

Name \_\_\_\_\_ KEY \_\_\_\_\_ Lab TA/time \_\_\_\_\_

1. (3 pts) How many grams of  $\text{KClO}_4$  are required to prepare 568.3 mL of a 0.685 M  $\text{KClO}_4$  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.

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

$$\begin{aligned} ? \text{ g KClO}_4 &= 568.3 \text{ mL soln} \times \frac{1 \text{ L soln}}{10^3 \text{ mL soln}} \times \frac{0.685 \text{ mol KClO}_4}{1 \text{ L soln}} \times \frac{138.55 \text{ g KClO}_4}{1 \text{ mol KClO}_4} \\ &= 53.\underline{9}35 = 53.9 \text{ g KClO}_4 \end{aligned}$$

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  $\text{H}_3\text{PO}_4$ ?



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  $\text{H}_3\text{PO}_4$

$$\begin{aligned} ? \text{ mol NaOH} &= 50.0 \text{ mL H}_3\text{PO}_4 \times \frac{1 \text{ L soln}}{10^3 \text{ mL soln}} \times \frac{0.141 \text{ mol H}_3\text{PO}_4}{1 \text{ L soln}} \times \frac{3 \text{ mol NaOH}}{1 \text{ mol H}_3\text{PO}_4} \\ &= 0.021\underline{1}5 \text{ mol NaOH (divide this by the volume, 45.0 mL, in liters, 0.0450 L)} \end{aligned}$$

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

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2. (Cont.)

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

$$\text{mol acid} = \text{mol base}$$

$$\text{mol H}^+ = \text{mol OH}^-$$

$$M_a * V_a = M_b * V_b$$

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

**NOTE:** You must be careful when using this eqn. The molarity of acid is the molarity of  $\text{H}^+$  and the molarity of base is the molarity of  $\text{OH}^-$ . If you look closely I multiplied the molarity of the acid,  $\text{H}_3\text{PO}_4$ , by 3 to get the molarity of  $\text{H}^+$ .

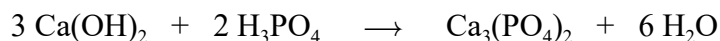
$$? \text{ M of H}^+ = 3 \times \text{M of H}_3\text{PO}_4 = 3 (0.141 \text{ M}) = 0.423 \text{ M H}^+ \text{ total}$$

$$? \text{ M of OH}^- = 1 \times \text{M of NaOH} = 1 (0.0521 \text{ M}) = 0.0521 \text{ M OH}^- \text{ total}$$

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  $\text{Ca(OH)}_2$  is required to neutralize 12.0 mL of 0.141 M  $\text{H}_3\text{PO}_4$  ?

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



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  $\text{Ca(OH)}_2$  required to react with (neutralize) 12.0 mL of 0.141 M  $\text{H}_3\text{PO}_4$  .

$$\begin{aligned} ? \text{ mL Ca(OH)}_2 &= 12.0 \text{ mL H}_3\text{PO}_4 \text{ soln.} \times \frac{1 \text{ L soln}}{10^3 \text{ mL soln}} \times \frac{0.141 \text{ mol H}_3\text{PO}_4}{1 \text{ L soln}} \times \frac{3 \text{ mol Ca(OH)}_2}{2 \text{ mol H}_3\text{PO}_4} \times \frac{1 \text{ L Ca(OH)}_2}{0.0521 \text{ mol Ca(OH)}_2} \\ &= 0.048\bar{7}14 \text{ L Ca(OH)}_2 \text{ soln} \\ &= 48.7 \text{ mL Ca(OH)}_2 \text{ soln} \quad (3 \text{ s.f.}) \end{aligned}$$

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3. (Cont.)

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

$$\text{mol acid} = \text{mol base}$$

$$M_a * V_a = M_b * V_b$$

$$V_b = (M_a * V_a) / M_b = \{(3(0.141 \text{ M}) * 12.0 \text{ mL}) / \{2(0.0521 \text{ M})\} = 48.7 \text{ mL H}_3\text{PO}_4$$

**NOTE:** You must be careful when using this eqn. The molarity of acid is the molarity of  $\text{H}^+$  and the molarity of base is the molarity of  $\text{OH}^-$ . If you look closely I multiplied the molarity of the base,  $\text{Ca(OH)}_2$ , by 2 to get the molarity of  $\text{OH}^-$  and I multiplied the molarity of the acid,  $\text{H}_3\text{PO}_4$ , by 3 to get the molarity of  $\text{H}^+$ .

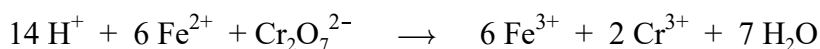
$$? \text{ M of } \text{H}^+ = 3 \times \text{M of } \text{H}_3\text{PO}_4 = 3 (0.141 \text{ M}) = 0.423 \text{ M}$$

$$? \text{ M of } \text{OH}^- = 2 \times \text{M of } \text{Ca(OH)}_2 = 2 (0.0521 \text{ M}) = 0.1042$$

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

4. (5 pts) The titration of 25.0 mL of potassium dichromate solution with 0.0350 M  $\text{Fe}^{2+}$  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.



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  $\text{Fe}^{2+}$  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.

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

$$\begin{aligned} ? \text{ mol K}_2\text{Cr}_2\text{O}_7 &= 27.5 \text{ mL Fe}^{2+} \text{ soln.} \times \frac{1 \text{ L soln}}{10^3 \text{ mL soln}} \times \frac{0.0350 \text{ mol Fe}^{2+}}{1 \text{ L soln}} \times \frac{1 \text{ mol Cr}_2\text{O}_7^{2-}}{6 \text{ mol Fe}^{2+}} \times \frac{1 \text{ mol K}_2\text{Cr}_2\text{O}_7}{1 \text{ mol Cr}_2\text{O}_7^{2-}} \\ &= 1.60416 \times 10^{-4} \text{ mol K}_2\text{Cr}_2\text{O}_7 \end{aligned}$$

$$\text{Molarity of K}_2\text{Cr}_2\text{O}_7 = \frac{1.60416 \times 10^{-4} \text{ mol K}_2\text{Cr}_2\text{O}_7}{0.0250 \text{ L soln}} = 6.41666 \times 10^{-3} = 6.42 \times 10^{-3}$$

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

This is about electrostatic potential energy from section 5.1,

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

$\kappa = 8.99 \times 10^9 \text{ J}\cdot\text{m}/\text{C}^2$  (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  $E_{\text{el}}$ . However, just as importantly understand what the eqn. is conveying about the variables. The eqn shows the absolute value of  $E_{\text{el}}$  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),

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

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  $\text{Mg}^{2+}$  and  $\text{O}^{2-}$  with the largest charges should have the greatest force of attraction and greatest electrostatic energy (most negative).

- |                     |   |
|---------------------|---|
| $w > 0$ (positive): | work done <b>ON</b> <b>system</b> by the surroundings                                       |
| $w < 0$ (negative): | work done <b>BY</b> <b>system</b> on the surroundings                                       |
| $q > 0$ (positive): | system gains heat (heat goes into the system from the surroundings)<br>- <b>endothermic</b> |
| $q < 0$ (negative): | system loses heat (heat leaves the system to the surroundings)<br>- <b>exothermic</b>       |

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

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

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

- a) The change in enthalpy,  $\Delta H$ , 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.

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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

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

- 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  $q > 0$ .

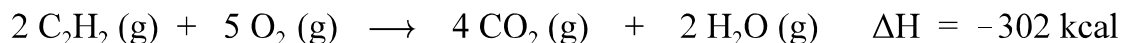
- d) What would be the sign of  $\Delta E$  or can that not be determined based on the information given? Explain!

What is the sign of  $\Delta E$  if  $w > 0$  and  $q > 0$ ?

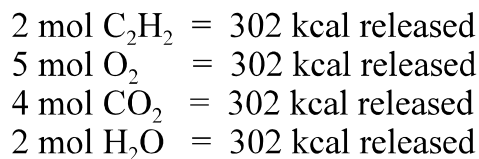
$$\begin{array}{ccc} \Delta E & = & q + w \\ (+) & & (+) + (+) \end{array}$$

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

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<sub>2</sub>H<sub>2</sub> = 26.04, O<sub>2</sub> = 32.00, CO<sub>2</sub> = 44.01, H<sub>2</sub>O = 18.02)



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)



$$\begin{aligned} ? \text{ g C}_2\text{H}_2 &= 1208 \text{ kcal} \times \frac{2 \text{ mol C}_2\text{H}_2}{302 \text{ kcal}} \times \frac{26.04 \text{ g C}_2\text{H}_2}{1 \text{ mol C}_2\text{H}_2} \\ &= 208 \text{ g C}_2\text{H}_2 \end{aligned}$$

208 g C<sub>2</sub>H<sub>2</sub> will produce 1208 kcal