Questions 20–22 should be answered with reference to the reaction

$$CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g)$$

which is believed to occur by the mechanism below

$$NO_2(g) + NO_2(g) \rightarrow NO_3(g) + NO(g)$$
$$CO(g) + NO_3(g) \rightarrow CO_2(g) + NO_2(g)$$

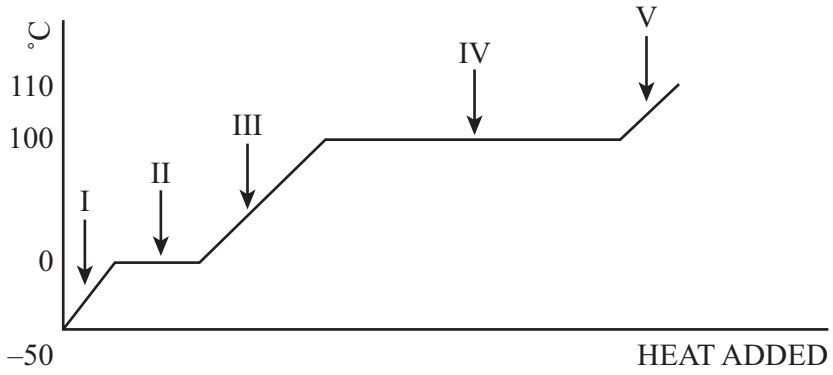
(A) $NO(g)$
(B) $NO_2(g)$
(C) $NO_3(g)$
(D) $CO(g)$

20. Which substance is a reaction intermediate?

21. This substance appears in the rate equation only if the second step is rate-determining.

22. This substance appears in the rate equation regardless of which mechanism step is rate-determining.

Questions 23–25 refer to the heating curve for water.



23. During which segment is the increase in potential energy the greatest?

(A) II
(B) III
(C) IV
(D) V

24. During which segment is the increase in kinetic energy the greatest?

(A) II
(B) III
(C) IV
(D) V

25. Which section represents the greatest increase in entropy (ΔS)?

(A) II
(B) III
(C) IV
(D) V

Questions 26–27 refer to the dissolving of potassium nitrate represented by the equation $KNO_3(s) \rightarrow K^+(aq) + NO_3^-(aq)$. This reaction was carried out in a Styrofoam insulated calorimeter and the following data were recorded:

Mass of solid KNO_3 dissolved	10.1 g
Mass of aqueous solution (sp. heat = 4.18 J/g°C)	100 g
T initial	30.0°C
T final	21.6°C
Molar Mass of KNO_3	101 g

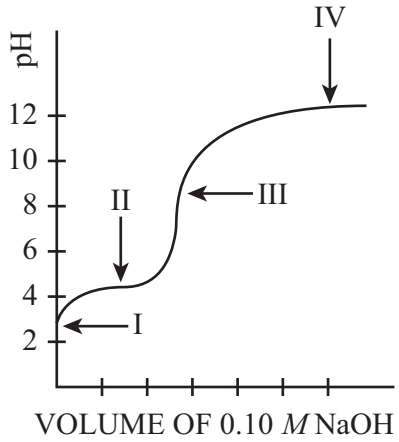
26. Which of the following equations correctly shows the heat of solution (kJ/mole) for the dissolving of KNO_3?

(A) $KNO_3(s) + 35.1\,kJ \rightarrow K^+(aq) + NO_3^-(aq)$
(B) $KNO_3(s) + 3.51\,kJ \rightarrow K^+(aq) + NO_3^-(aq)$
(C) $KNO_3(s) \rightarrow K^+(aq) + NO_3^-(aq) + 8.4\,kJ$
(D) $KNO_3(s) \rightarrow K^+(aq) + NO_3^-(aq) + 3510\,kJ$

27. If the mass of KNO_3 solid dissolved were doubled while all other experimental conditions were kept the same, what change would occur in ΔT, J per reaction, J/g of KNO_3 and kJ/mole KNO_3?

	ΔT of solution	J per reaction	J/gram KNO_3	kJ/mole KNO_3
(A)	Larger	Larger	Larger	Larger
(B)	Larger	Larger	Larger	No change
(C)	Larger	Larger	No change	No change
(D)	Larger	No change	No change	No change

Questions 28–30 should be answered with reference to the curve below for the titration of the acid HA with NaOH



(A) I
(B) II
(C) III
(D) IV

28. At which point are the concentrations of HA and A^- equal to one another?

29. Which point has the highest electrical conductivity?

30. Which point is the equivalence point?

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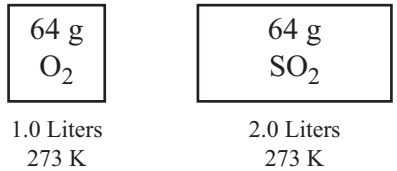
31. Consider two gases, O_2 and SO_2, in fixed containers pictured below:



All of the following statements comparing the two gases are correct EXCEPT

(A) Their average kinetic energies are equal.
(B) The density of O_2 is twice the density of SO_2.
(C) The pressure of O_2 is twice the pressure of SO_2.
(D) The average molecular velocity of O_2 is greater than SO_2.

47. For which of the following compounds does hydrogen bonding affect its physical properties?

(A) Ethane, $CH_3—CH_3$
(B) Ethanol, $CH_3—CH_3—OH$
(C) Dimethyl ether, $CH_3—O—CH_3$
(D) Methyl fluoride, $CH_3—F$

48. According to the Standard Reduction Potentials in the Table below, which metal listed would be the most effective sacrificial anode in the presence of the other metals?

Selected Standard Reduction Potentials at 25°C	E°, volts
$Cl_2(aq) + 2\,e^- \rightarrow 2\,Cl^-(aq)$	$+1.36$
$I_2(s) + 2\,e^- \rightarrow 2I^-(aq)$	$+0.54$
$Ag^+(aq) + e^- \rightarrow Ag(s)$	$+0.80$
$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$	$+0.34$
$Pb^{2+}(aq) + 2\,e^- \rightarrow Pb(s)$	-0.12
$Mg^{2+}(aq) + 2\,e^- \rightarrow Mg(s)$	-2.36

(A) Cu
(B) Ag
(C) Pb
(D) Mg

49. For the reaction, $2\,NO + O_2 \rightarrow N_2O_4$, what is its K value in terms of the K values for Reaction 1 and Reaction 2 below?

Reaction 1: $N_2 + 2\,O_2 \rightarrow N_2O_4$ K_1
Reaction 2: $N_2 + O_2 \rightarrow 2\,NO$ K_2

(A) $K = K_1 - K_2$
(B) $K = K_1 \times K_2$
(C) $K = K_1/K_2$
(D) $K = K_2/K_1$

50. Which of the following solids conducts electricity when melted?

(A) Sand, SiO_2
(B) Ice, H_2O
(C) Wax, $C_{25}H_{52}$
(D) Salt, NaCl

CONSTRUCTED-RESPONSE QUESTIONS

Question 1

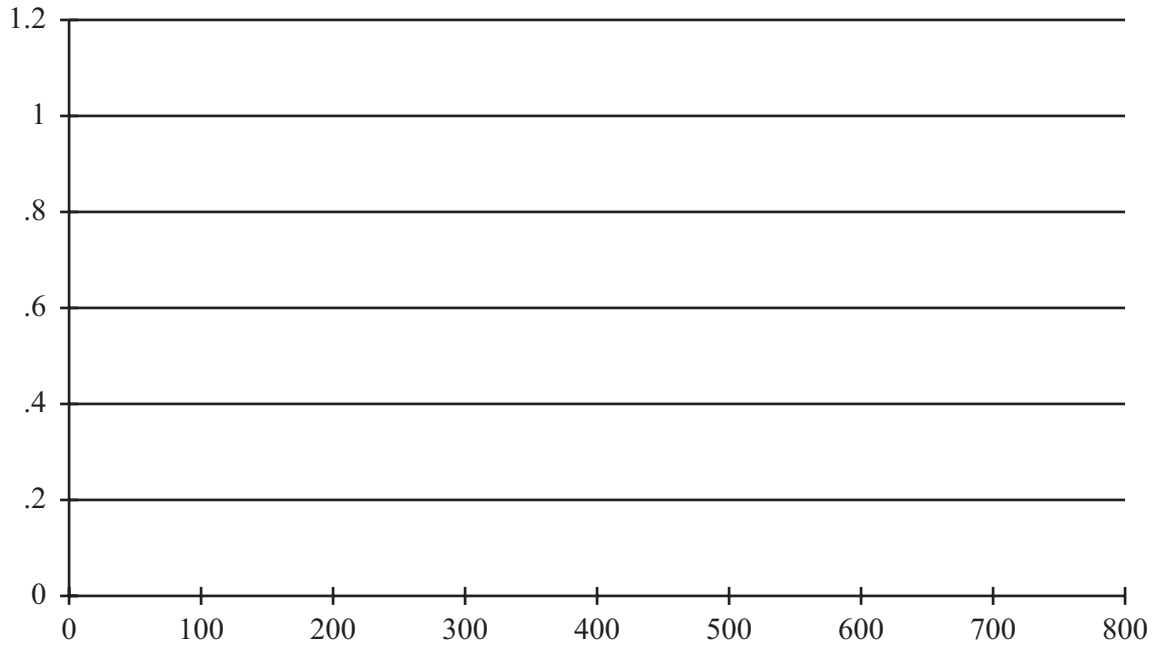
1. The visible portion of the electromagnetic spectrum has wavelengths measuring 400 to 750 nm.

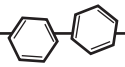
   (a) What is the frequency of red light with wavelength 651 nm?
   (b) What is the energy (J) for one photon of this red light?

2. Data to establish an absorption spectrum for the permanganate anion were taken across the visible spectrum:

Absorbance	0	0.40	0.91	1.02	0.42	0.37	0
λ (nm)	400	450	500	550	600	650	700

   (a) On the axes below, sketch the absorbance curve for the permanganate anion. Label each axis.
   (b) Although maximum absorbance occurs in the yellow (550-580 nm) part of the spectrum, permanganate anion has a characteristic purple color. Explain.





3. At 25°C, gaseous dinitrogen pentoxide decomposes into the gaseous products nitrogen dioxide and oxygen. The product nitrogen dioxide has a reddish-brown color while both dinitrogen pentoxide and oxygen gases are colorless. The progress of the reaction can be followed by measuring the absorbance as the reddish-brown product accumulates.

   (a) Write a balanced net ionic equation with lowest whole number coefficients to describe the decomposition.
   (b) The reaction is found to be first-order. Which function of $[N_2O_5]$ would give a straight line if plotted against time t? What is the significance of the slope of that line?
   (c) At 25°C, the rate constant k for the reaction is 4.12×10^{-3} min^{-1} but at 67°C, its value is 0.35 min^{-1}. Describe how you could use these values to determine the activation energy E_a for the reaction.