Dr. Zellmer
Time: 7 PM Sun.
35 min

Chemistry 1210
Autumn Semester 2022
Quiz V

All sections
October 2, 2022

Name KEY Lab TA/time ______________________

1. (3 pts) How many grams of $KClO_4$ are required to prepare 568.3 mL of a 0.685 M $KClO_4$ solution. (Atomic weights: K = 39.10, O = 16.00, Cl = 35.45)

Remember, molarity is (mol solute)/L soln and can be used as a conversion factor between moles of solute and volume of solution.

$$M = \frac{\text{mol solute}}{\text{L soln}}$$

$$? \text{ g } KClO_4 = 568.3 \text{ mL soln} \times \frac{1 \text{ L soln}}{10^3 \text{ mL soln}} \times \frac{0.685 \text{ mol } KClO_4}{1 \text{ L soln}} \times \frac{138.55 \text{ g } KClO_4}{1 \text{ mol } KClO_4}$$

$$= 53.\underline{\mathbf{9}}35 = 53.9 \text{ g } KClO_4$$

2. (5 pts) What is the concentration of a NaOH solution if 45.0 mL is required to neutralize 50.0 mL of 0.141 M H_3PO_4?

$$3\,NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3\,H_2O$$

This is like a gram-to-mole stoichiometry problem but instead of first converting grams to moles using molar mass you need to use volume and molarity. Remember, molarity (mol/L) is a conversion between moles of solute and volume of solution.

$$M = \frac{\text{mol solute}}{\text{L soln}}$$

First determine the mole of NaOH required to react with (neutralize) 50.0 mL of 0.141 M H_3PO_4

$$\underset{\text{soln}}{? \text{ mol NaOH}} = \underset{\text{soln.}}{50.0 \text{ mL } H_3PO_4} \text{ x } \frac{1 \text{ L soln}}{10^3 \text{ mL soln}} \text{ x } \frac{0.141 \text{ mol } H_3PO_4}{1 \text{ L soln}} \text{ x } \frac{3 \text{ mol NaOH}}{1 \text{ mol } H_3PO_4}$$

$= 0.021\underline{\mathbf{1}}5$ mol NaOH (divide this by the volume, 45.0 mL, in liters, 0.0450 L)

$$M = \frac{0.021\underline{\mathbf{1}}5 \text{ mol NaOH}}{0.0450 \text{ L soln}} = 0.47 \text{ M}$$

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2. (Cont.)

Also, remember at the equivalence point (which this is),

mol acid = mol base

mol H^+ = mol OH^-

$M_a{*}V_a = M_b{*}V_b$

$M_b = (M_a{*}V_a)/V_b = \{(\{3(0.141 \text{ M})) * 50.0 \text{ mL}\}/(45.0 \text{ mL}) = 0.470$ M NaOH soln

NOTE: You must be careful when using this eqn. The molarity of acid is the molarity of H^+ and the molarity of base is the molarity of OH^-. If you look closely I multiplied the molarity of the acid, H_3PO_4, by 3 to get the molarity of H^+.

? M of H^+ = 3 x M of H_3PO_4 = 3 (0.141 M) = 0.423 M H^+ total

? M of OH^- = 1 x M of NaOH = 1 (0.0521 M) = 0.0521 M OH^- total

This is essentially what I did in using the eqn. above, $M_a{*}V_a = M_b{*}V_b$

3. (4 pts) What volume (mL) of 0.0521 M $Ca(OH)_2$ is required to neutralize 12.0 mL of 0.141 M H_3PO_4 ?

This is a solution stoichiometry problem for an acid-base neutralization. Write the balanced equation.

$$3\, Ca(OH)_2 + 2\, H_3PO_4 \longrightarrow Ca_3(PO_4)_2 + 6\, H_2O$$

This is a volume-to-volume solution stoichiometry problem. It is like a gram-to-gram stoichiometry problem but instead of first converting grams to moles using molar mass you need to use volume and molarity. Remember, molarity (mol/L) is a conversion between moles of solute and volume of solution.

$$M = \frac{\text{mol solute}}{\text{L soln}}$$

Determine the vol. of 0.0521 $Ca(OH)_2$ required to react with (neutralize) 12.0 mL of 0.141 M H_3PO_4 .

$$? \text{ mL } Ca(OH)_2 = 12.0 \text{ mL } H_3PO_4 \text{ soln.} \text{ x } \frac{1 \text{ L soln}}{10^3 \text{ mL soln}} \text{ x } \frac{0.141 \text{ mol } H_3PO_4}{1 \text{ L soln}} \text{ x } \frac{3 \text{ mol } Ca(OH)_2}{2 \text{ mol } H_3PO_4} \text{ x } \frac{1 \text{ L } Ca(OH)_2}{0.0521 \text{ mol } Ca(OH)_2}$$

$= 0.048\underline{7}14$ L $Ca(OH)_2$ soln

$= 48.7$ mL $Ca(OH)_2$ soln (3 s.f.)

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3. (Cont.)

Also, remember at the equivalence point (which this is),

mol acid = mol base

$M_a*V_a = M_b*V_b$

$V_b = (M_a*V_a)/M_b = \{(3(0.141\ M)) * 12.0\ mL\}/\{2(0.0521\ M)\} = 48.7\ mL\ H_3PO_4$

NOTE: You must be careful when using this eqn. The molarity of acid is the molarity of H^+ and the molarity of base is the molarity of OH^-. If you look closely I multiplied the molarity of the base, $Ca(OH)_2$, by 2 to get the molarity of OH^- and I multiplied the molarity of the acid, H_3PO_4, by 3 to get the molarity of H^+.

? M of H^+ = 3 x M of H_3PO_4 = 3 (0.141 M) = 0.423 M

? M of OH^- = 2 x M of $Ca(OH)_2$ = 2 (0.0521 M) = 0.1042

This is essentially what I did in using the eqn. above, $M_a*V_a = M_b*V_b$

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4. (5 pts) The titration of 25.0 mL of potassium dichromate solution with 0.0350 M Fe^{2+} solution requires 27.5 mL of the iron solution. The iron and dichromate react according to the following equation. What is the molarity of the potassium dichromate? (Atomic weights: Fe = 55.85, Cr = 52.00, O = 16.000, H = 1.008)

This is a solution stoichiometry problem.

$$14\ H^+ + 6\ Fe^{2+} + Cr_2O_7^{2-} \longrightarrow 6\ Fe^{3+} + 2\ Cr^{3+} + 7\ H_2O$$

This is like a gram-to-mole stoichiometry problem but have to get moles of given by using volume and molarity instead of grams and molar mass. Can do this by first getting moles of Fe^{2+} used by using its volume and molarity and then doing a mole-to-mole problem or do it in one long step. Remember, molarity (mol/L) is a conversion between moles of solute and volume of solution.

$$M = \frac{\text{mol solute}}{\text{L soln}}$$

$$?\ \text{mol}\ K_2Cr_2O_7 = 27.5\ \text{mL}\ Fe^{2+}\ \text{soln.} \times \frac{1\ \text{L soln}}{10^3\ \text{mL soln}} \times \frac{0.0350\ \text{mol}\ Fe^{2+}}{1\ \text{L soln}} \times \frac{1\ \text{mol}\ Cr_2O_7^{2-}}{6\ \text{mol}\ Fe^{2+}} \times \frac{1\ \text{mol}\ K_2Cr_2O_7}{1\ \text{mol}\ Cr_2O_7^{2-}}$$

$$= 1.6\underline{\mathbf{0}}416 \times 10^{-4}\ \text{mol}\ K_2Cr_2O_7$$

$$\text{Molarity of}\ K_2Cr_2O_7 = \frac{1.6\underline{\mathbf{0}}416 \times 10^{-4}\ \text{mol}\ K_2Cr_2O_7}{0.0250\ \text{L soln}} = 6.4\underline{\mathbf{1}}666 \times 10^{-3} = 6.42 \times 10^{-3}$$

5. (3 pts) Which of the following pairs of ions would be expected to have a greater electrostatic force of attraction between them when separated by 1 nm?

a) Na^+ and Cl^-
b) Na^+ and O^{2-}
c) Ca^{2+} and Cl^-
d)* Mg^{2+} and O^{2-}
e) Mg^{2+} and Cl^-

This is about electrostatic potential energy from section 5.1,

$$E_{el} = \frac{\kappa Q_1 Q_2}{d} \quad \text{where,}$$

$\kappa = 8.99 \times 10^9\ \text{J•m/C}^2$ (proportionality constant)
Q_1 and Q_2 are the electrical charges on the particles
d is the distance separating the particles.

Certainly you should be able to use the eqn to do actual calculations to get E_{el}. However, just as importantly understand what the eqn. is conveying about the variables. The eqn shows the absolute value of E_{el} increases as the charges increase and as the distance gets smaller. The force of attraction is proportional to this energy, work = Force x distance (work is energy),

$$F_{el} = \frac{\kappa Q_1 Q_2}{d^2}$$ so bigger charges and shorter distance means greater force of attraction.

Since the ions in all the pairs of the ions are at the same distance between them you're looking at just the charges on the ions. So the Mg^{2+} and O^{2-} with the largest charges should have the greatest force of attraction and greatest electrostatic energy (most negative).

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6. (4 pts) The work done when a gas is compressed in a cylinder is 580.7 J. A heat transfer of 85.68 kJ occurs from the gas to the surroundings. Calculate ΔE of the gas in kJ.

$w > 0$ (positive):	work done **ON system** by the surroundings
$w < 0$ (negative):	work done **BY system** on the surroundings
$q > 0$ (positive):	system gains heat (heat goes into the system from the surroundings) - **endo**thermic
$q < 0$ (negative):	system loses heat (heat leaves the system to the surroundings) - **exo**thermic

$$\Delta E = q + w = q - P\Delta V \qquad \text{(for pressure-volume work at constant volume)}$$

If the piston is pushed down on the system (compressed) the **surroundings** is doing work **on** the **system**.

This means **$w > 0$, positive** (energy is entering the system).

The process is **exo**thermic, energy is **leaving** the **system** and therefore $q < 0$.

$$\Delta E = q + w = -85.6\underline{8}\ \text{kJ} + 0.580\underline{7}\ \text{kJ} = -85.0\underline{9}93\ \text{kJ} = -85.10\ \text{kJ}$$

7. (3 pts) Which of the following statements is **FALSE**?

a) The change in enthalpy, ΔH, does not depend on the path taken, only on the initial and final states.

b) $\Delta E = q_P - P\Delta V$

c)* For an exothermic process the products are at higher energy than the reactants.

d) $\Delta H = q_P$ (heat at constant pressure)

e) Heat, q, depends on the path taken.

a) **T**: Enthalpy, **H**, is a state function. It is a property of a system which is determined by specifying the system's conditions or state. The value of a state function depends only on the present state of the system and not how it got there. A change in a state function, **ΔH**, is path independent.

b) **T**: $\mathbf{\Delta E} = q + w$ and work for chemical systems usually arises out of pressure-volume changes. $\mathbf{\Delta E} = q - \mathbf{\Delta}PV$ (q = heat & w = work) Just another way to state the First Law of Thermodynamics (Conservation of energy). At constant pressure $\mathbf{\Delta E = q_P - P\Delta V}$, where q_P is the heat at constant pressure (**ΔH**), $\mathbf{\Delta E = \Delta H - P\Delta V}$.

c) **F**: For an exothermic process **ΔH** is negative ($H_f - H_i < 0$). This means the **products** are **LOWER** in **energy** than the reactants.

d) **T**: $\mathbf{\Delta H = q_P}$ The heat at constant pressure is the enthalpy. (Heat at constant volume is **ΔE**).

e) **T**: q & w are not state functions. They depend on the path taken. It takes more work to push a cart between two points if you go back and forth rather than in a straight. However, internal energy, E, and enthalpy, H, are state functions (path independent).

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8. (4 pts) A piston is pushed down on a reaction vessel containing a gas phase reaction.

$w > 0$ (positive): work done **ON system** by the surroundings
$w < 0$ (negative): work done **BY system** on the surroundings
$q > 0$ (positive): system gains heat (heat goes into the system from the surroundings)
- **endo**thermic

$q < 0$ (negative): system loses heat (heat leaves the system to the surroundings)
- **exo**thermic

$$\Delta E = q + w = q - P\Delta V$$ (for pressure-volume work at constant volume)

a) Does the system do work on the surroundings or is work done on the system by the surroundings?

If the piston is pushed down on the system the **surroundings** is **doing work on** the **system**.

b) What would be the sign of the work, w?

If a **surroundings does work ON** the **system** energy is entering the system. Anytime energy enters the system it's positive.

$w > 0$, positive (energy is entering the system)

c) If the process is also endothermic is heat being added to or removed from the system?

Since the process is **endo**thermic, energy is **entering** the **system** and therefore $q > 0$.

d) What would be the sign of ΔE or can that not be determined based on the information given? Explain!

What is the sign of ΔE if $w > 0$ and $q > 0$?

$$\begin{array}{ccc} \Delta E & = & q + w \\ (+) & & (+) + (+) \end{array}$$

$\Delta E > 0$ (+) if both $w > 0$ (+) and $q > 0$ (+).

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9. (5 pts) Given the following equation, how many **grams** of **acetylene** gas are required to produce 1208 kcal of heat energy by combustion with oxygen? (Atomic weights: C = 12.01, H = 1.008, O = 16.00; Mol. Wts.: C_2H_2 = 26.04, O_2 = 32.00, CO_2 = 44.01, H_2O = 18.02)

$$2\ C_2H_2\ (g) + 5\ O_2\ (g) \longrightarrow 4\ CO_2\ (g) + 2\ H_2O\ (g) \qquad \Delta H = -302\ \text{kcal}$$

This is an exothermic rx ($\Delta H < 0$) and 302 kcal of heat are released (as product) per mole of rxn (i.e. for eqn. with quantities as written)

2 mol C_2H_2 = 302 kcal released
5 mol O_2 = 302 kcal released
4 mol CO_2 = 302 kcal released
2 mol H_2O = 302 kcal released

$$?\ g\ C_2H_2 = 1208\ \text{kcal} \times \frac{2\ \text{mol}\ C_2H_2}{302\ \text{kcal}} \times \frac{26.04\ g\ C_2H_2}{1\ \text{mol}\ C_2H_2}$$

$$= 208\ g\ C_2H_2$$

208 g C_2H_2 will produce 1208 kcal

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