PART I
## Total Value: 50%

Instructions: Shade the letter of the correct answer on the computer scorable answer sheet provided.

1.   Why does decreasing the concentration of a reactant usually decrease the rate of reaction?

      (A)   causes more intense collisions
      (B)   decreases the number of collisions per second
      (C)   lowers the activation energy
      (D)   provides an alternate reaction mechanism

2.   Which graph represents the fastest exothermic reaction?

      (A)

      (B)

      (C)

      (D)
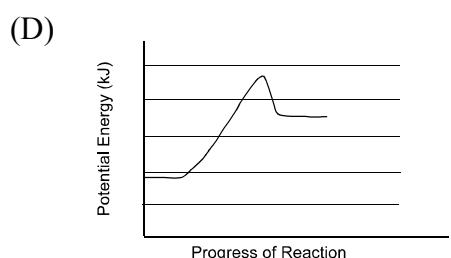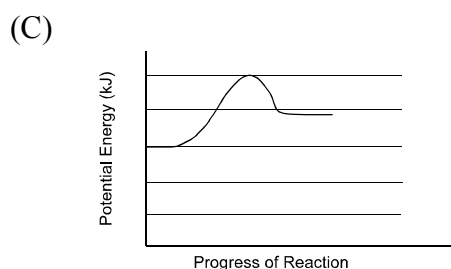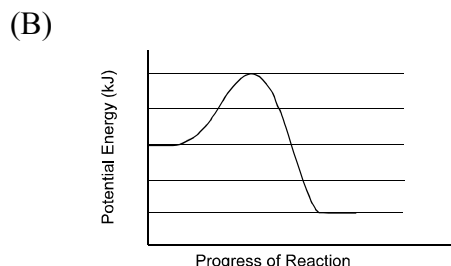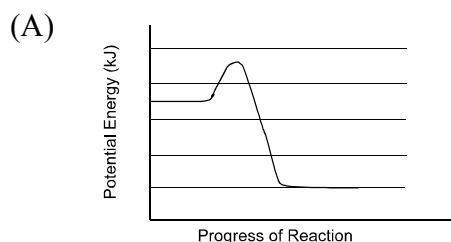
3.   A student placed 3.0 g of Mg(s) into some HCl(aq) in two different experiments giving the reaction below. It took more time for all of the Mg(s) to react in the second experiment. Which accounts for the slower rate in the second experiment?

$$Mg(s) \ + \ 2\,HCl(aq) \ \rightarrow \ MgCl_2(aq) \ + \ H_2(g)$$
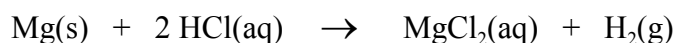
      (A)   a catalyst was added
      (B) $[H_2]$ was decreased
      (C)   Mg was crushed into a powder
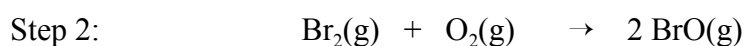   (D)   temperature was decreased

4.   How does adding a catalyst to a reaction affect the reaction pathway and the activation energy?

|	Reaction Pathway Provided	Activation Energy
(A)	alternate	higher
(B)	alternate	lower
(C)	same	higher
(D)	same	lower

5.   Which step of a reaction is the rate determining step?

(A)   fastest
(B)   first
(C)   last
(D)   slowest

6.   What is the role of $O_2(g)$ in the mechanism below?

Step 1: $O_3(g) + Br_2(g) \rightarrow Br_2O(g) + O_2(g)$

Step 2: $Br_2(g) + O_2(g) \rightarrow 2\,BrO(g)$

Step 3: $2\,BrO(g) \rightarrow Br_2O_2(g)$

(A)   catalyst
(B)   intermediate
(C)   product
(D)   reactant

7.   The diagram below illustrates the reverse reaction rate for the equilibrium shown. Which explains what happens at t_1?

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g) + energy$$
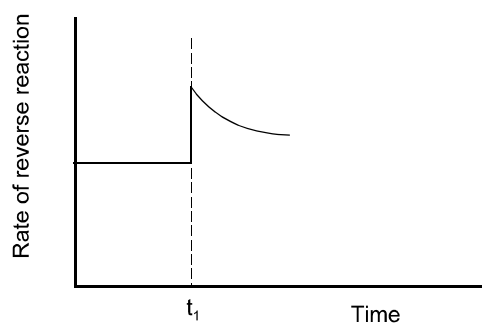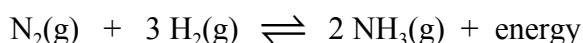

(A) $[NH_3]$ decreased
(B) $[NH_3]$ increased
(C)   pressure is increased
(D)   temperature is decreased

8.   Which is necessary for equilibrium to occur?

(A)   closed system
(B)   open system
(C)   rate of the forward reaction is zero
(D)   rate of the reverse reaction is zero

9. Some $Fe(NO_3)_3(aq)$ and $NaSCN(aq)$ are added to a sealed flask and allowed to reach equilibrium. What happens to the reverse reaction rate and $[Fe^{3+}]$ as equilibrium is being reestablished?

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$$
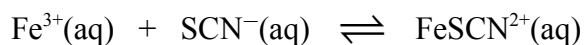
	Reverse Rate	$[Fe^{3+}]$
(A)	decreased	decreased
(B)	decreased	increased
(C)	increased	decreased
(D)	increased	increased

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

$$C_6H_5CH_2CH_3(g) + 123\ kJ \rightleftharpoons C_6H_5CHCH_2(g) + H_2(g)$$
$$\text{styrene}$$
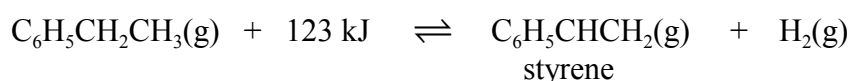
	Temperature	Pressure
(A)	high	high
(B)	high	low
(C)	low	high
(D)	low	low

11. Which chemical equation corresponds to the equilibrium constant expression shown below?

$$K_{eq} = \frac{[A]^2[B]^3}{[C]}$$

(A) $2A + 3B \rightleftharpoons C$
(B) $A + B \rightleftharpoons C$
(C) $C \rightleftharpoons A + B$
(D) $C \rightleftharpoons 2A + 3B$

12. At equilibrium, $[CCl_4] = 0.28$ mol/L and $[Cl_2] = 0.060$ mol/L. What is the value of K_{eq}?

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

(A) 3.9×10^{-4}
(B) 1.3×10^{-2}
(C) 2.1×10^{-1}
(D) 7.8×10^1

13. A sample of an unknown colourless liquid conducts electricity; however, the liquid does not react with Mg(s) to form small bubbles and it does not feel slippery. What is true of the liquid?

(A) acid
(B) amphoteric
(C) base
(D) ionic

14. Which represents the reaction of a Brønsted-Lowry base?

(A) $NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)$

(B) $HNO_3(aq) \rightarrow H^+(aq) + NO_3^-(aq)$

(C) $CH_3COOH(aq) + C_2H_5OH(\ell) \rightleftharpoons CH_3COOCH_2CH_3(\ell) + H_2O(\ell)$

(D) $H_2C_2O_4(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + HC_2O_4^-(aq)$

15. Which species is amphoteric?

(A) $HNO_3(aq)$
(B) $H_2BO_3^-(aq)$
(C) $H_3BO_3(aq)$
(D) $NO_3^-(aq)$

16. Which is the strongest acid?

(A) $CH_3COOH(aq)$
(B) $HF(aq)$
(C) $H_2CO_3(aq)$
(D) $H_2SO_4(aq)$

17. In which acid-base equilibrium are the products favoured?

(A) $HS^-(aq) + HCN(aq) \rightleftharpoons H_2S(aq) + CN^-(aq)$
(B) $F^-(aq) + H_2SO_3(aq) \rightleftharpoons HSO_3^-(aq) + HF(aq)$
(C) $NO_2^-(aq) + HCN(aq) \rightleftharpoons HNO_2(aq) + CN^-(aq)$
(D) $SO_4^{2-}(aq) + HF(aq) \rightleftharpoons HSO_4^-(aq) + F^-(aq)$

18. Which species will react when solutions of HF and Na_2CO_3 are added together?

(A) $HF(aq)$ and $CO_3^{2-}(aq)$
(B) $HF(aq)$ and $Na^+(aq)$
(C) $H_3O^+(aq)$ and $CO_3^{2-}(aq)$
(D) $H_3O^+(aq)$ and $F^-(aq)$

19. Which are the acids in the equilibrium below?

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

(A) HPO_4^{2-} and H_3BO_3
(B) $H_2BO_3^-$ and HPO_4^{2-}
(C) $H_2BO_3^-$ and $H_2PO_4^-$
(D) $H_2PO_4^-$ and H_3BO_3

20. What is true of a substance having a pH of 8?

(A) $[H_3O^+]$ is greater than $[OH^-]$
(B) $[H_3O^+]$ is less than $[OH^-]$
(C) $[H_3O^+] = [OH^-]$
(D) $[H_3O^+] = 0$
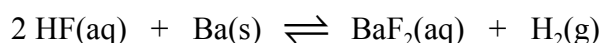
21. Which theory states that an acid is a proton donor?

(A) Arrhenius
(B) Brønsted-Lowry
(C) modified Arrhenius
(D) operational

22. What is the pH of a solution with $[OH^-] = 3.58 \times 10^{-4}$?

(A) 3.446
(B) 3.580
(C) 10.420
(D) 10.554

23. In the equilibrium below, which is true if NaOH(aq) is added to the system?

$$2\ HF(aq)\ +\ Ba(s)\ \rightleftharpoons\ BaF_2(aq)\ +\ H_2(g)$$

	Equilibrium Shift	pH
(A)	left	decrease
(B)	left	increase
(C)	right	decrease
(D)	right	increase

24. A 1.0×10^{-4} mol/L solution of KOH(aq) is diluted from 50.0 mL to 500.0 mL. What is the pOH of the final solution?

(A) 3.00
(B) 5.00
(C) 9.00
(D) 11.00

25. A clear colourless solution has a pH of 1.1. What is the colour of the solution after thymol blue indicator is added to it?

(A) blue
(B) orange
(C) red
(D) yellow

26. Which is true at the equivalence point of a titration?

(A) acid concentration equals base concentration
(B) indicator changes colour
(C) moles of hydronium equals moles of hydroxide
(D) volume of acid equals volume of base

27.   Which is necessary to perform a titration?

    (A)   burette
    (B)   crucible
    (C)   mass balance
    (D)   salt bridge

28.   Which titration curve represents the addition of NaOH(aq) to HF(aq)?

(A)

(B)

(C)

(D)
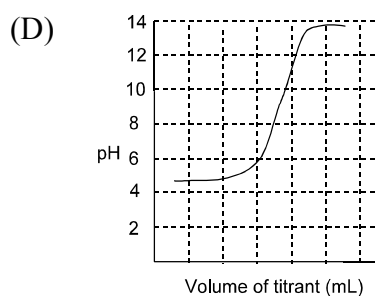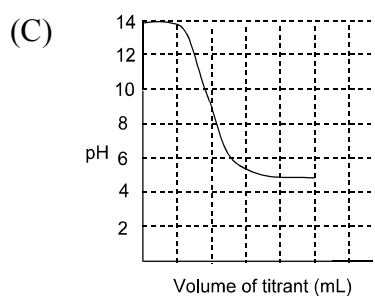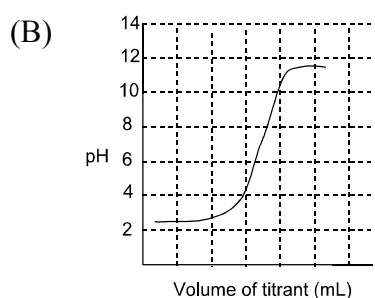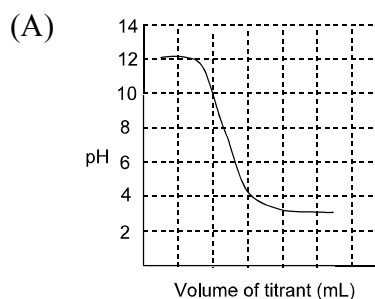
29.   Which describes an open system?

    (A)   matter and heat may be stationary
    (B)   matter and heat may be transferred
    (C)   only heat can flow in and out
    (D)   only matter can flow in and out

30.   What is the temperature change for a 15 g piece of iron that absorbs 26.5 J of heat?
    ($c_{Fe} = 0.444$ J/g·°C)

    (A)   0.25 °C
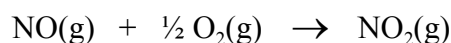   (B)   0.78 °C
    (C)   1.3 °C
    (D)   4.0 °C

31. Which refers to the amount of energy required to raise the temperature of 1.0 g of a substance by 1.0 °C?

(A)   heat capacity
(B)   molar enthalpy
(C)   molar heat
(D)   specific heat capacity

32. How much heat is absorbed by a bomb calorimeter if it increases in temperature by 23.2 °C? ($C_{calorimeter} = 17.9$ J/°C)

(A)   0.772 J
(B)   1.30 J
(C)   415 J
(D) 4.99×10^3 J

33. When a "cold pack" is crushed, NH_4NO_3(s) dissolves in water inside the package. The pack is then used as a cooling source for muscle injuries. Which best explains what happens?

(A)   The water temperature decreases due to the endothermic process.
(B)   The water temperature decreases due to the exothermic process.
(C)   The water temperature increases due to the endothermic process.
(D)   The water temperature increases due to the exothermic process.

34. What change is occurring if the temperature of a substance remains constant as energy is added to it?

(A)   gas to liquid
(B)   gas to solid
(C)   liquid to gas
(D)   liquid to solid

35. At its boiling point, what mass of methanol, CH_3OH (32.05 g/mol), is vaporized by 875 kJ of heat energy? ($\Delta H_{vap}(CH_3OH) = 35.2$ kJ/mol)

(A)   0.777 g
(B)   1.29 g
(C)   24.9 g
(D)   797 g

36. Which enthalpy notation represents the energy needed to melt iron?

(A) ΔH_{comb}
(B) ΔH_{fusion}
(C) ΔH_{solid}
(D) ΔH_{vap}

37. How many moles of chlorine is required to release 55.8 kJ of heat?

$$H_2 \ + \ Cl_2 \ \rightarrow \ 2\,HCl \qquad \Delta H = -335 \text{ kJ}$$

(A)   0.167 moles
(B)   0.334 moles
(C)   3.00 moles
(D)   6.00 moles

38. What is true for changes in the kinetic and potential energy for section B-C on the graph below?
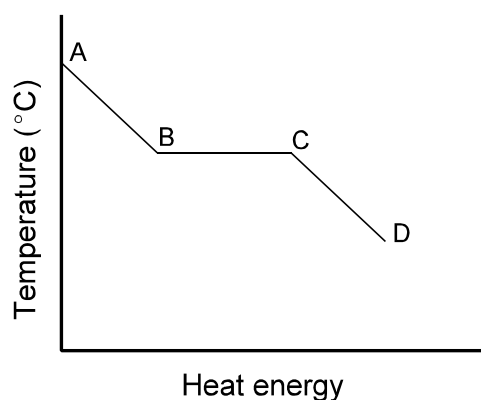

	Kinetic Energy	Potential Energy
(A)	constant	decreases
(B)	constant	increases
(C)	decreases	constant
(D)	increases	constant

39. Given the thermochemical equations below, what is the heat of reaction for the formation of nitrogen dioxide?

$$NO(g) \ + \ ½\,O_2(g) \ \rightarrow \ NO_2(g)$$

$$½\,N_2(g) \ + \ ½\,O_2(g) \ \rightarrow \ NO(g) \qquad \Delta H° = 91.3 \text{ kJ}$$

$$½\,N_2(g) \ + \ O_2(g) \ \rightarrow \ NO_2(g) \qquad \Delta H° = 33.2 \text{ kJ}$$

(A) -124.5 kJ
(B) -58.1 kJ
(C) $+58.1$ kJ
(D) $+124.5$ kJ

40. Using the reactions and data given, what is the bond energy for Cl-Cl?

$$H_2(g) \ + \ Cl_2(g) \ \rightarrow \ 2\,HCl(g) \ + \ 184.6 \text{ kJ}$$
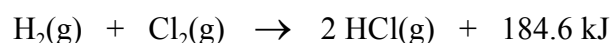
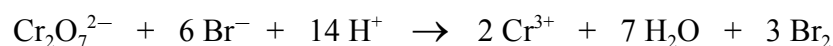| Bond	Bond Energy (kJ/mol)
H-H	436
H-Cl	432

(A)   243 kJ/mol
(B)   336 kJ/mol
(C)   520 kJ/mol
(D)   613 kJ/mol

41. What occurs in reduction half-reactions?

(A)   electrons are gained
(B)   electrons are lost
(C)   protons are gained
(D)   protons are lost

42. What is the oxidation number of S in $HS_2O_3^-$?

(A) -4
(B) -2
(C) $+2$
(D) $+4$

43. Which element is reduced in the reaction below?

$$Cr_2O_7^{2-} + 6\ Br^- + 14\ H^+ \rightarrow 2\ Cr^{3+} + 7\ H_2O + 3\ Br_2$$

(A)   Br
(B)   Cr
(C)   H
(D)   O

44. Which represents oxidation?

(A) $F_2 \rightarrow 2\ F^- + 2\ e^-$
(B) $H_2 \rightarrow 2\ H^+ + 2\ e^-$
(C) $F_2 + 2\ e^- \rightarrow 2\ F^-$
(D) $H_2 + 2\ e^- \rightarrow 2\ H^+$

45. Which half-reaction is balanced correctly?

(A) $2\ HCN + 2\ e^- \rightarrow C_2N_2 + 2\ H^+$
(B) $NO_3^- + 3\ H^+ + 3\ e^- \rightarrow HNO_2 + H_2O$
(C) $2\ Sb + 3\ H_2O + 6\ e^- \rightarrow Sb_2O_3 + 6\ H^+$
(D) $Sb_2O_5 + 6\ H^+ + 4\ e^- \rightarrow 2\ Sb(OH)_2^+ + H_2O$

46. Which describes the movement of potassium ions and electrons as the cell below operates?
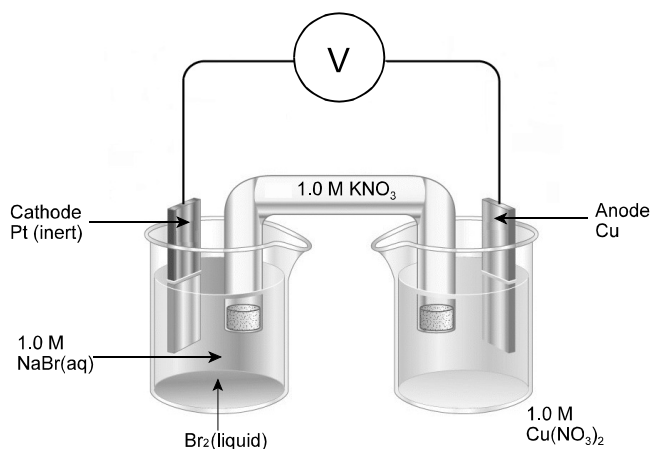
	K^+ Ion Movement	Electron Movement
(A)	toward Cu	toward Cu
(B)	toward Cu	toward Pt
(C)	toward Pt	toward Cu
(D)	toward Pt	toward Pt

47.   What is the unknown metal 'X' in the electrolytic cell represented by the equation below?

$$2\,Ag(s) \ + \ X^{2+}(aq) \ \rightarrow \ X(s) \ + \ 2\,Ag^{+}(aq) \qquad E^{\circ}_{cell} = -0.93\ V$$
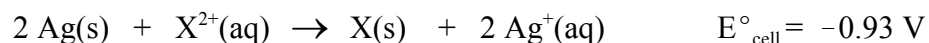
(A)   Cu (s)
(B) I_2 (s)
(C)   Ni (s)
(D)   Pb (s)

48.   An electrochemical cell has a solid lead electrode in a solution of 1.0 mol/L $Pb(NO_3)_2$ and a solid zinc electrode in a solution of 1.0 mol/L $Zn(NO_3)_2$. Which reactant will be oxidized?

(A)   Pb
(B) Pb^{2+}
(C)   Zn
(D) Zn^{2+}

49.   Which cell uses electrical energy to cause a non-spontaneous redox reaction?

(A)   electrochemical
(B)   electrolytic
(C)   galvanic
(D)   voltaic

50.   Which is an example of a primary electrochemical cell?

(A)   dry cell
(B)   hydrogen fuel cell
(C)   lead storage
(D)   nickel-cadmium

PART II
Total Value: 50%

Instructions: **Complete all items in this section.   Your responses should be clearly presented in a well-organized manner with proper use of units, formulae and significant figures where appropriate.**

Value

2%   51.(a)   The reaction below has an activation energy of 209 kJ. Sketch a potential energy diagram for the reaction, and label the activation energy and heat of reaction.

$$2\,NO_2(g)\ +\ O_2(g)\ +\ 199\,kJ\ \rightarrow\ 2\,NO_3(g)$$

Potential Energy (kJ)

Progress of Reaction
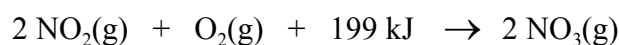
2%   (b)   For the reaction below, it takes longer to collect 35 mL of $CO_2(g)$ using acid at room temperature compared to acid at 60.0 °C. Explain why.

$$CaCO_3(s)\ +\ H_2SO_4(aq)\ \rightarrow\ CO_2(g)\ +\ CaSO_4(s)\ +\ H_2O(\ell)$$

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2%   51.(c) Using collision theory, explain why zinc metal reacts more rapidly in concentrated HCl(aq) than in dilute HCl(aq).

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2%   (d)   Inside a propane tank, the equilibrium below is created. When propane gas is released from the tank, explain why condensation forms on the outside of the tank.
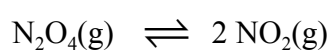
$$C_3H_8(\ell) \ + \ Energy \ \rightleftharpoons \ C_3H_8(g)$$

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_____

2%   51.(e) For the reaction below, the graph shows how $A_2(g)$ and $B_2(g)$ come to equilibrium with $AB(g)$ at constant temperature in a 1.0 L flask. Calculate the equilibrium constant.

$$A_2(g) \; + \; B_2(g) \; \rightleftharpoons \; 2\,AB(g)$$
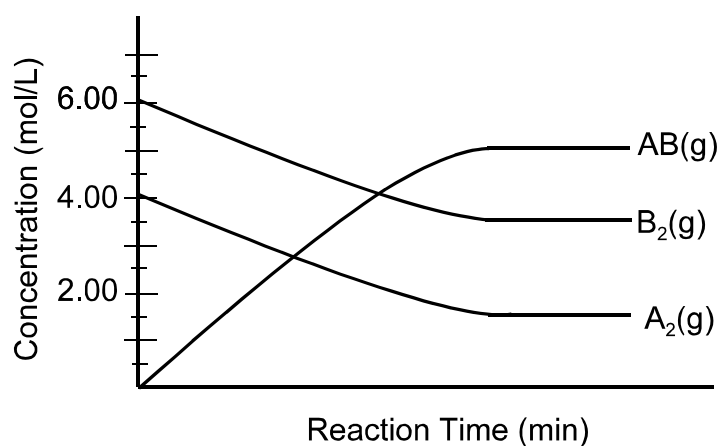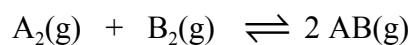
3%   (f)   Calculate K_{eq} if 1.0 mol of N_2O_4 is initially placed into a 1.0 L vessel, and at equilibrium 0.75 mol of N_2O_4 remains in the vessel.

$$N_2O_4(g) \; \rightleftharpoons \; 2\,NO_2(g)$$

4%   52.(a) Calculate the pH of a 0.25 mol/L solution of NH_3 ($K_b = 1.8 \times 10^{-5}$).

4%   (b)   Calculate the concentration of a 10.00 mL CH_3COOH solution using the data
            provided from the standardization with a 0.1404 mol/L NaOH solution.

Burette	Trial 1	Trial 2	Trial 3
Final (mL)	16.90	32.02	47.18
Initial (mL)	1.35	16.90	32.02
Volume NaOH used (mL)	15.55	15.12	15.16

4%   52.(c) A solution is prepared by dissolving a 15.00 g sample of an alkali metal hydroxide, MOH(s), in enough water to make a 5.00 L solution. If the resulting pH is 12.466, identify the metal, M.

2%   (d) A base is titrated with a strong acid to produce the graph below. Explain whether the base is strong or weak.


Volume of acid (mL)

_____

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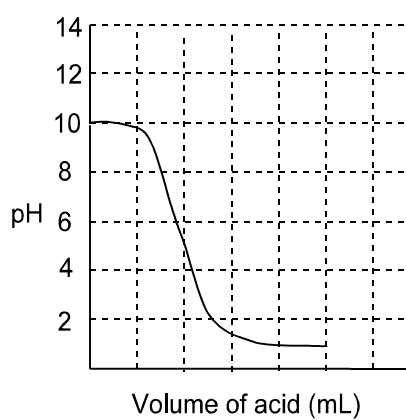
Value

2%   53.(a) A 100.0 g chocolate bar ($C_7H_8N_4O_2$) is burned in a bomb calorimeter that has a heat capacity of 6.50 kJ/°C. Calculate the molar heat of combustion of the chocolate bar if the temperature of the calorimeter and its contents increases from 21.90 °C to 27.40 °C.

4%   (b)   A mixture of 125.0 g of an unreactive metal and 250.0 g of water has a temperature of 25.0 °C. The mixture is heated to a final temperature of 70.0 °C. Calculate the specific heat capacity of the metal if the mixture absorbs 49.7 kJ of heat.
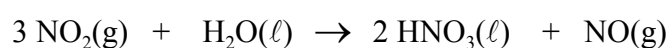
5%   53.(c) A 2.50 g sample of water is cooled from 95.0 °C to 0.00 °C and is completely frozen.

      i)   Draw the cooling curve for this process.
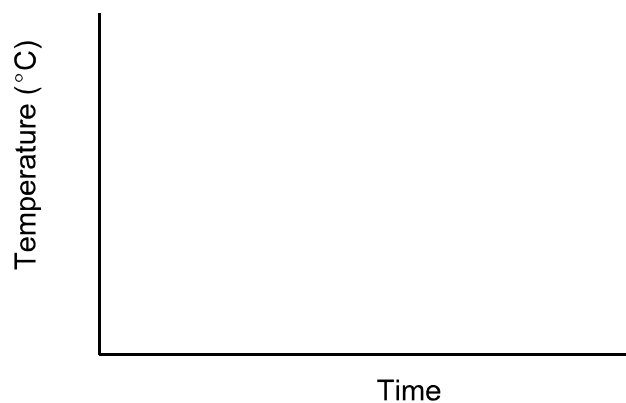
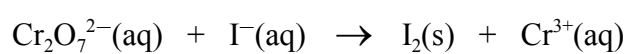   ii)   Calculate the energy released by the water sample.

2%   (d)   Calculate the enthalpy change for the reaction below.

$$3\ NO_2(g)\ +\ H_2O(\ell)\ \rightarrow\ 2\ HNO_3(\ell)\ +\ NO(g)$$

Substance	$\Delta H_f°$ (kJ/mol)
$HNO_3(\ell)$	-174.1
$H_2O(\ell)$	-285.8
$NO(g)$	91.3
$NO_2(g)$	33.2

Value

4%   54.(a)   Balance the redox reaction below under basic conditions.

$$Cr_2O_7^{2-}(aq) \ + \ I^-(aq) \ \rightarrow \ I_2(s) \ + \ Cr^{3+}(aq)$$

3%   (b)   The chromium cathode in an electrolytic cell increases in mass by 1.37 g in 25.5 minutes at a current of 5.00 A. Calculate the charge on the chromium ion in solution.

54.(c) Give the overall cell reaction and calculate the standard cell potential for the cell below.