A Green Culture:

Practicing and Teaching Responsibility in General Chemistry

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Why Green Chemistry?

- "Why do we save this stuff? I bet you just throw it away after we leave anyway."
- Safety-Kleen Corp's hazardous waste landfill in Pinewood, SC was forced to close in September 2000.

What is Green Chemistry?

- Get off to a safe start.
- Use renewable resources.
- Find safer solvents.
- Economize on atoms.
- Lower energy output.
- Return safe substances to the environment.

-Introduction to Green Chemistry, 2002
American Chemical Society

R134a

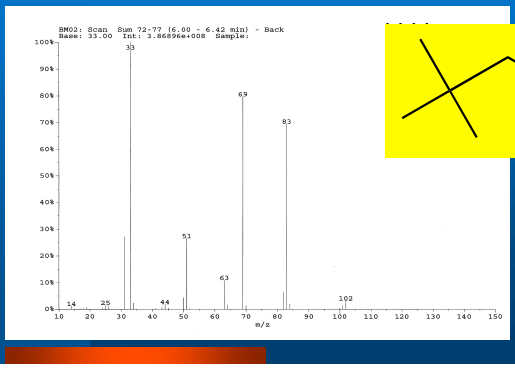
1,1,1,2-tetrafluoroethane

-boiling pt -26.15°C
-melting pt -101°C
- LC50 (4 hr) in rats:
2215000 mg/m3 (>500000 ppm)
-Uses: Refrigerant, propellant for pharmaceuticals; blowing agent for foams.

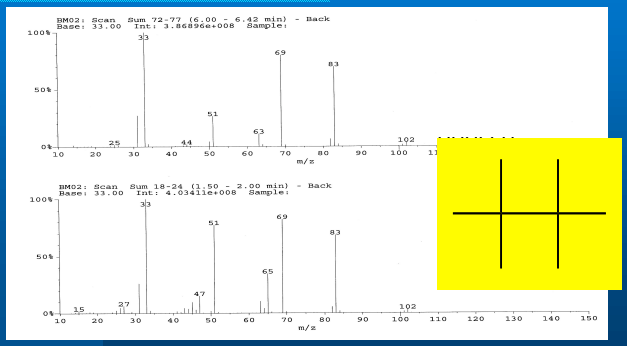
Introducing R134a

- Replacement for freon 12 (CCl_2F_2)
- Nonflammable and dense gas
  -molar mass 102g/mol
- Demonstrate by displacing air in a beaker extinguishing a flame.

Mass Spectrum of R134a



Good and Bad R134a



Molar Mass of a Gas

- **Determine the Molar Mass of R134a and He**
  - **Bottle and Helium 27.61g**
  - **Bottle and Air 28.25g**
  - **Bottle and R134a 30.20g**

What is the mass of the Bottle?

bottle volume = 614mL

Moles of gas = 0.025 moles

Bottle Mass from:

Helium	**27.51g**
Air	**27.65g**
R134a	**27.53g**

Results

- **Using the He data the R134a M_m = 107.5 g/mol**
- **Using the Air data the R134a M_m = 102 g/mol**
- **Using the Air data the He M_m = -1.6 g/mol**

Phase Transitions

See all three states of matter

Refrigeration

Heat of vaporization (0°): 47.52 cal/g

Supercritical Fluids

	Crit. Temp.	Crit. Pres.
CO_2	31.3°C	72.9 atm
R134a	101.05°C	40.64 atm

- **R134a is good at isolating fragrance compounds and perfume essenses.**
- **It can break down into highly toxic compounds at high temps.**

Atom Economy

Which reaction scheme is better?

#1 $Al + H_2SO_4 \_ Al_2(SO_4)_3 + H_2$

$Al_2(SO_4)_3 + NaOH \_ Al(OH)_3 + Na_2SO_4$

#2 $Al + NaOH + H_2O \_ Na[Al(OH)_4] + H_2$

$Na[Al(OH)_4] + H_2SO_4 \_ Al(OH)_3 + Na_2SO_4 + H_2O$

-Song, Wang, & Geng
J. Chem. Ed. 2004, 81, 691.

Atom Economy

Which reaction scheme is better?

#1 $2Al + 3H_2SO_4 \_ Al_2(SO_4)_3 + 3H_2$

$Al_2(SO_4)_3 + 6NaOH \_ 2Al(OH)_3 + 3Na_2SO_4$

#2 $2Al + 2NaOH + 6H_2O \_ 2Na[Al(OH)_4] + 3H_2$

$2Na[Al(OH)_4] + 1H_2SO_4 \_ 2Al(OH)_3 + 1Na_2SO_4 + 2H_2O$

-Song, Wang, & Geng
J. Chem. Ed. 2004, 81, 691.

Hydrates – Stoichiometry in the Lab

- **Current Lab in Student Lab Book**
  - **Determine product of $BaCl_2 \cdot 2H_2O$**
    Calculate theoretical yield of possible products and compare to actual yield.
  - **Qualitatively consider thermal decomposition of:**
    $CoCl_2 \cdot 6H_2O$
    $NiSO_4 \cdot 6H_2O$
    $CrCl_3 \cdot 6H_2O$

Alternative #1

$CuSO_4 \cdot 5H_2O \_ CuSO_4 + 5H_2O$

$CuSO_4 \quad \_ CuO + SO_2 + O_2$

Assignment

Run three reactions and determine the primary product of each reaction.

1. **crucible**
2. **hot plate**
3. **oven**

Alternative #1

$CuSO_4 \cdot 5H_2O \_ CuSO_4 + 5H_2O$

$CuSO_4 \quad \_ CuO + SO_2 + O_2$

Alternative #2

regular chalk $CaCO_3$

$CaCO_3$ _ $CaO + CO_2$

dust-free chalk $CaSO_4 \cdot 2H_2O$

$CaSO_4 \cdot 2H_2O$ _ $CaSO_4 + H_2O$

$CaSO_4$ _ $CaO + SO_3$

Assignment

Run three reactions and determine the primary product of each reaction.

1. crucible
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Alternative #2

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$CaSO_4$ _ $CaO + SO_3$

Typical Results for Chalk

Theoretical Yield	.28g
Actual Yield	.30g
Percent Yield	107%

Malachite

$Cu_2CO_3(OH)_2$ _ $2CuO + CO_2 + H_2O$

15 minutes

>95% yield

-Yee, Eddleton, and Johnson
J. Chem. Ed. 2004, 81, 1777.

Conclusions

- Thread "Green" concepts throughout the course.
- The students take ownership of lab exercises.

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