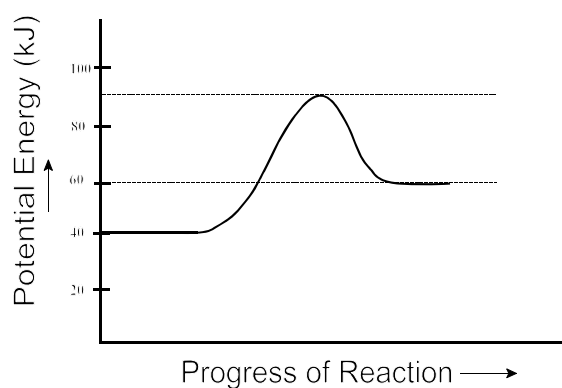


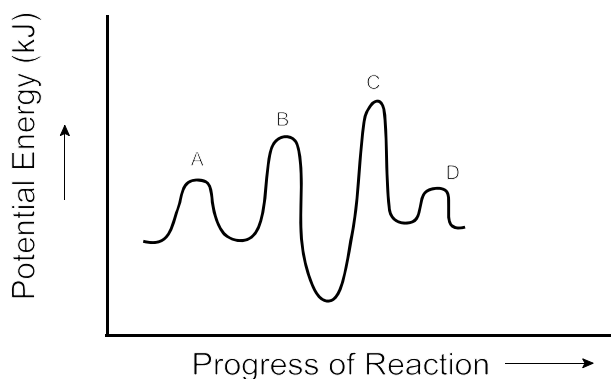
Part I
Total Value: 50%

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

- Which observation can be explained using the kinetic molecular theory?
 - A basketball is inflated with air.
 - Butane C_4H_{10} burns faster than pentane C_5H_{12} .
 - Powdered coal is more explosive than lumps of coal.
 - Silver metal reacts slower than aqueous silver nitrate.
- Which factor best explains why the combustion of candle wax, $C_{25}H_{52}$, is slower than the combustion of decane, $C_{10}H_{22}$?
 - concentration
 - nature of reactants
 - pressure
 - temperature
- For the diagram below, what is the activation energy for the reverse reaction?

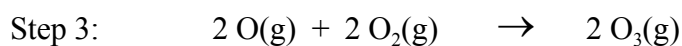
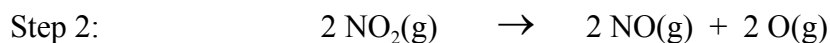
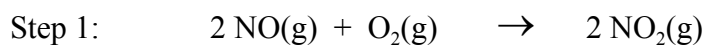


- 20 kJ
 - 30 kJ
 - 40 kJ
 - 50 kJ
- What is the rate determining step in the mechanism below?



- A
- B
- C
- D

5. Using the mechanism below, which species is the catalyst?

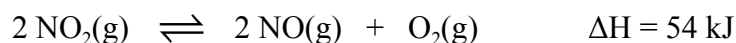


- (A) NO(g)
(B) NO₂(g)
(C) O(g)
(D) O₂(g)
6. Given the table below, order the reaction trials from fastest to slowest.

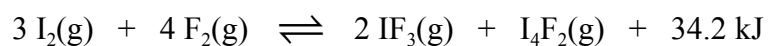
Trial #	Concentration (mol/L)	Temperature (°C)
1	0.020	30
2	0.020	20
3	0.20	50
4	0.20	40

fastest → slowest

- (A) 1 → 2 → 3 → 4
(B) 2 → 1 → 4 → 3
(C) 3 → 4 → 1 → 2
(D) 4 → 3 → 2 → 1
7. Which change will affect the value of K in the equilibrium system below?

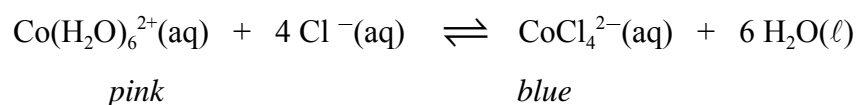


- (A) decreasing temperature
(B) decreasing volume
(C) increasing [NO]
(D) increasing [NO₂]
8. Which change in the equilibrium below would result in the highest concentration of IF₃?



- (A) decreasing [I₂]
(B) decreasing volume
(C) increasing [I₄F₂]
(D) increasing temperature

9. Which is true, for the equilibrium as written, if the system changes from blue to pink when placed in an ice bath?

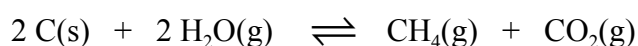


	Reaction Type	ΔH
(A)	endothermic	negative
(B)	endothermic	positive
(C)	exothermic	negative
(D)	exothermic	positive

10. Which K value indicates the highest concentration of reactants?

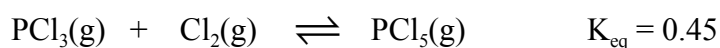
- (A) 1.9×10^{-8}
 (B) 1.3×10^{-7}
 (C) 2.6×10^7
 (D) 3.9×10^8

11. What is the equilibrium constant expression for the system below?



- (A) $\frac{[\text{CH}_4][\text{CO}_2]}{[\text{H}_2\text{O}]^2}$
 (B) $\frac{[\text{CH}_4][\text{CO}_2]}{[\text{C}]^2[\text{H}_2\text{O}]^2}$
 (C) $\frac{[\text{H}_2\text{O}]^2}{[\text{CH}_4][\text{CO}_2]}$
 (D) $\frac{[\text{C}]^2[\text{H}_2\text{O}]^2}{[\text{CH}_4][\text{CO}_2]}$

12. 0.100 mol of PCl_3 , Cl_2 , and PCl_5 are each introduced into the same 1.0 L evacuated flask. What is true of the concentration of each substance as the equilibrium below is established?



	$[\text{PCl}_3]$	$[\text{Cl}_2]$	$[\text{PCl}_5]$
(A)	decreases	decreases	increases
(B)	decreases	increases	decreases
(C)	increases	decreases	increases
(D)	increases	increases	decreases

13. Which pH value would best describe a substance that tastes sour?

- (A) 6.8
- (B) 7.0
- (C) 7.2
- (D) 14.0

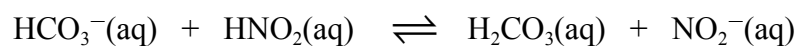
14. What is the conjugate base of H_2PO_4^- (aq)?

- (A) HPO_4^{2-} (aq)
- (B) H_3PO_4 (aq)
- (C) OH^- (aq)
- (D) PO_4^{3-} (aq)

15. Which substance is amphoteric?

- (A) CH_3COO^- (aq)
- (B) CO_3^{2-} (aq)
- (C) HCO_3^- (aq)
- (D) SO_3^{2-} (aq)

16. Which is an acid-base conjugate pair?



	Acid	Conjugate Base
(A)	HCO_3^-	H_2CO_3
(B)	HCO_3^-	NO_2^-
(C)	HNO_2	H_2CO_3
(D)	HNO_2	NO_2^-

17. Which best describes a 10.0 mol/L solution of hydrofluoric acid?

- (A) strong and concentrated
- (B) strong and dilute
- (C) weak and concentrated
- (D) weak and dilute

18. The pH of a sample of rainwater has changed from 5.4 to 4.4. What is true of the rainwater?

	$[\text{H}_3\text{O}^+]$	Factor
(A)	decrease	1
(B)	decrease	10
(C)	increase	1
(D)	increase	10

19. What is the pH of a 0.00946 mol/L solution of barium hydroxide, Ba(OH)₂?
- (A) 1.723
(B) 2.024
(C) 11.976
(D) 12.277
20. What is the pH of a solution made by diluting 10.0 mL of a 0.214 mol/L solution of nitric acid, HNO₃(aq), to a volume of 200.0 mL?
- (A) 0.670
(B) 1.971
(C) 12.029
(D) 13.330
21. What is [H₃O⁺] of a solution with a pH of 2.00?
- (A) 0.0010 mol/L
(B) 0.010 mol/L
(C) 0.020 mol/L
(D) 2.0 mol/L
22. Which is representative of the weakest acid?
- (A) $K_a = 6.9 \times 10^{-8}$
(B) $K_a = 3.6 \times 10^{-6}$
(C) $K_a = 2.6 \times 10^{-4}$
(D) $K_a = 1.9 \times 10^{-2}$
23. Which acid would be expected to have the lowest K_a value?
- | | Volume (mL) | pH | Conductivity |
|-----|-------------|------|--------------|
| (A) | 50.2 | 3.25 | poor |
| (B) | 40.5 | 3.25 | good |
| (C) | 20.7 | 5.50 | good |
| (D) | 15.0 | 5.50 | poor |
24. What is the K_a of a weak acid, HA, if the pH at equilibrium for the acid is 2.20 and the equilibrium concentration of HA is 0.930 mol/L?
- (A) 4.3×10^{-5}
(B) 6.8×10^{-3}
(C) 1.5×10^2
(D) 2.3×10^4
25. The blood's natural buffering system (H₂CO₃(aq)/HCO₃⁻(aq)) allows it to maintain a pH of 7.35. When a small amount of base enters the blood, with what species does it react?
- (A) H₃O⁺(aq)
(B) HCO₃⁻(aq)
(C) H₂CO₃(aq)
(D) H₂O(l)

26. A solution was tested with three indicators to give the results shown. What is the approximate pH of the solution?

Indicator	Final Colour
bromocresol green	blue
indigo carmine	blue
thymolphthalein	blue

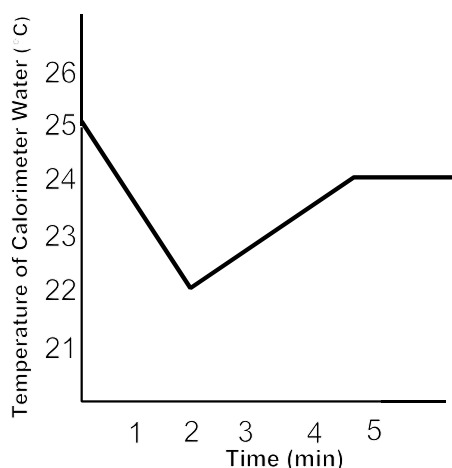
- (A) 5.00
(B) 9.00
(C) 10.8
(D) 11.6
27. Which term describes the colour change when an acid-base indicator is used?
- (A) end point
(B) equilibrium point
(C) equivalence point
(D) neutralization point
28. If the K_a expression for an acid is $K_a = \frac{[\text{H}_3\text{O}^+][\text{NO}_2^-]}{[\text{HNO}_2]}$, what is the K_b expression for its conjugate base?
- (A) $K_b = \frac{[\text{HNO}_2]}{[\text{H}_3\text{O}^+][\text{NO}_2^-]}$
(B) $K_b = \frac{[\text{H}_3\text{O}^+][\text{HNO}_2]}{[\text{NO}_2^-]}$
(C) $K_b = \frac{[\text{OH}^-][\text{HNO}_2]}{[\text{NO}_2^-]}$
(D) $K_b = \frac{[\text{OH}^-][\text{NO}_2^-]}{[\text{HNO}_2]}$
29. What is a measure of the average kinetic energy of particles?
- (A) heat capacity
(B) molar enthalpy
(C) specific heat
(D) temperature

30. What is the molar enthalpy change for the reaction below?



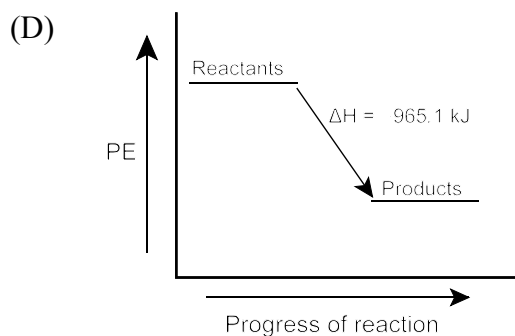
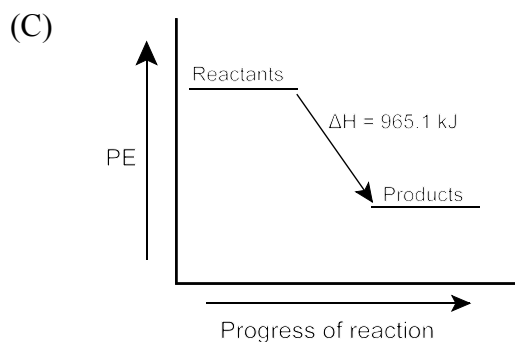
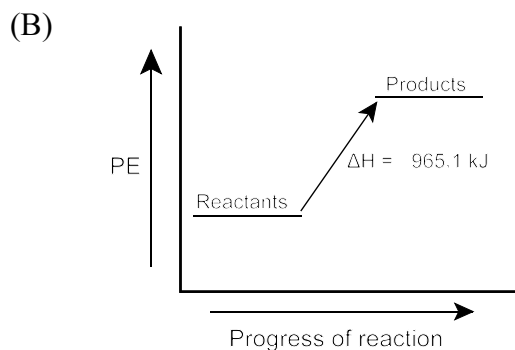
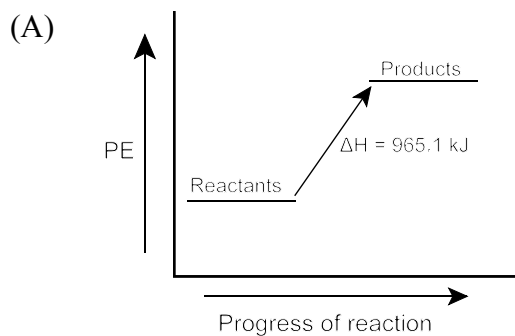
Chemical	ΔH_f° (kJ/mol)
MgCO ₃ (s)	-1113
MgO(s)	-602
CO ₂ (g)	-394

- (A) -2109 kJ/mol
(B) -117 kJ/mol
(C) 117 kJ/mol
(D) 2109 kJ/mol
31. A piece of ice was dropped into liquid water to determine the molar heat of fusion of water. What is the best interpretation of the results as shown in the graph below?



- (A) The ice finishes melting at 2 minutes and heat enters the container.
(B) The ice finishes melting at 2 minutes and heat leaves the container.
(C) The ice finishes melting at 5 minutes and heat enters the container.
(D) The ice finishes melting at 5 minutes and heat leaves the container.
32. If it takes 588 J of energy to change the temperature of a 28.7 g strip of copper from 26.3 °C to 79.5 °C, what is the specific heat capacity of copper?
- (A) 0.258 J/g·°C
(B) 0.385 J/g·°C
(C) 2.60 J/g·°C
(D) 20.5 J/g·°C
33. Which phase change is exothermic?
- (A) gas to liquid
(B) liquid to gas
(C) solid to gas
(D) solid to liquid
34. Which energy change occurs when water is heated from 37.0 °C to 95.0 °C?
- (A) kinetic energy decreases
(B) kinetic energy increases
(C) potential energy decreases
(D) potential energy increases

35. Which enthalpy diagram best represents the reaction below?

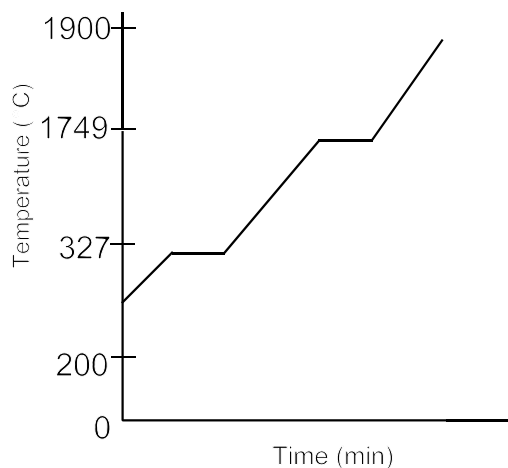


36. The molar heat of solution for $\text{NaOH}(\text{s})$ is -44.6 kJ/mol . What is true if a sample of $\text{NaOH}(\text{s})$ is dissolved in water in a calorimeter?

	Temperature of Water	Reaction
(A)	decreases	absorbs energy
(B)	decreases	releases energy
(C)	increases	absorbs energy
(D)	increases	releases energy

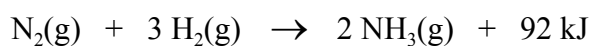
37. Samples of two compounds X and Y have identical masses and initial temperatures. They are placed in an insulated container and a quantity of heat is added. What can be concluded if the final temperature of X is lower than that of Y?
- (A) The molar mass of X is greater than that of Y.
 (B) The molar mass of X is less than that of Y.
 (C) The specific heat capacity of X is greater than that of Y.
 (D) The specific heat capacity of X is less than that of Y.

38. The graph below shows the heating curve of a substance. What is its melting point?



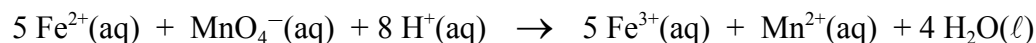
- (A) 250 °C
 (B) 327 °C
 (C) 1749 °C
 (D) 1900 °C
39. A student walks to school in 0.50 hours travelling at 6 km/h. Before she leaves her house she eats 60.0 g of granola. How much energy will remain when she arrives at school? (FV of granola is 20.3 kJ/g; walking at 6 km/h burns 1675 kJ/h of energy.)
- (A) 380 kJ
 (B) 460 kJ
 (C) 840 kJ
 (D) 1200 kJ

40. Given the reaction below, what is the molar enthalpy of formation for $\text{NH}_3(\text{g})$?

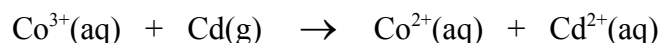


- (A) -92 kJ/mol
 (B) -46 kJ/mol
 (C) 46 kJ/mol
 (D) 92 kJ/mol
41. Which is a balanced oxidation half-reaction?
- (A) $\text{Br}_2(\ell) + 2 \text{e}^- \rightarrow 2 \text{Br}^-(\text{aq})$
 (B) $2 \text{H}^+ + 2 \text{e}^- \rightarrow \text{H}_2(\text{g})$
 (C) $\text{Sn}^{2+}(\text{aq}) \rightarrow \text{Sn}(\text{s}) + 2 \text{e}^-$
 (D) $\text{Sn}^{2+}(\text{aq}) \rightarrow \text{Sn}^{4+}(\text{aq}) + 2 \text{e}^-$

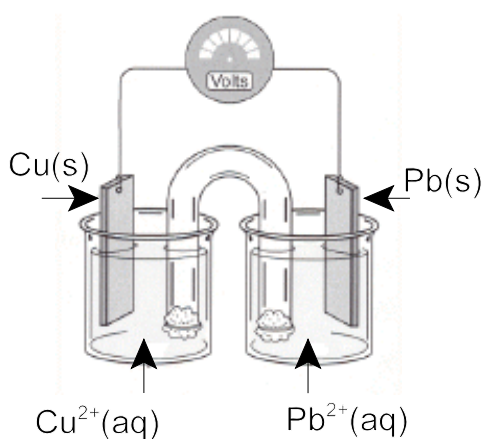
42. Which species is the reducing agent in the reaction below?



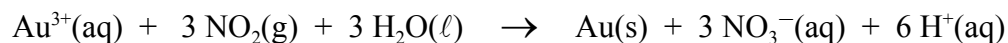
- (A) $\text{Fe}^{2+}(\text{aq})$
(B) $\text{Fe}^{3+}(\text{aq})$
(C) $\text{Mn}^{2+}(\text{aq})$
(D) $\text{MnO}_4^{-}(\text{aq})$
43. What is the balanced equation for the reaction below?



- (A) $\text{Co}^{3+}(\text{aq}) + \text{Cd}(\text{g}) \rightarrow \text{Co}^{2+}(\text{aq}) + \text{Cd}^{2+}(\text{aq})$
(B) $\text{Co}^{3+}(\text{aq}) + 2 \text{Cd}(\text{g}) \rightarrow \text{Co}^{2+}(\text{aq}) + 2 \text{Cd}^{2+}(\text{aq})$
(C) $2 \text{Co}^{3+}(\text{aq}) + \text{Cd}(\text{g}) \rightarrow 2 \text{Co}^{2+}(\text{aq}) + \text{Cd}^{2+}(\text{aq})$
(D) $2 \text{Co}^{3+}(\text{aq}) + 2 \text{Cd}(\text{g}) \rightarrow 2 \text{Co}^{2+}(\text{aq}) + 2 \text{Cd}^{2+}(\text{aq})$
44. Which is the cathode in the diagram below?



- (A) $\text{Cu}(\text{s})$
(B) $\text{Cu}^{2+}(\text{aq})$
(C) $\text{Pb}(\text{s})$
(D) $\text{Pb}^{2+}(\text{aq})$
45. What is the overall cell potential for the cell in which the reaction below occurs?



- (A) -0.90 V
(B) -0.70 V
(C) 0.70 V
(D) 0.90 V
46. How many moles of electrons are transferred if a current of 1.80 A is allowed to run for 125 s ?
- (A) $3.89 \times 10^{-5} \text{ mol}$
(B) $2.33 \times 10^{-3} \text{ mol}$
(C) $4.29 \times 10^2 \text{ mol}$
(D) $1.39 \times 10^3 \text{ mol}$

47. Which is the strongest reducing agent in the table below?

✓ indicates evidence of reaction
✗ indicates no evidence of reaction

	W(s)	X(s)	Q(s)	Z(s)
W ⁻ (s)	✗	✓	✓	✗
X ²⁻ (s)	✗	✗	✓	✗
Q ²⁻ (s)	✗	✗	✗	✗
Z ³⁻ (s)	✓	✓	✓	✗

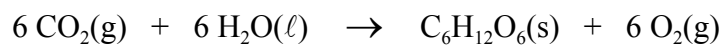
- (A) Q(s)
(B) Q⁻(aq)
(C) Z(s)
(D) Z³⁻(aq)
48. Nickel (II) subsulfide, Ni₃S₂, is mined at Voisey's Bay. What is the oxidation number of S in Ni₃S₂?
- (A) -3
(B) -2
(C) -1
(D) 0
49. What type of cell is a rechargeable nickel-cadmium cell?
- (A) fuel
(B) hydrogen
(C) primary
(D) secondary
50. Which describes the energy conversion that occurs in an electrolytic cell?
- (A) chemical to electrical
(B) chemical to mechanical
(C) electrical to chemical
(D) electrical to mechanical

Part II
Total Value: 50%

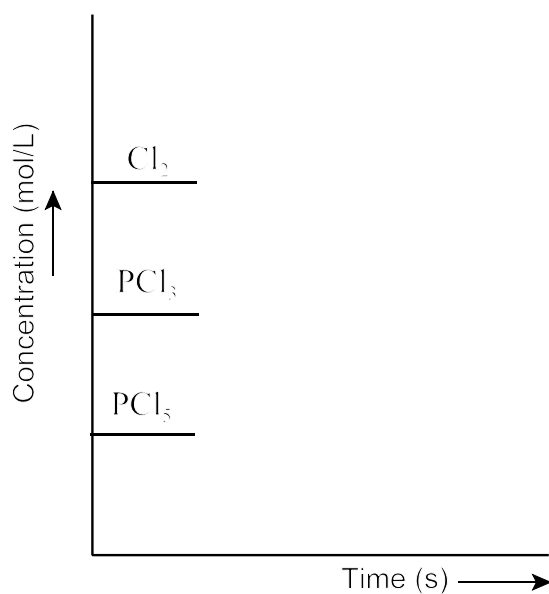
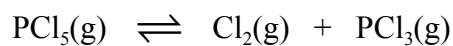
Instructions: Complete all items in this section. Your responses should be clearly presented in a well-organized manner with proper use of units, formulae and significant digits where appropriate.

Value

- 2% 51.(a) For the reaction shown, explain how increasing the temperature would increase the rate of production of $O_2(g)$.



- 3% (b) For the equilibrium reaction shown, sketch the change in concentration for each reactant and product as the volume of the container is decreased and the system re-establishes equilibrium.



Value

2% 52.(a) Use an appropriate acid-base theory to explain why an aqueous solution of lithium hydrogen sulfate ($\text{LiHSO}_4(\text{aq})$) turns blue litmus red.

4% (b) What is the pH of the resulting solution prepared by mixing 25.00 mL of a 0.220 mol/L $\text{KOH}(\text{aq})$ solution with 30.00 mL of a 0.150 mol/L $\text{HCl}(\text{aq})$ solution?

Value

4% 52.(c) A 0.10 mol/L acid HA(aq) has a K_a value of 5.9×10^{-6} .

(i) What is the pH of the solution?

(ii) Calculate the percent ionization of the acid.

4% (d) A pipette is used to transfer four 25.00 mL samples of hydrochloric acid, HCl(aq), to flasks. Each sample is then titrated to the equivalence point using a solution prepared by dissolving 0.200 g of sodium carbonate, Na_2CO_3 , to form 100.0 mL of solution. The results below were obtained. What is the concentration of HCl(aq)?

Trial	1	2	3	4
Final burette reading (mL)	20.98	33.26	33.12	45.43
Initial burette reading (mL)	8.08	20.98	20.83	33.12
Volume of Na_2CO_3 added (mL)	12.90	12.28	12.29	12.31



Value

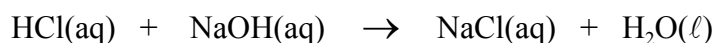
4% 53.(a) A 2.71 g sample of mercury at 72.1 °C is cooled to -38.8 °C and solidified.

- (i) Draw a cooling curve for this process.

melting point Hg	-38.8 °C
specific heat	0.140 J/g·°C
ΔH_{fusion}	8.9 kJ/mol

- (ii) How much heat is released during this process?

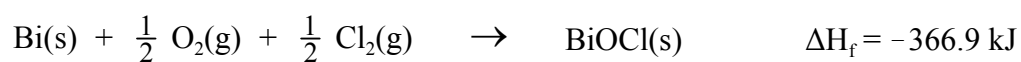
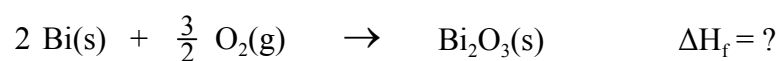
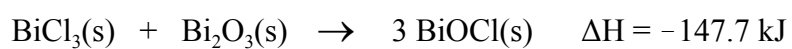
5% (b) 50.0 mL of 0.500 mol/L HCl(aq) is mixed with 50.0 mL of 0.500 mol/L NaOH(aq) in a coffee cup calorimeter. The initial temperature of each solution is 18.2 °C and the highest recorded temperature is 23.2 °C.



- (i) Calculate the enthalpy of neutralization of HCl.
- (ii) State two assumptions that must be made in this case in determining the enthalpy of neutralization.

Value

4% 53.(c). Using the data below, calculate the enthalpy of formation for $\text{Bi}_2\text{O}_3(\text{s})$.



3% 54.(a) Under acidic conditions, balance the half-reaction below.

