. 3.0×10^{-3} M

26. Which of the ions below could be used in a precipitation reaction to determine the $\left[SO_4^{2-}\right]$ in a water sample?

A. H^+
B. Cs^+
C. Sr^{2+}
D. NH_4^+

27. Which of the following is a characteristic of basic solutions?

A. They accept OH^- ions.
B. They have a pOH greater than 7.
C. They react with Mg to produce H_2 gas.
D. They turn bromcresol green a blue colour.

28. Which of the following is a common base found in drain cleaners?

A. bleach
B. vinegar
C. milk of magnesia
D. sodium hydroxide

OVER

29. Identify the two conjugate pairs in the equilibrium provided.

$$H_2PO_4^- + HCO_3^- \rightleftarrows HPO_4^{2-} + H_2CO_3$$

	Pair 1	Pair 2
A.	$H_2PO_4^-/H_2CO_3$	HCO_3^-/HPO_4^{2-}
B.	$H_2PO_4^-/HPO_4^{2-}$	HCO_3^-/H_2CO_3
C.	HCO_3^-/HPO_4^{2-}	$H_2PO_4^-/H_2CO_3$
D.	$H_2PO_4^-/HCO_3^-$	HPO_4^{2-}/H_2CO_3

30. Which of the following saturated salt solutions would have the greatest electrical conductivity?

A. PbS

B. $CsNO_2$

C. Ag_2CrO_4

D. $Ba_3(PO_4)_2$

31. What is the main difference between a strong acid and a weak acid?

A. their degree of ionization
B. their reactivity with platinum
C. their concentration in solution
D. their effect on phenolphthalein

32. Which equation best describes the interaction of a weak base with water?

A. $NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

B. $CH_3CH_2OH_{(\ell)} \rightarrow CH_3CH_2OH_{(aq)}$

C. $HPO_4^{2-}{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows PO_4^{3-}{}_{(aq)} + H_3O^+_{(aq)}$

D. $N_2H_{4(aq)} + H_2O_{(\ell)} \rightleftarrows N_2H_5^+{}_{(aq)} + OH^-_{(aq)}$

33. Consider the ionization of water:

$$2H_2O_{(\ell)} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$$

What happens to the pH when 0.1M NaOH is added to water?

A. pH increases since $\left[H_3O^+\right]$ increases.

B. pH increases since $\left[H_3O^+\right]$ decreases.

C. pH decreases since $\left[H_3O^+\right]$ increases.

D. pH decreases since $\left[H_3O^+\right]$ decreases.

34. Since the ionization of water is endothermic, which of the following is true at 40°C?

A. $K_w = \frac{K_a}{K_b}$

B. $K_w = \frac{K_b}{K_a}$

C. $K_w > 1.0 \times 10^{-14}$

D. $K_w < 1.0 \times 10^{-14}$

35. What is the value of pK_w for water at 25°C ?

A. 1.0×10^{-14}

B. 1.0×10^{-7}

C. 7.00

D. 14.00

OVER

36. What is the K_a expression for H_3PO_4 ?

A. $K_a = \dfrac{\left[PO_4^{3-}\right]}{\left[H^+\right]^3}$

B. $K_a = \dfrac{\left[H_3O^+\right]\left[PO_4^{3-}\right]}{\left[H_3PO_4\right]}$

C. $K_a = \dfrac{\left[H_3O^+\right]\left[HPO_4^{2-}\right]}{\left[H_3PO_4\right]}$

D. $K_a = \dfrac{\left[H_3O^+\right]\left[H_2PO_4^{-}\right]}{\left[H_3PO_4\right]}$

37. Which of the following equations describes the dissociation of the salt, ammonium chloride, in water?

A. $NH_4Cl_{(s)} \rightarrow NH_4^+{}_{(aq)} + Cl^-_{(aq)}$

B. $NH_4^+{}_{(aq)} + Cl^-_{(aq)} \rightarrow NH_4Cl_{(s)}$

C. $Cl^-_{(aq)} + H_2O_{(\ell)} \rightarrow HCl_{(aq)} + OH^-_{(aq)}$

D. $NH_4^+{}_{(aq)} + H_2O_{(\ell)} \rightarrow H_3O^+_{(aq)} + NH_{3(aq)}$

38. What is the predominant net ionic equation for the hydrolysis of $(NH_4)_2HPO_{4(aq)}$?

A. $NH_4^+{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows H_3O^+_{(aq)} + NH_{3(aq)}$

B. $HPO_4^{2-}{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)}$

C. $(NH_4)_2HPO_{4(aq)} \rightleftarrows 2NH_4^+{}_{(aq)} + HPO_4^{2-}{}_{(aq)}$

D. $HPO_4^{2-}{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows H_2PO_4^-{}_{(aq)} + OH^-_{(aq)}$

39. Which of the following salt solutions is acidic?

A. KBr
B. $FeCl_3$
C. $Li_2C_2O_4$
D. $NaHCO_3$

40. Consider the equilibrium for the indicator, thymolphthalein $(HThy)$:

$$HThy + H_2O \rightleftarrows H_3O^+ + Thy^-$$

What happens when NaOH is added to a sample of this indicator in water?

	Equilibrium	Colour
A.	shifts left	turns blue
B.	shifts right	turns blue
C.	shifts left	turns colourless
D.	shifts right	turns colourless

41. Which indicator below has a $K_a = 1.0 \times 10^{-6}$?

A. methyl red
B. phenolphthalein
C. bromthymol blue
D. chlorophenol red

42. Which of the following is a piece of equipment typically used in acid-base titrations?

A. burette
B. test tube
C. litmus paper
D. graduated cylinder

OVER

43. What volume of 0.250 M KOH is required to titrate 2.30×10^{-3} mol of the weak acid $H_2C_2O_4$?

A. 1.15 mL
B. 4.60 mL
C. 9.20 mL
D. 18.4 mL

44. What is the net ionic equation for the titration of $H_3PO_{4(aq)}$ with $Sr(OH)_{2(aq)}$?

A. $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(\ell)}$

B. $6H^+_{(aq)} + 6\,OH^-_{(aq)} \rightarrow 6H_2O_{(\ell)}$

C. $2H_3PO_{4(aq)} + 3Sr^{2+}_{(aq)} + 6\,OH^-_{(aq)} \rightarrow Sr_3(PO_4)_{2(s)} + 6H_2O_{(\ell)}$

D. $6H^+_{(aq)} + 2PO_4{}^{3-}_{(aq)} + 3Sr^{2+}_{(aq)} + 6\,OH^-_{(aq)} \rightarrow 3Sr^{2+}_{(aq)} + 2PO_4{}^{3-}_{(aq)} + 6H_2O_{(\ell)}$

45. Which of the following could typically be used to prepare a buffer solution?

A. H_2S and NaHS
B. H_2S and ZnS
C. HNO_3 and $NaNO_3$
D. HNO_2 and $NaNO_3$

46. What pH would most likely result when CO_2 dissolves naturally in rainwater?

A. 3.5
B. 6.5
C. 7.0
D. 7.5

47. Identify the reducing agent in the following equation:

$$Zn + 2MnO_2 + 2H_2O \rightarrow Zn(OH)_2 + 2MnO(OH)$$

A. Zn
B. H_2O
C. MnO_2
D. $Zn(OH)_2$

48. Consider the following equation:

$$Co + SO_4^{2-} + 4H^+ \rightarrow Co^{2+} + H_2SO_3 + H_2O$$

Which statement is correct?

A. The sulphur is oxidized and the cobalt is reduced.
B. The cobalt is oxidized and the sulphur is reduced.
C. The hydrogen is reduced and the cobalt is oxidized.
D. The hydrogen is reduced and the oxygen is oxidized.

49. Which of the following gives the correct oxidation numbers for the nitrogen atoms in all three chemical species?

	N_2	Li_3N	NO_2^-
A.	0	–3	+3
B.	–3	–3	+3
C.	0	+3	–3
D.	–3	–3	–3

50. The oxidation number of manganese changes as MnO_4^- is converted to MnO_2. How many electrons are gained or lost by the manganese during the change?

A. 1 e^- lost
B. 1 e^- gained
C. 3 e^- lost
D. 3 e^- gained

OVER

51. A solution of $AuCl_4^-$ is mixed with a solution of Sn^{2+} under standard conditions. Which of the following best describes the result?

A. $AuCl_4^- + Sn^{2+} \rightarrow Sn^{4+} + Au_{(s)} + 4Cl^-$

B. $2AuCl_4^- + 3Sn^{2+} \rightarrow 3Sn^{4+} + 2Au_{(s)} + 8Cl^-$

C. $AuCl_4^- + e^- + Sn^{2+} \rightarrow Sn^{4+} + Au_{(s)} + 4Cl^-$

D. $2AuCl_4^- + 3Sn^{2+} \rightarrow 2Au_{(s)} + 8Cl^- + 3Sn_{(s)}$

52. Consider the following skeletal equation for a redox reaction in acidic solution:

$$Br^- + BrO_3^- \rightarrow Br_2$$

What is the equation for the balanced reduction half-reaction?

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

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

C. $5e^- + 6H^+ + BrO_3^- \rightarrow Br_2 + 3H_2O$

D. $10e^- + 12H^+ + 2BrO_3^- \rightarrow Br_2 + 6H_2O$

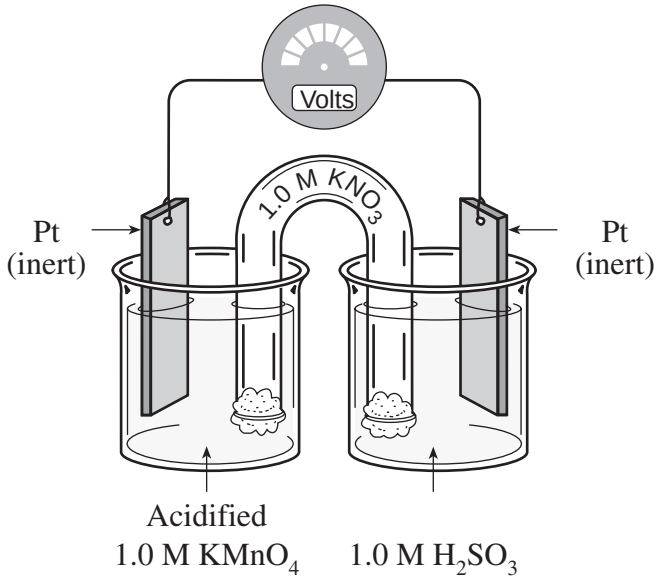
53. A 10.0 mL water sample was analyzed for $\left[Fe^{2+}\right]$ using a redox titration with acidified $KMnO_4$. The equation for the reaction is:

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

A 10.0 mL sample was titrated with 12.5 mL of 0.10 M $KMnO_4$ solution. What is the $\left[Fe^{2+}\right]$ in the water sample?

A. 0.025 M
B. 0.13 M
C. 0.28 M
D. 0.63 M

Use the following diagram to answer questions 54 to 56.



54. In the above cell, which of the following best describes the movement of the electrons through the wire?

A. They move from left to right towards the anode.
B. They move from right to left towards the anode.
C. They move from right to left towards the cathode.
D. They move from left to right towards the cathode.

55. Which of the following best describes what happens to the mass of the anode and the mass of the cathode as the cell operates?

	Anode Mass	Cathode Mass
A.	decreases	increases
B.	decreases	stays constant
C.	stays constant	decreases
D.	stays constant	stays constant

56. What is the standard voltage (E°) for the cell?

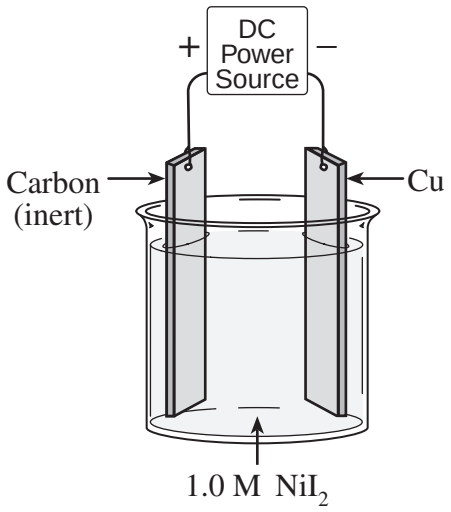
A. +0.43 V
B. +0.77 V
C. +1.34 V
D. +1.68 V

OVER

57. Which of the following best describes the term *electrolysis*?

A. a process that uses electrical energy to cause a spontaneous reaction
B. a process that generates electrical energy using a spontaneous reaction
C. a process that uses electrical energy to cause a non-spontaneous reaction
D. a process that generates electrical energy using a non-spontaneous reaction

Use the following diagram to answer questions 58 and 59.



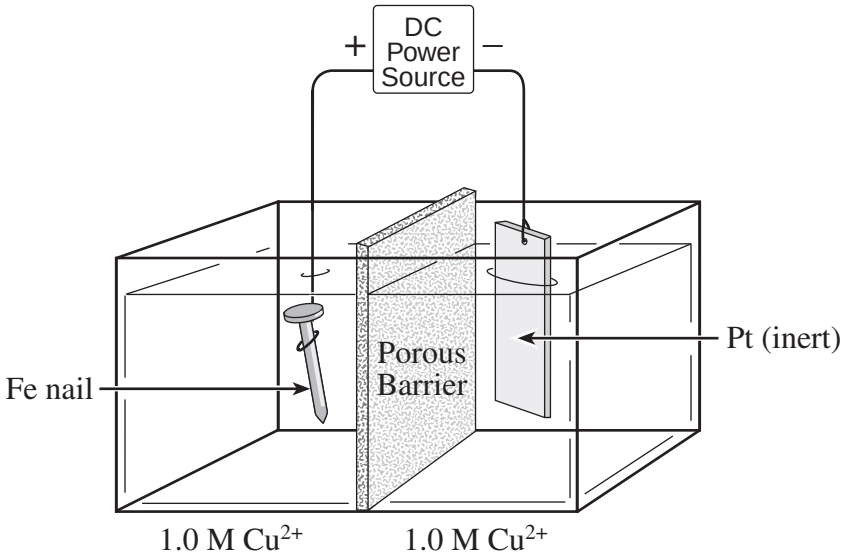
58. What products would form at the anode and cathode as this cell operates?

	Anode	Cathode
A.	I_2	Ni
B.	Ni	I_2
C.	O_2	H_2
D.	Cu^{2+}	Ni

59. In the above cell, if 1.0 M NiI_2 is replaced with molten NiI_2, what products would form at the electrodes?

	Anode	Cathode
A.	I_2	Ni
B.	Ni	I_2
C.	O_2	H_2
D.	Cu^{2+}	Ni

60. Consider the following diagram:



Why would this cell fail to electroplate the Fe nail with copper?

A. The Pt is inert.
B. The Fe nail is the anode.
C. The Fe nail is the cathode.
D. The porous barrier prevents reaction.

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

OVER

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. Consider the following overall reaction which is exothermic:

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

a) Complete the proposed two-step reaction mechanism. **(2 marks)**

Step 1	$NO + NO \rightarrow N_2O_2$
Step 2	_____

b) Describe how adding a catalyst would affect the activation energy and ΔH for the overall reaction? **(2 marks)**

_____

_____

2. Consider the following equilibrium:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)} \qquad K_{eq} = 8.1 \times 10^{-3}$$

A $2.0\,L$ container is filled with $0.15\,mol\ N_2$, $0.15\,mol\ O_2$ and $0.050\,mol\ NO$. Does the $[NO]$ increase or decrease as equilibrium is established? Support your answer with appropriate calculations. **(4 marks)**

3. Calculate the iodate ion concentration in a saturated copper (II) iodate solution at $25°C$. **(3 marks)**

OVER

4. Describe **two** lab tests and how their outcomes could be used to distinguish between a strong acid and a weak acid of equal molar concentrations. **(4 marks)**

Test 1: _____

_____

Outcome: _____

_____

Test 2: _____

_____

Outcome: _____

_____

5. Calculate the pH of a sample of 1.5 M CH_3COOH. Begin by writing the equation for the predominant equilibrium reaction. **(5 marks)**

6. State the sequence of events that occur when a small amount of $HCl_{(aq)}$ is added to a buffer such as:

$$NH_{3(aq)} + H_2O_{(\ell)} \rightleftarrows NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$$

Be sure to describe the stress, the shift and the effect on pH that occur. **(3 marks)**

OVER

7. A 2.000 g strip of cobalt metal is suspended in 100.0 mL of 0.20 M $AgNO_3$ and a reaction occurs. When the reaction is complete, there is an excess of cobalt. The excess cobalt is removed from the solution, washed and dried and its mass is found to be 1.411 g.

   a) Using the table of Standard Reduction Potentials of Half-cells, write the balanced net ionic equation for the redox reaction. **(2 marks)**

   b) Using the experimental data, calculate the moles of Co and Ag^+ reacting, and show how these values support the balanced equation. **(2 marks)**

8. Draw a diagram of a standard electrochemical cell which could make use of the reaction $Zn_{(s)} + Cl_{2(g)} \rightarrow Zn^{2+}_{(aq)} + 2Cl^{-}_{(aq)}$. Identify all of the chemical species in the cell. **(3 marks)**

END OF EXAMINATION

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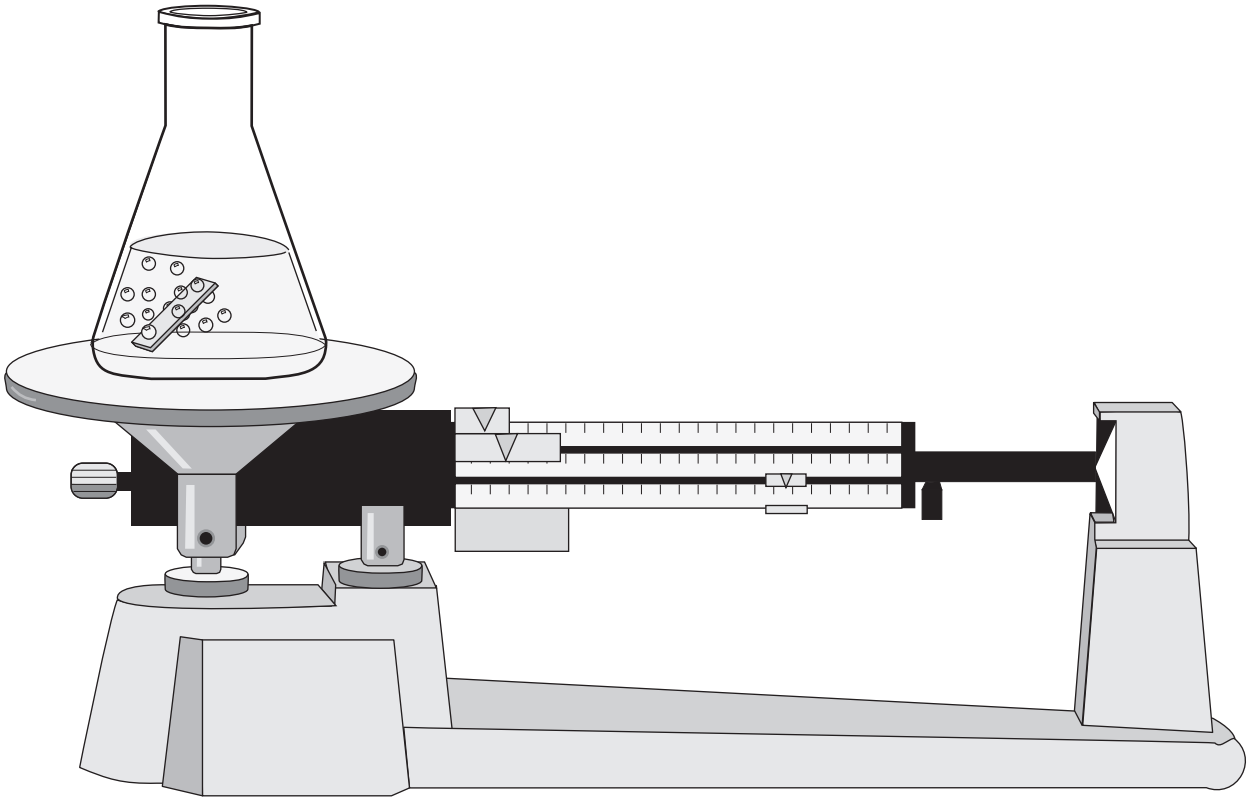
Data Booklet

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